MATSOPA MINERALS (PTY) LTD

Geohydrological Assessment for Koppies Bentonite Mine

Report date: 15 March 2022

SHANGONI AquiScience

A division of Shangoni Management Services Pty Ltd

Project:	Geohydrological Impact Assessment
Title:	Geohydrological Assessment for Koppies Bentonite Mine
Client:	Cabanga Concepts for Matsopa Minerals Pty Ltd
Site:	Koppies Bentonite Mine
Location:	Koppies
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Report date:	15 March 2022

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DECLARATION OF INDEPENDANCE

I, Ockert F. Scholtz declare that

General declaration:

- I act as the independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application.
- I have no, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.

Signature of the specialist: Ockert F. Scholtz, *Pr.Sci.Nat*

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd

Name of company:

14 March 2022

Date:

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ABBREVIATIONS

Br	– Bromide
Ca	– Calcium
Cl	– Chloride
DWA	– Department of Water Affairs
DWAF	– Department of Water Affairs and Forestry
EC	– Electrical conductivity
EMP	– Environmental Management Programme
F	– Fluoride
Fe	– Iron
GAI	– Geochemical abundance indices
HCO_3^-	– Bicarbonate anion
K	– Potassium
l/s	– Litres per second
mamsl	– Meters above mean sea level
mbs	– Meters below surface
Mg	– Magnesium
mg/l	– Milligrams per litre
mm/a	– Millimetres per annum
Mm^3/a	– Million cubic meters per annum
meq/l	– Milli-equivalents per litre
Mn	– Manganese
N	– Nitrogen
NGA	– National Groundwater Archive
NGDB	– National Groundwater Database
Na	– Sodium
NH_4-N	– Free and saline ammonia as nitrogen
NO_3-N	– Nitrate as nitrogen
NWA	– National Water Act
P	– Phosphorous
Pb	– Lead
PO_4-P	– Orthophosphate as phosphorous
SANAS	– South African National Accreditation System
SANS	– South African National Standards
SO_4	– Sulphate
T-Alk	–Total alkalinity
TCLP	– Toxicity characterisation leachate procedure
TDS	– Total dissolved solids
WMA	– Water Management Area
XRD	– X-ray diffraction

XRF – X-ray fluorescence

1. INTRODUCTION AND BACKGROUND

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd, was appointed by Cabanga Concepts cc, to conduct a geohydrological assessment for Koppies Bentonite Mine located near the town of Koppies in the Free State Province. The Koppies bentonite deposits on the farm Oceaan and Blaauwboshpoort have been mined by G&W Base and Industrial Minerals (Pty) Ltd (G&W) since the early 1960's. Matsopa Minerals (Pty) Ltd (Matsopa), a subsidiary of G&W, is currently mining the bentonite clay in the Koppies region.

This geohydrological investigation forms part of the environmental impact assessment process. This is required to determine the potential contamination risk on the receiving groundwater environment resulting from the mining activities.

2. STUDY OBJECTIVE

The objectives of this assessment were to provide information on the status quo of the associated groundwater system, characterisation of the site and predict potential environmental impacts on the receiving groundwater environment posed by the mining activities. This included a hydrocensus to identify groundwater users and a review of water quality and geochemistry for status quo contamination or potential contaminants of concern.

3. SCOPE OF WORK AND TERMS OF REFERENCE

The scope of the project was to i) determine baseline geohydrological conditions; ii) assess probable water related impacts; and iii) propose management plans and monitoring protocols to pro-actively manage and assess all potential water related impacts. The following was concluded:

- Hydrocensus (2 km radius);
- Desktop geohydrological investigation (aquifer classification, aquifer characterisation, aquifer vulnerability, aquifer types, flow pathways & gradients and local geology).
- Groundwater quality analyses; and
- Identification of sensitive groundwater users.
- High-level identification of risk.

4. METHODOLOGY

To meet the aims and objectives for the current project, the following phases were completed.

4.1 Phase 1: Desk study

i) Desk study and review of historical groundwater baseline information, specialist reports as well as DWS supported groundwater databases i.e. National Groundwater Archive (NGA) and National Groundwater Database (NGDB).

4.2 Phase 2: Hydrogeological baseline investigation and site characterisation

i. Site visit and hydrocensus user survey to evaluate and verify existing surface and groundwater uses, local and neighbouring borehole locations and depths, spring localities and seepage zones, regional water levels, abstraction volumes, groundwater application as well as environmental receptors in the vicinity of the proposed development.
ii. Sampling of existing boreholes according to best practise guidelines including laboratory analysis of samples to determine the background and baseline macro and micro inorganic chemistry (analyses at SANAS accredited laboratory).

4.3 Reporting, risk assessment and monitoring framework

i. Consolidation of findings regarding the following:
   a. Combine and interpret available topographical, geohydrological and related information.
   b. Baseline description of geohydrology for the study area.
   c. Assessment of contaminants of concern and sources of pollution.
   d. Development of a conceptual geohydrological model for the project area.
   e. Identify potential impacts.

5. MINING METHOD AND DESCRIPTION

The Ocean and Blaauwboshpoort ore bodies are mined by opencast methods. One pit exists on the Ocean Section, while three sections, namely “A”, “B” and “C” exist on the Bloubospoort Section of the mine. The mineral processing consists of a screening, mixing and drying facility. For the processing of Calcium Bentonite, no water is added but for the Sodium Bentonite we add water because it has low moisture content, which assists with the activation of soda ash. and can be summarised as follows (EMP, 2012):
The mineral processing consists of a screening, mixing and drying facility and can be summarised as follows (EMP, 2012):
The mineral processing consists of a screening, mixing and drying facility and can be summarised as follows:

- A front-end loader transports the crude to the feed bin and the soda ash gets transported to the plant in 1 Ton bulk bags with the forklift.
- A conveyor belt transfers the product from the storage bin past the soda ash feeder, where soda ash is added to the crude, and then to the mixer where it is mixed. Water is added to the process only when Mozambique bentonite is mixed.
- Bentonite gets drawn from the storage bin, soda ash is added on the material while being transported via conveyor belt into the mixers where it is mixed for 6min then discharged into the intermediate bin then fed into the rotary kiln where it is dried.
- After drying it is stockpiled outside the plant until it is cooled down, it is then loaded with a front-end loader onto trucks and transported off site.

The mine has a water license to discharge the pit water, which they do at the beginning of each dry season before mining. No mining is undertaken in the wet season, only processing. During this time, water collects within the pits and needs to be discharged before the start of each dry season when mining re-commences.

6. GENERAL ENVIRONMENTAL SETTING

6.1 Location and setting

The Koppies Bentonite Mine is located at 27°36'E and 27°06'S in the Fezile Dabi District Municipality of the Free State Province, South Africa. The mine falls under the regional services council authority of the Northern Free State Regional Services Council. The Koppies Bentonite Mine lies approximately 14 km north-northeast of the town Koppies in the Free State Province.

The local and regional setting of the site is provided in Figure 1.

6.2 Climate

The area falls within the Climate Region H, namely the Highveld. The average annual precipitation in this region varies from 900 mm on its eastern border to about 650 mm in the west (EMP, 2012). The Koppies Bentonite Mine is situated close to the western boundary of this region. The rainfall occurs almost exclusively as showers and thunderstorms that fall mainly in summer, from October to March. The maximum fall occurs during January. Approximately 85% of the annual rainfall falls in the summer months, while winter months are normally dry. Heavy falls of 125 mm to 150 mm occasionally fall in a single day (South African Weather Bureau, 1979). These thunderstorms are often violent with severe lightning and strong (but short-lived) gusty south-westerly winds and are sometimes accompanied by hail. About four to seven occurrences of hail may be expected annually at any one point.

The average daily maximum temperatures for the Highveld Climatic Region is 27°C in January and 17°C in July, but in extreme cases temperatures may rise to 38°C and 26°C, respectively. Average daily minimum temperatures range from 13°C in January to 0°C in July, whereas extremes can sink to 1°C and -13°C, respectively. The period during which frost is likely to form lasts on the average for about 120 days from May to September (South African Weather Bureau, 1979). Winds are mostly light, except for short periods of intense winds during thunderstorms. Very occasionally, tornadoes do occur and cause tremendous damage if they happen to strike a populated area (South African Weather Bureau 1979). Sunshine duration within the Highveld Climate Region is about 60% in summer and about 80% in winter of the possible sunshine hours (EMP, 2012).

The mean annual rainfall is 476.97 mm. There are on average approximately 80 rain days per annum. The 24-hour maximum recorded rainfall is 81.8 mm, recorded in January 2010 (EMP, 2012).

Koppies Bentonite Mine Location

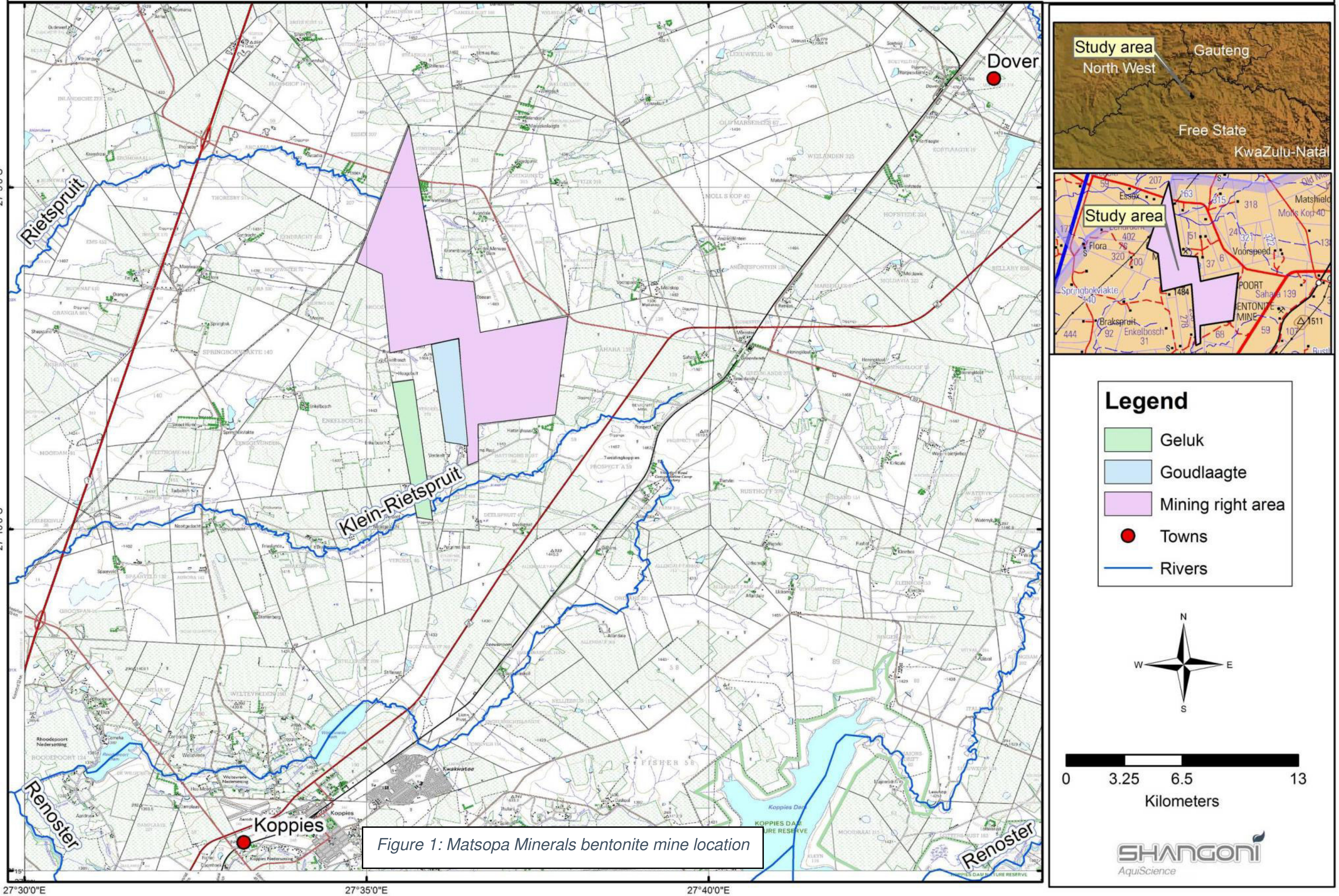

Figure 1: Matsopa Minerals bentonite mine location

6.3 Topography and drainage

The project area and surroundings are flat with a gentle gradient of 1:300. The area is part of the slightly undulating plains category of the Terrain Morphological Class. The relief of the site itself is approximately between 1420- and 1480 mamsl (meters above mean sea level).

The mining right area is located on a SW-NE surface water divide with a hight of approximately 1480. Surface water is directed from this divide and flow occurs towards the major drainage lines to the north-west and towards the south (Figure 2).

6.4 Catchment and groundwater use

The mine is in the C70E quaternary catchment of South Africa (Figure 3). The main rivers in the catchment are Rietspruit and Klein Rietspruit. Both originates near and slightly east of the mine and meander west where they confluence approximately 20 km west. The Rietspruit flows further west where it confluences with the Renosterspruit - a major tributary of the Vaal River.

The drainage systems are part of the Middle Vaal Water Management Area (WMA). The Middle Vaal WMA is located downstream of the confluence of the Vaal and the Rietspruit Rivers and upstream of Bloemhof Dam. It extends to the headwaters of the Schoonspruit River in the north and the Vet River in the south, covering a total catchment area of 52 563 km^2. The Middle Vaal WMA includes parts of Free State and North-West provinces.

The Vaal River is probably the most developed and regulated river in Southern Africa, while some of the largest dams in Africa have been built in Lesotho and on the main stem of the Orange River. Although linked together by the natural watercourses, a particular characteristic of the Orange/Vaal WMAs is the extensive inter-catchment transfer of water within WMAs as well as interbasin transfers between these and other adjoining WMAs.

Table 1 provides additional water management information pertaining to the catchment.

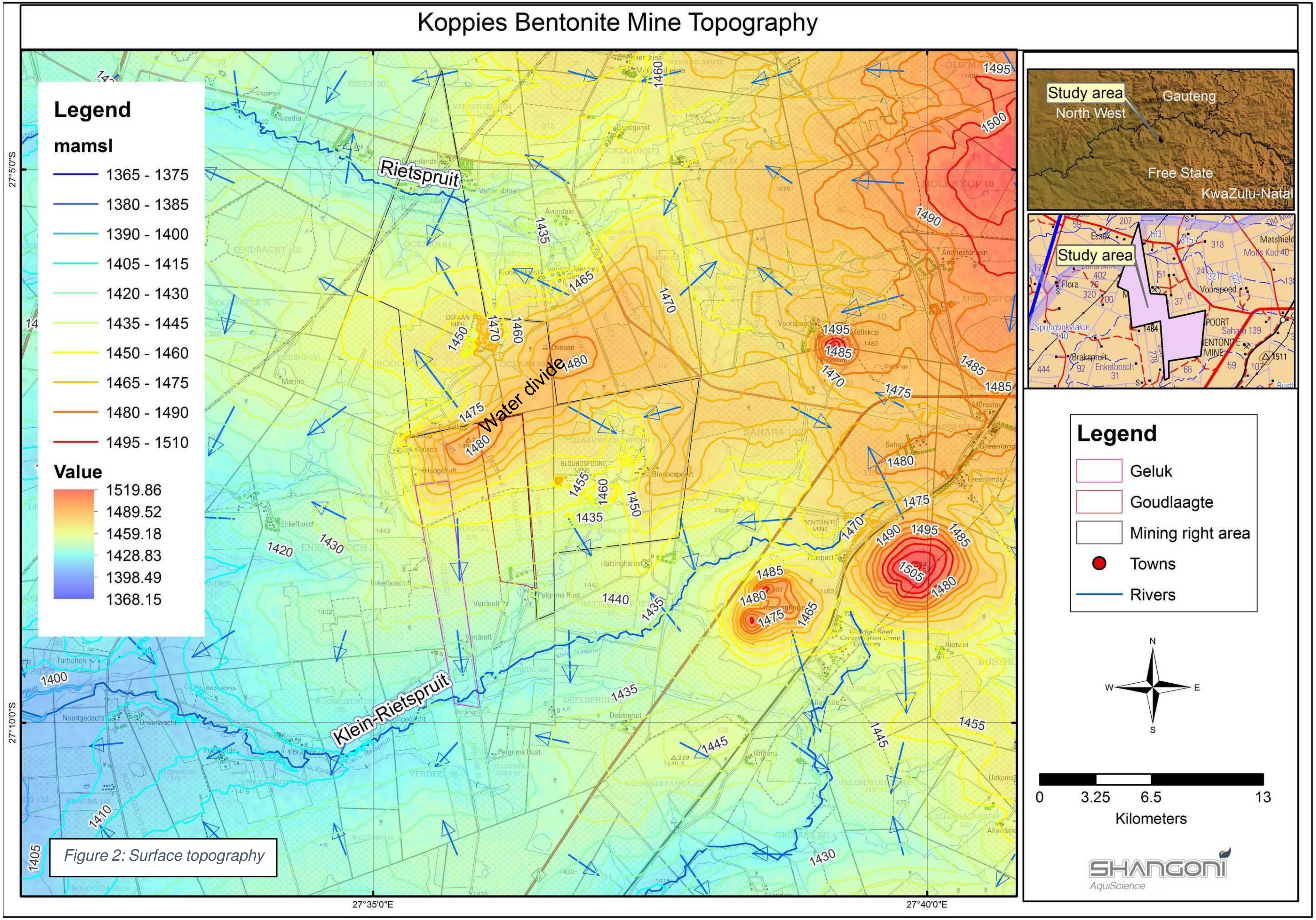

Figure 2: Surface topography

Koppies Bentonite Mine Quaternary Catchment

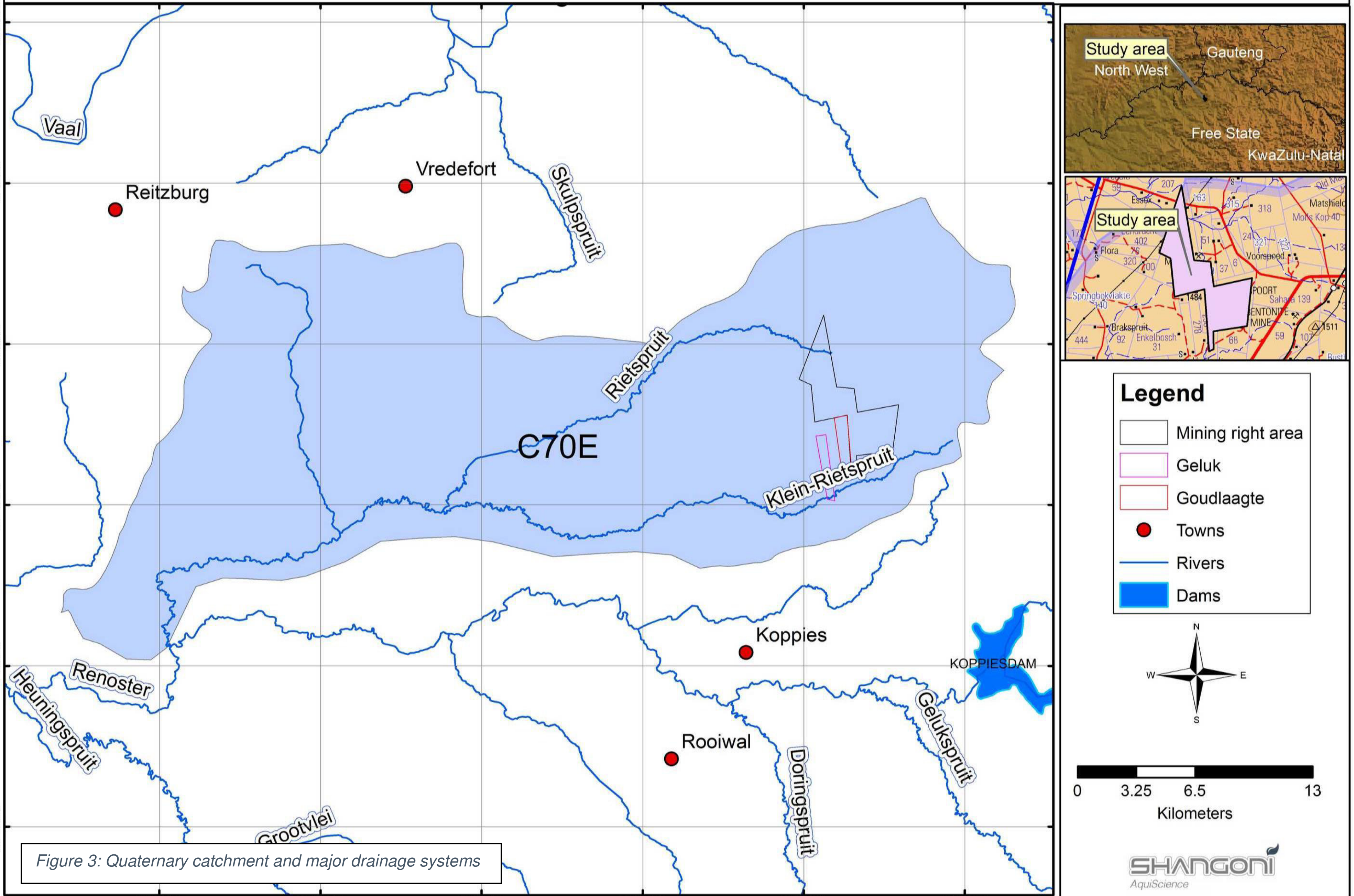

Figure 3: Quaternary catchment and major drainage systems

Table 1: Quaternary catchment information (WR,2012)

Attribute/Catchment	C70E
Quaternary catchment area (km^2)	629
Rainfall zone	C7B
Mean annual rainfall (mm/a)	578
Mean annual runoff (mm/a)	32
Baseflow (mm/a)	3
Mean S-Pan annual evaporation (mm/a)	1630
Total groundwater use (Mm^3/a)	7.83
Ecoregion	Highveld
Present Eco Status Category	B*
Recharge (mm/a)	28
Exploitation potential (Mm^3/a)	6
Vegetation type	Moist Cool Highveld Grassland
Soil	Sandy-clay loam-Sandy clay (SaClLm-SaCl)
Groundwater General Authorization $m^3/ha/a$	75

* Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged. (Kleynhans, 1996 & Kleynhans and Louw, 2007).

Total groundwater use in the Middle Vaal Water Management Area is approximately 7.834 Mm^3/a, of which rural (70%) is the greatest user in the catchment (Table 2). This is followed by agriculture, including livestock use (17%) and irrigation (11%).

In the C70E catchment livestock is the greatest user (~100%) (Table 2; Figures 4 & 5).

Table 2: Total groundwater use in the Upper Vaal Water Management Area and quaternary catchment C70E (WR, 2012)

Type of use	Upper Vaal	C70E
	Value (Mm^3/a)	
Total	~7.834	~0.2479
Rural	5.451	0
Municipality	0.1002	0
Agriculture	0.8899	0
Livestock	1.3674	0.2479
Mining	0.0025	0
Industrial	0.023	0
Aquatic	0	0

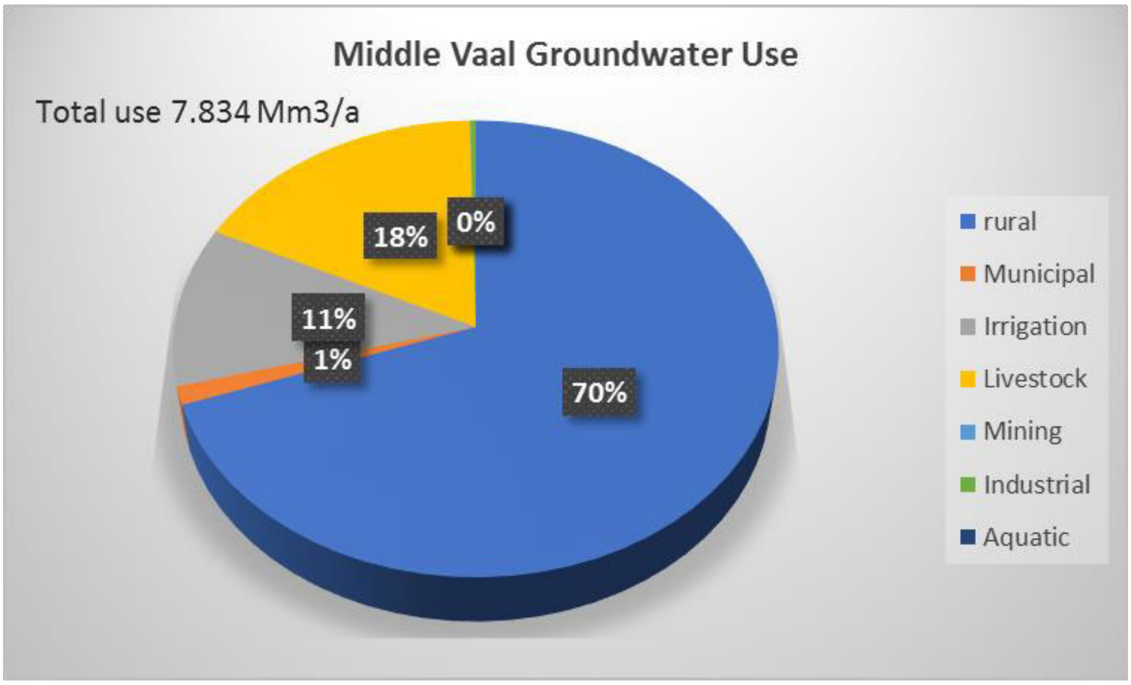

Figure 4: Groundwater use in the Middle Vaal Water Management Area

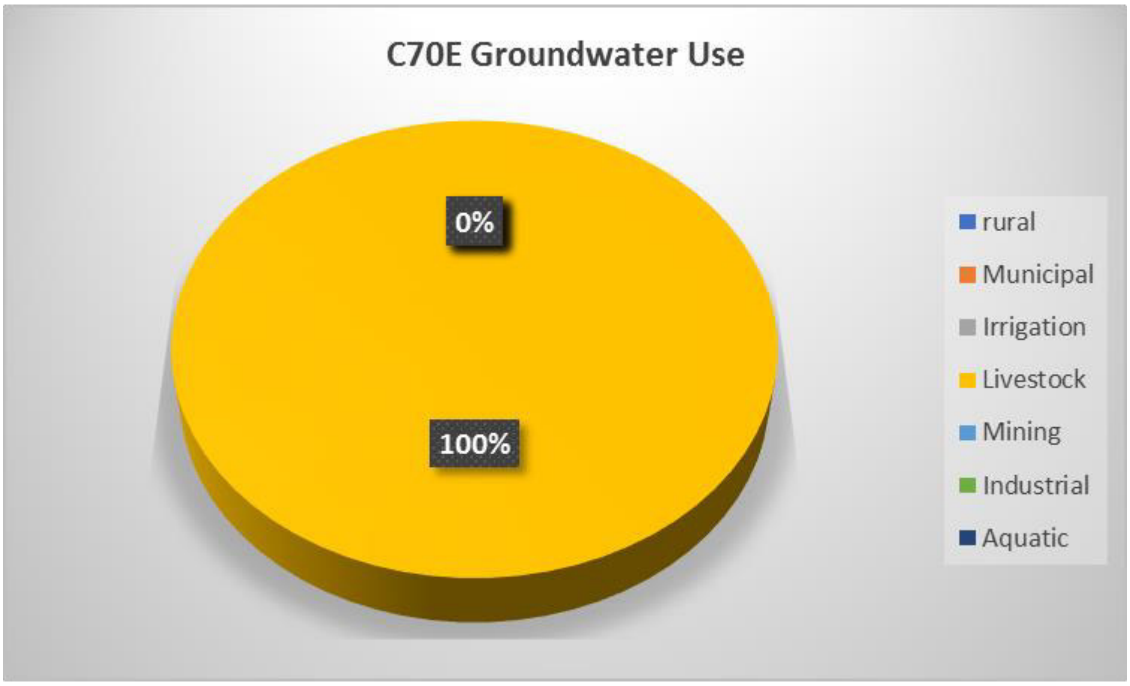

Figure 5: Groundwater use in the C70E Quaternary Catchment

6.5 Geology

6.5.1 Local and regional geology

The Koppies bentonite deposits occur in the Ecca Sediments (Volksrust Formation) of the Ecca Group and Karoo Supergroup comprising mostly of mudstone, siltstone and shale (Figure 6).

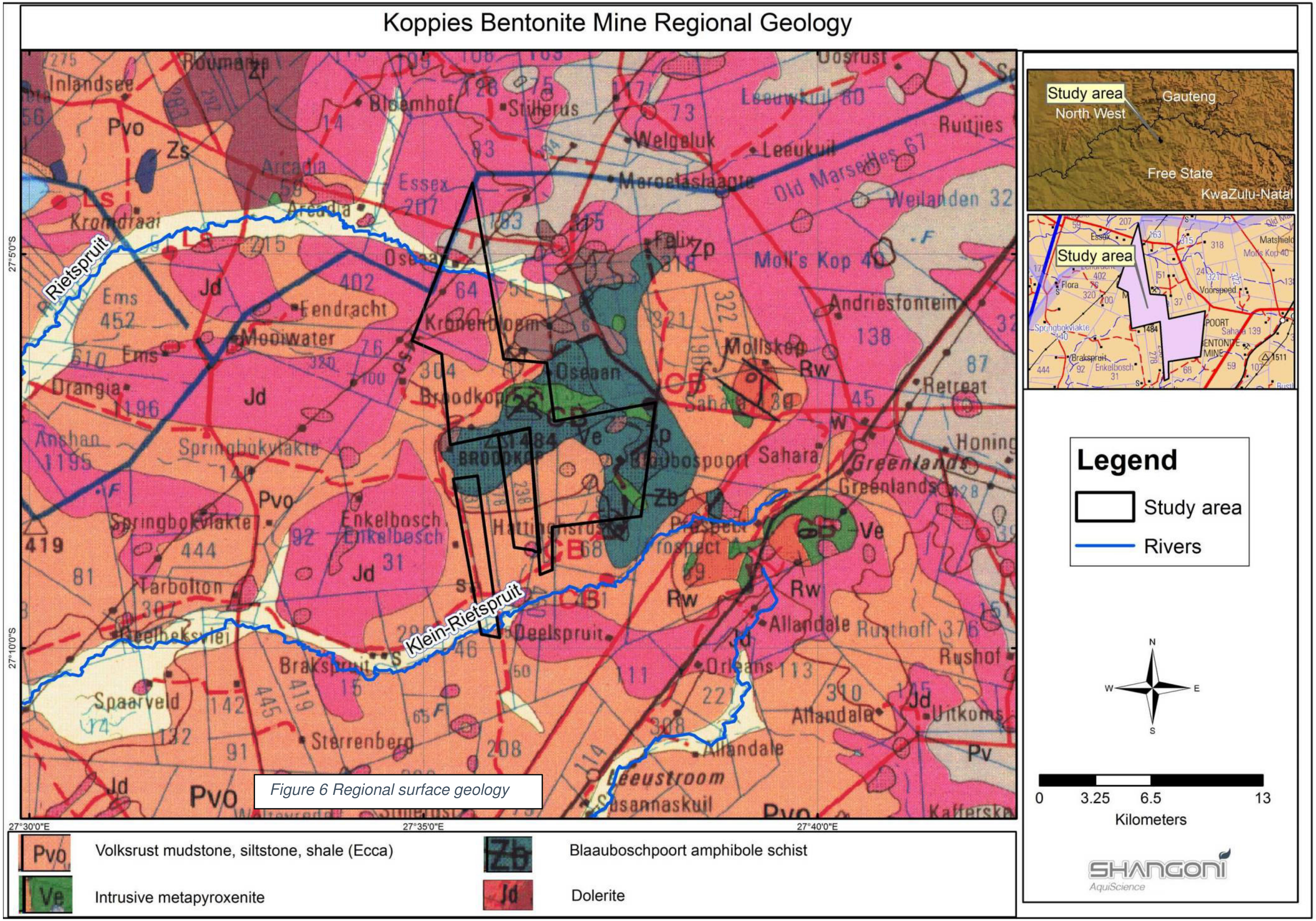

Figure 6 Regional surface geology

Beneath the Volksrust beds are the older formations of the Ecca Group, including the important and coal rich Vryheid Formation. The lower Vryheid Formation is mainly arenaceous while the overlying Volksrust Formation is predominantly argillaceous in nature.

The area is blanketed by deep sandy loam and even clayey soils derived from in-situ decomposed mudstone and shale of the Volksrust Formation. The basement rocks comprise a greenstone suite extensively intruded by granite and associated pegmatite and quartz veins. Although various dolerite sills are present regionally, no major regional geological features such as dolerite dykes intersect the site on a local level.

6.6 Geohydrology

6.6.1 Unsaturated zone (vadose zone)

The characteristics of vadose zone vulnerability dominating factors are closely related to the migration and transformation mechanisms of contaminants in the vadose zone, which directly affect the state of the contaminants percolating to the groundwater. The permeability and thickness of the unsaturated zone are some of the main factors determining the infiltration rate, the amount of runoff and consequently the effective recharge percentage of rainfall to the aquifer. The type of material forming the unsaturated zone as well as the permeability and texture will significantly influence the mass transport of surface contamination to the underlying aquifer(s). Factors like ion exchange, retardation, biodegradation and dispersion all play a role in the unsaturated zone.

6.6.2 Saturated zone

6.6.2.1 Weathered horizon

The weathered zone hosts the unconfined to semi-confined shallow weathered aquifer or hydro-stratigraphic zone. The zone is on average 10 – 15 m thick and water levels are often shallow (few meters below ground level). Due to direct rainfall recharge and dynamic groundwater flow through the unconfined aquifer in weathered sediments, the water quality is generally good, but also vulnerable to pollution. A weathered water bearing horizon is defined as groundwater saturated strata which possesses a secondary porosity associated with weathering of rock strata. The weathered water bearing horizon may or may not be hydraulically connected with the regional fractured water bearing horizon, depending on the presence, thickness and weathering of confining layers (typically horizontal sills or shale layers). Water intersections in the weathered aquifer are mostly above or at the interface of fresh bedrock, where less permeable layers of weathering products and capillary forces limit the vertical percolation of water and promote lateral water movement. Groundwater at places daylights as springs (contact springs) where the flow path is obstructed by impermeable layers or where the surface topography cuts into the groundwater level at e.g. drainage lines (free draining springs).

The weathered horizon is typically not regarded as good aquifers but suitable for household supply, with yields ranging between 0.1 and 1.0 l/s but typically less than 0.5 l/s. Where the weathered aquifer does become significant is from a pollution transport and vulnerability perspective.

6.6.2.2 Fractured horizon

The Volksrust argillaceous rocks underlying a large part of the study area are typical of a fractured water bearing horizon. It is defined as a groundwater saturated stratum displaying secondary porosity due to fracturing. Fractured horizons are common in sedimentary and shale host rock of the Karoo. The permeability within fresh matrix rocks (especially mudstones and shales) is extremely low and the matrix is not expected to allow any significant groundwater flow. Therefore, groundwater flow in the sedimentary rocks is expected only along weathered zones and fractures.

The fractured horizon is confined but may be semi-confining at places of extreme weathering. The aquifer depth extends to a depth of ±20-100 mbs with limited yields at depth, indicating the absence of major water bearing fractures and low permeability at levels between 80-100 mbs. The aquifer can be regarded as heterogeneous having a moderate fracture network formed in the consolidated and mostly impermeable Volksrust argillaceous rocks. Movement of groundwater is mostly restricted to fracture flow.

The fractured rock aquifer is a more reliable source of groundwater compared to the weathered zone aquifer. Typical characteristics of the regional fractured flow aquifer include:

- They are present as either confined or semi-confined aquifers. In the former instance, the aquifer is overlain by sediments or rock of a confining nature, thus limiting direct recharge from rainfall.
- Less weathering and fracturing are suspected in the argillaceous Volksrust Formation compared to the underlying and more competent arenaceous Vryheid Formation.
- Volksrust shales is reasonably impermeable and artesian conditions may be found in some boreholes.
- The natural aquifers in the regional area typically have a low hydraulic conductivity, but are known to be highly heterogeneous with yields ranging from 0.5 up to 5 l/s.
- Higher yields are typically associated with higher hydraulic conductivities along contact zones with intrusive rocks.
- Where present, the contact zones of dolerite dykes with the host rock provide preferential flow pathways, while the dolerite itself is rather impermeable. This setting promotes groundwater flow along, but not across dykes or sills.
- Depending on the residence time of water in the aquifer, groundwater quality is good to moderate.
- Recharge from rainfall is generally low and averages between 0.5 to 4% of the annual rainfall.
- Characteristics of the aquifer vary greatly over short distances.
- Contaminant transport through fracture flow aquifers is comparatively fast.
- There is hardly any attenuation of pollutants in fractures.

6.6.2.3 Pre-Karoo aquifer

The pre-Karoo rocks, consisting mainly of felsites of the Bushveld Igneous Complex, are present below the Dwyka group tillites/diamictite. At places, the Ecca Group rocks do, however, rest directly on the felsites and granites of the pre-Karoo Basement rocks. Groundwater is mostly present in very small and low yielding fractures. The pre-Karoo is considered not to be a reliable source of groundwater given its great depth, compactness of the host rock and inability to fracture, inferior quality associated with felsites and granites (mostly fluoride), and low recharge because of the overlying impermeable Dwyka tillite. However, reliable sources of groundwater may be encountered on bedding plane fractures or lithological contact zones.

6.6.2.4 Dolerite intrusions

The process of emplacement of dolerite bodies in host rock formations created zones of fracturing both in the host rock and in the dolerite itself. The zones of fracturing became a natural underground drainage system of groundwater stored in the weathered (fractured and intergranular rock). Deeper fractures are also created, but to a lesser extent.

The dolerite related zones of fracturing usually occur on both sides of the dolerite bodies and the subsequent weathering process enhanced their permeability, increasing the potential for larger yields compared to the host matrix.

Some sills are apparent on the 1: 250 000 Geological Map 2726 Kroonstad but no dykes.

7. FIELD INVESTIGATONS

7.1 Hydrocensus

A field hydrocensus was performed on and around the study area to try and locate groundwater users and baseline data. The survey was conducted between 7 and 22 February 2022. During the hydrocensus, all available and where possible details of boreholes and borehole-owners were collected and recorded. Where possible, information was collected on water use, water levels and yields of boreholes, etc. This information was used to assess the potential risk on the groundwater regime and users thereof. The following parameters (where available) were captured during the hydrocensus:

- XYZ Coordinates
- Existing equipment
- Current use
- Drill depth
- Static/dynamic water level
- Water quality
- Photograph

A total of 49 boreholes and 18 surface water localities were identified within a ~2-3 km radius from the mining right boundary. Hydrocensus information and locations relative to the site are shown in Table 3 and Figure 7.

The water levels taken range between 0.57- and 17.82 mbs. One borehole (H/BH30) was recorded as dry and water levels could not be taken from 12 boreholes due to pump infrastructure obstructions. Six boreholes were pumping at the time of the survey and 3 were recorded as recovering water levels. Twenty-seven of the water levels measured were recorded as static (not influenced by pumping).

Thirty-nine boreholes are in use, while ten are not in use or used for monitoring purposes. The majority of boreholes surveyed are used for livestock watering purposes while some are used for domestic purposes and small-scale irrigation.

Hydraulic head elevations range between 1415 and 1474 mamsl. The hydraulic heads calculated were used to construct a regional hydraulic head contour map for the aquifer from which flow directions were inferred. Where data points lacked, an interpolation technique known as Kriging was used to interpolate data points at locations with respect to data points in close relation to it (mathematically related to regression analysis). The contour map is shown in Figure 8. Note that expected dynamic heads, either influenced by pumping or recovering, were removed from the interpolation.

Based on the contours and flow vectors, the first indication of groundwater flow is that the eastern boundary of the mining right area is located on a groundwater divide with flow, dependant on a pressure gradient, being directed mainly towards the south-west and north-west towards the Klein-Rietspruit and Rietspruit, respectively.

Table 3: Hydrocensus information (February 2022)

Field ID	Coordinates		Z	SWL	Borehole	Equipped (Y/N)	Application	Owner	Farm name	Sampled Y/N
	Latitude	Longitude		(mbs)	depth					
Borehole/Groundwater										
H/BH 01	-27.116421	27.618056	1474	12.91	Static	Windpump	Stock Water	H. Oosthuizen	Van de Merwe Dam 37	Y
H/BH 02	-27.110384	27.608866	1480	6.47	Static	Windpump	Not in Use	Matsopa Minerals	Oceaan 99	N
H/BH 03	-27.123024	27.610232	1470	2.52	Static	Windpump	Not in Use	Matsopa Minerals	Blaauwboschpoort RE/13	N
H/BH 04	-27.128431	27.625872	1468	0.57	Static	Not Equipped	Not in Use	Matsopa Minerals	Blaauwboschpoort RE/13	Y
H/BH 05	-27.130531	27.625327	1470	5.20	Static	Not Equipped	Not in Use	Matsopa Minerals	Blaauwboschpoort RE/13	Y
H/BH 06	-27.127360	27.623180	1457	13.74	Recovering	Submersible	Mine	Matsopa Minerals	Blaauwboschpoort RE/13	Y
H/BH 07	-27.147550	27.607802	1438	2.67	Recovering	Monopump	Water Supply	D. Herbst	Vrede 450	Y
H/BH 08	-27.145893	27.606462	1436	1.23	Recovering	Powerhead	Stock Water	. Herbst	Vrede 450	Y
H/BH 09	-27.148947	27.602136	1437		Obstructed	Windpump	Stock Water	F. Smit	Verdeel 278	N
H/BH 10	-27.148213	27.602403	1438		Obstructed	Powerhead	Stock Water	F. Smit	Verdeel 278	Y
H/BH 11	-27.143596	27.604184	1441	4.90	Static	Powerhead	Stock Water	D. Herbst	Goudlaagte 238	Y
H/BH 12	-27.133125	27.600612	1458	10.30	Pumping	Windpump	Stock Water	F. Smit	Verdeel 278	N
H/BH 13	-27.132013	27.604349	1457		Obstructed	Windpump	Stock Water	D. Herbst	Goudlaagte 238	Y
H/BH 14	-27.127574	27.591347	1469	17.82	Static	Submersible	Water Supply	F. Smit	Hooge Bult 54	Y
H/BH 15	-27.163250	27.590468	1423	2.85	Pumping	Windpump	Water Supply	PW Loggenberg	Verdeel 2/46	Y
H/BH 16	-27.163440	27.588605	1422	1.98	Static	Submersible	Water Supply	PW Loggenberg	Verdeel 1/46	N
H/BH 17	-27.165564	27.585007	1422	2.43	Static	Submersible	Water Supply	PW Loggenberg	Nooitgedacht 286	Y

Field ID	Coordinates		Z	SWL	Borehole	Equipped (Y/N)	Application	Owner	Farm name	Sampled Y/N
	Latitude	Longitude		(mbs)	depth					
H/BH 18	-27.165833	27.585303	1422	3.23	Static	Windpump	Not in Use	PW Loggenberg	Nooitgedacht 286	N
H/BH 19	-27.154915	27.596870	1431		Obstructed	Windpump	Stock Water	P. Loggenberg	Geluk 237	Y
H/BH 20	-27.139774	27.591523	1448		Obstructed	Windpump	Stock Water	P. Loggenberg	Geluk 237	Y
H/BH 21	-27.143145	27.588917	1444	5.43	Static	Windpump	Stock Water	P. Loggenberg	Enkelbosch 8/31	Y
H/BH 22	-27.169683	27.572958	1418	2.51	Static	Submersible	Water Supply	A. Zitske	Brakspruit 3/15	N
H/BH 23	-27.142400	27.626354	1451	7.92	Static	Not Equipped	Not in Use	J. van Wyk	Hattings Rust 68	N
H/BH 24	-27.143424	27.625604	1451		Obstructed	Submersible	Water Supply	J. van Wyk	Hattings Rust 68	Y
H/BH 25	-27.087363	27.589192	1436	5.05	Static	Submersible	Water Supply	G. Olivier	Oceaan 64	N
H/BH 26	-27.085954	27.587756	1438	5.83	Static	Submersible	Stock Water	G. Olivier	Oceaan 64	N
H/BH 27	-27.086490	27.589336	1437	6.41	Static	Not Equipped	Not in Use	G. Olivier	Oceaan 64	Y
H/BH 28	-27.081143	27.593325	1446	13.70	Static	Submersible	Water Supply	G. Olivier	Oceaan 64	Y
H/BH 29	-27.092901	27.593054	1442	6.01	Static	Submersible	Stock Water	G. Olivier	Oceaan 64	Y
H/BH 30	-27.098732	27.593111	1453		Dry	Windpump	Not in Use	G. Olivier	Oceaan 64	N
H/BH 31	-27.121213	27.593160	1463	6.43	Static	Windpump	Stock Water	G. Olivier	Broodkop 1/304	Y
H/BH 32	-27.131620	27.581171	1436	5.00	Pumping	Windpump	Stock Water	G. Olivier	Enkelbosch Re/31	Y
H/BH 33	-27.132251	27.571076	1429		Obstructed	Submersible	Stock Water	G. Olivier	Enkelbosch 3/31	N
H/BH 34	-27.136567	27.569461	1434	8.25	Static	Submersible	Stock Water	G. Olivier	Enkelbosch 4/31	N
H/BH 35	-27.112034	27.578368	1451	8.78	Pumping	Windpump	Stock Water	G. Olivier	Broodkop RE/304	Y
H/BH 36	-27.097930	27.587593	1445		Obstructed	Windpump	Stock Water	G. Olivier	Oceaan 64	Y
H/BH 37	-27.090558	27.574094	1443	15.43	Pumping	Windpump & Submersible pump	Stock Water	G. Olivier	Eendracht 402	N
H/BH 38	-27.099835	27.522805	1415		Obstructed	Windpump	Stock Water	G. Olivier	Eendracht 402	N

Field ID	Coordinates		Z	SWL (mbs)	Borehole depth	Equipped (Y/N)	Application	Owner	Farm name	Sampled Y/N
	Latitude	Longitude								
H/BH 39	-27.153197	27.634390	1448		Obstructed	Monopump	Stock Water	D. Smallberger	Prospect 1/59	N
H/BH 40	-27.157213	27.635945	1447		Obstructed	Windpump	Stock Water	D. Smallberger	Prospect 3/59	N
H/BH 41	-27.156443	27.644714	1454	4.75	Static	Submersible	Water Supply	D. Smallberger	Prospect 3/59	N
H/BH 42	-27.161905	27.627516	1438		Obstructed	Windpump	Not in Use	D. Smallberger	Prospect 1/59	N
H/BH 43	-27.141488	27.654338	1465	5.45	Static	Submersible	Stock Water	Mr. Aucamp	Prospect 1/59	N
H/BH 44	-27.141232	27.655032	1467	6.43	Static	Submersible	Stock Water	Mr. Aucamp	Prospect RE/59	N
H/BH 45	-27.141117	27.650424	1457	5.12	Pumping	Submersible (Solar)	Water Supply	Mr. Aucamp	Prospect RE/59	N
H/BH 46	-27.136079	27.639533	1450		Static	Windpump	Stock Water	Mr. Aucamp	Prospect 4/59	Y
H/BH 47	-27.130325	27.645805	1456	3.88	Static	Windpump	Stock Water	L. Ludwig	Sahara RE/139	N
H/BH 48	-27.116692	27.649990	1470	4.89	Static	Windpump	Stock Water	L. Ludwig	Sahara RE/139	N
H/BH 49	-27.138520	27.619737	1447	3.51	Static	Windpump	Not in Use	H. Oosthuizen	Enkelbosh 98	N
Surface water										
SW 01	-27.109927	27.602843	na	na	na	na	Livestock	Matsopa Minerals	Oceaan 99	Y
SW 02	-27.129990	27.620541	na	na	na	na	Mine water	Matsopa Minerals	Blaauwboschpoort RE/13	N
SW 03	-27.141918	27.634961	na	na	na	na	Livestock	J. van Wyk	Prospect 2/59	N
SW 04	-27.211354	27.592679	na	na	na	na	Livestock	(Provincial Road)	R82 (Next to Road)	N
SW 05	-27.149034	27.606327	na	na	na	na	Livestock	D. Herbst	Vrede 450	N
SW 06	-27.151758	27.605010	na	na	na	na	Livestock	F. Smit	Verdeel 278	N
SW 07	-27.171036	27.572691	na	na	na	na	Livestock	A. Zitske	Brakspruit 3/15	Y
SW 08	-27.172984	27.591796	na	na	na	na	Livestock	PW Loggenberg	Verdeel 2/46	Y
SW 09	-27.151967	27.624943	na	na	na	na	Livestock	J. van Wyk	Hattings Rust 68	N

Field ID	Coordinates		Z	SWL (mbs)	Borehole depth	Equipped (Y/N)	Application	Owner	Farm name	Sampled Y/N
	Latitude	Longitude								
SW 10	-27.087498	27.589299	na	na	na	na	Livestock	G. Olivier	Oceaan 64	N
SW 11	-27.119419	27.591678	na	na	na	na	Livestock	G. Olivier	Broodkop 1/304	N
SW 12	-27.099663	27.551080	na	na	na	na	Livestock	G. Olivier	Eendracht 402	N
SW 13	-27.157480	27.645437	na	na	na	na	Livestock	D. Smallberger	Prospect 3/59	N
SW 14	-27.136457	27.618453	na	na	na	na	Not in use	-	Blaauwboschpoort 1/13	N
SW 15	-27.135558	27.615397	na	na	na	na	Mine water	Matsopa Minerals	Blaauwboschpoort 1/13	Y
SW 16	-27.138491	27.608018	na	na	na	na	Not in use		Blaauwboschpoort RE/13	N
SW 17	-27.139330	27.608871	na	na	na	na	Mine water	Matsopa Minerals	Enkelbosh 98	Y
SW 18	-27.123975	27.623339	na	na	na	na	Mine water	Matsopa Minerals	Blaauwboschpoort 1/13	Y

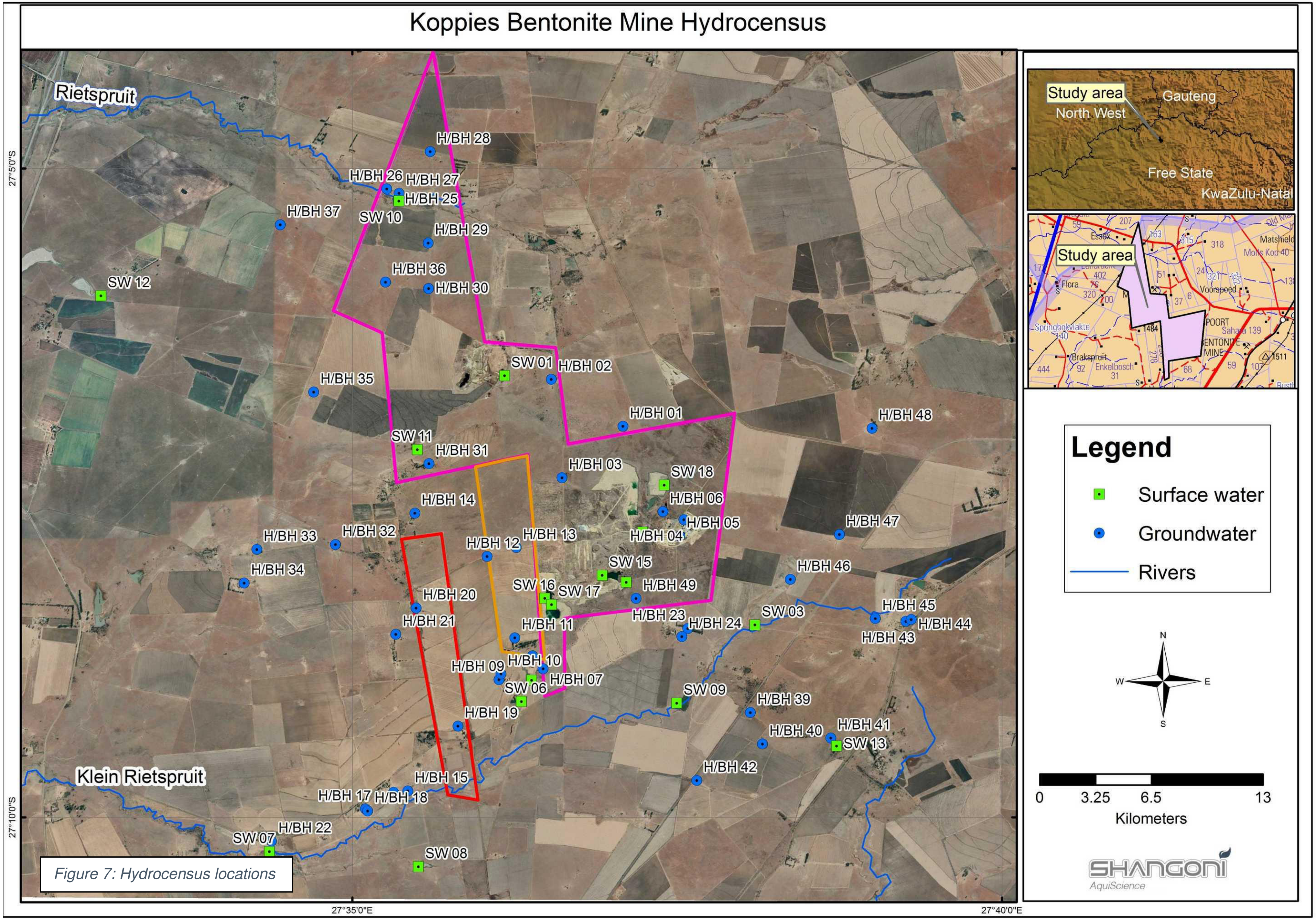

Figure 7: Hydrocensus locations

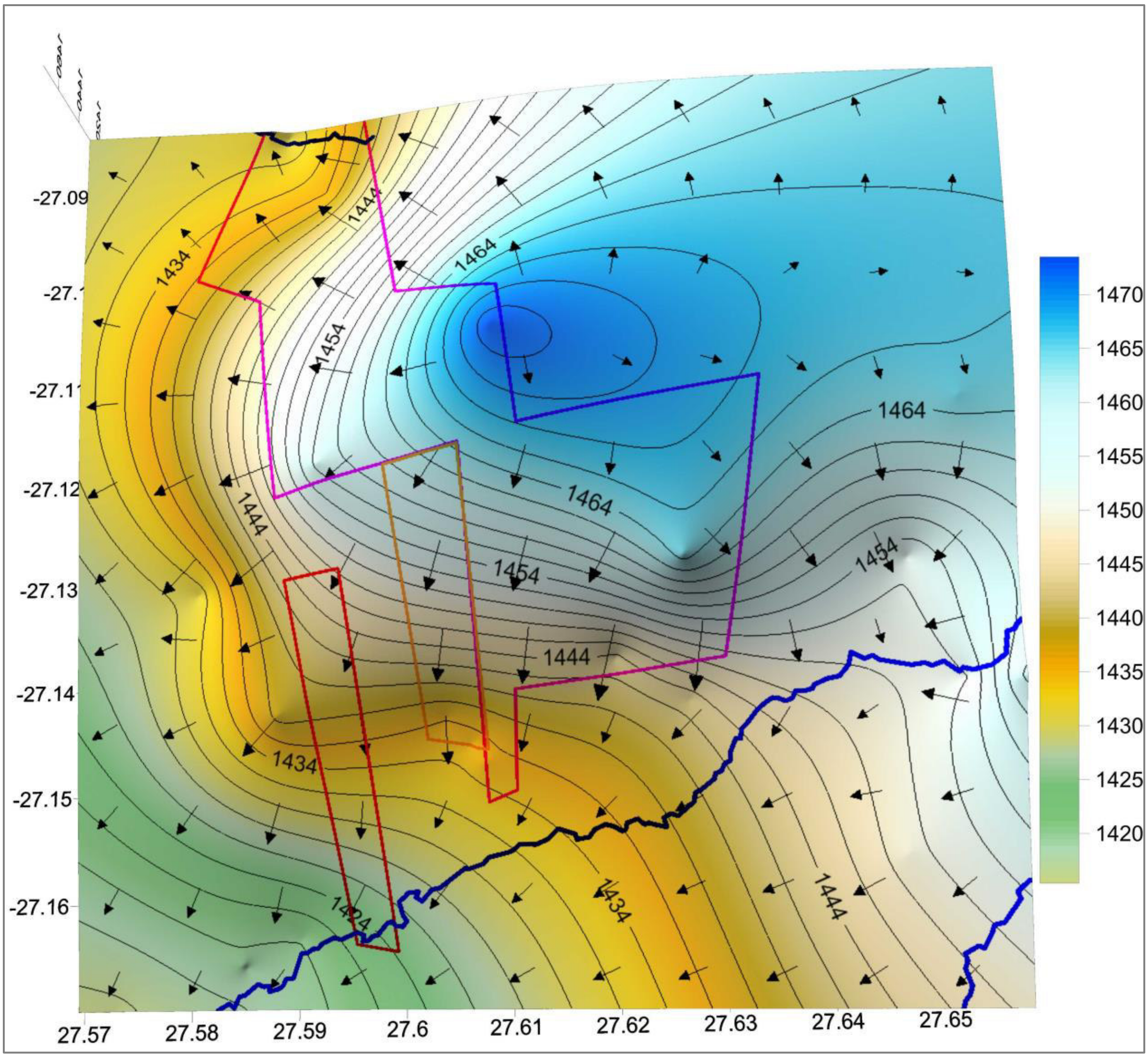

Figure 8: Interpolated (Kriging) hydraulic head contours

In many South African fractured rock aquifers, the water table or hydraulic head measured in mamsl, correlates well with topography as it contributes to groundwater movement across many spatial scales. Steeper topography can be associated with deeper water table depths, more regional groundwater flow and increased groundwater imports and exports to surface water bodies.

Figure 9 show that the linear regression between the hydraulic heads and their respective height in mamsl achieved a fair correlation of 0.94. However, some groundwater levels were recorded to be influenced by either pumping or recovery and when these were consequently removed from the correlation (Figure 10), an almost perfect fit was achieved (r^2 = 0.99). It can therefore be assumed with relative confidence that ambient groundwater flow mimics surface water flow directions.

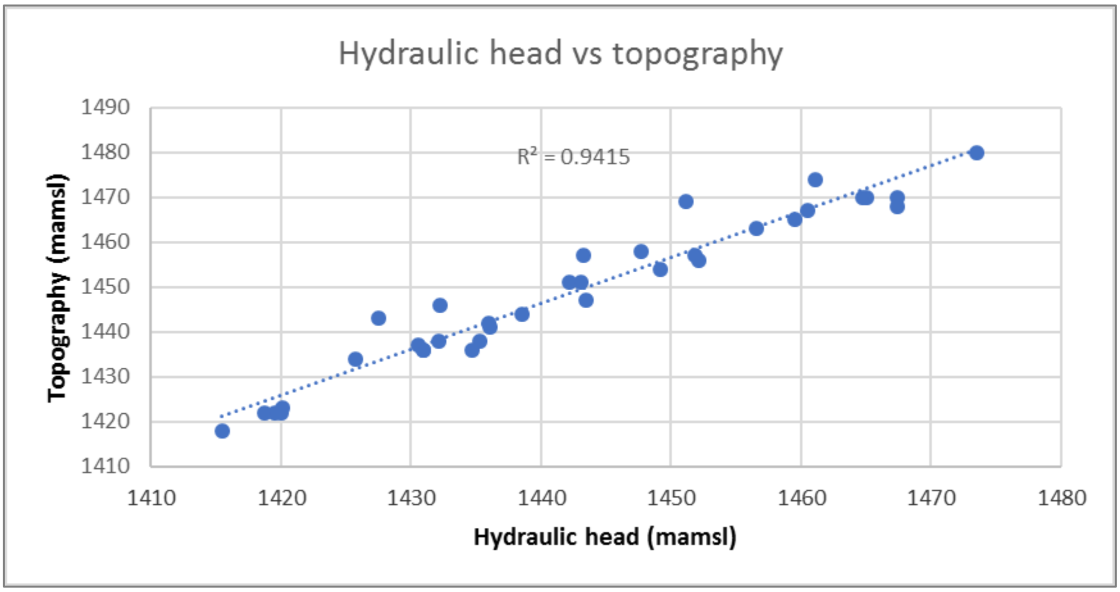

Figure 9: Straight line fit between head elevations from all boreholes and topography in mamsl

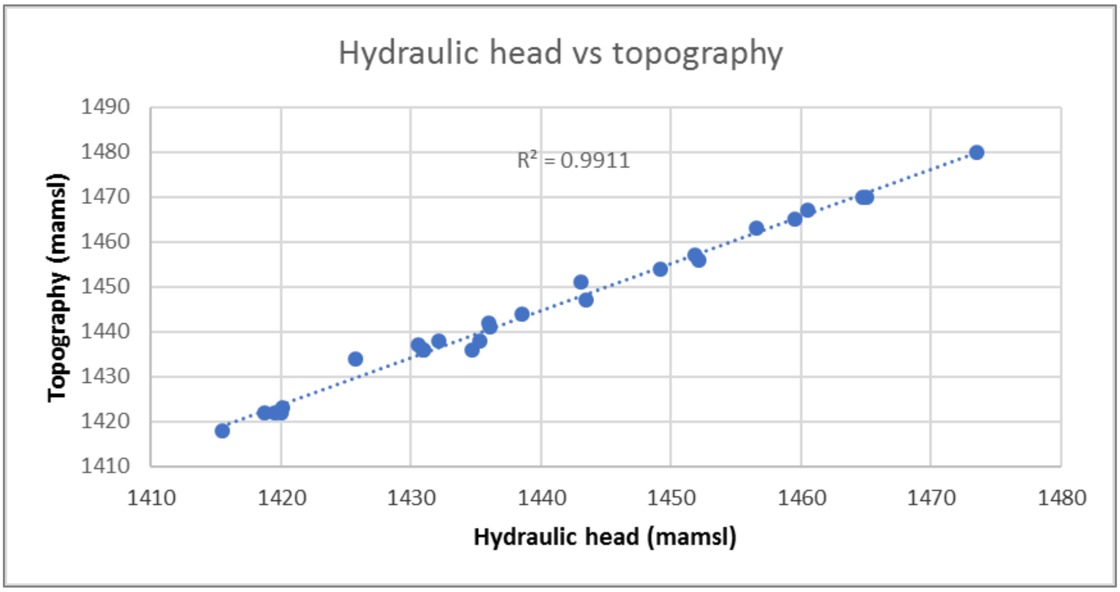

Figure 10: Straight line fit between head elevations from expected static water levels and topography in mamsl

7.2 Water quality

During the hydrocensus, selected samples were taken from surveyed surface and groundwater localities and analysed for hydrochemistry. Groundwater samples taken include boreholes located on the mine site while others were taken from privately owned groundwater users. The results are discussed in the sections that follow. The laboratory certificate of analysis can be viewed in Appendix A.

7.2.1 Surface water quality

Four samples were taken from mine water including mine pits and dams (SW01, SW15, SW17 & SW18), while the remaining samples were taken from dams located on private land (SW05, SW06, SW08 & SW09). The data recorded for the surface water localities are displayed in Table 4. Stiff diagrams illustrating the concentrations of macro-ions in milli-equivalents per litre (meq/l) are displayed in Figure 11.

The results for the mine water samples indicate circum-neutral, non-saline and moderately soft to very hard water and generally low levels of nutrients. Orthophosphate (PO_4) and ammonium (NH_4) were recorded as slightly raised in SW1 and SW15. Most trace metals recorded in the low to undetected levels except for fluoride (F) in SW18, bromide (Br) in SW01 and iron (Fe) in SW17, which recorded in slightly raised levels but remain within drinking water standards (*not a suggestion of use or used as compliance objective but merely used as reference guideline*). None of the mine water sources recorded in concentrations exceeding the relevant guidelines.

The Stiff diagrams in Figure 11 show that the mine pit water, as sampled in SW17, has raised salts levels including SO_4, Cl, Na and Mg.

Water quality results for the farm dams are also displayed in Table 4 while Stiffs are shown in Figure 12. The results indicate circum-neutral, non-saline and soft to hard water with generally low levels of nutrients and trace metals. Orthophosphate is slightly raised in the surface dams while NH_4 is slightly raised in SW06. Bromide (Br) is raised in SW08 and SW09.

All parameters recorded well within drinking water and livestock watering guidelines. Note that no South African standard/guideline is available for Br. Where relevant, the Word Health Organization’s (WHO) guidelines were sourced.

The Stiffs for the farm dams in Figure 12 show raised major ion activity for SW05 and SW06. These dams are located directly downstream from the mine.

Table 4: Hydrochemical quality of surface water sampled

Locality / Guideline Parameter	Unit	SANS 241:2015[a]	Livestock Watering[b]	SW01	SW15	SW17	SW18	SW05	SW06	SW08	SW09
pH	-	≥5and≤9.7	-	7.19	8.39	8.36	8.14	8.52	7.55	7.25	7.29
EC	mS/m	≤ 170	-	13.9	55.5	138	61.7	82.6	75.3	9.98	40.5
TDS	mg/l	≤ 1200	1000-3000	73.4	315	811	363	491	433	78.0	238
Calcium (Ca)	mg/l	-	1000	9.80	26.4	29.8	36.4	41.7	37.6	5.18	31.4
Magnesium (Mg)	mg/l	-	500	7.29	22.9	59.0	36.6	33.1	30.3	5.97	15.7
Sodium (Na)	mg/l	≤ 200	2000	4.15	53.4	170	41.0	85.1	72.1	7.04	27.8
Potassium (K)	mg/l	-	-	3.02	8.20	16.8	3.41	10.6	13.4	9.07	7.98
Alkalinity	mg $CaCO_3$/l	-	-	57.2	158	136	183	147	187	53.4	135
Chloride (Cl)	mg/l	≤ 300	1500-3000	5.40	72.8	340	71.6	176	126	3.89	51.6
Sulphate (SO_4)	mg/l	≤ 500	1000	3.17	30.1	112	47.2	52.6	38.0	8.19	15.6
Nitrate as N (NO_3-N)	mg/l	≤ 11	10-100	<0.35	1.01	<0.35	3.54	0.69	<0.35	0.68	0.74
Total ammonia (NH_3-N)	mg N/l	2.5	-	0.60	0.61	<0.45	<0.45	<0.45	1.10	<0.45	<0.45
Ortho-phosphate (PO_4-P)	mg P/l	-	-	1.25	0.12	<0.03	<0.03	0.21	0.37	0.26	0.21
Fluoride (F)	mg/l	≤ 1.5	2-6	0.47	0.47	0.68	1.50	0.34	0.38	0.40	0.40
Bromide (Br)	mg/l	2-6[b]	-	1.12	<0.01	<0.01	<0.01	0.10	0.25	1.95	2.09
Iron (Fe)	mg/l	≤ 2	10	<0.01	<0.01	1.13	0.20	<0.01	<0.01	<0.01	<0.01
Lead (Pb)	mg/l	≤ 0.01	0.1-0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	mg/l	≤ 0.4	-	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.08	0.02
Total Hardness	mg $CaCO_3$/l	-	-	54.5	160	317	242	240	219	37.5	143

a – South African National Standards of 2015 Drinking Water Quality Standards

b – World Health Organization (WHO, 2011)- Guidelines for Drinking-Water Quality

c – DWAF (1998) – Livestock Watering Standards

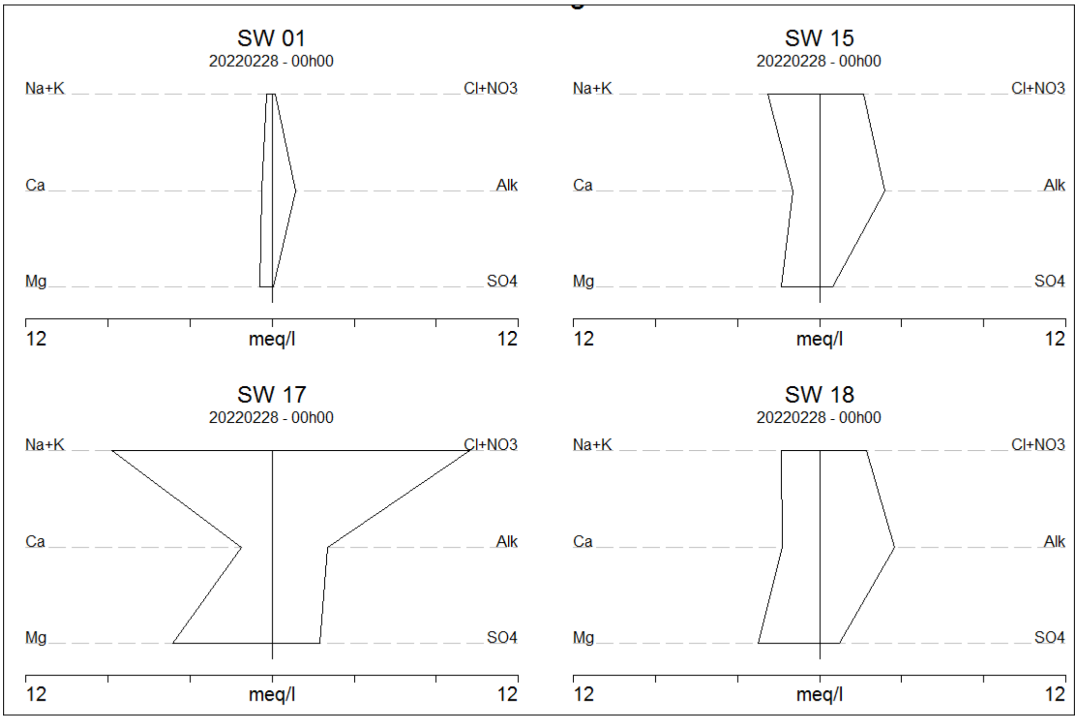

Figure 11: Stiff diagrams for mine surface water based on concentrations of major cations and anions in meq/l

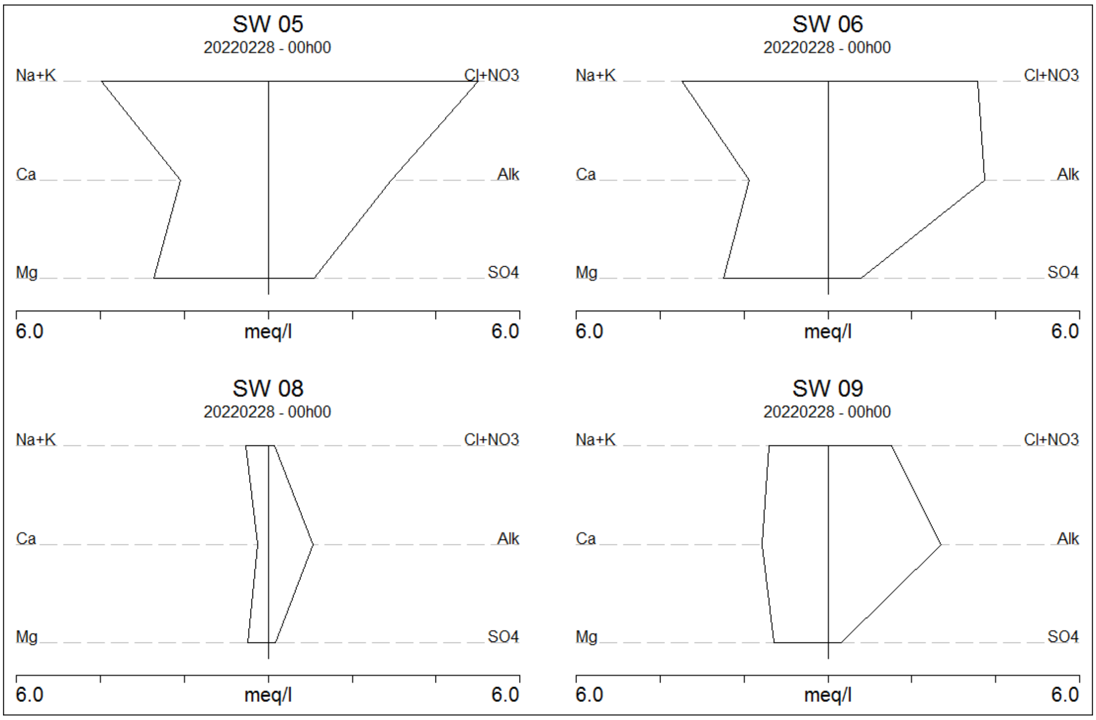

Figure 12: Stiff diagrams for farm dams based on concentrations of major cations and anions in meq/l

7.2.2 Groundwater quality

Selected groundwater samples were taken and analysed for hydrochemistry. Three of these are located in the near vicinity to the active mining site. H/BH04 and H/BH05 are used for monitoring purposes and are not equipped while H/BH06 is equipped and in use on the mine. Seven other boreholes are located either within the mining right area or immediately adjacent to it and will be discussed together with the boreholes mentioned above. The data are displayed in Table 5 and Stiffs and an Expanded Durov diagram in figures 13 and 14, respectively.

The data is indicative of circum-neutral, non-saline and slightly hard to very hard water with generally low trace metals but low to high NO_3 levels. NO_3 exceeding the SANS drinking water standards was recorded in boreholes H/BH07, H/BH08 and H/BH10 located on the farms Vrede and Verdeel. Other than NH_4 exceeding domestic standards in borehole H/BH05, all other parameters recorded for the on-mine boreholes recorded well within the SANS standards.

Stiffs and the Expanded Durov show groundwater profiles generally of Mg(Ca)-HCO_3 types indicative fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange, or Na in the case of borehole H/BH11. It is important to note that the three boreholes, H/BH04, H/BH05 and H/BH06 plot in Field 2 of the Expanded Durov diagram typical of fresh, clean and unimpacted water.

The remaining groundwater samples were taken from selected farm localities surveyed during the hydrocensus. The results are displayed in tables 6 and 7 and figures 15 and 16 below.

Baseline data for these groundwater localities indicate fairly similar groundwater quality with sporadic raised NO_3 and Fe levels. The general quality can be described as circum-neutral, non-saline and hard to very hard. Nitrate (NO_3) levels recorded in relatively raised to high concentrations in a number of boreholes with the SANS standard of ≤ 11 mg N/l being exceeded. Iron (Fe) was also recorded as raised in the majority of boreholes but only exceed the standards in two boreholes, H/BH17 and H/BH27. Fluoride (F) recorded an elevated concentration in borehole H/BH27 with a concentration of 4.58 mg/l, exceeding the SANS standard of ≤ 1.5 mg/l.

Stiffs and the Durov in figures 15 and 16 show moderately dissimilar chemical profiles. Groundwater samples plot in fields 1, 3, 5, 6 and 8 on the Expanded Durov which can be interpreted as:

- Field 2 (H/BH15, 20, 24, 29, 31, 36): Fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange.
- Field 3 (H/BH32): Fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na enriched felsic rocks such as dolerite.
- Field 5 (H/BH19, 21, 22): Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing/contamination or old stagnant NaCl dominated water that has mixed with clean water.
- Field 6 (H/BH36): Groundwater from field 5 that has been in contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock/material.
- Field 8 (H/BH17, 27 46): Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4, but especially Cl mixing/contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg.

Table 5: Hydrochemistry of groundwater sampled in the mining right and in the immediate vicinity

Locality / Guideline Parameter	Unit	**SANS 241:2015[a]**	H/BH 01	H/BH 04	H/BH 05	H/BH 06	H/BH 07	H/BH 08	H/BH 10	H/BH 11	H/BH 13	H/BH 14
pH	-	≥5and≤9.7	7.14	6.97	7.19	7.16	7.05	7.09	7.08	7.55	7.03	7.49
EC	mS/m	≤ 170	97.5	147	72.9	138	130	93.4	102	50.4	84.7	81.4
TDS	mg/l	≤ 1200	456	866	415	795	781	580	650	309	480	487
Calcium (Ca)	mg/l	-	48.7	90.9	20.3	99.7	88.2	60.9	68.6	12.9	48.0	55.5
Magnesium (Mg)	mg/l	-	61.2	130	59.9	119	70.4	43.0	48.7	18.7	44.7	61.0
Sodium (Na)	mg/l	≤ 200	33.2	27.7	43.5	20.4	82.2	75.5	78.4	68.1	61.1	22.2
Potassium (K)	mg/l	-	6.33	19.1	8.95	5.55	7.31	16.2	13.3	16.7	13.9	19.5
Alkalinity	mg $CaCO_3$/l	-	329	478	280	428	336	326	318	214	332	318
Chloride (Cl)	mg/l	≤ 300	38.0	204	36.9	172	177	63.8	72.2	30.2	50.3	35.6
Sulphate (SO_4)	mg/l	≤ 500	68.6	101	71.3	81.6	73.9	70.4	73.0	24.5	30.4	99.2
Nitrate as N (NO_3-N)	mg/l	≤ 11	0.37	0.72	0.47	8.81	**17.8**	**12.0**	**23.4**	2.06	7.06	0.78
Total ammonia (NH_3-N)	mg N/l	2.5	<0.45	1.11	**2.65**	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Ortho-phosphate (PO_4-P)	mg P/l	-	<0.03	0.35	<0.03	<0.03	<0.03	0.03	0.11	0.06	<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	0.27	0.31	<0.09	0.20	0.39	0.27	0.32	<0.09	0.27	<0.09
Bromide (Br)	mg/l	2-6[b]	<0.01	0.07	0.36	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron (Fe)	mg/l	≤ 2	0.21	0.12	<0.01	1.09	1.00	0.58	0.69	0.40	0.37	0.10
Lead (Pb)	mg/l	≤ 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	0.03	0.13	<0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	374	762	297	739	510	329	372	109	304	390

a – South African National Standards of 2015 Drinking Water Quality Standards

b – World Health Organization (WHO, 2011)- Guidelines for Drinking-Water Quality

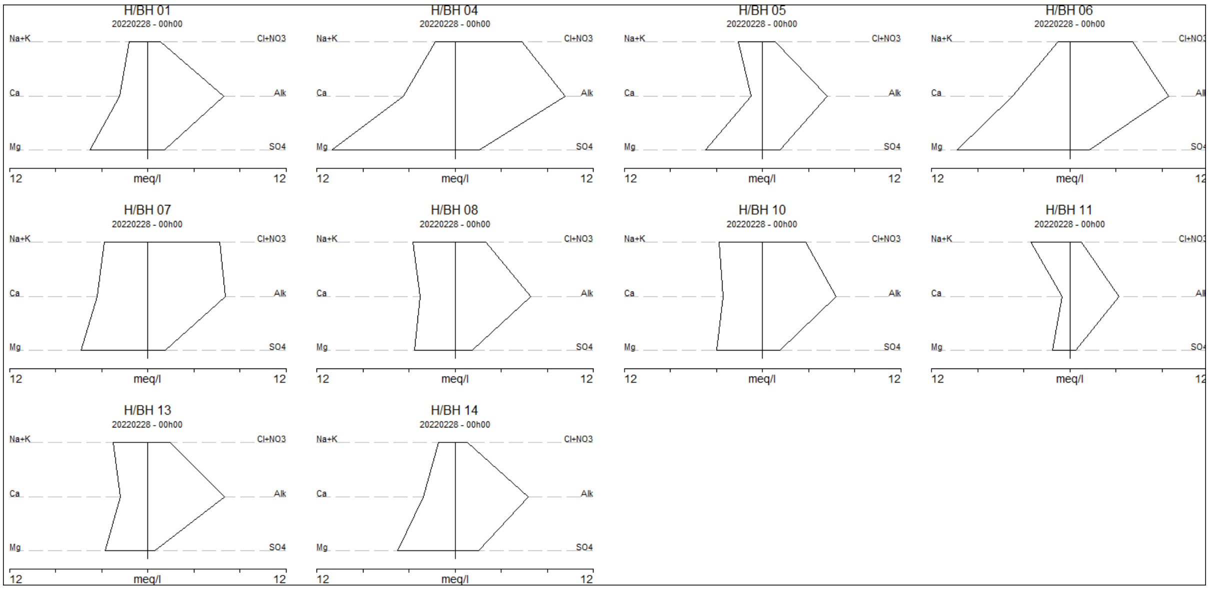

Figure 13: Stiff diagrams for groundwater located near in or near to the mining right area

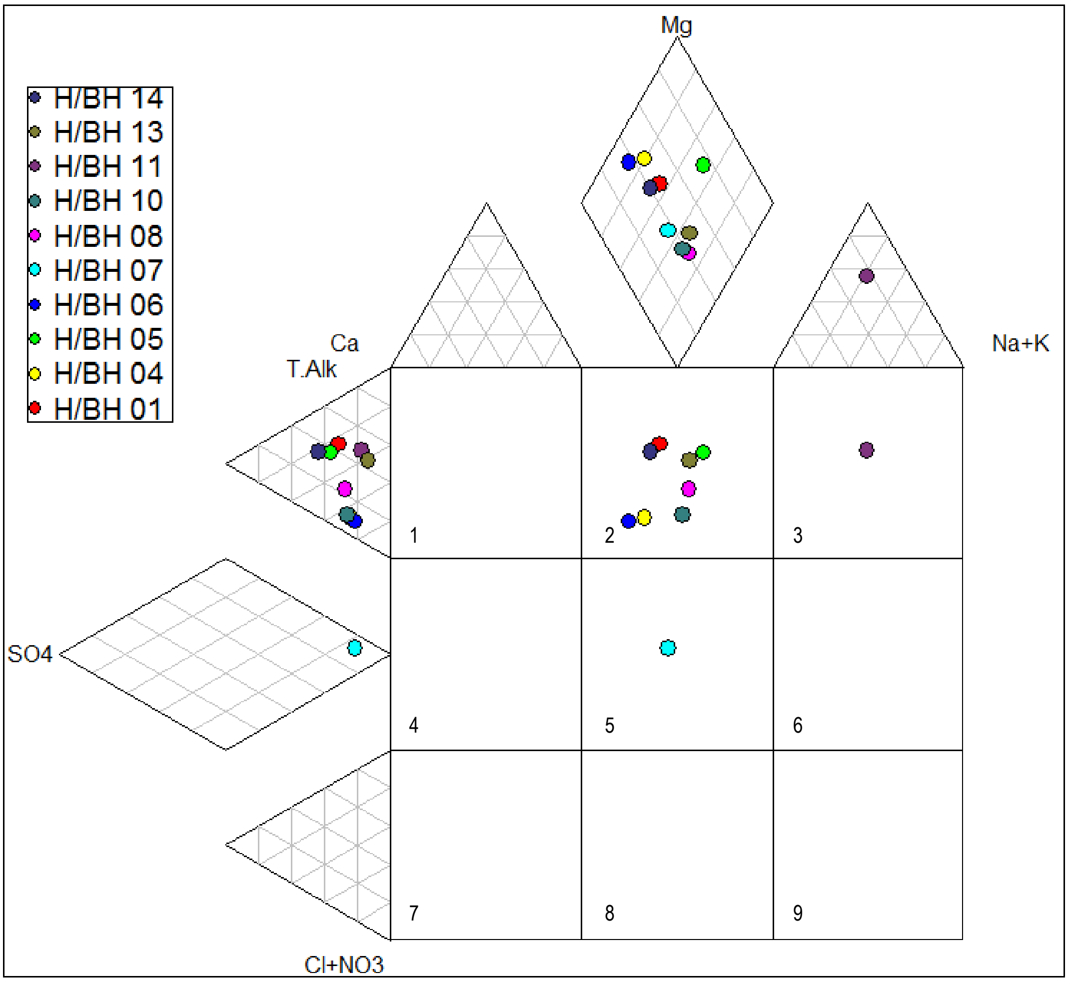

Figure 14: Expanded Durov for groundwater located near in or near to the mining right area

Table 6: Hydrochemistry of groundwater sampled from farm boreholes

Locality / Guideline Parameter	Unit	**SANS 241:2015[a]**	H/BH 15	H/BH 17	H/BH 19	H/BH 20	H/BH 21	H/BH 22	H/BH 24	H/BH 27	H/BH 28
pH	-	≥5and≤9.7	7.29	7.04	7.86	7.36	7.61	7.41	7.42	7.28	7.41
EC	mS/m	≤ 170	102	**237**	105	85.6	122	135	84.4	**255**	108
TDS	mg/l	≤ 1200	587	**1493**	647	548	769	877	491	**1470**	650
Calcium (Ca)	mg/l	-	61.8	168	27.1	36.8	81.9	86.4	57.9	116	78.7
Magnesium (Mg)	mg/l	-	49.3	129	61.4	58.8	78.6	57.9	58.1	95.7	40.4
Sodium (Na)	mg/l	≤ 200	85.1	145	97.0	57.6	53.4	119	31.6	**293**	93.2
Potassium (K)	mg/l	-	10.5	27.0	21.2	18.8	22.1	27.1	8.58	1.90	16.9
Alkalinity	mg $CaCO_3$/l	-	314	354	244	284	250	340	300	318	386
Chloride (Cl)	mg/l	≤ 300	95.5	459	100	57.5	181	133	59.7	**652**	96.3
Sulphate (SO_4)	mg/l	≤ 500	65.4	239	179	90.3	143	185	53.5	106	45.9
Nitrate as N (NO_3-N)	mg/l	≤ 11	6.70	**24.7**	2.66	**12.8**	**13.0**	**13.9**	9.24	0.46	10.3
Total ammonia (NH_3-N)	mg N/l	2.5	<0.45	<0.45	0.89	0.76	<0.45	<0.45	<0.45	<0.45	<0.45
Ortho-phosphate (PO_4-P)	mg P/l	-	<0.03	<0.03	0.28	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	0.52	0.36	0.39	0.14	<0.09	0.58	0.28	**4.58**	0.53
Bromide (Br)	mg/l	2-6[b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01
Iron (Fe)	mg/l	≤ 2	0.65	**3.62**	0.46	<0.01	0.78	1.19	0.35	**4.93**	0.81
Lead (Pb)	mg/l	≤ 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	<0.01
Total Hardness	mg $CaCO_3$/l	-	357	951	321	334	528	454	384	684	363

a – South African National Standards of 2015 Drinking Water Quality Standards

b – World Health Organization (WHO, 2011)- Guidelines for Drinking-Water Quality

Table 7: Hydrochemistry of groundwater sampled from farm boreholes

Locality / Guideline Parameter	Unit	**SANS 241:2015[a]**	H/BH 29	H/BH 31	H/BH 32	H/BH 35	H/BH 36	H/BH 46
pH	-	≥5and≤9.7	7.54	7.32	7.31	7.26	7.30	7.36
EC	mS/m	≤ 170	119	60.4	88.4	140	109	**177**
TDS	mg/l	≤ 1200	738	341	515	876	657	1088
Calcium (Ca)	mg/l	-	65.7	34.1	37.9	63.8	60.4	124
Magnesium (Mg)	mg/l	-	46.7	49.8	28.3	43.3	37.5	90.1
Sodium (Na)	mg/l	≤ 200	139	16.1	124	169	124	124
Potassium (K)	mg/l	-	8.93	7.90	2.43	41.1	14.9	11.2
Alkalinity	mg $CaCO_3$/l	-	382	268	363	359	377	237
Chloride (Cl)	mg/l	≤ 300	152	21.2	53.9	166	97.2	**407**
Sulphate (SO_4)	mg/l	≤ 500	78.4	41.1	30.5	96.5	63.3	155
Nitrate as N (NO_3-N)	mg/l	≤ 11	3.70	2.18	4.10	**17.6**	7.14	7.37
Total ammonia (NH_3-N)	mg N/l	2.5	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Ortho-phosphate (PO_4-P)	mg P/l	-	<0.03	<0.03	<0.03	<0.03	0.04	<0.03
Fluoride (F)	mg/l	≤ 1.5	0.59	0.14	0.80	0.69	0.68	0.36
Bromide (Br)	mg/l	2-6[b]	<0.01	<0.01	0.08	0.08	<0.01	<0.01
Iron (Fe)	mg/l	≤ 2	1.01	0.21	0.28	1.19	0.71	1.26
Lead (Pb)	mg/l	≤ 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	356	290	211	338	305	681

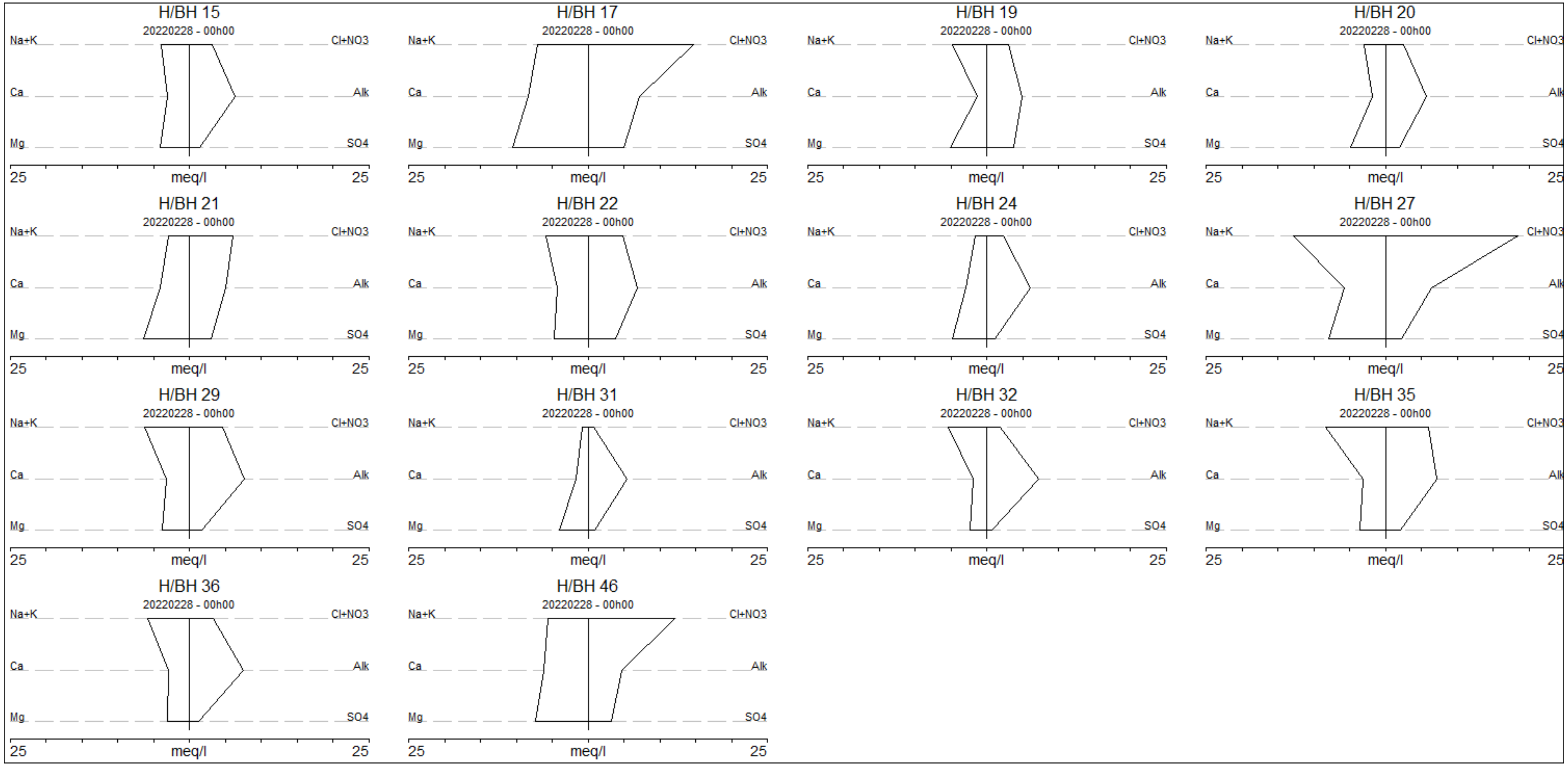

Figure 15: Stiff diagrams based on concentrations of major ions in meq/l of farm borehole quality

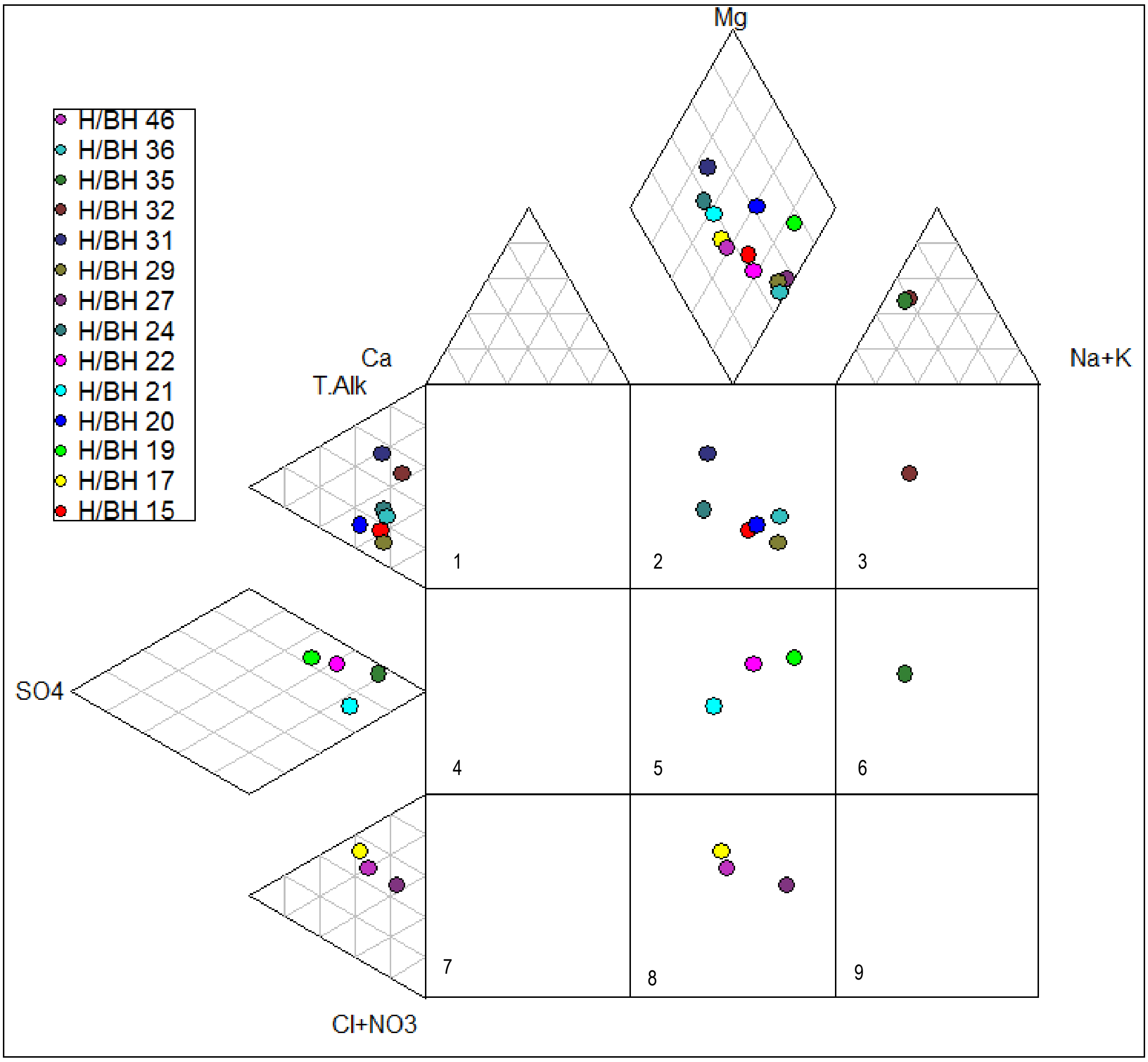

Figure 16: Expanded Durov diagram based on relative percentages of major ion concentrations in meq/l

8. GROUNDWATER RISK CHARACTERISATION

8.1 Aquifer vulnerability

Groundwater plays an important role in supplying water to many regions of Southern Africa due to its low annual average precipitation of 460 mm, which is well below the world average of 860 mm. The quality of groundwater resources in South Africa has therefore received considerable focus and attention on the need for a proactive approach to protect these sources from contamination (Lynch *et. al*., 1994). Groundwater protection needs to be prioritised based upon the susceptibility of an aquifer towards pollution. This can be done in two ways, namely i) pollution risk assessments and ii) aquifer vulnerability. Pollution risk assessments consider the characteristics of a specific pollutant, including source and loading while aquifer vulnerability considers the characteristics of the aquifer itself or parts of the aquifer in terms of its sensitivity to being adversely affected by a contaminant should it be released.

The DRASTIC model concept developed for the USA (Aller *et. al.*, 1987) is well suited for producing a groundwater vulnerability evaluation for South African aquifers. The DRASTIC model evaluates the intrinsic vulnerability (*IV*) of an aquifer by considering factors including **D**epth to water table, natural **R**echarge rates, **A**quifer media, **S**oil media, **T**opographic aspect, **I**mpact of vadose zone media, and hydraulic **C**onductivity. Different ratings (r) are assigned to each factor and then summed together with respective constant weights (w) to obtain a numerical value to quantify the vulnerability:

$$\text{DRASTIC Index } (IV) = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw$$

Where *D*, *R*, *A*, *S*, *T*, *I*, and *C* are the parameters, *r* is the rating value, and *w* the constant weight assigned to each parameter (Lynch *et al*, 1994). The scores associated with the vulnerability of South African aquifers are shown in Table 8.

Table 8: South African National Groundwater Vulnerability Index to Pollution (Lynch et al, 1994)

Score	Vulnerability
50-87	Least susceptible
87 - 109	Moderate susceptible
109 - 226	Most susceptible

The concept of DRASTIC in vulnerability assessments is based on:

- A contaminant is introduced at the surface of the earth or just below it.
- A contaminant is flushed into the groundwater by precipitation.
- A contaminant has the mobility of water.
- The area evaluated is 0.4 km^2 or larger.

The weighting for each parameter is constant. The minimum value for the DRASTIC index that one can calculate (assuming all seven factors were used in the calculation) is therefore 24 with the maximum value being 226. The higher the DRASTIC index the greater the vulnerability and possibility of the aquifer to become polluted if a pollutant is introduced at the surface or just below it.

Table 10 summarizes the aquifer classification vulnerability scores for the aquifer in vicinity of the project area. The final DRASTIC score of 96 indicates that the fractured aquifer in the region has a medium susceptibility to pollution.

Table 9: DRASTIC vulnerability scores for the regional aquifer

Factor	Range/Type	Weight	Rating	Total
D	0 - 15 m	5	9	45
R	10 - 50 mm	4	1	4
A	Weathered & fractured	3	3	9

Factor	Range/Type	Weight	Rating	Total
S	Sandy-clay-loam	2	4	8
T	0-2%	1	10	10
I	Karoo	5	4	20
C	-	3	-	-
DRASTIC SCORE = 96				

8.2 Aquifer classification and characterisation

The South African Aquifer System Management Classification is presented by five major classes listed below and defined in Table 10:

- Sole Source Aquifer System
- Major Aquifer System
- Minor Aquifer System
- Non-Aquifer System
- Special Aquifer System

Table 10: Aquifer classification scheme (Parsons, 1995)

Aquifer system	Defined by Parsons (1995)	Defined by DWA minimum requirements (DWAF, 1998)
Sole source aquifer	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable alternative sources should the aquifer become depleted or impacted upon. Aquifer yields and natural water quality are immaterial.	An aquifer, which is 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	Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good.	High yielding aquifer (5-20 l/s) of acceptable water quality.
Minor aquifer	These can be fractured or potentially fractured rocks that do not have a high primary hydraulic conductivity, or other formations of variable hydraulic conductivity. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are both important for local supplies and in supplying base flow for rivers.	Moderately yielding aquifer (1-5 l/s) of acceptable quality or high yielding aquifer (5-20 l/s) of poor-quality water.
Non-aquifer	These are formations with negligible hydraulic conductivity that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it	Insignificantly yielding aquifer (< 1 l/s) of good quality water or moderately yielding aquifer (1-5 l/s) of poor quality or aquifer

Aquifer system	Defined by Parsons (1995)	Defined by DWA minimum requirements (DWAF, 1998)
	renders the aquifer unusable. However, groundwater flow through such rocks does occur, although imperceptible, and needs to be considered when assessing risk associated with persistent pollutants.	which will never be utilised for water supply and which will not contaminate other aquifers.
Special aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	

The DWS has further characterised South African aquifers based on the rock formations in which they occur together with its capacity to transmit water to boreholes drilled into specific formations. The water bearing properties of rock formations in South Africa can be classified into four classes defined as:

1. ***Class A - Intergranular***
   - Aquifers associated either with loose and unconsolidated formations such as sands and gravels or with rock that has weathered to only partially consolidated material.
2. ***Class B - Fractured***
   - Aquifers associated with hard and compact rock formations in which fractures, fissures and/or joints occur that are capable of both storing and transmitting water in useful quantities.
3. ***Class C - Karst***
   - Aquifers associated with carbonate rocks such as limestone and dolomite in which groundwater is predominantly stored in and transmitted through cavities that can develop in these rocks.

4. ***Class D - Intergranular and fractured***
   - Aquifers that represent a combination of Class A and B aquifer types. This is a common characteristic of South African aquifers. Substantial quantities of water are stored in the intergranular voids of weathered rock but can only be tapped via fractures penetrated by boreholes drilled into the fractured aquifer.

Each of these classes is further subdivided into groups relating to the capacity of an aquifer to transmit water to boreholes, typically measured in l/s. The groups therefore represent various ranges of borehole yields.

The study area is predominantly located in a d2 aquifer class region. The groundwater yield potential is classed as low on the basis that most of the boreholes on record in vicinity of the study area produce between 0.1 and 0.5 l/s. Higher yields do, however, occur where groundwater is held in good water yielding fractures but these seem to be largely absent in the immediate vicinity.

The Volksrust aquifer has been identified as a rather impermeable and minor aquifer with fair groundwater quality, a medium vulnerability and a medium susceptibility towards contamination.

8.3 Aquifer protection classification

In order to achieve the Groundwater Quality Management Index a point scoring system as presented in tables 11 and 12 was used for the naturally occurring aquifers in the wider study area.

The occurring aquifer, in terms of the above definitions, is classified as a minor aquifer system. The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer is classed as low.

Table 11: Ratings for the Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	-
Major Aquifer System	4	-
Minor Aquifer System	2	2
Non-Aquifer System	0	-
Special Aquifer System	0-6	-
Second Variable Classification (fractured)		
High	3	-
Medium	2	2
Low	1	-

Table 12: Ratings for the Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	
Major Aquifer System	4	
Minor Aquifer System	2	2
Non-Aquifer System	0	
Special Aquifer System	0-6	
Aquifer Vulnerability Classification		
High	3	
Medium	2	2
Low	1	

GQM Index = Aquifer System Management x Aquifer Vulnerability: 2 X 2 = 4

The level of groundwater protection based on the Groundwater Quality Management Classification is shown in Table 13.

Table 13: GQM index for the study area

GQM Index	Level of Protection	Study Area
<1	Limited	
1-3	Low level	
3-6	Medium level	4
6-10	High level	
>10	Strictly non-degradation	

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a GQM index of 4 for the study area, indicating that a **medium-level groundwater protection** is required to adhere to DWS's water quality objectives. Reasonable and sound groundwater protection measures are therefore recommended to ensure that no cumulative pollution affects the aquifer, during short- and long-term. DWS water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that if any potential polluting risks exist, measures must be taken to limit the impact to the environment, which in this case is the protection of the underlying aquifer.

9. POTENTIAL GROUNDWATER CONTAMINANTS

9.1 Geochemical assessment on mineral waste

Digby Wells (2013) conducted a waste classification procedure on mineral waste generated by the mine to identify potential contaminants of concern. As part of the study they performed the following geochemical tests:

- XRD (X-ray diffraction) and XRF (X-ray fluorescence) analysis to determine the mineralogical and chemical make-up of the solid material.
- Moisture content and pH.
- TCLP (toxicity characterisation leachate procedure) extraction performed to determine the major, minor and trace elements by ICP MS.

Digby Wells (2013) found that silicon oxide (SiO_2) and aluminium oxide (Al_2O_3) are the two main oxides present in the mineral waste, which is indicative of the sample source material largely being from clay materials.

The total elemental analysis, as per the XRF, was also compared by Digby Wells (2013) to the various elemental geochemical abundance indices (GAI). The GAI compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a particular rock type). The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance. It can give an indication of whether a sample shows a higher than normal concentration of an element.

The Digby Wells (2013) results indicated that the heavy metal concentrations of the samples were well below the GIA. They concluded that this shows that heavy metals should not leach in significant quantities from the material.

The TCLP test conducted by Digby Wells (2013), is a chemical leachate analysis process used to determine whether there are hazardous elements present in a waste. The test involves a simulation of leaching through a waste material and can provide a rating that can prove if the waste is dangerous to the environment or not. The acidic pH of this solution (≤ 3) will predict worst case scenarios regarding the solubility of metals.

Major salts of Na and Ca and the trace metal Mn leached in significant concentrations. The high concentrations of salts also resulted in a highly raised total dissolved solids. Sulphate was also recorded to be relatively raised.

Digby Wells (2013) concluded that Mn is the only element of concern based to the waste classification criteria. Mn is a highly soluble and common element in the earth's crust and may become soluble under reduced or acidic conditions, the latter being not relevant to the bentonite mine.

9.2 Quality of mine water

Water quality analyses of mine water can also provide an indication of the potential groundwater contaminants that pose a risk towards the natural water resources. As discussed previously in Section 7.2.1, four mine water samples were taken during the hydrocensus (refer to Table 4 and Figure 11). The results show the mine water contains slightly raised levels of major ions such as Cl, Mg, Na and SO_4 but all remain well within drinking water and livestock watering standards. Trace metals including Fe, Mn, Pb and Br together with the nutrients, NO_3, NH_4 and PO_4 recorded in relatively low concentrations. All parameters except for NH_4 in one sample recorded below the relevant standards and pose little contamination concern.

No concerns regarding trace metals could be identified in the mine water samples or even based on worst-case scenarios, which as was simulated by the TCLP leach test.

10. CONCLUSIONS AND RECOMMENDATIONS

Shangoni AquiScience, a division of Shangoni Management Services conducted a geohydrological investigation into the bentonite mining operations at Matsopa Minerals, located near Koppies. The study was compiled using all relevant available information and generated data to define the groundwater regime and to highlight current and foreseeable risks towards the receiving surface and groundwater environment.

In order to identify risk from future contamination, the potential sources of contamination were considered as well as potential pathways and receptors. The objective is to place the geological and geohydrological information obtained in the context of a risk-based framework.

The pollutant linkage concept relies on the identification of a potential contaminant (source) in, on or under the land at a concentration likely to have the potential to cause harm and also the likely presence of a receptor, which may suffer harm, and finally a pathway must be present to link the source and receptor.

Leachate generation is often considered as an essential component of waste disposal. However, no substantial contamination effects are evident from the operational activities presently underway at the bentonite mine. The ore and waste rock excavated, including the mine water contain no significant concentrations of hazardous or any other constituents to be of any contamination concern. This together with the low permeability and limited fracturing expected for the Volksrust argillaceous aquifer, the risk that the mine poses on the receiving natural ground and surface water environment is low.

The study area is predominantly located in low yield aquifer class region. The groundwater yield potential is classed as low on the basis that most of the boreholes in vicinity of the study area produce relatively low yields. The aquifer has been identified as a minor aquifer with fair groundwater quality, a medium vulnerability and a medium susceptibility towards contamination. A medium-level groundwater protection is required to adhere to DWS's water quality objectives. Reasonable and sound groundwater protection measures are therefore recommended to ensure that no cumulative pollution affects the aquifer, during short- and long-term. Therefore, the significance of this aquifer classification is that if any potential polluting risks exist, measures must be taken to limit the impact to the environment, which in this case is the protection of the underlying aquifer for future uses/generations. Regular water quality monitoring should be undertaken of pit water quality and on up- and downstream surface water localities relative to the mine and the mine water discharge point/s.

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APPENDIX A

Laboratory certificate

YANKA LABORATORIES
(Pty) Ltd.

Registration No. 2012/113891/07 **VAT No. 4380263659**

PO Box 11396, AERORAND, 1055, South Africa
Office: 6 Drakensberg Str., Aerorand, MIDDELBURG, MP
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E-Mail: yanka@yanka.co.za

Shangoni Management Services
Attention: Ockie Scholtz
P.O. Box 74726
LYNWOOD RIDGE
40

Job No: **E53553 - W22_0980**
Report Reference: **ER_SHA_2022-03-02_09789_001**
Enquiries: **Rita Botha**
Date: **2022/03/02**
RitaB@yanka.co.za
Job Reference: **W22/0980 - Advice Note 2203W053**

Job Description: **33 x Routine Analysis**

Project: **MATSOPA SAMPLES**

TEST RESULTS FOR Shangoni - Matsopa Water - 01 March 2022

This report contains results pertaining only to the water/dust samples analysed.

For Standards referenced, and methods base, please see http://www.yanka.co.za/TestsAndStandards.htm

Please contact us if you have any queries concerning the information contained herein. Thank you for your support.

Electronically approved

RITA BOTHA (Technical Signatory)
ENVIRONMENTAL SERVICES

ANALYSED WITHIN 1 March 2022 - 2022/03/02
SANAS Certificate obtainable from the address below
http://www.yanka.co.za/Services.htm

*Results not marked with a Test Method YE###***, as well as results marked "Subcontracted" or "Outsourced" , in this report, are not included in the SANAS Schedule of Accreditation for this laboratory. However, outsourced results may be within the Schedule of Accreditation of the source laboratory.*
Opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
Limits shown to the right of results are for information only and may need further interpretation, and is not suitable for conformance evaluation as shown.

ANALYSTS
Marné, Magda, Venna, Drieka, Sue, Rosemary, Vida, Elize, Charnelle, Petricia, Jeandre, Nadine

YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 1	SpShangoni 2	SpShangoni 3	SpShangoni 4	SpShangoni 5	SpShangoni 6	SpShangoni 7	SpShangoni 8	SpShangoni 9
SAMPLE DESCRIPTION			H / BH 01	H / BH 04	H / BH 05	H / BH 06	H / BH 07	H / BH 08	H / BH 10	H / BH 11	H / BH 13
SAMPLE NUMBER			E53553-001	E53553-002	E53553-003	E53553-004	E53553-005	E53553-006	E53553-007	E53553-008	E53553-009
SAMPLED		Test Method **	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00
Remarks			Clear	Yellowish	Rusty	Clear	Clear	Clear	Clear	Brownish	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	329	478	280	428	336	326	318	214	332
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	329	478	280	428	336	326	318	214	332
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	329	478	280	428	336	326	318	214	332
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	97.5	147	72.9	138	130	93.4	102	50.4	84.7
pH (Laboratory)		YE030pH	7.14	6.97	7.19	7.16	7.05	7.09	7.08	7.55	7.03
Total Hardness	mg $CaCO_3$/L	YE061H	374	762	297	739	510	329	372	109	304
Calcium Hardness	mg $CaCO_3$/L	YE061H	122	227	50.7	249	220	152	171	32.2	120
Magnesium Hardness	mg $CaCO_3$/L	YE061H	252	535	247	490	290	177	201	77.0	184
Total Dissolved Solids (TDS)	mg/L	Calculation	456	866	415	795	781	580	650	309	480
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	1.11	2.65	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	48.7	90.9	20.3	99.7	88.2	60.9	68.6	12.9	48.0
Chloride	mg Cl/L	YE070AK	38.0	204	36.9	172	177	63.8	72.2	30.2	50.3
Magnesium	mg Mg/L	YE060ICP	61.2	130	59.9	119	70.4	43.0	48.7	18.7	44.7
Nitrate and Nitrite (TON)	mg N/L	YE070AK	0.37	0.72	0.47	8.81	17.8	12.0	23.4	2.06	7.06
Ortho Phosphate	mg P/L	YE070AK	<0.03	0.35	<0.03	<0.03	<0.03	0.03	0.11	0.06	<0.03
Potassium	mg K/L	YE060ICP	6.33	19.1	8.95	5.55	7.31	16.2	13.3	16.7	13.9
Sodium	mg Na/L	YE060ICP	33.2	27.7	43.5	20.4	82.2	75.5	78.4	68.1	61.1
Sulphate	mg SO_4/L	YE070AK	68.6	101	71.3	81.6	73.9	70.4	73.0	24.5	30.4
Bromide	mg Br/L	YE070AK	0.21	0.12	<0.01	1.09	1.00	0.58	0.69	0.40	0.37
Fluoride	mg F/L	YE070AK	0.27	0.31	<0.09	0.20	0.39	0.27	0.32	<0.09	0.27
Iron	mg Fe/L	YE060ICP	<0.01	0.07	0.36	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	mg Pb/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	0.03	0.13	<0.01	<0.01	<0.01	0.03	0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-0.20	0.03	-0.60	0.22	-0.05	-0.17	-0.14	-0.53	-0.32
pHs (indicative, not SANS)		Calculation	7.34	6.94	7.79	6.94	7.10	7.26	7.22	8.08	7.35
Sodium Absorption Ratio (indicative)		Calculation	0.74	0.43	1.09	0.32	1.58	1.80	1.76	2.82	1.52
TDS to EC Ratio (indicative, not SANS)		Calculation	4.67	5.89	5.69	5.76	6.01	6.21	6.38	6.14	5.66
Corrosion Ratio (indicative, not SANS)		Calculation	0.43	1.31	0.50	1.23	1.60	0.66	0.76	0.46	0.48
Ryznar Index (indicative, not SANS)		Calculation	7.54	6.91	8.38	6.72	7.15	7.43	7.36	8.62	7.66
Anion Sum			9.14	17.60	8.17	15.83	14.62	10.70	11.66	5.81	9.24
Cation Sum			9.15	17.17	8.35	15.95	14.06	10.34	11.26	5.60	9.15
Difference			0.01	-0.43	0.18	0.12	-0.56	-0.35	-0.40	-0.21	-0.08
% Difference			0.07%	-1.24%	1.09%	0.38%	-1.96%	-1.69%	-1.74%	-1.84%	-0.45%

Methods adapted to accommodate local laboratory conditions. SM refers to the Standard Methods for the Examination of Water and Wastewater.

Unless analysis is indicated as "Total", tests are performed on filtered samples as per ISO 11885.

Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or other national or international standards,**

YANKA LABORATORIES
CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 10	SpShangoni 11	SpShangoni 12	SpShangoni 13	SpShangoni 14	SpShangoni 15	SpShangoni 16	SpShangoni 17	SpShangoni 18
SAMPLE DESCRIPTION			H / BH 14	H / BH 15	H / BH 17	H / BH 19	H / BH 20	H / BH 21	H / BH 22	H / BH 24	H / BH 27
SAMPLE NUMBER			E53553-010	E53553-011	E53553-012	E53553-013	E53553-014	E53553-015	E53553-016	E53553-017	E53553-018
SAMPLED		Test Method **	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00
Remarks			Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Brownish
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	318	314	354	244	284	250	340	300	318
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	318	314	354	244	284	250	340	300	318
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	318	314	354	244	284	250	340	300	318
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	81.4	102	237	105	85.6	122	135	84.4	255
pH (Laboratory)		YE030pH	7.49	7.29	7.04	7.86	7.36	7.61	7.41	7.42	7.28
Total Hardness	mg $CaCO_3$/L	YE061H	390	357	951	321	334	528	454	384	684
Calcium Hardness	mg $CaCO_3$/L	YE061H	139	154	419	67.7	91.9	205	216	145	290
Magnesium Hardness	mg $CaCO_3$/L	YE061H	251	203	531	253	242	324	238	239	394
Total Dissolved Solids (TDS)	mg/L	Calculation	487	587	1493	647	548	769	877	491	1470
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	0.89	0.76	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	55.5	61.8	168	27.1	36.8	81.9	86.4	57.9	116
Chloride	mg Cl/L	YE070AK	35.6	95.5	459	100	57.5	181	133	59.7	652
Magnesium	mg Mg/L	YE060ICP	61.0	49.3	129	61.4	58.8	78.6	57.9	58.1	95.7
Nitrate and Nitrite (TON)	mg N/L	YE070AK	0.78	6.70	24.7	2.66	12.8	13.0	13.9	9.24	0.46
Ortho Phosphate	mg P/L	YE070AK	<0.03	<0.03	<0.03	0.28	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium	mg K/L	YE060ICP	19.5	10.5	27.0	21.2	18.8	22.1	27.1	8.58	1.90
Sodium	mg Na/L	YE060ICP	22.2	85.1	145	97.0	57.6	53.4	119	31.6	293
Sulphate	mg SO_4/L	YE070AK	99.2	65.4	239	179	90.3	143	185	53.5	106
Bromide	mg Br/L	YE070AK	0.10	0.65	3.62	0.46	<0.01	0.78	1.19	0.35	4.93
Fluoride	mg F/L	YE070AK	<0.09	0.52	0.36	0.39	0.14	<0.09	0.58	0.28	4.58
Iron	mg Fe/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.11
Lead	mg Pb/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10
Langelier Index (indicative, not SANS)		Calculation	0.19	0.02	0.22	0.12	-0.17	0.35	0.30	0.11	0.25
pHs (indicative, not SANS)		Calculation	7.30	7.27	6.82	7.74	7.53	7.26	7.11	7.31	7.03
Sodium Absorption Ratio (indicative)		Calculation	0.49	1.95	2.04	2.34	1.36	1.01	2.42	0.70	4.85
TDS to EC Ratio (indicative, not SANS)		Calculation	5.99	5.76	6.30	6.16	6.40	6.30	6.49	5.82	5.76
Corrosion Ratio (indicative, not SANS)		Calculation	0.48	0.97	4.01	1.54	0.74	2.34	1.39	0.65	5.96
Ryznar Index (indicative, not SANS)		Calculation	7.11	7.25	6.61	7.62	7.71	6.90	6.80	7.20	6.78
Anion Sum			9.50	10.89	27.01	11.71	10.13	14.09	15.50	9.50	27.60
Cation Sum			9.34	11.19	26.22	11.31	9.80	13.56	15.07	9.35	26.58
Difference			-0.16	0.30	-0.79	-0.40	-0.33	-0.53	-0.44	-0.16	-1.01
% Difference			-0.87%	1.36%	-1.49%	-1.75%	-1.67%	-1.93%	-1.42%	-0.82%	-1.87%

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YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 19	SpShangoni 20	SpShangoni 21	SpShangoni 22	SpShangoni 23	SpShangoni 24	SpShangoni 25	SpShangoni 26	SpShangoni 27
SAMPLE DESCRIPTION			H / BH 28	H / BH 29	H / BH 31	H / BH 32	H / BH 35	H / BH 36	H / BH 46	SW 01	SW 05
SAMPLE NUMBER			E53553-019	E53553-020	E53553-021	E53553-022	E53553-023	E53553-024	E53553-025	E53553-026	E53553-027
SAMPLED		Test Method **	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00
Remarks			Clear	Clear	Clear	Clear	Clear	Clear	Clear	Yellowish	Yellowish
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	386	382	268	363	359	377	237	57.2	147
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	386	382	268	363	359	377	237	57.2	51.0
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.0
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	386	382	268	363	359	377	237	57.2	98.6
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.0
Conductivity (Laboratory)	mS/m	YE020CON	108	119	60.4	88.4	140	109	177	13.9	82.6
pH (Laboratory)		YE030pH	7.41	7.54	7.32	7.31	7.26	7.30	7.36	7.19	8.52
Total Hardness	mg $CaCO_3$/L	YE061H	363	356	290	211	338	305	681	54.5	240
Calcium Hardness	mg $CaCO_3$/L	YE061H	197	164	85.1	94.6	159	151	310	24.5	104
Magnesium Hardness	mg $CaCO_3$/L	YE061H	166	192	205	117	178	154	371	30.0	136
Total Dissolved Solids (TDS)	mg/L	Calculation	650	738	341	515	876	657	1088	73.4	491
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	0.60	<0.45
Calcium	mg Ca/L	YE060ICP	78.7	65.7	34.1	37.9	63.8	60.4	124	9.80	41.7
Chloride	mg Cl/L	YE070AK	96.3	152	21.2	53.9	166	97.2	407	5.40	176
Magnesium	mg Mg/L	YE060ICP	40.4	46.7	49.8	28.3	43.3	37.5	90.1	7.29	33.1
Nitrate and Nitrite (TON)	mg N/L	YE070AK	10.3	3.70	2.18	4.10	17.6	7.14	7.37	<0.35	0.69
Ortho Phosphate	mg P/L	YE070AK	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	1.25	0.21
Potassium	mg K/L	YE060ICP	16.9	8.93	7.90	2.43	41.1	14.9	11.2	3.02	10.6
Sodium	mg Na/L	YE060ICP	93.2	139	16.1	124	169	124	124	4.15	85.1
Sulphate	mg SO_4/L	YE070AK	45.9	78.4	41.1	30.5	96.5	63.3	155	3.17	52.6
Bromide	mg Br/L	YE070AK	0.81	1.01	0.21	0.28	1.19	0.71	1.26	<0.01	<0.01
Fluoride	mg F/L	YE070AK	0.53	0.59	0.14	0.80	0.69	0.68	0.36	0.47	0.34
Iron	mg Fe/L	YE060ICP	<0.01	<0.01	<0.01	0.08	0.08	<0.01	<0.01	1.12	0.10
Lead	mg Pb/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	0.33	0.37	-0.25	-0.10	0.04	0.09	0.25	-1.51	0.76
pHs (indicative, not SANS)		Calculation	7.08	7.17	7.57	7.41	7.22	7.21	7.11	8.70	7.76
Sodium Absorption Ratio (indicative)		Calculation	2.12	3.19	0.41	3.70	3.99	3.08	2.06	0.24	2.38
TDS to EC Ratio (indicative, not SANS)		Calculation	6.02	6.21	5.65	5.82	6.26	6.03	6.14	5.28	5.95
Corrosion Ratio (indicative, not SANS)		Calculation	0.77	1.23	0.30	0.46	1.44	0.81	5.18	0.30	3.56
Ryznar Index (indicative, not SANS)		Calculation	6.75	6.80	7.82	7.52	7.17	7.11	6.87	10.22	6.99
Anion Sum			12.21	13.94	6.99	9.78	15.26	12.21	20.16	1.51	9.15
Cation Sum			11.81	13.47	6.77	9.74	15.25	11.94	19.44	1.46	8.83
Difference			-0.40	-0.46	-0.22	-0.04	-0.01	-0.27	-0.72	-0.05	-0.32
% Difference			-1.67%	-1.70%	-1.60%	-0.23%	-0.04%	-1.11%	-1.83%	-1.61%	-1.78%

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YANKA LABORATORIES
CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 28	SpShangoni 29	SpShangoni 30	SpShangoni 31	SpShangoni 32	SpShangoni 33
SAMPLE DESCRIPTION			SW 06	SW 08	SW 09	SW 15	SW 17	SW 18
SAMPLE NUMBER			E53553-028	E53553-029	E53553-030	E53553-031	E53553-032	E53553-033
SAMPLED		Test Method **	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00	2022/02/07 00:00
Remarks			Yellowish	Brown	Murky	Yellowish	Clear	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	187	53.4	135	158	136	183
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	187	53.4	135	106	114	183
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	51.6	22.0	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	187	53.4	135	132	125	183
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	25.8	11.0	0.00
Conductivity (Laboratory)	mS/m	YE020CON	75.3	9.98	40.5	55.5	138	61.7
pH (Laboratory)		YE030pH	7.55	7.25	7.29	8.39	8.36	8.14
Total Hardness	mg $CaCO_3$/L	YE061H	219	37.5	143	160	317	242
Calcium Hardness	mg $CaCO_3$/L	YE061H	93.9	12.9	78.4	65.9	74.4	90.9
Magnesium Hardness	mg $CaCO_3$/L	YE061H	125	24.6	64.7	94.3	243	151
Total Dissolved Solids (TDS)	mg/L	Calculation	433	78.0	238	315	811	363
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	1.10	<0.45	<0.45	0.61	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	37.6	5.18	31.4	26.4	29.8	36.4
Chloride	mg Cl/L	YE070AK	126	3.89	51.6	72.8	340	71.6
Magnesium	mg Mg/L	YE060ICP	30.3	5.97	15.7	22.9	59.0	36.6
Nitrate and Nitrite (TON)	mg N/L	YE070AK	<0.35	0.68	0.74	1.01	<0.35	3.54
Ortho Phosphate	mg P/L	YE070AK	0.37	0.26	0.21	0.12	<0.03	<0.03
Potassium	mg K/L	YE060ICP	13.4	9.07	7.98	8.20	16.8	3.41
Sodium	mg Na/L	YE060ICP	72.1	7.04	27.8	53.4	170	41.0
Sulphate	mg SO_4/L	YE070AK	38.0	8.19	15.6	30.1	112	47.2
Bromide	mg Br/L	YE070AK	<0.01	<0.01	<0.01	<0.01	1.13	0.20
Fluoride	mg F/L	YE070AK	0.38	0.40	0.40	0.47	0.68	1.50
Iron	mg Fe/L	YE060ICP	0.25	1.95	2.09	<0.01	<0.01	<0.01
Lead	mg Pb/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg Mn/L	YE060ICP	0.10	0.08	0.02	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-0.14	-1.76	-0.59	0.49	0.40	0.43
pHs (indicative, not SANS)		Calculation	7.69	9.01	7.88	7.90	7.96	7.71
Sodium Absorption Ratio (indicative)		Calculation	2.11	0.50	1.01	1.83	4.13	1.14
TDS to EC Ratio (indicative, not SANS)		Calculation	5.75	7.81	5.87	5.67	5.88	5.89
Corrosion Ratio (indicative, not SANS)		Calculation	2.01	0.29	1.14	1.40	7.50	1.24
Ryznar Index (indicative, not SANS)		Calculation	7.83	10.77	8.48	7.42	7.56	7.28
Anion Sum			8.19	1.45	4.59	5.98	14.81	7.02
Cation Sum			7.99	1.41	4.41	5.81	14.24	6.75
Difference			-0.20	-0.04	-0.19	-0.17	-0.57	-0.27
% Difference			-1.26%	-1.25%	-2.06%	-1.42%	-1.97%	-1.99%

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