

**DEVELOPING STRATEGIES FOR SUSTAINABLE
GROUNDWATER MANAGEMENT IN THE
B60D QUATERNARY SUBCATCHMENT
OF THE OLIFANTS WATER MANAGEMENT AREA**

Retshedisitswe Letuka

Master of Engineering
in Civil Engineering

Department of Civil Engineering
Faculty of Engineering, Built Environment and Information Technology
Central University of Technology, Free State

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Supervisor: Prof. S. Oke

BLOEMFONTEIN
2023

DECLARATION

I, Retshedisitswe Thuto Letuka (_____), the undersigned, declare that the dissertation hereby submitted by me for the degree *Master of Engineering (Engineering: Civil)* at the Central University of Technology, Free State, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any engineering qualification.

Signature: Date: 03 March 2024

Retshedisitswe Thuto Letuka

Signature: Date:

Supervisor: Prof Oke Saheed

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ABSTRACT

Water supply in rural areas has changed dramatically over the past years, especially in the northern parts of the Mpumalanga province of South Africa. The role of hydrogeology and the understanding of groundwater has increased to a degree where groundwater is now prioritised over bulk water from rivers and dams. This is evident in the Leroro, Matibidi and Moremela villages in the northern areas of the Thaba Chweu Local Municipality (TCLM). In the past, groundwater was considered as an emergency, short-term solution to water needs. Boreholes were usually sited and drilled in the proximity to the demand. An example is where a water reticulation system is constructed first, and then the hydrogeologist is tasked to find water near the water reticulation reservoir. This practice has resulted in low-yielding boreholes with little or no recharge, and as a result, boreholes are drying up.

In this dissertation, the B60D quaternary subcatchment of the Olifants water management area has been studied as a paradigmatic case of a catchment area with human pressure on its groundwater resources, as well as a region with a failing water supply system. The hydrogeological system of the Olifants basin was described using hydrological, geophysical and hydrogeochemical characterisations of the geological formations taken from the different field surveys. The objective for these techniques was to show the effects of groundwater exploitation on the hydrodynamics of the system and also on consumers. In addition, this study highlighted the principal water-related problems such as identifying existing water shortages using SWOT analysis. The study further developed strategies such as the monitoring of groundwater level, water quality and maintenance of groundwater facilities and other management strategies for a sustainable utilisation of the water.

In conclusion, this dissertation described the monitoring and management system for the infrastructure of the B60D subcatchment groundwater system. From a broader point of view, this explication highlights the value of having monitoring strategies to alleviate the excessive pumping of groundwater resources and mismanagement of groundwater infrastructure.

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LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
μ/ℓ	Microlitre
AADD	Average Annual Daily Demand
cfu	Colony-forming unit
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation
<i>E. coli</i>	<i>Escherichia coli</i>
ha	Hectare
IWRM	Integrated Water Resources Management
km	Kilometre
km^2	Square kilometre
kW	Kilowatt
$\ell/\text{c}/\text{d}$	Litre per capita per day
ℓ/hr	Litre per hour
ℓ/s	Litre per second
m	Metre
m^3	Cubic metre
m^3/day	Cubic metre per day
m^3/h	Cubic metre per hour
m/day	meter per day
m/s	Metres per second
m^3/a	Cubic metres per annum
m^3/s	Cubic metres per second
$\text{m}^3/\text{km}^2/\text{a}$	Cubic metres per square kilometre per annum
Ma	Mega annum (one million years)
mamsl	Metres above mean sea level
mbc	Minimum Bactericidal Concentration
$\text{M}\ell/\text{day}$	Mega litres per day
meq/ℓ	Milliequivalents per litre
mg/ℓ	Milligram per litre
mbgl	Metres below ground level
mm	Millimetres
Mm^3/a	Million cubic meters per annum
mS/m	Millisiemens per metre

ABBREVIATION	DEFINITION
ND	No detected
NO ₂	Nitrogen dioxide
NO ₃	Nitrate
SABS	South African Bureau of Standards
SADC	Southern African Development Community
S	Storage coefficient
SANAS	South African National Accreditation System
S/m	Siemens per metre
SO ₄	Sulphate
Stats SA	Statistics South Africa
TCLM	Thaba Chweu Local Municipality
UNECA	United Nations Economic Commission for Africa
WMA	Water management area
WSDP	Water Service Development Plan

TERMINOLOGY AND DEFINITIONS

Terminology	Meaning (Adapted from Constantinides, 2007)
Apparent losses – Also known as commercial losses	Include unauthorised consumption and meter inaccuracies.
Aquifer	A geological formation made up of one or more layers of rock; where water can be stored or flow out. They are located on the saturated zone of the Earth's crust.
Inefficient use of water	Water used for a specific purpose over and above the accepted and available best practices and benchmarks, or water used for a purpose where very little benefit is derived from it.
Integrated water resource planning	A way of analysing the change in demand and operation of water institutions that evaluate a variety of supply-side and demand-side management measures to determine the optimal way of providing water services.
Real losses	Also known as physical losses – include leakage on transmission and distribution lines; leakage and overflows at storage tanks; and leakage at service connections.
Reticulation management	Any function related to the management, maintenance and operation of any system of structures, pipes, valves, pumps, meters or other associated equipment, including all mains, connection pipes and water installations that are used or intended to be used in connection with the supply of water.
Retrofitting	The modification, adaptation, or replacement of an existing device, fitting or appliance.
Supply-side management	Any measure or initiative that will increase the capacity of a water resource or water supply system to supply water.
Unbilled authorised consumption	Water used for backwashing of filters, flushing of pipes, washing streets, firefighting, public taps, fountains and parks.
Unaccounted for water	Part of the non-revenue water that remains after deducting unbilled authorised consumption.
Water institutions	Water institutions include both water management institutions and water services institutions as defined in the National Water Act and the Water Services Act, respectively.
Water wastage	Water lost through leaks or water usage, which does not result in any direct benefit to a consumer or user.
Water conservation	The minimisation of loss or waste, care and protection of water resources and the efficient and effective use of water.
Water demand management	The adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

INTRODUCTION

1.1 Background

Water, a major source of life, is required by all, either in small or large quantities. The quality and quantity of water required for domestic and industrial use must be taken into consideration (Senbore, 2018). In the quest for sustainable development, the management and conservation of water resources emerge as critical priorities (UNESCO, 2021). Groundwater, being a vital component of the hydrological cycle, plays an important role in meeting the needs of human societies and ecological systems (DWAF, 2004). Water security is a paramount concern for the sustainable development and socio-economic well-being of any region (UNECA, 2018). In the context of the B60D quaternary subcatchment, surface water resources and tourism play significant roles, ensuring that water security becomes even more critical (DWS, 2013). The subcatchment, located within the Olifants water management area (WMA), is known for its rich biodiversity, scenic landscapes, and thriving tourism industry (DWS, 2019).

However, increasing demands for water resources, coupled with climate variability and competing needs, pose challenges to water availability and sustainability. In addition, population increase, as well as anthropogenic activities, have led to the depletion and degradation of groundwater resources, calling for holistic strategies for management of resources (AghaKouchak *et al.*, 2021).

Groundwater includes all the subsurface water reaching a depth where the capillaries, openings and other cavities of the soil and rocks are completely filled with water (Davis, 2018). It is a significant part of the hydrologic cycle containing 21% of the world's supply of freshwater.

The availability of quality potable water resources has been the primary concern of communities in semi-arid regions like South Africa, as well as areas of more abundant rainfall. The problem of obtaining an adequate supply of potable water is generally becoming more acute due to an ever-increasing population and a lack of maintenance of water infrastructure (Midgley *et al.*, 1994).

The ever-increasing demand for water resources, coupled with the challenges posed by climatic change and population growth, has led to a need for sustainable groundwater management. Groundwater is a vital source of freshwater supply for various human activities, agricultural practices, and industrial processes in the Olifants WMA in the Mpumalanga province of South Africa (Gyamfi *et al.*, 2016). However, unsustainable exploitation and management of groundwater resources in this subcatchment have led to various consequences, including declining water levels, deteriorating water quality and environmental degradation (Bengeza, 2019).

The Olifants WMA is renowned for its diverse ecological habitats and is considered a significant water resource for both rural and urban communities. The B60D quaternary subcatchment, in particular, is characterised by intricate hydrogeological systems that are susceptible to various stressors. Uncontrolled abstraction, land use changes and pollution have the potential to adversely affect groundwater quantity and quality in the region (Lerner and Harris, 2009).

The B60D quaternary subcatchment, like many other regions, face complex challenges in balancing water availability and demand, while preserving its ecosystem and biodiversity. In light of these challenges, it becomes imperative to formulate effective and holistic strategies for sustainable groundwater management that consider both the socio-economic needs of the communities and the preservation of natural resources.

Understanding the geohydrological properties of the aquifer units in connection to their environmental susceptibility is crucial for effective groundwater usage and protection against loss of its pristine state (Oke *et al.*, 2015). In addition, strategies must be developed to help communities adapt and mitigate against the effects of overutilisation of the groundwater.

The study aimed at formulating strategies for sustainable groundwater management in the B60D quaternary subcatchment by developing comprehensive strategies that balance water utilisation and conservation.

1.2 Study Area

The Olifants Basin is a principal sub-catchment of the Limpopo River. It rises in the north of South Africa specifically Mpumalanga and flows into Mozambique. A detailed description of the biophysical and demographic characteristics of the Olifants catchment is presented in (de Lange *et al.*, 2005). For the purpose of managing water in the catchment, the Olifants

catchment has been divided into 5 regions namely:

- i. Upper Olifants River.
- ii. Upper Middle Olifants River.
- iii. Mountain Region.
- iv. Lower Middle Olifants River.
- v. Lower Olifants Region.

Where our study area (B60D) falls within the lower region. The selected study area itself is located approximately 34 km directly north-north-west of Graskop and 25 km north-east of Ohrigstad in the Thaba Chweu Local Municipality (TCLM), in the province of Mpumalanga, South Africa. The villages are located on the farms Elandsfontein 435KT, Lander 434KT, Dientje 453KT and Willemsoord 476KT. According to the 1:50 000 topographical sheets, 2430DA and 2430DB are framed by lines of latitude 24° 34' and 24° 41' S and lines of longitude 30° 43' and 30° 50' E (Figure 1.1) and Appendix A.

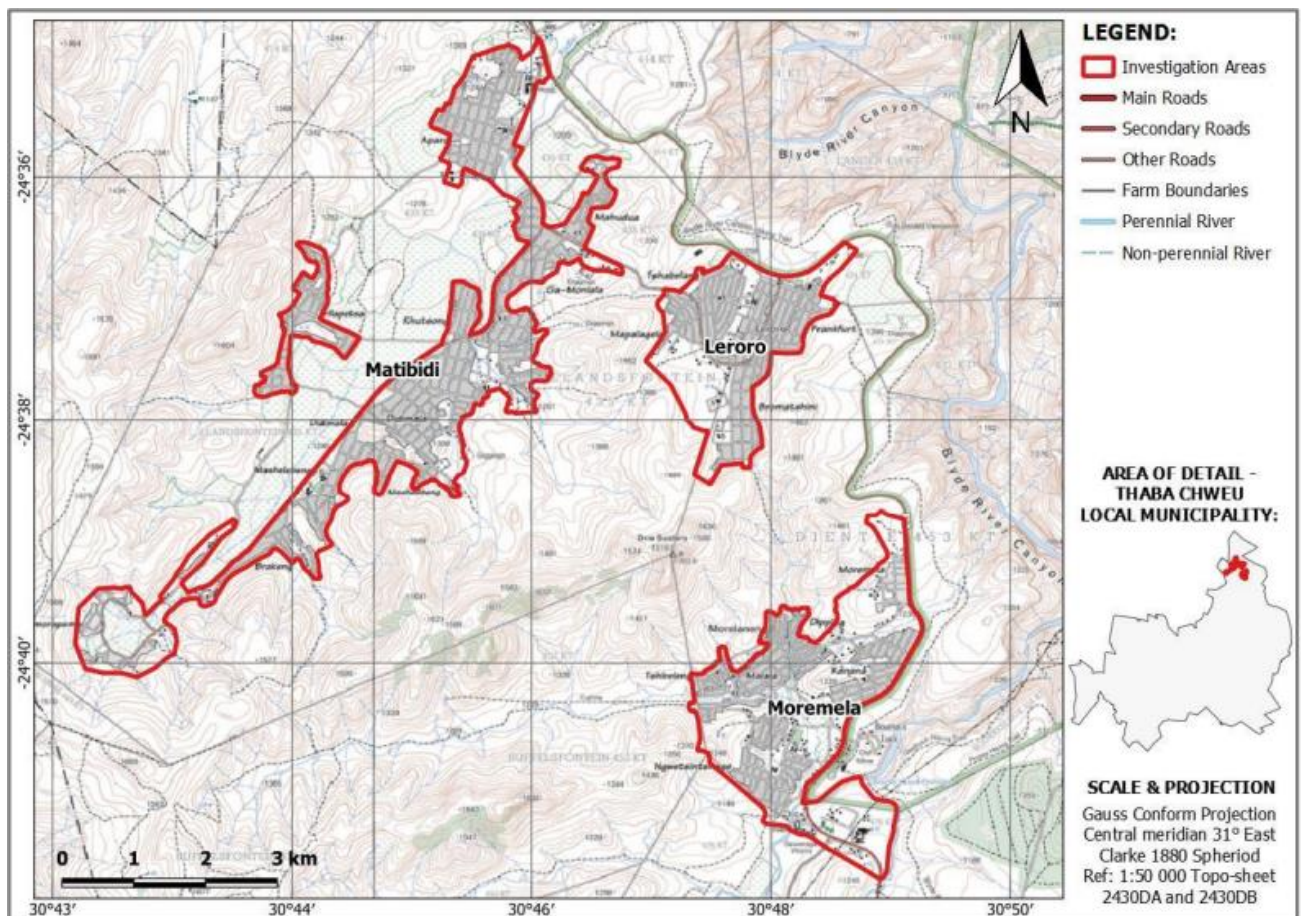


Figure 1.1: Regional locality (hydrogeological map series of South Africa, Phalaborwa Map, 1999, scale 1:50 000 series topographical maps 2430DA and 2430DB)

Figure 1.2 shows the subcatchment identification of the Olifants River management area that have Malmani dolomites. Dolomites play a major role in underground flow and water retention within their compartments.

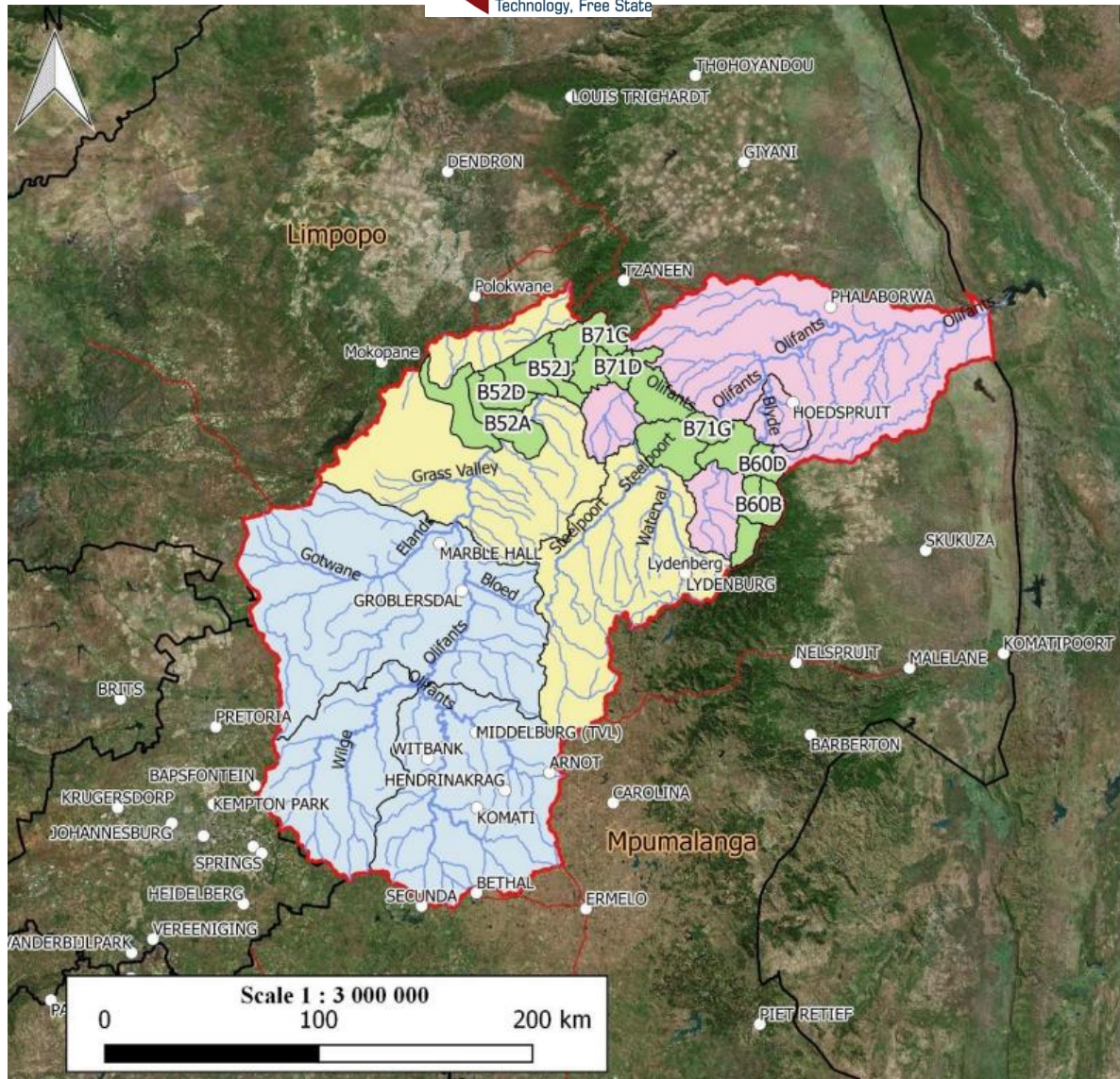


Figure 1.2: Catchment identification (Botha *et al.*, 2018) feasibility plan for groundwater resource development of the Malmani dolomites within the Olifants River water supply system

A detailed description of the biophysical and demographic characteristics of the Olifants catchment is presented in Figure 1.3. The catchment was divided into five regions to ease water management within the catchment (De Lange *et al.*, 2005). Each of these regions consists of several quaternary catchments, which are the principal water management units in South Africa and were demarcated for the whole country as part of a comprehensive national water resource assessment, known as the WR90 study (Midgley *et al.*, 1994).

This study focused on the Lower Olifants region, namely the B60D of the Blyde River, where:

- i. B6 = Secondary catchment identifier.
- ii. 0 = Tertiary catchment identifier.
- iii. D = Quaternary catchments identifier.
- iv. Blyde River = Description of tertiary catchment.

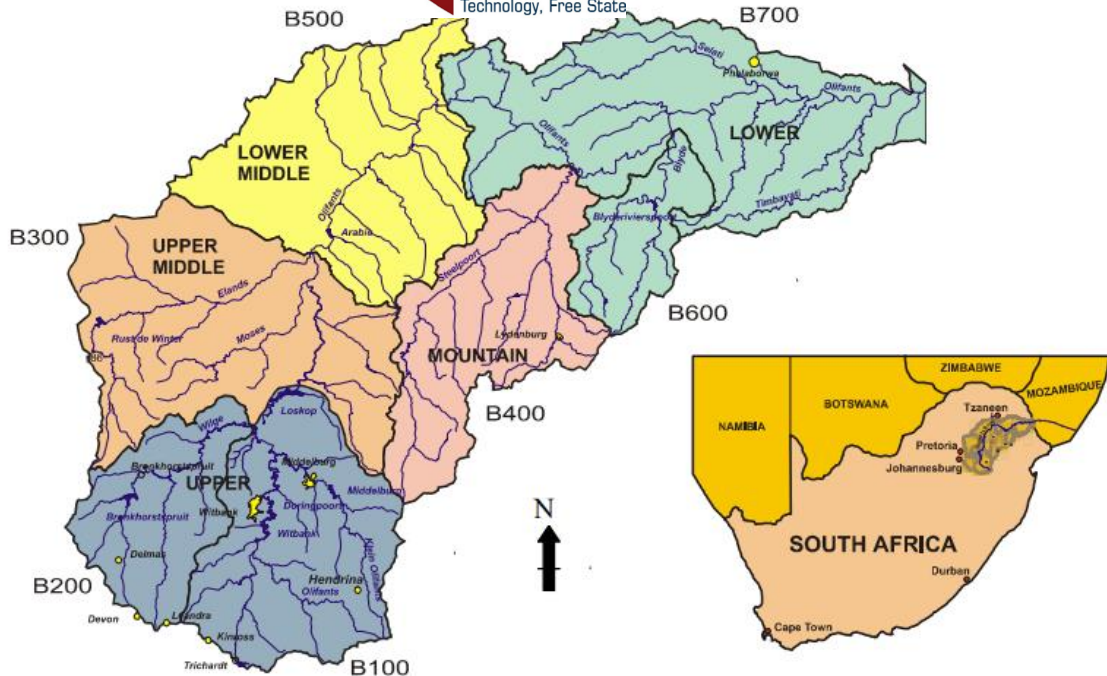


Figure 1.3: Location of the Olifants River water management area and the boundaries of the five water management regions (De Lange *et al.*, 2005)

1.3 Problem statement

According to Stone (2009), water in South Africa, as in the rest of the world, is both a rare and critical resource, owing to the fact that both people and industries require water and power to survive (Dunn *et al.*, 2012). Thaba Chweu Local Municipality, specifically the areas of Matibidi, Leroro and Moremela, is no exception as many households do not receive a regular supply of water. As the number of families in the villages grows rapidly, the problem is rising at an alarming rate. As a result of these developments, an examination into the causes and consequences of water scarcity, groundwater availability, and surface abstraction is required.

The main source of water supply in the investigated catchment and villages inhabiting the catchment is groundwater as the Blyde river is a protected river and water use license for abstraction at the Ohrigstad dam has been exhausted. A total number of 109 boreholes were drilled by the TCLM and private contractors to access groundwater for these villages in the TCLM. Currently, only 61 of these boreholes were identifiable. Of the 61, only 28 were operational, where they were run for a period of 24 hours daily non-stop. A further 48 boreholes on the municipal database could not be identified. Twenty-six boreholes were identifiable within the Leroro village. Only five of these 26 boreholes were still in use during the study period, with a combined daily abstraction rate of approximately 706.07 m³/day.

Within the Matibidi village, 28 boreholes were identifiable, of which 18 boreholes were still in use, with a combined abstraction rate of 5 081.9 m³/day. Of the 18, nine boreholes were not functional, and one was used as a monitoring borehole. The non-functional boreholes were dry and/or blocked.

In the Moremela village, seven boreholes were identifiable, four of the seven boreholes were still in use, with a combined abstraction rate of 580.21 m³/day, and three were not functional.

Due to the overpumping of the aforementioned boreholes, many of them were stressed and unsustainable in the current trajectory. In addition, some areas received more water and some less water. Likewise, the storativity and transmissivity differed widely in the catchment and, therefore, there was a possibility of balancing the supply of water within one area of the catchment to the other.

To compound the problems of the villages in the catchment, the risk to groundwater contamination was high due to the lack of sanitation infrastructure and widespread use of pit latrines. In addition, the surface water abstraction at the Blyde River was not permitted as it is a protected river under the *National Environmental Management: Protected Areas Act 57 of 2003*. The region is also a tourist attraction point such as the Mac Mac Pools, the Blyde River Canyon and the Bourke's Luck Potholes. Therefore, there was a need to formulate a management strategy for an effective and sustainable use of groundwater resources for the subcatchment.

1.4 Study significance

Water is essential for life, as well as for economic growth, social development, and environmental sustainability. (UNESCO, 2021). Water scarcity is a global issue that impacts individuals, industry, and the economy, rather than merely a local, regional, or national concern. (Khadka and Pathak, 2021). Hence, the significance of this study was to develop strategies for sustainable groundwater management in Thaba Chweu Local Municipality villages, namely Leroro, Moremela and Matibidi. Furthermore, the socio-economic aspect of sustainable groundwater management had to be addressed through stakeholder engagement, and the consideration of local community needs. By understanding the water demands of various sectors, including agriculture, industry, and domestic usage, the research worked towards developing strategies that promote equitable and efficient groundwater allocation.

The proposed strategies for sustainable groundwater management were designed with scalability and duplicability in mind. Lessons learned from this research can be applied to

similar regions facing groundwater challenges, making it relevant and applicable in various contexts beyond the B60D quaternary subcatchment.

1.5 Aim of the study

The main aim of this study was to formulate groundwater adaptation plans for sustainable water management for the B60D quaternary subcatchment of the Olifants WMA in order to provide hydrogeological information important to those responsible for planning, development and management of the study area.

1.6 Research objectives

To achieve the main aim of the study, the following specific objectives were set:

- i. To conduct a complete hydrocensus of groundwater resources.
- ii. To assess aquifer potential through pump testing.
- iii. To investigate the current operations and maintenance of groundwater facilities.
- iv. To formulate an adaptation and management strategy for groundwater sustainability within the subcatchment.

1.7 Research questions

To achieve the objectives, the following research questions were assessed.

The following questions refer to the technical information that was generated:

- i. What is the pump installation depth?
- ii. What is the borehole depth?
- iii. What is the depth of water level?
- iv. What is the yield of the borehole?
- v. What is the depth of the water strike(s)?
- vi. What is the volume abstracted from each borehole?

The sub questions that were asked were:

- i) Is the borehole/pump currently working?
- ii) What are the operational boreholes being used for?

These questions helped the study in understanding the dynamics of the operations of the infrastructure and the abstraction rate of the groundwater.

1.8 Research limitations

The hydrological tests could only be conducted upon consultation with the operators; thus the selection of boreholes was done in accordance with the availability of the borehole. The primary data were first collected between the period 26 November 2020 to 01 December 2021, excluding the winter months. Data collection during the winter period was inadvisable because the comparison was between the water table in the rainy and dry seasons. This assisted in extracting water reduction levels of the study area.

Only limited information could be obtained from the TCLM with regard to the following:

- i. Settlements where water meters were installed (number of meters per settlement).
- ii. Number of customers in specific settlements billed for water through meter reading records (customers per settlement).
- iii. Number of customers in settlements billed for water through flat rates (customers per settlement).
- iv. Records of billing to businesses through meter readings with payments received from businesses.
- v. Records of billing to institutions through meter readings with payments received from institutions such as government buildings, schools, and police stations.
- vi. Average revenue collection for water and sanitation per month for previous year (R/month) per yearly income for the last two years.
- vii. Yearly operations and maintenance budgets for water and sanitation.
- viii. Unaccounted for water strategy – any information available.
- ix. Cost recovery strategy.

In addition, the hydrocensus was done by the researcher with assistance of a consultancy firm, G-Seal Consulting, when a scoping report was done for the development of wellfields within the study area.

A sample of chemistry results was done using random selection within the study area. Not all water from the listed boreholes was tested as the main source of water in the study area is groundwater and a prolonged disturbance would cause conflict with the community.

1.9 Structure of the dissertation

The dissertation is structured as follows:

The first chapter (Chapter 1) of the study is an introduction that highlights the study's background, issue statement, significance, aims, and research limitations.

Chapter 2 is the literature review. The research in the Olifants WMA, as well as other research studies relative to the supply of water within the northern areas of Mpumalanga, the geology, hydrogeology of the study area, water supply demand of the villages, the groundwater use in the study area and South Africa, sustainable groundwater management and geophysical investigations are discussed.

Chapter 3 gives a detailed description of the study area, the geological setting, hydrogeology setting and morphology of the region.

Chapter 4 details the methodology of the study.

The results of the hydrocensus conducted at the Olifants WMA in the B60D subcatchment are detailed in Chapter 5. The geophysical investigations are described, as are the hydraulic tests carried out as part of the inquiry to examine the hydraulic parameters of the aquifer system linked with dolomites. The outcomes of hydrochemical studies performed on groundwater samples collected during the hydrocensus are also discussed.

In **Chapter 6**, a groundwater monitoring and management system is proposed to prevent overutilisation of the aquifer system while ensuring safe use of the groundwater for its intended purpose.

Chapter 7 contains the recommendations and conclusion of the study.

LITERATURE REVIEW

2.1 Introduction

This chapter reviews relevant literature to the current research. Therefore, this literature review focused on the following:

- i. water security in South Africa;
- ii. the geology and hydrogeology of the Malmani Subgroup, with specific emphasis on the dolerite intrusions and their influence on the aquifer systems;
- iii. the water supply and demand in South Africa and the TCLM;
- iv. catchment overview of the Olifants WMA;
- v. the current use of groundwater in South Africa and the sustainable management of the groundwater resources; and
- vi. the geophysical techniques used during the current investigations to detect and delineate the dolerite structure.

2.2 Groundwater use in South Africa

2.2.1 Water security

South Africa's water resources are becoming increasingly stressed, and the country is expected to suffer severe water shortages in the near future due to increased water demand and climate driven factors (Falkenmark, 2007). Localised population growth coupled with profligate water use exert pressure on available resources, resulting in gross imbalances between water demand and supply (dhs, 2019). Population increase, combined with climate change and ongoing economic development, places constant strain on water resources and infrastructure (Blignaut and Van Heerden, 2009). Groundwater is a critical component of water supplies. The rising pressure on surface water resources as a result of increasing water supply needs has raised the relevance of groundwater not only in South Africa, but globally. South Africa's water supply is already being jeopardized by poor water quality in rivers and dams, a drought epidemic, and poisoning of soil-rock-groundwater systems. (Makiwane, 2019).

Water security has been an important concept that has gained attention over the past years. In 2009, the World Economic Forum described water security as the gossamer that links

together the web of food, energy, c growth and human security challenges that the world economy will be facing over the next two decades (UNESCO, 2021). Water security is defined in this study as sustainable access to adequate quantities of water of acceptable quality on a catchment basis to support human and environmental health. This definition establishes continual baseline standards for water resource management in the catchment; appropriate quantities of acceptable quality water must be available for both humans and the environment. (Dunn *et al.*, 2012).

Water security encompasses various aspects, including availability, accessibility, and water quality, all of which directly impact the well-being of local communities and the thriving tourism industry (Bazaanah and Mothapo, 2023). The B60D quaternary subcatchment, located within the Olifants WMA, is renowned for its natural beauty, diverse ecosystems, and touristic attractions (DWAF, 2004). As a result, maintaining sustainable surface water resources is of utmost importance to ensure a thriving tourism sector and the preservation of the region's ecological integrity.

Surface water is a vital component of the water balance in the B60D quaternary subcatchment (DWAF, 2004). Precipitation and surface run-off contribute to the replenishment of surface water bodies, supporting both local water needs and the aesthetic appeal that attracts tourists (Katsifarakis *et al.*, 2015). However, the interplay of various factors, including climate variability, population growth, and anthropogenic activities, poses challenges to surface water availability and quality. Hence, comprehensive water balance assessments are essential to understanding the dynamics of surface water resources and formulating effective water management policies (Maswanganye *et al.*, 2022).

The tourism sector, as a major economic driver in the region, is directly linked to surface water availability and ecological health (Pérez *et al.*, 2020). Tourists visit the study area to indulge in recreational activities such as boating, fishing, and wildlife viewing, all of which heavily depend on sufficient and pristine surface water resources. Therefore, ensuring water security is not only crucial for the livelihoods of local communities but also instrumental in sustaining the tourism industry's prosperity (Manzoor *et al.*, 2019).

Water security necessitates a higher priority for water. As such, it is a wide notion of integrated water management that strives to strike a balance between resource protection and resource usage. (Mishra *et al.*, 2021). It is important to measure water security because this approach examines the watershed as a whole. Setting a goal of water security could enable decision-makers to effectively assess and mediate between conflicting demands for water use and minimize potentially adverse impacts from land and water management practices (Dunn *et al.*, 2012).

Water balance is described as water demand, based on the flow of water in and out of a catchment (Pollard *et al.*, 2020). Water enters a catchment by precipitation, runoff, and groundwater intake and outflow via evapotranspiration, river flow, and other human and industrial uses. The annual water balance compares the available water to the demand to determine which subcatchments are in water surplus, balance, or deficit. (Pollard *et al.*, 2020).

Water security issues have been a growing concern in this study region. These problems flow, in part, from the fact that water is a multipurpose resource, with multiple sets of users operating at different scales. In turn, this creates competing uses and diverse views of stakeholders within the policy debate (DWA, 2013). For example, communities sit within catchments, and the water within cities is often the subject of competing claims both upstream and downstream: industrial, tourism, amenity, residential, agricultural, and resource uses (Syafri *et al.*, 2020), for example, hunting and fishing. In essence, water security is an overarching conceptual framework that articulates the desirability of balancing competing land and water use practices, much like integrated water resource management (Bakker and Morinville, 2013).

2.2.2 Groundwater utilisation

The entire volume of renewable groundwater in South Africa is projected to be 10.34 billion m³ per year. The country now uses between two and four billion m³ of groundwater, indicating that there is significant potential to significantly enhance groundwater resources in South Africa (Makoe, 2018). These volumes should be compared with the assured yield of surface water resources that amounts to 12 billion cubic meters per year, of which more than 80% has already been allocated (DWS, 2010).

Secondary aquifers are the primary sources of groundwater in South Africa, according to Pavelic *et al.* (2012). The amount of water held in secondary aquifers is insufficient, and the permeability of such aquifers is typically low, due to particularly fine grained shale, mudstone and similar layers, in which groundwater flow is largely via fractures and other discontinuities, and storage capacity is limited (Pietersen 2004). Pavelic *et al.* (2012) states that overall, the Malmani forms low to moderately productive aquifers, with typical borehole yields 1 to 3 l/s.

According to Makoe (2018), census survey data show a distinct pattern of groundwater use in South Africa, with different sectors utilising different portions of the extracted groundwater. It is estimated that 78% of all groundwater abstracted is used for irrigation, 7% for rural domestic purposes and 6.7% for stock watering.

Only 4% of groundwater abstraction in the urban environment (Makoe, 2018). Traditionally, however, the urban users have received the most groundwater research and investigation attention. As a result, little is known about the status of groundwater used by the agricultural sector in South Africa.

In the TCLM – primarily the study areas Matibidi, Leroro and Moremela – groundwater is currently used as a source of potable water. The boreholes are maintained and operated by the TCLM. There are also a number of privately-owned boreholes that are also used as a source of potable water and irrigation of gardens (Makoe, 2018).

The use of groundwater resources is much more reliable, as opposed to the surface water resources because of the following reasons:

- i. Groundwater is a proximal source that does not need to be pumped at great distances.
- ii. It is not a costly resource, meaning it does not require extensive installations.
- iii. It does not need to be purified like surface water.

According to the national water and sanitation master plan of the DWS (2019), groundwater resources are more reliable for the following reasons:

- i. Groundwater is often not subject to contamination from surface pollution.
- ii. In times of disease outbreaks, such as cholera, it is regarded as a safe supply if the borehole is protected.
- iii. Supply systems can be implemented by community members in many cases.
- iv. It is not subject to the extremes of surface water resources, such as flooding.
- v. In times of drought, groundwater can continue to provide a reliable source of water if properly managed.

2.3 Land use

Land use is one of the most important factors influencing water quantity and quality in watersheds (Cheng *et al.*, 2022). Changes in land cover can lead to significant changes in leaf area index, evapotranspiration, soil moisture content, infiltration capacity, surface and subsurface flow regimes including groundwater flow contributions to streams (Tu, 2009). According to DeFries and Eshleman (2004), land use is a major issue for this century, and understanding the effects of land use change on hydrological systems is a critical research priority for the future.

In the regions of the subcatchment B60D of the Olifants catchment along the Blyde River, population growth is considered a dominant contributor to the over-abstraction of

groundwater as there are no alternative water reticulation sources (DWAF, 2004). Many factors contributed to the rapid deterioration in the catchment which, in turn, impacts on the livelihood of all the catchment residents such as poor enforcement of regulations, unchecked land and resource use as well as pollution (Pollard *et al.*, 2020).

2.4 Water quantity

2.4.1 Catchment overview

Due to the intensive use of scarce water resources by diverse sectors, including forestry, agriculture, and mining (Pollard *et al.*, 2014), the Olifants basin is developed and water stressed. As a result, the basin's intense water use has a negative impact on both water quantity and quality, which compromises the security of the catchment's water supply (Pollard *et al.*, 2020). According to Cook and Bakker (2012), water security is the availability of water in an acceptable amount and quality for human health, livelihoods, ecosystems, and production, as well as a level of water-related hazards that are acceptable for the protection of people, the environment, and economies.

The Olifants basin's water needs have significantly increased in recent years as a result of a variety of activities (Pollard *et al.*, 2020). The need to meet reserve or ecological water requirements is one of these activities, along with mining, urban growth, better service delivery to rural areas, irrigation, and power generation (De Lange, 2005).

The Olifants catchment is a crucial water management area situated in Southern Africa, encompassing parts of South Africa, and Mozambique (DWS, 2018). Spanning approximately 120 000 km², the catchment is named after the Olifants River, a major watercourse that runs through the region (Olifants Catchment Management Agencies, 2021). The Olifants catchment plays a vital role in sustaining water resources, supporting diverse ecosystems, and facilitating socio-economic development for the local communities (DWAF, 2005).

The Olifants catchment extends across the provinces of Limpopo, Mpumalanga, and Gauteng in South Africa, as well as portions of the Inhambane Province in Mozambique (DWAF, 2004). It covers various landscapes, including highveld grasslands, savannas, woodlands, and mountainous terrains. The catchment's hydrological significance lies in the Olifants River and its tributaries, such as the Blyde, Steelpoort and Selati Rivers (DWAF, 2004; DWS, 2018). These watercourses provide water resources for domestic and forestry use, supporting various economic activities in the region.

The Olifants catchment is renowned for its rich biodiversity, supporting a wide range of plant and animal species. The catchment encompasses several protected areas, including the Kruger National Park, which is home to diverse wildlife and iconic African species (DWAF, 2006). However, human activities, such as agriculture, mining, and urbanisation, have put pressure on the region's ecosystems, raising concerns about biodiversity conservation.

2.4.2 Groundwater occurrence associated with the dolerite intrusions

Dolerite intrusions are common geological features found in various regions around the world. These intrusive igneous rocks can significantly influence groundwater occurrence and movement due to their unique hydrogeological properties (Botha *et al.*, 1998). Dolerite intrusions are widespread in various geological settings, occurring in both sedimentary and metamorphic terrains (Woodford and Chevallier, 2002). These igneous formations can create both vertical (dykes) and horizontal (sills and plugs) structures that cross-cut existing rock formations. The interplay between dolerite intrusions and adjacent lithologies is critical in shaping the groundwater system's hydrogeological behaviour. (Van Wyk, 1963).

For Kirchner *et al.* (1991), Vegter (1995) and Woodford (1990), understanding the interactions between dolerite intrusions and groundwater is essential for sustainable groundwater management and resource exploration. Dolerite intrusions are formed when molten magma intrudes into existing rock formations, cooling and solidifying underground. These intrusive igneous rocks typically possess a coarse-grained texture, characterised by interlocking mineral crystals (Loock, 2011; Woodford and Chevallier, 2002). Dolerite is known for its high density, low porosity, and limited permeability, resulting from the compact arrangement of minerals.

The presence of dolerite intrusions can significantly affect groundwater occurrence in the surrounding geological formations (Holland and Witthüser, 2011). Their low permeability restricts the flow of groundwater, creating barriers that impede lateral movement. In contrast, fractures and fissures commonly associated with dolerite intrusions can act as conduits for groundwater flow, allowing localised preferential flow paths (Campbell *et al.*, 2016). Depending on the extent and geometry of the intrusion, it can create both confined and unconfined aquifer conditions. The interplay between the dolerite intrusion and the adjacent rock formations governs the groundwater flow patterns and hydraulic conductivity (Woodford and Chevallier, 2002).

The interactions between surface water and groundwater systems in many catchments across the world are still poorly understood, despite the fact that they are critical for efficiently

managing the quantity and quality of water resources (Tanner and Hughes, 2015). Many surface water features, such as rivers, lakes, dams, and wetlands, have variable degrees of connectivity with groundwater systems (Tanner and Hughes, 2015).

Dolerite intrusions can experience hydrofracturing, a process where the presence of water exerts pressure, leading to the creation of fractures in the rock mass (Senger *et al.*, 2015). Hydrofracturing can significantly enhance the permeability of the dolerite, facilitating the movement of groundwater through these newly created pathways. Consequently, hydrofractured dolerite intrusions may act as significant conduits for groundwater flow, influencing regional aquifer systems (Senger *et al.*, 2015).

The interaction of dolerite intrusions with surrounding aquifer systems can lead to complex hydrogeological conditions. In some cases, the presence of dolerite intrusions may create confined aquifers, where groundwater is trapped and pressurised within the fractures (Wada, 2010). In contrast, the fractured dolerite can also serve as a semi-confined or unconfined aquifer, depending on the hydraulic connections with adjacent formations (Senger *et al.*, 2015).

The lithology of geological materials, regional geological structure, geomorphology of landforms, and the availability of recharge sources all influence groundwater occurrence and emergence at the surface (Hiscock and Bense, 2014). Dolerite intrusions produce more groundwater than sedimentary rocks, and boreholes in the former are statistically more successful (Van Wyk, 1963). Sedimentary rock yields are typically less than one litre per second, but dolerites produce yields of more than five litres per second.

Dolerite dykes are usually preferred drilling targets because their secondary permeability is increased due to shrinkage joints that developed during cooling of the intrusion, and because they act as conduits for groundwater flow (Allan and Matsuo, 2002). Dolerite sill and ring complexes have seldom been targeted.

2.5 Sustainable management of groundwater resources

2.5.1 Groundwater sustainability

Groundwater sustainability is described as the ability of pumping to continue eternally if water management define safe yield as the maximum prolonged pumping that meets all logistical, environmental, legal, social, economic, and physical restrictions (Elshall *et al.*, 2020). Groundwater sustainability can be further evaluated as a function of aquifer performance relative to aquifer governance.

The safe yield of an aquifer can be assessed as the amount of water that can be withdrawn from it without producing an undesired effect during a drought period. According to Meyland (2011), the sustainable yield of an aquifer must be considerably less than the recharge if enough water is to be available to sustain both the quantity and quality of streams, springs, wetlands, and groundwater-dependent ecosystems. Scientific evaluation of groundwater sustainability addresses multiple aquifer performance and governance factors (Israel et al, 2021). Understanding the hydrological foundations while being aware of the science-policy link is essential for groundwater sustainability (Sophocleous, 2000). According to the DWA (2010), one of the key concepts of the 1998 National Water Act is sustainability, along with fair access to water. Sustainability in groundwater refers to groundwater use that does not degrade the total resources in terms of quality and quantity over time (Makoe, 2018).

Urbanisation, population increase, and the effects of climate change all have a substantial impact on the amount and quality of water (Makoe, 2018). When there is growth in the region, the population grows as a result of new job possibilities and improved housing. As a result, individuals leave their rural areas in search of an allegedly better living. Migration generates overstressed systems per area; water supplies become stressed as a result of high demand for supply, and water quality deteriorates as demand rises (Makoe, 2018). Furthermore, regional developments might pollute water sources and contribute to climate change. As a result, it is prudent to evaluate the need of balancing economic growth and development with water resources (DWA, 2006). Groundwater differs from surface water in that it is far beneath the earth's surface, making it less vulnerable to the aforementioned consequences. Unconfined aquifers, on the other hand, are more vulnerable to pollution than confined aquifers (Makoe, 2018).

Groundwater management in Southern Africa faces challenges due to increasing demands, population growth, and the competition between various water users. The reliance on groundwater for both rural and urban water supply puts pressure on aquifer systems. Unplanned and unregulated abstraction, coupled with limited monitoring and data availability, exacerbates the risk of groundwater depletion and quality deterioration (Bengeza, 2019). Groundwater plays a crucial role in supporting livelihoods, ecosystems, and economic development in Southern Africa. As one of the most water-stressed regions globally, ensuring groundwater sustainability is of paramount importance to meet the growing water demands, mitigate climate-induced variability, and protect precious water resources (UNECA, 2018).

Groundwater sustainability in Southern Africa depends on effective governance and regulation. Collaborative efforts among states in the Southern African Development

Community (SADC) are essential for harmonising policies, sharing best practices, and addressing transboundary groundwater issues (DWS, 2016). Introducing robust legal frameworks, licensing systems, and monitoring systems are important for sustainable groundwater management.

The DWS (2016) gives the following strategies for groundwater sustainability in Southern Africa:

- i. *Integrated water resources management (IWRM)*: Southern African countries are increasingly adopting IWRM principles to promote integrated and participatory water management, including groundwater. IWRM emphasises the consideration of social, economic, and environmental aspects of water use and conservation.
- ii. *Groundwater recharge enhancement*: Implementing artificial recharge techniques, such as managed aquifer recharge and rainwater harvesting, can bolster groundwater recharge and improve aquifer storage.
- iii. *Sustainable land use practices*: Promoting sustainable land use practices, including soil conservation, afforestation, and agroforestry, can positively impact groundwater recharge and protect water quality.
- iv. *Community-based management*: Engaging local communities in groundwater management decisions fosters ownership and encourages sustainable water use practices.
- v. *Data collection and monitoring*: Expanding groundwater monitoring networks and data collection efforts is critical for understanding aquifer behaviour, identifying trends, and making informed decisions.

2.5.2 Groundwater monitoring

Groundwater monitoring is a critical component of water resource management, providing essential data on groundwater levels, quality, and trends (Makoae, 2018). It involves systematic data collection and analysis to understand the behaviour and health of groundwater systems. Groundwater monitoring and management are critical to the dependability and efficiency of groundwater supplies (DWS, 2016). This applies to both tiny borehole schemes and huge wellfields servicing urban areas. Borehole water level, water quality, and pumping rate monitoring are critical components of good groundwater management (Makoae, 2018).

The importance of groundwater monitoring described by Elshall *et al.* (2020) are listed as follows:

- i. *Water resource management:* Groundwater monitoring helps quantify water availability, enabling effective planning and allocation of this vital resource for drinking water supply, agriculture, and industrial use.
- ii. *Early warning systems:* Continuous groundwater monitoring serves as an early warning system for potential issues such as declining water levels, saltwater intrusion, and contamination, allowing timely intervention and mitigation.
- iii. *Pollution detection:* Groundwater monitoring identifies pollutant sources and assesses the impact of human activities on groundwater quality, supporting pollution control and remediation efforts.
- iv. *Climate and hydrological studies:* Groundwater monitoring contributes to climate and hydrological research, providing data on aquifer responses to climate variability and informing models for water resource projections.

Good monitoring and management of groundwater resources is the key to reliable, efficient groundwater supplies (Makoe, 2018). Groundwater monitoring involves systematic and regular measurement of water levels, quality parameters, and other relevant data in wells, boreholes, and piezometers. According to the DWS (2010, 2016) the principles of groundwater monitoring are listed as follows:

- i. *Spatial distribution:* Monitoring wells are strategically located to capture variations in aquifer behaviour, reflecting the spatial distribution of groundwater levels and quality.
- ii. *Temporal variability:* Groundwater monitoring is conducted over extended periods to observe seasonal and long-term fluctuations, and to identify trends and anomalies.
- iii. *Data consistency:* Standardised measurement techniques and protocols are essential to ensure data consistency and comparability over time.
- iv. *Multi-parameter approach:* Monitoring involves measuring multiple parameters, such as water levels, temperature, electrical conductivity, pH, dissolved oxygen, and concentrations of major ions and contaminants, to obtain a comprehensive understanding of aquifer conditions.

Applications of groundwater monitoring:

- i. *Water resource assessment:* Groundwater monitoring data assists in evaluating groundwater potential, estimating sustainable yields, and determining safe abstraction rates.
- ii. *Drought and climate resilience:* Groundwater monitoring helps to manage water resources during droughts and periods of water scarcity, enhancing climate resilience for communities and ecosystems.
- iii. *Pollution control and remediation:* Groundwater monitoring identifies polluted sites and guides remediation actions to protect groundwater quality and prevent further contamination.
- iv. *Environmental impact assessments:* Groundwater monitoring supports environmental impact assessments for infrastructure projects, ensuring sustainable development and minimising potential harm to groundwater resources.
- v. *Groundwater modelling:* Groundwater monitoring data forms the basis for constructing and calibrating groundwater models, aiding in predictive simulations and management scenarios.

2.5.3 Groundwater abstraction

The rate at which groundwater should be utilized is not different from the rate at which surface water should be used, as both are governed by the National Water Act 36 of 1998, Section 26(1) (South Africa, 1998). This Act requires that water use from a water resource be monitored, measured, and recorded, and Section 26, subsection 4(c) and (e) state that "when making regulations, the Minister must take into account all relevant considerations, including the need to prevent wasteful water use and to facilitate the management of water use and waterworks" (see also Makoae, 2018).

The amount of recharge to the aquifer must be understood in order to reach the water balance equilibrium and assign the rate at which each individual should abstract water. In accordance with the National Water Act, DWAF (2000) bears responsibility for groundwater abstraction control in order to prevent over-abstraction and aquifer drying.

Depletion or damage to the reserve results in:

- i. Temporary or permanent loss of the use of aquifers through over-abstraction or unnecessary dewatering.
- ii. Loss of surface water base flow or damage to wetlands and riverine environments that depend on groundwater.
- iii. Deterioration of groundwater quality.
- iv. Intrusion of saline or contaminated groundwater into otherwise uncontaminated aquifers.

In South Africa, the total volume of exploitable groundwater potential is 10 343 million m³ per annum or 7 500 million m³ per annum under drought conditions (Makoe, 2018). Figure 2.1 depicts different locations based on the quantity of usable groundwater extraction potential per cubic metre per square kilometer per year (m³/Km²/a). The highest values were reported in coastal regions and very elevated places, such as the Drakensberg and Lebombo mountains, at around 100 000 m³/km²/a, as shown by a blue color (DWS, 2010). The lowest values can largely be observed on lower lands and arid regions as indicated by a dark pink colour. The management zone of the study area is the Olifants WMA area, and the utilisable groundwater exploitation potential is 619.2 million m³/a and is indicated in blue in Figure 2.1.

Figure 2.2 shows the potential yields within the South African WMAs. The Olifants WMA falls within the high-yielding zones within South Africa's aquifers.

Figure 2.3 shows the groundwater use per water management area. The water management area of the study area is covered by rural usage, followed by irrigation, mining and industry.

**Utilisable Groundwater Exploitation Potential
(UGE_P) (m³/km²/a)**

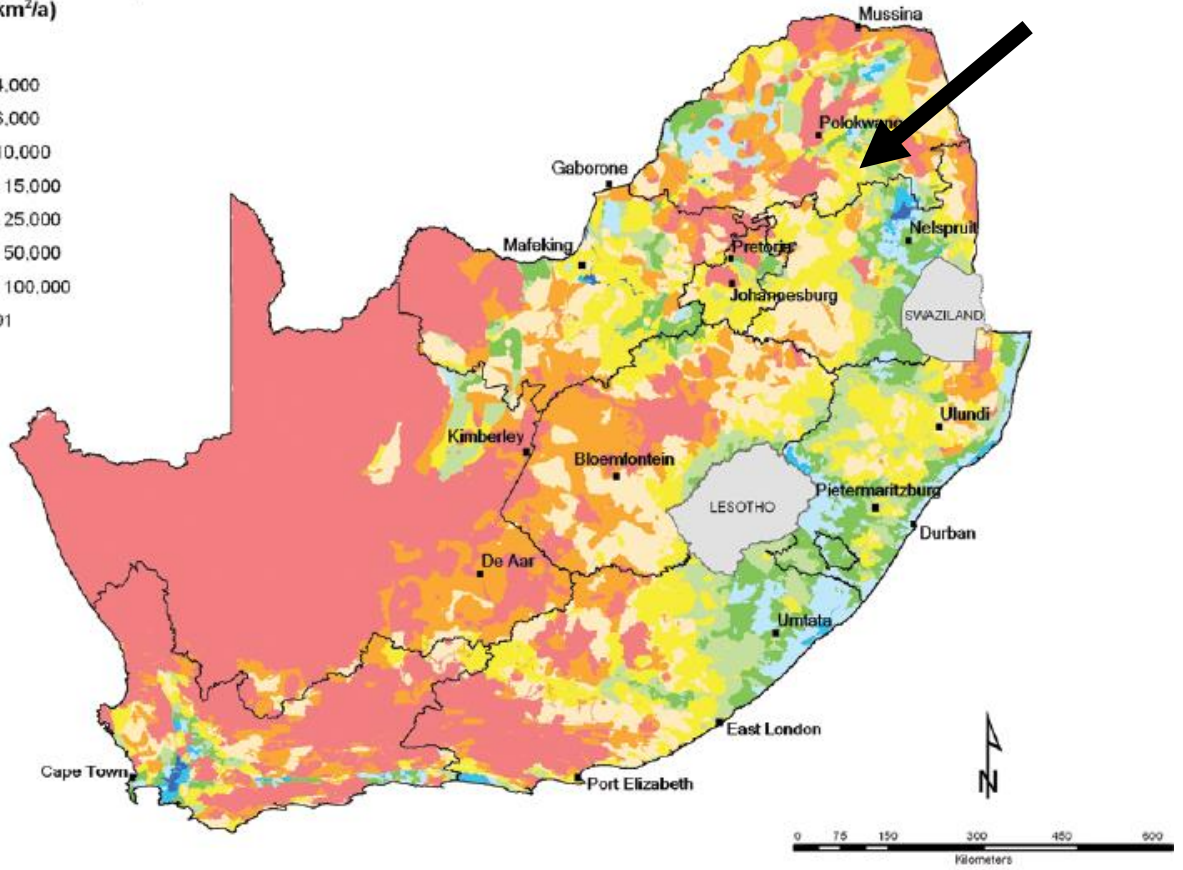
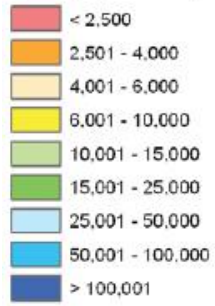


Figure 2.1: Utilisable groundwater exploitation potential for South Africa (DWA, 2010)

Yield Map

l/s

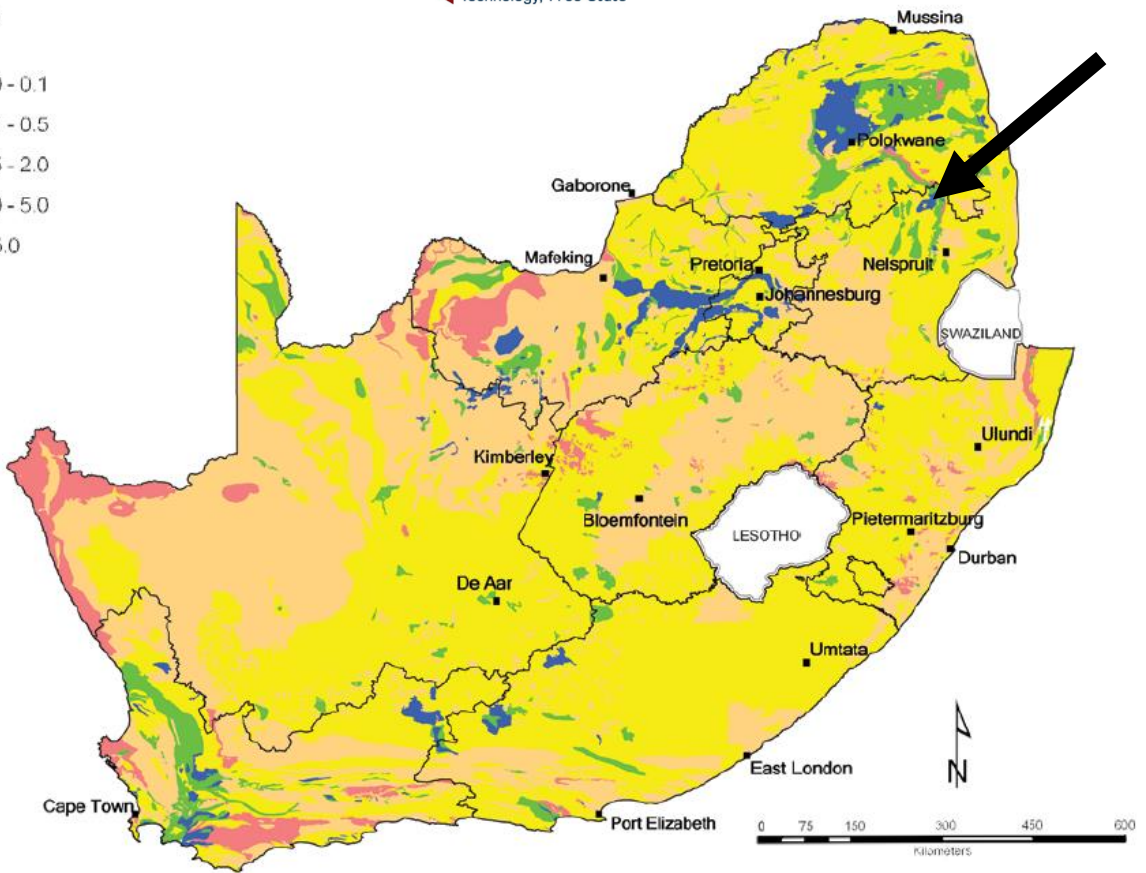
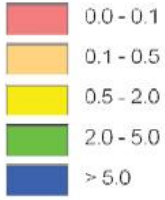


Figure 2.2: Yield map of South Africa (DWA, 2010)

Groundwater Use per Water Management Area

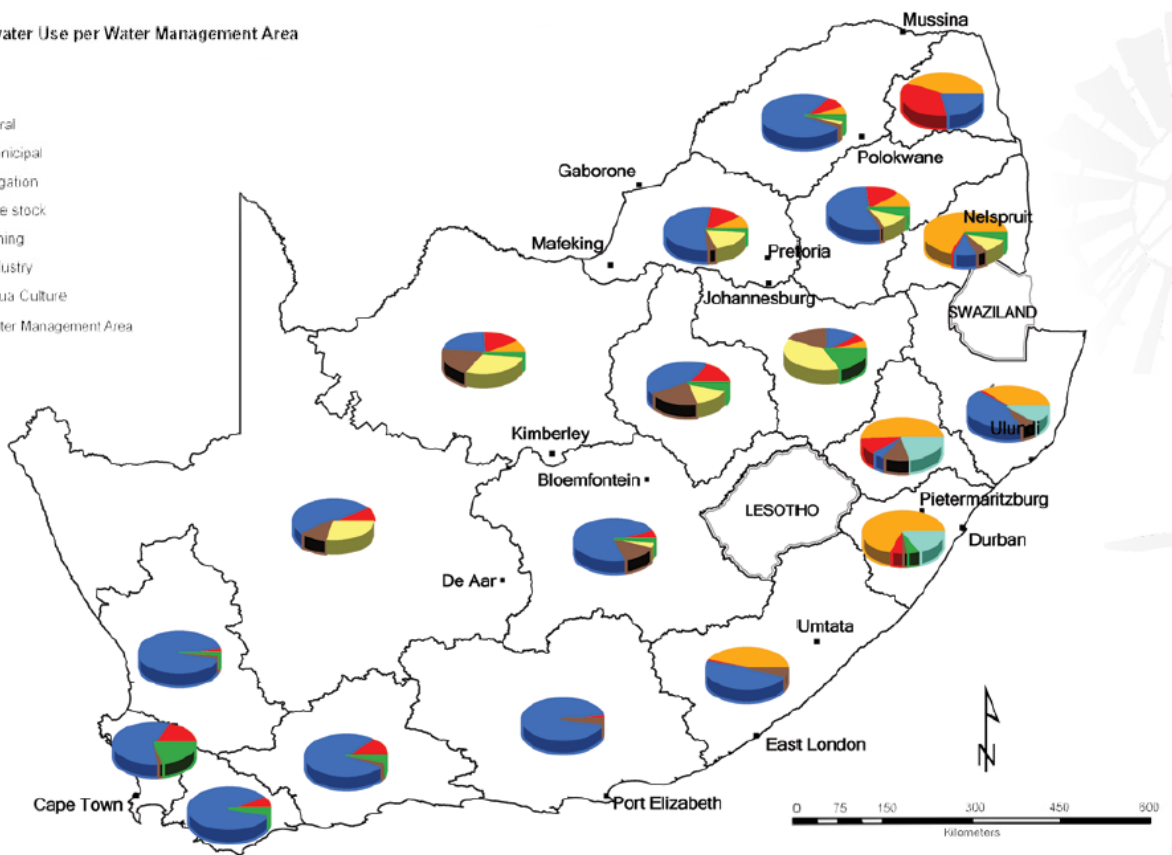


Figure 2.3: Total groundwater use per sector in water management area (DWA, 2010)

2.5.4 Natural groundwater quality

Groundwater is usually safe to drink without treatment, unlike surface water, because pathogens such as bacteria cannot survive for long periods of time in aquifers (DWS, 2016). However, it is normal for chlorination to be carried out as a precaution and as per the DWS guidelines.

Groundwater contains dissolved minerals, such as chloride, sodium, iron and others, in the same way as surface water (DWS, 2016). The natural dissolved mineral content of groundwater depends on a number of factors, including the aquifer material and the groundwater residence time (Harbison, 2007). Figure 2.4 indicates electrical conductivity (in mS/m) of natural groundwater in South Africa. In some cases, high levels of dissolved minerals cause groundwater to be brackish or even saline. In some (relatively rare) cases, naturally high levels of dissolved constituents, such as fluoride, arsenic or nitrate, render groundwater unfit to drink, even though it may taste perfectly fresh (DWA, 2010).

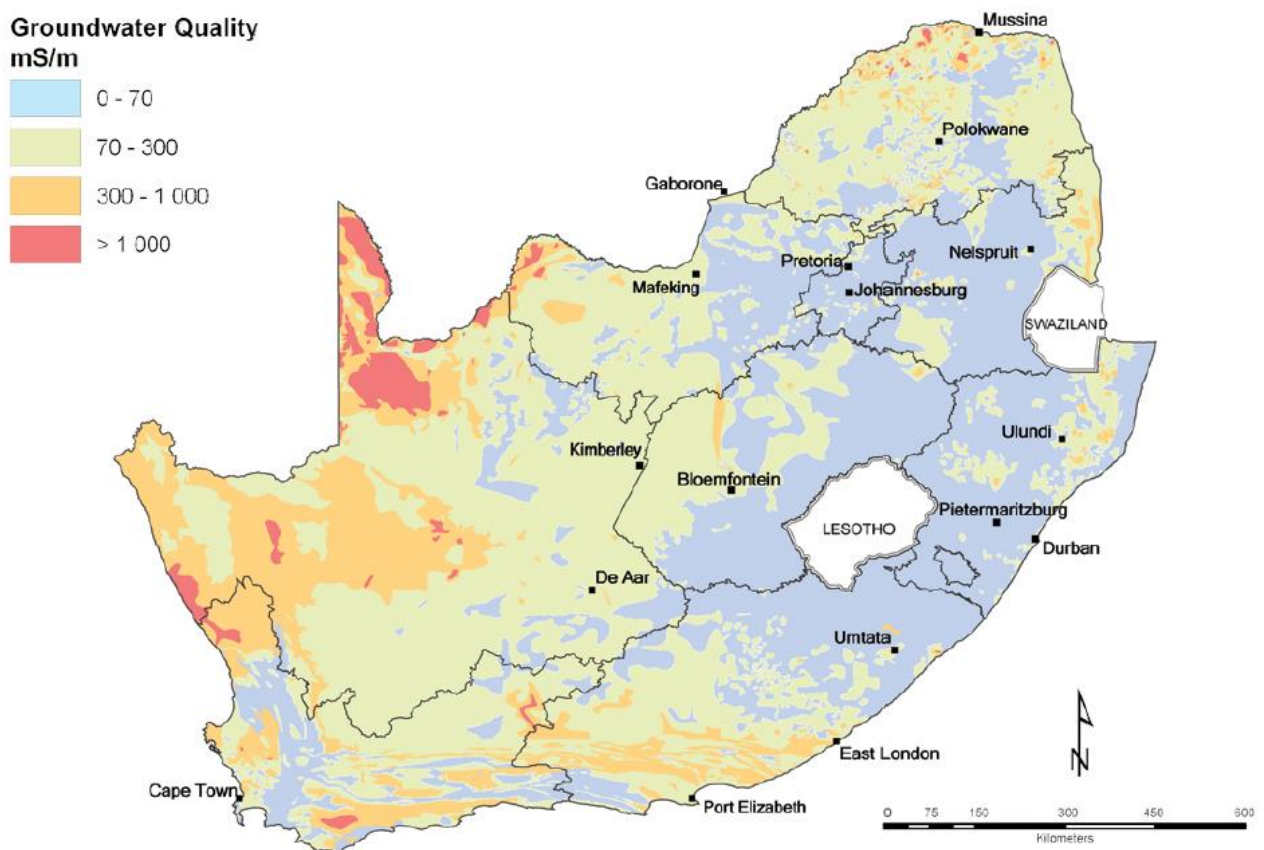


Figure 2.4: Electrical conductivity map of groundwater in South Africa (DWA, 2010)

Natural groundwater quality in SADC regions is influenced by geological formations, climate, land use, and hydrological processes (DWS, 2010, 2016). Understanding the baseline

groundwater quality is essential for sustainable water resource management, ensuring safe drinking water supply, and preserving aquatic ecosystems. According to Córdoba et al. (2010), the concept of water quality is directly related or dependent on the intended use of water. Thus, different uses of water, such as drinking, irrigation or for recreation, require different criteria (Córdoba et al., 2010).

Factors affecting groundwater quality:

- i. *Geological composition*: The geological formations in SADC regions play a significant role in determining groundwater quality. Different rock types and minerals may contribute dissolved substances, such as calcium, magnesium, iron, and various trace elements, to groundwater (Nur *et al.*, 2012).
- ii. *Climate and rainfall*: Climate variability influences groundwater recharge and affects the concentration of dissolved substances in groundwater. Seasonal variations in rainfall can cause fluctuations in groundwater quality, particularly in areas with limited dilution (Herring *et al.* 2002).
- iii. *Land use and anthropogenic activities*: Human activities, including agriculture, industry, mining, and waste disposal, can introduce contaminants into groundwater, such as nitrates, phosphates, heavy metals, and organic pollutants (Beamonte *et al.* 2007).
- iv. *Hydrological processes*: Groundwater flow paths, residence times, and mixing with surface water can impact groundwater quality. Interaction with surface water bodies or polluted sites may degrade natural groundwater quality (Hiscock, 2005).

The purpose of the guidelines for drinking water quality is the protection of public health and to improve access to potable water (World Health Organization, 2004). The World Health Organization's water guidelines are divided into four aspects: microbial aspects, chemical aspects, radiological aspects and the acceptability aspect, which all affect potable and irrigation water.

2.6 Hydrocensus

2.6.1 The need for a hydrocensus

Hydrocensus is a comprehensive and systematic data collection process focused on gathering essential hydrological information within a specific region (Wallingford, 2003). According to DWAF (2006), a hydrocensus is a task that involves gathering information on water features, water supply sources and sources of potential water pollution

in a particular area or region. The outputs of a hydrocensus should include a map that summarises and simplifies information on available water sources.

According to DWAF (2004), a hydrocensus aims to:

- i. identify details of water-related features and disused or abandoned boreholes;
- ii. identify features where water could collect in rainy periods; for example, borrow pits and quarries;
- iii. identify potential sources of contamination;
- iv. identify visible features and indicators for potential water contamination; and
- v. identify water sources and, where possible, indicate the flow rate and the quality of each water source.

A hydrocensus provides a comprehensive database of hydrological information, including surface water flows, groundwater levels, water quality, and water demand patterns. This wealth of data aids water resource planners in understanding water availability, distribution, and variability. By identifying areas with water stress and abundance, planners can develop strategies to allocate water resources more efficiently and effectively, ensuring a reliable and sustainable water supply for various users (UNECA, 2018).

Data from the hydrocensus serve as an evidence base for decision-makers in various sectors, such as agriculture, industry, urban planning, and environmental management (UNECA, 2018). The availability of accurate and up-to-date hydrological data empowers decision-makers to make informed decisions on water-related projects, infrastructure development, and policies that are both socially and economically viable (DWAF, 2006). Accurate hydrocensus data are essential for designing and effectively implementing water infrastructure projects (World Meteorological Organization, 2016).

2.6.2 Challenges and limitations

Hydrocensus involves extensive data collection efforts, including field surveys, remote sensing, and laboratory analysis (World Meteorological Organization, 2016). These activities can be time-consuming and resource-intensive, particularly in large and remote areas (Kummu and Varis, 2011). Accessing certain regions, such as rugged terrains, dense forests, or politically sensitive areas, may pose logistical challenges, leading to data gaps and limitations in understanding the complete hydrological picture. The challenges and limitations are listed and discussed below:

- i. *Resource constraints*: Conducting a hydrocensus requires significant financial and human resources. Smaller or economically challenged regions may face limitations in mobilising adequate resources for comprehensive data collection (Kummu and Varis, 2011). As a result, the hydrocensus coverage and frequency of data collection may be constrained, potentially impacting the accuracy and completeness of the hydrological dataset.
- ii. *Data accuracy and representativeness*: The accuracy of hydrocensus data depends on the quality of field measurements, laboratory analyses, and remote sensing data. Variability in measurement techniques, equipment, and expertise can introduce uncertainties in the dataset. Additionally, ensuring the representativeness of data is challenging, as hydrological conditions can vary significantly across space and time.
- iii. *Temporal variability*: Hydrological systems exhibit dynamic temporal variability due to seasonal changes, climate fluctuations, and human activities (Xie *et al.*, 2013). Conducting a hydrocensus at a specific time may not fully capture these temporal variations.
- iv. *Complexity of hydrological systems*: Hydrological systems are complex and interconnected, making it challenging to accurately isolate individual hydrological processes (Dawes *et al.*, 2012). The presence of multiple water sources, such as surface water, groundwater, and wetlands, along with their interactions, requires sophisticated modelling and analysis techniques to understand their contribution to the overall hydrological balance (Cuthbert *et al.*, 2013).
- v. *Data management and sharing*: Handling and managing vast volumes of hydrocensus data can be a formidable task. The lack of standardised data formats, data-sharing protocols, and data accessibility may hinder effective data integration and collaboration among stakeholders (Beven, 2012).

2.7 Water quality standards

Legislation and Regulatory Framework: The National Water Act of 1998 and the National Environmental Management: Water Quality Act of 1999 serve as the primary legislative frameworks for water quality management in South Africa. The DWS is responsible for implementing these laws and setting water quality standards. The legislation outlines water resource classes and the associated water quality objectives, as well as the roles and responsibilities of stakeholders involved in water quality management.

2.7.1 Water resource classes and objectives

South Africa classifies water resources into different categories, each with specific water quality objectives (Makoe, 2018). The water resource classes range from 0 to 5, with Class 0 representing water sources of high ecological significance or protected areas, and Class 4 representing poor quality water with limited use potential (SANS 241-1:2015). The water quality objectives are based on key parameters such as nutrient levels, microbiological indicators, and toxic substances, with the aim of safeguarding water quality for various uses, including drinking water, recreational activities, and industrial processes.

2.7.2 Monitoring parameters and frequency

The DWS monitors various water quality parameters to assess compliance with the prescribed water quality objectives (South African Bureau of Standards [SABS], 2015). Commonly monitored parameters include pH, dissolved oxygen, temperature, turbidity, nutrients (nitrate and phosphate), heavy metals (lead and mercury), faecal coliforms, and other microbiological indicators. The frequency of monitoring varies depending on the water resource class, potential pollution sources, and the overall water quality status (Kotze *et al.*, 2021).

2.7.3 Parameters for assessment

The South African water quality standards consider a wide range of physical, chemical, and biological parameters for assessment. Some of the key parameters in accordance with the SANS 241-1:2015 potability standards include:

- i. *Microbiological indicators*: These include the presence of coliform bacteria and *E. coli*, which are indicative of faecal contamination and potential health risks for human consumption and recreational water use.
- ii. *Physical parameters*: Temperature, turbidity, and colour are monitored to assess the aesthetic quality and potential environmental impacts of the water.
- iii. *Chemical parameters*: The South African water quality standards set maximum allowable concentrations for various chemical constituents such as pH, dissolved oxygen, nutrients (for example, nitrate, nitrite, ammonia, and phosphate), heavy metals (for example, lead, cadmium, and chromium), and organic pollutants (e.g., pesticides and volatile organic compounds).

iv. Nutrient load limits: The South African water quality standards set limits on nutrient concentrations, such as total nitrogen and total phosphorus, to control eutrophication and algal blooms in water bodies.

v. Dissolved solids: Parameters such as electrical conductivity and total dissolved solids help in assessing water salinity, particularly in arid and semi-arid regions.

If consumers' health is to be maintained, the water quality of residential water used for human consumption and food preparation must be safe to use. Water quality is assessed using the most recent SANS 241-1:2015 potability criteria, as well as the second edition of the Department of Health and the Water Research Commission's Quality of Domestic Water Supplies (1998). This study makes it easier to evaluate water based on five water quality classes:

- i. *Class 0 (Blue)*: Ideal water quality. Suitable for lifetime use.
- ii. *Class 1 (Green)*: Good water quality. Suitable for use. Rare instances of negative effects.
- iii. *Class 2 (Yellow)*: Marginal water quality – conditionally acceptable. Negative effects may occur.

According to SANS 241-1:2015 Ed. 2 (SABS, 2015), this water is classified as Class 3 (poor water quality) due a high total hardness value. This is very hard water; the maximum allowable consumption period is seven years as sensitive individuals may be affected (Bengeza, 2019). Scaling may form in operating systems:

- i. Sensitive groups.
- ii. *Class 3 (Red)*: Poor water quality. Unsuitable for use without treatment. Chronic effects may occur.
- iii. *Class 4 (Grey)*: Dangerous water quality. Totally unsuitable for use. Acute effects may occur.

Table 2.1 and Table 2.2 shows the chemical testing requirements for domestic water used for human consumption and food.

Table 2.1: Compliance requirements as per SANS 241-1:2015 Ed. 2 – Drinking water: physical, aesthetic, operational and chemical determinants

SANS 241-1:2015 Ed. 2 – Drinking water			
Determinant	Risk	Unit	Std limits
pH @ 26 °C	Operational	pH Units	≥5 to ≤9.7
Conductivity @ 25 °C	Aesthetic	mS/m	≤ 170
Total alkalinity as CaCO ₃	–	mg/l	–
Chloride as Cl	Aesthetic	mg/l	≤ 300
Nitrate as N ^{oT}	A–H	mg/l	≤ 11
Fluoride as F	C–H*	mg/l	≤ 1.50
Turbidity	Operational	NTU	≤ 1
	Aesthetic	NTU	≤ 5
Total dissolved solids	Aesthetic	mg/l	≤ 1 200
pH _s at 20 °C ^b	–	–	–
Langelier Index @ 20 °C*	–	–	–0.5 to 0.5
Ca hardness as CaCO ₃	–	mg/l	–
Mg hardness as CaCO ₃	–	mg/l	–
Aluminium as Al	Operational	mg/l	≤ 0.30
Arsenic as	C–H*	mg/l	≤ 0.01
Boron as B**	–	mg/l	≤ 0.30
Calcium as Ca	–	mg/l	–
Cadmium as Cd	C–H*	mg/l	≤ 0.003
Cobalt as Co	–	mg/l	–
Chromium as Cr	C–H*	mg/l	≤ 0.05
Copper as Cu	C–H*	mg/l	≤ 2
Iron as Fe	C–H*	mg/l	≤ 2
	Aesthetic	mg/l	≤ 0.30
Mercury as Hg	C–H*	mg/l	≤ 0.006
Potassium as K	–	mg/l	–
Magnesium as Mg	–	mg/l	–
Manganese as Mn	C–H*	mg/l	≤ 0.40
	Aesthetic	mg/l	≤ 0.10
Molybdenum as Mo**	–	mg/l	≤ 0.07
Sodium as Na	Aesthetic	mg/l	≤ 200
Nickle as Ni	C–H*	mg/l	≤ 0.07
Phosphorous as P**	–	mg/l	≤ 5
Sulphate as SO ₄	A–H	mg/l	≤ 500
	Aesthetic	mg/l	≤ 250
Antimony as Sb	C–H*	mg/l	≤ 0.02
Selenium as Se	C–H*	mg/l	≤ 0.04
Silicon as Si	–	mg/l	–
Vanadium as V	–	mg/l	–
Acute health	Aesthetic	mg/l	≤ 5

*Chronic health.

**Norm from source other than SANS 241-1:2015 Ed. 2.

^aLow pH values can result in structural problems in the distribution system.

^bIndicator of unacceptable microbial water quality, could be tested instead of E. coli, but is not the preferred indicator of

Table 2.2: SANS 241-1:2015 Ed. 2 – Drinking water: microbiological determinants

SANS 241-1:2015 Ed. 2 – Drinking water			
Microbiological determinants			
Determinant	Risk	Unit	Limits
E. coli ^a or faecal coliforms ^b	A–H*	Count/100 mℓ	Not detected
Total coliforms ^d	Operational	Count/100 mℓ	≤ 10

*Acute health.

^aDefinitive, preferred indicator of faecal pollution.

^bIndicator of unacceptable microbial water quality, could be tested instead of E. coli, but is not the preferred indicator of faecal pollution. Also provides information on treatment efficiency and after growth in distribution networks.

^dProvides information on treatment efficiency and after growth.

2.8 Electroseismic surveying

The electroseismic method, also known as the electrokinetic survey method, is a geophysical approach that seeks to offer the depth to groundwater as well as an estimate of the permeability and thus yield that could be expected from a well drilled into the aquifer (Beamish, 1999). Locating geological features with this method in the field is of outmost importance when siting large quantities of water supply (Beamish, 1999).

The electroseismic approach is connected to the well-known phenomenon known as streaming potential, in which flowing subterranean water generates a voltage that may be measured on the ground surface (Beamish, 1999). Seismic waves, typically p-waves, cause relative motion between the rock matrix and the fluid within the rock pores, resulting in electroseismic phenomena. Ionic fluid flows through rock cracks, with cations preferentially adhering to the capillary walls, so that the applied pressure and consequent fluid flow relative to the rock matrix separates the cations and anions, forming an electric dipole (Dejam et al., 2014). This is referred to as the electroseismic effect.

2.8.1 Principles of electroseismic surveying

Electroseismic surveying is based on the principle that when an electric field is applied to the ground, it induces electrical currents within the subsurface materials (Dejam *et al.*, 2014). These currents generate mechanical vibrations or seismic waves due to the electrokinetic effect. Geophones or other seismic receivers are used to detect these seismic waves, providing information about subsurface properties and structures.

Equipment used in electroseismic surveying (Beamish, 1999):

- i. *Electrodes*: The survey employs pairs of electrodes that are placed on the ground surface. One electrode injects the electric current into the ground, while the other serves as a reference point.
- ii. *Seismic receivers*: Geophones or other seismic sensors are used to detect the seismic waves generated by the electrokinetic effect. These receivers are typically deployed in an array to record data at various points.
- iii. *Data acquisition system*: A data acquisition system records the signals received by the seismic receivers, allowing the creation of seismic waveforms and the subsequent data analysis.
- iv. *Power source*: An external power source, such as batteries or generators, supplies the electric current to the electrodes.

2.8.2 Applications of electroseismic surveying

- i. *Subsurface imaging*: Electroseismic surveying is used to investigate the subsurface structure, such as the presence of geological faults, bedrock depth, and the distribution of geological formations.
- ii. *Hydrogeological studies*: The method is employed in groundwater exploration to identify potential aquifers and characterise their properties.
- iii. *Environmental studies*: Electroseismic surveying is used in environmental investigations to assess soil properties, monitor soil moisture, and detect potential contamination from subsurface sources.

2.8.3 Advantages of electroseismic surveying

- i. *Non-invasive*: Electroseismic surveying is a non-invasive method, minimising disturbance to the natural environment and reducing the need for drilling.
- ii. *Cost-effective*: Compared to other geophysical methods, electroseismic surveying can be a cost-effective option for subsurface exploration.
- iii. *High resolution*: The method provides high-resolution data, allowing for detailed imaging and interpretation of subsurface features.
- iv. *Rapid data collection*: Electroseismic surveys can cover large areas relatively quickly, making them suitable for regional investigations.

v. Versatility: Electro seismic surveying can be adapted to various terrains and subsurface conditions, providing valuable information in different geological settings (Beamish, 1999).

2.9 Electromagnetic subsurface exploration

Electromagnetic subsurface exploration is a geophysical technique used to investigate the subsurface by measuring the electromagnetic response of geological structures and materials (Roux, 1980). This non-invasive method is widely applied in various fields, including mineral exploration, groundwater studies, environmental assessments, and engineering investigations.

Electromagnetic subsurface exploration is based on the principle that subsurface materials and structures have different electrical conductivities and dielectric properties. When an electromagnetic field is induced in the ground through a transmitter coil, it generates secondary electromagnetic fields in the subsurface (Ntusko Business Enterprise, 2022). The interaction between the primary and secondary fields results in measurable electromagnetic responses, which are recorded by receivers at the surface. The analysis of these responses provides valuable information about the subsurface properties and structures.

An EM-34-3, a horizontal loop frequency domain electromagnetic sensor, is used to test the apparent conductivity of the underlying geology. The CMD DUO EM conductivity meter from The Electromagnetic Instrument is intended for surveys with varying depth ranges between 15 and 60 feet (Acmet Consulting, 2020). The system employs a contactless approach that enables quick conductivity and in phase measurements in all field circumstances, including extremely dry and frozen ground. According to Ntusko Business Enterprise (2022) the DUO is a single depth, two-person controlled probe with good temperature stability. This way, it makes for high resolution depth graded mapping, as well as imaging of sections possible and useful for a wide range of walking and moving applications. The 20 m and 40 m cable spacing with horizontal and vertical coil configurations was used to investigate the various depths of the resistive terrains by measuring small changes in conductivity, that is 5–10 mS/m.

Applications of electromagnetic subsurface exploration:

- i. *Mineral exploration:* Electromagnetic subsurface exploration is widely used in mineral exploration to detect conductive ore bodies and map geological structures associated with mineralisation.
- ii. *Groundwater studies:* The method aids in groundwater investigations by mapping aquifer boundaries, detecting potential water-bearing formations, and assessing groundwater quality.
- iii. *Environmental assessments:* Electromagnetic surveys are employed in environmental investigations to detect subsurface contaminants, identify buried waste materials, and assess groundwater pollution.
- iv. *Engineering and geotechnical studies:* This technique is used in engineering projects to evaluate subsurface soil and rock properties, map geotechnical features, and assess the integrity of infrastructure.

PHYSIOGRAPHIC, HYDROGEOLOGICAL AND WATER DEMAND MANAGEMENT SETTING

3.1 Catchment Description

3.1.1 Morphology

The TCLM is a municipality located in the north-western region of the province of Mpumalanga in the Ehlanzeni district. It shares its northern boundaries with Limpopo. The municipality is on the Lowveld escarpment of Mpumalanga, with an average elevation of 1 400 m above sea level and with altitudes varying from 600 m to 2 100 m. The municipality's main places include Graskop, Mashishing, Sabie and Ohrigstad. It is located in the Eastern Bushveld complex hydrogeological region of the province of Mpumalanga.

Table 3.1 indicates that the elevation of the area varies between 600 and 2 200 m above sea level. The larger part (63%) of the area is situated between 1 201 m and 1 800 m above sea level.

Table 3.1: Elevation of the study area

Class	Area (ha)	Percentage
Level (0–3%)	49 162	8.1
Moderate (4–5%)	207 821	34.5
Steep (16–25%)	129 609	21.5
Very steep (25+%)	216 760	35.9

Physiographically, the study area consists of steep terrain with elevations ranging between 1 120 mamsl and 1 480 mamsl; the landscape generally slopes in a north-eastern direction, draining towards the Blyde River Canyon (Botha et al., 2018). The area is underlain by moderate to deep clayey loam that is covered by mesic Highveld grassland.

The majority of the area has steep to very steep slopes (57.4%), thus potentially not fit for urbanisation. Moderate and flat slopes occur in 42.6% of the area.

The study area falls within soil mapping Unit 3 of the Institute for Soil, Climate and Water, the broad natural homogeneous soil zone regions (Kotze et al., 2021). This assigns a soil depth of 900 mm to 1 200 mm, of which 60% of the soil consists of sand and clay and 30% of sandy,

clay loam, which typically allow for a slow drainage rate. Figure 3.1 shows the soil classification derived from the Soil Map of the World (FAO, 2022) and drawn using the Soil and Water Assessment Tool.

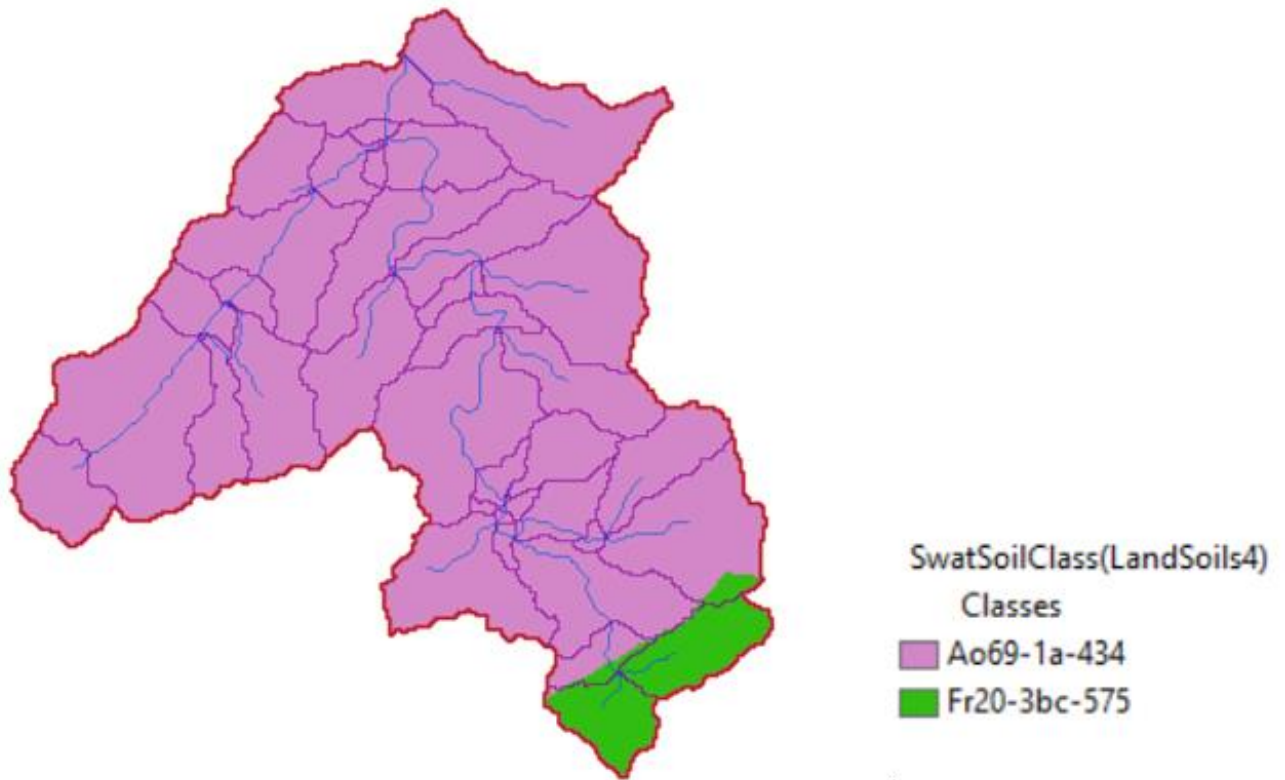


Figure 3.1: Soil classification derived from the Soil Map of the World (FAO, 2022)

According to the CSIR Köppen-Geiger map, based on the South African Weather Services temperature and precipitation data from 1985 to 2005, the climate in this area is classified as warm temperate, with dry winters and, warm summers.

3.1.1.1 Climate and rainfall

The TCLM falls within the summer rainfall region with the rainy season, normally lasting from October to March. The average mean annual precipitation for the Thaba Chweu area varies between approximately 500 mm to 1 700 mm, with averages varying from approximately 450 mm to 550 mm on the eastern areas, to 1 500 mm at the escarpment and higher lying areas (DWAF, 2000). The area falls within a mist belt.

3.1.1.2 Vegetation

The area is in the Bushveld region, which is characterised by deciduous tall, open bush (parkland) with a well-developed tall grass layer, occurring on low to high mountains, with undulating plains, mainly at the base and on the lower to middle slopes of the north-western escarpment.

3.1.1.3 Land use

The study area mainly comprises of protected zones due to the biodiversity – the Blyde River Canyon, Three Rondavels and the Blyde River. In addition, the study area is overlain by housing developments, forestry and agriculture.

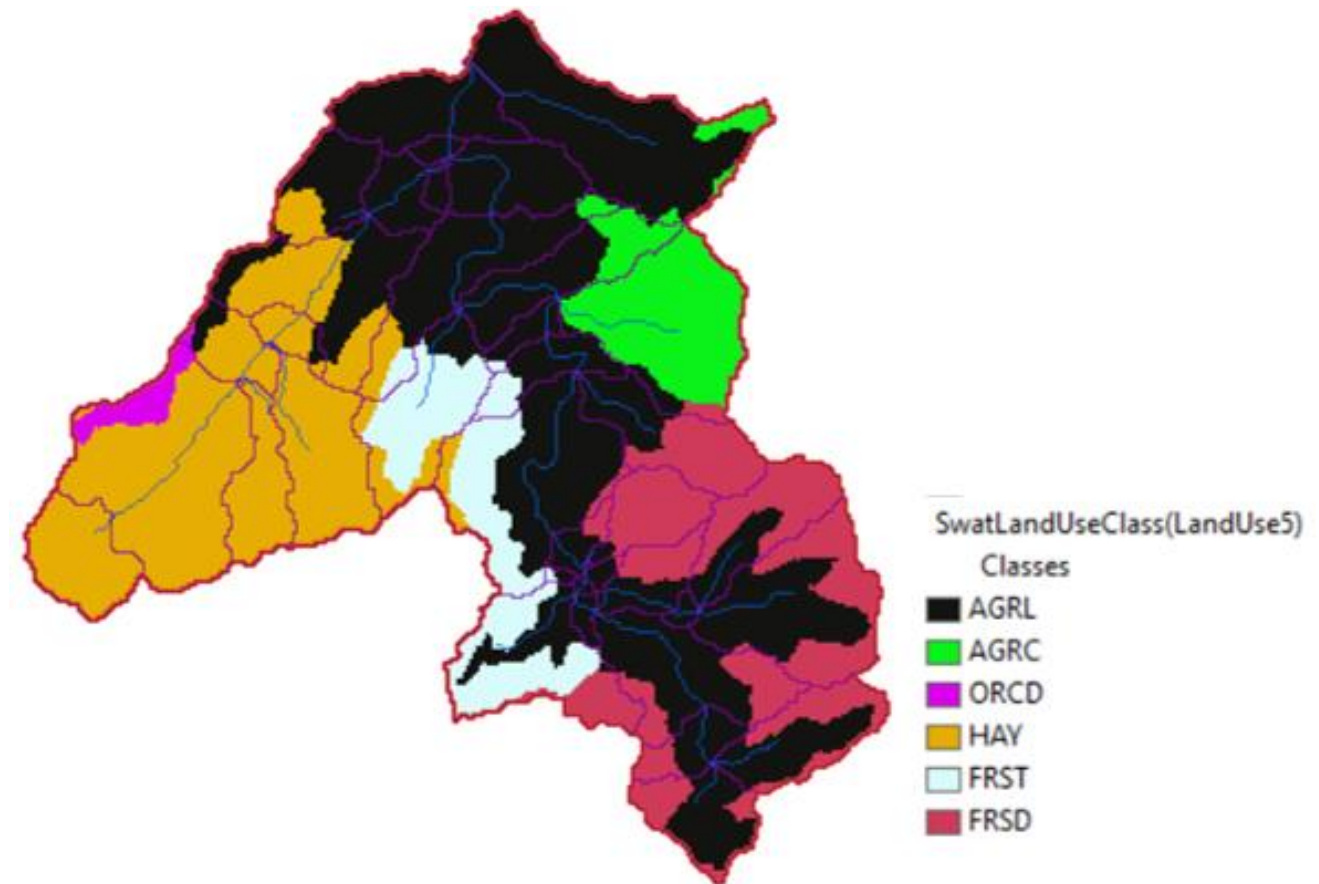


Figure 3.2: Land use classification derived from the Soil Map of the World (FAO, 2022).

3.1.2 Geology and hydrogeological setting

3.1.2.1 General geology

The study area is underlain by grey to greyish blue and pink, compact, and poorly bedded dolomite and limestone with chert layers (Vmd – dolomite and limestone) of the Malmani Subgroup of the Chuniespoort Group in the Transvaal Supergroup. Large sections of the dolomite and limestone are overlain by quaternary surficial deposits, including alluvium and scree (Q – alluvium and scree). Green, fine- to medium-grained diabase (Vdi – fine of the Vaalian era), and fine-grained dolerite (Jd – fine to grained diabase dolomite of the Jurassic era) dykes and sills are present in and around the villages (Kotze et al., 2021).

Prominent north-east and south-west striking lineaments are indicated on the geological map. A characteristic feature of the regional geology is the network of intersecting dykes. These

are narrow, vertical, intrusive formations subdividing the dolomite into various groundwater compartments. Leakage through dykes is likely to occur. The rate of leakage is controlled by the hydraulic gradient and the permeability of the dyke (Botha et al., 2018).

The Malmani Subgroup forms part of the Late Archaean to Early Proterozoic (~2 650–2 000 Ma) Transvaal Supergroup (Botha et al., 2018), which overlies the Archaean (~3 500–3 000 Ma) basement greenstones and granitites of the Kaapvaal Craton, which outcrop to the north and east of the study area. The Transvaal Supergroup stratigraphy consists of the Black Reef Formation, overlain by the Chuniespoort Group and overlain by the Pretoria Group and Postmasburg Group in the Northern Cape. The Malmani Subgroup forms the major component of the Chuniespoort Group, and is

- i. underlain by 20 m to 50 m thick, clean quartzites (quartzitic sandstones), lower conglomerates and thin subordinate shales of the Black Reef Formation – with the contact between the Malmani Subgroup and Black Reef Formation being comprised of alternating sandstone and shale (Botha et al., 2018; Walraven, 1989); and
- ii. overlain by the banded ironstones of the Penge Formation, mudstones, dolomites, and limestones of the Duitschland Formation (both upper Chuniespoort Group), and ultimately the 6–7 km thick shales (with interlayered sandstone and volcanic units) of the Pretoria Group – with a regional unconformity existing at the Chuniespoort Group (Botha et al., 2018).

The geological maps of Leroro, Matibidi and Moremela are shown in Appendix B. Appendix C depicts the harvest potential of the study area of Matibidi, Leroro and Moremela.

Table 3.2 shows the simplified regional stratigraphy of the study area.

Table 3.2: Simplified regional stratigraphy and hydrostratigraphy of the Malmani Subgroup dolomite study area

Stratigraphy					Hydrostratigraphy	
Age (Ma)	Supergroup	Group	Formation	Description	Unit	
Quaternary to recent (-2.5 to 0)	Various unclassified alluvial deposits			Dolomitic gravel and gravelly quartzitic sand	Minor to major primary aquifer	
Unconformity						
-2 060	Bushveld complex			Felsic to ultramafic layered igneous intrusion	Aquiclude	
Unconformity						
2 650–2 000	Transvaal	Pretoria	Various	Sandstones and shales	Aquitard	
		Unconformity				
			Duitschland	Mudstone, dolomite and limestone		
			Penge	Banded ironstone		
			Malmani Subgroup	Frisco	Stromatolite-bearing dolomites, limestones and chert (with minor shale and quartzite)	Major fractured karst aquifer
				Eccles		
				Lyttleton		
				Monte Cristo		
	Oak Tree					
Unconformity						
		-	Black Reef	Quartzite	Minor to moderate fractured aquifer	
Unconformity						
2 800–2 700	-	Wolkberg	Protobasinal sedimentary and volcanic rocks		Aquitard	
Unconformity						
3 500–3 000	various	KAAPVAAL CRATON Archaean basement granitoids and greenstones			Basement aquicludes	

3.1.2.2 Hydrogeological setting

The study area falls within the B60D quaternary subcatchment, of the Olifants WMA, as defined by the water research commission (Midgley et al., 1994).

Dolomite is a magnesium-rich calcium carbonate rock that can dissolve in the presence of water combined with carbon dioxide (for example, carbonic acid, H_2CO_3), which generally happens naturally as part of weathering processes (DWA, 2010). This dissolution weathering can result in subsurface solution cavities or cave systems and surface sinkholes or dolines forming, with the resulting dissolution landscape being known as karst terrain.

Any local, regional fault, fracture systems, or fracturing and hydrothermal alteration adjacent to dolerite intrusions, can further enhance dissolution and karst development. These subsurface dissolution systems form excellent secondary porosity features, along which strong-flowing groundwater can occur, often forming high-yielding karst aquifer systems, provided sufficient recharge is present, for example the escarpment in the vicinity of Pilgrim's Rest.

The Malmani Subgroup dolomites within the study area form such a fractured dolomitic karst aquifer, with sustainable borehole yields generally ranging from 2–5 l/s, and potentially > 10 l/s per borehole. In the vicinity of large regional fractures or dolerite intrusions, these yields are significantly higher than most other rock formations in the surrounding region (Botha et al., 2018). An example of the potential high yields from the Malmani Subgroup fractured dolomitic karst aquifer (other than the wide range of high yielding boreholes already drilled) is the ~5 km long tunnel that drains the Malmani Subgroup in the vicinity of a (now ceased) gold mining operation at Lydenburg, which yields ~500 l/s and supplies water to Sabie south of the study area (Botha et al., 2018).

Wetlands, pans, springs, sinkholes, and a lack of surface drainage may also be indicative of subsurface groundwater-bearing solution cavities. Generally, the Malmani Subgroup dolomite karst aquifers are unconfined to semi-confined, with compartmentalisation by dolerite dykes a possible effect (if the dykes are large and extensive enough) due to the dykes acting as aquitards or barriers to groundwater flow (Botha et al., 2018). The contact zones between the dolomite formations and dolerite dykes are usually fractured; however, together with any other faults and fractures, this leads to preferential dolomite dissolution and the development of groundwater flow paths in the area.

Higher yielding boreholes are likely to occur some distance away from thicker dykes (40–80 m from the dyke contact) and closer to thinner dykes (within 10 m from the dyke contact) (DWAF, 2006). This is likely a result of either metamorphism from the dyke's intrusion, resulting in the formation of low permeability, non-brucite altered marble-like material immediately adjacent to it, or the presence of low permeability, sheared mylonites and shales (if dolerite intrusion occurred along a pre-existing fracture). Higher yielding zones may also be present within the Malmani Subgroup dolomites, and were overlain by thick, saturated, gravelly to sandy alluvium, for example as present within the Ohrigstad River Valley.

The geological and hydrogeological features responsible for dolomites being such good aquifers (as described, namely unconfined to semi-confined in nature, and surface to depth

dissolution features with high transmissivities and yields) also result in them being highly vulnerable to anthropogenic contamination. The Malmani Subgroup dolomite aquifers within the study area have been nationally classified as major aquifers that are also highly vulnerable and, hence, highly susceptible or at high risk to groundwater contamination.

3.1.2.3 Water sources and drainage regions

The TCLM has four river systems: The Elands River, the Blyde River, the Sabie River Timbavati River and Steelpoort River. Flowing from the Highveld plateau over the Drakensberg escarpment towards the Indian Ocean. The sizes of the drainage areas of the respective rivers are presented in Table 3.3.

Table 3.3: Thaba Chweu Local Municipality drainage areas (Botha et al., 2018)

Source			Area (km ²)	Percentage (%)
Primary	Secondary	Tertiary		
Elands River	Elands River	Elands River	56 987.1	9.4
Elands River	Elands River	Nels River	82 315.3	13.6
Sabie River	Sabie River	Sabie River	99 446.2	16.5
Sabie River	Sabie River	Sand River	11 150.2	18
Blyde River	Blyde River	Blyde River	139 094.2	23.1
Steelpoort River	Steelpoort River	Steelpoort River	45 425.3	7.5
Steelpoort River	Steelpoort River	Watervals River	160 668.0	26.6
Timbavati River	Timbavati River	Timbavati River	8 264.4	1.4

Table 3.4: Available dams and their capabilities in the Thaba Chweu Local Municipality (Botha et al., 2018)

Dam	Primary drainage region river	Capacity (million m ³)
Blyderivierspoort	Olifants River	55.2
Buffelskloof	Olifants River	5.3
Kwena	Crocodile River/Komati River	161.0
Ohrigstad	Olifants River	13.5
Witklip	Crocodile River/Komati River	12.3

3.1.2.4 Natural drainage of the three villages

The natural drainage of Leroro village is from south to north towards the Blyde River, north-east to south in Moremela towards the Moremela Stream, and east to south in Matibidi village. The Blyde River and its tributaries are the major surface waters of the northern regions. The river flows northeast of the villages forming a confluence with the Treur River. The Blyde River enters the Blyde River Canyon which ends at the Blyderivierspoort Dam. The Moremela

Stream and Kadisi River flowing through Moremeia and Matibidi villages enter the Blyde River upstream of Bourke's Luck Potholes and the Blyderivierspoort Dam.

The highest mountain central to the three villages area is the Three Sisters (1 703 m). The highest areas surrounding Leroro (from south-west to south-east) are Boromatshiwe (1 486 m) and Shabelang (1 463 m); surrounding Moremela (from north-east to west) are Ishirelang (1 672 m) and Ngwetsinshiroje (1 376 m), and near Matibidi (from north to east) are Apara (1 327 m) and Seuwe (1 462 m). The three villages are mostly situated at approximately 1 300 m high. The natural drainage of the Matibidi region is thus easterly towards the rivers. Landmarks in the region include the Three Rondavels situated between the three villages, the Three Rondavels situated north of the villages next to the Blyderivierspoort Dam, Mariepskop situated north-east of the villages and the Blyde River Canyon situated east of the villages.

3.1.2.5 Drainage and sanitation system

The local high points in the villages coincide with the locations of reservoirs in these villages. Existing on-site sanitation consists mainly of unlined ventilated and unventilated pit latrines. The camp of the South African Police Service in Leroro, however, has waterborne sewage reticulation with oxidation ponds for treatment of effluent before discharge. The public hospital in Matibidi A has an activated sludge treatment work to treat sewage effluent from the hospital. However, neither were assessed in this study. The hydrogeological setting for the study area is summarised in Table 3.5.

Table 3.5: Quaternary subcatchment hydrological conditions (Midgley et al., 1994 [WRC Report No. 298/1.1/94])

Sub-catchment	Catchment area in km ²	Mean annual precipitation (mm/a)	Mean annual evaporation range (mm/a) (Witthüser et al., 2009)	Mean annual run-off range (mm/a)	Groundwater recharge (mm/a) (Vegter, 1995)
B60D	244	700–1 000 Average: 757	1 300–2 000	200–500	65–95 Mean: 82.36

The aquifer system underlying the study area is classified as a major aquifer that is most vulnerable and highly susceptible. This is an indication as to how critical it is to protect this dolomitic aquifer. Major aquifers are defined as a highly permeable geological formation that is a high-yielding system of good water quality. Except for those strongly absorbed or easily changed in many pollution scenarios, the aquifers are most susceptible to many pollutants.

Highly susceptible aquifers represent both the aquifer's susceptibility and its relative significance in terms of its classification as a qualitative indicator of how easily a groundwater body may be potentially contaminated by human activities.

3.1.3 Demographics

The departure point for the updated population projections for TCLM is the census conducted by Statistics South Africa [Stats SA] (2011) based on a sample of households, because this is the most recent source of official population statistics (not considering the 2016 Community Survey) and the municipal head count that is available. The 2011 census estimated the population of the study area to have been 15 753. The current 2021 Stat SA database and municipal database estimates the population to be at 29 111 people.

Based on the analyses that were done for the TCLM 2016 Water Services Master Plan, it can be assumed that the rural complex (the study area) accommodated 29,6% of the municipal population, or 29 111 people, as indicated in Table 3.6. The household size analysis that was done at that time provides sufficient evidence to assume that the average household size in the study area was 3.3 people per household.

To determine the actual number of households within the project area, an updated Stats SA 2021 survey was used. From this count, the total number of households in the northern areas was 8 752 households or 29 111 people, using a number of 3.3 people per household (average Stats SA figure) and a growth rate of 1.86% proposed by Stats SA. Table 3.6 shows a summary of the population.

Table 3.6: Demography of the northern areas

Demographics for northern areas					
Settlement	Source	Year	Population	Stands	People per household
Matibidi	Stats SA	2011	6,476	1,864	3.5
	DWS WSDP*	2016	11,305	2,261	5
	Updated Stats SA Population	2021	14,801	4,366	3.39
Leroro	Stats SA	2011	4,165	1,219	3.4
	DWS WSDP	2016	6,690	1,338	5
	Updated Stats SA Population	2021	6,857	2,075	3.31
Moremela	Stats SA	2011	5,112	1,395	3.6
	DWS WSDP (Moremela SP1)	2016	6,345	1,269	5
	Updated Stats SA Population	2021	7,453	2,311	N/A
Total	Stats SA	2011	15,753	4,478	3.5
	DWS WSDP	2016	24,340	4,868	5
	Updated Stats SA Population	2021	29 111	8,752	3.3

*Water Service Development Plan

3.1.4 Income and poverty profile

To determine the percentage of poor households in the northern area, the StatsSA annual household income table was used. Based on the Indigent Policy (Department: Provincial and Local Government, 2012), a household is declared indigent or poor if the total monthly earnings are less than twice the state pension fund. Thus, 11.2% of the population of the northern areas can be declared as indigent.

Figure 3.3 and Table 3.7 shows the income profile of the study area for 2020/2021.

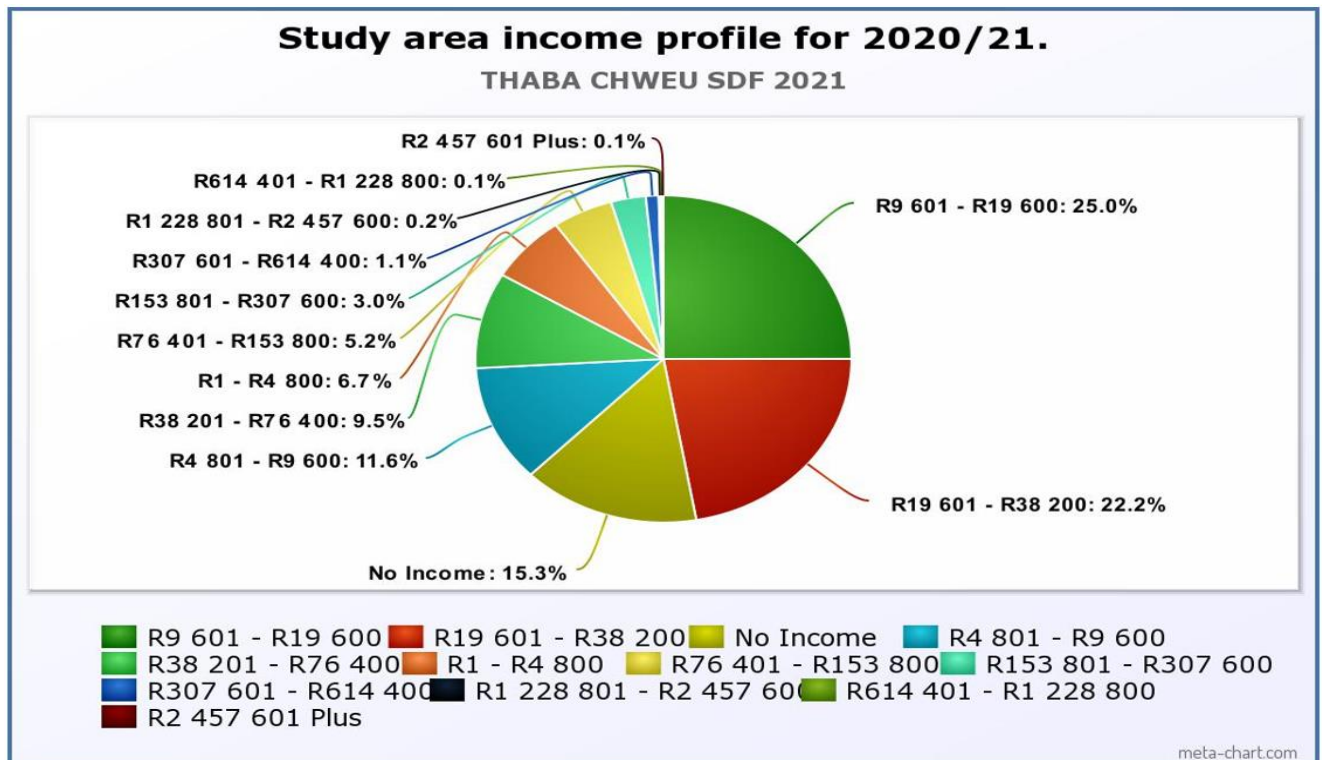


Figure 3.3: Study area income profile for 2020/2

Table 3.7: Study area income profile for 2020/21

Settlement	No Income	R1– R4 800	R4 801– R9 600	R9 601– R19 600	R19 601–R3 8 200	R38 201–R7 6 400	R76 401–R1 53 800	R153 801–R 307 600	R307 601–R 614 400	R614 001–R 1 228 800	R1 228 801– R2 457 600	R2 457 601+
Leroro	13.7%	6.7%	12.8%	23.4%	21.0%	10.6%	5.8%	4.1%	1.5%	0.0%	0.3%	0.1%
Matibidi	15.0%	6.5%	11.8%	27.6%	23.2%	7.9%	4.3%	2.5%	0.7%	0.1%	0.1%	0.1%
Moremela	17.3%	6.8%	10.2%	24.0%	22.5%	10.0%	5.4%	2.4%	1.0%	0.0%	0.3%	0.1%
Northern areas	15.3%	6.7%	11.6%	25.0%	22.2%	9.5%	5.2%	3.0%	1.1%	0.1%	0.2%	0.1%

3.2 Current status of water supply business

3.2.1 Service level profile and water demand

Water reticulation infrastructure has historically been installed in settlements and standpipes at 200 m walking distance. With time, the residents made their own informal connections to the water reticulation pipes. The water reticulation infrastructure installed in recent years consisted of formal and informal yard connections, and in some cases water meters were installed. There are areas in settlements (where there is normal growth), either on the outskirts or inside the settlements where new households settled, where no infrastructure existed to service these households and, to compound the problem, water did not reach the intended targets as some households were situated higher than the respective reservoirs (water from reservoirs is fed by gravity and not pumped to the community).

From the information discussed, it is clear that the service levels in the villages consisted of the following:

- i. Formal house connection.
- ii. Informal house connection.
- iii. Street standpipes.
- iv. No services.

Table 3.8 shows the supply levels of the water services infrastructure of the study area. This shows the percentage distribution of water service levels within the region. In some cases, households have installed private boreholes from where water is pumped to a tank and then reticulated to the house. These boreholes were not investigated as they did not form part of the municipal infrastructure.

Table 3.8: Water services infrastructure supply levels

Region	Time frame	Settlement name	Category	Total population	Total households	Household density	Annual population growth	Annual household growth	Population with access to RDP* level water	Population with access to functional water infrastructure	Population with access to reliable water infrastructure
Thaba Chweu	April 2021	Matibidi	Rural	14 801	4 366	3.390059551	190	56	13 375	13 375	10 189
Thaba Chweu	April 2021	Leroro	Rural	6 857	2 075	3.304578313	88	27	6 198	6 198	4 720
Thaba Chweu	April 2021	Moremela	Rural	7 453	2 311	3.225010818	96	30	6 736	6 736	5 128

*Reconstruction and Development Programme

Table 3.8 (continued)

Piped water inside dwelling population	Piped water inside yard population	Distribution	Borehole population	Spring population	Rain water tank population	Dam/pool/stagnant water population	River/stream population	Other water population
4 942	7 206	1 227	604	0	0	61	700	61
2 289	3 338	571	281	0	0	24	328	26
2 487	3 629	620	301	0	0	35	352	29

Various households of the study area have installed private water tanks. These tanks are problematic as they increase the overall storage availability in the villages and water is only available to a few households. The implication is that when water flows out of the central reservoirs to the individual households, the households with individual tanks in low-lying areas will take a significant amount of the water. This reduces the water availability to other parts of the villages. However, the challenge and reality is that there was no method of restricting the overall water use of households. It was, therefore, anticipated that the litre per capita per day for households with tanks would be much higher than households without water tanks. It is also important for equitable distribution of water upon availability.

3.3 Water and sewerage infrastructure profile

3.3.1 Surface or raw water supply

The existing raw water supply (Moremela Stream) was only located at the Moremela rural node of the northern areas (study area), while the rest of the rural node (Matibidi and Leroro) was supplied by groundwater sources.

The abstraction pump station had two heavy duty raw water pumps at 30 kW each. Both pumps ran on a direct online system where one pump was a duty pump and the other a standby pump.

3.3.2 Bulk storage

Water usage in the Matibidi village is supplied from groundwater sources through approximately 18 working boreholes that deliver via borehole pumps to four reservoirs strategically placed across the region. Water gravitates from the reservoirs to the different supply zones.

Moremela has an abstraction pump station with two KSB WKLN 80/8 pumps with a potential duty point of 63 m³/h and a pumping head of 105 m alongside the Moremela Stream that delivers water to the reservoir of the regional Ehlanzeni District Municipality. The raw water is treated with a chlorine dosing system with a 20 second set timer. When the raw water station is operating at full capacity for eight hours a day, it can supplement the water demand with 504 000 l per capita per day.

The scheme, originally designed to be controlled by an automatic time/pressure switch in the pump station and float valve mechanism on the reservoir inlet, was not operational in some reservoirs or pump stations and has fallen into disrepair. The water system is augmented by groundwater sources in the form of four boreholes and a booster pump station to the reservoirs. There are two reservoirs in the Moremela village. Water gravitates from the reservoirs to the different supply zones.

Water usage in the Leroro village is also supplied from groundwater sources through approximately five boreholes that deliver via borehole pumps to a booster pump station, which is pumped to three reservoirs strategically placed across the region. Water gravitates from the reservoirs to the different supply zones.

3.3.3 Sewer network

There were no domestic sewage collection systems in the study area. The only form of sewage collection was by means of unventilated toilets and normal unimproved pit latrines. Some stands, however, had standalone septic tank units. The existing sewerage systems are for the institutions of Matibidi Hospital and Dientjie Police Station in Leroro, and are not available to the communities. As such, these did not form part of this study. Except for possible pollution due to the proximity of the latrines to existing boreholes, no major problems with the sanitation have been reported.

The study region in question did not have any waterborne sewage network systems. Most dwellings were serviced with unlined ventilated and unventilated pit latrines as stated above. However, there were several households with yard connections and standalone waterborne septic tank units.

Groundwater pollution constituted a significant threat in several villages due to the proximity of some latrines to borehole pump stations. Boreholes in Moremela and Leroro, for example, were less than the recommended guidelines for human settlement planning and design volume 2 of 30m from the nearest pit-latrines. According to StatsSA database estimates updated in April 2021, over 90% of households had sanitation levels below the reconstruction development program's standard, indicating that a large percentage of households still relied on pit latrines. As a result, more groundwater quality sampling studies are needed to estimate the polluting potential of these toilets on the village's groundwater supply.

3.4 Operations and maintenance

The water supply network for the three villages consisted of abstraction works, 28 working pump stations, several bulk supply mains, storage reservoirs and approximately 3.5 km of secondary and tertiary distribution pipelines. These must be operated and maintained on an ongoing basis to retain the water infrastructure in an effective and efficient condition. The focus should be on preventative and routine maintenance rather than on repair (re-active), as was currently the case.

For the components to be more functional, all structures must be kept clean, locked, and rust-free, and cracks or spalling must be fixed before they influence structural strength, function, and beauty. Operating and maintaining a facility requires dedicated, experienced, and trained personnel with full access to resources such as materials, plant, equipment, spare parts, support staff, and consumables, as well as written manuals, operational procedures, layout plans, database information, support documentation, historic records, and maintenance schedules.

Within the municipality, operational knowledge is concentrated with a few employees hired by the municipality and is primarily based on experience rather than explicitly documented processes. Thus, the operation will only operate as well as the experience of the operators engaged. The absence of recordkeeping and operational manuals and procedures is viewed as a key impediment to the continued successful operation of water and wastewater infrastructure and networks/plants.

3.5 Associated services

The study area had associated services that influenced the water demand and supply to the settlements. Such services are depicted in Table 3.9.

Table 3.9: Summary of associated services in the study area

Associated service facility	Number of facilities
Education	
Primary school	7
Secondary school	5
New Partnership for Africa's Development (NEPAD) E-school	0
Combined schools	0
Moremela, Leroro, Matibidi Colleges of Education	0
Total	12

Associated service facility	Number of facilities
Health	
Hospitals	1
Health centres	2
Clinics	0
Total	3
Other	
Total	2

3.6 Groundwater supply

Figures 3.4, 3.5, and 3.6 show the geolocation of the boreholes of the villages of the study area. As mentioned previously the majority of these boreholes were damaged and/or over-utilised.

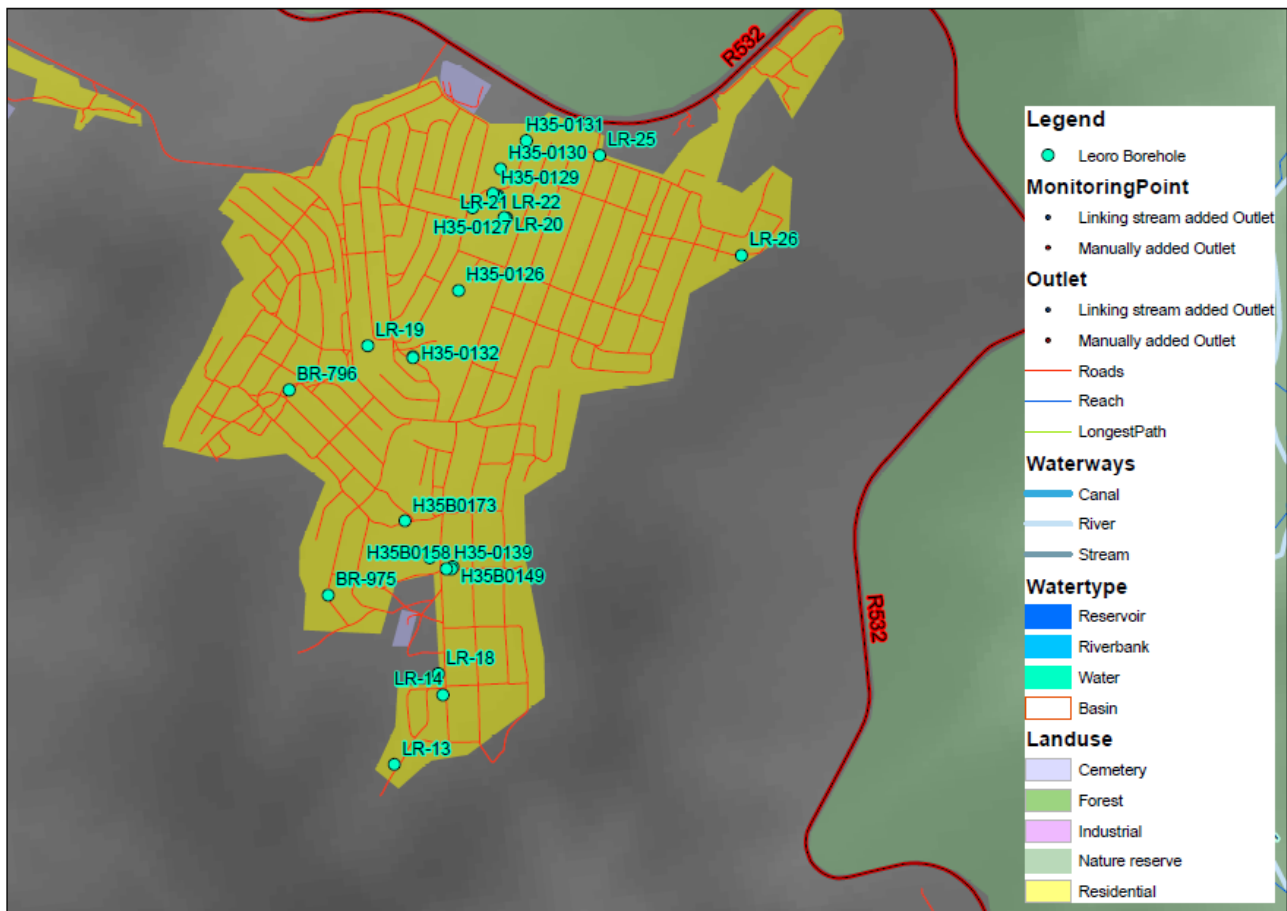


Figure 3.4: Boreholes in Leroro using ArcMAP

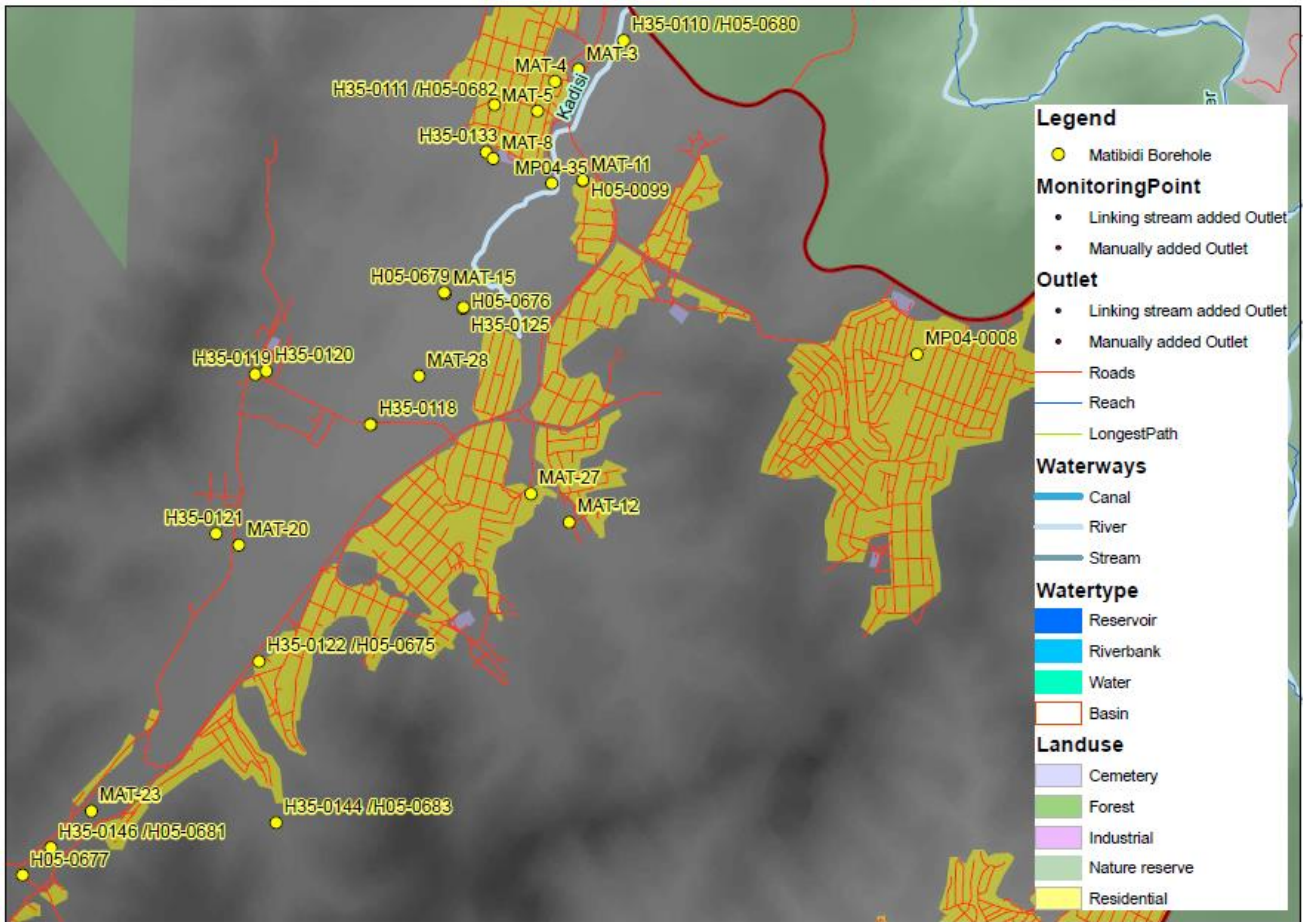


Figure 3.5: Boreholes in Matibidi using ArcMap

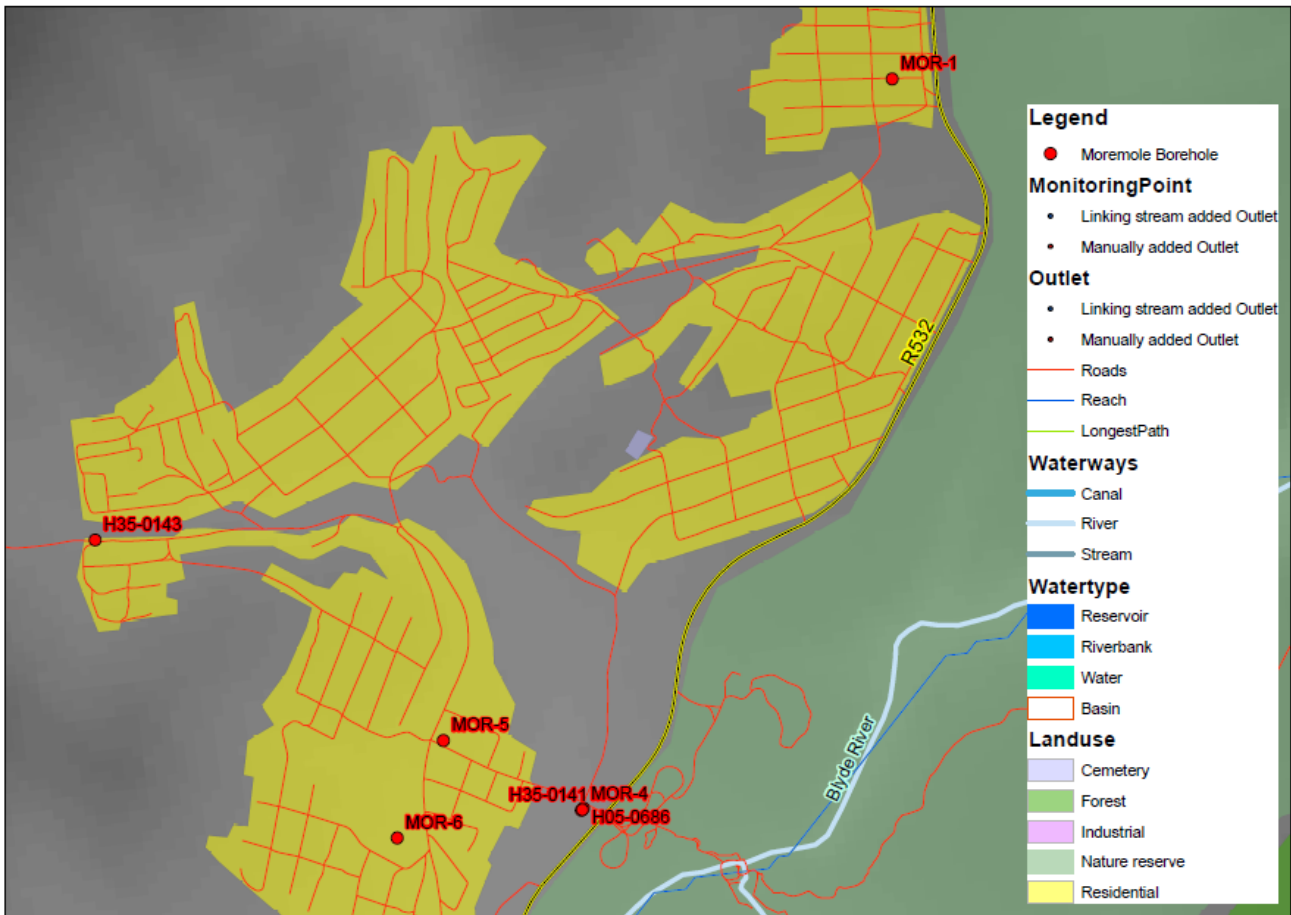


Figure 3.6: Boreholes in Moremela using ArcMap

3.7 Water treatment

The study area consisted mostly of groundwater, except for in Moremela where groundwater augments the raw water supply from the Moremela Stream. Most of the boreholes recorded in the study area ranged from Class 0 to Class 2, which is acceptable for human consumption as per the DWS and SANS 241-1:2015 (SABS, 2015) potability standards. It is worth noting that there were boreholes that had a greater than Class 2 parameter, yet there was no chemical dosing.

The Moremela Stream had an on-site automated Grundfos chemical (chlorine) dosing system that worked on a 20-second timer.

3.8 Water demand management of Thaba Chweu Local Municipality

3.8.1 Current water demand

In TCLM, the rate at which water was used increased due to an increasing population rate. According to the municipality's Strategic Development Plan and their Integrated Development Plan, the current water demand for the northern areas (study area) was 7.68 Mℓ/day. The major usage for TCLM is agriculture, industry and domestic usage.

3.8.2 Future water demand

Population increase and local economic growth are two important variables that drive demand for water supplies in every place (Blignaut, 2009). Because the TCLM is one of South Africa's developing municipalities, such variables have a detrimental impact on water delivery. Because development in a place is often accompanied with an influx of people, the causes might work together.

Other factors that contribute to water demand in a region include the level of service delivery as indicated by the 2011 Stats SA Census, improvements in educational facilities and levels, improvements in water services, sanitation, health awareness, and better housing facilities.

For this municipality's future water demand, two possibilities have been identified: High growth water requirement scenarios will be heavily influenced by rapid population growth and improved service delivery. When past numbers for population growth and water demand are considered, the pace at which water consumption has grown is around 1.86 percent per year (TCLM, 2021). The high growth scenario was based on a historical growth rate of 3% per year.

Low growth water requirement scenarios were determined to be based on 1% annual water requirement growth, taking into account that this will be impacted by low population growth and low economic growth.

Chapter 4

METHODOLOGY

4.1 Introduction

A proper research methodology encompasses both the physical research methods and the technique for understanding the particular study that needs to be done. Therefore, in order to carry out the research efficiently, supplementary information such as a theory of hydrology, hydraulics and distribution systems is required. After the aforementioned is established, data is gathered for analysis.

4.2 Type of data

4.2.1 Primary data

Primary data are data that are collected by the researcher, such as metadata and surveys. They are collected with the objectives from primary sources in mind. Salkind (2010) stated that the term *primary data* is mainly used to encompass all the original sources of information or data. The primary data collected in this study was from the hydrocensus, test results (both aquifer and chemistry results) and the electroseismic survey. This data was collected from the study area and observed for analysis.

4.2.2 Secondary data

The term *secondary data* is defined as data which are taken from other researchers' data sets. Secondary data incorporate articles, books, documents and other sources of information that has already been published (Creswell and Poth, 2018). Published documents and unpublished documents, such as journal articles from scholars, were used to provide relevant literature for this study. Web sources were also utilised as a secondary source of data revolving around the topic of hydrogeology. Furthermore, government publications such as documents from the DWS, spatial development frameworks and integrated development plans provided useful information.

4.3 Sampling

Data for the study were collected by means of sampling using both random selection and random assignments. Where a hydrocensus investigation of existing groundwater sources

such as boreholes was conducted to confirm the locations and status of the current and potential abstraction points. Data such as rainfall, temperature, evaporation, topography of the catchment, land use, land cover and flow data were collected for the study area to be used for the hydrocensus analysis.

4.3.1 Random sampling

Samples are drawn from a population and are associated with the external validity of a study's findings. More specifically, random sampling reduces sample bias and, as a result, approximates results gained from researching an entire population (Dattalo, 2010). The boreholes selected from the hydrocensus were chosen using random sampling.

4.3.2 Random assignment

Samples are assigned to distinct groups, such as intervention versus control, and this is related to the internal validity of a study's results. Although assignment bias is a danger to external validity, it affects study results, resulting in erroneous estimations of the correlations between variables in a population (Konikow, 2021). The emphasis here is on the use of techniques to reduce (1) sampling bias as a danger to external validity and (2) assignment bias as a threat to internal bias.

4.4 Hydrocensus investigation

A hydrocensus of groundwater abstraction points was required within the investigation areas to confirm the locations and status of current or potential abstraction points. The hydrocensus was also used to show how many boreholes were within each village, namely Leroro, Matibidi, and Moremela; from this data, the hydrocensus was used to show the current abstraction of the boreholes, geological formations and water levels.

The hydrocensus was used to indicate the current level of the water table relative to historical data, meaning that the results showed whether the aquifer was showing signs of dewatering, or whether it was recovering well. The static water level data were used to generate groundwater contour maps by performing a regression analysis using a digital elevation model of the area (obtained from Shuttle Radar Topography Mission data) as reference, as this was a mostly unconfined aquifer system and water levels generally followed the topography (Kotze et al., 2021).

4.5 Aquifer sustainability testing

Pump tests are field studies in which a borehole is pumped at a regulated rate and drawdown is monitored in one or more surrounding observation boreholes and, if desired, in the pumped borehole itself (the control borehole). Pumping test response data is then used to estimate aquifer hydraulic parameters, evaluate well performance, and define aquifer borders. Pumping tests are also known as aquifer tests and aquifer performance tests.

The correct operation and utilisation of boreholes result from the assessment of the productive capacity (yield potential) of the borehole as well as the productivity of the aquifer supporting the borehole. Subjecting boreholes, and consequently aquifers to different pumping tests, provides such knowledge. The borehole-testing programme consists of a step drawdown test and constant discharge test. In short, aquifer testing consists of calibration tests, step tests, constant discharge tests and recovery readings.

Borehole operation and use are determined by assessing the yield of the borehole as well as the productivity of the aquifer supporting the borehole. Subjecting boreholes, and consequently aquifers, to different pumping tests provides such information. The borehole-testing programme consists of a step drawdown test and constant discharge test. In short, aquifer testing entails the following:

4.5.1 Step tests

The borehole was pumped at varying abstraction rates for periods of 60 minutes each and water levels were measured in the borehole at predetermined intervals. The test effectively stressed the aquifer and gave an indication of its capable yield. The abstraction rate for the longer duration aquifer sustainability test was then determined from the analysis of the step test data.

4.5.2 Constant discharge test

The constant discharge test was carried out for a period of approximately 24 hours and involved measuring the water levels in the borehole, while abstracting the water and thus creating “drawdown” within the borehole. Drawdown is the difference between the measured water levels at any time during the test and the position at which the water level would have

been (static water level) if abstraction had not taken place. The main aim of the test was to lower the water level in the borehole to approximately 65% of the available drawdown and maintain the water level at this depth for a specific period of 24 hours. The constant discharge test was performed to assess the productivity of the aquifer, according to its response to the abstraction of water.

4.5.3 Recovery readings

The rate at which the borehole recovers was also measured and recorded, once the pump was switched off. This data was useful in determining the storage available to the borehole and the position of the main water strikes. The sustainable yields for boreholes were calculated using two methods: the basic sustainable borehole method and the flow characteristic method. The FC method could precisely predict long-term sustainable borehole yields of the single boreholes in the fractured aquifer as it used drawdown derivatives and subjective information on no-flow boundaries to estimate a sustainable borehole yield that would not cause a drop below the fracture.

4.6 Chemistry results

Water samples were collected from boreholes H35-0111 and H35-0143 and sent to LabServe laboratories in Mbombela for potability analyses; these tests were sent at the time testing was conducted with In-Situ Consulting. The laboratory analyses expressed in mg/l are presented in the Management recommendation reports as Appendix D. To determine the various analytical criteria by which groundwater quality in the investigation region might be evaluated, laboratory analysis (reported as mg/l) was converted to meq/l using the conversion formulas described in Hem (1970). Additional tests were done for boreholes BH35-0146, BH35-0118, BH35-0120 and sent to the laboratory for analysis.

The samples were taken according to the SABS (2015) standards, at the end of the constant discharge test, in order to be representative of the water of a wider zone around the borehole.

4.7 Groundwater monitoring

The success of a water supply scheme based on groundwater resources follows a step-by-step process that starts with the scientific search for these resources. Success normally leads to the development and utilisation of these resources. Groundwater monitoring was formulated after testing data have been gathered and assessed. The functionality and monitoring of each of the boreholes were based on yield and recovery rate of the boreholes.

The monitoring framework was formulated to include regular evaluations of the monitoring data to ensure that the groundwater supply scheme was functioning within its limits. The early identification of an inability of the scheme to continue functioning as required, provided the means to implement and take corrective actions before a possible crisis is reached.

4.8 Operations and maintenance

The study area's water supply networks contained the following information:

- i. Abstraction pump stations.
- ii. Bulk supply mains to storage.
- iii. Storage reservoirs.
- iv. Secondary and tertiary distribution pipelines with isolating valves.
- v. Pit latrines.

Formulating a management strategy for maintenance of existing infrastructure was conducted after identifying and inspecting the existing network relative to the growth of the regions. Along with the management strategy, operational procedures were recommended to keep the infrastructure in optimum conditions to meet the demand requirements of the regions.

4.9 Instrumentation

4.9.1 Desktop study

A desktop study was conducted where existing information was gathered from topographical maps, orthophotos, geological maps, hydrological information, published and unpublished reports, querying the National Groundwater Data Base, and data bases of various institutions such as In-Situ Consulting and TCLM for information on existing boreholes.

4.9.2 Electro seismic surveying

Electro seismic surveying was utilized, with electro seismic signals created by the relative movement of water against the subsurface rock substrate. The movement of groundwater is determined by a seismic wave. The presence of groundwater, its estimated depth, and probable geometry could be identified by correct processing and interpretation of the electrokinetic signal. This method was used to identify the general rock type for water strikes

and to show the general probability of water availability in the region. This also assisted in understanding why boreholes have high yields or low yields.

4.9.3 Electromagnetic CMD-DUO / Geonics EM-34-3

4.9.3.1 Data interpretation and drill target selection

The targets using ground geophysical investigations, which appeared to have the best hydrogeological potential, were identified. The description of the drilling target presented the interpretation of the geophysical data. A number of geological structures were targeted, and included some of the following:

- i. Intrusive dyke, and country rock contact.
- ii. Zone of deep weathering.
- iii. Intrusive dyke centre.
- iv. Geological fractures.

A detailed structural interpretation of the project area was achieved by interpreting available aerial photographs in conjunction with published geological mapping information.

Magnetic data was acquired at a constant pace, producing data points every one metre along each pass. The electromagnetic measurements were taken at ten-metre intervals along areas of the magnetic data that produced plausible abnormalities. The data was transmitted to a computer, and the resulting profiles were examined separately and in combination. Drill locations were chosen based on the following criteria based on the full analyses:

- i. The anomalies were not produced by man-made constructions (such as fences, power lines, or phone lines).
- ii. The anomalies were not caused by excessive terrain effects, and the magnetic readings were complementary.
- iii. The findings were credible, and the explanations were geologically sound.

The survey results revealed that there was no discernible pattern in the magnetic data. The goal of a pumping test, as in any aquifer test, is to estimate hydraulic properties of an aquifer system. For the pumped aquifer, transmissivity, hydraulic conductivity (horizontal and vertical) and storativity (storage coefficient) were determined. In layered systems, pumping

tests were also used to estimate the properties of aquitards (vertical hydraulic conductivity and specific storage).

4.9.4 Equipment and materials

Borehole testing was performed precisely and effectively using the test unit and its associated equipment and supplies. The following information is provided:

- i. *Test unit:* The test unit consisted of a positive displacement type pump element and a pump head driven by a motor fitted with an accelerator, gearbox and clutch.
- ii. *Discharge piping:* This comprised both the pipe (rising main or pump column), which brought the water to surface and the pipe (discharge hose) used to lead the pumped water away from the borehole being tested. The discharge pipe was capable of discharging the pumped water at a point further away than 50 m from the borehole being tested.
- iii. *Discharge measuring equipment/instrumentation:* Ungraduated electrical contact meters (dip meters) were used for this purpose.

4.9.5 Sustainable yields

The pumping test of the aquifer was conducted to estimate sustainable yield, which focused on the following:

- i. Calibration test.
- ii. Determining the length of the constant rate test.
- iii. Measuring of drawdown during the pumping period.
- iv. Recommendation of sustainable borehole yields.
- v. Choosing of pump size.

A single borehole pumping test was employed in all places because no observation well was available. The sustainable yields for boreholes were calculated using two methods: the basic sustainable borehole method and the flow characteristic method. The sustainable borehole yield method uses the following equation:

$$Q_{sust} = \left(\frac{Q}{S_r}\right) \times S$$

Where: Q (ℓ/s) is the rate used during the pumping test; s' (m) is the maximum available drawdown; and S (m) is the available drawdown during pump test. The flow characteristic method, which is a more conservative approach, uses the derivatives and subjected information about boundaries surrounding tested boreholes.

Chapter 5

RESULTS AND DATA ANALYSIS

5.1 Hydrocensus

5.1.1 Hydrocensus investigation

A hydrocensus of all groundwater abstraction points was conducted from 26 November to 1 December 2020, within the investigation areas to confirm the locations and status of current or potential abstraction points.

The findings were as follows:

- i. Twenty-six existing boreholes were identified and visited within Leroro village.
- ii. Only five of the twenty-six boreholes were in use during the study period, with a combined daily abstraction rate of approximately 706.07 m³/day.
- iii. Thirteen boreholes were reported as blocked, destroyed, or dry.
- iv. Eight boreholes were unused (refer to Table 5.1, and Appendix E for more information).
- v. It is assumed that two boreholes in the Leroro village were being over-abstracted.

The prior recommended abstraction rate for Borehole *H35-0133/H05-0786* was calculated as 2.6 l/s for a 24-hour duty cycle in March 2009. From the 18.5 kW pump installation it was estimated that this borehole was pumped at a discharge rate of approximately 5 l/s, 24 hours per day for seven days a week. Borehole *H35-0128* was equipped with a 15 kW pump, whereas borehole *H35-0127* was equipped with a 5.5 kW pump in 2011.

Table 5.1 shows a summary of the boreholes identified in Leroro and their status.

Table 5.1: Summary of boreholes identified at the Leroro village

Borehole name	Coordinates (Location)	Borehole depth (m)	Previous static water level (mbgl)	Static water level 2020 (mbgl)	Aquifer geological formation	Observed water use	Status of borehole
H35-0128	E30.796857° S24.614856°	±28	10.09	24.00	Possible dyke (Igneous rock)	Domestic	In use. Partially collapsed. This borehole required rehabilitation.
Pump 12A	E30.797003° S24.614841°	18.4	Unknown	Dry	Unknown	Domestic	Pump removed. Blocked at 18.4 m, used to be 60 m deep
Pump 12B	E30.796951° S24.614868°	34.4	Unknown	25.49	Dyke (Igneous rock) (Igneous rock)	Domestic/Agriculture	Pump removed. Collapsed to 34.4 m, was drilled to 100 m.
H35-0129	E30.796791° S24.614766°	33.36	22.19	24.00	Possible Dyke (Igneous rock)	Domestic	Pump burned out. Collapsed from 65 m to 33.32 m.
H35-0127	E30.795976° S24.615276°	Blocked, was 75	18.39	Unknown	Unknown	Domestic	Blocked with stones. Mono pump removed.
H35-0126	E30.795413° S24.618304°	63.17	16.15	28	Zone of deep weathering (Dolomite)	Domestic	Currently not in use. Pump burned out. Tested 13/12/2020.
H05-0786 / H35-0133	E30.793598° S24.620718°	59.59	20.34 24/01/1996 23.20 14/03/2009	39.00 (dyn)	Possible dyke (Igneous rock)	Domestic	Currently in use. This borehole was being over-abstracted.
H35-0132	E30.793597° S24.620757°	0	20.47	Unknown	Unknown	Domestic	Destroyed. Use to have a diesel pump. Required rehabilitation.
H35-0138	E30.794268° S24.628052°	10.28	Unknown	Dry	Contact zone/possible dyke (Dolomite)	Domestic	Blocked at 10.28 m. Drilled dry in 1995.
H35B0149	E30.795182° S24.628384°	Unknown	Unknown	Unknown	Unknown	Domestic	Unused. Destroyed.
H35B0158	E30.795127° S24.628459°	Unknown	Unknown	Unknown	Unknown	Domestic	Unused. Destroyed.
H35-0139	E30.794922° S24.628462°	Unknown	Unknown	Unknown	Unknown	Agriculture	Unused. Closed. Possibly dry.
LER-13	E30.792848° S24.635592°	Unknown	Unknown	Unknown	Unknown	Domestic	Unused. Closed.
LER-14	E30.794784° S24.633064°	Unknown	Unknown	Unknown	Unknown	Domestic	Blocked to top. Destroyed.
BR-975	E30.790211° S24.629427°	100+	Unknown	Unknown	Unknown	Domestic	Unused. Closed.
BR-796	E30.78864°S24.621931	100+	Unknown	Unknown	Unknown	Domestic	Unused. Destroyed.
H35B0173	E30.793273° S24.626703°	130	Unknown	>100 (dyn*) 26/11/2020	Dyke (Igneous rock)	Domestic	11 hours to fill 5 000 l.
LER-18	E30.794612° S24.632287°	30	Unknown	Dry	Fracture/Dyke (Sedimentary rock)	Domestic	Dry. School.

Borehole name	Coordinates (Location)	Borehole depth (m)	Previous static water level (mbgl)	Static water level 2020 (mbgl)	Aquifer geological formation	Observed water use	Status of borehole
LER-19	E30.791787 S24.620322	150	Unknown	93.28 (dyn*)	Fracture/Dyke (Sedimentary rock)	Domestic	High school. Pumped three hours per day.
LER-20	E30.797348 S24.615660	Unknown	Unknown	Dry	Unknown	Domestic	Destroyed.
LER-21	E30.797314 S24.615655	120	Unknown	Dry	Fracture/Dyke (Sedimentary rock)	Domestic	Dry drilled to 120 m.
LER-22	E30.797234 S24.615635	75	Unknown	29.28	Unknown	Domestic	Unused. Very low yielding.
H35-0130	E30.797100 S24.613864	37	Unknown	22 (dyn*)	Possible dyke (Igneous rock)	Domestic	In use. Police station pump. Abstraction estimated.
H35-0131	E30.798117 S24.612831	Unknown	Unknown	22.00	Unknown	Domestic	Unused. Open borehole with rock on top.
LER-25	E30.801048 S24.613366	Unknown	Unknown	Unknown	Unknown	Domestic	Unused. Closed.
LER-26	E30.806732 S24.617016	57+	Unknown	Dry	Unknown	Domestic	Unused. Closed.

The findings for Matibidi village were as follows:

- i. Twenty-eight existing boreholes were identified and visited within Matibidi village.
- ii. Eighteen boreholes were in use, with a combined approximate daily abstraction rate of 5 081.90 m³/day.
- iii. Four boreholes were reported as blocked, destroyed, or dry.
- iv. Five were unused.
- v. One was a monitoring borehole.

When comparing previous abstraction rates to the current abstraction volumes obtained from the hydrocensus, it is apparent that at least five boreholes in the Matibidi village were being over-abstracted. These boreholes included *H35-0111/H05-0680*, *H35-0118*, *H35-0122/H05-0675*, *H35-0146/H05-0681* and *H35-0144/H05-0683*.

Table 5.2 shows a summary of the boreholes identified in Matibidi and their status.

Table 5.2: Summary of boreholes identified at the Matibidi village

Borehole name	Coordinates (location)	Borehole depth (m)	Previous static water level (mbgl)	Static water level 2020 (mbgl)	Aquifer geological formation	Observed water use	Status of borehole
MP04-0008	E30.796857° S24.614856°	Unknown	Unknown	19.18	Unknown	Domestic	Monitoring borehole. Closed.
H35-0110 / H05-0680	E30.772140° S24.590690°	58.84	2.27	22.20 (dyn*)	Alluvium (Silty Clay)	Domestic	In use.
MAT-3	E30.768330° S24.592910°	Unknown	Unknown	Unknown	Unknown	Domestic	Closed. School borehole. The 20 000 ℓ tank takes three days to fill.
MAT-4	E30.766340° S24.593840°	40	Unknown	28.00	Unknown	Domestic	Out of order. School.
MAT-5	E30.764860° S24.596130°	11	Unknown	Dry	Unknown	Agriculture	Dry.
H35-0111 / H05-0682	E30.761260° S24.595650°	32.33	23.90	26.68	Alluvium (Silty Clay)	Domestic/ Agriculture	Tested 10/12/2020
H35-0133	E30.760560° S24.599280°	Unknown	Unknown	54.68 (dyn*)	Unknown	Domestic	Pumps 2 hours per day to top up 10 000 ℓ water.
MAT-8	E30.76114° S24.59978°	Unknown	Unknown	Unknown	Unknown	Domestic	Pump from 06:00 to 17:00 every weekday.
MP04-00035	E30.766080° S24.601690°	Unknown	7.21	Unknown	Unknown	Agriculture	Mono-pump.
H05-0099	E 30.768688° S24.601501°	1.8	Unknown	Unknown	Unknown	Domestic	Blocked at 1.8 m.
MAT-11	E30.768700° S24.601460°	Unknown	Unknown	Unknown	Unknown	Domestic	Closed – Hand pump.
MAT-12	E30.767549° S24.627788°	Unknown	Unknown	Unknown	Unknown	Domestic/ Agriculture	Closed – in use. Three hours to fill 10 000 ℓ.
H35-0125	E30.758587° S24.611304°	49.87	22.28	29.54	Zone of deep weathering (Dolomite)	Domestic	Not in use. Used to be 78 m deep.
H05-0676	E30.75862° S24.61125°	64.25	22.28	30 (dyn*)	Contact zone (Dolomite)	Domestic/ Agriculture	In use 24/7. Used to be 77.7 m deep.
MAT-15	E30.757083° S24.610213°	0	Unknown	Unknown	Unknown	Domestic	Destroyed.
H05-0679	E30.757000° S24.610100°	41.64	27.87	34.14	Alluvium (Silty Clay)	Domestic	Unused. Not enough drawdown available.
H35-0118	E30.75086° S24.62026°	55.60	40.05	Unknown	Alluvium (Silty Clay)	Domestic	In use – closed.
H35-0119	E30.750778° S24.620285°	19.00	Unknown	Dry	Possible dyke (Igneous rock)	Domestic	Dry, not in use.
H35-0120	E30.741077° S24.616392°	50	38.05	Unknown	Unknown	Domestic	In use – closed. Pumps for 12 hours once a week.

Borehole name	Coordinates (location)	Borehole depth (m)	Previous static water level (mbgl)	Static water level 2020 (mbgl)	Aquifer geological formation	Observed water use	Status of borehole
MAT-20	E 30.742016° S24.616144°	Unknown	Unknown	22.70	Unknown	Domestic/ Agriculture	In use – submersible. Three hours to fill 2 500 ℓ.
H35-0121	E30.739706° S24.629540°	44.66	25.65	31 (dyn*)	Contact Zone/Fracture (Dolomite)	Domestic/ Agriculture	In use 24/7. Used to be 71 m deep.
H35-0122 / H05-0675	E30.737763° S24.628663°	71.00	23.90 22/05/2002 16.50 24/01/1996	Unknown	Possible dyke (Igneous rock)	Domestic/ Agriculture	In use 24/7.
MAT-23	E30.741405° S24.638505°	85	Unknown	Unknown	Unknown	Domestic/ Agriculture	In use. Pump once a week to fill 10 000 ℓ. Closed.
H35-0146 / H05-0681	E30.727279° S24.650034°	40.40	Unknown	Unknown	Unknown	Domestic	In use. Closed. Used to be 46.4 m deep.
H05-0677	E30.723846° S24.652832°	64.49	Unknown	Unknown	Unknown	Domestic/ Agriculture	In use 24/7.
H35-0144 / H05-0683	E30.721460° S24.654940°	41.74	18.34	Unknown	Unknown	Domestic/ Agriculture	In use 24/7. Used to be 71 m deep.
MAT-27	E30.742827° S24.650915°	Unknown	Unknown	19.18	Unknown	Domestic	Windmill.
MAT-28	E30.764311° S24.625585°	Unknown	Unknown	Unknown	Unknown	Domestic	In use. School. Closed. 12 hours two times a week

The findings for Moremela village were as follows:

- i. Seven existing boreholes were identified and visited.
- ii. Four of the seven boreholes were in use at the time of the study, with a combined approximate daily abstraction rate of 580.21 m³/day.
- iii. Two boreholes were reported as being dry.
- iv. One borehole was unused.

There is a raw water pump station in Moremela, located at 24°39'52.4" S 30°47'25.92" E, directly opposite the Moremela Stream. The pump station was fitted with two KSB WKLN 80/8 centrifugal pumps, each with a potential duty of 63 m³/h and pumping head of 105 m, delivering water from the Moremela Stream to the Ehlanzeni District Municipality reservoir.

The raw water from the stream was treated with chlorine, using an automated dosing system with a pulsator set at 20 seconds.

Table 5.3 shows a summary of the boreholes identified in Moremela and their status.

Table 5.3: Summary of boreholes identified at the Moremela village

Borehole name	Coordinates (Location)	Borehole depth (m)	Previous static water level (mbgl)	Static water level 2020 (mbgl)	Aquifer geological formation	Observed water use	Status of borehole
MOR-1	E30.815929° S24.651627°	31.00	Unknown	25.27	Zone of deep weathering (Dolomite)	Domestic	Unused.
H05-0686	E30.806267° S24.672459°	41.95	13.24 12/06/2002 5.65 17/10/1995	Dry	Contact zone (Dolomite)	Domestic	Blocked. Used to be 41.95 m deep.
H35-0141	E30.806205° S24.672520°	48.85	3.14	40 (dyn*)	Alluvium (Silty clay)	Domestic	In use.
MOR-4	E30.806240° S24.672505°	Unknown	Unknown	Unknown	Unknown	Domestic	Blocked at 3.89 m.
MOR-5	E30.801884° S24.670531°	Unknown	Unknown	Unknown	Unknown	Domestic	School – 2 hours to fill 5 000 l tank. Closed in manhole.
MOR-6	E30.800441° S24.673311°	Unknown	Unknown	Unknown	Unknown	Domestic	1 hour to fill 5 000 l tank.
H35-0143	E30.790999° S24.664803°	52.02	10.44	23.59	Alluvium (Silty Clay)	Domestic	Tested 14/12/2020. Used to be 72 m deep.

5.1.2 Geophysical Survey

A geophysical survey was undertaken at different locations, as shown in Table 5.4 during the hydrocensus investigation, in order to identify the type of geological structures as well as potential groundwater – bearing targets within the Malmani Subgroup dolomites. The results are shown in detail in Table 5.4 and the associated figures are the results of the survey as shown in Appendix F – Geophysical Results.

Table 5.4 shows a summary of the results from the electromagnetic testing.

Table 5.4: Randomly selected test points

No	Village name	Targeted drilling point (Priority 1)	Targeted drilling point (Priority 2)	Description of drilling target	Probability of drilling a successful borehole	Expected drilling depth
1	Matibidi (Ward 8)	-24.601593 30.777972	-24.602422 30.777829	Contact zone	Priority 1 = 50% Priority 2 = 40%	120 m
2	Leroro A (Ward 9)	-24.616871 30.787976	-24.616041 30.788279	Possible dyke	Priority 1 = 45% Priority 2 = 35%	120 m
3	Leroro B	II	Nil	Possible dyke	Priority 1 = 50%	120 m
4	Apara	-24.613974 30.763373	Nil	Alluvium	Priority 1 = 50%	120 m
5	Apara	-24.594878 30.768944	Nil	Alluvium	Priority 1 = 50%	120 m
6	Hlapetsa	-24.62355 30.751567	Nil	Zone of deep weathering	Priority 1 = 45%	120 m
7	Matibidi 1	-25.577983 30.768213	Nil	Contact zone	Priority 1 = 50%	120 m
8	Matibidi 2	-25.582143 30.765638	Nil	Contact zone	Priority 1 = 50%	120 m

Lydenburg falls within the same catchment as the study area, thus having the geological formations. The geological formations can be extrapolated to the study area.

Table 5.5 shows the results for Lydenburg.

Table 5.5: Lydenburg test points

No	Village name	Targeted drilling point (Priority 1)	Targeted drilling point (Priority 2)	Description of drilling target	Probability of drilling a successful borehole	Expected drilling depth
1	Lydenburg Ext 108	-25.095250 30.432454	-25.095973 30.432528	No target	Priority 1 = 50% Priority 2 = 35%	150 m
2	Lydenburg	-25.090298 30.438148	-25.091056 30.437105	No target	Priority 1 = 50% Priority 2 = 40%	150 m

Figure 5.1 shows the results of the test for Leroro A.

Leroro A

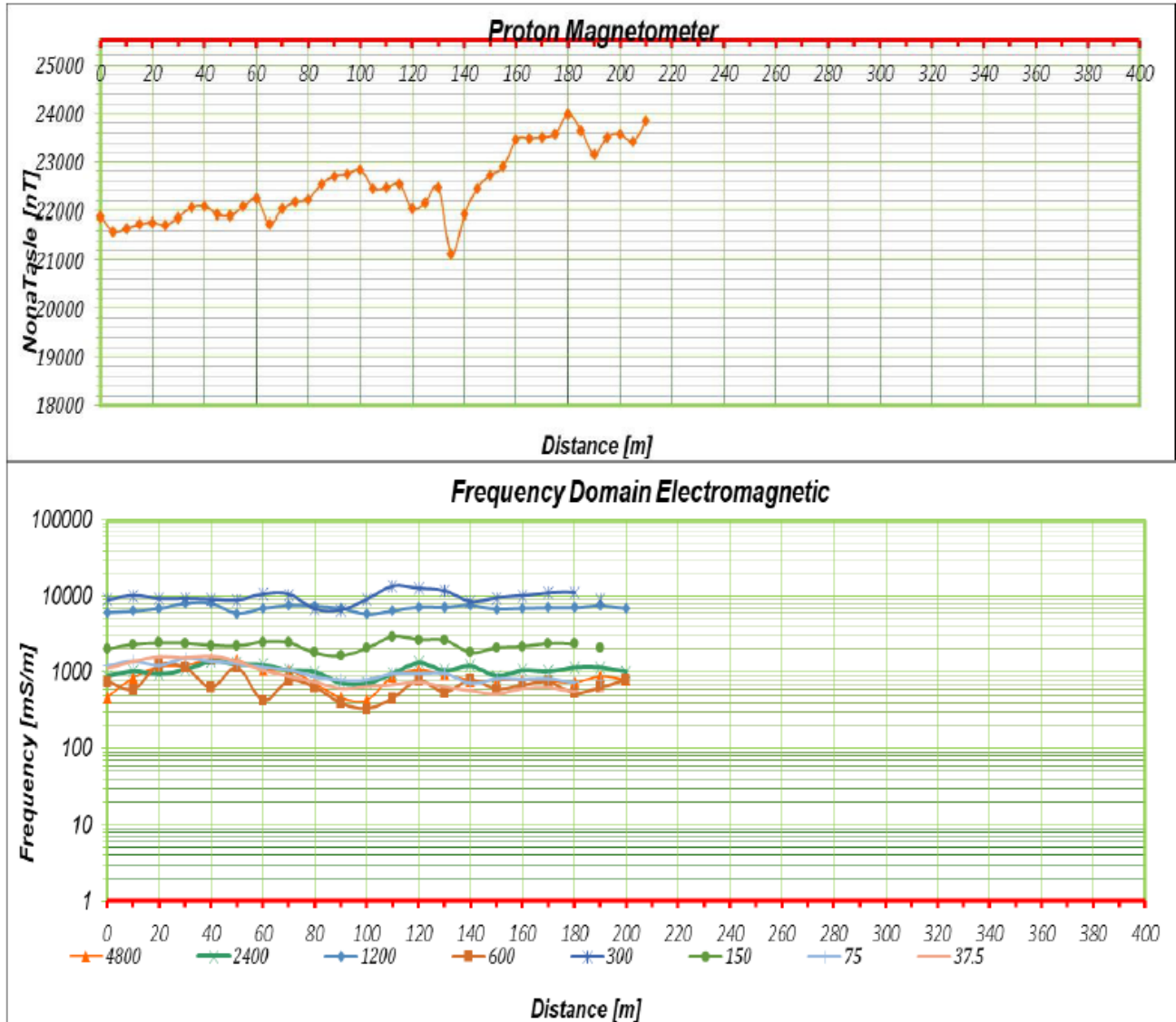


Figure 5.1: Results of the test for Leroro A

As per the geophysical results, the study area has a presence of:

- i. enhanced faulting/fracturing;
- ii. alluvium;
- iii. dyke intrusion;
- iv. elevated recharge areas of >50 mm (Matibidi);
- v. high yielding aquifer zones (Matibidi);
- vi. good water quality zones; and
- vii. poor existing groundwater data, requiring further investigation.

The geophysical survey indicated the correlation between the groundwater and geological formation. The yield of the groundwater is directly proportional the geology/aquifer. This gives an understanding on what type of drilling is required in a region e.g odex drilling and pumping rates.

5.2 Aquifer sustainability testing

5.2.1 Aquifer testing results

Boreholes *H35-0126* (Leroro), *H35-0111* (Matibidi) and *H35-0143* (Moremela) was aquifer-tested.

5.2.1.1 Borehole *H35-0126* (Leroro)

Borehole *H35-0126* was subjected to aquifer testing. The details of the previous and most recent aquifer tests set-up are shown in Table 5.6.

Table 5.6: Pumping details for Borehole H35-0126

Borehole depth (m)	Date tested	Static water level	Test pump depth (MBC*)	Available drawdown	Location (Coordinates)
63.22	17/10/2011	16.15	51.45	35.30	E30.795413°
63.22	14/12/2020	28.00	59.64	31.64	S24.618304°

* MBC = Minimum bactericidal concentration

In 2011, the constant discharge test was carried out for a period of 24 hours, and achieved a maximum drawdown of 16.15 m or 45.8% of the available drawdown. The water level in the borehole recovered to 95% of the initial static water level within 24 hours after pumping stopped. During the recent constant discharge test, the available drawdown of 31.64 m was reached eight hours into the 24-hour test and the water level recovered to 100% of the initial static water level within five hours after pumping stopped. The step-drawdown tests done in 2020 yielded a constant discharge test 468l/hr (0.13l/s).

5.2.1.2 Borehole *Leroro* (New borehole – No borehole number)

The borehole was subjected to aquifer testing after construction. Details of the previous and most recent aquifer tests set-up are shown in Table 5.7.

Table 5.7: Pumping details for Borehole H35-0126

Borehole depth (m)	Date tested	Static water level	Test pump depth (m)	Available drawdown	Location (Coordinates)
60.00	12/04/2021	9.62	54.00	34.38	S23°36.8815' E30°47.7829'

5.2.1.4 Borehole H35-0111 (Matibidi)

Borehole *H35-0111* was previously subjected to aquifer testing by an unknown contractor (limited information available). Details of the previous and most recent aquifer tests set-up are shown in Tables 5.8.

Table 5.8: Pumping details for Borehole H35-0111

Borehole depth (m)	Date tested	Static water level	Test pump depth (m)	Available drawdown	Location (Coordinates)
35.54	20/05/1995	23.90	Unknown	Unknown	E30.761260°
32.33	12/08/2022	26.68	30.50	3.82	S24.595650°

An analysis of the latest step-drawdown data indicated that a constant discharge test could be performed at a rate of 9 180 l/hr (2.55 l/s). The maximum available drawdown of 3.82 was reached 22 hours into the 24-hour constant discharge test. The water level in the borehole fully recovered to the initial static water level within 22 hours after pumping stopped. The static water level in Borehole *H35-0111* decreased by 2.78 m since 1995.

5.2.1.5 Borehole Matibidi (No borehole number)

The borehole was subjected to aquifer testing after construction. The details of the previous and most recent aquifer tests set-up are shown in Table 5.9.

Table 5.9: Borehole identified in Matibidi (solar powered)

Borehole depth (m)	Date tested	Static water level	Test pump depth (m)	Available drawdown	Location (Coordinates)
128	12/03/2021	42	84	42	24.6013933S, 30.77876833E

5.2.1.7 Borehole H35-0143 (Moremela)

Borehole *H35-0143* was previously subjected to aquifer testing by an unknown contractor (limited information available). Details of the previous and most recent aquifer tests set-up is shown in Table 5.10.

Table 5.10: Borehole H35-0143 identified in Moremela

Borehole depth (m)	Date tested	Static water level	Test pump depth (m)	Available drawdown	Location (Coordinates)
72.00	19/06/2002	10.44	Unknown	Unknown	E30.790999°
52.02	16/08/2022	23.59	43.00	19.41	S24.664803°

An analysis of the latest step-drawdown data indicated that a constant discharge test could be performed at a rate of 26 676 l/hr (7.4 l/s). The constant discharge test was carried out for a period of 24 hours and achieved a maximum drawdown of 7.41 m or 38% of the available drawdown. The water level in the borehole recovered to 99% of the initial static water level within three hours after pumping stopped.

Additional water sustainability tests were done on 16 August 2022 to reflect the current groundwater conditions due to population statistics and the rainy season. Tables 5.11 to 5.18 show the tested boreholes.

Shown in Table 5.11 are the testing data for Borehole *BH35-0146*.

Table 5.11: Pumping details for Borehole BH35-0146 pumping details

Borehole depth (m)	Static water level	Test pump depth (m)	Available drawdown	Location (Coordinates)	Status
87.00	37.00	81.00	44.00	-24.6500 30.72400	Equipped

Table 5.12 shows the drawdown data for Borehole *BH35-0146*.

Table 5.12: Borehole drawdown data

Borehole name	Step test	Average yield (l/s)	Total drawdown (m)	Percentage of available drawdown
BH35-0146	Step 1	0.90 (60 mins)	0.08	0.004
BH35-0146	Step 2	2.00 (60 mins)	0.12	0.27
BH35-0146	Step 3	5.00 (60 mins)	0.19	0.43

Figure 5.2 shows a graphical summary of the stepped discharge tests with drawdown of the tested borehole.

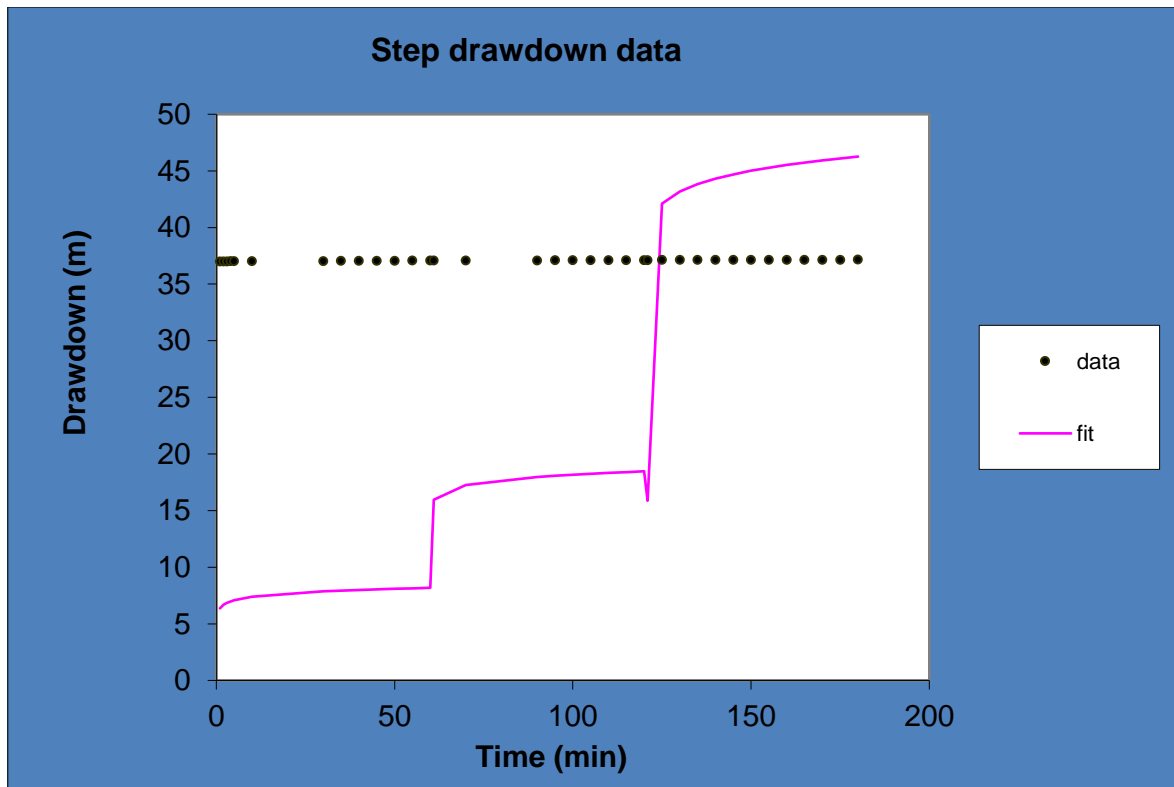


Figure 5.2: Borehole BH35-0146 stepped discharge test (drawdown vs time)

Where:

r_e (m) =	0.11
T (m ² /d) =	14.0
S =	1.00E-06

Table 5.13 shows the constant discharge test details.

Table 5.13: Borehole BH35-0146 drawdown – Constant discharge test

Borehole name	Average yield (ℓ/s)	Total drawdown (m)	Percentage of available drawdown	Status
BH35-0146	5	0.71	1.61	Equipped

The constant discharge test was carried out for a period of 24 hours. It achieved a maximum drawdown of 37.71 m and recovered to 100% of the initial static water level, three minutes after pumping stopped.

Figure 5.3 shows a graphical summary of the constant discharge test with drawdown and recovery.

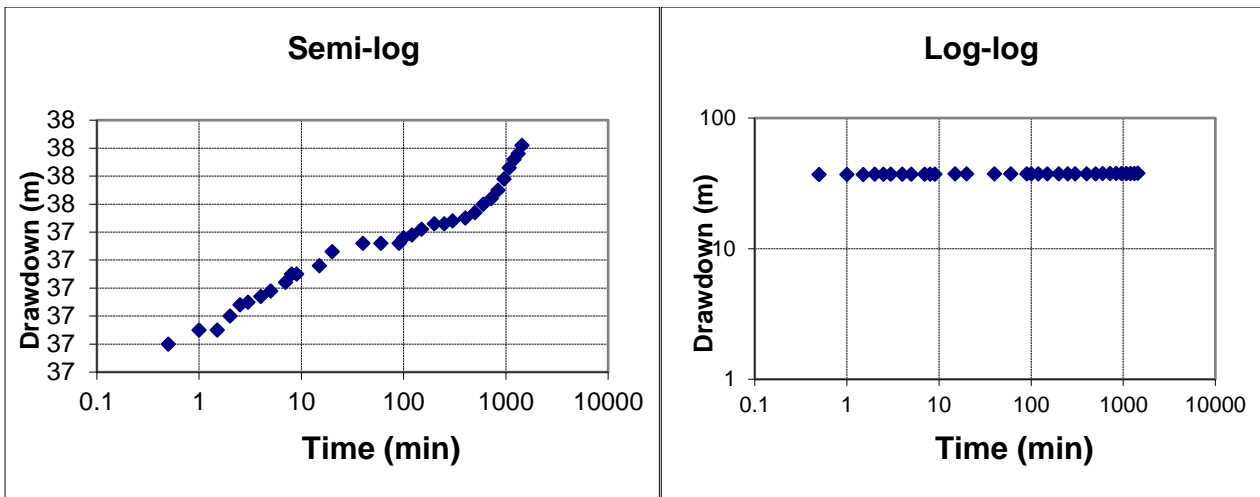


Figure 5.3: Constant discharge test and recovery (drawdown vs time) for borehole BH35-0146 (Semi-log and Log-Log graphs).

The drawdown curve produced from the constant rate test data is shown in Figure 5.3. After 10 minutes, the drop curve flattens, indicating that we are working with an unconfined aquifer. The drawdown is less than one meter each log cycle and is fairly consistent. This implies that the effect is due to dolomite rather than a barrier like dyke development. If there had been a boundary influence, the drop every log cycle would have been doubled. The projected yield of 5 l/s resulted in the recovery $T = 14.4$ (m^2/d) using the Logan equation.

Table 5.14 shows the pumping details for Borehole *BH35-0118*.

Table 5.14: Pumping details for Borehole BH35-0118

Borehole depth (m)	Static water level	Test pump depth m	Available drawdown	Location (Coordinates)	Status
120.00	16.00	111.00	95.00	-24.6203 30.7509	Equipped

Table 5.15 below shows Borehole *BH35-0118* drawdown data.

Table 5.15: Drawdown data for borehole BH35-0118

Borehole name	Step test	Average yield (ℓ/s)	Total drawdown (m)	Percentage of available drawdown
BH35-0118	Step Test 1	0.27 (60 mins)	15.05	15.84
BH35-0118	Step Test 2	1.57 (60 mins)	36.60	38.52
BH35-0118	Step Test 3	2.50 (60 mins)	73.91	77.80

Figure 5.4 presents a graphical summary of the stepped discharge tests with drawdown of the tested borehole.

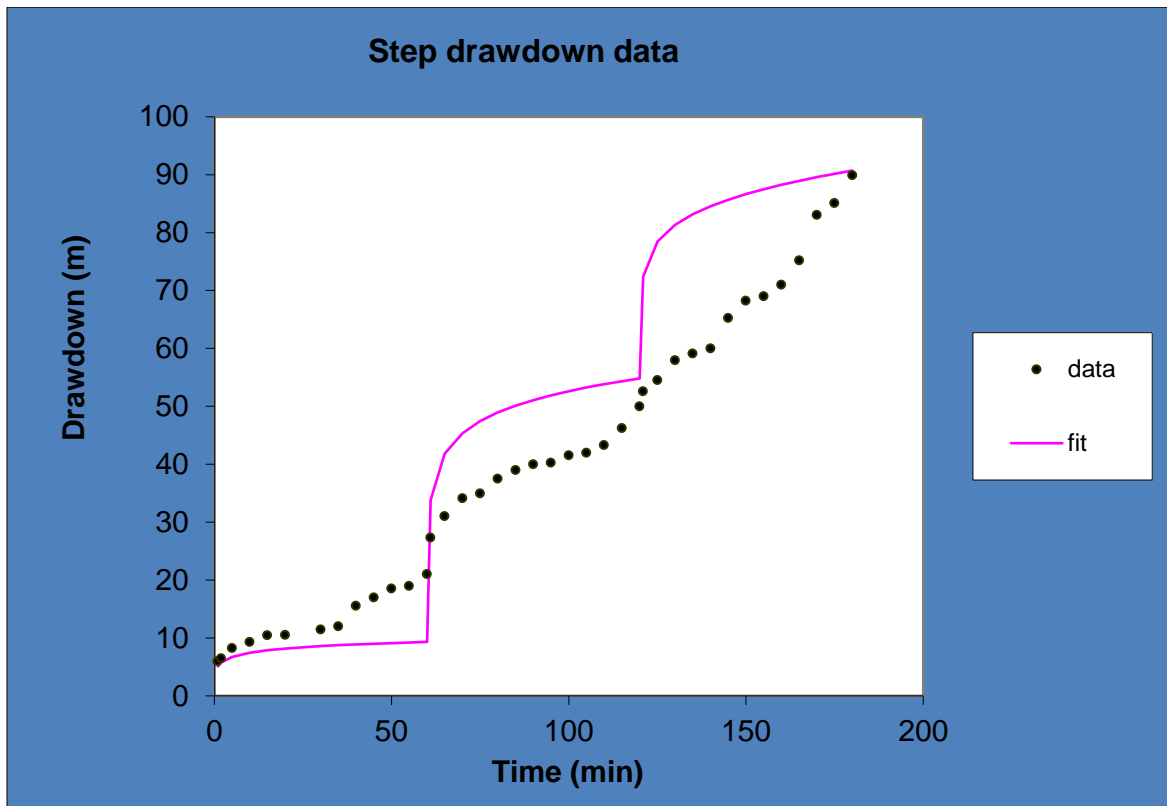


Figure 5.4: Borehole BH35-0118 stepped discharge test (drawdown vs time)

Where:

r_e (m) =	0.11
T (m^2/d) =	1.8
S =	1.68E-03

Table 5.16 shows the constant discharge test details.

Table 5.16: Borehole BH35-0118 drawdown – Constant discharge test

Borehole name	Average yield (ℓ/s)	Total drawdown (m)	Percentage of available drawdown
BH35-0118	1.15	84.25	88.68

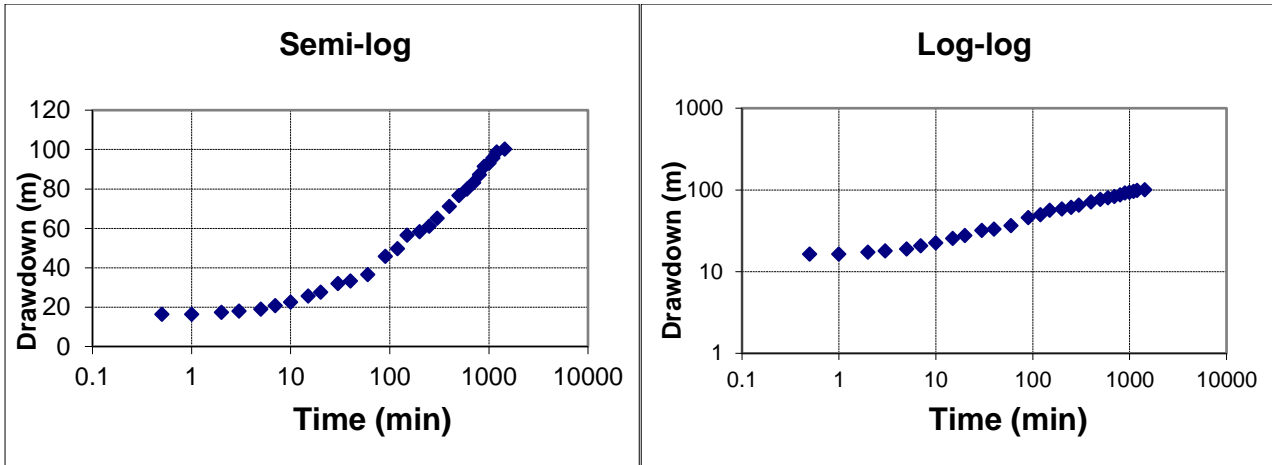


Figure 5.5: Constant discharge test and recovery (drawdown vs time) for Borehole BH35-0118 (Semi-Log and Log-Log graphs).

A log-log plot of the drawdown data and derivative of the drawdown observed at borehole BH35-0118 is shown in Figure 5.5. During the test, the derivative plot becomes partially horizontal, and the drawdown begins to steepen after 30 minutes. The drawdown is more than 10m during early pumping and grows exponentially later on, indicating a boundary effect such as dyke formation. Using the Logan equation, the predicted yield of 1.15 l/s resulted in $T = 1.8 \text{ (m}^2/\text{d)}$.

The testing data for Borehole *BH35-0120* are shown in Table 5.17.

Table 5.17: Pumping details for Borehole BH35-0120

Borehole depth (m)	Static water level (mbgl)	Test pump depth (mbgl)	Available drawdown	Location (Coordinates)	Status
54.31	9.32	50.00	40.68	-24.6164, 30.74096	Not equipped

Table 5.18 shows the drawdown data for Borehole *BH35-0120*.

Table 5.18: Drawdown data for Borehole BH35-0120

Borehole name	Step test	Average yield (ℓ/s)	Total drawdown (m)	Percentage of available drawdown
BH35-0120	Step Test 1	0.31 (60 mins)	0.33	0.81
BH35-0120	Step Test 2	0.77 (60 mins)	0.95	2.34
BH35-0120	Step Test 3	1.56 (60 mins)	2.06	5.06
BH35-0120	Step Test 4	4.20 (30 mins)	40.68	100.00

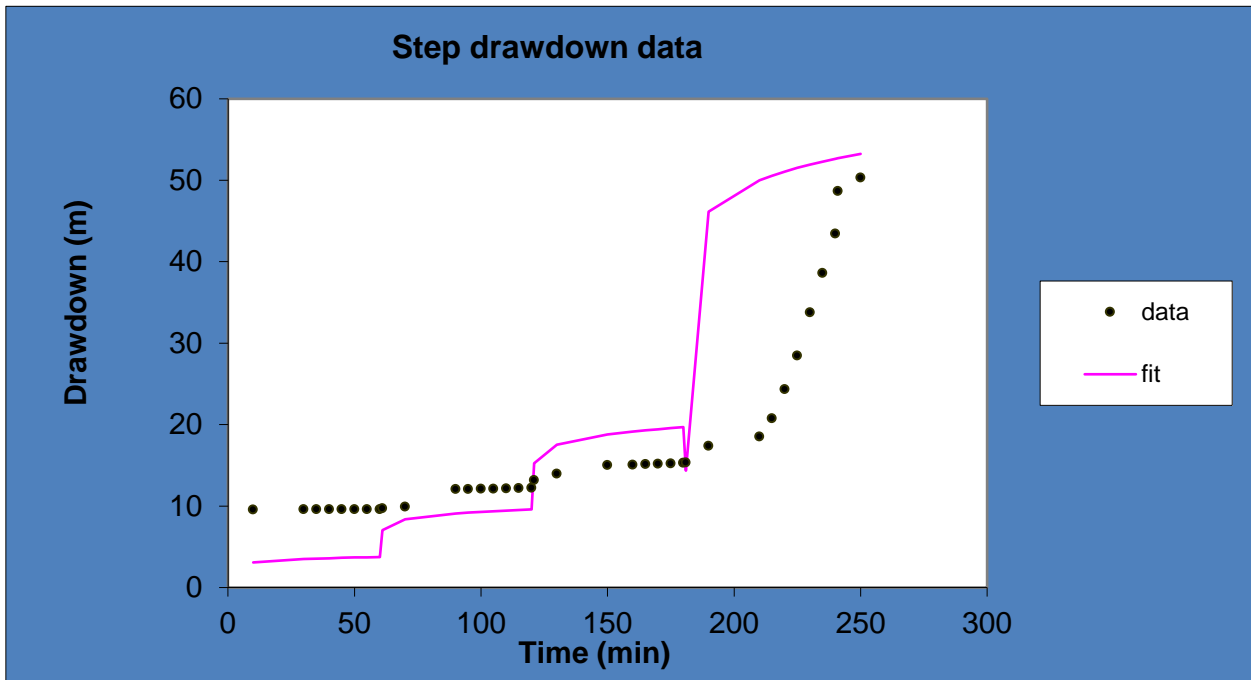


Figure 5.6: Borehole BH35-0120 stepped discharge test (drawdown vs time).

Where:

r_e (m) =	0.11
T (m^2/d) =	5.7
S =	2.01E-03

Table 5.19 shows the drawdown data for Borehole *BH35-0120*.

Table 5.19: Borehole BH35-0120 drawdown – Constant discharge test

Borehole name	Average yield (ℓ/s)	Total drawdown (m)	Percentage of available drawdown
BH35-0120	2.20	31.47	77.35

The constant discharge test was carried out for a period of 24 hours at a constant discharge of 2.20 ℓ/s and it recovered to 96% of the initial static water level, 120 minutes after pumping stopped.

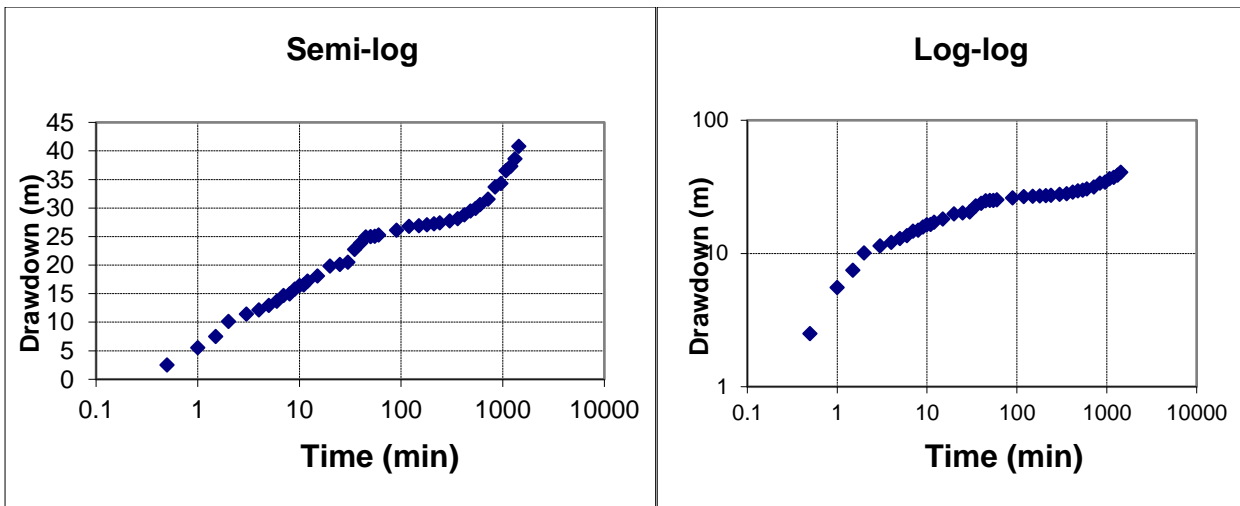


Figure 5.7: Constant discharge test and recovery (drawdown vs time) for Borehole BH35-0120 (Semi-Log and Log-Log graphs).

Figure 5.7 depicts a log-log plot of the drawdown data and derivative of the drawdown measured in borehole BH35-0120. During the test, the derivative plot does not become horizontal, indicating that infinite-acting, radial flow conditions are not produced. The type curve takes into account delayed yield due to unconfined aquifer and wellbore storage. The drawdown data primarily represent the unconfined aquifer's later-time, delayed-yield reaction. Using the Logan equation, the predicted yield of 2.20 l/s resulted in $T = 5.7 \text{ (m}^2/\text{d)}$.

5.2.2 Static water level analysis

Table 5.20 shows the static water levels of Leroro, from the data retrieved from existing groundwater sources.

Table 5.20: Static water level comparison of groundwater in Leroro

Borehole name	First static water level reading and date in (mbgl)	Second static water level reading and date (mbgl)	Third static water level reading (mbgl)	Difference in static water levels (mbgl)	Timeframe in years (first reading and last reading)
H35-0128	10.09 12/04/2002	24.00 20/10/2011	Could not be measured	13.91	9
H35-0129	Data not available	22.19 22/10/2011	24.00	1.81	10
H35-0126	Data not available	16.15 17/11/2011	28.00	11.85	10
H05-0786/ H35-0133	15.80 06/04/2002	23.20 14/03/2009	39 (dynamic)	7.40	7
New borehole	9.62 12/04/2021	Nil	Nil	0	New borehole

Table 5.21 shows the static water levels of Matibidi, from the data retrieved from existing groundwater sources.

Table 5.21: Static water level comparison of groundwater in Matibidi

Borehole name	First static water level reading and date in (mbgl)	Second static water level reading and date (mbgl)	Third static water level reading (mbgl)	Difference in static water levels (mbgl)	Timeframe in years (first reading and last reading)
H35-0110/H05-0680	3.40 17/10/1995	2.27 23/04/2002	22.20 (dynamic)	1.13	8
H35-0111	23.90 20/05/1995	Data not available between 1995 and 2020	26.68 (dynamic)	2.78	26
H35-0.125	Data not available	22.28 29/05/2002	29.54	7.26	19
H05-0676	28.98 17/10/1995	22.28 29/05/2002	30 (dynamic)	6.7	8
H05-0679	27.87 17/10/1995	20.89 04/06/2002	34.14 (dynamic)	6.27	26
H35-0122/ H05-0675	16.50 24/01/1996	23.90 22/05/2002	Could not be measured	7.40	7
New borehole	42 12/03/2021	Nil	Nil	0	New borehole

Table 5.22 shows the static water levels of Matibidi, from the data retrieved from existing groundwater sources.

Table 5.22: Static water level comparison of groundwater in Moremela

Borehole name	First static water level reading and date in (mbgl)	Second static water level reading and date (mbgl)	Third static water level reading (mbgl)	Difference in static water levels (mbgl)	Timeframe in years (first reading and last reading)
H05-0686	5.65 17/10/1995	13.24 12/06/2002	Could not be measured	7.59	8
H35-0143	Data not available	10.44 19/06/2002	23.59	13.15	19

The boreholes in the study area are run on a 24-hour duty cycle and, therefore, static water levels could not be obtained, only a sample of the groundwater sources could be assessed.

To mitigate against any negative impacts of over-abstraction, the following are to be adhered to:

- i. A regional monitoring network and programme needs to be implemented in order to timeously detect any negative impacts of groundwater abstraction.
- ii. Verification and ongoing recording of water abstraction from community boreholes and abstraction boreholes.
- iii. Water level measurements in community boreholes, abstraction boreholes and dedicated monitoring boreholes.
- iv. Water level and stage flow measurements along streams or river reaches in the vicinity of abstraction points.

The regional model should be updated regularly with new monitoring data available. This should include the following:

- i. Calibration of compartments against seasonal and long-term water level fluctuations.
- ii. Link of groundwater and surface water modelling to evaluate the impact of abstraction on surface water flow, especially at Moremela.
- iii. Linking of groundwater infrastructure to the Geographic Information System (GIS) interface.

Based on the static water readings on tables 5.20, 5.21, and 5.22 the groundwater levels of the study area have decreased. This is probably due to the heterogeneous nature of the larger dolomitic compartment and the specific lesser transmissive aquifer zone associated with the Leroro and Moremela villages.

Figure 5.8 shows a groundwater yield potential of the study area. Matibidi is in a lower-lying area shown in blue and has a higher yield potential. Leroro is at the highest point of the study area.

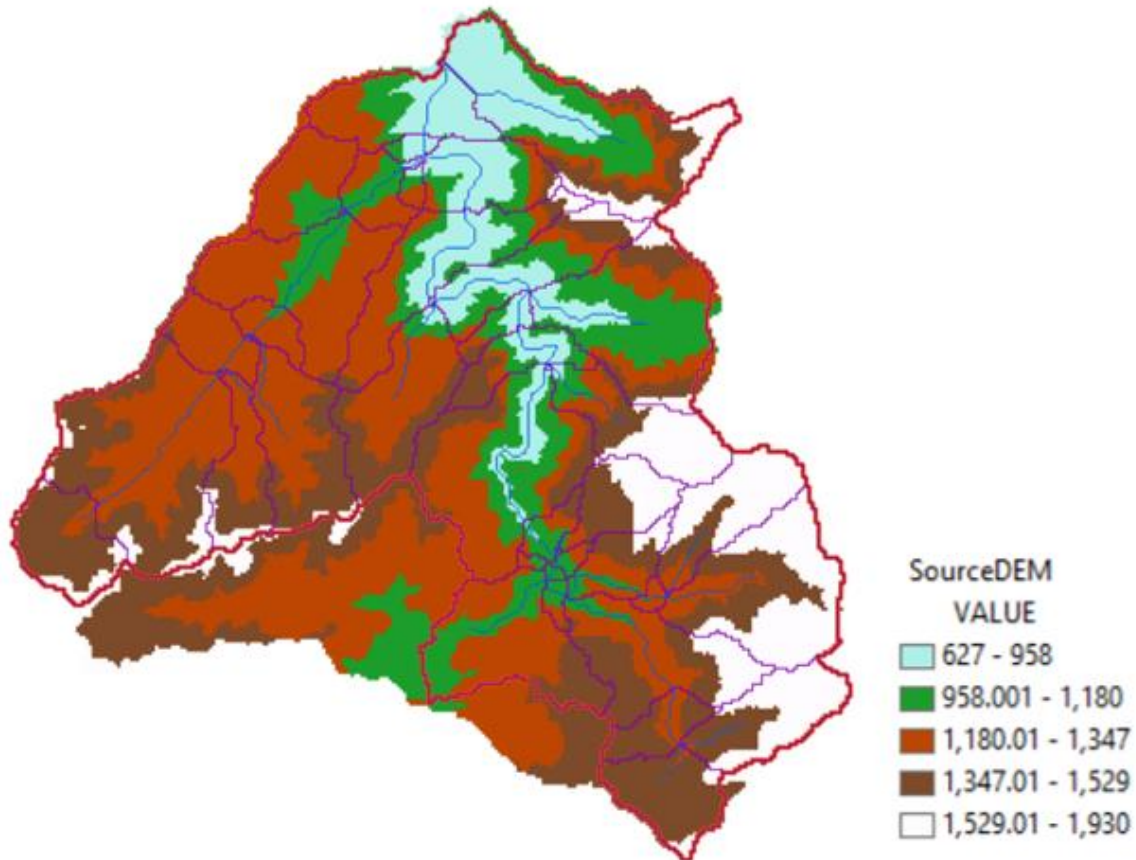


Figure 5.8: Groundwater yield potential derived from the Soil and Water Assessment Tool for the B60D quaternary catchment

As part of this study, a regression analysis was done to determine the net difference in groundwater levels. With cognisance of both seasonality and the heterogeneous nature of the aquifer, the net differences are not that excessive. They do, however, highlight over-utilisation and exceeding sustainable safe yields on a local level.

The positive water balance for the larger dolomitic compartment highlights the localised nature of the water supply issues pertaining to Leroro and Moremela. Cognisance should, however, be taken that subcompartmentalisation was not investigated.

5.3 Groundwater chemistry results

Water from both Boreholes *H35-0143* (Moremela) and *H35-0111* (Matibidi) were tested in accordance to the SANS 241-1:2015 limits (SABS, 2015). The analysis performed by LabServe found the water for Borehole *H35-0143* to be fit for human consumption as it has Class 2 marginal water quality, which is conditionally acceptable as shown in Table 5.23.

Table 5.23: Summary of chemistry results for Borehole H35-0143 (Moremela) according to DWS standards

Parameter	Results	Health / Other effects	Water treatment		
			Home	Conventional	Advanced
Microbial properties					
Total coliforms	2 cfu/100 ml	Insignificant risk of microbial infection	Acceptable for human consumption		
Physical properties					
Calcium (Ca)	51 mg/l	No health effects Increased scaling problems and lathering of soap impaired	Acceptable for human consumption		
Total hardness	222 mg/l	Hard water	Acceptable for human consumption		

Table 5.24 shows the analysis of results for the tested Borehole *H35-0111*. According to the analysis performed by LabServe, the water for Borehole *H35-0111* is classified as Class 3 (poor water quality), due to a high total hardness value. This is very hard water; the maximum allowable consumption period is seven years as sensitive individuals may be affected. Sensitive groups affected by total hardness include:

- i. Individuals with a history of kidney or gall-bladder stones (where calcium is the main contributor to the total hardness).
- ii. Infants under the age of one year (where magnesium is the main contributor to the total hardness).

Class 3 (Red): Poor water quality. Unsuitable for use without treatment. Chronic effects may occur. In cases where water tested is class 3 as for borehole *H35-0111*, the water is not recommended for human consumption. Alternative sources should be explored.

Table 5.24: Summary of chemistry results for Borehole H35-0111 (Matibidi) according to (SABS, 2015)

Parameter	Results	Health / Other effects	Water Treatment		
			Home	Conventional	Advanced
Microbial properties					
Total coliforms	2 cfu/100mℓ	Insignificant risk of microbial infection	Acceptable for human consumption		
Physical properties					
Calcium (Ca)	74 mg/ℓ	No health effects Increased scaling problems and lathering of soap impaired	Acceptable for human consumption		
Total hardness	397 mg/ℓ	Very hard water, maximum consumption period allowable is seven years	No treatment (Non-potable water)	Lime treatment	Ion exchange Precipitation with sodium carbonate, settlement and filtration

Further tests were recommended as the study area did not have a sewerage reticulation system, but primarily functioned on pit latrines.

The following chemical constituents were analysed by an accredited laboratory in terms of the South African National Accreditation System (SANAS) ISO/IEC 17025:2005:

- i. Macro chemistry – pH, electrical conductivity, total dissolved solids, chemical oxygen demand, dissolved organic carbon, alkalinity, hardness, calcium, magnesium, sodium, potassium, chloride, fluoride, sulphate, phosphate, ammonia, nitrate and nitrite.

Additional water sustainability tests were done on 16 August 2022 on boreholes namely BH-0118, BH35-0146, BH35-0111, and BH35-0120-the boreholes were sampled at the lower-lying zone of the study area (Matibidi) as it has higher yields, as Leroro and Moremela is situated in higher lying areas. Table 5.25 shows the chemical test for the additional boreholes.

Table 5.1: Chemical results for additional boreholes

Chemical constituent	Std limits	BH35-0146	BH35-0118	BH35-0120
pH	≥5 to ≤9.7	7,06	6,83	6.71
Total coliforms	≤ 10	3,00	45,00	5
Conductivity (mS/m)	≤ 170	26,90	61,20	79.6
E. coli	-	>200	>200	>200
Chemical determinants				
Total dissolved solids	≤ 1 200	176	438	517.40
Total alkalinity	-	42	49	115.00
Total hardness	<200	-	-	243.30
Turbidity	≤ 5	55,90	4,47	49,70
Fluorides	≤ 1.50	0,32	0,42	ND
Dissolved sulphate as SO ₄	≤ 250	<1,0	14,40	103,82
Nitrate as N	≤ 11	11,00	29,20	29,18
Chloride Cl	≤ 300	31,80	79,40	96,24
Ammonium as N		ND	ND	0,15
Nitrite as N	≤ 11	< 0	< 0,1	0,01
Total hardness as CaCO ₃	-	42,00	86,00	243,30
Calcium hardness as CaCO ₃	-	25,00	46,00	87,50
Magnesium hardness as CaCO ₃	-	17,00	40,00	155,80
Dissolved potassium as K	-	7,64	11,20	4,91
Dissolved calcium as Ca	-	10,00	18,50	35,00
Dissolved magnesium as Mg	-	4,21	9,71	38,00
Dissolved sodium as Na	≤ 200	37,30	89,70	66,60
Dissolved zinc as Zn	-	ND	ND	0,22
Dissolved iron as Fe	-	0,41	0,08	0,01
Dissolved manganese as Mn	≤ 0.10	0,08	0.02	ND
Dissolved copper as Cu	≤ 2	ND	ND	0,02

*ND: Not detected

Tested water from the boreholes on table 5.25 generally met the SANS 241:2015 except for the dissolved metals and total hardness on borehole H35-0120. Borehole H35-0118 had an abnormally high count of total coliforms. Based on the test results above the boreholes will require filtering before consumption.

Additional data were retrieved from the DWS Feasibility Plan for Groundwater Resource Development of the Malmani dolomites within the Olifants River water supply system – Final ORWSS Dolomite Groundwater Resource Development Project Report (2018).

Table 5.2: Macrochemical and dissolved metal results for the 2016 hydrochemical samples within the ORWSS study area

Chemical constituent	Std Limits	H12-1640 Ohrigstad borehole (Vmd)	H35-0121 Matibidi borehole (Vmd)	BR01-M02 Blyde River borehole (Vmd)
Date	N/A	06 December 2016	07 December 2016	08 December 2016
pH	≥5 to ≤9.7	7.7	7.6	7.8
Conductivity (mS/m)	≤ 170	16	53	28
Macrochemistry (in mg/ℓ)				
Total dissolved solids	≤ 1 200	78	280	166
Total alkalinity	-	75	245	124
Total hardness	<200	64	250	127
Bicarbonate		75	245	124
Calcium	-	12	49	23
Magnesium	-	8.2	31	17
Sodium	≤ 200	2.1	4.9	2.7
Potassium	-	0.2	<0.06	0.3
Chloride	≤ 300	2	6	4
Fluoride	≤ 1.50	0.06	0.15	<0.05
Sulphate	≤ 250	3.29	4.06	4.12
Orthophosphate	≤ 5	<0.03	<0.03	<0.03
Ammonia	-	<0.22	<0.22	<0.22
Nitrate	≤ 11	0.11	2.91	0.95
Nitrite	≤ 11	<0.1	<0.1	0.14
Dissolved organic carbon		<1	1.03	<1
Chemical oxygen demand	≤ 15	16	12	12
Dissolved metals (in µℓ)				
Aluminium	≤ 0.30	4.61	2.26	5.21
Antimony	≤ 0.02	<1	<1	<1
Arsenic	≤ 0.01	<1	<1	<1
Barium		24	22	6.97
Beryllium		<1	<1	<1
Boron	≤ 0.30	46	49	9.96
Cadmium	≤ 0.003	<1	<1	<1
Chromium	≤ 0.05	<1	1.86	1.63
Cobalt	-	<1	<1	<1
Copper	≤ 2	<1	5.09	3.93
Iron	≤ 2	<1	<1	3.97
Lead		<1	4.13	<1
Lithium		1.85	<1	1.56
Manganese	-	1.82	<1	<1

Chemical constituent	Std Limits	H12-1640 Ohrigstad borehole (Vmd)	H35-0121 Matibidi borehole (Vmd)	BR01-M02 Blyde River borehole (Vmd)
Mercury	≤ 0.006	<1	<1	<1
Molybdenum	≤ 0.07	<1	<1	<1
Nickel	≤ 0.07	<1	<1	<1
Selenium	≤ 0.04	<1	<1	<1
Silver		<1	<1	<1
Strontium		28	38	5.98
Thallium		<1	<1	<1
Tin		<1	<1	<1
Titanium		<1	<1	<1
Uranium		<1	<1	<1
Vanadium		<1	<1	<1
Zinc		2.11	3.35	91

Collected 2016 Malmani Subgroup dolomite groundwater and averaged DWS borehole data generally met the SANS 241:2015 (SABS, 2015) drinking water quality standards for all constituents, with the exception of slightly elevated dissolved metals such as:

- i. boron;
- ii. copper;
- iii. lithium;
- iv. manganese; and
- v. strontium.

The Malmani Subgroup samples generally had an electrical conductivity of < 50 mS/m with slightly elevated electrical conductivity, although well within the SANS 241:2015 electrical conductivity limit of 170 mS/m in a range of 10–60 mS/m. As expected, groundwater from the Malmani Subgroup boreholes was of magnesium–calcium–bicarbonate nature (due to dolomite composition), with a slightly alkaline pH of 7.6–7.8 and elevated hardness/alkalinity.

Dolomitic aquifers are highly susceptible to anthropogenic groundwater contamination, due to their unconfined to semi-confined nature and surface to depth dissolution features with high transmissivities and yields. The presence of nitrate, although below the drinking and irrigation water quality limits (see Table 2.10), within some of the tested boreholes, is potentially either due to fertiliser or human and livestock contamination. It is worth noting that the study area predominantly had pit latrines.

Chapter 6

OVERVIEW OF WATER CONSERVATION AND WATER DEMAND MANAGEMENT OF THABA CHWEU LOCAL MUNICIPALITY

6.1 SWOT analysis

Thaba Chweu is one of the poorer rural municipalities in the Ehlanzeni district in Mpumalanga. Management of water resources is crucial to its sustainability. Water conservation and water demand does not only require technical and financial power, it also requires a strong organisational capability. Therefore, Figure 6.1 shows the SWOT analysis that indicates the strengths, weaknesses, threats and opportunities that face the TCLM and are discussed below.

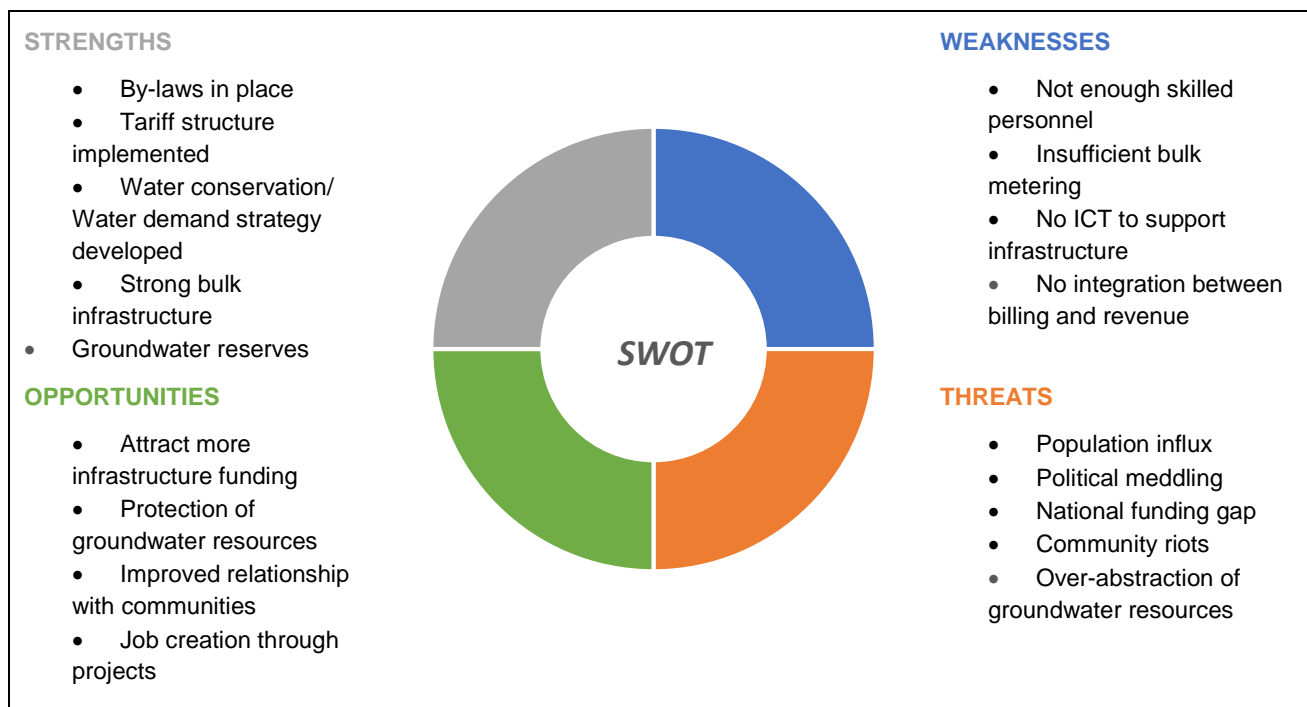


Figure 6.1: SWOT analysis of the Thaba Chweu Local Municipality

- i. **Strengths:** The TCLM has developed projects that were still to be gazetted to help them enforce management and conservation of water resources within the municipality. The tariff structure will increase municipal revenue collection and enable it to be able to increase the quality of water supplied to the communities and be able to maintain the current bulk infrastructure. The fact that the area has groundwater reserves, does not mean it is abundant and care should be taken to conserve the water.
- ii. **Opportunities:** The water conservation and water demand management is a national priority and, therefore, implementation of the water conservation and water demand management strategy will make the TCLM noticeable to both the national and provincial authorities and can attract more funding for infrastructure. It can also help with protection of water resources and improve the relationship with communities, as it can create job opportunities.
- iii. **Weaknesses:** The challenge facing the TCLM is the lack of skilled human resources to maintain and manage the existing infrastructure. This is coupled with the fact that the bulk water infrastructure is not sufficiently metered, the municipality is not able to ascertain how much bulk supply is drawn from the system and how much is lost through unauthorised connections and/or leakages. Incorporation of information and communications technology will better the monitoring and management of infrastructure, which can also be used to integrate the billing and revenue systems to optimise collection.
- iv. **Threats:** The TCLM has a lucrative tourism market and fertile ground for agriculture, therefore, creating economic opportunities and population influx. This can also cause strain to the water resources and lead to over-abstraction of water. In addition, lack of funds to sustain infrastructure can cause strain to water supply.

It is important to understand that the activities for water conservation and water demand management is in most cases interrelated and dependant on each other. The planning of activities and the implementation of management information systems to gather vital management information are, therefore, of critical importance before maintenance work and projects can be done and field teams are engaged. The key is to work intelligently and to understand the cost–benefit ratios before work is undertaken. Failure to do so can lead to unnecessary activities, projects and wasted funds. Examples of such typical issues without adequate planning are as follows:

- i. No consumer meters in the region.
- ii. Removal of unauthorised connections on main distribution systemsNo systems or procedures in place to prevent the reconnection of unauthorised connections.
- iii. Water demand management and water conservation measures implemented in areas before adequate information was available to establish the extent of non-revenue (key performance indicators).
- iv. The implementation of public awareness campaigns or leak detection in areas where physical water losses are high; minimal water, or the water pressure is low.
- v. Cost–benefit ratios are not determined before work is done, resulting in wasted expenditure.
- vi. Root cause analysis not done to establish problematic infrastructure before leak repair programmes are undertaken, such as records of bursts, type of material, high pressures.
- vii. Leak detection exercises are commissioned without adequate preparation.

It is important to implement a strategy and action plan to combat wastage and prioritise water demand management.

6.2 Water demand projections

The demand projections for Scenario 1 (realistic and theoretical) can be seen in Table 6.1 and Table 6.2. The two scenarios were calculated as follows:

- i. *Realistic scenario* – future population calculated using Stats SA (2011) updated populations as the basis and growth rates per year as recommended at 1.86%. The household size used was 3.3 people per household.
- i. *Theoretical scenario* – future population calculated using Stats SA (2011) updated populations as the basis and growth rates per year as recommended at 1.86%. The household size used was five people per household as per the DWS WSDP recommendation. The income levels were also varied to increase the income profile (fewer poor people) over a 20-year term.

Both scenarios include an addition of 15% for losses (10%) for institutional, municipal, or other use. In South Africa, the DWS has set the minimum requirement to 25 ℓ per person per day.

Table 6.1: Population statistics and water demand for Leroro

Population		Year (1.86% per annum – Stats SA)					
Leroro	Household size	2021	2022	2025	2030	2035	2040
Low income	Recommended household size: 3.3 people per household	7 513	7 652	8 087	8 868	9 724	10 662
Middle class		12 445	12 677	13 398	14 691	16 109	17 664
High income		2 670	2 720	2 874	3 152	3 456	3 790
Total population		22628	23 049	24 359	26 710	29 289	32 116
Low income	3.4 people per household (Stats SA)	7 740	7 884	8 332	9 137	10 018	10 986
High income		2 751	2 802	2 961	3 247	3 561	3 904
Total households		10 491	10 686	11 294	12 384	13 579	14 890

Average annual daily demand (AADD) (kℓ/day)		Year					
Leroro	Household size	2021	2022	2025	2030	2035	2040
Low income (80 ℓ/c/d)	Recommended household size: 3.3 people per household	601.00	612.18	646.98	709.43	777.91	852.99
Middle class (150 ℓ/c/d)		1 866.82	1 901.54	2 009.63	2 203.61	2 416.31	2 649.55
High income (250 ℓ/c/d)		667.53	679.94	718.60	787.96	864.02	947.41
Businesses and institutions (10% AADD)		313.53	319.37	337.52	370.10	405.82	445.00
Total AADD (kℓ/day)		3 448.88	3 513.03	3 712.73	4 071.10	4 464.06	4 894.95

2AADD (kℓ)		Year					
Leroro		2021	2022	2025	2030	2035	2040
Recommended household size 3.3 per household		6 897.77	7 026.07	7 425.46	8 142.20	8 928.12	9 789.90

Summer daily demand (kℓ/day)		Year					
Leroro		2021	2022	2025	2030	2035	2040
Recommended household size 3.3 per household		5 949.33	6 059.98	6 404.46	7 022.65	7 700.50	8 443.79

Table 6.2: Population statistics and water demand for moremeia

Population		Year (1.86% per annum – Stats SA)					
Moremela	Household size	2021	2022	2025	2030	2035	2040
Low income	Recommended household size: 3.3 people per household	8 436	8593	9 081	9 958	10 919	11 973
Middle class		13 896	14 155	14 959	16 403	17 986	19 723
High income		2 263	2 305	2 436	2 671	2 929	3 211
Total population		24 595	25 052	26 476	29 032	31 834	34 907
Low income	3.6 people per household (Stats SA)	9 203	9 374	9 907	10 863	11 912	13 062
High income		2 468	2 514	2 657	2 914	3 195	3 503
Total households		11 671	11 888	12 564	13 777	15 107	16 565

AADD (kℓ/day)		Year					
Moremela	Household size	2021	2022	2025	2030	2035	2040
Low income (80 ℓ/c/d)	Recommended household size: 3.3 people per household)	674.88	687.44	726.51	796.64	873.54	957.85
Middle class (150 ℓ/c/d)		20 84.42	2 123.19	2 243.88	2 460.47	2 697.96	2 958.38
High income (250 ℓ/c/d)		565.68	576.20	608.96	667.74	732.19	802.87
Business and institutions (10% AADD)		332.50	338.68	357.94	392.48	430.37	471.91
Total AADD (kℓ/day)		3 657.48	3 725.51	3 937.29	4 317.33	4 734.06	5 191.01

2AADD (kℓ)		Year					
Moremela		2021	2022	2025	2030	2035	2040
Recommended household size: 3.3 per household		7 314.97	7 451.02	7 874.57	8 634.66	9 468.12	10 382.03

Summer daily demand (kℓ/day)		Year					
Moremela		2021	2022	2025	2030	2035	2040
Recommended household size: 3.3 people per household		6 309.16	6 426.51	6 791.82	7 447.40	8 166.25	8 954.50

Table 6.3: Population statistics and water demand for matibidi

Population	Household size	Year (1.86% per Annum – Stats SA)					
Matibidi		2021	2022	2025	2030	2035	2040
Low income	Recommended household size: 3.3 people per household	16 265	16 567	17 509	19 199	21 052	23 084
Middle class		28 671	29 204	32 023	35 114	38 504	42 220
High income		3 810	3 881	4 255	4 666	5 116	5 610
Total population		48 746	49 652	54 445	59 700	65 463	70 915
Low income	3.5 people per household (Stats SA)	17 251	17 571	19 267	21 127	23 167	25 403
High income		4 041	4 116	4 350	4 949	5 426	5 950
Total households		21 291	21 687	23 781	26 076	28 593	31 353

AADD (kℓ/day)	Household size	Year					
Matibidi		2021	2022	2025	2030	2035	2040
Low income (80 ℓ/c/d)	Recommended household size: 3.3 people per household	1301.19	1325.39	1453.32	1593.60	1747.42	1916.09
Middle class (150 ℓ/c/d)		4300.65	4380.64	4803.48	5267.14	5775.55	6333.03
High income (250 ℓ/c/d)		952.44	970.16	1063.80	1166.49	1279.08	1402.54
Business and institutions (10% AADD)		655.43	667.62	732.06	802.72	880.21	965.17
Total AADD (kℓ/day)		7209.71	7343.81	8052.67	8829.95	9682.26	10616.83

2AADD (kℓ)	Year					
Matibidi	2021	2022	2025	2030	2035	2040
Recommended household size: 3.3 people per household	14 419.42	14 687.62	16 105.34	17 659.90	19 364.51	21 233.66

Summer daily demand (kℓ/day)	Year					
Matibidi	2021	2022	2025	2030	2035	2040
Recommended household size: 3.3 people per household	12 436.75	12 668.07	13 890.85	15 231.66	16 701.89	18 314.04

6.3 Water use analysis – two scenarios

In the analysis, two scenarios were applied in the comparison of water demand versus groundwater supply. The first scenario – depicted in Table 6.4 as Scenario 1, using the annual average daily demand. Currently, the combined total water demand for the study area cannot be met by the current groundwater contribution. The shortfall within Leroro and Moremela was probably due to a less transmissive aquifer locally, as well as infrastructure-related losses. Implementing the same water demand criteria for 2022 and 2030, the groundwater contribution indicated a higher shortfall. Considering this, the commissioning of additional boreholes at Leroro and Moremela in a lesser transmissive aquifer would not resolve the demand problem.

An unknown volume of the surplus groundwater from Matibidi is pumped to Leroro's reservoirs to section a portion of their shortfall. The production boreholes in Matibidi run on a 24-hour duty cycle to keep up with the demand some of the boreholes are over-abstracted, increasing the pressure on the system. Shown in Table 6.4, Scenario 2, is an analysis of the water demand met by groundwater in litres per day. Currently, the combined total water demand cannot be met by the current groundwater contribution.

The commissioning of additional groundwater infrastructure should target highly transmissive aquifer zones, where they are to be found, for Leroro and Moremela. The development of additional wellfields should incorporate subcompartment delineations and water balance calculations. Alternatively, surface water supply should be considered to alleviate shortfall and the ever-increasing demand. The raw water pump station at Moremela Stream has a potential of $63 \text{ m}^3/\text{hr}$ which is $63\,000 \text{ l/hr}$. Should this raw water station be fully operational for eight hours a day, it can supplement the water demand with $504\,000 \text{ l/day}$. This does not alleviate the water shortfall, but reduces the groundwater abstraction from proposed wellfields.

Table 6.4: Scenario 1 – Water demand vs groundwater supply

Village	Number of households (2021)	2021 population	2022 Population at 1.86% growth/ annum	2030 Population at 1.86% growth/ annum	Daily demand at total AADD for 2021	Daily demand at total AADD for 2022	Daily demand at total AADD for 2030	Groundwater contribution (ℓ/day)	Water demand met by groundwater shortfall/ surplus (ℓ/day) 2021	Water demand met by groundwater shortfall/ surplus (ℓ/day) 2022	Water demand met by groundwater shortfall/ surplus (ℓ/day) 2030
Leroro	6 857.00	22 628.10	23 048.98	26 710.45	3 448 884.49	3 513 033.74	4 071 099.30	706 070.00	-2 742 814.49	-2 806 963.74	-3 365 029.30
Matibidi	14 801.00	48 745.61	49 652.28	57 539.83	7 209 710.67	7 343 811.29	8 510 417.84	5 081 904.00	-2 127 806.67	-2 261 907.29	-3 428 513.84
Moremela	2 311.00	24 594.90	25 052.37	29 032.08	3 657 482.98	3 725 512.17	4 317 331.14	580 210.00	-3 077 272.98	-3 145 302.17	-3 737 121.14
Total for overall area			97 753.63	113 282.35	14 316 078.14	14 582 357.20	16 898 848.28	6 368 184.00	-7 947 894.14	-8 214 173.20	-10 530 664.28

Table 6.5: Scenario 2 – Water demand vs groundwater supply

Village	Number of households (2021)	2021 population	2022 Population at 1.86% growth/ annum	2030 Population at 1.86% growth/ annum	Daily Demand at total 80 ℓ/c/d for 2021	Daily Demand at total 80 ℓ/c/d for 2022	Daily Demand at total 80ℓ/c/d for 2030	Groundwater Contribution (ℓ/day)	Water Demand met by Groundwater Shortfall/Surplus (ℓ/day)	Water Demand met by Groundwater Shortfall/Surplus (ℓ/day)	Water Demand met by Groundwater Shortfall/Surplus (ℓ/day)
Leroro	6 857.00	22 628.10	23 048.98	26 710.45	1 810 248.00	1 843 918.61	2 136 835.66	706 070.00	-1 104 178.00	-1 137 848.61	-1 430 765.66
Matibidi	14 801.00	48 745.61	49 652.28	57 539.83	3 899 649.07	3 972 182.54	4 603 186.53	5 081 904.00	1 182 254.93	1 109 721.46	478 717.47
Moremela	2 311.00	24 594.90	25 052.37	29 032.08	1 967 592.00	2 004 189.21	2 322 566.16	580 210.00	-1 387 382.00	-1 423 979.21	-1 742 356.16
Total for overall area			97 753.63	113 282.35	7 677 489.07	7 820 290.37	9 062 588.35	6 368 184.00	-1 309 305.07	-1 452 106.37	-2 694 404.35

6.4 Water conservation and demand management strategy

The department of water and sanitation is a custodian of water services and water resources in South Africa and have outlined the role that water conservation and demand management should play within the overall context of the management and protection of water resources.

In order to create a water management strategic framework, strategy outputs for water services authorities, in this instance TCLM, should be developed. The intention is that water management and water services institutions should interpret the outputs and implement them accordingly to their own specific circumstances, needs, requirements, constraints and opportunities.

To create sustainable management of the catchment and its water resources, the following outputs should form part of the strategic outputs and interventions of the region:

- i. Implement efficient distribution management measures.
- ii. Ensure adequate information to support decision-making.
- iii. Promote the efficient use of water among consumers and customers.
- iv. Adopt integrated planning principles.
- v. Ensure the implementation of water catchment and water demand management best practices in new developments.
- vi. Contribute to the management strategy of the catchment.
- vii. Ensure adequate institutional and financial capacity for water catchment and water demand management.

A paradigmatic approach has been taken to assess and implement intervention methods for sustainability of the quaternary catchment. Table 6.6 outlines these intervention methods.

Table 6.6: Proposed intervention strategies for Thaba Chweu Local Municipality

Area targeted	Intervention focus	Intervention type
Areas without water	Interventions to improve water supply	Pressure reduction
		Remove informal connections
		Install reservoir control valves
		Repair leaks on reticulation lines and main distribution lines
		Community education on reducing demand and conservation
Areas with water	Interventions to maintain water supply integrity and water management	Pro-active operations and maintenance
		Continued pressure management
		Meter installation to stands
		Installation of flow limiters
		Installation of water reticulation in areas without reticulation to reduce unauthorised connections to formal reticulated areas
		Financial interventions – Billing system
		Community education on water management
Reduce and maintain the non-revenue demand of water within accepted National and International benchmarks. Such can be achieved by reducing leaks and reticulation lines, distribution mains and reservoir overflows.		
Technical	Commercial data validation	It is important for TCLM to reconcile and validate the customer data –include information on all water meters and large consumers.
	Recharge Rate	Sustainable borehole pumping should be introduced to determine the sustainable pumping rate (SPR) of each borehole.
	Borehole Monitoring	Water level sensors should be installed in the boreholes as well as the reservoirs and monitored monthly – a telemetry managed system should be installed with limiting parameters for each borehole. Telemetry systems is essential for operation functions: <ul style="list-style-type: none"> Monitoring of the operation of key water supply components. Centralised operation of some components. Monitoring of rate of pumping. Water quality should be sampled monthly. Repair/replace equipment regularly as proposed by manufacturers, and preventative maintenance to be done daily.
	Sustainable Yield	Pump testing should be redone to update the records and determine the sustainable yield of each borehole.
	Groundwater vulnerability testing	Establish sensitive areas in which surface pollution can affect groundwater using either processed based methods, overlay and index-based methods or statistical methods. Or the methods can be used in unison.
	Training	Training of technical staff on groundwater infrastructure maintenance and the management team on effective management of groundwater systems for sustainable outcomes.
	Conservation of resources	Reduction of the future projected potable groundwater demand by promoting alternative water resources and technologies.

CHAPTER 7

RECOMMENDATIONS AND CONCLUSIONS

7.1 Introduction

Monitoring, maintenance, and population growth in the research area necessitates a quicker assessment of water yields for improved planning, management, and long-term use of water resources. As a result, finding an appropriate hydrological model that mimics the water yield of ungauged catchments is a crucial step that must be taken alongside the water yield assessment.

The conclusions and recommendations from the above desktop groundwater potential assessment and hydrogeological exploratory investigations, are discussed in detail.

7.2 Aim and objectives

The main aim of the research was to formulate groundwater adaptation plans for sustainable water management for the B60D quaternary subcatchment of the Olifants WMA in order to provide hydrogeological information important to those responsible for planning, development and management of the study area. The focus of this study was on the development and implementation of input data, and testing of boreholes to represent the hydrological components of the study area to improve and sustain the aquifer.

7.2.1 To conduct a complete hydrocensus of groundwater resources and assess aquifer potentials through pump testing.

From the hydrocensus results, it is apparent that the local water table has decreased. This is probably due to the heterogeneous nature of the larger dolomitic compartment and specific lesser transmissive aquifer zone associated with the Leroro and Moremela villages. The significantly positive water balance for the larger dolomitic compartment highlights the localised nature of the water supply issues pertaining to the Leroro and Moremela villages.

The positive water balance for the larger dolomitic compartment (Matibidi) highlights the localised nature of the water supply issues pertaining to Leroro and Moremela.

The commissioning of additional boreholes in lesser transmissive aquifers (Leroro and Moremela) would not resolve the water demand problem. In addition, the boreholes listed

as blocked and unused in Appendix E (List of Boreholes), must be rehabilitated and the yield tested to assist in alleviating the water shortage in the study area. Development of groundwater infrastructure should target highly transmissive aquifer zones.

Based on the above factors, the B60D quaternary catchment can be identified as a potential hydrogeological target for wellfields, further hydrological modelling and water balancing is recommended. Based on the pump testing data and geophysical investigation, the Matibidi–Moremela zone can be targeted as a wellfield target zone, as Leroro has a drier aquifer. The wellfield target zone should supplement for further testing to achieve borehole yields greater than 10 l/s prior to wellfield development, through a phased monitor model managing approach. Additionally, detailed air-based gravity, electromagnetic and magnetic geophysical surveys with land-based magnetic, gravity and electromagnetic ground surveys are required for local correlation for optimal wellfield borehole siting.

Alternatively, surface water should be considered to alleviate shortfall and the ever-increasing demand.

7.2.2 To investigate the current operations and maintenance of groundwater facilities.

At present, TCLM faces a lack of human resources, starting from basic operational and maintenance personnel needs, up to key strategic and management positions. This problem is not only jeopardising any attempt to reduce non-revenue water levels but also basic operational and maintenance tasks. It has been ascertained that there is no formal operations and maintenance system in place at the TCLM. Events and tasks are only recorded in a book and dealt with by (seemingly) under resourced operation and maintenance staff.

Apart from addressing the staff and skills shortage, serious consideration should be given to implementation of a formal maintenance and management system, which keeps track of all complaints and incidents, issuing job cards to address or fix them, monitors all stock in the store, monitors efficiency of the team and individual staff members, and monitors all associated costs. There are many such systems available on the open market, and it is suggested that the appropriate one be selected via a tender process. It is imperative that the profile of water conservation and demand management is elevated to as senior a level as possible within the client organisation as discussed in Chapter 5. This will enhance the focus on water conservation and demand management activities from this directorate,

without distraction from other initiatives. This is a critical part of the success of the recommendations contained in this dissertation.

The local municipality is encouraged to address the lack of revenue system in place in the study area. A billing system coupled with an integrated quality management system will be beneficial in managing and controlling water systems and creating revenue to fund further water projects and development in the region.

The immediate interventions required to address the crisis of proportion water losses are summarised as follows. These interventions do not require any further studies or investigations, and should be considered as of critical importance to rectify the dire situation.

7.2.2.1 Administrative interventions

- i. Appoint more skilled staff to manage the water systems.
- ii. Introduce systems-related interventions.
- iii. Appoint a consultant to clean up the billing data, and its link to the geographic information system cadastre.
- iv. Appoint a contractor to audit all water consumers (starting with the top 20) with a view to reducing apparent losses (compare, by matching meter numbers, the information captured on site with the one on the billing database to confirm latest billing readings and highlight differences).
- v. Implement a maintenance and management system.

7.2.2.2 Physical interventions

- i. Appoint a contractor(s) to implement the proposed works to configure and zone the systems.
- ii. As part of configuration, the contractor should ensure that water demand zones are defined and isolated.
- iii. As part of configuration, the contractor should ensure that bulk and reticulation systems are split and that pumps are being operated at optimal levels.
- iv. As part of configuration, the contractor should investigate all pump and reservoir level controls to prevent pumping into full reservoirs or water towers that leads to overflows and spillage.

- v. After configuration has resulted in splitting of bulk and reticulation, install and monitor bulk meters on the outlets of all reservoirs.
- vi. Appoint a contractor and/or train own personnel to service and maintain all pressure reducing valves and other control valves.

7.2.2.3 *Inspection frequencies*

- i. 25 mm to 50 mm pressure-reducing valves to be inspected at least once a year.
- ii. 80 mm to 100 mm pressure-reducing valves to be inspected every six months.
- iii. 150 mm and above sizes to be inspected every three months.
- iv. Undertake a pipe replacement prioritisation study and replace the worst pipes in the systems.

7.2.3 To formulate an adaptation and management strategy for groundwater sustainability within the subcatchment

The main objective of a water conservation and demand management strategy and programme is to actually minimise water wastage, for example, to result in water savings, and to do so not as a once-off but in a sustainable and measurable manner.

The boreholes in the study area are overly utilised. Of the three villages, Matibidi has the highest yielding boreholes and a higher population. The additional boreholes were tested based on this demographic. Based on the results of the investigation, the data analysis and recommendations are extrapolated over a two-year period with a safety factor of 68%. The production borehole should be subjected to a full aquifer testing programme every four to five years to ensure continued sustainability.

Borehole *BH35-0118* has a total depth of 120 m, and a static water level of 16 m. This borehole would be able to deliver a sustainable yield of 3 600 l/hr or 43 200 l/day at the recommended pumping rate of 1.00 l/s.

- i. It is recommended that a 12-hour pumping cycle be used.
- ii. The borehole pump installations must be determined by the recommended borehole sustainable yield as well as other parameters such as total head.

Borehole *BH35-0120* has a total depth of 54.331 m, and a static water level of 9.32 m. This borehole would be able to deliver a sustainable yield of 2.5 l/s over a 12-hour pumping day

or volume of 108 000 ℓ /day. As a result of the lack of surface water reticulation in the region, boreholes are run for 24 hours a day, Therefore:

- i. The recommended sustainable yield is 1.68 ℓ /s (24-hour pumping cycle) with a volume of 144 720 ℓ /day.

Borehole *BH35-0146* has a total depth of 87 m, and a static water level of 37 m. This borehole would be able to deliver a sustainable yield of 36 000 ℓ /hr or 864 000 ℓ /day at the recommended pumping rate of 10 ℓ /s. This is a high-yielding borehole, therefore:

- i. It is recommended that a 24-hour pumping cycle be used.
- ii. The borehole pump installations must be determined by the recommended borehole sustainable yield as well as other parameters such as total head.

Based on the water test results from the sampled boreholes and fresh water pump station in Moremela, the water is acceptable for human consumption (Class 0 to Class 1), despite the high total hardness, nitrate/nitrite and the presence of *E. coli* in the water.

As mentioned in the problem statement in Chapter 1, there is no waterborne sanitation in the study area. Additional boreholes were tested in a higher-yielding region (Matibidi) and the results depicted the same scenario. Where water shows a high content of chemical constituents, water treatment options should be implemented.

7.2.3.1 *Treatment options*

Sedimentation, absorption, coagulation, and flocculation are all traditional water purification procedures that result in the partial elimination of microorganisms in water. However, these treatments do not always inactivate the germs, and further disinfection procedures must be used. Chlorine disinfection is commonly used. Disinfection, on the other hand, necessitates meticulous process control of the disinfection species, dosage, and contact duration. Microorganisms can be killed by boiling water before use in instances where no conventional treatment is used.

Nitrate is difficult to remove from home water supplies. Slow sand filtering can reduce nitrate levels to some extent, but it is not a dependable procedure. In the presence of an adequate carbon source, biological reduction of nitrate to nitrogen gas (denitrification) is possible, however the rise in carbonaceous matter is incompatible with a high quality water supply. Non-specific nitrate removal methods include running the water through an ion exchange

column with a selective affinity for nitrates. This method is costly since, depending on the nature of the resin used, other anions will be removed at the same time. However, it may be appealing on a household size if only drinking water is treated. Reverse osmosis successfully removes nitrate from water, as well as high percentages of almost all other ions and numerous organic substances. A low-pressure household unit can satisfactorily treat modest amounts of drinking water. When the module becomes clogged due to fouling or scaling, it is replaced.

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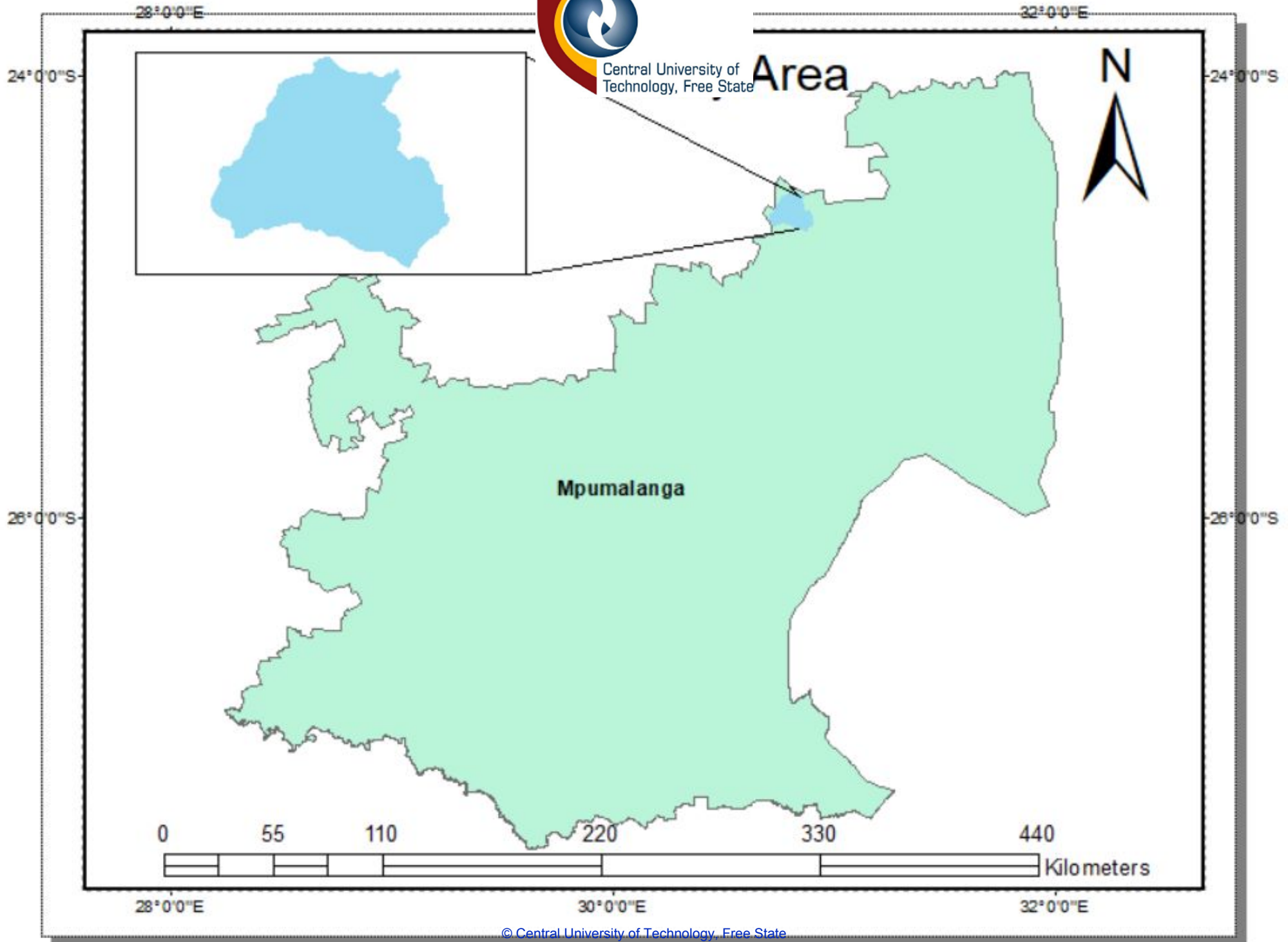
Appendix A

REGIONAL LOCALITY



Central University of
Technology, Free State

Area

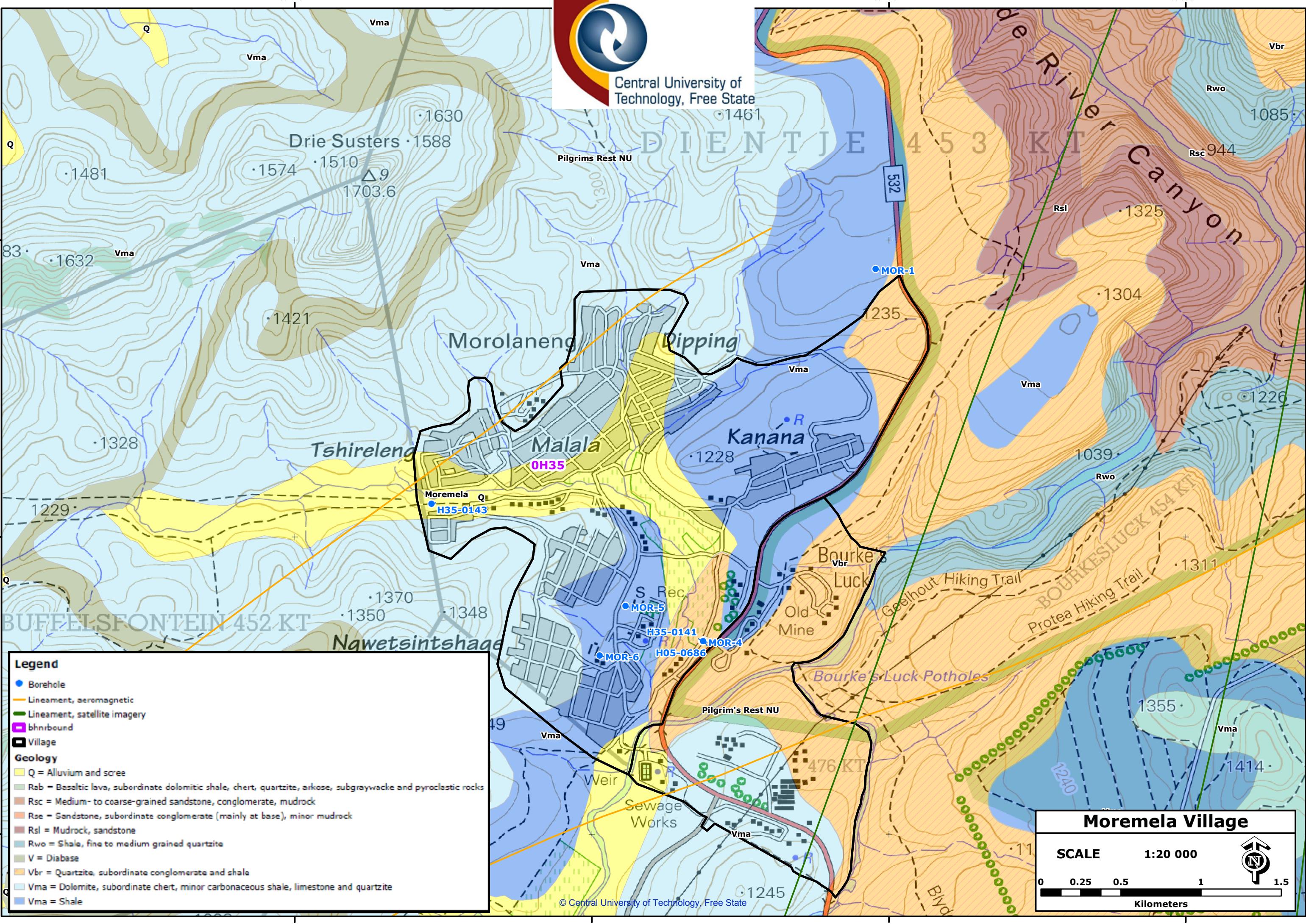


Appendix B

REGIONAL TOPOGRAPHY OF STUDY AREA



Central University of Technology, Free State



Legend

- Borehole
- Lineament, aeromagnetic
- Lineament, satellite imagery
- bhnrbound
- Village

Geology

- Q = Alluvium and scree
- Rab = Basaltic lava, subordinate dolomitic shale, chert, quartzite, arkose, subgraywacke and pyroclastic rocks
- Rsc = Medium- to coarse-grained sandstone, conglomerate, mudrock
- Rse = Sandstone, subordinate conglomerate (mainly at base), minor mudrock
- Rsl = Mudrock, sandstone
- Rwo = Shale, fine to medium grained quartzite
- V = Diabase
- Vbr = Quartzite, subordinate conglomerate and shale
- Vma = Dolomite, subordinate chert, minor carbonaceous shale, limestone and quartzite
- Vma = Shale

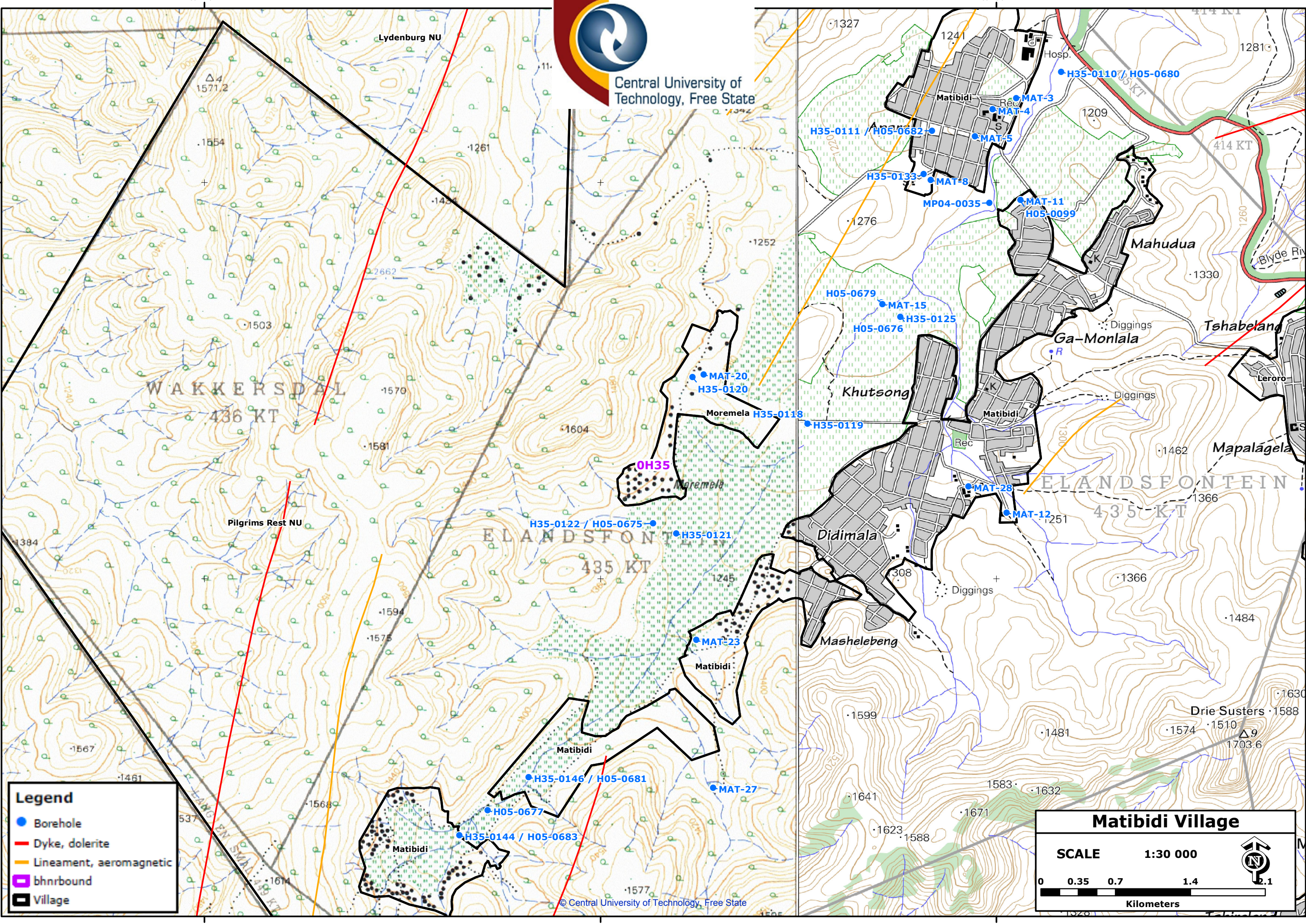
Moremela Village

SCALE 1:20 000

Kilometers



Central University of Technology, Free State



Legend

- Borehole
- Dyke, dolerite
- Lineament, aeromagnetic
- bhnrbound
- Village

Matibidi Village

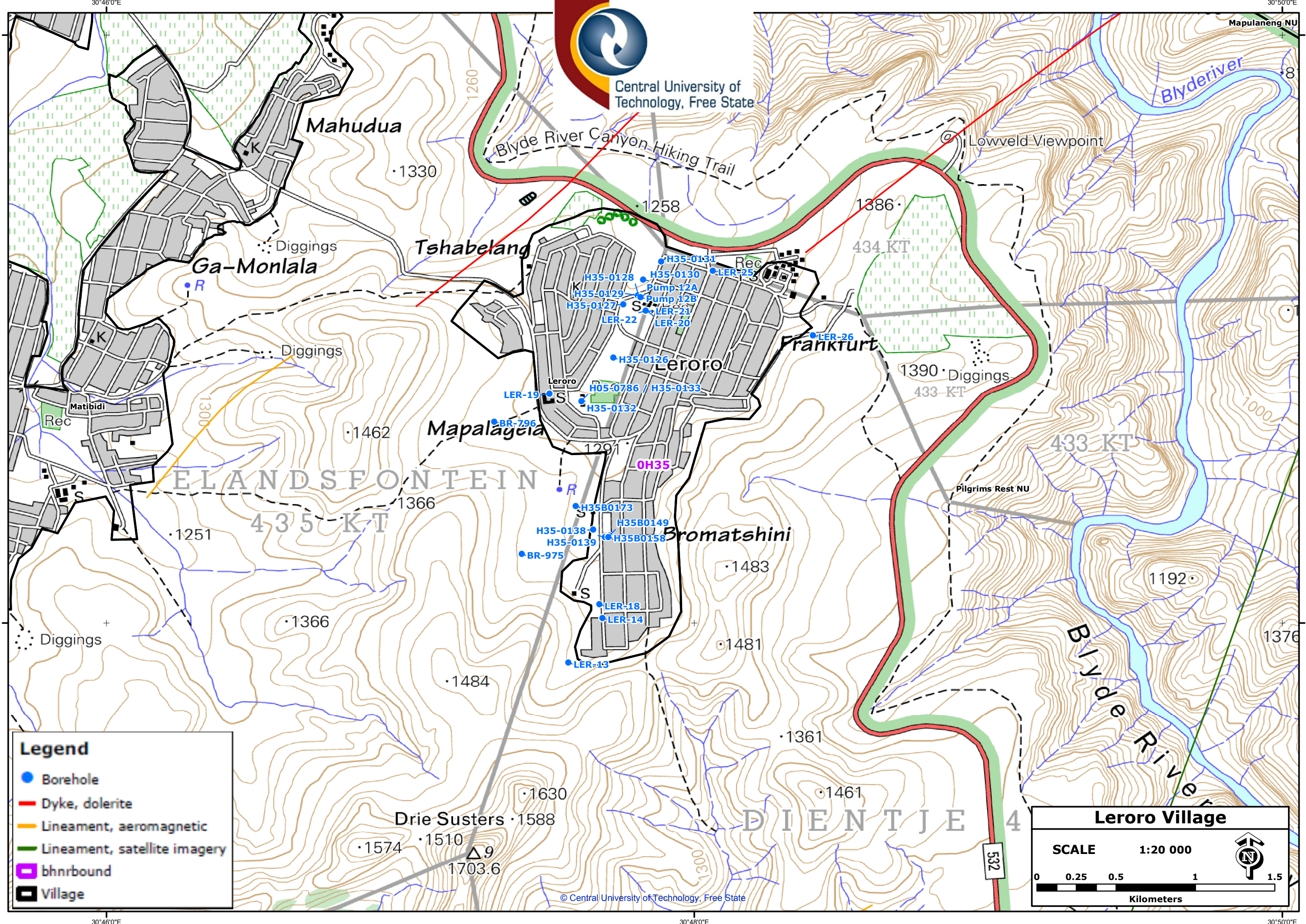
SCALE 1:30 000

0 0.35 0.7 1.4 2.1

Kilometers



Central University of Technology, Free State



Legend

- Borehole
- Dyke, dolerite
- Lineament, aeromagnetic
- Lineament, satellite imagery
- bhnrbound
- Village

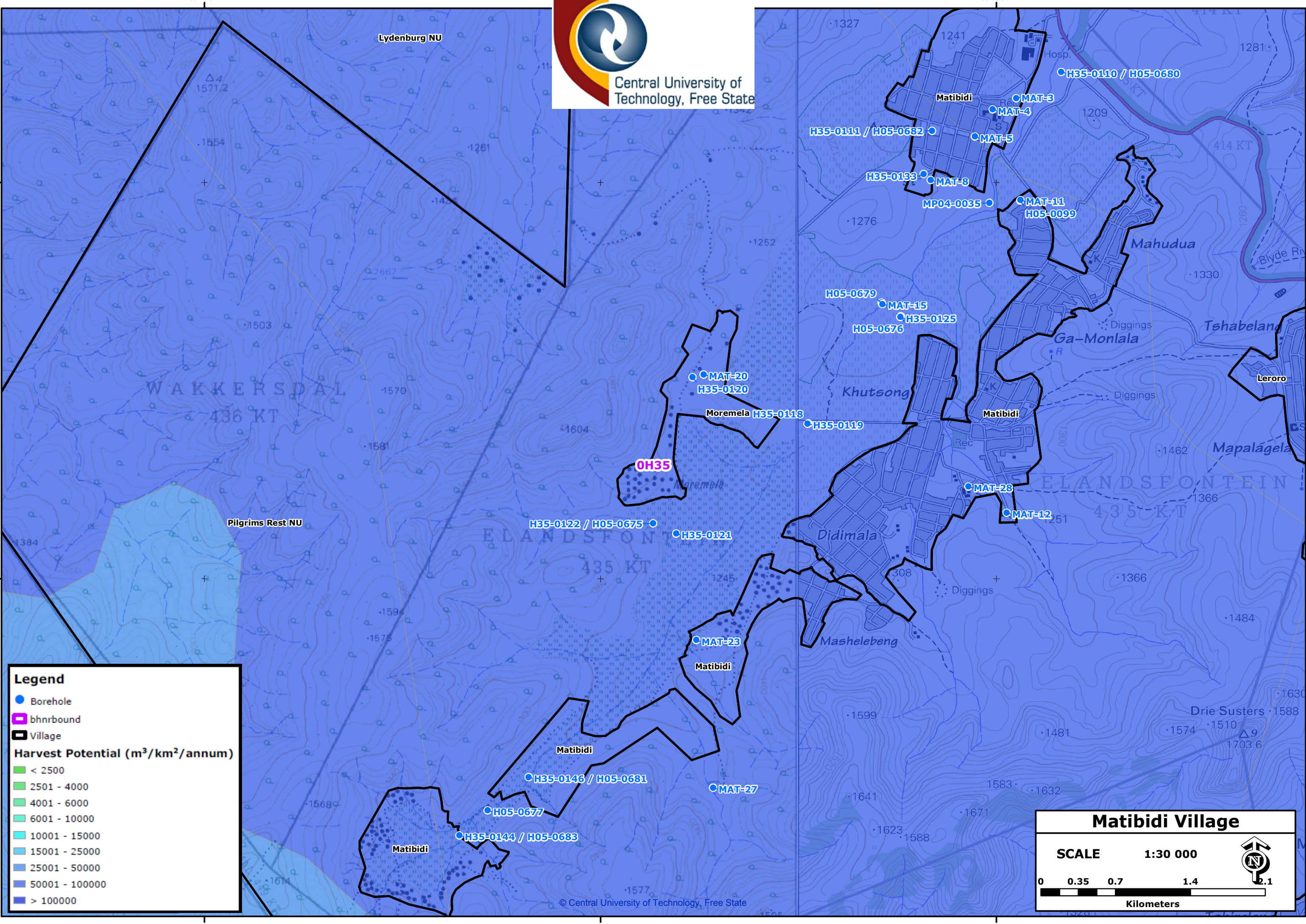
Leroro Village

SCALE 1:20 000

Kilometers

Appendix C

HARVEST POTENTIAL OF STUDY AREA



Legend


- Borehole
- bhnrbound
- Village

Harvest Potential (m³/km²/annum)


- < 2500
- 2501 - 4000
- 4001 - 6000
- 6001 - 10000
- 10001 - 15000
- 15001 - 25000
- 25001 - 50000
- 50001 - 100000
- > 100000

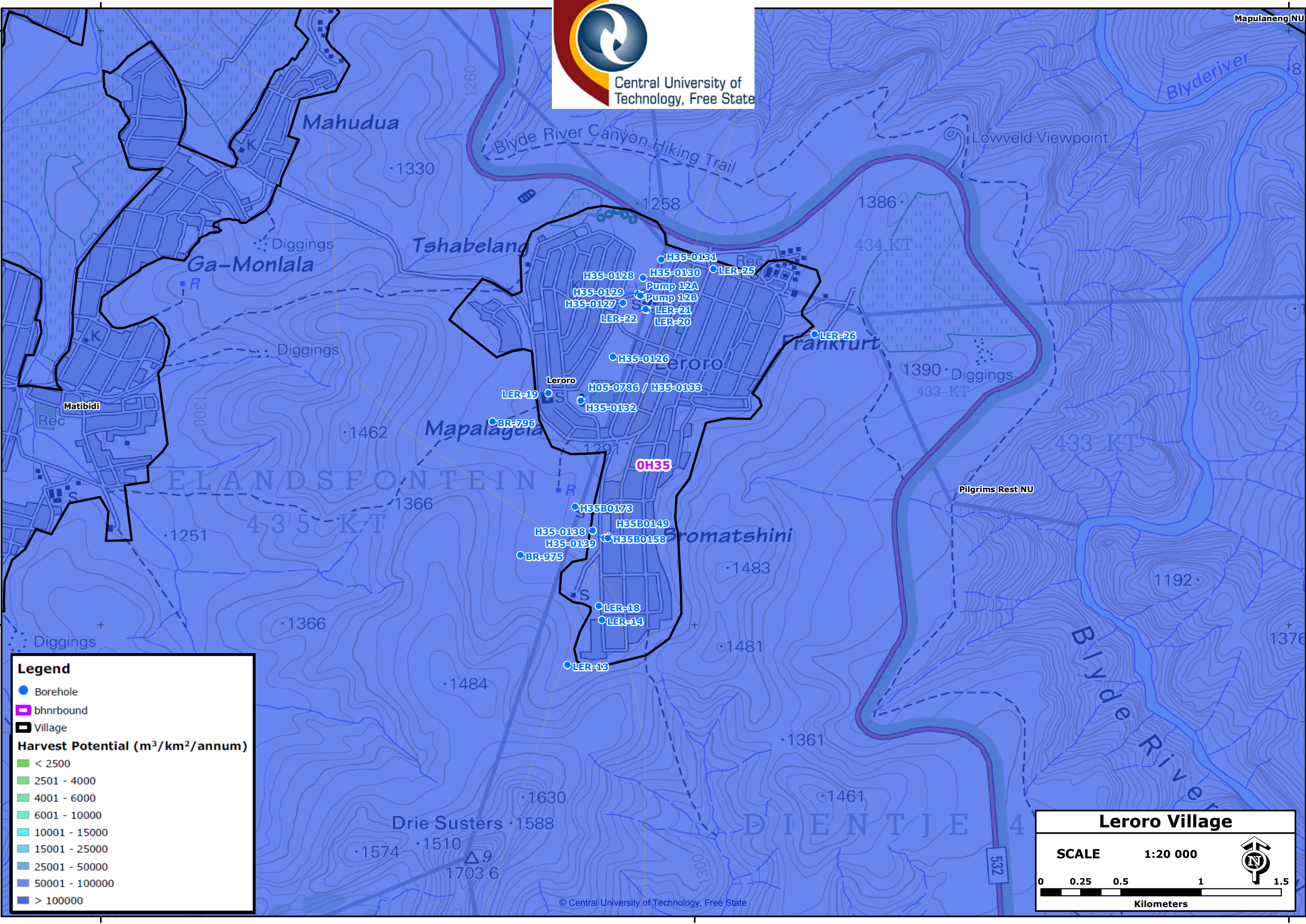
Matibidi Village

SCALE 1:30 000



Kilometers





Legend


- Borehole
- bhnrbound
- Village

Harvest Potential (m³/km²/annum)


- < 2500
- 2501 - 4000
- 4001 - 6000
- 6001 - 10000
- 10001 - 15000
- 15001 - 25000
- 25001 - 50000
- 50001 - 100000
- > 100000

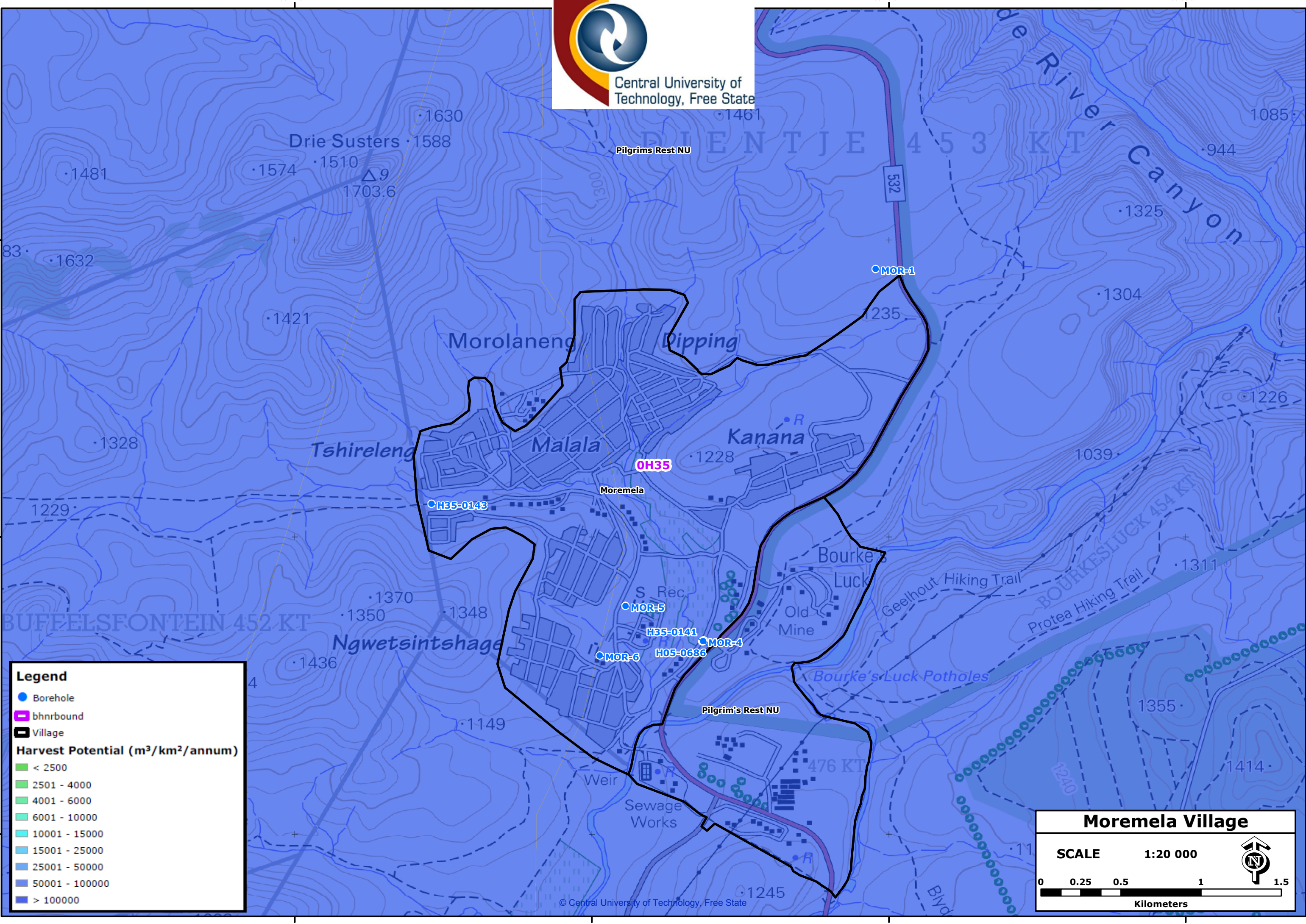
Leroro Village

SCALE 1:20 000



Kilometers





Legend


- Borehole
- bhnrbound
- Village

Harvest Potential (m³/km²/annum)


- < 2500
- 2501 - 4000
- 4001 - 6000
- 6001 - 10000
- 10001 - 15000
- 15001 - 25000
- 25001 - 50000
- 50001 - 100000
- > 100000

Moremela Village

SCALE 1:20 000



Kilometers



Appendix D

MANAGEMENT RECOMMENDATIONS

MANAGEMENT RECOMMENDATIONS



BASIC SITE INFORMATION: *Site Identifier:* 2330DBR0001 *Number:* TB-01605 *Site Type:* Borehole
Distr./Farm No.: MPK476 *Site Name:* WILLEMSOORD/MOREMELA
Latitude [°]: -24.6896029 *Alt. No. 1:* *Diam. [mm]:* 165 *Last static water lev. [m]:* 0.00
Longitude [°]: 30.8017212 *Alt. No. 2:* *Depth [m]:* 51.00 *Piezometer:* 0
Altitude [m]: 165.00 *Rep. Inst.:* No info or invalid code *Col. Ht. [m]:* 0.00 *Date WL meas.:* 20120317
 Coordinate System: WGS 84 / Lat/Long

EXISTING EQUIPMENT:		USE APPLICATION:
PUMP:	ENGINE:	<i>Site Status:</i> Unused
<i>Type of Inst.:</i>	<i>Type of Power:</i>	<i>Purpose:</i> Production (water supply)
<i>Manufacturer:</i>	<i>Manufacturer:</i>	<i>Consumer:</i> Farm(s)
<i>Depth to intk. [m]:</i>	<i>Power Rating [kW]:</i>	<i>Application:</i> Agricultural and domestic use

WATER CHEMISTRY:

Sample No.: 6-12/640 *Date sampled:* 19/03/2012 *Depth sampl. [m]:* 0.00 *Comment:* GOOD QUALITY

Chemical and Physical Parameters:				Bacteriol. Parameters:		Calculated Parameters:	
<i>pH:</i> 7.40	<i>Na:</i> 6.23	<i>Cl:</i> 3.80		<i>E. Coli:</i>		<i>Langelier:</i>	
<i>EC [mS/m]:</i> 49.00	<i>K:</i> 1.22	<i>NO3 as N:</i> 1.40		<i>Faec. Col.:</i>		<i>Aggr. Index:</i>	
<i>TDS:</i> 318.5	<i>Si:</i> 6.29	<i>SO4:</i> 43.26		<i>Total Col.:</i>		<i>Ion Bal. Err. [%]:</i> 61.168	
<i>Tot. Alk.:</i>	<i>Al:</i>	<i>F:</i> 0.10		<i>SPC:</i>		<i>Tot. Hardness:</i> 262.136	
<i>Ca:</i> 59.22	<i>Fe:</i> 0.01					<i>SAR:</i> 0.167	
<i>Mg:</i> 27.81	<i>Mn:</i> 0.24						

Concentrations in [mg/l] where applicable
 Bacteriological parameters in [counts/100ml]

AQUIFER INFORMATION:

<i>Depth to top [m]</i>	<i>Depth to bot. [m]</i>	<i>Yield [l/s]</i>	<i>Meth. meas.</i>	<i>Aquifer type</i>	<i>Comment</i>
9.00	10.00	0.20	Notch (V- or U-notch)	Weathered basin	
23.00	24.00	0.20	Notch (V- or U-notch)	Weathered basin	

CASING DETAILS:

<i>Depth to top [m]</i>	<i>Depth to bot. [m]</i>	<i>Diam. [mm]</i>	<i>Material</i>	<i>Thickn.</i>		<i>Openings [mm]:</i>			<i>Hor. Dist.</i>	<i>Vert. Dist.</i>
				<i>[mm]</i>	<i>Type of openings</i>	<i>Length</i>	<i>Width</i>	<i>Dist.</i>		
0.00	8.00	165	Steel	4	Plain casing	0	0	0	0	0
8.00	20.00	165	Steel	4	Perforated or slotted	0	0	0	0	0

TESTING DETAILS:

<i>Description</i>	<i>Date</i>	<i>Durat. [min]</i>	<i>Depth to intk. [m]</i>	<i>Disch. rate [l/s]</i>	<i>Drawd. [m]</i>	<i>Recovery [%]</i>	<i>Spec. T [m²/d]</i>	<i>Storage</i>	<i>capac.</i>	<i>Comment</i>	
											<i>[min]</i>
STEP TEST 1	20120317	60	44.40	0.21	3.02	1000000	0.0	0	0.00	0.000	0.000
STEP TEST 2	20120317	60	44.40	0.48	5.98	1000000	0.0	0	0.00	0.000	0.000
STEP TEST 3	20120317	60	44.40	0.76	24.09	1000000	0.0	0	0.00	0.000	0.000
STEP TEST 4	20120317	60	44.40	2.08	44.40	1.13	97.0	60	0.00	0.000	0.000
CONSTANT DISCHARGE TEST	20120317	1440	44.40	0.76	17.73	0.68	96.0	720	0.00	0.000	0.000

RECOMMENDATIONS:

<i>Prior.</i>	<i>Rec. equipm.</i>	<i>Depth to intk. [m]</i>	<i>Type of power</i>	<i>Duty cyc. [hrs]</i>	<i>Disch. rate [l/s]</i>	<i>Water quality</i>	<i>Dyn. water level [m]</i>	<i>Crit. water level [m]</i>
1	No information	32.00	No information	12	0.50	CLASS 1 / C1-S1	18.00	30.00

Note: Borehole would be able to deliver a sustainable yield of 1 800L/hr or 21 600L/day at recommended pumping rate.

Water classified as Class 1 (Good Water Quality), due to a slightly elevated manganese concentration.

Irrigation Class C1-S1: Low salinity water suitable for irrigation on most soils without danger of salinity or sodium problems developing.

BASIC SITE INFORMATION: Site identifier: 2330DBR0001 Number: TB-01605

Site type: Borehole

Distr./Farm No.: MPK476

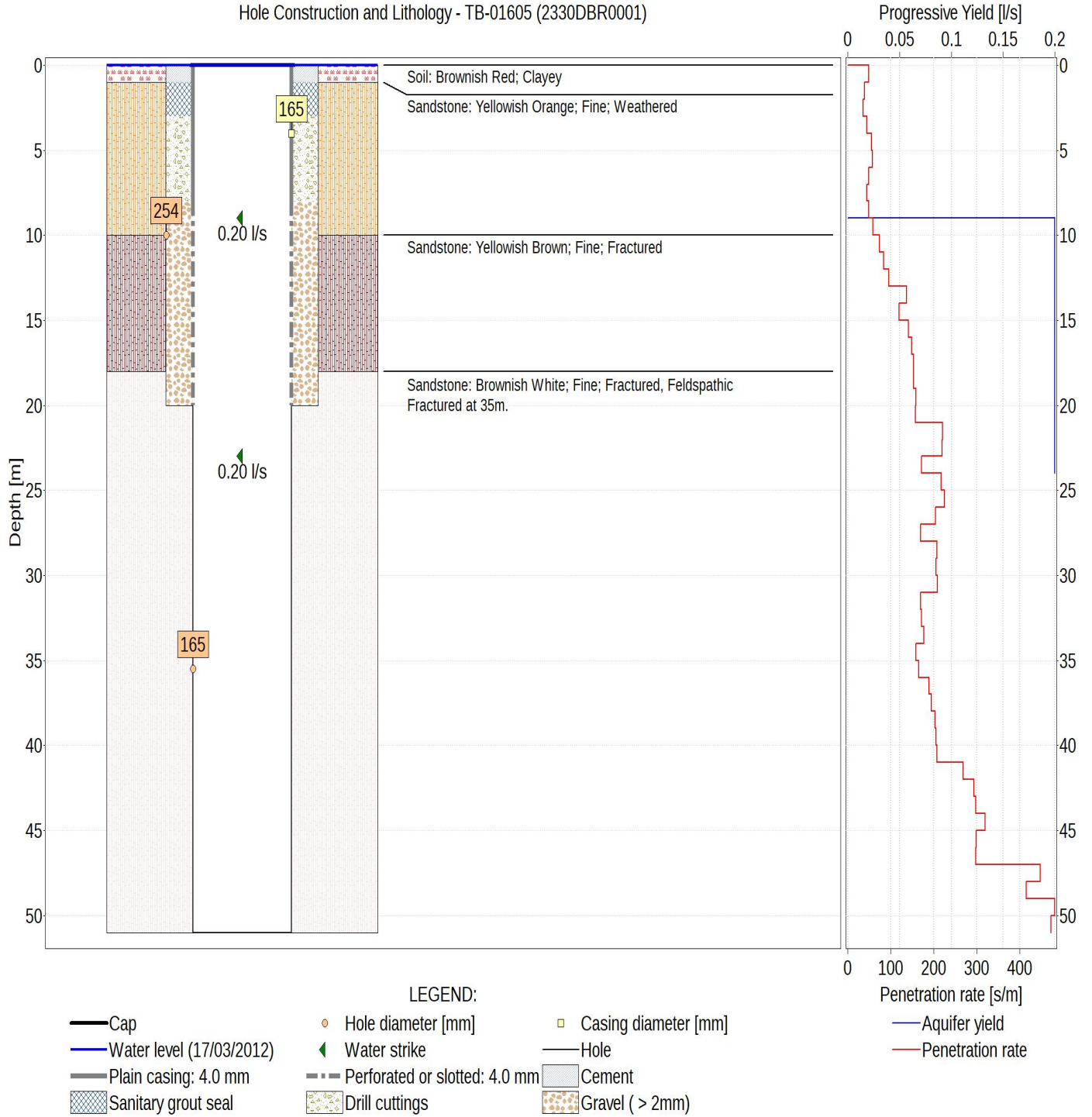
Site name: WILLEMSOORD/MOREMELA

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

Latitude [°]: -24.6896029	Alt. No. 1:	Diam. [mm]: 165	Site status: Unused
Longitude [°]: 30.8017212	Alt. No. 2:	Depth [m]: 51.00	Purpose: Production (water supply)
Coord. acc.: Accurate to within 100 units	Reg./BB.:	Col. ht. [m]: 00000	Consumer: Farm(s)
Coord. meth.: Global Positioning System (handheld)	Reporting institution:		Use applic.: Agricultural and domestic use
Altitude [m]: 165.00	No info or invalid code		Topo. sett.: Hillside (slope)
Surv. meth.: No information	Coord. System: WGS 84 / Lat/Long		Drain. regn.: B60B

Hole Construction and Lithology - TB-01605 (2330DBR0001)





BASIC SITE INFORMATION: Site identifier: 2330DBR0001 Number: TB-01605

Site type: Borehole

Distr./Farm No.: MPK476

Site name: WILLEMSOORD/MOREMELA

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

Latitude [°]	-24.6896029	Alt. No. 1:	Diam. [mm]:	165	Site status:	Unused
Longitude [°]	30.8017212	Alt. No. 2:	Depth [m]:	51.00	Purpose:	Production (water supply)
Coord. acc.:	Accurate to within 100 units	Reg./BB.:	Col. ht. [m]:	00000	Consumer:	Farm(s)
Coord. meth.:	Global Positioning System (handheld)	Reporting institution:	Use applic.:			Agricultural and domestic use
Altitude [m]:	165.00	No info or invalid code	Topo. sett.:			Hillside (slope)
Surv. meth.:	No information	Coord. System: WGS 84 / Lat/Long	Drain. regn.:			B60B

CONSTRUCTION

Date constr.	Contractor	Construction method	Reporting institution	Inform. source	Comment
03/02/2011	No info or invalid code	Air percussion	In-Situ Consulting	Driller's logs	

FINISH AND DEVELOPMENT

Collar

Depth	Type of finish	Hgt. [m]	Development method	Dev. durat.	Special treatment	Constr. cost
51.00	Open bottom (partially cased)	0.00000	Pumped with air lift (no inducto 60		No information	0

HOLE DIAMETER:

Date constr.	Depth to:		Diam. [mm]	Reporting institution	Comment
	Top [m]	Bot. [m]			
04/02/2012	0.00	20.00	254	In-Situ Consulting	
04/02/2012	20.00	51.00	165	In-Situ Consulting	

CASING DETAILS:

Date inst.	Depth to:		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]		Hor. Dist.	Vert. Dist.
	Top [m]	Bot. [m]					Length	Width		
04/02/2012	0.00	8.00	165	Steel	4	Plain casing	0	0	0	0
04/02/2012	8.00	20.00	165	Steel	4	Perforated or slotted	0	0	0	0

AQUIFER:

Report. Institution	Depth to:		Yield [l/s]	Meth. meas.	Aquifer type	Info. source	Comment
	Top [m]	Bot. [m]					
INSI	9.00	10.00	0.20	Notch (V- or U-notch)	Weathered basin	No information	
INSI	23.00	24.00	0.20	Notch (V- or U-notch)	Weathered basin	No information	

GEOLOGY: Lithology Colour, texture & feature

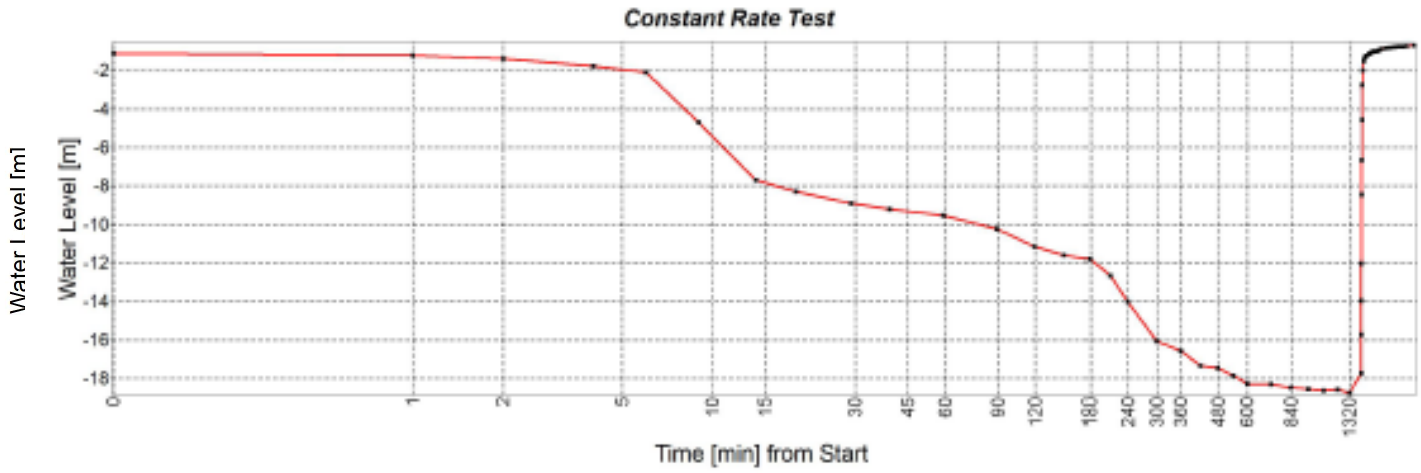
Depth to: Top [m]	Bot. [m]	Lithology	Prim.	Second.	Primary Feature	Secondary Feature	Feature Attribute	
			Colour	Colour				Texture
0.00	1.00	Soil	Red	Brownish	No information	Clayey	No information	No information
1.00	10.00	Sandstone	Orange	Yellowish	Fine	Weathered	No information	No information
10.00	18.00	Sandstone	Brown	Yellowish	Fine	Fractured	No information	No information
18.00	51.00	Sandstone	White	Brownish	Fine	Feldspathic	Fractured	No information

PUMPING TEST REPORT



Date Compiled: 31/08/2021

BASIC SITE INFORMATION: *Site Identifier:* 2330DBR0001 *Number:* TB-01605 *Site Type:* Borehole
Distr./Farm No.: MPK476 *Site Name:* WILLEMSOORD/MOREMELA
Latitude [°]: -24.6896029 *Alt. No. 1:* *Diam. [mm]:* 165 *Water level [m]:*
Longitude [°]: 30.8017212 *Alt. No. 2:* *Depth [m]:* 51.00 *Piezometer:* 0
Altitude [m]: 165.00 *Rep. Inst.:* No info or invalid code *Col. Ht. [m]:* 0.00 *Date WL meas.:* 17/03/2012
 Coordinate System: WGS 84 / Lat/Long



PUMPING TEST		Depth to	Starting	End	Transm.		Storativity	
Rep. Inst.	Meth. tested	intk. [m]	Date	Time	Date	Time	[m ² /d]	
In-Situ Consulting	Multirate test	44.40	17/03/2012	07:20	17/03/2012	12:19	0	0
In-Situ Consulting	Constant rate test	44.40	17/03/2012	12:30	19/03/2012	00:29	0	0

TESTING DETAILS:	Time	Durat.	Depth to	Disch.	Drawd.	Recovery:	Durat.	Transm.	Perm.	Spec.			
Description	started	[min]	intake [m]	rate [l/s]	[m]	[m]	%	[min]	[m ² /d]	[m/d]	Storat.	Capac.	Q/st
STEP TEST 1	07:20	60	44.40	0.21	3.02		0	0	0.00	0.000	0.000	0.000	0.070
STEP TEST 2	08:20	60	44.40	0.48	5.98		0	0	0.00	0.000	0.000	0.000	0.080
STEP TEST 3	09:20	60	44.40	0.76	24.09		0	0	0.00	0.000	0.000	0.000	0.032
STEP TEST 4	10:20	60	44.40	2.08	44.40	1.13	97	60	0.00	0.000	0.000	0.000	0.047
CONSTANT DISCHARGE TE	12:30	1440	44.40	0.76	17.73	0.68	96	720	0.00	0.000	0.000	0.000	0.043

WATER LEVEL:		Time		Water lev.		Comment	
Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	[m]	
Electrical contact meter	Static	0	17/03/2012	07:20	0	0.00	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:21	0	1.35	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:22	0	1.43	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:24	0	1.39	



WATER LEVEL:

<i>Meth. meas.</i>	<i>Level status</i>	<i>Piezom.</i>	<i>Date meas.</i>	<i>Time meas.</i>	<i>Secs.</i>	<i>Water lev. [m]</i>	<i>Comment</i>
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:26	0	1.59	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:29	0	1.79	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:34	0	1.83	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:39	0	1.75	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:49	0	1.67	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	07:59	0	3.04	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:09	0	2.94	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:19	0	3.02	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:20	0	3.44	STEP TEST 1
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:21	0	3.94	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:22	0	4.24	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:24	0	4.80	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:26	0	5.08	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:29	0	5.31	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:34	0	5.44	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:39	0	5.50	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:49	0	5.69	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:59	0	5.86	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:09	0	5.92	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:19	0	5.89	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:20	0	6.45	STEP TEST 3
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:21	0	6.99	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:22	0	7.57	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:24	0	8.19	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:26	0	9.23	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:29	0	10.55	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:34	0	12.60	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:39	0	14.52	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:49	0	16.95	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:59	0	19.85	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:09	0	22.35	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:19	0	24.09	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:20	0	26.50	STEP TEST 4
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:21	0	27.60	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:22	0	31.25	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:24	0	36.01	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:26	0	41.19	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	11:19	0	44.40	
Electrical contact meter	Recovering	0	17/03/2012	11:20	0	41.46	RECOVERY
Electrical contact meter	Recovering	0	17/03/2012	11:21	0	38.11	
Electrical contact meter	Recovering	0	17/03/2012	11:22	0	34.49	
Electrical contact meter	Recovering	0	17/03/2012	11:24	0	28.28	
Electrical contact meter	Recovering	0	17/03/2012	11:26	0	22.66	
Electrical contact meter	Recovering	0	17/03/2012	11:29	0	16.13	
Electrical contact meter	Recovering	0	17/03/2012	11:34	0	7.42	
Electrical contact meter	Recovering	0	17/03/2012	11:39	0	4.04	
Electrical contact meter	Recovering	0	17/03/2012	11:49	0	1.88	
Electrical contact meter	Recovering	0	17/03/2012	11:59	0	1.38	
Electrical contact meter	Recovering	0	17/03/2012	12:19	0	1.13	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:30	0	1.12	CONSTANT
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:31	0	1.22	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:32	0	1.39	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:34	0	1.76	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:36	0	2.08	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:39	0	4.69	



WATER LEVEL:

<i>Meth. meas.</i>	<i>Level status</i>	<i>Piezom.</i>	<i>Date meas.</i>	<i>Time meas.</i>	<i>Secs.</i>	<i>Water lev. [m]</i>	<i>Comment</i>
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:44	0	7.70	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:49	0	8.29	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	12:59	0	8.90	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	13:09	0	9.20	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	13:29	0	9.54	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	13:59	0	10.24	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:29	0	11.15	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:59	0	11.61	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	15:29	0	11.79	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	15:59	0	12.66	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	16:29	0	14.01	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	17:29	0	16.07	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	18:29	0	16.57	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	19:29	0	17.36	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	20:29	0	17.47	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	21:29	0	17.84	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	22:29	0	18.27	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	00:29	0	18.31	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	02:29	0	18.48	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	04:29	0	18.55	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	06:29	0	18.64	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	08:29	0	18.58	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	10:29	0	18.76	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:29	0	17.73	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:30	0	15.73	RECOVERY
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:31	0	13.98	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:32	0	12.02	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:34	0	8.44	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:36	0	6.66	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:39	0	4.57	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:44	0	2.75	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:49	0	1.99	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	12:59	0	1.52	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	13:09	0	1.32	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	13:29	0	1.24	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	13:59	0	1.13	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	14:29	0	1.06	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	14:59	0	1.01	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	15:29	0	1.00	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	15:59	0	0.96	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	16:29	0	0.87	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	17:29	0	0.83	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	18:29	0	0.80	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	19:29	0	0.77	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	20:29	0	0.76	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	21:29	0	0.75	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	22:29	0	0.72	
Electrical contact meter	Pumped (abstraction in hole)	0	19/03/2012	00:29	0	0.68	

MANAGEMENT RECOMMENDATIONS



BASIC SITE INFORMATION: Site Identifier: 2431DAR0001 Number: TB-01606 Site Type: Borehole
 Distr./Farm No.: MPKT435 Site Name: ELANDSFONTEIN/MATIBIDI
 Latitude [°] -24.6509229 Alt. No. 1: Diam. [mm]: 165 Last static water lev. [m]: 12.68
 Longitude [°] 30.7427912 Alt. No. 2: Depth [m]: 44.00 Piezometer: 0
 Altitude [m]: 1320.00 Rep. Inst.: No info or invalid code Col. Ht. [m]: 0.40 Date WL meas.: 20120320
 Coordinate System: WGS 84 / Lat/Long

EXISTING EQUIPMENT:				USE APPLICATION:			
PUMP:		ENGINE:		Site Status: In use			
Type of Inst.:	Windpump	Type of Power:	Wind	Purpose: Production (water supply)			
Manufacturer:	POLDAW WIND PUMPS	Manufacturer:		Consumer: Farm(s)			
Depth to intk. [m]:	27.50	Power Rating [kW]:	0	Application: Agricultural and domestic use			

WATER CHEMISTRY:

Sample No.: 5-12/640 Date sampled: 21/03/2012 Depth sampl. [m]: 0.00 Comment: IDEAL QUALITY

Chemical and Physical Parameters:				Bacteriol. Parameters:		Calculated Parameters:	
pH:	7.20	Na:	5.32	Cl:	9.60	E. Coli:	Langelier:
EC [mS/m]:	44.40	K:	0.21	NO3 as N:	1.70	Faec. Col.:	Aggr. Index:
TDS:	288.6	Si:	8.62	SO4:	4.25	Total Col.:	Ion Bal. Err. [%]: 72.652
Tot. Alk.:		Al:		F:	0.10	SPC:	Tot. Hardness: 238.429
Ca:	48.02	Fe:	0.01				SAR: 0.150
Mg:	28.84	Mn:	0.01	Concentrations in [mg/l] where applicable			
Bacteriological parameters in [counts/100ml]							

AQUIFER INFORMATION:

Depth to top [m]	Depth to bot. [m]	Yield [l/s]	Meth. meas.	Aquifer type	Comment
20.00	20.50	0.10	Notch (V- or U-notch)	Fractured	
32.00	32.50	0.83	Notch (V- or U-notch)	Fractured	

CASING DETAILS:

Depth to top [m]	Depth to bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Hor. Dist.	Vert. Dist.
0.00	10.80	177	Steel	4	Plain casing	0	0	0

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate [l/s]	Drawd. [m]	Recovery %	Spec. T [m²/d]	Storage	capac.	Comment
STEP TEST 1	20120320	60	26.00	0.82	12.84	100.0000	0.0	0	0.000	0.000
STEP TEST 2	20120320	60	26.00	1.46	12.92	100.0000	0.0	0	0.000	0.000
STEP TEST 3	20120320	60	26.00	3.31	13.32	12.70	95.0	60	0.000	0.000
CONSTANT DISCHARGE TEST	20120320	1440	26.00	2.14	13.18	12.23	93.0	120	0.000	0.000

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	No information	20.00	No information	12	2.00	CLASS 0 / C1-S1	14.00	17.00

Note: Borehole would be able to deliver a sustainable yield of 7 200L/hr or 86 400L/day at recommended pumping rate.

Water classified as Class 0 (Ideal Water Quality), suitable for life-time use.

Irrigation Class C1-S1: Low salinity water suitable for irrigation on most soils without danger of salinity of sodium problems developing.

BASIC SITE INFORMATION: Site identifier: 2431DAR0001 Number: TB-01606

Site type: Borehole

Distr./Farm No.: MPKT435

Site name: ELANDSFONTEIN/MATIBIDI

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

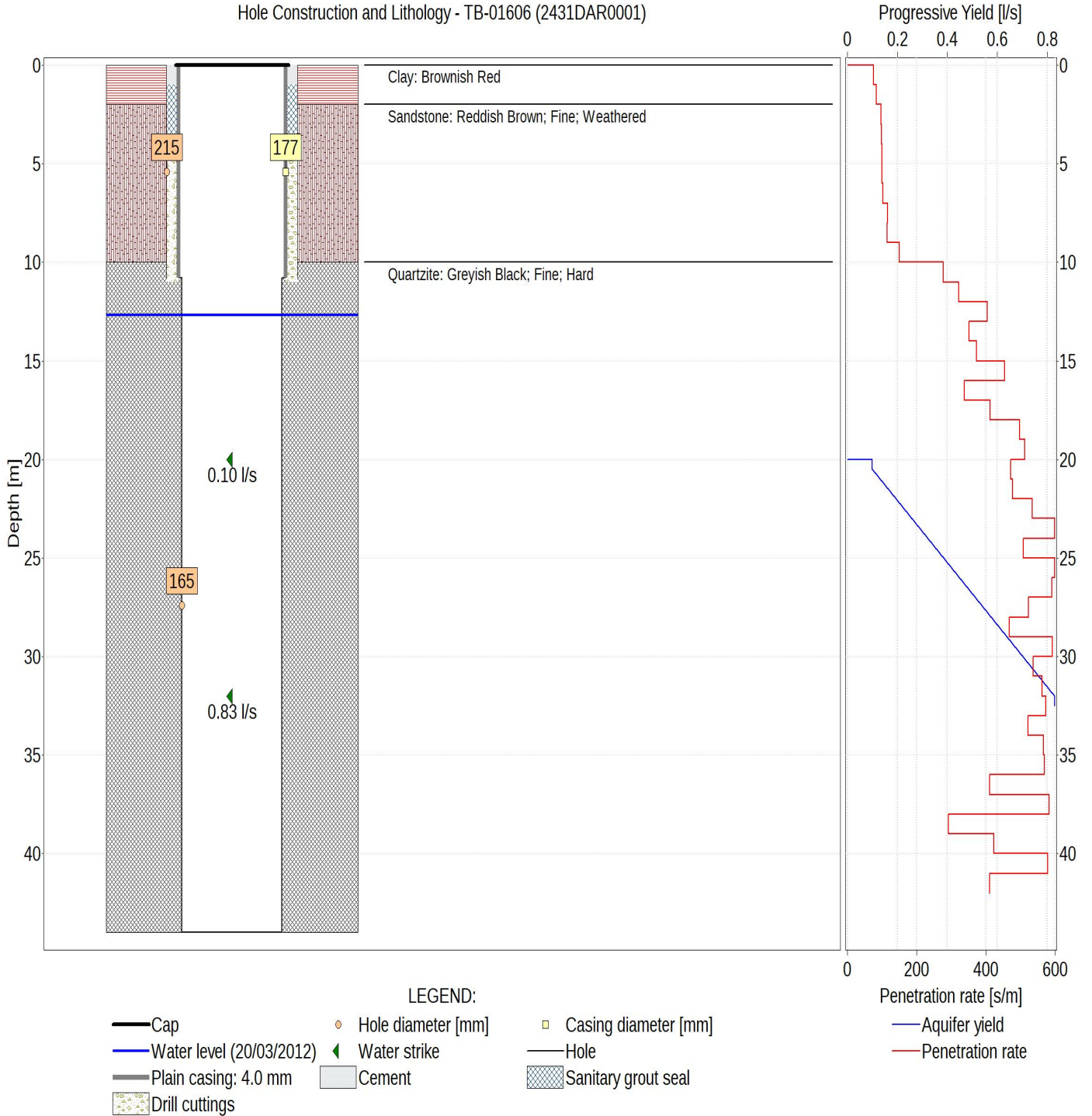
Latitude [°] -24.6509229
 Longitude [°] 30.7427912
 Coord. acc.: Accurate to within 100 units
 Coord. meth.: Global Positioning System (handheld)
 Altitude: [m]: 1320.00
 Surv. meth.: No information

Alt. No. 1:
 Alt. No. 2:
 Reg./BB.:
 Reporting institution:
 No info or invalid code
 Coord. System: WGS 84 / Lat/Long

Diam. [mm]: 165
 Depth [m]: 44.00
 Col. ht. [m]: 0.40

Site status: In use
 Purpose: Production (water supply)
 Consumer: Farm(s)
 Use applic.: Agricultural and domestic use
 Topo. sett.: Valley
 Drain. regn.: B60D

Hole Construction and Lithology - TB-01606 (2431DAR0001)



BASIC SITE INFORMATION: Site identifier: 2431DAR0001 Number: TB-01606

Site type: Borehole

Distr./Farm No.: MPKT435

Site name: ELANDSFONTEIN/MATIBIDI

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

Latitude [°]	-24.6509229	Alt. No. 1:	Diam. [mm]:	165	Site status:	In use
Longitude [°]	30.7427912	Alt. No. 2:	Depth [m]:	44.00	Purpose:	Production (water supply)
Coord. acc.:	Accurate to within 100 units	Reg./BB.:	Col. ht. [m]:	0.40	Consumer:	Farm(s)
Coord. meth.:	Global Positioning System (handheld)	Reporting institution:	Use applic.: Agricultural and domestic use			
Altitude [m]:	1320.00	No info or invalid code	Topo. sett.: Valley			
Surv. meth.:	No information	Coord. System: WGS 84 / Lat/Long	Drain. regn.: B60D			

CONSTRUCTION

Date constr.	Contractor	Construction method	Reporting institution	Inform. source	Comment
01/02/2012	No info or invalid code	Air percussion	In-Situ Consulting	Driller's logs	

FINISH AND DEVELOPMENT

Collar

Depth	Type of finish	Hgt. [m]	Development method	Dev. durat.	Special treatment	Constr. cost
44.00	Open bottom (partially cased)	0.40	Pumped with air lift (no inducto 60		No information	0

HOLE DIAMETER:

Date constr.	Depth to:		Diam. [mm]	Reporting institution	Comment
	Top [m]	Bot. [m]			
01/02/2012	0.00	10.80	215	In-Situ Consulting	
01/02/2012	10.80	44.00	165	In-Situ Consulting	

CASING DETAILS:

Date inst.	Depth to:		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]		Hor. Dist.	Vert. Dist.
	Top [m]	Bot. [m]					Length	Width		
01/02/2012	0.00	10.80	177	Steel	4	Plain casing	0	0	0	0

AQUIFER:

Report. Institution	Depth to:		Yield [l/s]	Meth. meas.	Aquifer type	Info. source	Comment
	Top [m]	Bot. [m]					
INSI	20.00	20.50	0.10	Notch (V- or U-notch)	Fractured	No information	
INSI	32.00	32.50	0.83	Notch (V- or U-notch)	Fractured	No information	

GEOLOGY: Lithology Colour, texture & feature

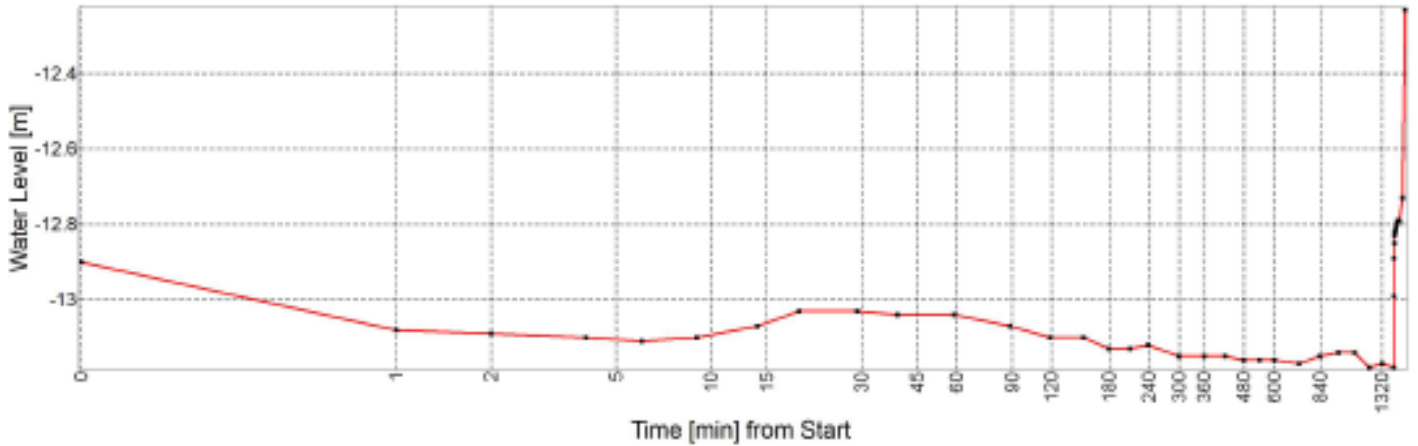
Depth to:			Prim. Colour	Second. Colour	Texture	Primary Feature	Secondary Feature	Feature Attribute
Top [m]	Bot. [m]	Lithology						
0.00	2.00	Clay	Red	Brownish	No information	No information	No information	No information
2.00	10.00	Sandstone	Brown	Reddish	Fine	Weathered	No information	No information
10.00	44.00	Quartzite	Black	Greyish	Fine	Hard	No information	No information

PUMPING TEST REPORT



BASIC SITE INFORMATION: Site Identifier: 2431DAR0001 Number: TB-01606 Site Type: Borehole
 Distr./Farm No.: MPKT435 Site Name: ELANDSFONTEIN/MATIBIDI
 Latitude [°] -24.6509229 Alt. No. 1: Diam. [mm]: 165 Water level [m]: 12.68
 Longitude [°] 30.7427912 Alt. No. 2: Depth [m]: 44.00 Piezometer: 0
 Altitude [m]: 1320.00 Rep. Inst.: No info or invalid code Col. Ht. [m]: 0.40 Date WL meas.: 20/03/2012
 Coordinate System: WGS 84 / Lat/Long

Constant Rate Test



PUMPING TEST		Depth to	Starting	End	Transm.			
Rep. Inst.	Meth. tested	intk. [m]	Date	Time	Date	Time	[m ² /d]	Storativity
In-Situ Consulting	Multirate test	26.00	20/03/2012	11:50	20/03/2012	15:49	0	0
In-Situ Consulting	Constant rate test	26.00	20/03/2012	15:55	21/03/2012	17:54	0	0

TESTING DETAILS:												
Description	Time started	Durat. [min]	Depth to intake [m]	Disch. rate [l/s]	Drawd. [m]	Recovery: [m]	%	Durat. [min]	Transm. [m ² /d]	Perm. [m/d]	Spec. Storac.	Capac. Q/st
STEP TEST 1	11:50	60	26.00	0.82	12.84		0	0	0.00	0.000	0.000	0.064
STEP TEST 2	12:50	60	26.00	1.46	12.92		0	0	0.00	0.000	0.000	0.113
STEP TEST 3	13:50	60	26.00	3.31	13.32	12.70	95	60	0.00	0.000	0.000	0.248
CONSTANT DISCHARGE TE15:55		1440	26.00	2.14	13.18	12.23	93	120	0.00	0.000	0.000	0.162

WATER LEVEL:								
Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment	
Electrical contact meter	Static	0	20/03/2012	11:50	0	12.68	STATIC W/L	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	11:51	0	12.73		
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	11:52	0	12.75		
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	11:54	0	12.79		
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	11:56	0	12.80		

PUMPING TEST REPORT



WATER LEVEL:

Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	11:59	0	12.82	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:04	0	12.83	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:09	0	12.83	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:19	0	12.83	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:29	0	12.84	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:39	0	12.84	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:49	0	12.84	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:50	0	12.86	STEP TEST 2
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:51	0	12.87	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:52	0	12.90	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:54	0	12.89	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:56	0	12.90	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	12:59	0	12.87	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:04	0	12.90	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:09	0	12.90	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:19	0	12.89	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:29	0	12.90	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:39	0	12.91	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:49	0	12.92	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:50	0	13.20	STEP TEST 3
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:51	0	13.21	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:52	0	13.22	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:54	0	13.22	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:56	0	13.23	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	13:59	0	13.24	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:04	0	13.29	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:09	0	13.30	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:19	0	13.32	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:29	0	13.32	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:39	0	13.32	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	14:49	0	13.32	
Electrical contact meter	Recovering	0	20/03/2012	14:50	0	12.78	RECOVERY
Electrical contact meter	Recovering	0	20/03/2012	14:51	0	12.76	
Electrical contact meter	Recovering	0	20/03/2012	14:52	0	12.75	
Electrical contact meter	Recovering	0	20/03/2012	14:54	0	12.75	
Electrical contact meter	Recovering	0	20/03/2012	14:56	0	12.75	
Electrical contact meter	Recovering	0	20/03/2012	14:59	0	12.74	
Electrical contact meter	Recovering	0	20/03/2012	15:04	0	12.71	
Electrical contact meter	Recovering	0	20/03/2012	15:09	0	12.70	
Electrical contact meter	Recovering	0	20/03/2012	15:19	0	12.70	
Electrical contact meter	Recovering	0	20/03/2012	15:29	0	12.70	
Electrical contact meter	Recovering	0	20/03/2012	15:49	0	12.70	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	15:55	0	12.90	CONSTANT
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	15:56	0	13.08	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	15:57	0	13.09	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	15:59	0	13.10	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:01	0	13.11	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:04	0	13.10	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:09	0	13.07	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:14	0	13.03	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:24	0	13.03	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:34	0	13.04	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	16:54	0	13.04	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	17:24	0	13.07	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	17:54	0	13.10	

PUMPING TEST REPORT



WATER LEVEL:

Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	18:24	0	13.10	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	18:54	0	13.13	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	19:24	0	13.13	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	19:54	0	13.12	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	20:54	0	13.15	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	21:54	0	13.15	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	22:54	0	13.15	
Electrical contact meter	Pumped (abstraction in hole)	0	20/03/2012	23:54	0	13.16	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	00:54	0	13.16	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	01:54	0	13.16	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	03:54	0	13.17	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	05:54	0	13.15	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	07:54	0	13.14	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	09:54	0	13.14	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	11:54	0	13.18	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	13:54	0	13.17	
Electrical contact meter	Pumped (abstraction in hole)	0	21/03/2012	15:54	0	13.18	
Electrical contact meter	Recovering	0	21/03/2012	15:55	0	12.99	RECOVERY
Electrical contact meter	Recovering	0	21/03/2012	15:56	0	12.89	
Electrical contact meter	Recovering	0	21/03/2012	15:57	0	12.85	
Electrical contact meter	Recovering	0	21/03/2012	15:59	0	12.83	
Electrical contact meter	Recovering	0	21/03/2012	16:01	0	12.82	
Electrical contact meter	Recovering	0	21/03/2012	16:04	0	12.82	
Electrical contact meter	Recovering	0	21/03/2012	16:09	0	12.82	
Electrical contact meter	Recovering	0	21/03/2012	16:14	0	12.81	
Electrical contact meter	Recovering	0	21/03/2012	16:24	0	12.80	
Electrical contact meter	Recovering	0	21/03/2012	16:34	0	12.79	
Electrical contact meter	Recovering	0	21/03/2012	16:54	0	12.79	
Electrical contact meter	Recovering	0	21/03/2012	17:24	0	12.73	
Electrical contact meter	Recovering	0	21/03/2012	17:54	0	12.23	

MANAGEMENT RECOMMENDATIONS



BASIC SITE INFORMATION: Site Identifier: 2430DAR0001 Number: TB-01607 Site Type: Borehole
 Distr./Farm No.: MPKT435 Site Name: ELANDSFONTEIN/MASIDIBENG
 Latitude [°] -24.6470929 Alt. No. 1: Diam. [mm]: 165 Last static water lev. [m]: 7.77
 Longitude [°] 30.7472812 Alt. No. 2: Depth [m]: 48.00 Piezometer: 0
 Altitude [m]: 1331.00 Rep. Inst.: No info or invalid code Col. Ht. [m]: 0.43 Date WL meas.: 20120317
 Coordinate System: WGS 84 / Lat/Long

EXISTING EQUIPMENT:		USE APPLICATION:	
PUMP:	ENGINE:	Site Status:	Unused
Type of Inst.: No equipment	Type of Power: No information	Purpose:	Production (water supply)
Manufacturer: No info or invalid code	Manufacturer:	Consumer:	Farm(s)
Depth to intk. [m]:	Power Rating [kW]: 0	Application:	Agricultural and domestic use

WATER CHEMISTRY:

Sample No.: 3-12/640 Date sampled: 18/03/2012 Depth sampl. [m]: 0.00 Comment: IDEAL QUALITY

Chemical and Physical Parameters:				Bacteriol. Parameters:		Calculated Parameters:	
pH: 7.20	Na: 4.24	Cl: 11.00	E. Coli:	Langelier:			
EC [mS/m]: 47.80	K: 0.33	NO3 as N: 1.40	Faec. Col.:	Aggr. Index:			
TDS: 310.7	Si: 6.12	SO4: 20.19	Total Col.:	Ion Bal. Err. [%]: 67.704			
Tot. Alk.:	Al:	F: 0.14	SPC:	Tot. Hardness: 264.502			
Ca: 54.25	Fe: 0.01			SAR: 0.113			
Mg: 31.40	Mn: 0.01						

Concentrations in [mg/l] where applicable
 Bacteriological parameters in [counts/100ml]

AQUIFER INFORMATION:

Depth to top [m]	Depth to bot. [m]	Yield [l/s]	Meth. meas.	Aquifer type	Comment
6.00	15.50	8.30	Notch (V- or U-notch)	Weathered basin	
38.00	38.50	7.10	Notch (V- or U-notch)	Fractured	
41.50	42.50	5.00	Notch (V- or U-notch)	Fractured	

CASING DETAILS:

Depth to top [m]	Depth to bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]:			Hor. Dist.	Vert. Dist.
						Length	Width	Dist.		
0.00	15.90	169	Steel	6	Plain casing	0	0	0	0	0

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate [l/s]	Drawd. [m]	Recovery %	Storage T [m²/d]	Storage	Spec. capac.	Comment	
											STEP TEST 1
STEP TEST 2	20120317	60	32.00	3.80	8.72	100000	0.0	0	0.00	0.000	0.000
STEP TEST 3	20120317	60	32.00	4.88	9.31	8.00	86.0	180	0.00	0.000	0.000
CONSTANT DISCHARGE TEST	20120317	1440	32.00	4.92	12.26	9.30	76.0	720	0.00	0.000	0.000

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	No information	22.00	No information	12	2.50	CLASS 0 / C1-S1	10.00	20.00

Note: Borehole would be able to deliver a sustainable yield of 9 000L/hr or 108 000L/day at recommended pumping rate.

Water classified as Class 0 (Ideal Water Quality), suitable for life-time use.

Irrigation Class C1-S1: Low salinity water suitable for irrigation on most soils without danger of salinity or sodium problems developing.

BASIC SITE INFORMATION: Site identifier: 2430DAR0001 Number: TB-01607

Site type: Borehole

Distr./Farm No.: MPKT435

Site name: ELANDSFONTEIN/MASIDIBENG

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

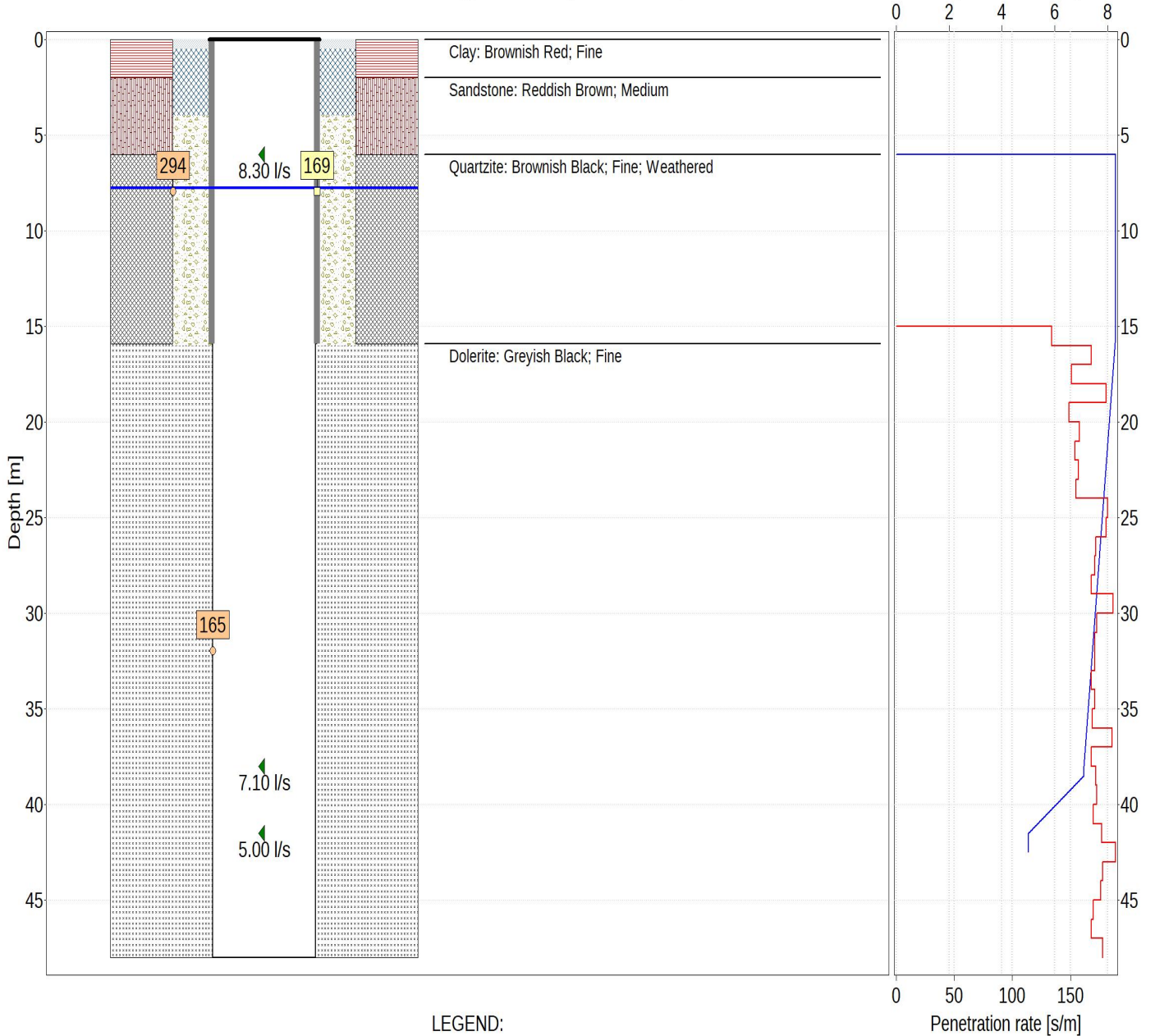
Latitude [°] -24.6470929
 Longitude [°] 30.7472812
 Coord. acc.: Accurate to within 100 units
 Coord. meth.: Global Positioning System (handheld)
 Altitude: [m]: 1331.00
 Surv. meth.: No information

Alt. No. 1:
 Alt. No. 2:
 Reg./BB.:
 Reporting institution:
 No info or invalid code
 Coord. System: WGS 84 / Lat/Long

Diam. [mm]: 165
 Depth [m]: 48.00
 Col. ht. [m]: 0.43

Site status: Unused
 Purpose: Production (water supply)
 Consumer: Farm(s)
 Use applic.: Agricultural and domestic use
 Topo. sett.: Hillside (slope)
 Drain. regn.: B60D

Hole Construction and Lithology - TB-01607 (2430DAR0001)





BASIC SITE INFORMATION: Site identifier: 2430DAR0001 Number: TB-01607

Site type: Borehole

Distr./Farm No.: MPKT435

Site name: ELANDSFONTEIN/MASIDIBENG

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

Latitude [°]	-24.6470929	Alt. No. 1:	Diam. [mm]:	165	Site status:	Unused
Longitude [°]	30.7472812	Alt. No. 2:	Depth [m]:	48.00	Purpose:	Production (water supply)
Coord. acc.:	Accurate to within 100 units	Reg./BB.:	Col. ht. [m]:	0.43	Consumer:	Farm(s)
Coord. meth.:	Global Positioning System (handheld)	Reporting institution:	Use applic.:			Agricultural and domestic use
Altitude [m]:	1331.00	No info or invalid code	Topo. sett.:			Hillside (slope)
Surv. meth.:	No information	Coord. System: WGS 84 / Lat/Long	Drain. regn.:			B60D

CONSTRUCTION

Date constr.	Contractor	Construction method	Reporting institution	Inform. source	Comment
03/02/2012	No info or invalid code	Air percussion	In-Situ Consulting	Driller's logs	

FINISH AND DEVELOPMENT

Collar

Depth	Type of finish	Hgt. [m]	Development method	Dev. durat.	Special treatment	Constr. cost
48.00	Open bottom (partially cased)	0.43	Pumped with air lift (no inducto 60		No information	0

HOLE DIAMETER:

Date constr.	Depth to:		Diam. [mm]	Reporting institution	Comment
	Top [m]	Bot. [m]			
03/02/2012	0.00	15.90	294	In-Situ Consulting	
03/02/2012	15.90	48.00	165	In-Situ Consulting	

CASING DETAILS:

Date inst.	Depth to:		Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]		Hor. Dist.	Vert. Dist.
	Top [m]	Bot. [m]					Length	Width		
03/02/2012	0.00	15.90	169	Steel	6	Plain casing	0	0	0	0

AQUIFER:

Report. Institution	Depth to:		Yield [l/s]	Meth. meas.	Aquifer type	Info. source	Comment
	Top [m]	Bot. [m]					
INSI	6.00	15.50	8.30	Notch (V- or U-notch)	Weathered basin	No information	
INSI	38.00	38.50	7.10	Notch (V- or U-notch)	Fractured	No information	
INSI	41.50	42.50	5.00	Notch (V- or U-notch)	Fractured	No information	

GEOLOGY: Lithology Colour, texture & feature

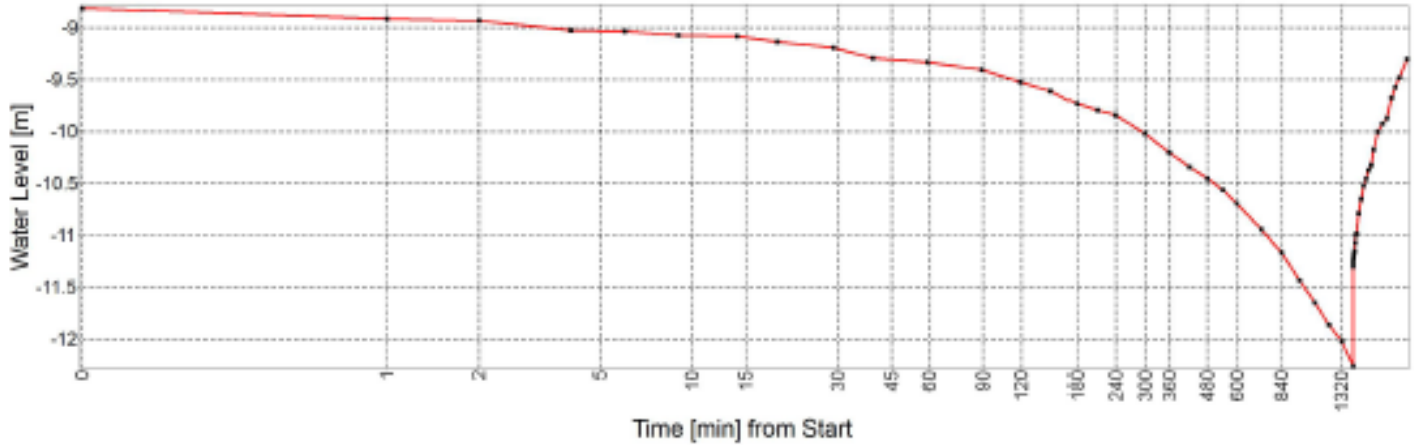
Depth to: Top [m]	Bot. [m]	Lithology	Prim.	Second.	Texture	Primary	Secondary	Feature
			Colour	Colour		Feature	Feature	Attribute
0.00	2.00	Clay	Red	Brownish	Fine	No information	No information	No information
2.00	6.00	Sandstone	Brown	Reddish	Medium	No information	No information	No information
6.00	15.90	Quartzite	Black	Brownish	Fine	Weathered	No information	No information
15.90	48.00	Dolerite	Black	Greyish	Fine	No information	No information	No information

PUMPING TEST REPORT



BASIC SITE INFORMATION: Site Identifier: 2430DAR0001 Number: TB-01607 Site Type: Borehole
 Distr./Farm No.: MPKT435 Site Name: ELANDSFONTEIN/MASIDIBENG
 Latitude [°] -24.6470929 Alt. No. 1: Diam. [mm]: 165 Water level [m]: 7.77
 Longitude [°] 30.7472812 Alt. No. 2: Depth [m]: 48.00 Piezometer: 0
 Altitude [m]: 1331.00 Rep. Inst.: No info or invalid code Col. Ht. [m]: 0.43 Date WL meas.: 17/03/2012
 Coordinate System: WGS 84 / Lat/Long

Constant Rate Test



PUMPING TEST		Depth to	Starting	End	Transm.		Storativity	
Rep. Inst.	Meth. tested	intk. [m]	Date	Time	Date	Time	[m ² /d]	
In-Situ Consulting	Multirate test	32.00	17/03/2012	08:00	17/03/2012	13:59	0	0
In-Situ Consulting	Constant rate test	32.00	17/03/2012	14:00	19/03/2012	01:59	0	0

TESTING DETAILS:												
Description	Time started	Durat. [min]	Depth to intake [m]	Disch. rate [l/s]	Drawd. [m]	Recovery: [m]	%	Durat. [min]	Transm. [m ² /d]	Perm. [m/d]	Spec. Stor. [m]	Capac. Q/st
STEP TEST 1	08:00	60	32.00	2.05	8.13		0	0	0.00	0.000	0.000	0.252
STEP TEST 2	09:00	60	32.00	3.80	8.72		0	0	0.00	0.000	0.000	0.436
STEP TEST 3	10:00	60	32.00	4.88	9.31	8.00	86	180	0.00	0.000	0.000	0.524
CONSTANT DISCHARGE TE	14:00	1440	32.00	4.92	12.26	9.30	76	720	0.00	0.000	0.000	0.401

WATER LEVEL:								
Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment	
Electrical contact meter	Static	0	17/03/2012	08:00	0	7.77	STATIC W/L	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:01	0	7.87		
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:02	0	7.88		
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:04	0	7.91		
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:06	0	7.92		

PUMPING TEST REPORT



WATER LEVEL:

Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:09	0	7.92	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:14	0	7.93	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:19	0	7.94	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:29	0	8.05	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:39	0	8.10	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:49	0	8.11	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	08:59	0	8.13	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:00	0	8.38	STEP TEST 2
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:01	0	8.39	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:02	0	8.44	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:04	0	8.46	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:06	0	8.49	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:09	0	8.53	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:14	0	8.60	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:19	0	8.62	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:29	0	8.64	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:39	0	8.66	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:49	0	8.68	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	09:59	0	8.72	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:00	0	8.93	STEP TEST 3
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:01	0	8.95	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:02	0	8.97	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:04	0	9.00	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:06	0	9.02	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:09	0	9.04	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:14	0	9.05	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:19	0	9.10	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:29	0	9.17	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:39	0	9.24	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:49	0	9.26	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	10:59	0	9.31	
Electrical contact meter	Recovering	0	17/03/2012	11:00	0	8.39	RECOVERY
Electrical contact meter	Recovering	0	17/03/2012	11:01	0	8.34	
Electrical contact meter	Recovering	0	17/03/2012	11:02	0	8.32	
Electrical contact meter	Recovering	0	17/03/2012	11:04	0	8.28	
Electrical contact meter	Recovering	0	17/03/2012	11:06	0	8.25	
Electrical contact meter	Recovering	0	17/03/2012	11:09	0	8.22	
Electrical contact meter	Recovering	0	17/03/2012	11:14	0	8.19	
Electrical contact meter	Recovering	0	17/03/2012	11:19	0	8.17	
Electrical contact meter	Recovering	0	17/03/2012	11:29	0	8.16	
Electrical contact meter	Recovering	0	17/03/2012	11:39	0	8.14	
Electrical contact meter	Recovering	0	17/03/2012	11:59	0	8.10	
Electrical contact meter	Recovering	0	17/03/2012	12:29	0	8.07	
Electrical contact meter	Recovering	0	17/03/2012	12:59	0	8.04	
Electrical contact meter	Recovering	0	17/03/2012	13:29	0	8.02	
Electrical contact meter	Recovering	0	17/03/2012	13:59	0	8.00	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:00	0	8.81	CONSTANT
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:01	0	8.91	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:02	0	8.93	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:04	0	9.02	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:06	0	9.03	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:09	0	9.07	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:14	0	9.08	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:19	0	9.13	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:29	0	9.19	

PUMPING TEST REPORT



WATER LEVEL:

Meth. meas.	Level status	Piezom.	Date meas.	Time meas.	Secs.	Water lev. [m]	Comment
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:39	0	9.29	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	14:59	0	9.33	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	15:29	0	9.40	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	15:59	0	9.52	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	16:29	0	9.61	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	16:59	0	9.73	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	17:29	0	9.79	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	17:59	0	9.84	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	18:59	0	10.02	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	19:59	0	10.20	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	20:59	0	10.34	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	21:59	0	10.45	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	22:59	0	10.56	
Electrical contact meter	Pumped (abstraction in hole)	0	17/03/2012	23:59	0	10.69	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	01:59	0	10.94	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	03:59	0	11.17	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	05:59	0	11.43	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	07:59	0	11.65	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	09:59	0	11.86	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	11:59	0	12.02	
Electrical contact meter	Pumped (abstraction in hole)	0	18/03/2012	13:59	0	12.26	
Electrical contact meter	Recovering	0	18/03/2012	14:00	0	11.30	RECOVERY
Electrical contact meter	Recovering	0	18/03/2012	14:01	0	11.27	
Electrical contact meter	Recovering	0	18/03/2012	14:02	0	11.24	
Electrical contact meter	Recovering	0	18/03/2012	14:04	0	11.21	
Electrical contact meter	Recovering	0	18/03/2012	14:06	0	11.19	
Electrical contact meter	Recovering	0	18/03/2012	14:09	0	11.17	
Electrical contact meter	Recovering	0	18/03/2012	14:14	0	11.15	
Electrical contact meter	Recovering	0	18/03/2012	14:19	0	11.07	
Electrical contact meter	Recovering	0	18/03/2012	14:29	0	11.00	
Electrical contact meter	Recovering	0	18/03/2012	14:39	0	10.98	
Electrical contact meter	Recovering	0	18/03/2012	14:59	0	10.79	
Electrical contact meter	Recovering	0	18/03/2012	15:29	0	10.65	
Electrical contact meter	Recovering	0	18/03/2012	15:59	0	10.52	
Electrical contact meter	Recovering	0	18/03/2012	16:29	0	10.45	
Electrical contact meter	Recovering	0	18/03/2012	16:59	0	10.37	
Electrical contact meter	Recovering	0	18/03/2012	17:29	0	10.32	
Electrical contact meter	Recovering	0	18/03/2012	17:59	0	10.17	
Electrical contact meter	Recovering	0	18/03/2012	18:59	0	10.00	
Electrical contact meter	Recovering	0	18/03/2012	19:59	0	9.92	
Electrical contact meter	Recovering	0	18/03/2012	20:59	0	9.87	
Electrical contact meter	Recovering	0	18/03/2012	21:59	0	9.67	
Electrical contact meter	Recovering	0	18/03/2012	22:59	0	9.57	
Electrical contact meter	Recovering	0	18/03/2012	23:59	0	9.48	
Electrical contact meter	Recovering	0	19/03/2012	01:59	0	9.30	

MANAGEMENT RECOMMENDATIONS



BASIC SITE INFORMATION: Site Identifier: 2430DAR0002 Number: TB-01607A Site Type: Borehole

Distr./Farm No.: MPKT435 Site Name: ELANDSFONTEIN/MATIBIDI A

Latitude [°] -24.6464079 Alt. No. 1: Diam. [mm]: 165 Last static water lev. [m]:
 Longitude [°] 30.7463812 Alt. No. 2: Depth [m]: 90.00 Piezometer:
 Altitude [m]: 322.00 Rep. Inst.: No info or invalid code Col. Ht. [m]: 0.00 Date WL meas.:
 Coordinate System: WGS 84 / Lat/Long

EXISTING EQUIPMENT:

PUMP: ENGINE:
 Type of Inst.: Type of Power:
 Manufacturer: Manufacturer:
 Depth to intk. [m]: Power Rating [kW]:

USE APPLICATION:

Site Status: Unused
 Purpose: Production (water supply)
 Consumer: Non-urban
 Application: Agricultural and domestic use

WATER CHEMISTRY:

Sample No.:	Date sampled:	Depth sampl. [m]:	Comment:
Chemical and Physical Parameters:		Bacteriol. Parameters:	Calculated Parameters:
pH:	Na:	Cl:	E. Coli:
EC [mS/m]:	K:	NO3 as N:	Faec. Col.:
TDS:	Si:	SO4:	Total Col.:
Tot. Alk.:	Al:	F:	SPC:
Ca:	Fe:		SAR:
Mg:	Mn:	Concentrations in [mg/l] where applicable Bacteriological parameters in [counts/100ml]	

AQUIFER INFORMATION:

Depth to top [m]	Depth to bot. [m]	Yield [l/s]	Meth. meas.	Aquifer type	Comment
21.00	21.50	0.26	Notch (V- or U-notch)	Solution chanel	
69.00	70.00	0.26	Notch (V- or U-notch)	No information	

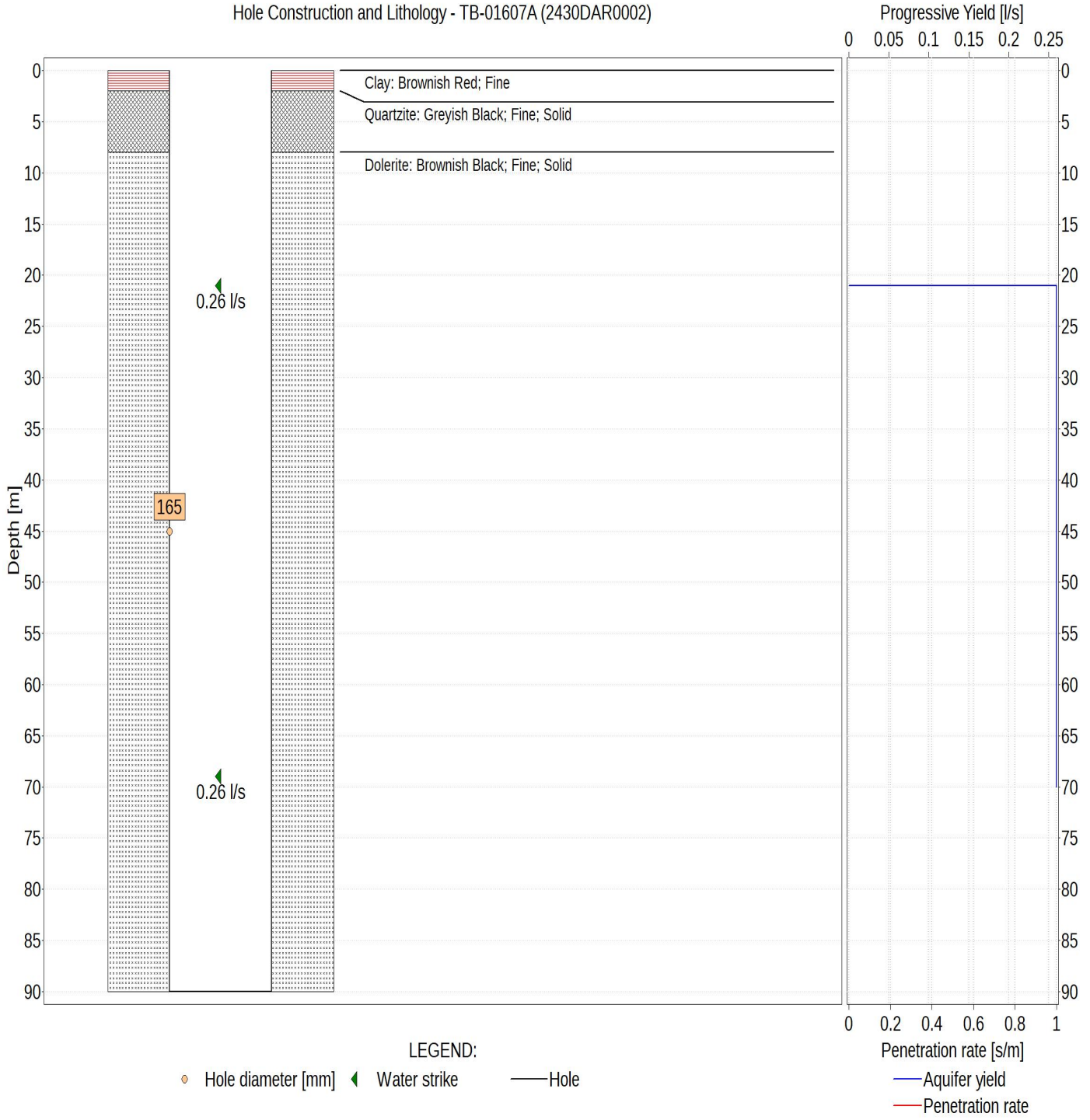
RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1	No information	0.00	No information	0	0.00	NO SAMPLE	0.00	0.00

Note: Dry Borehole. Stone Plugged.

BASIC SITE INFORMATION: Site identifier: 2430DAR0002 Number: TB-01607A Site type: Borehole	
Distr./Farm No.: MPKT435	Site name: ELANDSFONTEIN/MATIBIDI A
Region type: District Council	Region descr.: EHLANZENI/THABA CHWEU
Latitude [°] -24.6464079	Alt. No. 1:
Longitude [°] 30.7463812	Alt. No. 2:
Coor. acc.: Accurate to within 100 units	Reg./BB.:
Coor. meth.: Global Positioning System (handheld)	Reporting institution:
Altitude [m]: 322.00	No info or invalid code
Surv. meth.: No information	Coord. System: WGS 84 / Lat/Long
Diam. [mm]: 165	Site status: Unused
Depth [m]: 90.00	Purpose: Production (water supply)
Col. ht. [m]: 00000	Consumer: Non-urban
	Use applic.: Agricultural and domestic use
	Topo. sett.: Valley
	Drain. regn.: B60D

Hole Construction and Lithology - TB-01607A (2430DAR0002)



BASIC SITE INFORMATION: Site identifier: 2430DAR0002 Number: TB-01607A

Site type: Borehole

Dist./Farm No.: MPKT435

Site name: ELANDSFONTEIN/MATIBIDI A

Region type: District Council

Region descr.: EHLANZENI/THABA CHWEU

Latitude [°]	-24.6464079	Alt. No. 1:	Diam. [mm]:	165	Site status:	Unused
Longitude [°]	30.7463812	Alt. No. 2:	Depth [m]:	90.00	Purpose:	Production (water supply)
Coord. acc.:	Accurate to within 100 units	Reg./BB.:	Col. ht. [m]:	00000	Consumer:	Non-urban
Coord. meth.:	Global Positioning System (handheld)	Reporting institution:	Use applic.:			Agricultural and domestic use
Altitude [m]:	322.00	No info or invalid code	Topo. sett.:			Valley
Surv. meth.:	No information	Coord. System: WGS 84 / Lat/Long	Drain. regn.:			B60D

CONSTRUCTION

Date constr.	Contractor	Construction method	Reporting institution	Inform. source	Comment
01/02/2012	No info or invalid code	No information	In-Situ Consulting	Driller's logs	

FINISH AND DEVELOPMENT

Collar

Depth	Type of finish	Hgt. [m]	Development method	Dev. durat.	Special treatment	Constr. cost
90.00	No information	0.00000	No information	0	No information	0

HOLE DIAMETER:

Date constr.	Depth to:		Diam. [mm]	Reporting institution	Comment
	Top [m]	Bot. [m]			
01/02/2012	0.00	90.00	165	In-Situ Consulting	

AQUIFER:

Report. Institution	Depth to:		Yield [l/s]:	Meth. meas.	Aquifer type	Info. source	Comment
	Top [m]	Bot. [m]					
INSI	21.00	21.50	0.26	Notch (V- or U-notch)	Solution chanel	No information	
INSI	69.00	70.00	0.26	Notch (V- or U-notch)	No information	No information	

GEOLOGY: Lithology Colour, texture & feature

Depth to:			Prim. Colour	Second. Colour	Texture	Primary Feature	Secondary Feature	Feature Attribute
Top [m]	Bot. [m]	Lithology						
0.00	2.00	Clay	Red	Brownish	Fine	No information	No information	No information
2.00	8.00	Quartzite	Black	Greyish	Fine	Solid	No information	No information
8.00	90.00	Dolerite	Black	Brownish	Fine	Solid	No information	No information

Appendix E

LIST OF BOREHOLES IN STUDY AREA

Appendix E

LIST OF BOREHOLES IN STUDY AREA

MATIBIDI			
Borehole name	Longitude	Latitude	Borehole depth (m)
MP04-0008	E30.796857°	S24.614856°	Unknown
H35-0110 /H05-0680	E30.772140°	S24.590690°	58,84
MAT-3	E30.768330°	S24.592910°	Unknown
MAT-4	E30.766340°	S24.593840°	40
MAT-5	E30.764860°	S24.596130°	11
H35-0111 /H05-0682	E30.761260°	S24.595650°	32,33
H35-0133	E30.760560°	S24.599280°	Unknown
MAT-8	E30.76114°	S24.59978°	Unknown
MP04-35	E30.766080°	S24.601690°	Unknown
H05-0099	E 30.768688°	S24.601501°	1,8
MAT-11	E30.768700°	S24.601460°	Unknown
MAT-12	E30.767549°	S24.627788°	Unknown
H35-0125	E30.758587°	S24.611304°	49,87
H05-0676	E30.75862°	S24.61125°	64,25
MAT-15	E 30.757083°	S24.610213°	0
H05-0679	E30.757000°	S24.610100°	41,64
H35-0118	E30.75086°	S24.62026°	55,6
H35-0119	E30.750778	S24.620285°	19
H35-0120	E 30.741077°	S24.616392°	50
MAT-20	E 30.742016°	S24.616144°	Unknown
H35-0121	E 30.739706°	S24.629540°	44,66
H35-0122 /H05-0675	E 30.737763°	S24.628663°	71
MAT-23	E 30.741405°	S24.638505°	85
H35-0146 /H05-0681	E 30.727279°	S24.650034°	40,4
H05-0677	E 30.723846°	S24.652832°	64,49
H35-0144 /H05-0683	E 30.721460°	S24.654940°	41,74
MAT-27	E 30.742827°	S24.650915°	Unknown
MAT-28	E 30.764311°	S24.625585°	Unknown

LERORO			
Borehole name	Longitude	Latitude	Borehole depth (m)
H35-0128	E30.796857°	S24.614856°	±28
Pump 12A	E30.797003°	S24.614841°	18,4
Pump 12B	E30.796951°	S24.614868°	34,4
H35-0129	E30.796791°	S24.614766°	33,36
H35-0127	E30.795976°	S24.615276°	Blocked, was 75
H35-0126	E30.795413°	S24.618304°	63,17
H05-0786	E30.793598°	S24.620718°	59,59
H35-0132	E30.793597°	S24.620757°	0
H35-0138	E30.794268°	S24.628052°	10,28
H35B0149	E30.795182°	S24.628384°	Unknown
H35B0158	E30.795127°	S24.628459°	Unknown
H35-0139	E30.794922°	S24.628462°	Unknown
LER-13	E30.792848°	S24.635592°	Unknown
LER-14	E30.794784°	S24.633064°	Unknown
BR-975	E30.790211°	S24.629427°	100+
BR-796	E30.788641°	S24.621931	100+
H35B0173	E30.793273°	S24.626703°	130
LER-18	E30.794612°	S24.632287°	30
LER-19	E30.791787°	S24.620322°	150
LER-20	E30.797348°	S24.615660°	Unknown
LER-21	E30.797314°	S24.615655°	120
LER-22	E30.797234°	S24.615635°	75
H35-0130	E30.797100°	S24.613864°	37
H35-0131	E30.798117°	S24.612831°	Unknown
LER-25	E30.801048°	S24.613366°	Unknown
LER-26	E30.806732°	S24.617016°	57+

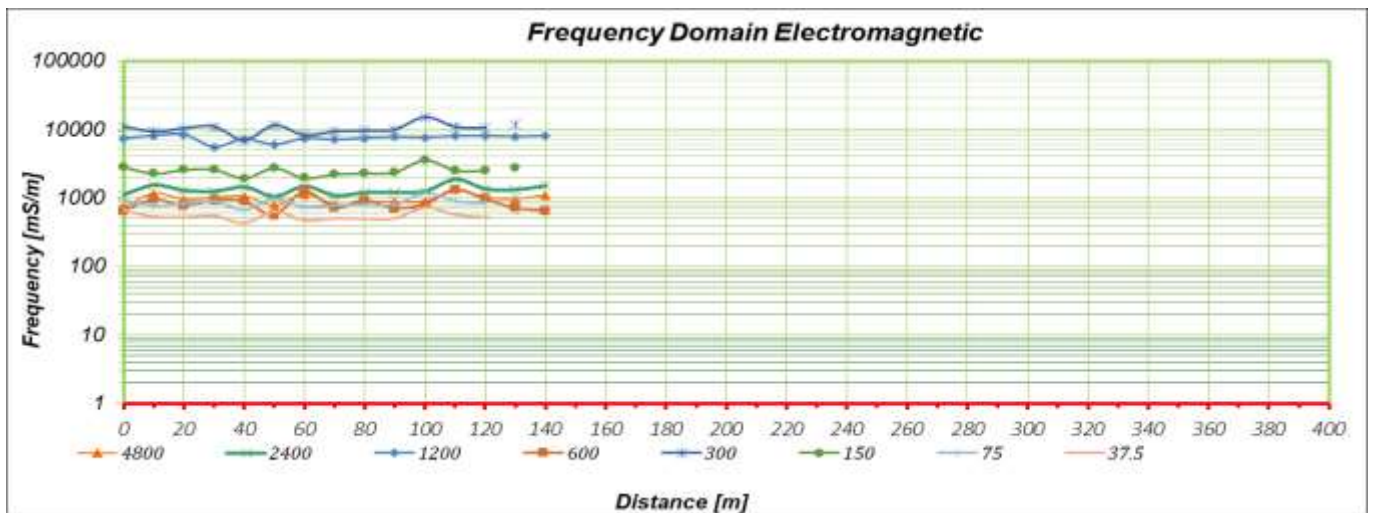
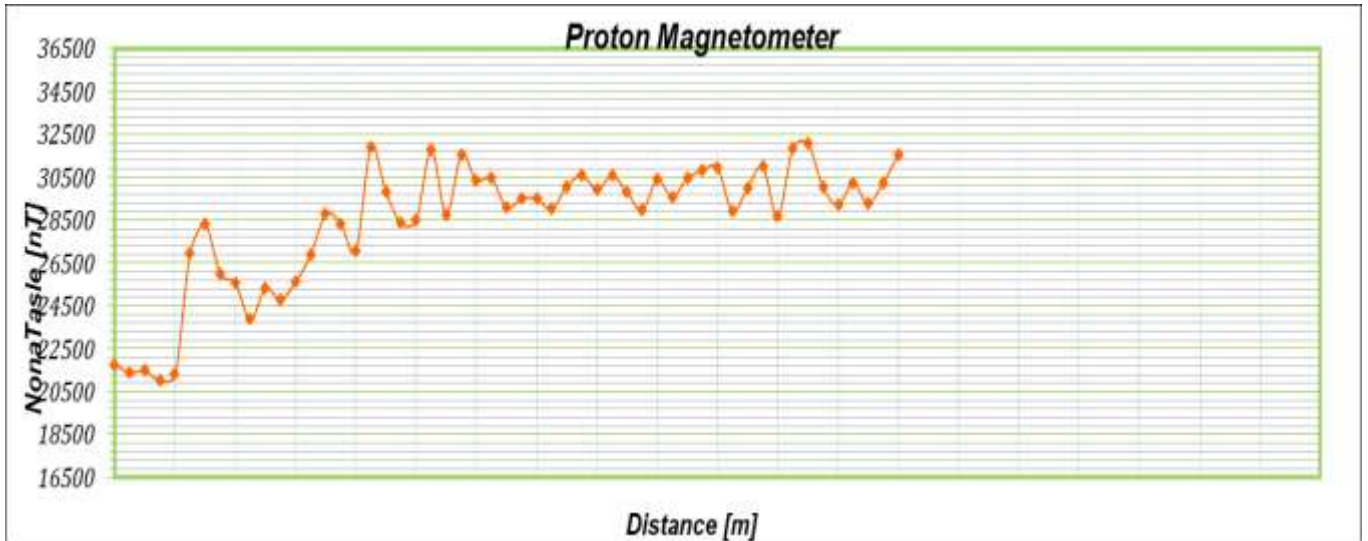
MOREMELA			
Borehole name	Longitude	Latitude	Borehole Depth (m)
MOR-1	E30.815929°	S24.651627°	31
H05-0686	E30.806267°	S24.672459°	41.95
H35-0141	E30.806205°	S24.672520°	48.85
MOR-4	E30.806240°	S24.672505°	Unknown
MOR-5	E30.801884°	S24.670531	Unknown
MOR-6	E30.800441°	S24.673311°	Unknown
H35-0143	E30.790999°	S24.664803°	52.02

Appendix F

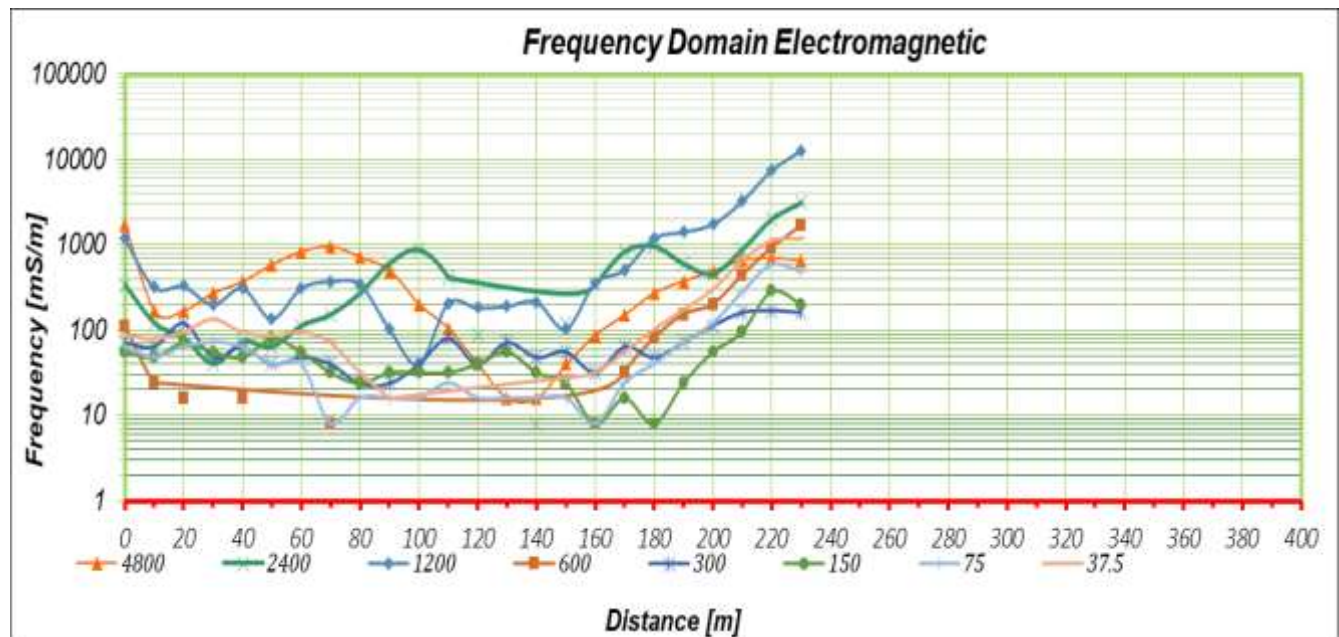
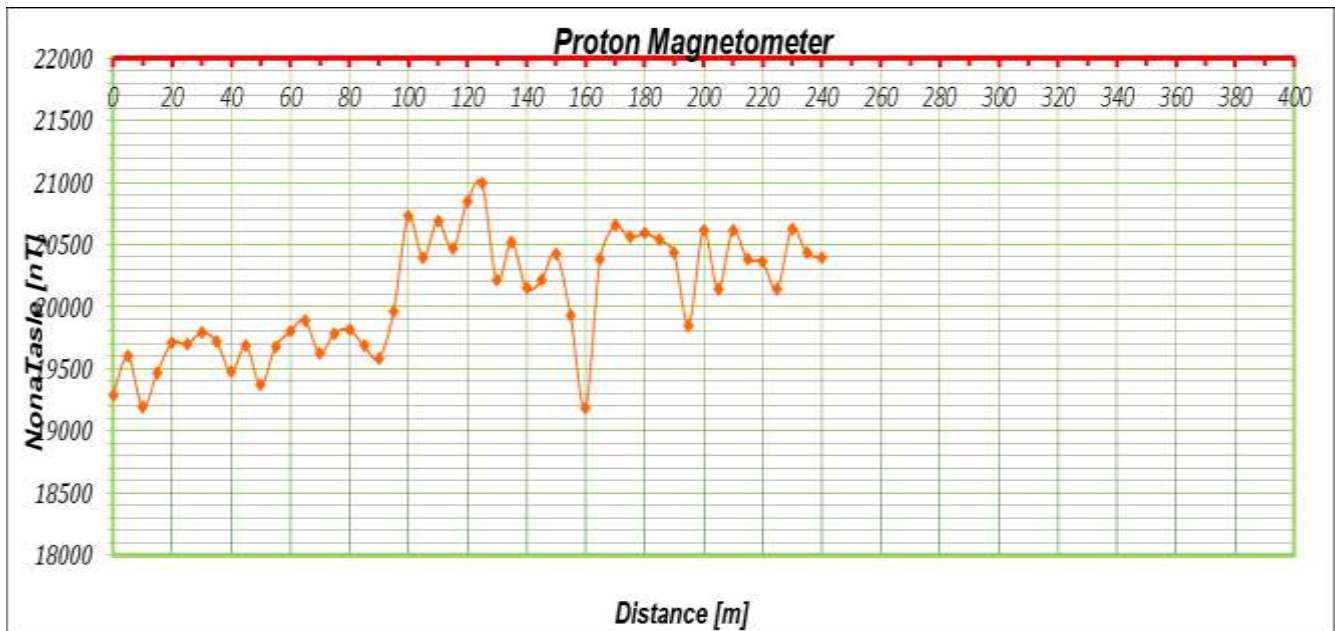
GEOPHYSICAL RESULTS

GEOPHYSICAL RESULTS

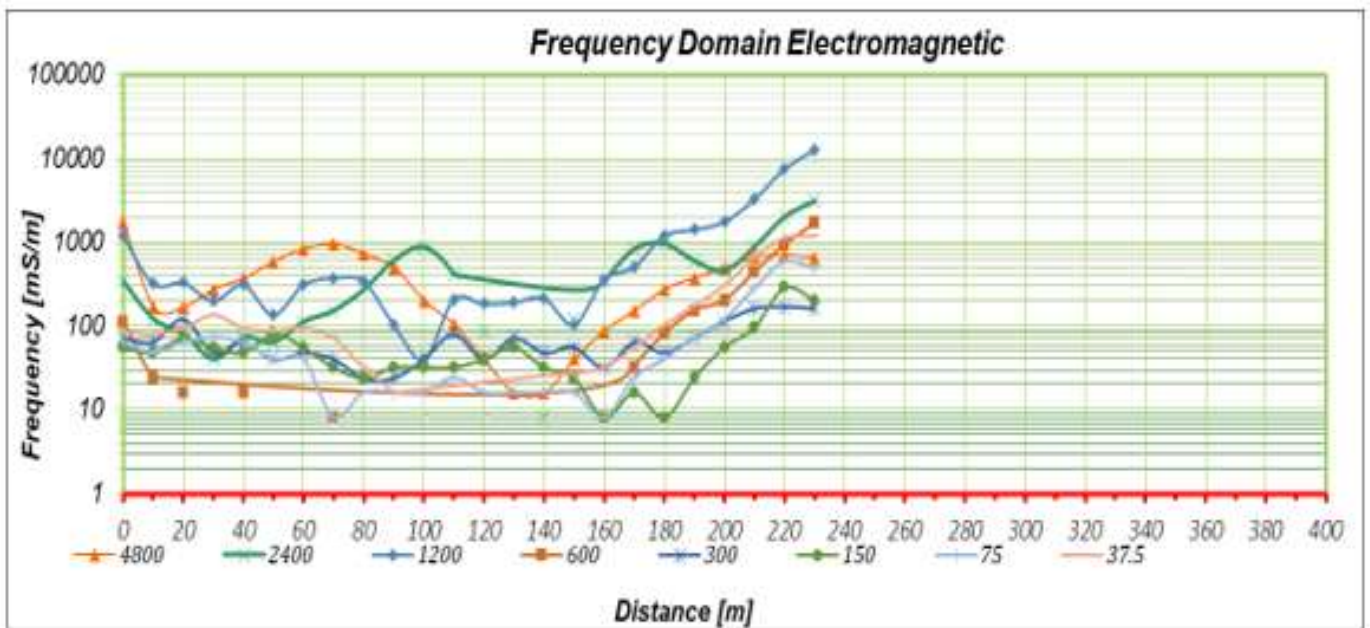
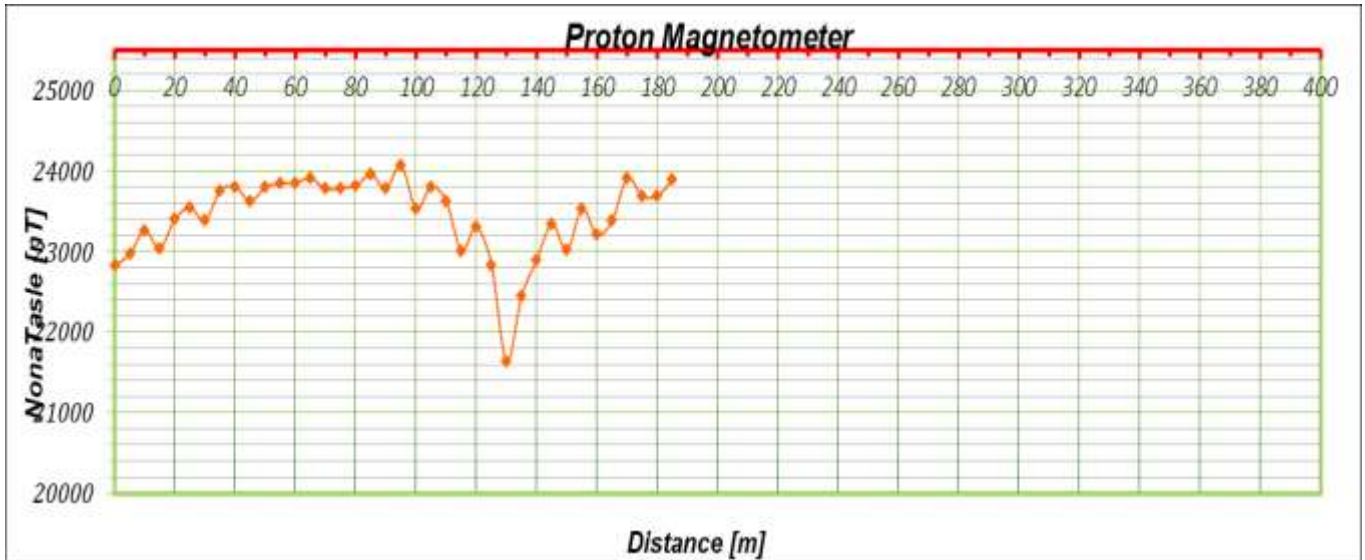
Leroro B



Lydenburg Ext 108



Lydenburg



Matibidi

