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Geohydrological Investigation on Remainder of Portion 3 of Coniston 699MS, Makhado LM, Limpopo Province

May 2022

Prepared for: Bertie van Zyl (Edms) Bpk
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Geohydrological Investigation on Remainder of Portion 3 of Coniston 699MS, Makhado LM, Limpopo Province

27 May 2022

Prepared For:
Bertie van Zyl (Edms) Bpk

For Attention:
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Executive Summary

AGES Alpha (Pty) Ltd was approached by ZZ2 to determine the available sustainable yield from the existing boreholes on the Remainder of Portion 3 of **Coniston 699MS** in the Makhado Local Municipality and to conduct a geohydrological investigation in support of licensing the proposed groundwater use.

The study area is located approximately 8 km east of Waterpoort and is approximately 595 ha in extent. The study area is underlain by various sedimentary formation of the Karoo Supergroup and is recharge predominantly from rainfall runoff from the Soutpansberg mountains. A total of 9 boreholes have been tested with a total sustainable yield recommendation of 74.5 m^3/a. Based on the yield assessment it was determined that:

1. No geohydrological boundaries were encountered during the yield test
2. The moderate yielding boreholes indicated that matrix flow is predominant and that no fractures where dewater during the testing process. This supports the proposition that impact from the regional faults have not been encountered in these boreholes.
3. The boreholes have a good water quality, indicative of fresh rainfall recharge

The geological setting of the study area is such that a localised aquifer or geohydrological response unit (GRU) can be determined for the study area. This is based on the local structural geological setting, geohydrological character of the geological formations and the topography.

Based on the groundwater balance for the area it was determined that a total amount of 846 500 m^3/a is available for abstraction in the specific aquifer.

Based on evaluation of the yield assessment data, sustainable groundwater abstraction recommendations where determined. The following presents a summary of the recommendations:

Item	*Amount*
Total Sustainable Yield per annum (m^3/a)	652,620 m^3/a
Total Sustainable Yield (m^3/hr)	74.50 m^3/hr
Total Sustainable Yield (l/s)	20.69 l/s
Average Installation Depth (mbgl)	83.00 m
Total Maximum Daily Abstraction (m^3/day)	1,785.20 m^3/day
Average Dynamic Water Level (mdgl)	58.22 m
Average Critical Water Level (mdgl)	69.78 m
Total Borehole Maximum Yield (m^3/hr)	98.40 m^3/hr

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1 Introduction

1.1 Background

AGES Alpha (Pty) Ltd was approached by ZZ2 to determine the available sustainable yield from the existing boreholes and to conduct a geohydrological investigation in support of the water use licence application (WULA) for the proposed groundwater use on Remainder of Portion 3 of **Coniston 699MS**. The farm is located north of the Soutpansberg in the Makhado Local Municipality of Limpopo.

1.2 Objectives

The objective of the investigation is to:

1. Conduct a localised hydro-census to identify other water users in the vicinity,
2. Determine the status of the boreholes on the farm,
3. Calculate the sustainable yield of the boreholes and the groundwater water quality, and
4. Compile a geohydrological report detailing the findings in support of the WULA as per the required format and guidelines set out by DWS.

1.3 Terms of Reference

Based on a submitted proposal, AGES was appointed by Bertie van Zyl (Edms) Bpk (ZZ2) to conduct the groundwater resource assessment and geohydrological investigation in support of the water use licence application (WULA).

1.4 Project Locality

Details regarding the location and spatial extent of the project area are presented in Table 1 and illustrated in Figure 1.

Table 1: Project Locality

Province	Limpopo
Municipality	Makhado Local Municipality
Study area	Coniston 699MS is situated approximately 8 km east of Waterpoort. The farm is accessed from the R523 which links the N1 north of Louis Trichardt and R521 north of Vivo.
Farms	Remainder of Portion 3 of Coniston 699, MS
Size	593.94 ha (based on SG data)
Location	Latitude: **-22.8747°S** Longitude: **029.6869°E** Altitude: 1 345 to 1 346 mamsl

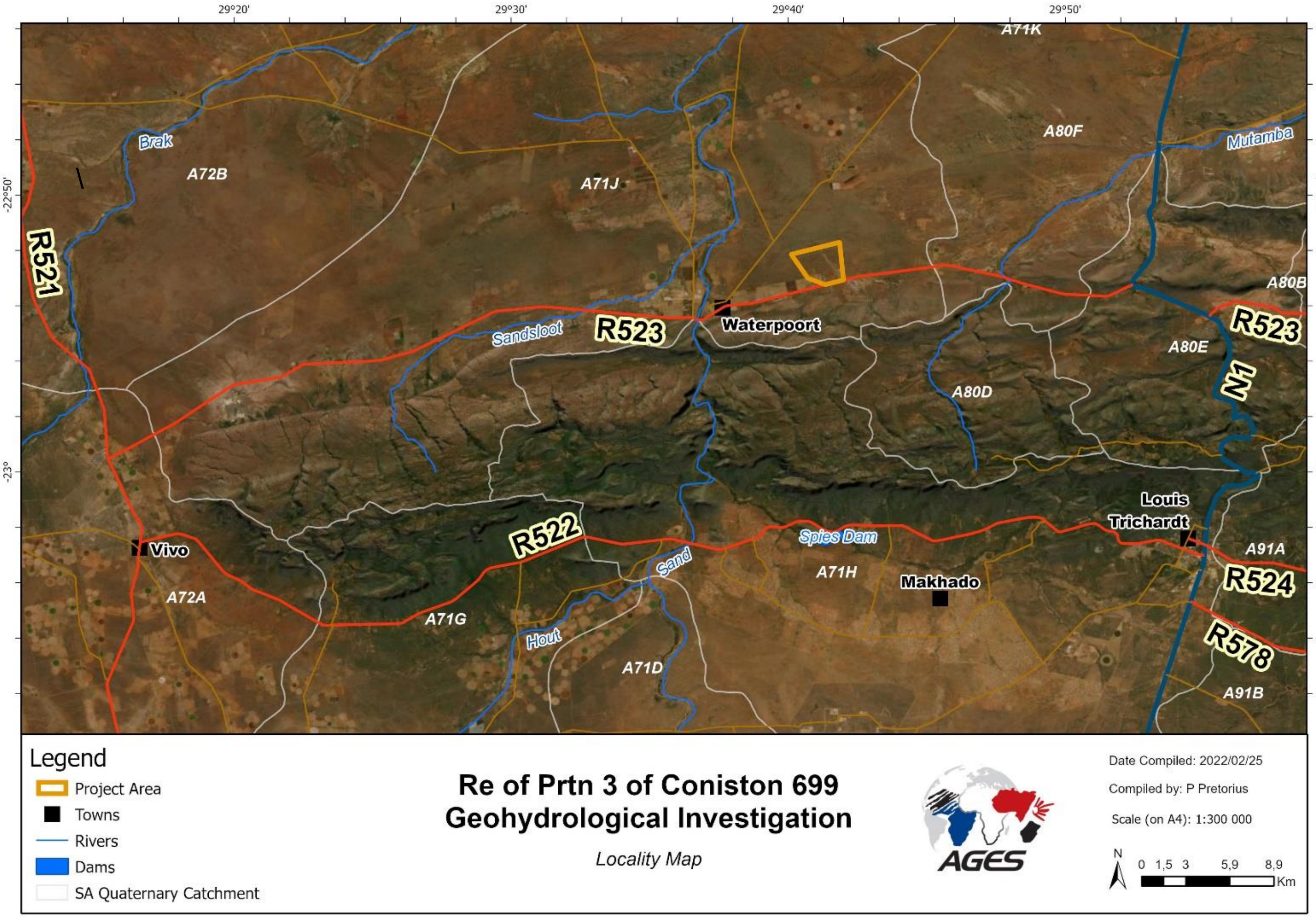

Figure 1: Project Locality Map

Photo 1: Photos from the Study Area

2 Geographic Setting

The geohydrological character of a specific area is generally influenced by the surface topography, drainage systems, climate, vegetation, the underlying geology, and the hydrogeological properties of the geological formation. Table 2 presents the general setting which is considered in evaluation of the groundwater potential of the area:

Table 2: Geographic setting

Climate and Rainfall	The area falls in the summer rainfall region of South Africa, with rainfall typically occurring between October and April. The Mean Annual Precipitation (MAP) for the area is highly variable, with a minimum of 90 mm/year, maximum of 620 mm/year - an average of **330 mm/year**. The average year on year variation of 145 mm/year. The average evaporation of the study area is 2300 mm/year (Figure 2).
Topography	The study area is at the foot of the Soutpansberg mountain, but is characterised as slightly undulating, with an elevation difference of 20 m across the site. The maximum slope across the study area is 1.8%.
Surface Water Drainage and Dams	Surface water from the study area drains in a north-north-western direction towards the Sand River located 5.5km away from the study area. The upstream surface water catchment area for the study area is 4 200 ha and is presented on Figure 2.
Quaternary Catchment	A71J
Water Management Area	Limpopo WMA
Vegetation	The natural vegetation cover is bush and savanna type (bushveld) dominated by grasses and shrubs, with scattered trees.
Regional Geology	The project area is directly underlain by sedimentary formations of the **Karoo Supergroup**, with a complex network of faulting systems.
Regional Geohydrology	The regional geohydrological setting of the study area is influenced by a complex network of geological faults and fractures. Groundwater flow will be in a general east-west direction (WSM, 2021).
Groundwater Recharge	• 12 – 20 mm/year (3.6 to 6 % of MAP; Vegter, 1995) • 10 – 30 mm/year (3 – 9.1 % of MAP, WR 2012)
Groundwater Exploitation Potential	7 800 to 10 000 m^3/ Km^3/ annum (WR2012 – PGEP Dry) 7 800 m^3/ Km^2/ annum (Harvest Potential)
Aquifer Type	Intergranular and fractured aquifer
Expected Transmissivity	<250 m^2/day
Typical Yield	2 to 5 ℓ/s, per borehole

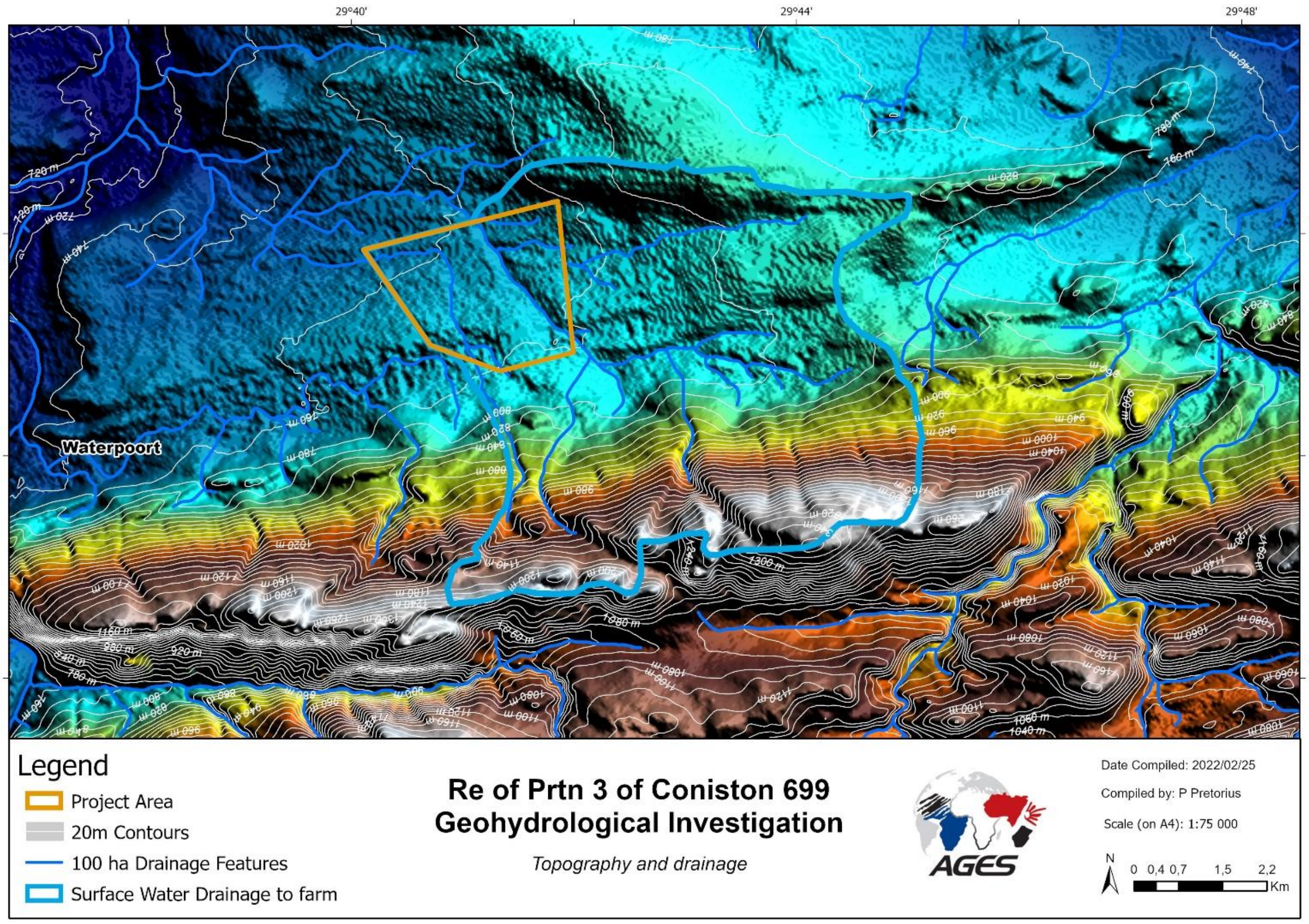

Figure 2: Regional Topography

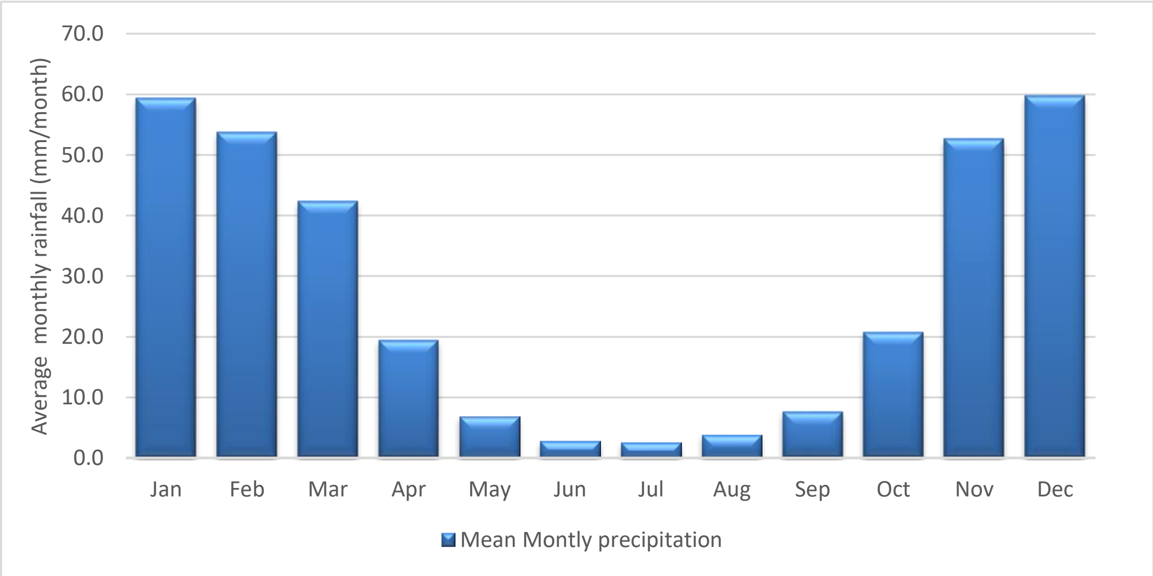

Figure 3: Monthly Rainfall

3 Nature of Investigation

The aim of the project is to establish the available, sustainable groundwater potential from the aquifer(s) underlying the study area and to determine the sustainable yield from the existing boreholes. The geohydrological investigation is in support of the water use licence application for proposed groundwater use on the Remainder Portion 3 of Coniston 699MS.

3.1 Desk Study

Desktop assessment of geological and geohydrological properties of the study area, including:

- Available geological and geohydrological information (1:250 000 3122 Pretoria)
- Review of existing reports for the local and regional area
- Evaluation of aerial imagery and topography data of the study area
- Review the existing geohydrological and other pertinent information regarding the development and use of boreholes in the vicinity
- Compile base maps illustrating the known geological- and geohydrological information

3.2 Site Assessment

Evaluation of the study area to determine if any possible aquifer pollution sources may be present, to establish the current practices on site and to review the general geological setting of the study area.

3.3 Hydro-census – Existing Boreholes

A hydro-census was conducted in the study area. This includes borehole positions, use, status, water level and borehole depth (where possible).

3.4 Testing of Existing Boreholes

Yield tests have been conducted on the nine (9) existing boreholes in November 2018. The pumping tests were conducted according to DWS and SANS 10299-4 minimum standards to determine the sustainable yield of the groundwater resource. This included conducting a Step Test, Constant Discharge Test and Water Level Recovery Test. The results from the yield tests were used to calculate the hydraulic properties of the local aquifer, to determine the sustainable yield of the boreholes and to make recommendations regarding the long-term use of the groundwater. Based on the 2022 borehole water level survey the tests are still representative no major changes in the water level has taken place.

3.5 Sighting and Drilling of New Boreholes

No geophysical surveying or sighting of new boreholes was conducted as part of this investigation.

3.6 Sampling and Chemical Evaluation

Groundwater water samples were collected from 4 of the production boreholes. The water samples were analysed, and the results are used to determine the suitability of the groundwater as supplementary irrigation water supply to the **agricultural activities** on site. Further, the results of the groundwater quality provide a background water quality and can be used as a **baseline reference** to determine the impact of activities on site on the groundwater regime. Finally, the concentration of the conservative ions (chloride) in the groundwater analysis is used to improve the **estimated recharge** to the localised aquifer, and hence the sustainable groundwater potential for the area.

3.7 Groundwater Recharge Calculations

Groundwater recharge is a measure of the rate/ volume of replenishment of water into the aquifer. This water may be from rainwater, surface water runoff, rivers, or surface water features such as dams/ ponds. The recharge may be represented as a total volume, a percentage of rainfall, or as a measure of rainfall. The choice for recharge calculations in this investigation are based on the availability of long-term monitoring and point data. The recharge parameters presented in this report are based on the Groundwater Resource Assessment II (DWAF, 2006), the recharge maps by Vegter (1995), and the localised recharge calculated using the chloride method.

3.8 Groundwater Balance

To determine the sustainable volume of groundwater abstractable from the aquifer, a "box model" based groundwater balance was calculated for the study area. This includes groundwater recharge and groundwater losses – including baseflow, changes in groundwater storage and groundwater abstraction.

3.9 Aquifer Classification

The aquifer classification scheme (Parson, 1995) was created for strategic purposes as it allows the grouping of aquifer areas into types according to their supply potential, water quality and local importance as a resource. Parson's classification system together with the revised version produced by DWS in 1998 is shown in Table 3.

The strata underlying the study area is deemed to define a **MINOR AQUIFER** in the southern section of the study area and a **MAJOR AQUIFER** in the northern section. The southern section is a localised aquifer system recharged from rainfall runoff from the Soutpansberg, whereas the northern aquifer is related to deep fault systems in the Karoo Sequence, where the material has become brittle and highly fractured.

Table 3: Aquifer Classification Scheme (Parson, 1995)

Aquifer System	Defined by Parsons (1995)	Defined by DWAF Min Requirements (1998)
Sole Source Aquifer	An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. 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	High 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 (<150 mS/m).	High yielding aquifer (5-20 L/s) of acceptable water quality.
Minor Aquifer	These can be fractured or potentially fractured rocks, which do not have a high primary permeability or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying baseflow 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 permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and need to be considered when assessing the risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 L/s) of good quality water or moderately yielding aquifer (1-5 L/s) of poor quality or aquifer 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.	An aquifer designated as such by the Minister of Water Affairs, after due process.

3.10 Impact Assessment

The possible environmental impacts that may arise from the groundwater abstraction on a local and regional geohydrological environment are considered using the industry-standard semi-quantitative risk assessment methodology. The impact assessment is done according to:

- Severity of the impact
- Duration of the impact
- Extent of the impact
- Frequency of the impact
- Probability of the impact

This system derives environmental significance on the basis of the consequence of the impact on the environment and the likelihood of the impact occurring. Consequence is calculated as the average of the sum of the ratings of severity, duration, and extent of the environmental impact, while likelihood considers the frequency of the activity together with the probability of an environmental impact occurring. These factors are addressed as follows:

Consequence is calculated as the average of the sum of the ratings of severity, duration, and extent of the environmental impact, and **Likelihood** considers the frequency of the activity together with the probability of the environmental impact associated with that activity occurring.

Table 4: Impact Assessment Methodology

Rating		Description		
Severity	1	Insignificant	Negligible/ non-harmful / minimal deterioration	**Consequence**
	2	Minor	Minor/ potentially harmful / measurable deterioration	
	3	Moderate	Moderate / harmful / moderate deterioration	
	4	Major	Significant / very harmful / substantial deterioration	
	5	Catastrophic	Irreversible / permanent	
Duration	1	Short term	Less than 1 month / quickly reversible	
	2	Construction	Less than 1 year / quickly reversible	
	3	Life of project	More than 1 year / reversible over time	
	4	Post project	More than 10 years / reversible over time / life of project or facility	
	5	Permanent	Beyond life of project of facility / permanent	
Extent	1	Site specific	Within immediate area of activity	
	2	Local	Surrounding area within project area	
	3	District	Beyond project boundary	
	4	Provincial	Gauteng	
	5	National	Across all provinces	
Frequency	1	Less than once a year	Occurrence of impact less than once per year	**Likelihood**
	2	Once a year	Occurrence of impact once per year	
	3	Quarterly	Quarterly occurrence of impact	
	4	Weekly	Weekly occurrence of impact	
	5	Daily	Daily occurrence of impact	
Probability	1	Almost impossible	May occur in exceptional cases	
	2	Unlikely	Could occur at some time	
	3	Probable	Might occur at some time	
	4	Highly likely	Will occur in most circumstances	
	5	Definite	Expected to occur	

Overall significance of an event on the risk of groundwater pollution is determined using the matrix below to determine the overall risk rating:

	Consequence				
Likelihood	1	2	3	4	5
	2	4	6	8	10
	3	6	9	12	15
	4	8	12	16	20
	5	10	15	20	25

Rating	Score
Low (L)	0 – 4
Medium (M)	5 – 14
High (H)	15 – 25

A Low, Medium, or High risk is then allocated to the specific impact to determine if the proposed mitigation measures are adequate.

3.11 Reporting

All the data is assessed, and the methodology, results and recommendations are collated into a single report which is based on:

- Regulations regarding the procedural requirements For Water Use License Applications and Appeals – Geohydrology Technical Report Framework. Government Gazette. 24 March 2017. No.40713.
- Requirements for Water Use License Application: Groundwater Abstraction [S21(a)]

4 Geohydrological Description

4.1 Regional Geology

The regional geology is presented on the 1:250 000 scale geological map series (2228, Beit Bridge) by three main lithological groups, The Soutpansberg Group, the Karoo Sequence, and the Limpopo Mobile Belt.

4.1.1 The Limpopo Belt

Although the rocks from the Limpopo Belt do not outcrop in the study area, it is important to note that the Karoo Formations describe below are set in graben type basins on top of the Limpopo Belt that were formed before the break-up of Gondwanaland (Brand, 2002). The Limpopo Belt is an E-NE trending zone of high metamorphic grade rocks that developed between the Zimbabwe Craton to the north and the Kaapvaal Craton to the south. The Limpopo Mobile Belt has outcrops that extend over a distance of 600km and are up to 300km wide in places, (Pretorius, 1986).

4.1.2 Soutpansberg Group

The northern foot of the prominent Soutpansberg Mountain range is underlaying the southern part of the Study area. The Soutpansberg Group consist of a ~ 1850 Ma volcano-sedimentary sequence deposited in an E-W extended rift basin (Brandl, 2002).

The Soutpansberg Group consist of different formations of which only the Wylliespoort Formation occurs in the study area. This formation consists of a thick layer of weathered, resistant quartzite that give rise to the topographical elevated mountainous area formed by reversed topography. Only a shallow soil covers the massive quartzite layers that dips between 20 to 50° to the North. This give rise to topographical ridges to the north where the Soutpansberg Group is bordered discordant by the Klein Tsipise fault with the Karoo Group to the north.

4.1.3 Karoo Sequence

The study area is mainly underlain by chronological units from sedimentary origin which form part of the Karoo Sequence in the Limpopo Province.

It forms part of the so called Soutpansberg Coalfield in the Karoo Sequence as hosted by the Soutpansberg Basins (Malaza 2014), situated north of the Soutpansberg Mountain Range, and extend from Waterpoort in the west to the Kruger National Park in the east, and extent of over 200 km in length (Bandl 1981).

The shape and setting of the Karoo Sequence is controlled by ENE-WSW faults, developed regionally over hundreds of kilometres, and responsible for the development of a horst and graben delineation of the formations. The rocks of the Karoo Sequence strike E-W dipping between 5 to 15° to the north (Brandl 1981).

The Karoo Sequence is represented by the following subdivisions in the study area, and occur sequentially from north to south, in E-W extended zones through the study area (2228 Alldays 1:250 000 Geological map, council for Geoscience, 2000 with reference to Brandl 2002).

- The Tsidzi formation is the deepest and oldest deposit of the Karoo Super Group and consist of small patches of diamictites (glacial tillite) adjacent to the Klein Tsipise fault seated in argillaceous matrix and interbedded with course-grained sandstone, with maximum 10m thick. (This formation can be correlated to the Dwyka Tillite in the man Karoo Basin).
- This is followed by the Madzaringwe Formation to the north, the most prominent coal containing Formation in the Karoo Super Group. It consists of alternating felspathic sandstone, siltstone and shale with various prominent coal seams (Brandl 1981). The coal seams in this formation may of economic potential is some specific geo-spatial setting but is also an important zone for aquifer development in the study area. This zone can reach a thickness of 190m.
- The Mikanbeni Formation overlaying the main coal zone and consist of alternating dark grey mudstone and black shale, sandstone and minor coal seams to a total depth of 140m (Johnson et al., 2006). (The Madzaringwe and Mikanbeni Formations is correlated to the Ecca Group in the main Karoo Basin).
- This lower Karoo formations above is overlaying by the Fripp Sandstone Formation. This is a 10 to 20 thick formation of course felspathic sandstone that form sporadic prominent outcrops in the study area. This act as a marker horizon to distinguish between the lower Karoo with the Middle Karoo that consist more of alternating sandstone and variations in mudstones. The occurrence of the Fripp Sandstone is therefore also used to distinguish between different aquifer domains in the study area.
- The Solitude formation occur to the north of and overlaying the Fripp Sandstone and consist of purple to grey mudstone with occasional bands of black shale and coal at bottom parts. Greenish to reddish fine to course grained sandstones is developed to a 5 m thickness in places, with the Solitude formation developed to a total thickness of 110m.
- The Klopperfontein Formation consist of a medium to coarse grained felspathic sandstone with maximum depth of 20m.
- This is followed by the Bosbokpoort Formation consisting of red mudstone to very fine-grained red sandstone. This formation is developed to a 200 m thickness in the study area. It is flanked to the north with a prominent fault system developed throughout the study area. This fault zone narked the northern border of the aquifer area delineate

throughout the study area and represent a prominent change in geohydrological regime. A number of hot springs occurred along this fault in the past and drilling direct north of the fault indicate a totally different geological regime consisting mostly of a more homogeneous massive red mudstone succession.

- The Clarens Formation followed north of the Bosbokpoort formation and related fault system and consist of a lower sandstone member consisting of fine grained, light red argillaceous sandstone with patched of cream-coloured sandstone to a 150m width. This is overlain by the Tsipese member consisting of fine grained, well sorted, white or cream-coloured sandstone developed over a 150m width (Brandl 1981).

4.1.4 Recent Alluvial Formations

Erosion of Soutpansberg quartzite and Sandstone has formed alluvial deposits at the foot of the mountains in prominent drainage systems resulting in alluvial fans overlaying the prominent fault system between the Soutpansberg and Karoo formations. A prominent alluvial zone also occurs in association with the Sand River that defines the major drainage system through the study area. Saline evaporation pans are formed to the north of the Soutpansberg. The pans are formed by the leaching of the lower Karoo formations with salt then precipitating and concentrating in the evaporative pans. The saline alluvium occurs in the western portion of the study area and are important for this study as it is a potential source of contamination to deeper aquifers (AGES, 2007).

4.2 Structural Geology

The following structural geology plays a role in the definitions f the geological setting and in the development of a conceptual model to characterise the groundwater regimes in the study area.

4.2.1 Major Fault System

The tectonic evolution of the region has affected the geological setting of the Limpopo Belt, Soutpansberg Group and the Karoo Sequence on a regional scale - including the study area. This tectonic process has given rise to mega E-NE orientated fault structures developed over hundreds of kilometres with remobilisation over many geological periods, leading to duplication and displacements of formations on a regional scale.

In the study area this give rise to a faulted contact between the Soutpansberg Group to the south of the study area, and the Karoo Sequence to the north of the Soutpansberg Mountain. This fault system (referred to as the Soutpans Fault in some literature and the Klein Tsipese fault in others) is recorded as an almost vertical prominent fault zone between the two geological regimes (Barker 1983). The fault has a vertical displacement of up to 500 m along this major fault system (Brandl 1981).

This is a very important aspect in understanding the groundwater regime. The vertical orientation may lead to a "super" groundwater recharge zone at the foot of the Soutpansberg Mountain from surface water runoff from the mountain area. Recharge into this vertical fault zone may occur from where recharge to the Karoo strata to the north takes place.

One aspect of the structural geology of the region is that the major E-N-E orientated faults are accompanied by related ancillary fault connection which are interconnection with each other and spatially spread out through the region.

There is evidence that the contact between the Bosbokpoort Formation and the lower redbeds of the Tshipise formation is defined by such a fault system:

- Prominent linear structure observed on arial photos
- Interconnected with major faults to the west and the east of the study area
- Evidence of the presence of hot springs and hydro-thermal activity inferred from high water temperatures in boreholes
- Major difference in drilling results to a 500-m depth on both sides of the fault system.

This contact zone and fault system is therefore used as the northern border of the groundwater regime in the study area.

4.2.2 Ancillary Faults

It is also important to note that various such related ancillary faults with a major E-N-E orientation may occur in the study, giving rise to a complex spatial setting and inhomogeneity throughout the study area. The expected variation in different layers and displacement giving rise to a higher grade of weathering in depth, and the development of a wide spread of higher groundwater potential zones throughout the study area. The observation by Malaza (2014) that the Karoo Formations is defined and broken up in many fault blocks by strike faults on a regional scale may therefore also be true on a smaller scale within the study area.

4.2.3 Intersecting Fault Systems

The identification of linear structures with use of Aerial Photo Imagery interpretation indicates the existing of a different orientated intersecting set of N-NW faults. This is confirmed on a regional scale and relate to post Karoo tectonic activity on a more regional scale (Brandl 1981).

It is of interest to note that a main stress field reported in the regional coalfields' occurrence are characterised by a E-W to ENE-WSW extension and a N-S to NNW-SSE compression (Malaza 2014). This implies that the N-NW faults may be a more open structure than the E-W fault system that may give rise to preferred groundwater pathways of recharge from the southern Soutpansberg Mountain area and related fault on the foot of the mountain. This may be an important framework to the development of the conceptual groundwater model of the study area.

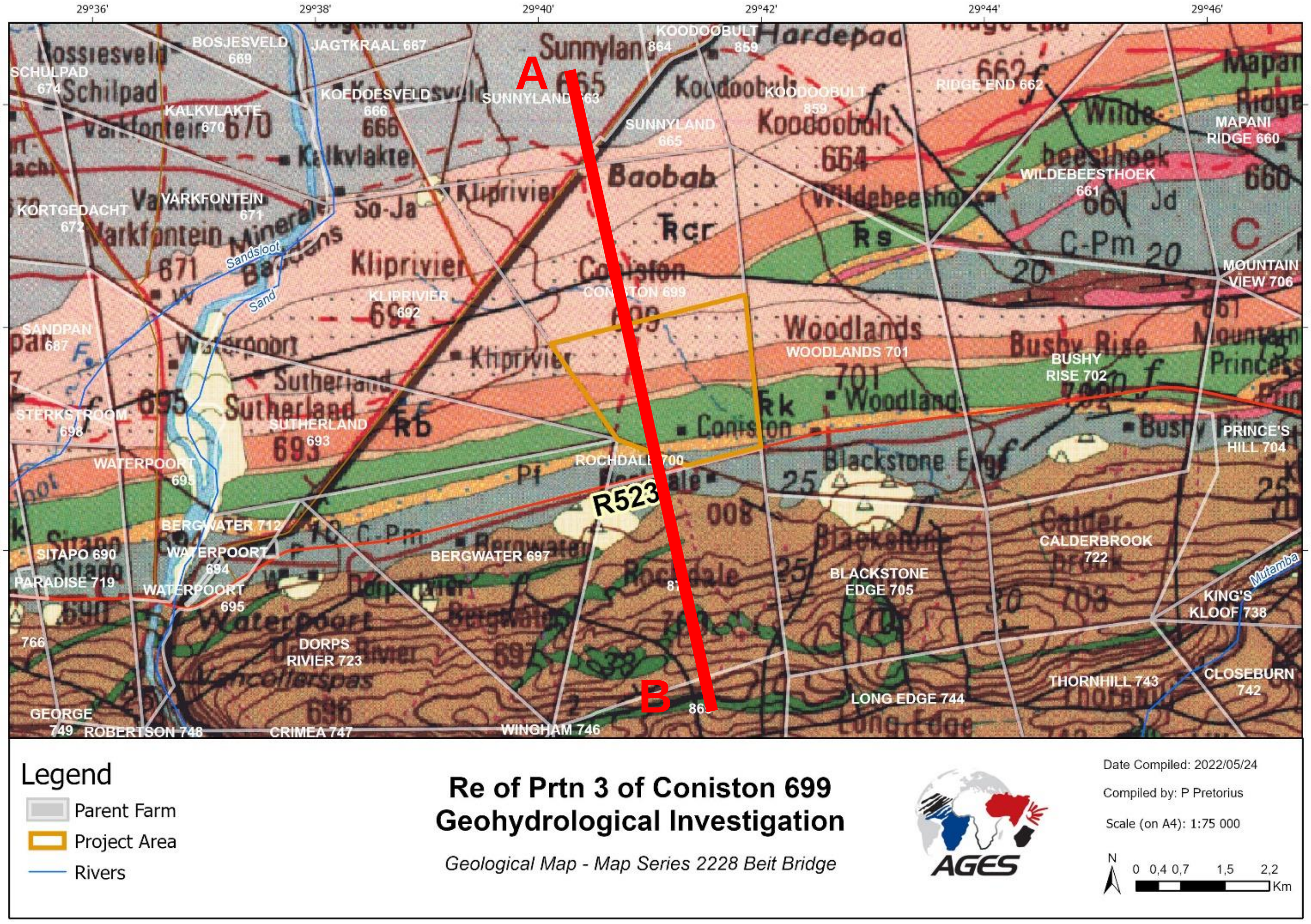

Figure 4: Geological Map

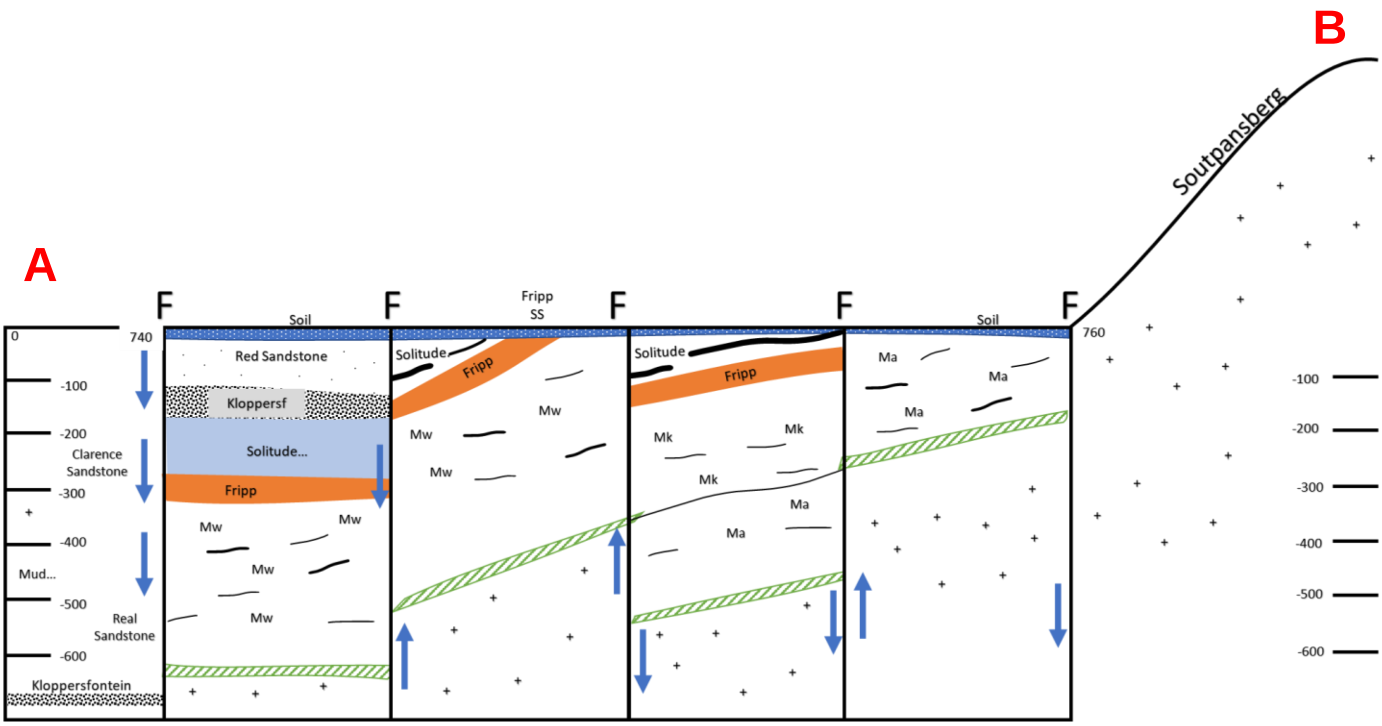

Figure 5: Geological Cross Section

4.3 Regional Hydrogeology – Aquifer Yield and Water Quality

Based on the available regional datasets, (1:500 000 Hydrogeological map series of RSA, 2127, Messina and Vegter, 1995) the aquifer is characterised as an intergranular and fractured aquifer with an expected borehole yields of between 2 l/s and 5 l/s. The Soutpansberg group to the south of the study area features as the prominent Soutpansberg, with runoff towards the north. The predominant quartzite formation has eroded to a shallow sandy soil with high recharge properties.

The East-West fault zones in the Karoo strata are characterised by zones of high transmissivity. Groundwater movement in these fault systems will occur in a predominantly East-West orientation. The regional aquifers are therefore recharge by rainfall recharge moving in a northern direction, infiltrating onto the SW-NE orientated fault systems. Groundwater recharge from the Soutpansberg related aquifers is fresh water (loe EC), with the Karoo related recharge tending to generally be more saline.

On a regional scale the identification of groundwater resource units is the basis to sustainable groundwater resource management. Internationally, the following criteria is used to identify groundwater management areas (Pretorius 2009):

- Differences is the nature of water-bearing rocks in various formations due to difference in fracturing and weathering character.
- Differences in sustainable volume of groundwater per area (harvest potential).
- Lithostratigraphic and structural geological differences and variations
- Topography and geomorphological character
- Surface water features
- Surface and groundwater interaction and groundwater recharge potential
- Management and functional criteria

Based on these criteria, the following aspects were used to delineate the groundwater management areas in the Waterpoort Area:

- The southern border of the aquifer zones is defined by the vertical fault system between the formations of the Soutpansberg Group to the south and the Karoo Sequence to the north.
- The northern border of the aquifer zones is defined by a prominent strike fault that occur in a E-NE direction through the study area. This fault defines a prominent different in the geological character and nature of water-bearing rocks on the northern and southern side of the fault. A massive almost homogenic red stone/ mudstone package characterise the geology to the north of the fault system, with almost no water-bearing rocks to a recorded depth of 500m. Drilling to the south of the fault reveal a prominent variation of sedimentary succession with various layers of water-bearing

rocks in depth as recorded to a 500m drilling depth. This represents the different north dipping formations from the lower Karoo to the south of the fault, displaced by the fault in depth to the north.

- The aquifer zone is divided along strike in a N-NE direction along the strike of the Fripp Sandstone horizon. This sandstone act as a marker horizon to distinguish between the Lower Karoo and the Middle Karoo. The Lower Karoo to the south (and underlaying) the Fripp sandstone included various horizons of water-bearing rocks as part of different shale, sandstone, and coal layers. The Middle Karoo to the north (and overlaying) the Fripp sandstone consist more of alternating sandstone and variations in mudstones, with less water-bearing rock horizons.
- The western groundwater management area is defined by this northern and southern border as above, with western side the disappearing of Karoo Formations against a set of N-NW orientated faults. The easter border of this aquifer is delineated against a prominent N-S fault system distinguishing between differences in surface drainage patterns and soil conditions with more salty surface water to the west.
- To the east, the central groundwater management area is also defined by the same northern and southern borders as above and represents an aquifer well known and monitored from ZZ2 management data at Sitapo. It is an area of high recharge from the mountains and in combination from the Sandriver drainage zone. To the east, this management zone is delineated against a N-NW orientated fault that distinguish a different in surface drainage patters as well as structural geology to the east.
- The eastern groundwater management area that includes the ZZ2 Coniston operation, is also defined by the same northern and southern borders as describe above. More homogeneous succession in the different Karoo formations is expected in this area, with various N-NW fault systems that can act as groundwater conduits, with recharge to deeper Karoo formations from the Soutpansberg Mountain and related major E-NE trending faults. The water divide is used as eastern border of this water management area.

4.4 Local Aquifer Properties – Hydro-census Data

Borehole data for the farm and adjacent farms has been collected on various occasions. The data presented on the map below includes data for Remainder of Portion 3 of Coniston 699MS, Woodlands 701, Rochdale 870, Blackstone and Portion 2 of Bergwater 697. A total of 11 boreholes were identified in the study area, with an additional 20 boreholes identified within a 3 km radius.

Table 5: Hydrocensus Data

Farm Name	ZZ2 WB Num	BH Num	Lat	Long	Elevation (mamsl)	Date	Data Source	Borehole Depth (m)	Water Lev (m)	Status
Bergwater	WB888	Bergwater 2	-22.88882	29.67551	774	2022	ZZ2	-	-	NIU
Bergwater	WB887	Bergwater 3	-22.88895	29.67464	776	2022	ZZ2	-	26.64	IU
Coniston	WB1594	Coniston 1	-22.88446	29.69846	785	2022	ZZ2	165	24.22	Proposed
Coniston	WB1595	Coniston 2	-22.88526	29.69639	786	2022	ZZ2	156	22.01	Proposed
Coniston	WB1596	Coniston 3	-22.88509	29.69596	786	2022	ZZ2	182	17.43	Proposed
Coniston	WB1597	Coniston 4	-22.88631	29.69182	783	2022	ZZ2	155	21.92	Proposed
Coniston	WB1598	Coniston 5	-22.88624	29.69103	784	2022	ZZ2	102	23.77	Proposed
Coniston	WB1599	Coniston 6	-22.88673	29.69034	782	2022	ZZ2	112	23.67	Proposed
Coniston	WB1600	Coniston 7	-22.88716	29.68921	782	2022	ZZ2	134	22.89	Proposed
Coniston	WB1601	Coniston 8	-22.88655	29.68869	781	2022	ZZ2	132	19.98	Proposed
Coniston	WB1602	Coniston 9	-22.88227	29.68726	778	2022	ZZ2	75	19.22	Proposed
Coniston	WB1736	Coniston 10	-22.88245	29.68862	779	2022	ZZ2	-	-	NIU
Coniston	WB1737	Coniston 11	-22.87067	29.68591	768	2022	ZZ2	-	-	NIU
Bergwater	WB755	Mynskag	-22.88762	29.67663	774	2022	ZZ2	-	-	NIU
Blackstone Edge	-	Bedg-B3	-22.88461	29.71074	789	2013	Ages	-	29.9	IU
Blackstone Edge	-	Bedg-B4	-22.88763	29.72727	805	2013	Ages	-	-	NIU
Blackstone Edge	-	Bedg-B5	-22.88213	29.73095	803	2013	Ages	-	12.5	NIU
Blackstone Edge	-	Bedg-B6	-22.88679	29.70869	782	2013	Ages	-	21.3	NIU
Blackstone Edge	-	Bedg-B7	-22.88940	29.70934	789	2013	Ages	-	18.3	NIU
Blackstone Edge	-	Bedg-BH21a	-22.88424	29.71078	782	2013	Ages	-	30.9	IU
Blackstone Edge	-	Bedg-BH21b	-22.88758	29.71292	788	2013	Ages	-	26	IU
Blackstone Edge	-	Bedg-S1	-22.88841	29.72790	807	2013	Ages	-	-	NIU
Bushy Rise	-	Brise-BH23	-22.87694	29.72972	804	2005	GCS	-	50.5	NIU
Rochdale	-	Roch-BH19	-22.89028	29.69250	786	2005	GCS	90	-	IU
Woodlands	-	Woo-1	-22.88702	29.70941	784	2013	Ages	-	-	IU
Woodlands	-	Woo-2	-22.87723	29.71567	791	2013	Ages	-	15.3	NIU
Woodlands	-	Woo-3	-22.87921	29.71609	789	2013	Ages	-	15.3	NIU
Woodlands	-	Woo-4	-22.87566	29.72225	795	2013	Ages	94	>94	NIU
Woodlands	-	Woo-5	-22.87821	29.72259	793	2013	Ages	-	-	NIU
Woodlands	-	Woo-BH20	-22.87833	29.70944	788	2005	GCS	-	16	NIU

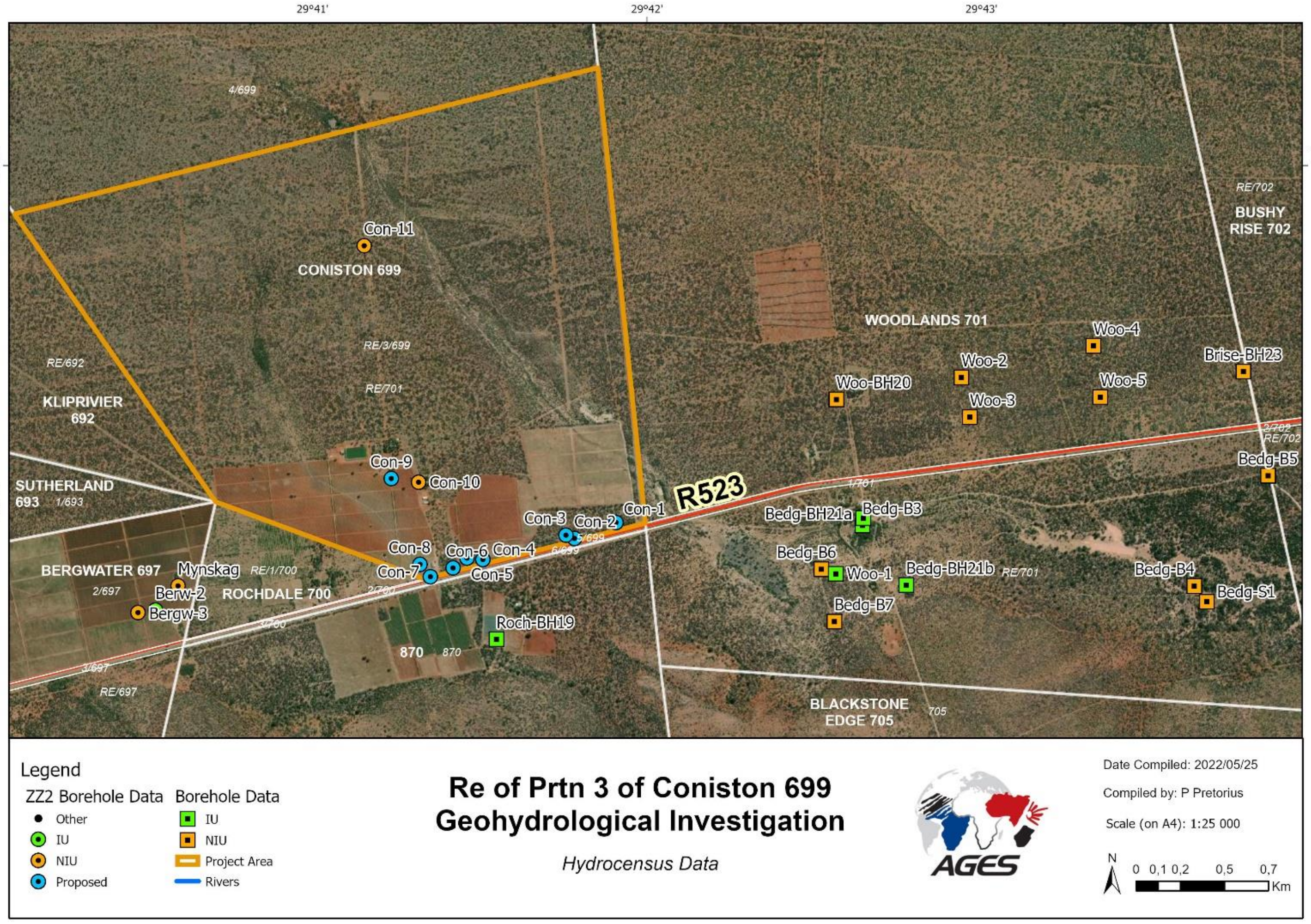

Figure 6: Hydro-census Data

Based on the hydro-census it was determined that no large-scale groundwater abstraction is currently taking place in the direct vicinity of the study area. Groundwater use in the 1km area is limited to use that can be regarded as General Authorisation use (although legal status of the boreholes has not been confirmed).

4.5 Local Aquifer Properties – Yield Testing

Sustainable utilization of a borehole is related to the development and yield potential of the borehole, as well as the productivity of the aquifer supporting the borehole. This information is obtained from the results of pumping tests performed on a borehole. The purpose for which the borehole is to be used, and the amount of water required from the borehole determine the nature and duration of the pump test conducted at the borehole.

Although pumping test pumping cannot be considered the ideal way of evaluating the long-term sustainability of a ground water resource, it does provide a quick and simple way of evaluating the short- to medium-term performance characteristics of a borehole. It must be emphasized that the results of calculations obtained from pump test data are only representative of the aquifer characteristics in the immediate vicinity of the borehole. Factors such as the duration of a test and the aquifer transmissivity will determine the area of influence reached during testing (the longer the test, the greater the area of influence). The greater the area of influence impacted, the greater the degree of certainty with which recommendations are made.

Typically, a short duration calibration pumping test is first conducted to identify a 'first order' borehole response to pumping. The calibration also helps to determine the depth of the primary groundwater bearing fracture. A constant rate pumping test rate is then selected based on the results of the calibration test. Ideally, a constant rate test is conducted at a sufficiently high rate, and for an adequate duration so that the declining water level reaches the main water bearing fracture. The greater the drawdown (expressed as a percentage of the available drawdown), the more accurate the assessment, and the greater the level of assurance for the recommended pumping rate.

It is very important to remember that sustainable utilisation of boreholes is a factor of the aquifer groundwater potential and aquifer management. Individual borehole tests are sufficient for making recommendations for pump size selection and for determining the sustainable yield of individual boreholes.

The properties of the local aquifer were determined based on the borehole yield assessments that were conducted on 9 boreholes across the site (Table 6).

Table 6: BH Testing Summary

Borehole Name	Coniston 1	Coniston 2	Coniston 3	Coniston 4	Coniston 5	Coniston 6	Coniston 7	Coniston 8	Coniston 9
Borehole Number	WB1594	WB1595	WB1596	WB1597	WB1598	WB1599	WB1600	WB1601	WB1602
Latitude	-22.88446	-22.88526	-22.88509	-22.88631	-22.88624	-22.88673	-22.88716	-22.88655	-22.88227
Longitude	29.69846	29.6963867	29.69596	29.69182	29.69103	29.69034	29.68921	29.68869	29.68726
Pump Test Date	20-11-2018	21-11-2018	21-11-2018	27-11-2018	4-12-2018	28-11-2018	29-11-2018	29-11-2018	13-11-2022
Tested By	Lukas	Lukas	Lukas Jnr	Lukas Jnr	Lukas	Lukas	Lukas	Lukas	Lukas
Borehole Depth	165	156	182	155	167	112	134	132	75
Static Water level (mbgl)	36.45	38.3	23.11	40.00	42.21	43.3	39.95	39.8	21
Pump Installation Depth	96	96	78	78	78	96	78	78	66
Available Drawdown	59.6	57.7	54.9	38.0	35.8	52.7	38.1	38.2	45.0
Calibration Test									
Comment	Constant inflow of 17m3/hr	Constant inflow of 17.5m3/hr	Casing in borehole not suitable for a 5 inch pump	Constant inflow of 25m3/hr	Constant inflow of 17.5m3/hr	Constant inflow of 37.5m3/hr		Constant inflow of 9.5m3/hr	Constant flow of 3.0 m3/hr
	Installation setting: 14m3/hr for 12hr pumping cycle	Installation setting: 14m3/hr for 12hr pumping cycle	Constant flow 9.5m3/hr	Installation at 20m3/hr	Installation setting at 105m, 12m3/hr for 12 hr pumping cycle.	Installation setting: 25m3/hr for 24hour pumping cycle or 30m3/hr for a 12hour pumping cycle.			
	Borehole and casing rehabilitation is needed	Borehole recovery = 100% after 15min	Installation setting: 6m3/hr						

Constant Rate Test									
CR - Abstraction Rate	17.5 m3/h	17 m3/h	9.5 m3/h	20 m3/h	17.5 m3/h	37.5 m3/h	18 m3/h	9.5 m3/h	3.1 m3/h
Duration (minutes)	360	360	360	300	210	360	300	360	540
Max Drawdown (m)	34.75	21.06	46	9.31	28.29	17.2	24.48	21.95	15.28
Drawdown (%)	58%	36%	84%	25%	79%	33%	64%	57%	49%
Transmissivity (m2/day)					In the order of 20-24m2/d				
Storativity					Uncertain due to no monitoring data				
Comments									
	Only 27% of AD was reached, thus a sustainable water level is uncertain.	Only 18% of AD was reached, thus a sustainable water level is uncertain.	Only 29% of AD was reached, thus a sustainable water level is uncertain.	The pump installation depth was very shallow, decreasing the available drawdown during the pumping test. Only 10% of AD was reached when considering the entire depth of the borehole, thus a sustainable water level is uncertain.	The pump installation depth was very shallow, decreasing the available draw down during the pump test. Only 23% of AD was reached when considering the entire depth of the borehole, thus a sustainable dynamic water level is uncertain.	Only 33% of AD was reached, thus a sustainable dynamic water level is uncertain.	Only 26% of AD was reached, thus a sustainable dynamic water level is uncertain.	Only 32% of AD was reached, thus a sustainable dynamic water level is uncertain.	Only 49% of AD was reached, thus a sustainable dynamic water level is uncertain.

	Rate of drawdown decreases with increasing depth, indicating a good fracture network	A fracture was dewatered after 40min. Rate of drawdown decreases significantly after 3 hours of pumping, indicating a good fracture network	Water level stabilizes after 46m drawdown indicating a good fracture.	Water level stabilizes after 10m drawdown indicating a good fracture.	2 fractures were dewatered after at 24 and 26m drawdown. Water level there after stabilizes after 28m drawdown indicating a good fracture network.	2 fractures were dewatered after at 12 and 13m drawdown. Water level there after stabilizes after 17m drawdown indicating a good fracture network. Infinite acting radial flow exists between the two fractures.	Log derivative plot indicates a moderately good fracture network. Since the aquifer was not stress fully during the pump test, it is uncertain whether a better fracture network is situated below the drawdown reached during the pump test	Coniston 7 is an exception to the area with a low transmissivity of 6m2/day resulting in a lower yield	
	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data	Storativity uncertain due to no monitoring borehole data		
			No recovery data	No recovery data	No recovery data	No recovery data	No recovery data	No recovery data	

4.5.1 Coniston 1:

- The borehole recovered 86% within 15 min after pumping stopped
- No monitoring data was available - Storativity value is therefore uncertain
- Rate of drawdown decreases with increasing depth, indicating a good fracture network

Utilisation Recommendations

- **9 m³/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 216 m³/day
- Install at 100mbdl
- Dynamic water level = 58 mbdl
- Borehole maximum abstraction rate = 12 m³/hour

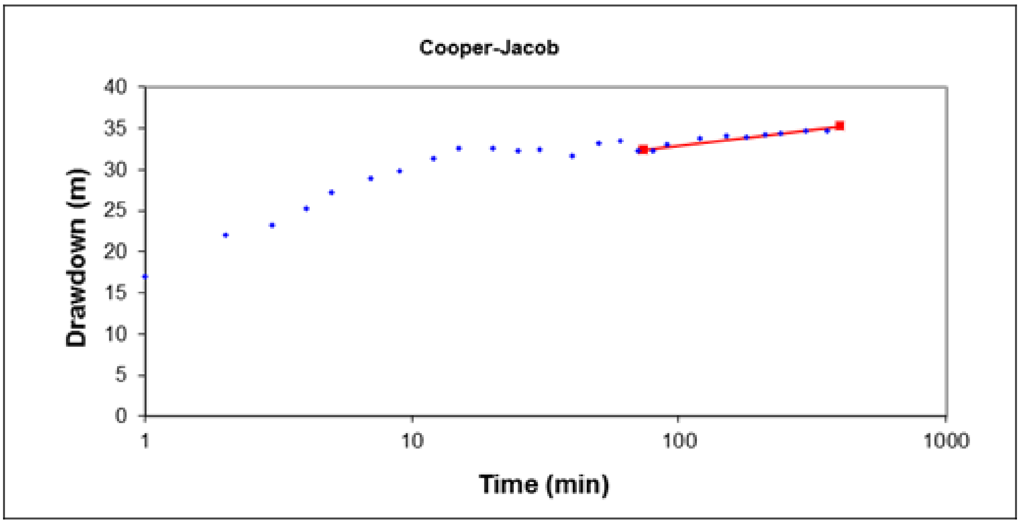

Figure 1: WB1594_Constant Rate Test

4.5.2 Coniston 2:

- The borehole recovered 90% within 15 min after pumping stopped
- No monitoring data was available - Storativity value is therefore uncertain
- A fracture was dewatered after 40 min
- Rate of drawdown decreases significantly after 3 hours of pumping, indicating a good fracture network
- Recovery measurements are not representative of the abstraction

Utilisation Recommendations

- **10 m³/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 240 m³/day
- Install at 100 mbdl
- Dynamic water level = 60 m
- Borehole maximum abstraction rate = 12.5 m³/hour

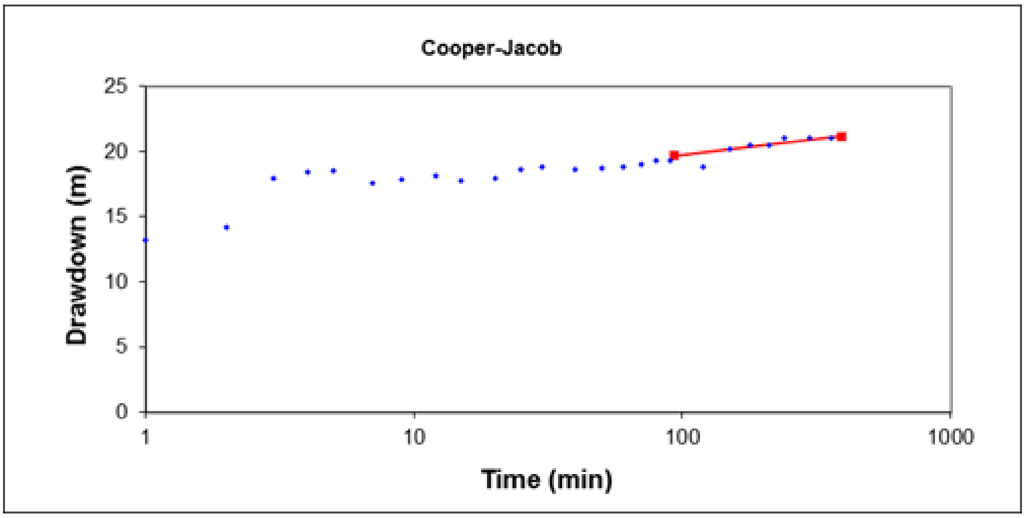

Figure 2: WB1595_Constant Rate Test

4.5.3 Coniston 3

- The borehole recovery data not given.
- No monitoring data was available - Storativity value is therefore uncertain
- Water level stabilizes after 46 m drawdown indicating a good fracture

Utilisation Recommendations

- **5 m^3/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 120 m^3/day
- Install at 80 mbdl
- Dynamic water level = 50 mblg
- Borehole maximum abstraction rate = 5.5 m^3/hour

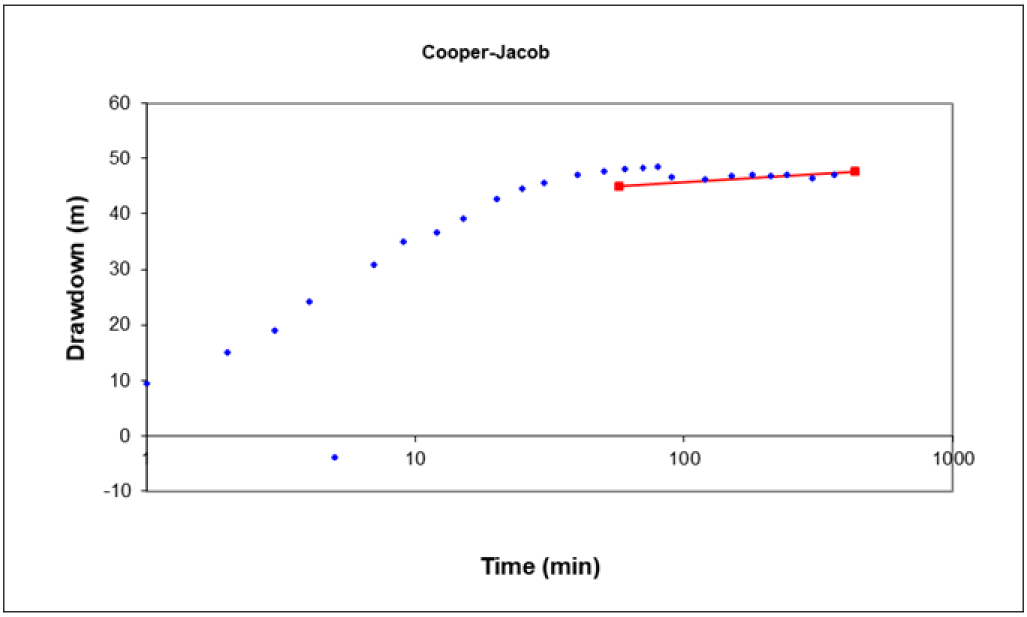

Figure 3: WB1596_Constant Rate Test

4.5.4 Coniston 4

- The borehole recovery data not given.
- No monitoring data was available - Storativity value is therefore uncertain
- Water level stabilizes after 9 m drawdown indicating a good fracture

Utilisation Recommendations

- **12 m^3/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 288 m^3/day
- Install at 80 mbdl
- Dynamic water level = 54 mblg
- Borehole maximum abstraction rate = 16 m^3/hour

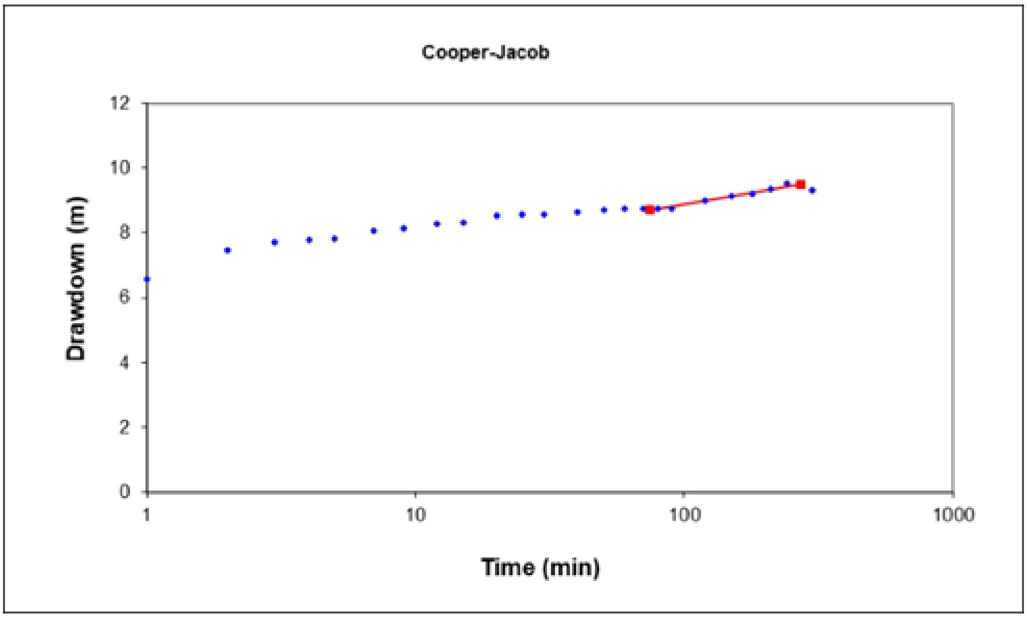

Figure 4: WB1597_Constant Rate Test

4.5.5 Coniston 5

- The borehole recovery data not given
- No monitoring data was available - Storativity value is therefore uncertain
- Water level stabilizes after 28 m drawdown indicating a good fracture

Utilisation Recommendations

- **7.2 m^3/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 170 m^3/day
- Install at 80 mbdl
- Dynamic water level = 71 mblg
- Borehole maximum abstraction rate = 9 m^3/hour

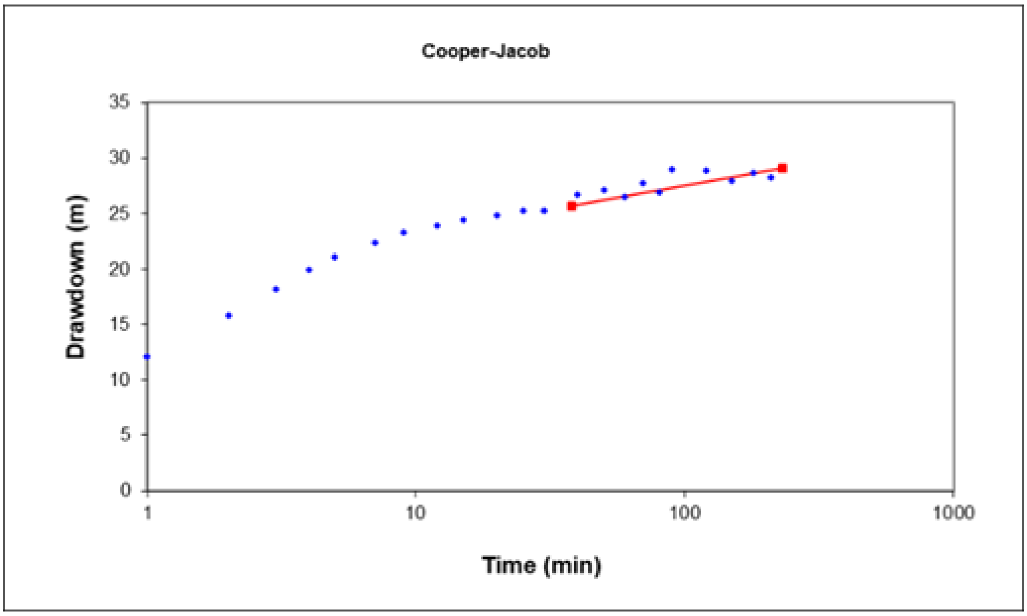

Figure 5: WB1598_Constant Rate Test

4.5.6 Coniston 6

- The borehole recovery data not given
- No monitoring data was available - Storativity value is therefore uncertain
- Water level stabilizes after 17 m drawdown indicating a good fracture

Utilisation Recommendations

- **18 m^3/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 432 m^3/day
- Install at 90 mbdl
- Dynamic water level = 65 mblg
- Borehole maximum abstraction rate = 24 m^3/hour

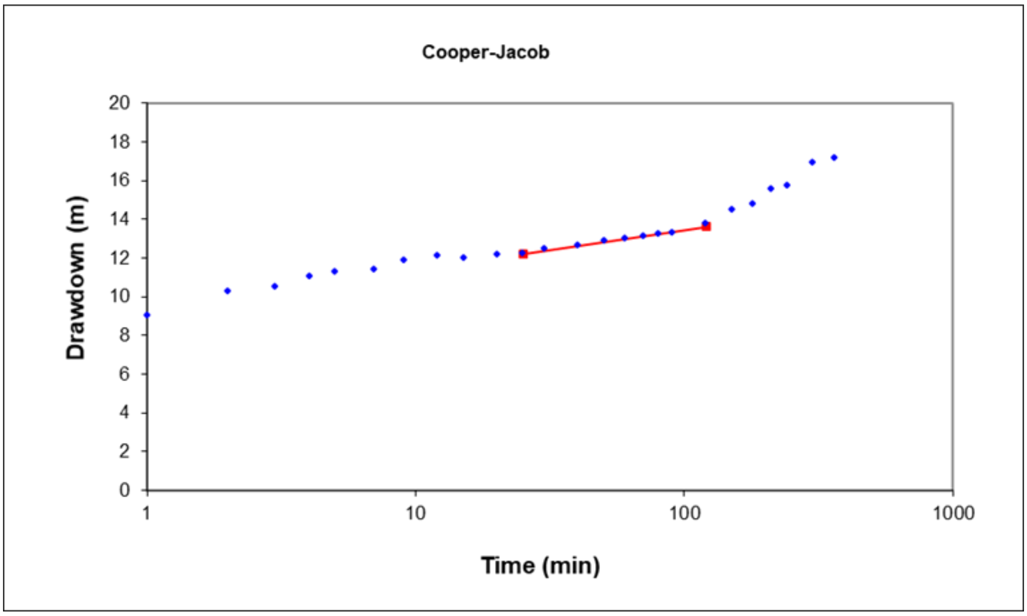

Figure 6: WB1599_Constant Rate Test

4.5.7 Coniston 7

- The borehole recovery data not given
- No monitoring data was available - Storativity value is therefore uncertain
- Moderate fracture network indicated by derivative plot

Utilisation Recommendations

- **8 m³/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 192 m³/day
- Install at 80 mbdl
- Dynamic water level = 62 mblg
- Borehole maximum abstraction rate = 12 m³/hour

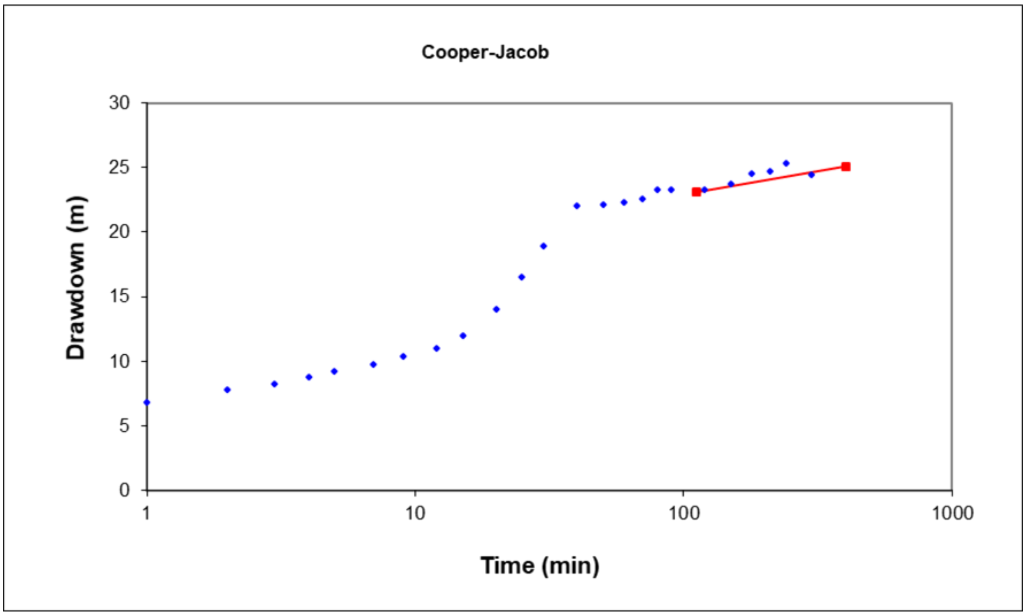

Figure 7: WB1600_Constant Rate Test

4.5.8 Coniston 8

- The borehole recovery data not given
- No monitoring data was available - Storativity value is therefore uncertain
- Moderate fracture network indicated by derivative plot

Utilisation Recommendations

- **3.5 m³/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 84 m³/day
- Install at 80 mbdl
- Dynamic water level = 62 mblg
- Borehole maximum abstraction rate = 5 m³/hour

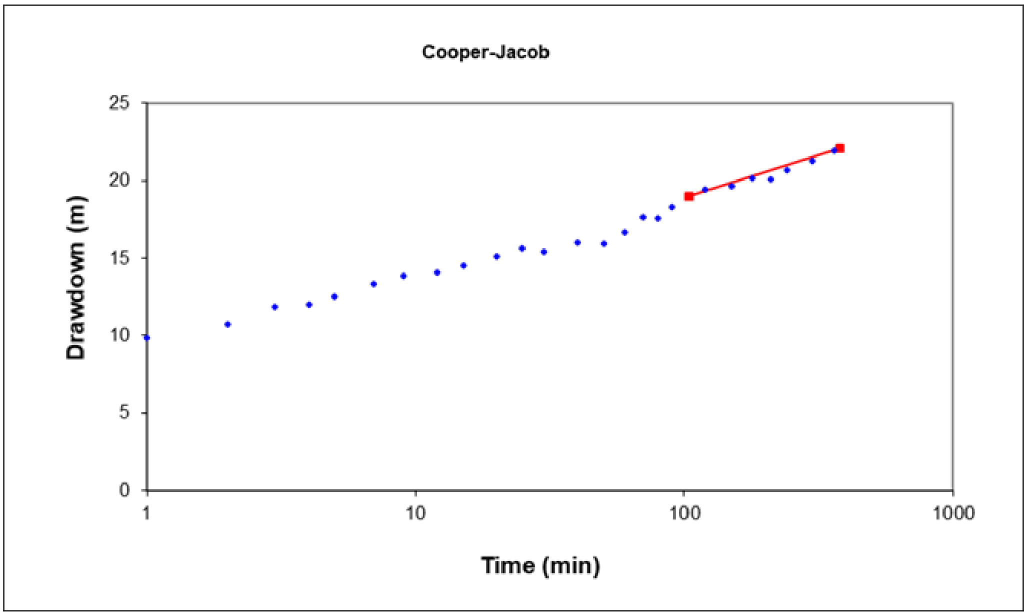

Figure 8: WB1601_Constant Rate Test

4.5.9 Coniston 9

- Quick recovery is indicative of higher Transmissivity along the fractures
- Indication of horizontal fracturing
- Not high yielding – but sustainable due to well-developed fracture network

Utilisation Recommendations

- **1.8 m^3/hr for 24 hr pumping cycle**
- Maximum Daily Abstraction = 43.2 m^3/day
- Install at 60mbdl
- Dynamic water level = 42 mbdl
- Borehole maximum abstraction rate = 2.4 m^3/hour

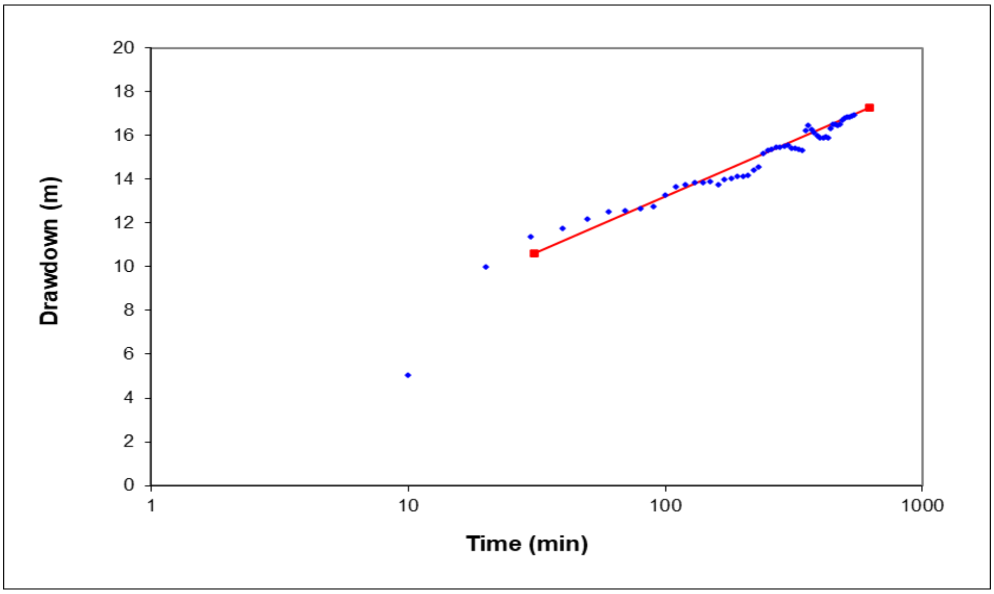

Figure 8: WB1602_Constant Rate Test

4.6 Groundwater Level and Flow Direction

Groundwater level data for the study area was acquired during the borehole yield testing programme and the borehole surveys. The adjacent farm water levels were acquired during the hydro-census that was conducted in the area. The borehole and water level data is presented in Table 8 below:

Table 7: Groundwater level data summary

Item	Local Setting	Regional Setting
Amount of data points	9	18
Average WL (mbgl)	37.7	29.2
Standard Deviation	5.6	10.5
Reliability of data	High (measured)	Moderate (time variation)

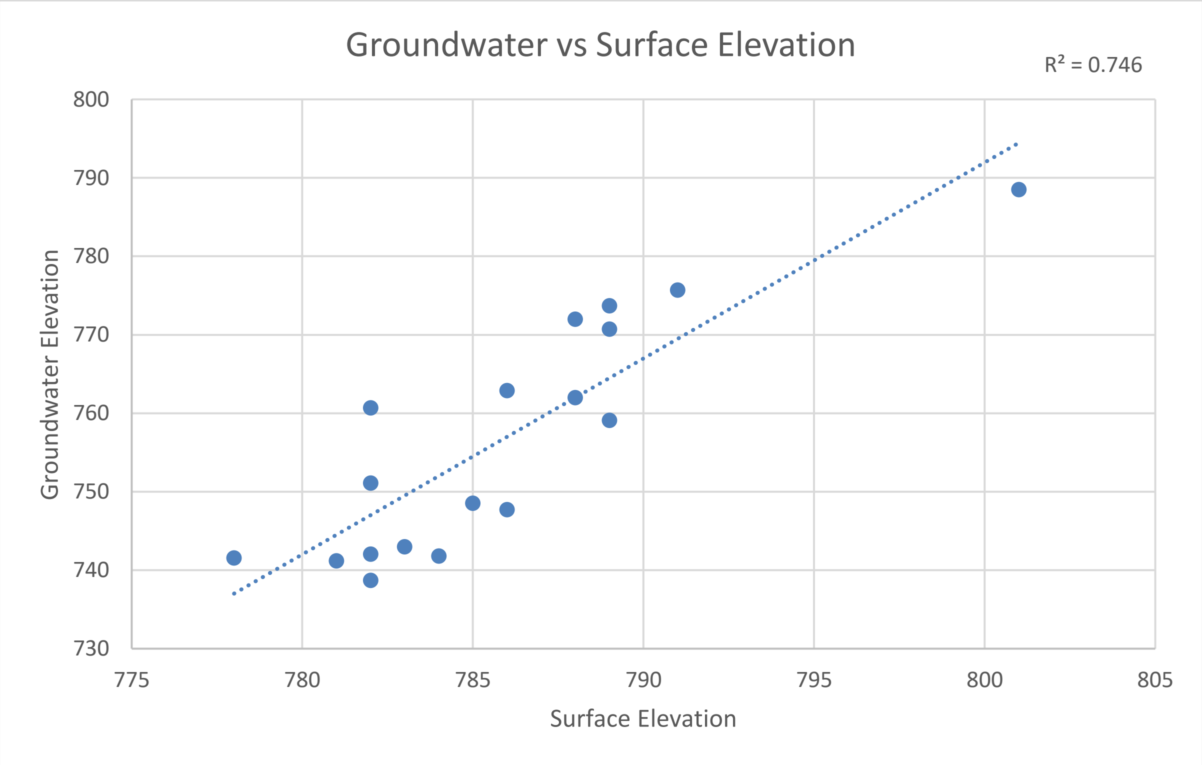

Figure 7: Groundwater Surface Elevation Correlation

Based on the relatively good correlation between the surface and groundwater, it is expected that the groundwater flow will very much resemble surface water flow (the tomography) across the study area. The available groundwater data point where used to create a groundwater contour and flow direction map, indicating a predominant western movement direction for the groundwater, following the surface water/ tomography.

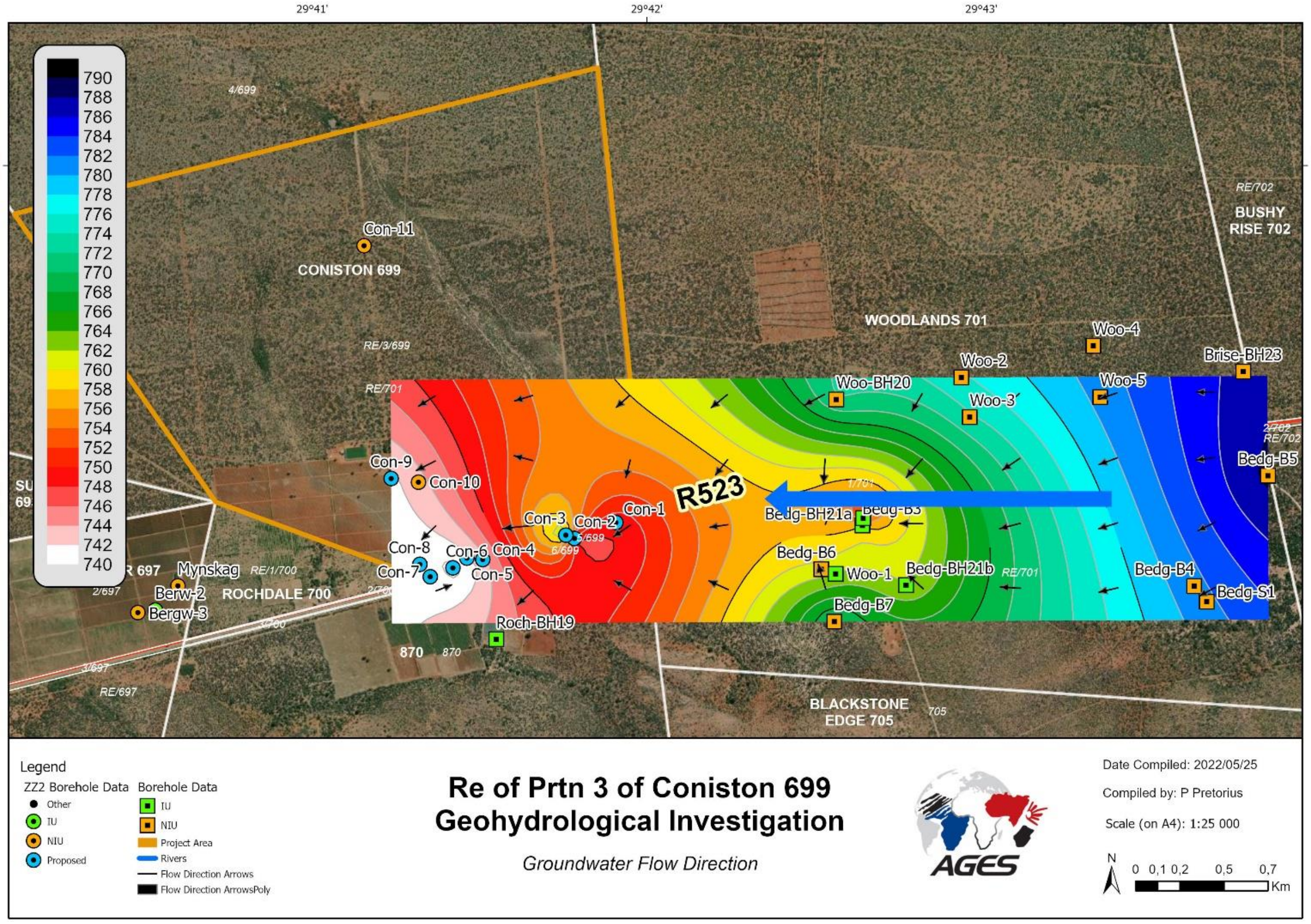

Figure 8: Groundwater Flow Direction

4.7 Groundwater Quality

Groundwater samples are generally taken at the end of the constant discharge tests to be representative of the water in a wider zone around each borehole. A total of four boreholes have been sampled across the study area and are representative for characterisation of the aquifer and as background reference. The water quality analysis from all the samples is indicative of good water quality, with no indications of groundwater pollution.

The table below represents the results from the water quality analysis:

Table 8: Water Quality Sampling

BH Number	WB1597	WB1597	WB1598	WB1600	WB1602
BH Name	Coniston 4	Coniston 4	Coniston 5	Coniston 7	Coniston 9
Date	2019/05/16	2019/10/17	2019/05/16	2019/05/16	2019/05/16
Ca (mg/l)	38.6	46.86	44.28	25.16	37.05
Mg (mg/l)	19.8	23.34	23.32	14.62	17.71
K (mg/l)	10	10	10	10	10
Na (mg/l)	12.93	16.83	16.42	11.39	13.09
SO4 (mg/l)	6.69	10.77	8.46	8.25	3.96
H2PO4 (mg/l)	1.16	0.75	1.32	1.32	1.13
Fe (ug/l)	12.5	180	12.5	12.5	12.5
Mn (ug/l)	230	260	6.25	6.25	6.25
Cu (ug/l)	20	20	20	20	20
Zn (ug/l)	20	20	20	20	20
B (ug/l)	29.49	36.22	36.64	35.54	31.38
NH4-N (mg/l)	0.1	0.21	0.1	0.1	0.1
NO3-N (mg/l)	0.01	0.15	0.12	1.26	0.01
pH	8.2	7.9	8	7.7	8.1
EC (mS/m)	36.7	45.5	44.9	28.9	35.5
TDS (mg/l)	235	291	287	185	227
Cl (mg/l)	16.49	33.29	35.49	17.59	16.99
HCO3 (mg/l)	222.78	224.21	129.45	129.45	207.73

4.8 Aquifer Classification and Vulnerability

Based on the Parsons groundwater classification scheme, (Parson, 2005), study area is characterised by two aquifer systems, a major aquifer in the north, having high yielding aquifers with good water quality, and a **minor aquifer** in the south. The southern section is a localised aquifer system recharged from rainfall runoff from the Soutpansberg and the northern aquifer is related to deep fault systems in the Karoo Sequence, where the material has become brittle and highly fractured.

The South African DRASTIC vulnerability map that was developed as part of the GRAII (DWAF, 2005) was used to evaluate the vulnerability of the aquifer underlying the study area. This includes various components, such as depth to groundwater, recharge, aquifer media, soil type, topography, impact of the vadose zone and conductivity. The aquifer vulnerability of the study area is characterised as being of a medium to high level. The areas of medium vulnerability may be attributed to areas on the southern sections of the farm where deeper faulting and fracturing in the Karoo Sequence has not been penetrated with the drilling. Areas of high vulnerability are linked to the regional faults systems. However since none of the boreholes have been drilled into this zone, the current abstraction boreholes in the study area are located in a **moderately vulnerable aquifer**.

4.9 Conceptual Geohydrological Model

The following physical features and criteria were identified as important in the development of a conceptual geohydrological model for the study area:

- The vertical orientated fault zone between the Soutpansberg and Karoo formations at the northern foot of the mountain may lead to a super groundwater recharge zone as this capture all surface water runoff from the mountains in a sandy soil environment. This is confirmed by several alluvial vans observed at the foot of the mountains, with indication of sudden water flow velocity drop, depositing of alluvium and recharge to the soil environment. Due to the vertical orientation of the fault, recharge may occur from the fault zone into various Karoo strata in depth to the north.
- Zones of high transmissivity occur where the Karoo formations were down faulted against the Soutpansberg quartzites. The brittle coal horizon, sandstone formations, dolerite sills is reported to be water-bearing rock horizons exploited for irrigation purposes (WSM Leshika, 2013)
- The Karoo formation dip between 5 and 15° to the north within fault bounded blocks, with water bearing rocks shallow in the south, dipping deeper to the north. Drilling results indicate an inconsistent distribution of different layers due to displacement of the geology along various strike faults that is spread out through the study area. It will be impossible to map out detailed differences throughout the aquifer zones, and the geohydrological model will included all into one zone with the death of aquifer determined by the expected depth of the lowest Karoo formation.
- The various sets of faults in the study area may act as preferred groundwater pathways of recharge to rock-bearing formations, reflecting a higher S and T value than the rest of the aquifer. It may be that the N-NW faults represent a more open structure system. This may give rise to preferred groundwater pathways that accommodate the flow of groundwater recharged from surface water runoff (from the Soutpansberg Mountain area) to the north in the aquifer.
- The eastern groundwater management area is characterised by higher water salinity. The groundwater derived from direct recharge in the more basal units of the Karoo formation is generally more saline, progressively becoming more saline moving north and east throughout this groundwater management area. The structural link between various Karoo strata, major fault systems and the runoff from the Soutpansberg, results in difference in water chemistry in different rock-bearing units. In the central groundwater management unit this leads to a high saline content in groundwater in upper parts of the aquifer, to be distinguished from groundwater with a much lower saline content in the deeper aquifer sones. Although it is very difficult to map out these

differences in detail, all drilling and groundwater development or interference (for example from mining), must take note of this reality and take care to isolate different layers to avoid deeper aquifer contamination over time.

- A more homogeneous succession in the different Karoo formations is expected to the eastern side of the aquifer area. In combination with the absence of prominent faulting in this area more and more to the east, a slow decreasing in groundwater harvest potential and borehole yields is expected in an easternly direction throughout the eastern groundwater management area.

4.10 Groundwater Recharge

The recharge parameters presented in this report are based on the Groundwater Resource Assessment II (DWAF, 2006), Vegter's (1995) recharge map, and measured groundwater Cl values. The recharge parameters are represented as mm/ annum and % of total recharge in the following table:

Table 9: Recharge Values

Vegter, 1995	12 – 20 mm/ annum (3.6 to 6 % of MAP)
WR 2012	10 – 30 mm/ annum (3 – 9.1 % of MAP)
Cl Method	17 mm/ annum (5.1 % of MAP)
Average	20 mm/ annum (6 % of MAP)

Based on the information presented in this report it is determined that the rainfall recharge on site is supplemented by rainfall/ runoff entering the aquifers as runoff from the Soutpansberg Mountain. A regional groundwater recharge area of 4 200 ha was established based on the regional and local geological setting, water levels, water levels during pump testing and the topography. It is also determined the no recharge is received from regional fault structures, as none of the boreholes are developed on these major fault systems.

The following table represents the possible recharge scenarios for the study area:

Table 10: Recharge Calculations

Focus	Area	Recharge	Volume of recharge
Regional	3 630 ha	25 mm/ annum	907,500 m^3/annum
Farm	595 ha	20 mm/ annum	119,000 m^3/annum
Total	4 225 ha	-	1,026,500 m^3/annum

4.12 Groundwater Balance and Availability/ Aquifer Yield

To determine the sustainable volume of groundwater abstractable from the aquifer, a "box model" based groundwater balance is calculated for the study area. This is based on the following:

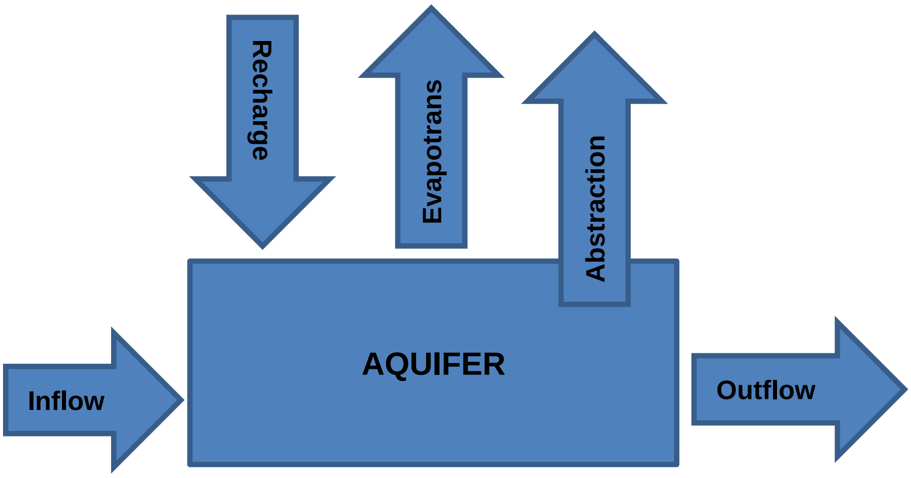

Figure 9: Groundwater Balance Box Model

Since all shallow groundwater movement will be intersected by the regional fault systems, it is expected that the baseflow component will be negligible. Inflow and outflow will therefore be regarded as 0. Abstraction from existing groundwater users in the area is estimated at 5 l/s for 12 hours per day as no large-scale irrigation is conducted in the vicinity of the boreholes. The aquifer recharge, evapotranspiration and outflow values are all based on the WR2012 data. The following table presents the groundwater balance for the study area:

Table 11: Groundwater Balance

Parameter	Value	Total Volume	Abstraction	Note
Total Area	4 225 ha	-	-	
Inflow	0 m³/ a/ ha	-	+ 0 l/s	Negligible
MAP (mm)	330 mm/ a	13.943 Mm³/ a	-	
Recharge value	20-25 mm/ a	+ 1.0265 Mm³/ a	+ 32.6 l/s	
Outflow (baseflow)	0 m³/ a/ ha	- 0 Mm³/ a	- 0 l/s	
Evapotranspiration	2 000 mm/ a	- 0.1 Mm³/ a	- 3.2 l/s	Approx 5 ha
Abstraction (existing)	5 l/s @ 12 hrs	- 0.08 Mm³/ a	- 2.5 l/s	
Additional Abstraction	**-**	***+ 0.8465 Mm³/ a***	***+ 26.9 l/s***	

Based on the groundwater balance of the area it is determined that a total amount of 846,500 m³/ a (26.9 l/s on a 24-hour pumping cycle) is available for abstraction in the specified aquifer. This does not include water from aquifers deriving recharge from the regional fault systems.

4.13 Aquifer Description (Summary)

The interaction between the geological setting, structural geology, together with the topographical and geomorphological setting determines the unique local groundwater potential in the Waterpoort / Coniston area. Both geological and geohydrological information is therefore integrated to develop a groundwater conceptual model.

Two predominant aquifers are identified in the study area: a moderately vulnerable aquifer recharged from the fresh rainfall run-off water from the Soutpansberg and a highly vulnerable aquifer recharged by east-west movement of groundwater in the highly fractured zones along the fault systems located in the Karoo Sequence.

The boreholes on site have all been drilled into the moderately vulnerable aquifer with limited rainfall runoff recharge. Should boreholes be drilled into regional fault systems, the borehole yield tests from those boreholes will be evaluated to determine the geohydrological characteristics of the related aquifer.

The geological setting of the study area is such that a localised aquifer or geohydrological response unit (GRU) can be determined for the study area. This is based on the local structural geological setting, geohydrological character of the geological formations, and the topography.

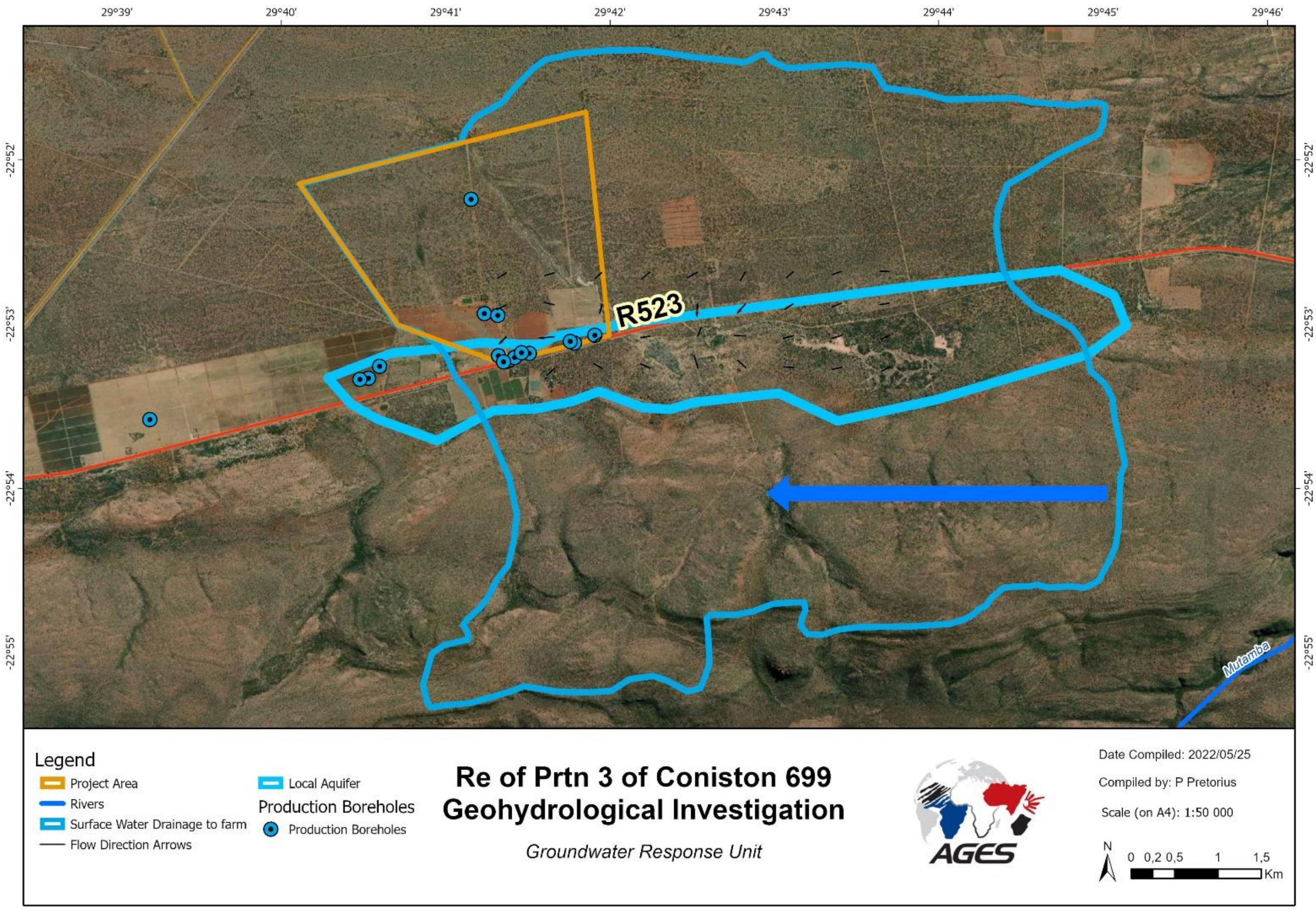

Figure 10: Groundwater Response Unit (GRU)

5 Groundwater Utilization

5.1 Groundwater Abstraction

The management of a groundwater resource needs to account for the cumulative impact of utilising multiple boreholes in a single aquifer unit, across farm boundaries. Sustainable development and use of the groundwater resource will be influenced by the regional groundwater potential and the regional geohydrological setting.

Sustainable groundwater use from a borehole is related to the yield potential of the borehole, as well as the hydraulic properties and characteristics of the aquifer supporting the borehole. This information is obtained from the results of pumping tests performed on the borehole. The purpose for which the borehole is to be used, and the amount of water required from the borehole determine the nature, and duration of the pumping test conducted.

Although pumping tests cannot be considered the most ideal way of evaluating the long-term sustainability of a groundwater resource, it does provide a quick and simple way of evaluating the short- to medium-term performance characteristics of a borehole. It must be emphasized that the results of calculations obtained from pumping test data is only representative of the aquifer characteristics in the immediate vicinity of the borehole. Factors such as aquifer transmissivity, as well as the duration of a test, will determine the area of influence reached during testing (the longer the test, the greater the area of influence), and hence the greater the degree of certainty with which recommendations are made. The yield assessment results are presented in Table 6.

Utilization recommendations are made with the aim of providing a sustainable water supply, even during prolonged periods when the annual rainfall is below average, and are based on the following:

- Well-established methodologies using mathematical relationships between abstraction rates, and the drawdown of water levels during pumping. This data is interpreted to determine the groundwater flow characteristics of the aquifer.
- The yield characteristics of production boreholes as determined by pumping tests conducted at these boreholes
- The geohydrological parameters as defined by the structural geology in the area.
- Evaluation of the testing data by means of the FC Method developed by IGS. The derivatives and boundary conditions were used to evaluate the sustainable yield of each borehole.

Utilisation recommendations for the boreholes are deemed conservative and will ensure a sustainable supply even during periods of prolonged drought (two years of no rain scenario).

Recommendations for sustainable groundwater abstraction are presented in Table 14 below:

Table 12: Utilisation Recommendations

Recommendation									
Borehole Name	**Coniston 1**	**Coniston 2**	**Coniston 3**	**Coniston 4**	**Coniston 5**	**Coniston 6**	**Coniston 7**	**Coniston 8**	**Coniston 9**
Borehole Number	WB1594	WB1595	WB1596	WB1597	WB1598	WB1599	WB1600	WB1601	WB1602
Latitude	-22.88446	-22.88526	-22.88509	-22.88631	-22.88624	-22.88673	-22.88716	-22.88655	-22.88227
Longitude	29.69846	29.6963867	29.69596	29.69182	29.69103	29.69034	29.68921	29.68869	29.68726
Sustainable Yield (m3/hr)	**9**	**10**	**5**	**12**	**7.2**	**18**	**8**	**3.5**	**1.8**
Sustainable Yield (l/s)	**2.5**	**2.8**	**1.4**	**3.3**	**2.0**	**5.0**	**2.2**	**1.0**	**0.5**
Installation Depth (mbgl)	100	100	80	80	80	90	80	80	60
Maximum Daily Abstraction (m3/day)	216	240	120	288	170	432	192	84	43.2
Dynamic Water Level (mdgl)	58	60	50	54	71	65	62	62	42
Critical Water Level (mdgl)	70	72	70	72	78	72	70	70	54
Borehole Maximum Yield (m3/hr)	12.0	12.5	5.5	16.0	9.0	24.0	12.0	5.0	2.4
Level of assurance	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate Infinite acting radial flow	Moderate short CR test resulted in low drawdown reached, storativity is also unknown Good fracture network	Moderate short CR test resulted in low drawdown reached, storativity is also unknown	Moderate short CR test resulted in low drawdown reached, storativity is also unknown

Table 13: Recommendation Summary

Item	*Amount*
Total Sustainable Yield per annum (m^3/a)	652,620 m^3/a
Total Sustainable Yield (m^3/hr)	74.50 m^3/hr
Total Sustainable Yield (l/s)	20.69 l/s
Average Installation Depth (mbgl)	83.00 m
Total Maximum Daily Abstraction (m^3/day)	1,785.20 m^3/day
Average Dynamic Water Level (mdgl)	58.22 m
Average Critical Water Level (mdgl)	69.78 m
Total Borehole Maximum Yield (m^3/hr)	98.40 m^3/hr

5.2 Impact of Groundwater Use

Based on the pumping tests and the recommendation the following zone of impact is defined for the recommended boreholes (impact at pumping for 24 hours day, 365 days/ annum):

Table 14: Groundwater Impact

BH Num	Trans (m/d)	Storativity	Yield	500 m	1000 m	1500 m	2000 m
Coniston 1	20	0.02	2.5 l/s	116 cm	33 cm	8 cm	2 cm
Coniston 2	33	0.02	2.8 l/s	104 cm	40 cm	14 cm	5 cm
Coniston 3	13	0.01	1.4 l/s	117 cm	39 cm	12 cm	3 cm
Coniston 4	53	0.03	3.3 l/s	79 cm	31 cm	12 cm	4 cm
Coniston 5	16	0.02	2 l/s	100 cm	24 cm	5 cm	1 cm
Coniston 6	76	0.03	5 l/s	99 cm	45 cm	20 cm	9 cm
Coniston 7	22	0.02	2.2 l/s	99 cm	30 cm	8 cm	2 cm
Coniston 8	7	0.02	1 l/s	56 cm	5 cm	0 cm	0 cm
Coniston 9	3	0.01	0.5 l/s	55 cm	4 cm	0 cm	0 cm

The closest existing water user to the site is located 450 m away. It is therefore evident that the groundwater use will not detrimentally influence any other groundwater users in the area.

5.3 Volume and Purpose of Water Use

The permissible groundwater abstraction for Quaternary Catchment A71J under General Authorisation is 45 m^3/ ha/ a. The GA for Portion 3 of the Remainder of Coniston 699MS is calculated as 45 x 595 = 26 775 m^3/a (73.35 m^3/d). Any proposed groundwater abstraction must therefore be done authorised (WULA – Section 21a). The purpose of this investigation is to determine the sustainable long term abstractable groundwater potential for the study area and to determine the available yield from the existing boreholes.

The groundwater that will be abstracted will be used as irrigation for various crops, including tomatoes. As such the volume of water that is applied for is based on the sustainable geohydrological supply and not on the current demand.

The total volume of water that is being applied for is 652 620 m^3/ annum (20.7 l/s @ 24 hours) out of the total available 846 500 m^3/ annum (27.0 l/s @ 24 hours) after all losses and other uses have been considered.

5.4 Scale of Abstraction

Based on the requirements of the Department of Water and Sanitation, it is required to present the necessary information to assess the scale of intended abstraction of the new water use license. This assessment is representative of the available groundwater from rainfall recharge on the farm property.

- Direct Impact Area = 5 950 000 m^2 (595 Ha)
- Recharge = @ 20 mm = 119 000 m^3/year
- Existing Groundwater = 0 m^3/day
- Proposed Groundwater Use = 652 620 m^3/year
- Scale of Abstraction = *Abstraction* / *Recharge* x *100*

= 652 620 / 119 000 x 100

> 100 %

Category C (Regional Recharge Area)

Utilising 652 620 m^3/year of groundwater from the boreholes on the farm equates to more than 100% use of the local recharge potential on the property.

The scale based on the localised recharge potential is a Scale C.

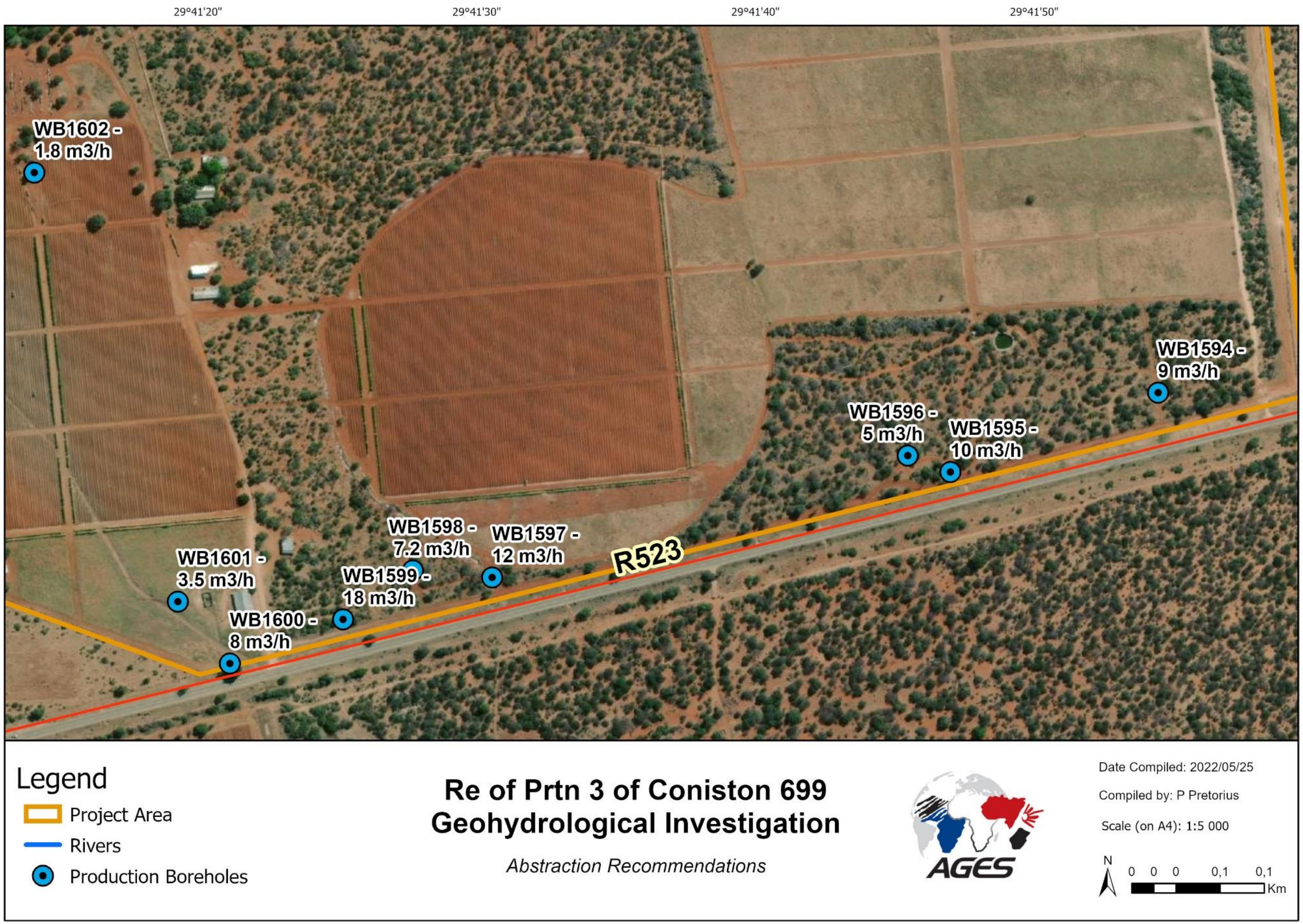

Figure 11: Abstraction Recommendations

6 Groundwater Impact Assessment

6.1 Impact Assessment

The impact assessment is based on identifying and rating the potential impacts and risks that may be associated to the groundwater abstraction for the Remainder of Portion 3 of Coniston 699MS. The purpose of groundwater abstraction will be to establish and irrigate agricultural crops – including tomatoes on the farm. Potential impacts have been identified and assessed based on the criteria defined in section 3.10. The significance of the impact is discussed based on two scenarios, "Without mitigation" and "With mitigation" - taking alternatives, preventative and mitigation measures into consideration. The impact assessment is provided in Table 15:

Table 15: Impact Assessment

Impact	Mitigation	S	D	E	F	P	OS	Mitigation Measures
Depleting of groundwater resource because of over-abstraction	With	2	2	3	*2*	*1*	**2**	Groundwater abstraction volumes must be adhered to. Water level must be monitored and assessed.
	Without	2	3	3	*2*	*2*	**6**	
	Discussion: Low impact significance The groundwater abstraction recommendations presented in this report are conservative and the calculations have already incorporated a 2-year drought period as part of the yield design. The aquifer where the boreholes are located is replenished by rainfall runoff and will therefore recover annually.							
Groundwater quality deterioration because of over-abstraction	With	1	2	3	2	1	4	Groundwater quality and levels must be monitored and assessed. No over abstraction to take place.
	Without	3	4	3	2	2	6	
	Discussion: Medium impact significance The water quality evaluation is indicative of good groundwater quality. Additional groundwater drawn into the aquifer will also be of good quality so any chemical deterioration over time will be remediated over time. Monitoring of the groundwater quality will ensure that early identification of any pollution may be identified and assessed, and a sufficient mitigation plan proposed.							
Depleting of groundwater in the Tsipese and related faults due to over abstraction	With	1	2	1	1	1	1	Groundwater abstraction volumes must be adhered to. Water level must be monitored and assessed.
	Without	1	2	2	1	1	2	
	Discussion: Negligible significance The borehole on the farm that are currently being applied for do not intersect any of the regional based east-west trending fault systems. Localised de-watering will lead only to localised dry boreholes, due to the localised extent of the aquifer. It is therefore not possible to have any impact on the groundwater in the Tsipese fault system.							

**** S – Severity, D – Duration, E – Extent, F – Frequency, P – Probability and OS – Overall significance**

Negligible	The impact is non-existent or is of no or little importance
Low	The impact is limited in extent and will not have a significant impact given the bigger picture
Moderate	The impact is significant to one or more stakeholders and management intervention may be required
High	The impact could render development options un-feasible and entire project unacceptable
Very high	The impact is such that mitigation alone is not sufficient and potential benefits will arise from project

6.2 Mitigation Measures

The following mitigation measures must be implemented to ensure the sustainability of the groundwater resource:

1. The borehole yields must be adhered to, and the boreholes must not be over pumped
2. Abstraction volumes must be monitored and adjusted based on installed yield
3. Adequate top structuring must be installed at all the boreholes to prevent the ingress of surface water/ mud/ debris into the borehole
4. Stormwater management must be pursued on the farm to maximise groundwater infiltration and to prevent the ingress of stormwater into the boreholes
5. Fertilisers should not be stored in close proximity to any of the boreholes
6. The recommended monitoring plan must be implemented and evaluated. Any variations should be noted and investigated.

6.3 Monitoring and Management

Monitoring and management are they key to success in sustainable groundwater use. A long-term monitoring programme must be implemented based on the guideline documented in Best Practice Guideline G3. Water Monitoring Systems (2007) available from DWS. These guidelines are summarised and implemented in the proposed monitoring plan. A monitoring plan is necessary because (DWA, 2006):

- Accurate and reliable data forms a key component of many environmental management actions.
- Water monitoring is a legal requirement
- The most common environmental management actions require data and thus the objectives of water monitoring include the following:
    - Development of environmental and water management plans based on impact and incident monitoring.

- Generation of baseline/background data
- Identification of sources of pollution and the extent of pollution
- Monitoring of water usage by users.
- Assessment of compliance with set standards and legislation (EMPs, water use licenses, etc.)
- Assessment of impact on receiving water environment.

Effective groundwater monitoring systems for the purposes of groundwater abstraction at Coniston may consist of the following components:

- Groundwater **level** monitoring
- Groundwater **quality** monitoring
- Surface **water runoff** and storage monitoring
- Data and information **management system**

6.4 Monitoring Framework

The standard ZZ2 groundwater monitoring framework and process must be implemented for all of the possible abstraction boreholes on the Remainder of Portion 3 of Coniston.

Item	Boreholes	Water level	Water Quality
Production Boreholes	Con-1 – WB1594 Con-2 – WB1595 Con-3 – WB1596 Con-4 – WB1597 Con-5 – WB1598 Con-6 – WB1599 Con-7 – WB1600 Con-8 – WB1601 Con-9 – WB1602	Monthly	Bi-annual
Monitoring Boreholes	Con-10 – WB1736 Con-11 – WB1737	Monthly	-
Rivers/ Streams		Season variation/ as per ZZ2 protocol	
Dams		Season variation/ as per ZZ2 protocol	
Constant level logger	Con-2 – WB1595 Con-6 – WB1599	Constant	

7 Conclusion

AGES was approached by ZZ2 to determine the available sustainable yield from the existing boreholes on the Remainder of Portion 3 of Coniston 699MS in the Makhado Local Municipality and to conduct a geohydrological investigation in support of licensing the proposed groundwater use.

The study area is located approximately 8 km east of Waterpoort and is approximately 595 ha in extent. The study area is underlain by various sedimentary formation in the Karoo Sequence and is recharge predominantly from rainfall runoff from the Soutpansberg mountain. A total of 9 boreholes have been tested with a total sustainable yield recommendation of 74.5 m^3/a. Based on the yield assessment it was determined that:

1. No geohydrological boundaries were encountered during the yield test
2. The moderate yielding boreholes indicated that matrix flow is predominant and that no fractures where dewater during the testing process. This supports the proposition that impact from the regional faults have not been encountered in these boreholes.
3. The boreholes have a good water quality, indicative of fresh rainfall recharge

The geological setting of the study area is such that a localised aquifer or geohydrological response unit (GRU) can be determined for the study area. This is based on the local structural geological setting, the geohydrological character of the geological formations and the topography.

Based on the groundwater balance for the area a total volume of 846 500 m^3/a is available for abstraction in the specific aquifer.

The sustainable groundwater abstraction recommendations were determined based on evaluation of the yield assessment data. The following is a summary of the recommendations:

Item	*Value*
Total Sustainable Yield per annum (m^3/a)	652,620 m^3/a
Total Sustainable Yield (m^3/hr)	74.50 m^3/hr
Total Sustainable Yield (l/s)	20.69 l/s
Average Installation Depth (mbgl)	83.00 m
Total Maximum Daily Abstraction (m^3/day)	1,785.20 m^3/day
Average Dynamic Water Level (mdgl)	58.22 m
Average Critical Water Level (mdgl)	69.78 m
Total Borehole Maximum Yield (m^3/hr)	98.40 m^3/hr

8 Recommendations

Based on the results from this investigation proving that the groundwater use is sustainable and viable, it is recommended that the application be approved. It will be important that the water user implements the mitigation and management guidelines presented in this report. The following recommendations are made towards the implementation of the program:

1. Installation of borehole pumps must be compliant to the guidelines in the report.
2. Water level monitoring tubes must be installed into each production borehole
3. Sampling taps must be installed at all the boreholes to aid groundwater sampling
4. A flow meter must be installed at each of the boreholes to monitor groundwater use.
5. The boreholes and pumps must be serviced regularly to ensure optimal operation

Since the current groundwater application is limited to the aquifer associated with the rainfall runoff from the Soutpansberg and not related to deep aquifer fault systems (Karoo faults), future development related to deep/ regional structures could be viable and additional groundwater may be available for development in such aquifer environments.

9 References

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