PROSPECTING RIGHT APPLICATION

BASIC HYDROGEOLOGICAL STUDY

Basic Hydrogeological Study for the Proposed Prospecting right of coal on the Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District In Mpumalanga Province, South Africa

REPORT PREPARED BY:

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Notre Coal

DMRE REF: MP 30/5/1/1/2/17548

Report Credentials.

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Project details

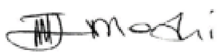
Report type	**Basic Hydrogeological Study for a Prospecting Right Application**	
Project title	Basic Hydrogeological Study for the Proposed Prospecting right of coal on the Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District IN Mpumalanga Province, South Africa	
Mineral (s)	Coal Resources	
Client	Notre Coal (Pty) Ltd	
Site location	on the Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District IN Mpumalanga Province, South Africa	
Version	1	
Date	19 October 2022	
		Electronic signatures
		Compiled by
Compiled by	Manare Judith Marweshi (Hydrogeologist Intern) Singo Consulting (Pty) Ltd	
Reviewed by	Mutshidzi Munyai (Hydrogeologist) Singo Consulting (Pty) Ltd (Water Resources Science (Candidate Natural Scientist), Environment Science (Candidate Natural Scientist) (SACNASP Registration Number 122464)	
Final review and approval	Dr. Kenneth Singo (Principal Consultant of Singo Consulting (Pty) Ltd) South African Council for Natural Scientific Professions (SACNASP: Earth Science Reg. No: 400069/16)	

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Table 1: Critical Report Information

Critical Information incorporated within the Basic Hydrogeological Study:	Relevant section in report
Details of the specialist who prepared the report	Project details, P: 3
The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A, P: 48
Project Background Information, including the proposed activities description	Introduction, P: 9
An indication of the scope of, and the purpose for which, the report was prepared	Scope of work, P: 10
An indication of the quality and age of base data used for the specialist report	Project details, P: 3
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Hydrogeological Impact assessment and management plan, P: 39
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Project details, P: 3
A description of the methodology implemented in preparing the report or carrying out the specialised process comprehensive of equipment and modelling used;	Methodology, P: 12
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative;	N/A
An identification of any areas to be avoided, including buffers	N/A
A map overlaying the proposed activity including the associated infrastructures on the environmental sensitivities of the site including containing buffer zones	N/A
A description of the findings and potential implications of such findings on the impact of the proposed activity or activities	Prospecting phase impacts, P: 39
Any mitigation and conditions measures for inclusion in the EMPr	Impact assessment and mitigation measures table, P: 41
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Managements measures, P: 39
An analytic opinion as to whether the proposed activity or portions thereof should be Authorised-i.e. specific recommendations	Recommendations, P: 44
Regarding the acceptability of the proposed activity or activities; and	Refer to bar
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Management measures, P: 39
A description of any consultation process that was undertaken during carrying out the study	Refer to bar
Any triggered Water Uses according to section 21 of the National Water Act 36, 1998.	Terms of reference, P: 11
Any other information requested by the competent authority.	N/A

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1 INTRODUCTION

1.1 Background Information

Notre Coal (Pty) Ltd has appointed Singo Consulting (Pty) Ltd as an independent consulting company to conduct a basic hydrogeological study. The basic hydrogeological study is being conducted in support of a prospecting right application basic hydrogeology for coal on the Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District in Mpumalanga Province, South Africa.

The proposed activity has a potential to contaminate the groundwater through possible accident of leakage and infiltration to the sub-surface. Chapter 3 of the National Water Act (Act 36 of 1998) requires that a person who owns, control, occupies, uses the land is responsible for preventing pollution of water resources and is also responsible to remedy (correct) the effects of the pollution. It is with this Act that the hydrogeological report was deemed necessary for the site to gather all relevant information related to groundwater and its related potential impacts.

Notre Coal (Pty) Ltd is planning to prospect for coal resources with the application of drilling to recover ores, which will be analysed for further delineation of the coal resources and other related lithologies.

The goal of this study:

- Prediction of the environmental impact of the proposed Prospecting activity on the geohydrological regime of the area.
- To assess the quality condition of surface and groundwater within and around the prospecting area, and to draft a water monitoring programme for the project site and provide recommendations
- Forecasting the effects of the activity on the receiving environment.

1.2 Proposed Activities

The activities involved during the life of the project will be in phases, the outlined activities considered are the ones which have the potential of negatively or positively impacting the groundwater regime in the area in terms of quality and quantity.

- Clearing of vegetation to create roads and drilling areas
- Drilling Process.

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- Removal of cores and core logging.

Prospecting activities will be undertaken over a period of five (5) years and are designed in phases, each phase conditional on the success of the previous phase. Both invasive and non-invasive methods will be implemented.

Non-Invasive method:

- Desktop study of the area has commenced, and this incorporates desktop geographical and geological mapping.
- Followed by a detailed geochemical and geotechnical surveys.
- In turn, this is followed by detailed geophysical studies.

Invasive method:

- A detailed drilling, sampling, assaying and mineralogical study will be carried out.
- Diamond method will be utilised to prospect Coal. To ensure or minimise impacts on the receiving environment, All the activities will be guided by the project's BAR & EMPr.

1.3 Scope of Work

The scope of hydrogeological assessment consisted of the following tasks:

- A desktop review and short baseline hydrogeological description of the site area, including review of:
    - Surface water drainage and its potential impact on groundwater.
    - Aquifer characterization.

- Aquifer Classification
- Hydrogeological Modelling
    - Numerical Groundwater flow.
        - Model inputs
        - Model Calibration
        - Scenario Modelling

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2 TERMS OF REFERENCE

The baseline hydrogeological assessment for the project area is mainly constructed by a combination of desktop study and site-specific field study. Most of the information used for this study was compiled with an aid of nearby study sites information and experience from similar geohydrological settings. All collected data will be compiled to construct a conceptual geohydrological model.

The following aspects were covered in this hydrogeological study:

Table 2:Hydrogeological aspects

Aspect	Description
Desktop Study	➢ Project Initiation and Data Collection ➢ Review available site specific hydrogeological and hydrological information to conceptualize the different aquifer systems and their interaction with surface water features in the area.
Aquifer classification	➢ Aquifers will be classified into either minor or major aquifer types and dominant water source will be identified
Reporting	Writing a comprehensive geohydrological report outlining all the findings and existing environment of the proposed project area. This groundwater specialist report compiles all methodologies, findings, quantitative analysis (geochemical assessment and modelling outcomes), impact assessments, recommendations (proposed monitoring programme and recommended mitigation measures for predicted impacts) and conclusions. Appendices to the specialist report will include laboratory results.

3 METHODOLOGY

3.1 Desktop Study

Desktop or literature review is defined as a task which involves review of existing research/ information which is relevant to the project needs.

A literature review of all available relevant data was undertaken to provide more data as needed. The data from the literature review was correctly referenced and incorporated into the final research report. Data was compiled using science literature (journals, textbooks, papers, maps, and so on), GIS data from Singo Consulting (Pty) Ltd, DWS, SAWS weather station records, and other relevant scientific work conducted on the subject region. A comprehensive list of all the literature sources utilized in the study report can be found in the reference list.

3.2 Drilling and sitting of boreholes.

Exploration boreholes will be dug one at a time at various locations throughout the proposed project area. Drill hole depths will average 100 meters and will be determined onsite as the drilling program advances, depending on past hole depths and dips. Between certain wetlands and waterways, a 100-meter buffer will be maintained. A 100-meter buffer must be maintained from public highways. Figure 1: Proposed Borehole Map shows the proposed boreholes for the current study area.

After the drill site has been gated off, cleared drilling will begin. Following the drilling, immediate rehabilitation will take place. The site will be repaired after each hole is drilled before the drilling crew moves on to the next planned hole. This procedure will be repeated until all holes have been drilled.

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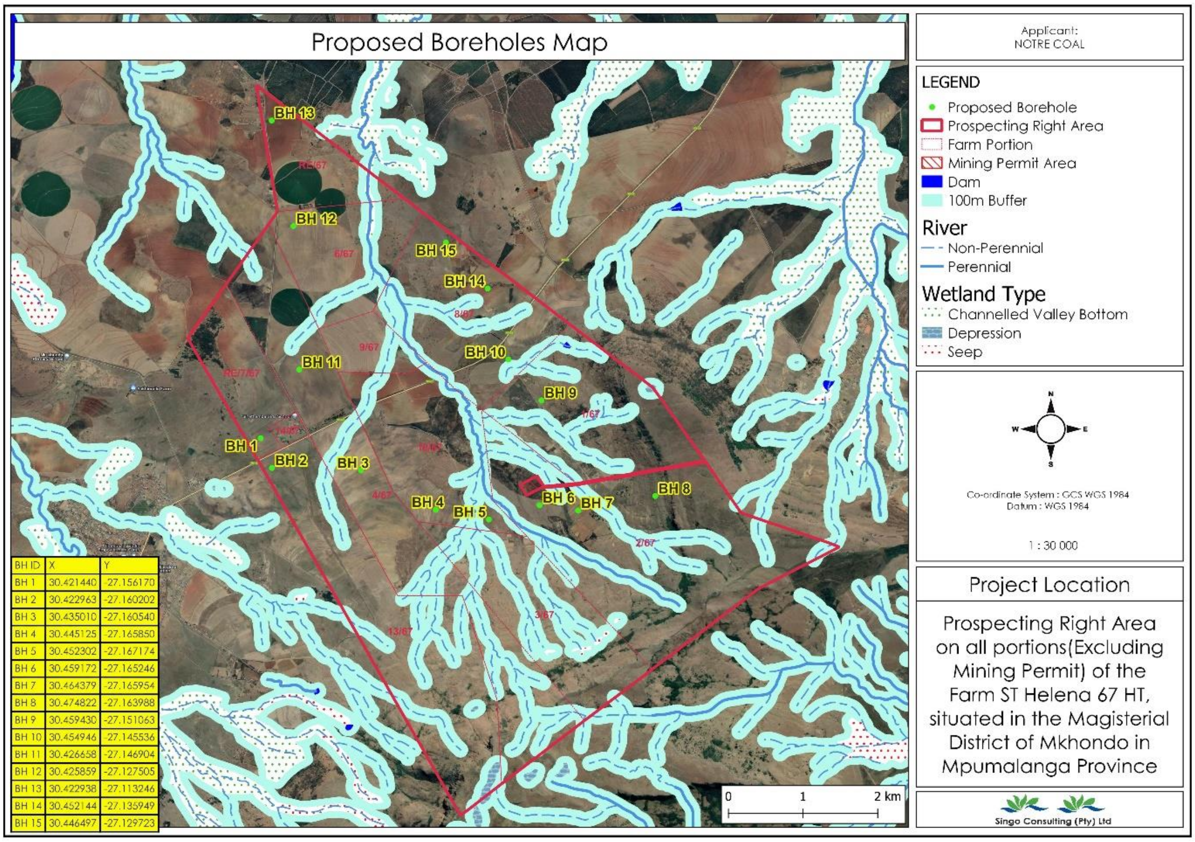

Figure 1: Proposed Borehole Map

3.3 Groundwater availability assessment

The availability of groundwater as a water source depends largely upon surface and subsurface geology as well as climate. The porosity and permeability of a geologic formation control its ability to hold and transmit water. Porosity is measured as a ratio of voids to the total volume of rock material and is usually described as a percentage.

Shallow, weathered and/or fractured rock and relatively low yielding aquifer systems are underlain over 80 percent of South Africa. By contrast, appreciable quantities of groundwater can be abstracted at relatively high rates from dolomitic and quarzitic aquifer systems located in the northern and southern parts of the country respectively, as well as from a number of primary aquifers situated along the coastline.

Groundwater systems

Aquifer types

The aquifer systems in South Africa can be divided into two major types: **primary** and **secondary** aquifers.

Primary aquifers: The primary aquifers are: 1. Coastal sand, gravel and unconsolidated material along the South African coast, such as areas along the west coast at Port Nolloth, Doringbaai, Lambertsbaai, Langebaan, Atlantis, Cape Flats, Gansbaai, Bredesdorp, Stilbaai, Alexandria, Boesmansriviermond, Kidds beach, Richards bay; 2. Sand and gravel along stream beds such as those along the Crocodile and Caledon rivers, at De Aar, De Doorns, Rawsonville, Pietersburg (Polokwane), Messina, and Makatini Flats (Kok, 1991).

Characteristics of Primary Aquifers include but not limited to:

- Usually, shallow unconfined systems and groundwater surface in the aquifer is at atmospheric pressure (100 kPa).
- Mostly consist of unconsolidated material, usually less than 30 m thick.
- Contain 1 to 20 percent water by aquifer volume
- Recharge rate is generally high. Some 15 to 30 percent of rainfall would infiltrate into aquifers.
- Geohydrological characteristics of aquifer do not vary greatly over short distances.
- The transportation of contaminants in the primary aquifers is slow because of high effective porosity.

Secondary aquifers: The degree of fracturing of rocks in South Africa is dependent upon the tectonic history of rocks as well as the rock composition. For example, competent rocks, such as dolerite and quartzite and sandstones, fracture more readily than incompetent or ductile rocks, such as dolomite and shale. The magnitude of fracturing does not necessarily determine how much water an aquifer can transmit. It is estimated that at depths greater than 60 m, about less than one percent of the fractures transmit significant amounts of water. However, within quartzite rocks, significant yields are possible at greater depths.

Typical characteristics of secondary or fracture flow aquifers are:

- Fractured flow aquifers are either confined or unconfined aquifers. The confined aquifers are overlain by sediments or rock of confining nature, which limits direct recharge from rainfall.
- They belong to shallow systems, usually less than 60 m thick and in exceptional circumstances can be about 200 m thick.
- Characteristics of aquifers as well as borehole yields vary greatly over short distances.

South Africa is characterized by primary and secondary aquifers.

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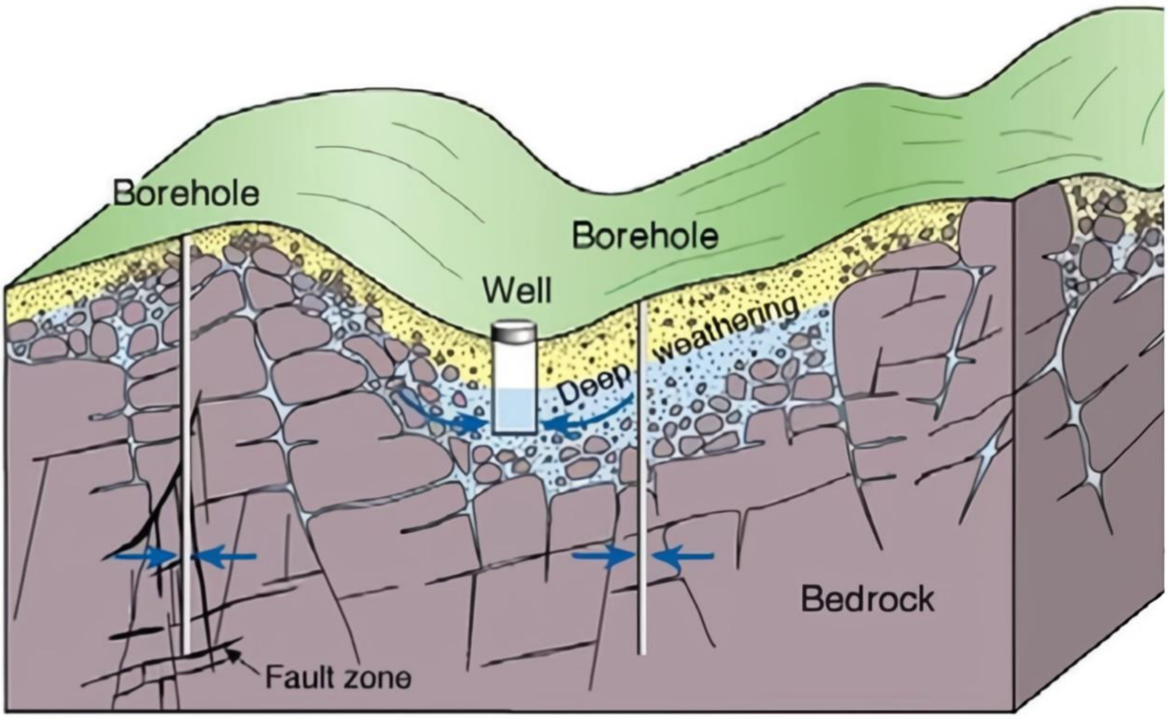

Figure 2: Fractured and weathered aquifer.

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4 PHYSIOGRAPHICAL AND GEOLOGICAL SETTING

4.1 Project Location

The locality map created by the QGIS illustrates the location of the proposed area is located on the Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District IN Mpumalanga Province, South Africa (Figure 3: Locality Map of the Study area). The area is situated approximately 8.5 km west of KwaNgema Clinic and can be accessed through the R543 Road.

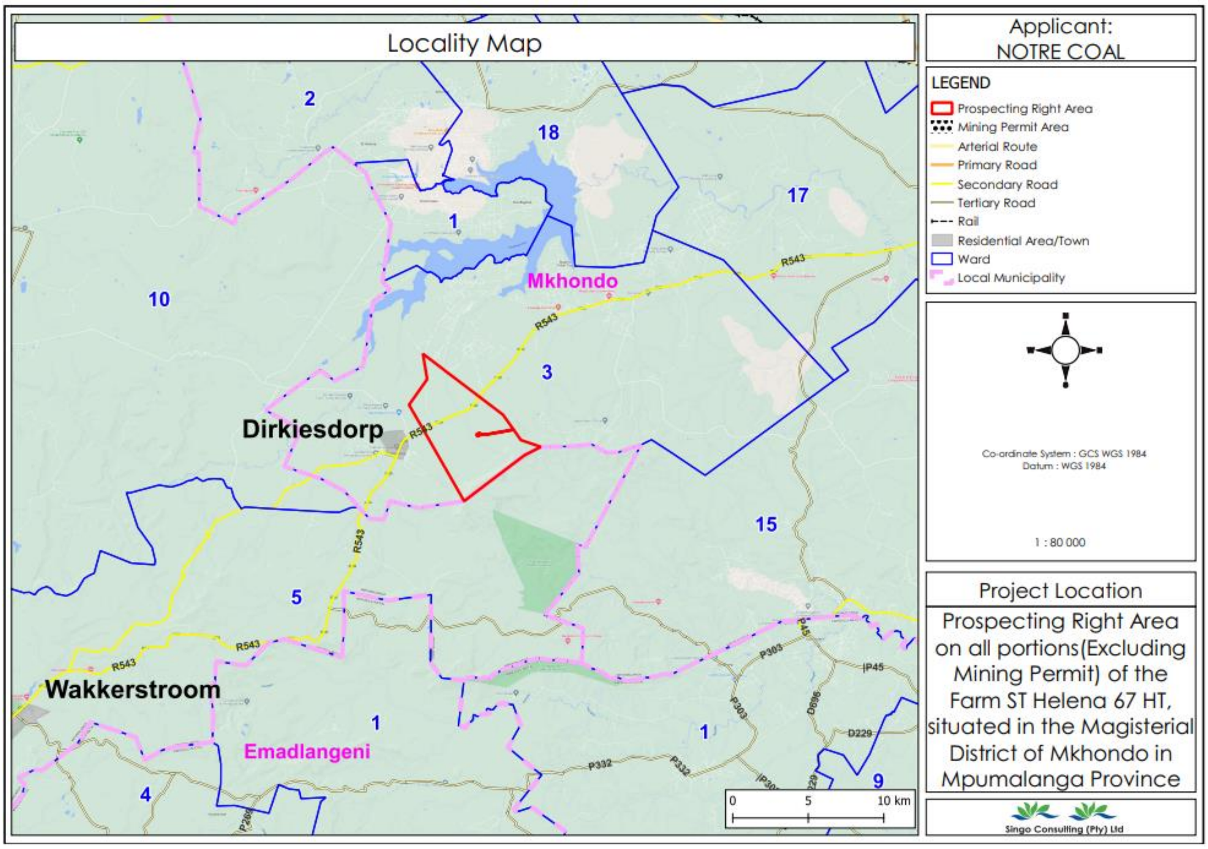

Figure 3: Locality Map of the Study area

4.2 Climate

Climate is the state of the atmosphere over long time periods, such as over years, decades, centuries or greater and weather is defined as atmospheric conditions of an area over a short period of time (Naomi, 2004). Climate for the purpose of the study is chosen based on the fact that it does not change over a long period of time whereas weather conditions fluctuate more rapidly, and its data cannot be relied upon. The climate here is mild, and

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generally warm and temperate. According to Köppen and Geiger, this climate is classified as Cwb. In Mkhondo, the average annual temperature is 16.1 °C. About 954 mm of precipitation falls annually. Precipitation is the lowest in June, with an average of 12 mm. The greatest amount of precipitation occurs in December, with an average of 165 mm. The study area receives a mean annual rainfall of 600 to 800 mm in the middle while the northern and southern part receiver higher rainfall between 801 to 1000 mm. Furthermore, a smaller portion in the south receives higher rainfall greater than 1000 mm. the project area dominantly experiences mean minimum annual temperatures between 0 and 2 °C.

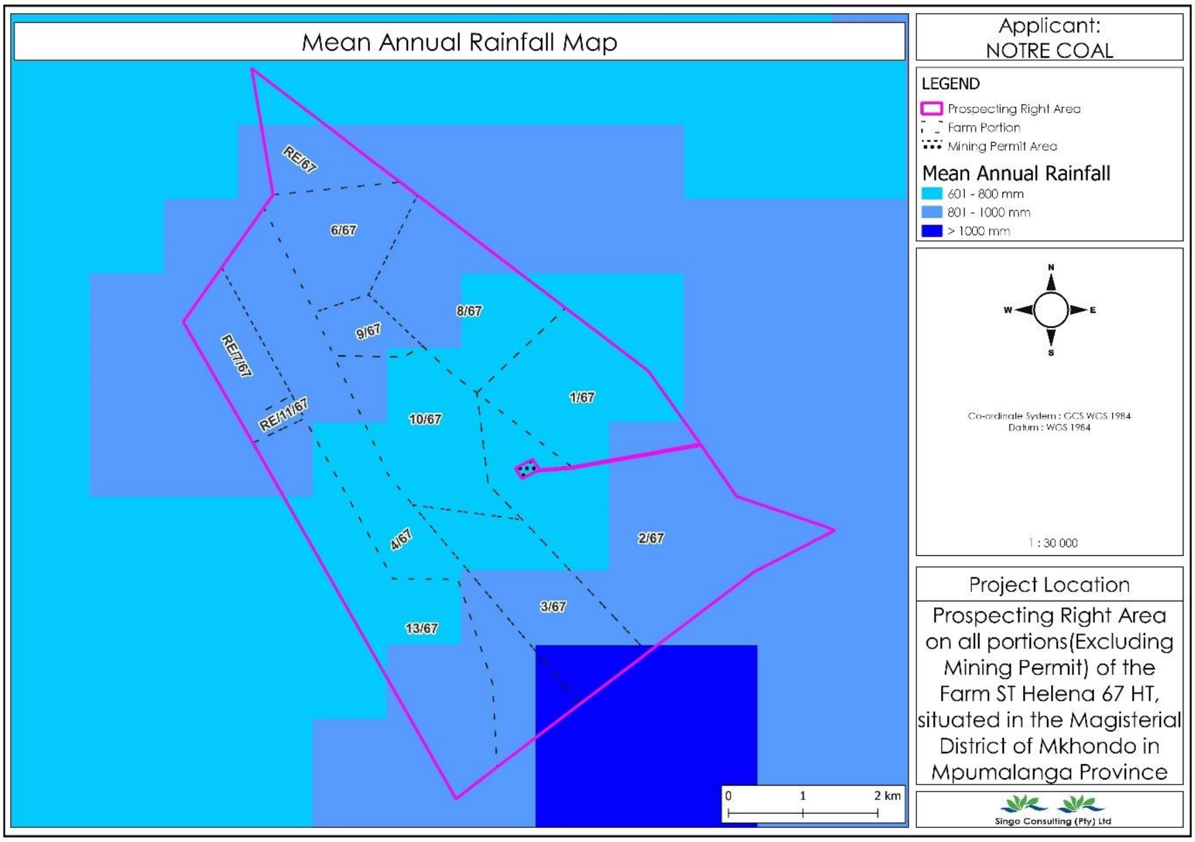

Figure 4: Mean annual rainfall

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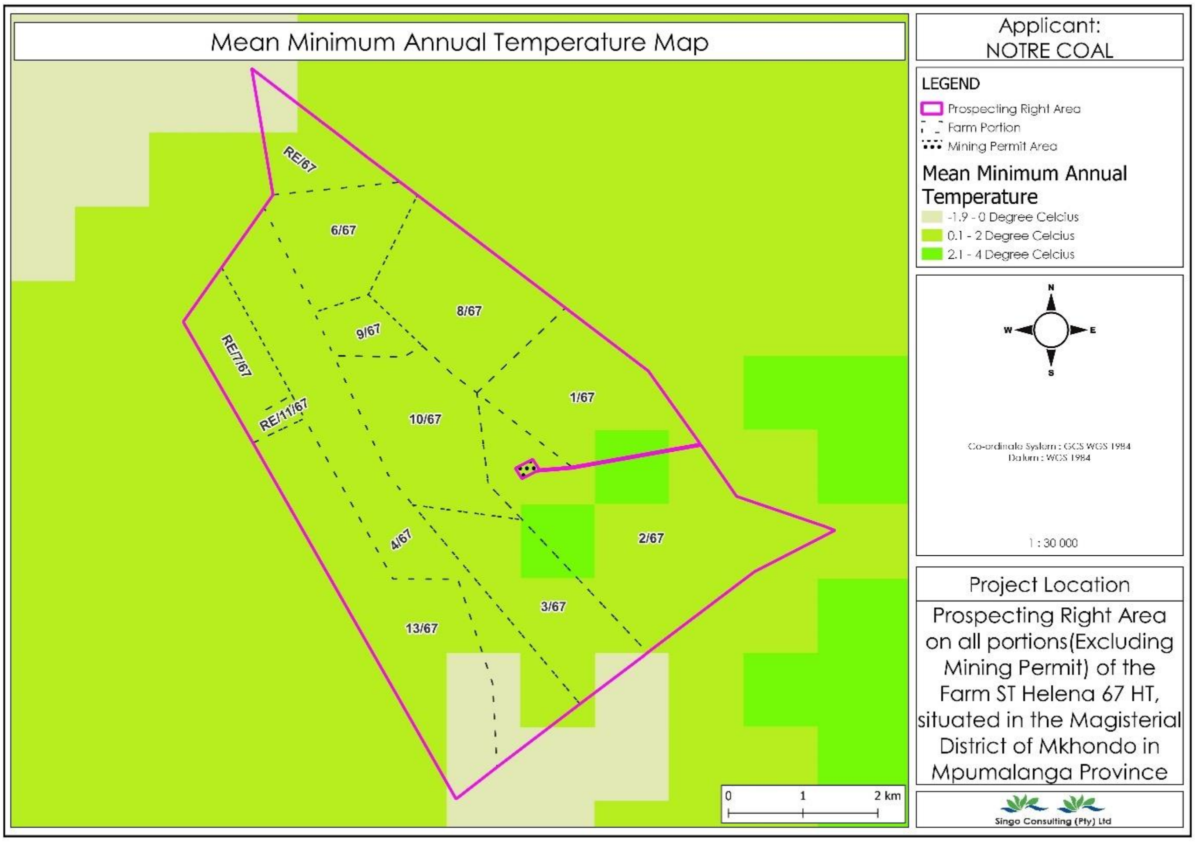

Figure 5: Mean minimum annual temperature map

4.3 Drainage and Topography

Topography is a field of geoscience and planetary science and is concerned with local detail in general, including not only relief but also natural and artificial features, and even local history and culture. The flow of water during rainy seasons flows from the area of high elevation to the area of low elevation.

The area is defined by a steep slope in the south to southeastern with gentler slope to the north. The southern part is characterised by several nonperennial rivers which may be recharging the main perennial river in the north. Considering the geomorphology of the area, groundwater recharge is more likely to in the northern section of the study area.

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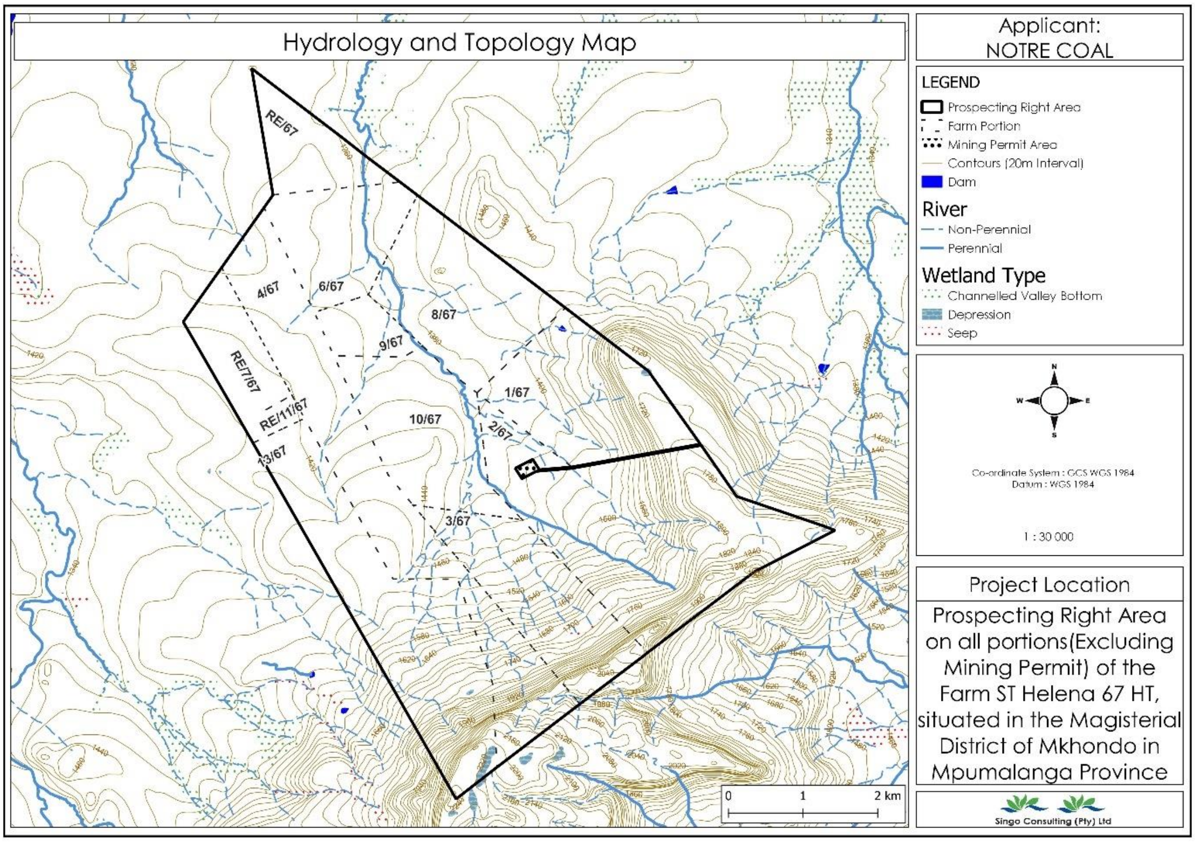

Figure 6: Hydrology and topology map

Figure 7: Photographs showing the topography and hydrology of the study area

There will be procedures and guidelines put in place for this project to avoid the risk of water contamination through onsite and nearby water resources, such as ensuring strict management of waste material and buffering of 100 m. It will be advised on more mitigation measures to ensure the waterbodies as seen on the hydrology map are not contaminated. As shown in Figure *8*, a 100m buffer will be applied around the water bodies present within the prospecting right area.

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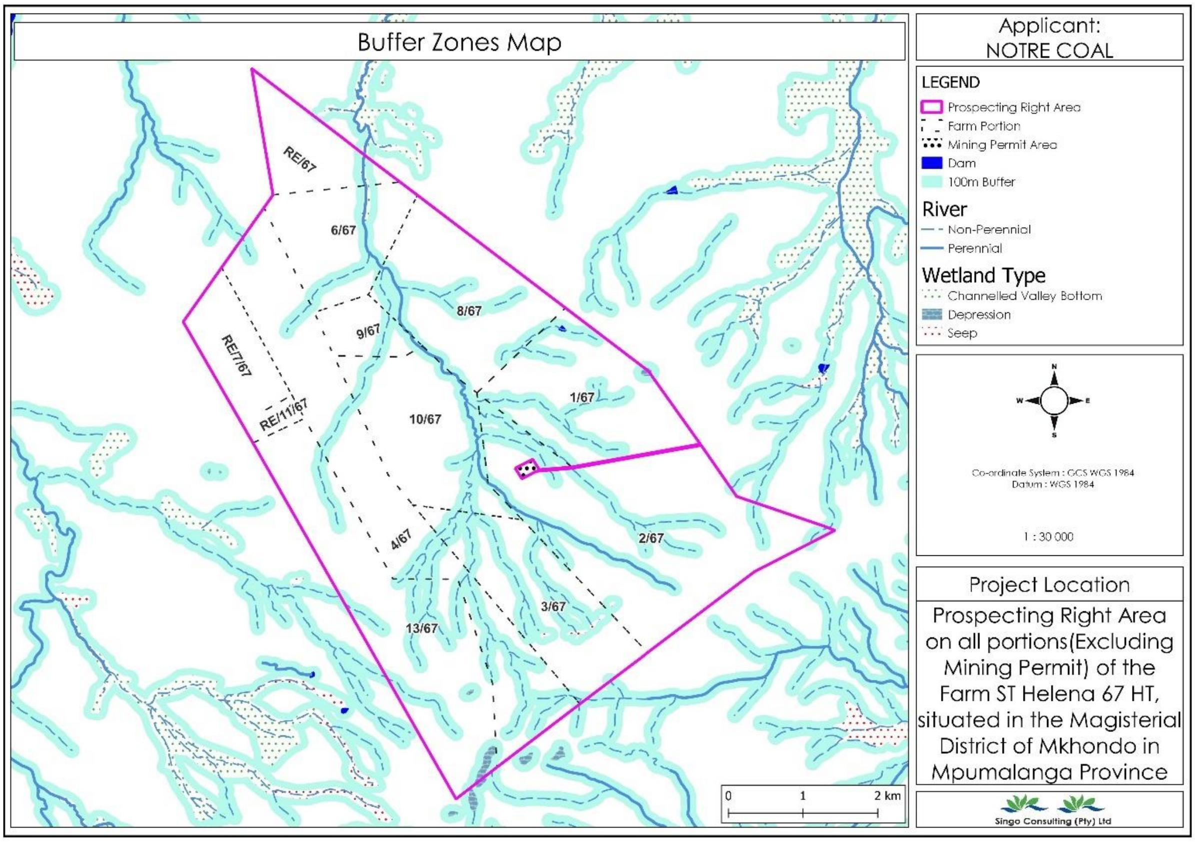

Figure 8: Buffer map of water bodies onsite

4.4 Catchment Information

South Africa's water resources are divided into quaternary catchments, which are the country's primary water management units (DWAF 2011). In a hierarchical classification system, a quaternary catchment is a fourth order catchment below the primary catchments. The primary drainages are further classified as Water Management Areas (WMA) and Catchment Management Agencies (CMA). In accordance with Section 5 subsection 5(1) of the National Water Act, 1998, the Department of Water and Sanitation (DWS) has established nine WMAs and nine CMAs as outlined in the National Water Resource Strategy 2 (2013). (Act No. 36 of 1998). The purpose of establishing these WMAs and CMAs is to improve water governance in various regions of the country, ensuring a fair and equal distribution of the Nation's water resources while ensuring resource quality is maintained.

The prospecting area falls within the Inkomati-Usuthu and Phongola-Mtamvuna Water Management Area (WMA). The quaternary catchments are W51B and W42 C. The WRC 2012 study, presents hydrological parameters for each quaternary catchment including area, mean annual precipitation (MAP) and mean annual runoff (MAR).

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Table 3: Quaternary Information Data

Quaternary Catchment	Water Management Area	Catchment Area	S-Pan Evaporation		Rainfall	
			Evaporation Zone	MAE (mm)	Rainfall Zone	MAP (mm)
W51B	Inkomati-Usuthu	417	13A	1400	W4B	939
W42C	Phongola-Mtamvuna	496	13A	1400	W5A	864

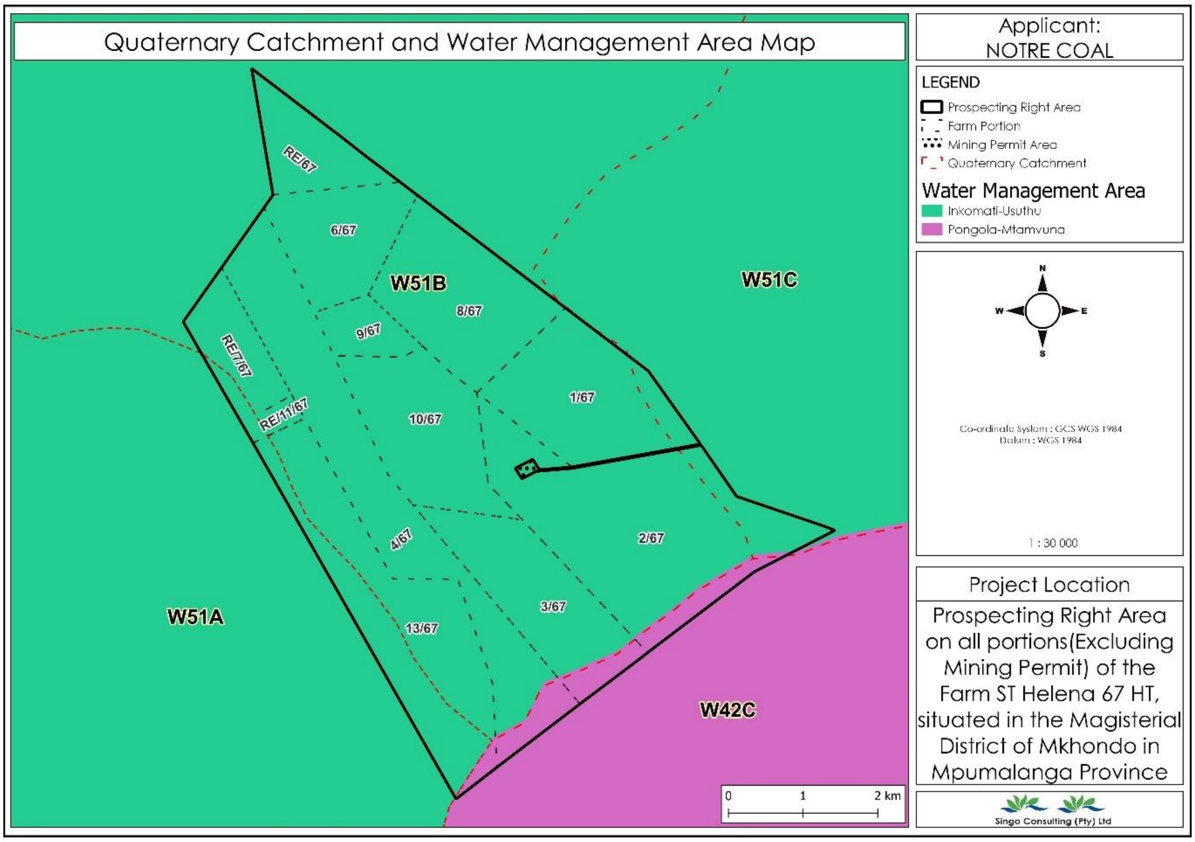

Figure 9: Quaternary Catchment of the study area

4.5 Geology

4.5.1 Regional Geology

Karoo Supergroup

In general, the coal deposits in South Africa are hosted in the Karoo Supergroup. The main Karoo Supergroup basin covers over 50% of South Africa's surface and consists of five age-based groups, which show a change of depositional environment in time. These groups are the Dwyka (glacial), Ecca (shallow marine and coastal plain), Beaufort (non-marine fluvial), Stormberg (aeolian) and the volcanic Lebombo or Drakensberg groups (Johnson et al., 2006). The proposed project area falls within the Ermelo coalfield. Sediments of Vryheid and Dwyka formations underlay the area which was deposited on a glaciated Pre-Karoo basement consisting of Rooiberg felsites. The Vryheid formation is essentially an interbedded succession of sandstone with lesser gritstone, siltstone and mudstone, which contains five coal seams of the Ermelo coalfield.

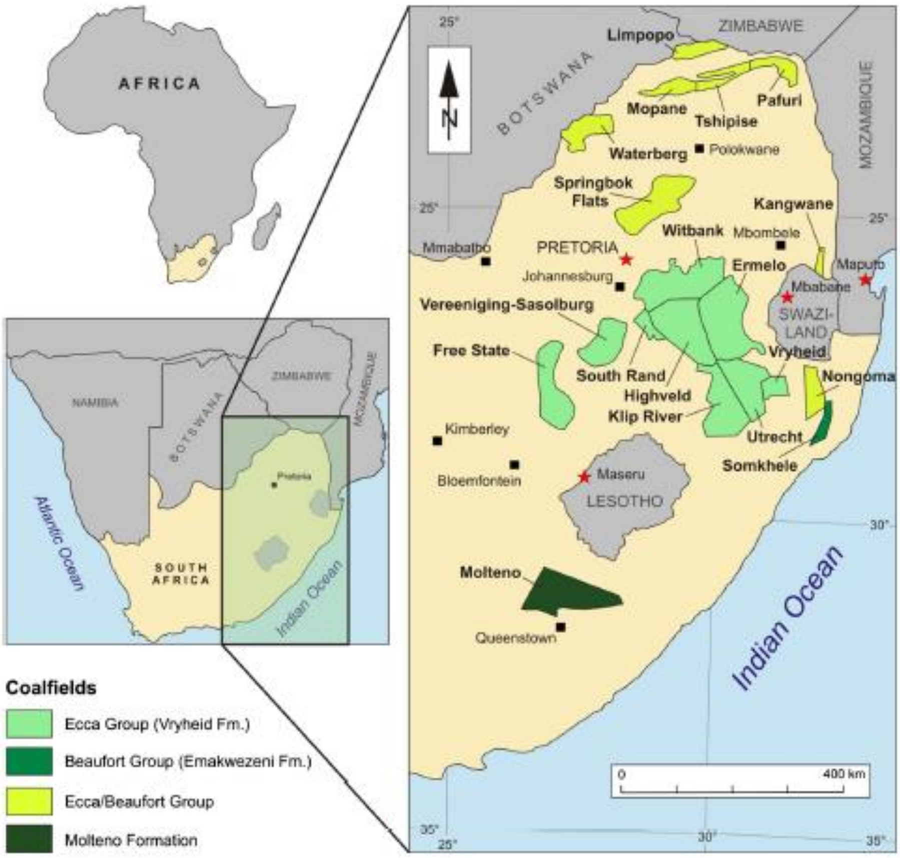

Figure 10: Coal field of South Africa (adopted from Hancox and Gotz, 2014)

Dwyka Group

At the commencement of the deposition of the Dwyka Group, it is thought that the development of the Karoo supergroup foreplay system had begun approximately 30 million years prior. The foreland system was caused by crustal uplift that had previously begun to take course due to the subduction of the Paleo-pacific plate beneath the Gondwana plate (Bejnar, 2012). The rocks of the Dwyka Group in South Africa are amongst the most important glaciogenic deposits from Gondwana. This Group is named for exposures along the Dwyka River east of Laingsburg and forms the basal succession of the Karoo Supergroup. Dwyka Group strata are mostly contained within bedrock valleys incised into Archean to lower Palaeozoic bedrock (Visser, 1990; Visser and Kingsley, 1982; Von Brunn, 1996).

The lithologies in the areas underlying the coalfields of South Africa consist of a heterolithic arrangement of massive and stratified polymictic diamictites, conglomerates, sandstones and dropstone-bearing varved mudstones. The easily identifiable lithologies form a good marker below the coal bearing Ecca Group. In the distal sector of the MKB these sedimentary strata accumulated largely as ground moraine associated with continental ice sheets and is generally composed of basal lodgement and supraglacial tills. These deposits are generally massive, but crude horizontal bedding occurs in places towards the top (Tankard et al., 1982).

Ecca Group

In the 1970s a number of studies (Cadle, 1974; Hobday, 1973, 1978; Mathew, 1974; Van Vuuren and Cole, 1979) showed that the Ecca Group could be subdivided into several informal units based on the cyclic nature of the sedimentary fills. In 1980 the South African Committee for Stratigraphy (SACS, 1980) introduced a formal lithostratigraphic nomenclature for the Ecca Group in the northern, distal sector of the MKB, which replaced the previously used informal Lower, Middle and Upper subdivisions with the Pietermaritzburg Shale Formation, the Vryheid Formation, and the Volksrust Shale Formation.

Local Geology

Vryheid Formation

This formation has been subdivided into three different lithofacies arrangements. They are dominated by fine-grained mudstone, carbonaceous shale with alternating layers of bituminous coal seams, and coarse-grained, bioturbated immature sandstones respectively. The rock sediments are predominantly arranged in upward-coarsening cycles, although

some fining-upward cycles are found in this formation's easternmost deposits. The alternating rock types observed in the Vryheid Formation indicate seasonal variations of storms and fairer weather in a pro-delta setting. The carbonaceous shales were formed below the water surface in anoxic conditions and the coal formed from compacted plant matter deposited at the bottom of peat swamps. These swamps formed on abandoned alluvial plains where stagnant water accumulated. The Vryheid Formation reaches a maximum of 1030m in Nongoma, KwaZulu-Natal, within the Nongoma Graben.

Diverse Glossopteris fossil coal floras are known from the Vryheid Formation, including their fertile organs and fruitifications, lycopods, rare ferns such as Asterotheca hammanskraalensis, horsetail species such as Annularia, cordaitales, conifers, ginkgoales, rare fossil wood, and diverse palynomorphs. Abundant, low diversity trace fossils, namely of Skolithos, Diplocraterion, Helminthopsis and planolites, rare insects, possible conchostracans, non-marine bivalves, and fish scales. The coal seams themselves are classified as compaction fossils. The majority of the economically extracted coal in South Africa occurs in rocks of the Vryheid Formation, which ranges in thickness in the MKB from less than 70.0 m to over 500.0 m. It is thickest to the south of the towns of Newcastle and Vryheid, where maximum subsidence took place (Du Toit, 1918; Cadle, 1975; Whateley, 1980a; Stavrakis, 1989; Cadle et al., 1982) and where the basin was the deepest.

Volksrust Formation

SACS (1980) applied the name Volksrust Shale Formation to the old "Upper Ecca Beds", with the choice of name based on a description given by Blignaut et al. (1952). The general thickness of the unit is between 150-250 m, and it is dominated by dark grey-green siltstones and mudstones, with phosphatic/carbonate/sideritic concretions. Cadle (1975) documents that the Volksrust Formation shows an overall coarsening-upward trend. Coals occur interbedded with the mudstones in places, The Volksrust Formation is postulated to have formed in shallow to deep water basinal conditions. Paleontologically the Volksrust Formation is probably best known for its low diversity trace fossil assemblage (Tavener-Smith et al., 1988) and various organic microfossils. Macrofaunal remains include only various insects (Van Dijk, 1981) and a rare bivalve assemblage (Cairncross et al., 2005). Plant remains and fossilised wood are also known.

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Karoo Dolerite Suite

The Karoo dolerite, which includes a wide range of petrological facies, consists of an interconnected network of dykes and sills and it is nearly impossible to single out any particular intrusive or tectonic event. It would, however, appear that a very large number of fractures were intruded simultaneously by magma and that the dolerite intrusive network acted as a shallow stockwork-like reservoir. Dolerite dykes, like many other magmatic intrusions, develop by rapid hydraulic fracturing via the propagation of a fluid-filled open fissure, resulting in a massive magmatic intrusion with a neat and transgressive contact with the country rock. This fracturing mechanism is in contrast to the slow mode of hydraulic fracturing responsible for breccia-intrusions (i.e., kimberlite). For the intrusion to develop the magma pressure at the tip of the fissure must overcome the tensile strength of the surrounding rock. Dykes can develop vertically upwards or laterally along-strike over very long distances, as long as the magma pressure at the tip of the fissure is maintained. The intrusion of dolerite and basaltic dykes are therefore never accompanied by brecciation, deformation or shearing of the host-rock, at least during their propagation. The average thickness of Karoo dolerite dykes ranges between 2 and 10m.

The country rock is often fractured during and after dyke emplacement. These fractures form a set of master joints parallel to its strike over a distance that does not vary greatly with the thickness of the dyke (between 5 and 15m). One of the most prominent features of the present Karoo landscape is the large number of dolerite sills and ring-complexes. These structures often display a subcircular saucer-like shape, the rims of which are commonly exposed as topographic highs and form ring-like outcrops. The Karoo dolerite sills and ring-complexes have the same geographical distribution as the dolerite dykes, and they are by far the most common type of intrusion in the Karoo basin. The dolerite sills and dykes form a complex intrusive network that probably acted as a shallow magma storage system. The lithology of the country-rock strongly controlled the emplacement of the sills.

Normandien Formation

The Normandien Formation comprises three sandstone members (lower Frankfort, Rooinek, upper Schoondraai) each overlain by an argillaceous interval. Two informal plant fossil assemblage zones are distinguished in the field: a "Christina assemblage zone" defined by Morphotype Pnc1, Morphotype Pnc2, Morphotype Pnc3 and Morphotype Pnc7, between

the Frankfort and Rooinek sandstones; a younger "Moorfield assemblage zone" between the Rooinek and Schoondraai sandstones, defined by Morphotype Pnm1, Morphotype Pnm2, Morphotype Pnm3, Rigbya arberioides and Sphenophyllum speciosum.

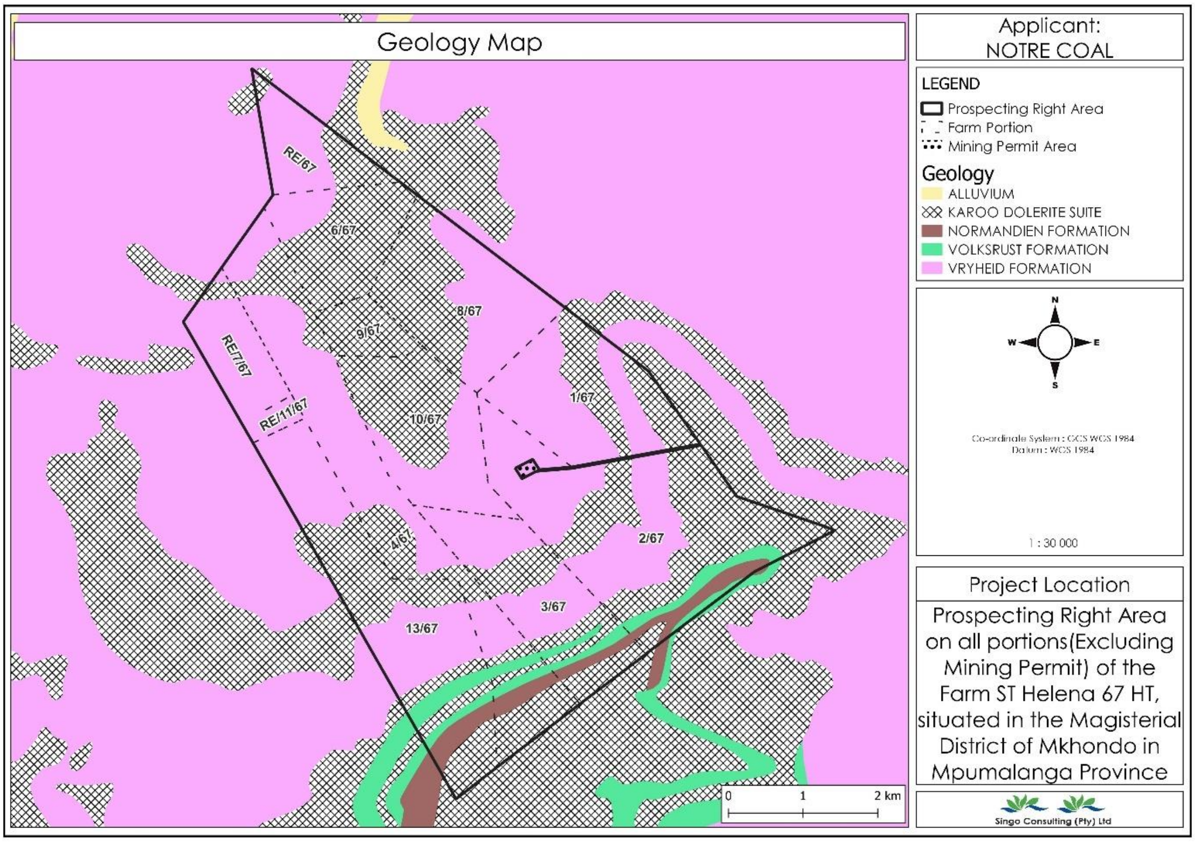

Figure 11: Geology map of the study area

5 GROUNDWATER INVESTIGATION

5.1 Hydrogeology

Typically, five distinct aquifer types:

- Basement (fractured Achaean-Proterozoic igneous/ metamorphic)
- Hard rock (e.g., Table Mountain TMG, Waterberg, and Natal Groups sandstone; fractured)
- Karst/ dolomite (dissolution)
- Karoo (fractured and influenced by dykes)
- Porous (intergranular Quaternary alluvial, coastal, Aeolian and other surficial unconsolidated deposits)

The study area falls under the Karoo (fractured and influenced by dykes). For effective borehole yields, the boreholes must target the fracture zones in this area.

Regional Groundwater Occurrence and Aquifers.

Based on the geology within the study area, the structural geology, and the geomorphology, the following conditions can arise to enhance aquifer development within the study area:

- The fractured transition zone between weathered and fresh bedrock
- Fractures along contact zones between the host rocks due to heating and cooling of rocks involved with the intrusions
- Contact zones between sedimentary rocks of different types
- Interbed or bedding plane fracturing
- Openings on discontinuities formed by fracturing
- Faulting due to tectonic forces
- Stratigraphic unconformities
- Zones of deeper weathering
- Fractures related to tensional and decompressional stresses due to off-loading of overlying material
- Groundwater occurs within the joints, bedding planes and along dolerite contacts. Groundwater potential is generally low in these rocks, with 87% of borehole yields < 3 l/s.

The lithology dolerite makes up the fractured aquifer. The pores of the geological units are generally strongly cemented, and fractured flow over secondary structures such as faults,

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bedding plane fractures, and so on is the primary flow mechanism. Due to the establishment of cooling joints, the intrusion of dolerite dykes and sills into the fractured aquifer has resulted in the formation of preferential flow routes along the contacts of these lithologies. The dykes may operate as permeable or semi-permeable barriers to prevent water from flowing across them.

5.2 Potential Contaminants

Because this activity will only take place for a brief period, the possible pollutants from prospecting are limited and can be easily handled. The following contaminants are expected to be of concern during the prospecting activity.

- Leakage of sewage waste into the soil and flowing to the nearby water resource.
- Hydrocarbon spill into the soil
- Water used as cooling agent of the drill bit
- Removal of the core, residual core might be left on the surface, during rainfall, there is more likely to be leaching.

5.3 Groundwater sources and sinks

Following the characterization of the aquifers, contaminant sources and groundwater receptors, the conceptual model was transformed into a numerical model so that the groundwater flow conditions, and mass transport can be solved numerically. A conceptual model is a simplified, but representative description of the groundwater system that illustrates the interaction of the sources, pathways, and receptors at the site.

The SPR conceptual model was first used in the field of environmental engineering in the late 1970"s to describe the flow of environmental pollutants from a source, through different pathways to potential receptors (Holdgate, 1979). Since then, the model has been used in several environmental risk assessments (e.g., Environment Agency, 2004, Scottish Government, 2010, Sneddon et al., 2009).

- The **sources** represent any entity that contributes to the groundwater quantity and/or quality
- The **pathways** are the aquifers through which the groundwater and contaminants migrate and

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- The **receptors** are humans, rivers or natural ecosystems that depend on the groundwater and will be impacted negatively if the water is depleted by dewatering or is contaminated.

5.4 Fieldwork/ Site Assessment

The field assessment is the most important aspect of the hydrogeological investigation, in that sense field observations are made.

5.4.1 Surface and Groundwater Quality

Surface water quality and groundwater quality is assessed by measuring parameters (Physical and Chemical), both in the field and laboratory.

<u>Site Measurements</u>

During site assessment, water bodies which were encountered within the study area and around the study area were sampled to understand the baseline information prior to the commencement of the prospecting project. The following precautions were taken during the sampling process.

- Latex gloves were worn during sampling, to prevent cross contamination between human sweat and water samples.
- The sampling/ measuring vessel was placed on a flat surface to stabilize the measuring probes.
- Field measurements such as temperature, pH and TDS were done immediately after taking the sample, this was to prevent their fluctuations as they change with locations, which could compromise the integrity of the results.

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Figure 12: Pictures showing of water sampling and onsite measurement of physical parameters

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6 AQUIFER CHARACTERIZATION

6.1 Groundwater vulnerability

Vulnerability of groundwater is a relative, non-measurable, dimensionless property (IAH, 1994). It is based on the concept that "some land areas are more vulnerable to groundwater contamination than others" (Vrba and Zaporozec 1994).

The main concerns in terms of possible groundwater contamination from the proposed prospecting activity are as follows:

- Heavy machinery on site. Spillages may occur which may impact both the soil and groundwater environment.
- During the prospecting phase, potential contamination may arise due to the drilling wastewater.

Because of the ensuing possibility of possible groundwater contamination from the sources or risks mentioned above, the aquifer's vulnerability is analysed. The following evaluation methodology was used to establish the aquifer's vulnerability to various pollution sources:

Method 1: Aquifer Vulnerability Rating (DRASTIC Method).

Method: 1 evaluates and rates seven key parameters within the hydrogeological setting to determine a final aquifer vulnerability rating.

Aquifer Vulnerability Rating (Drastic Method)

In the DRASTIC method, aquifer vulnerability is determined within hydrogeological settings by evaluating seven parameters denoted by the acronym:

- **D**epth to groundwater – Determined from DWA, GRA2 data, confirmed with a hydrocensus,
- **R**echarge – Obtained from DWA, GRA2 data
- **A**quifer media – Determined from geological maps and test pit profiles
- **S**oil media – Determined from test pit profiles
- **T**opography – Determined by digital elevation data
- **I**mpact on vadose zone – Determined from geological maps and test pit profiles
- Hydraulic **C**onductivity – Protocol to Manage the Potential of Groundwater Contamination form on-site Sanitation (DWAF, 1997).

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Each of the parameters is weighted according to its relative importance. The DRASTIC Index is determined by rating each parameter according to a set of tables, multiplying the assigned rating by the parameter weighting and summing the resulting products. The higher the DRASTIC Index; the higher the vulnerability to contamination.

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Table 4: DRASTIC model table rating for the aquifer underlying the study area.

Parameter	Effect	Rating 1	2	3	4	5	6	7	8	9	10	Weight	Site rating	Score
Depth to Water	Increasing depth to water increases time for natural attenuation or remediation of contaminant	> 33m	25 - 33m	17 - 25m		10 - 17m		5 - 10m		2 - 5m	0 - 2m	5	4	20
Recharge	Increasing recharge leads to faster movement of contaminant	0 - 10mm/a	10 - 25mm /a	25 - 37mm/a		37 - 50mm/a	50 - 75mm/a	75 - 110mm/a	110 - 160mm/a	160 - 200mm/a	>200mm/a	4	8	32
Aquifer Media	Increasing porosity increases movement of contaminants		Compact sedimentary rocks with widely spaced fractures	Igneous and/or crystalline metamorphic rocks: fractured	Igneous and/or crystalline metamorphic rocks: fractured and weathered	Compact sedimentary rocks: fractures directly below groundwater level		Compact sedimentary rocks: weathered and fractured	Massive dolomite / limestone. Sand and Gravel		Fractured dolomite / limestone with solution channels	3	4	12
Soil media (Drainage)	increasing soil drainage decreases time for natural attenuation or remediation		Clay loam and silty clay	Silty clay loam, sandy clay and silty loam	Sandy clay loam and loam	Sandy loam	Sandy loam	Shrinking and/or aggregate clay. Loamy sand	Sand. Shrinking and/or aggregate clay	Sand	Sand	2	4	8
Topography (%Slope)	increasing slope promotes runoff and decreases downward contaminant movement	> 18		12 to 18		6 to 12				2 to 7	0 - 2	1	10	10

Impact of the Vadose Zone	Increasing vadose zone conductivity decreases time for natural attenuation or remediation of contamination		Mainly compact tillite	Mainly compact tillite and shale. Lava and Intrusive	Mainly compact tillite, shale and sandstone. Assemblage of compact sedimentary strata, and extrusive and intrusive rocks	Compact sedimentary strata	Compact, dominantly arenaceous strata	Consolidated porous to compact sedimentary strata		Porous unconsolidated to semi consolidated sedimentary strata	Dolomite, chert, subordinate limestone	5	4	20
Hydraulic Conductivity	Increasing vadose zone conductivity decreases time for natural attenuation or remediation of contamination	0.03 - 0.69m	0.69 - 1.35m	1.35 - 2.02m	2.02 - 2.68m	2.68 - 3.34m	3.34 - 10m				>10m	2	10	20
Final Score														125

The vulnerability index score (DRASTIC index) for the site is 125. Below is a classification table indicating the class description for the index range.

Table 5: aquifer vulnerability table of the aquifer

Index Range	Class name
≤ 89	Very Low
90 – 105	Low
106 – 140	Medium
141 – 186	High
187 – 210	Very High
≥ 211	Extremely High

The aquifer vulnerability from possible pollution sources is classed as "Moderate". A moderate potential or likelihood for possible contaminated fluids originating from the site to reach the groundwater table exists. A moderate aquifer protection level is therefore recommended. As seen on Figure *13*: Aquifer Vulnerability of Nkomazi (Vegter & Seymour, 2012). the likelihood of groundwater contamination attributed to the material above the ground water table is classified as Moderate.

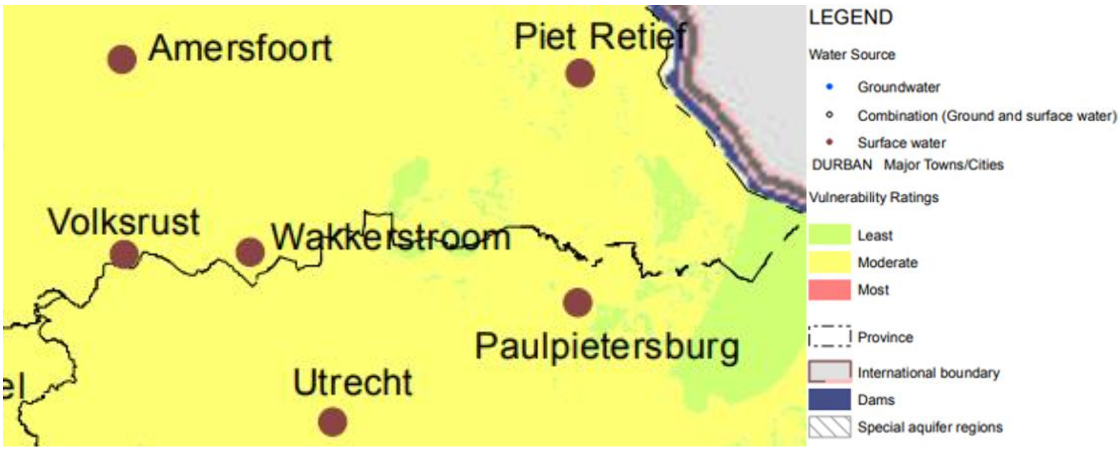

Figure 13: Aquifer Vulnerability of Nkomazi (Vegter & Seymour, 2012).

6.2 Aquifer classification

The Figure *14* below illustrates aquifer classification of different areas in South Africa. It can be deduced that the project area comprises of minor aquifers and the dominant water source is the surface water. **Error! Reference source not found.**Table 1 interprets the meaning of the a quifer classification and when an area is said to have minor aquifer it means that the aquifer is low yielding or unacceptable quality aquifer.

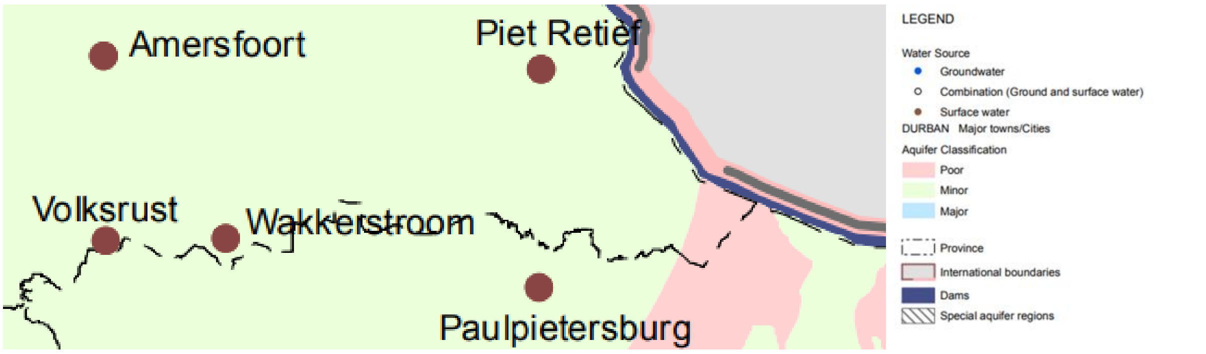

Figure 14: Aquifer Classification of the study area (Source: (Vegter & Seymour, 2012)).

Table 6: Aquifer characterisation

Sole source aquifer	An aquifer used to supply 50% or more of urban domestic water for a given area, for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major aquifer region	High-yielding aquifer of acceptable quality water.
Minor aquifer region	Moderately yielding aquifer of acceptable quality or high yielding aquifer of poor-quality water.
Poor aquifer region	Insignificantly yielding aquifer of good quality or moderately yielding aquifer of poor quality, or aquifer that will never be utilised for water supply and that will not contaminate other aquifers.

7 HYDROGEOLOGICAL IMPACT ASSESSMENT AND MANAGEMENT PLAN

7.1 Prospecting Phase Impacts

During the prospecting phase, the following impacts are envisioned:

- Clearing of vegetation leading to increased runoff and less infiltration.
- Diesel, oil and petrol spillages from the drill rig and site vehicles, and leaks from mobile toilets leads to soil contamination and water resource contamination (Groundwater and Surface water)
- Increase in volume of contaminated water that needs to be managed within the footprint.
- Increase in waste in the prospecting area (Metal and non-metal).
- Compaction of soil leading to increase in run-off, and decrease in infiltration, impacting groundwater quantity.

7.2 Management Measures

- All spillages will need to be cleaned up as soon as practically possible
- All equipment utilizing hydrocarbons will be stored on a hard-standing surface.
- Little to no machinery and vehicle repairs onsite, this could lead to hydrocarbon spills.
- Regular maintenance of the mobile toilets.
- Immediate clearing of the cores to avoid possible leaching.
- Drilled areas will be rehabilitated immediately once done.
- Availability of waste management bins around the prospecting area, for metals and non-metal waste.
- Prohibition signs will be placed at various location around the prospecting area.

Table 7: Mitigation Measures proposed for the prospecting phase

A	B

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7.3 Impact assessment and mitigation measures table

Table 8: Prospecting impacts and mitigation measures

CAUSE/ SOURCE OF THE IMPACT	RECOMMENDED MEASURES/REMARKS FOR MITIGATION	IMPACT RISK BEFORE MITIGATION	IMPACT RISK AFTER MITIGATION	RESPONSIBLE PERSON(S)	WHEN MITIGATION SHOULD BE IMPLEMENTED	POTENTIAL IMPACT/ EFFECTS
Oil, petrol, and diesel due to drill rigs, trucks, and cars.	➢ Diesel, petrol, and oil spill absorbent material available onsite. ➢ No machinery repairs onsite. ➢ Vehicle condition checklist available. ➢ No storage of diesel, oil, and petrol onsite.			➢ The project management team	Before and during the prospecting activities commence.	➢ Respiratory illness. ➢ Risk of cancer in humans. ➢ Reduce photosynthetic ability of plants.
Overflow of waste chamber and leakage of waste with toilet chemicals.	➢ Regular maintenance of the mobile toilets on site to avoid leakage and overflow.			➢ Toilets Hiring Company. ➢ Project management team	Throughout the prospecting phase, from when they start to when they finish.	➢ Biocides used are toxic can cause endocrine disrupting and reproductive effects if ingested.
Clearing of vegetation	➢ Rehabilitate the site by using a hoe to dig the			➢ The project management	After pegging and drilling	➢ Destroying local ecosystem.

leading to increased runoff and less infiltration.	compacted soil, this will allow infiltration.			team		➢ Decrease the availability of water in an area, Groundwater, and surface water.
Vehicles wash wastewater (VWW)	➢ No washing of Machinery or vehicles on site			The project management team	During prospecting period	➢ Harm surface water aquatic ecosystem. ➢ Degrade the quality of surface and groundwater quality. ➢ Muscle cramping or nausea.
Soil compaction during constructing gravel roads to access the site.	➢ Rehabilitate these roads by digging with tractors and ploughing vegetation			The project management team	After the prospecting phase	➢ Destruction of ecosystem. ➢ Increase run-off, decrease groundwater recharge.
Core logging	➢ The core logs of borehole should be cleared immediately after logging.			The project management team	After the prospecting phase	➢ Leaching of core logs into nearby wetlands (Seep and Valley bottom) and compromise water quality.
Disposal of waste	➢ There will be waste			The project	Before the	➢ Rust from metals causes

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such as metals E.g., Iron, around the prospecting area	management bins all around the site, to ensure there are no metals on the ground, or any other waste.			Management team	prospecting phase commences.	tetanus which affects nervous system. ➢ Degrades the quality of groundwater and surface water.

Low impact	Medium impact	High impact	Very high impact

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8 CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion and Summary

Singo Consulting (Pty) Ltd was appointed by Notre Coal (Pty) Ltd to conduct a basic Hydrogeological study in support of a prospecting right application for Farm ST Helena 67 HT, situated under the Mkhondo Magisterial District in Mpumalanga Province, South Africa. The primary concern is associated with hydrocarbon spillage, and reduction of infiltration due to clearing of vegetation in the prospecting area. The area falls on a minor aquifer, and the surrounding area mostly depends on surface water. The groundwater vulnerability according to the drastic model is classified as moderate, which implies that the aquifer requires moderate protection from the surface activity. The outlined groundwater management measures which include the availability of absorbent spill kits, regularly maintained of the mobile ablutions, and availability of the waste management bins. There should be compliance of the GN704 regulations, National waters Act No. 36 of 1998, NEMA Act 107 of 1998.

8.2. Recommendations

- On site there will be regular maintenance of the mobile toilets.
- Once drilling, the team will rehabilitate the area and ensure the core is out of site.
- Drilling within 100 meters of water resources should be avoided
- The drilling machine used should be of minimum vibrations to avoid creating fissures in underlying rocks which could influence groundwater migration and leads to water contamination
- Clearing of vast amount of vegetation will be avoided, this is to preserve infiltration.
- Constant availability of waste bins; Compliance of National Environmental Management: Waste Management Act 59 of 2008.
- Compliance of GN 704 4(b) and 7(a) and National Water Act 36 of 1998 (Chapter 3 – Part 4, Section 1 (a)(b).
- No onsite vehicle or machinery repairs such as changing oil.
- No onsite storage of oil, diesel, or petrol.
- Cores should be logged on an impervious surface and should be cleared from the site immediately after logging.

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APPENDICES

Appendix A: Specialist's qualifications available upon request

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