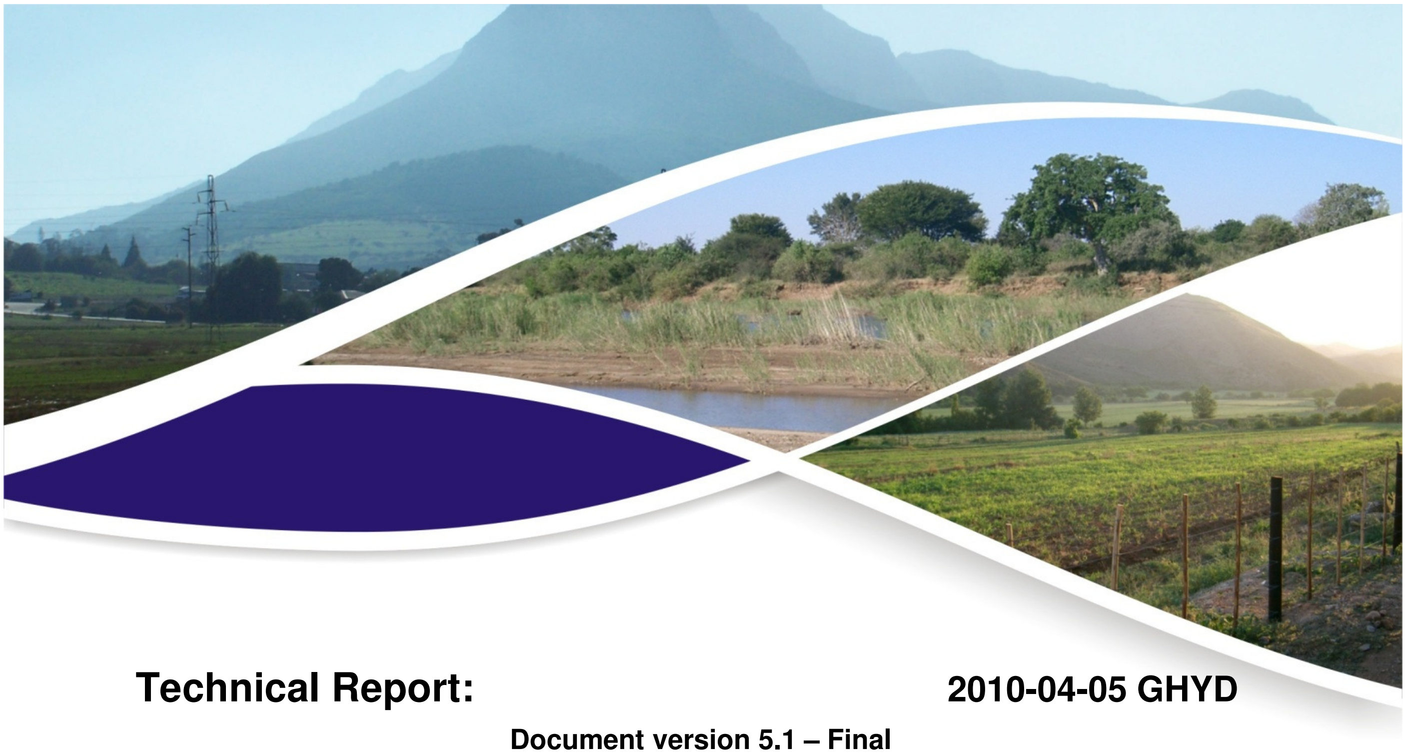

Technical Report: **2010-04-05 GHYD**

Document version 5.1 – Final

Geohydrological Assessment and Groundwater Flow Modelling for Potential Groundwater Use at the Proposed Development At and Adjacent to Klein Kariba, Bela Bela, LIMPOPO

Prepared for:
AJK Projects

February 2011

Compiled by:

R Crosby

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Geohydrological Assessment and Groundwater Flow Modelling for Potential Groundwater Use at the Proposed Development At and Adjacent to Klein Kariba, Bela Bela, LIMPOPO

07 February 2011

Conducted on behalf of:

AJK projects
Property Development & Project Management

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DOCUMENT HISTORY

Report no	Date	Version	Status
AS-R-2010-03-15	15 March 2010	1.0	Draft Model Report
2010-04-05 GHYD	19 April 2010	2.0	Draft
AS-R-2010-03-15	18 June 2010	3.0	Draft Model Report
AS-R-2010-03-15	5 July 2010	4.0	Final Model Report
2010-04-05-GHYD	6 July 2010	4.1	Final Report
2010-04-05-GHYD	22 November 2010	4.2	FINAL REPORT
2010-04-05-GHYD	07February 2011	5.1	FINAL REPORT

Amendments – v4.2 Updated Development Plan

V5.1 Concerns raised by Water Users at the Public Meeting – 22 November 2010

Notations and terms

Advection is the process by which solutes are transported by the bulk motion of the flowing groundwater.

Anisotropic is an indication of some physical property varying with direction.

Cone of depression is a depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a borehole from which water is being withdrawn. It defines the area of influence of a borehole.

A *confined aquifer* is a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

The *darcy flux*, is the flow rate per unit area (m/d) in the aquifer and is controlled by the hydraulic conductivity and the piezometric gradient.

Dispersion is the measure of spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

Drawdown is the distance between the static water level and the surface of the cone of depression.

Effective porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.

Groundwater table is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

A *fault* is a fracture or a zone of fractures along which there has been displacement.

Hydrodynamic dispersion comprises of processes namely mechanical dispersion and molecular diffusion.

Hydraulic conductivity (**K**) is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the area [L/T]. Hydraulic conductivity is a function of the permeability and the fluid's density and viscosity.

Hydraulic gradient is the rate of change in the total head per unit distance of flow in a given direction.

Heterogeneous indicates non-uniformity in a structure.

Karstic topography is a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and is characterised by sinkholes, caves and underground drainage.

Mechanical dispersion is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.

Molecular diffusion is the dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents.

Observation borehole is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.

Permeability is related to hydraulic conductivity, but is independent of the fluid density and viscosity and has the dimensions L^2. Hydraulic conductivity is therefore used in all the calculations.

Piezometric head (ϕ) is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a *piezometric surface*, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.

Porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.

Pumping tests are conducted to determine aquifer or borehole characteristics.

Recharge is the addition of water to the zone of saturation; also, the amount of water added.

Sandstone is a sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material.

Shale is a fine-grained sedimentary rock formed by the consolidation of clay, silt or mud. It is characterised by finely laminated structure and is sufficiently indurated so that it will not fall apart on wetting.

Specific storage (S_0), of a saturated confined aquifer is the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head. In the case of an unconfined (phreatic, watertable) aquifer, *specific yield* is the water that is released or drained from storage per unit decline in the watertable.

Static water level is the level of water in a borehole that is not being affected by withdrawal of groundwater.

Storativity is the two-dimensional form of the specific storage and is defined as the specific storage multiplied by the saturated aquifer thickness.

Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.

Transmissivity (T) is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated thickness.

An *unconfined, watertable or phreatic aquifer* are different terms used for the same aquifer type, which is bounded from below by an impermeable layer. The upper boundary is the watertable, which is in contact with the atmosphere so that the system is open.

Vadose zone is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

Water table is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

LIST OF ABBREVIATIONS

Abbreviation	Description
SWL	Static Water Level
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
TDS	Total Dissolved Solids
m	metre
km	Kilometre
mg/ℓ	milligram per litre
mS/m	milli-Siemens per meter
m^3/d	Cubic meters per day

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1 INTRODUCTION

1.1 Background

AGES was appointed to compile a geohydrological assessment to support the sustainable abstraction and use of groundwater for the proposed development on and adjacent to the existing Klein Kariba Resort. An existing geohydrological assessment compiled on portion of the proposed study area was available, but since both the extent and the scope of the proposed development had been redefined, additional groundwater is now required to support the proposed development.

1.2 Objectives

The objective of the geohydrological study is

- to determine the regional groundwater potential, and
- to evaluate the impact of groundwater abstraction by the proposed development on both the regional groundwater, and on neighbouring groundwater users and resources

1.3 Terms of Reference

AGES was appointed to conduct the geohydrological investigation and resource evaluation, which includes a detailed numerical model to support the sustainable utilisation of groundwater based on a cost proposal submitted on 3rd November 2009, and accepted by Messrs AJK projects in correspondence received on 5th November 2009.

1.4 Scope of Work

The scope of work is summarised as the following:

- Evaluate the existing geo-hydrological study completed on portion of the property (Appendix A)
- Conduct a detailed hydro-census in a 2km radius around the development, and on neighbouring properties
- Develop a detailed numerical groundwater model to determine the groundwater potential for the area
    - The scope of work for this phase includes groundwater flow modelling in Modflow Pro (software program), and is done by simulating the current geohydrological status around the area of investigation, which includes variable parameters such as aquifer Transmissivity, groundwater recharge and losses through abstraction and evapotranspiration.
    - The planned groundwater abstraction for the proposed development is then included in the model and run as a separate scenario to determine the

influence of the planned abstraction on both the regional aquifer, and on local water users.

- Results of the numerical model are presented as an attached report (appendix B), and motivate the sustainability of the groundwater abstraction.

- To make management recommendations regarding groundwater use, and the sustainable utilisation of the groundwater resource
- To compile a geohydrological report to support the water use license application

1.5 Study Area

In addition to the proposed development on portions 1, 2, 3, and 4 of the cadastral farm Valentia 449-KR covering an area of approximately 1km^2, current facilities and infrastructure at the existing resort are to be upgraded. The total study area is thus defined by the extent of the groundwater model boundary (see appendix B), and is approximately 138km^2 in extent.

Due to the relationship between the proposed development, and the Klein Kariba Resort, the area of the resort (portion 87 of Buiskop 464-KR) of some 5.3km^2 is included in the investigation for the development of proposed boreholes. Table 1 presents a summary of the areas included in the proposed development.

Table 1: Summary of the Proposed Development Area

Farm	Portion	Area (ha)	Area (m^2)
Valentia 449-KR	1	36.4648	364648
Valentia 449-KR	2	21.4133	214133
Valentia 449-KR	3	21.4133	214133
Valentia 449-KR	4	21.4133	214133
Buiskop 464-KR	87	528.6936	5286936
	TOTAL	**629.3983**	**6293983**

The study area falls within the quaternary catchment **A23G**.

Natural vegetation covers the majority of the study area, with the development of wildlife smallholdings along the northern boundary. To the south and west of the study area, a number of small scale agricultural activities are noted, with isolated incidence of irrigation.

1.6 Sources of information

The following sources of information were used during the investigation:

Geohydrological map:	2326 PIETERSBURG; scale 1 : 500 000
Geological maps:	2428 NYLSTROOM, scale 1 : 250 000
Topocadastral map:	2428 CD; scale 1 : 50 000
Preliminary site map:	Supplied in digital format by Messrs AJK Projects
Groundwater Harvest Potential of the Republic of South Africa Map	Alan Seymour and Paul Seward (1996), scale 1:3 000 000
Satellite Data	Google Earth ™ satellite data
	Digital Terrain Model (DTM) data obtained from GISCOE
Rainfall data	South African Weather Services
Hydrocensus Information	Information on groundwater verified during a hydrocensus
Geohydrological Report	Kruidenier, JHB (2008) Geohydrological and Sanitation Risk Assessment Study for the Proposed Resort on Portion 1 of the Farm Valencia 449-KR. (G2007/149)
Groundwater Modelling Report	Smit, JJ (2010) Klein Kariba Water Supply: Groundwater Flow Modelling Report (AS-R-2010-03-15)

2 SITE DESCRIPTION

2.1 Geographical setting

The area of investigation is located roughly five kilometres northeast of the town of Bela Bela in the Limpopo Province. The approximate coordinates of the Klein Kariba Resort are:

- Latitude: S -24.837663°
- Longitude: E 028.331313°

The area of the proposed new development is neighbouring on the northern boundary of the existing holiday resort, and is topographically and hydraulically up-gradient from the holiday resort. Any groundwater abstraction or pollution by the proposed development will impact the groundwater use at the resort (Figure 1), (Unpublished AGES report AS-R-2010-03-15 attached as appendix B).

2.2 Topographical setting

See the unpublished AGES report AS-R-2010-03-15 attached as appendix B.

The regional topography of the area is characterised by prominent outcrops of sandstone to the north, and flat areas to the south (known as the Springbok Flats). Local topography is characterised by the steep topographical changes created by the contact between the quartzite outcrops to the north of the study area, and the valley flanking the southern portions. The contact of the sandstone outcrops are incise by the drainage features from the higher lying areas to the north, and forms valleys that fan out to the flat lying areas to the south. Klein Kariba holiday resort is developed along one of these valleys. Most of the valleys are associated with linear geological structures that intersect the sandstone.

A prominent hill, knows as Buyskop, is located to the south of the entrance to Klein Kariba.

2.3 Geological setting

See the unpublished AGES report AS-R-2010-03-15 attached as appendix B.

The prominent sandstone outcrops to the north are part of the Waterberg Group sediments, and more specifically the Swaershoek Formation. The formation consists of various sedimentary lithologies including predominantly medium to coarse grained sandstone, pebble sandstone and conglomerate. Finer grained sedimentary rocks like shale and siltstone also occur in this formation.

The flat lying areas to the south are underlain by sandstone from the Clarens Formation of the Karoo Super Group, which is described as fine grained red to cream coloured sandstone. Buyskop, located in this formation, includes a layer of diabase sill as part of the lithostratigraphic sequence.

A regionally significant fault, the **Zebediela Fault** that extents for many kilometres defines the contact between the Waterberg Group, and the Karoo Super Group. The location of the fault was confirmed by a preliminary geophysical investigation on 18th February 2010 using resistivity, electro-magnetic and magnetic survey equipment. Graphical results are included in appendix D.

Further south the Clarens Formation is bound by the overlying Letaba Formation of the Karoo Super Group by an inferred faulted contact. This formation is described as volcanic and sedimentary rocks (Figure 2).

2.4 Geohydrological setting

The area of investigation falls in quaternary catchment A23G. According to the hydrogeological map (2326 Polokwane) the underlying aquifer is described as a Fractured Type Aquifer underlying the Waterberg sandstone and an Inter-granular and Fractured Type aquifer underlying the Clarens and Letaba Formations. In and around the area of investigation a borehole yield median of between 0.5 and 2.0 ℓ/s can be expected based on existing borehole data with a calculated Transmissivity of $7m^2$/day. The Letaba Formation can yield in excess of 5.0 ℓ/s further to the south according to the hydrogeological map. (Unpublished AGES report AS-R-2010-03-15 attached as appendix B)

The Zebediela Fault (Appendix D) is deemed to be a significant geohydrological feature, with Transmissivity an order of magnitude greater than the surrounding lithology (calibrated model results yield a Transmissivity of some $200m^2$/day). Borehole yields of greater than 5 ℓ/sec can be expected.

2.5 Climatic setting

See the unpublished AGES report AS-R-2010-03-15 attached as appendix B.

2.5.1 Rainfall

Rainfall data was obtained for the rainfall station 0589594 for the period 1903 to 2009. The area is located in the summer rainfall region, where most of the precipitation occurs in the form of thunder showers during the summer months. The data yielded an average rainfall of 581 mm/a, but the annual rainfall is very erratic, with annual figures ranging from less than 300 mm to over 1 000 mm (Figure 3).

2.5.2 Evaporation

According to the WR90 data contained on the GRDM software, the region experiences evaporation figures between 1 700 and 1 800 mm/a.

2.6 HYDRO CENSUS

2.6.1 Data review

On a local scale, based on existing information on the National Groundwater Data Base (NGDB), No community boreholes were identified within a 2km radius around the property.

Based on the existing geohydrological report (appendix A), 10 existing boreholes located north of the proposed study area are noted.

2.6.2 Field visit

In the period 12th – 15th January 2010, a hydrocensus was conducted by Messrs AGES in the vicinity of the Klein Kariba Resort to verify existing boreholes, and to identify groundwater users in a 2km radius around the proposed development.

At a public participation meeting on 22 November 2010 a number of water users in the area voiced their concern that groundwater would be adversely affected to the southwest of Klein Kariba. The concerns were based on shallow water levels, and very good water quality reported from boreholes in the area. A follow-up hydrocensus was thus conducted on 03 December 2010 to verify that borehole locations on selected neighbouring properties were correctly identified.

A total of 63 boreholes and one active spring were identified during the field visits. Forty (40) of the boreholes are currently in use, primarily for domestic application. The spring is deemed to be perennial, and is used by the Klein Kariba as the primary water supply for the resort's water needs. In the past dry season, the water flow from the spring did show a decline, and additional boreholes were developed to supply the resort with water (see unpublished GEO-LOGIC report attached as appendix A). It is noted that borehole BH50, and BH51, are equivalent to Borehole BH02, and BH01 defined and tested by Geo-Logic.

Table 2 below presents a summary of the existing boreholes identified in the vicinity of the Klein Kariba Resort, and deemed important as part of the evaluation of the impact on the regional groundwater due to proposed groundwater abstraction on the property.

The depth to regional groundwater system varies from artesian borehole north of the study area, to water levels in excess of 50m south of Klein Kariba. The existence of non-perennial springs associated with ferocrete indicates that the water table north of the study area is perched and intersects the ground surface, especially after rainfall events.

The local groundwater gradient is from the north-west towards the south. See the unpublished AGES report AS-R-2010-03-15 attached as appendix B.

Table 2: Hydrocensus Summary

Water use Ref	Property Description	Latitude	Longitude	Borehole Status	Borehole Dept (m)	Pump Dept (m)	Static Water Level Measured (m)	Static Water Level Confirmed by Owner (m)	Equipment	Estimated Daily Abstraction	Comments	Water Quality
BH01	Buisfontein 451-KR	-24.82400	28.33437	In Use	-		0	-	E-Sub	1.42 m3/day	40 mm pipe used. Borehole close to retention dam; Water used for domestic use; Septic tanks	
Dam 1	Buisfontein 451-KR	-24.82347	28.33327								Situated within a perennial stream; Damage to dam wal; No overflow. Water retention dam and game watering point	
BH02	Buisfontein 451-KR	-24.82807	28.32466	In Use	100			20	E-Sub	2400l per hour - 2 x week	Domestic use and small vegetable garden; Septic tank	Sample L701
BH03	Buisfontein 451-KR	-24.82235	28.32371	In Use	150	120		16	E-Sub	5000l per day	Domestic use and garden; primary borehole	
BH04	Buisfontein 451-KR	-24.82236	28.32371	Not in use	67			18	Not Equiped		Boreholes never been dry	
BH05	Buisfontein 451-KR	-24.82299	28.32042	In Use	180	155		12	E-Sub	5000l - 2 x week	Domestic use and garden; primary borehole; septic tank at house	
BH06	Buisfontein 451-KR	-24.82311	28.32320	In Use	85	65		20	E-Sub	5000l - 1 x week	Domestic use and garden; back-up borehole; septic tank at house	
Dam 2	Buisfontein 451-KR	-24.82312	28.32330								Retention dam; Non-perennial; gravel wall with overflow	
BH07	Buiskop 464-KR	-24.84328	28.34079	In Use	100	85		35	E-Sub	Boreholes BH07 and 8 together 12 000l per week on full capacity	Drilled in 1996; Used for garden and domestic use at different overnight accomodation facilities; borehole never been dry	Sample L696
BH08	Buiskop 464-KR	-24.84300	28.34062	In Use	100	85		35	E-Sub			
BH09	Buiskop 464-KR	-24.84339	28.34191	In Use	100	85		35	E-Sub	15 000l per hour once a week	Stongest borehole, used at school and garden	
BH10	Buiskop 464-KR	-24.82410	28.34322	In Use	100	85		35	E-Sub	Used primary for school	Photo of reservoir included - 5000l	
BH11	Buiskop 464-KR	-24.84284	28.34437	Not in use	100	-	-	-	Not Equiped		Drilled for Agricultural school not yet established	
Dam 3	Buiskop 464-KR	-24.83309	28.34722								Old quarry; game watering point	
Dam 4	Buiskop 464-KR	-24.83286	28.34872								Artificial wetland/retention dam; fed by fountain	
Dam 5	Buiskop 464-KR	-24.83286	28.34871								Old quarry; game watering point	
Dam 6	Buiskop 464-KR	-24.83286	28.34871								Old quarry; game watering point; fontain seeping directly into dam; flowing through out the year	Sample L700
BH12	Bospoort 450-KR	-24.84425	28.28939	In Use	90		10.4		E-sub	Approximately 13 500 per day	Automatic pump at reservoirs/water tanks; 3 permanent houses and 6 weekend residences	Sample L697
BH13	Bospoort 450-KR	-24.81262	28.29258	In Use	80		6.35		Generator	Unknown	Only used to fill up game watering point; not used during the rainy season	
Dam 7	Bospoort 450-KR	-24.84315	28.28829								Game watering point; Fed by BH13 during the dry season	
BH14	Bospoort 450-KR	-24.81136	28.27635	Not in use	80		3.92		Not Equiped		Old borehole, Available for back-up in future	
BH15	Bospoort 450-KR	-24.80512	28.29713	Not in use	30		17.8		Not Equiped		Borehole previously connected to mono-pump	
Dam 8	Bospoort 450-KR	-24.84315	28.28829								Retention and game watering dam	
BH16	Bospoort 450-KR	-24.84481	28.29270	In Use	90		-		E-Sub	Part of water provision for farm joined with BH12		
Dam 9 or Weir	Bospoort 450-KR	-24.84466	28.29458								Retention dam and game watering point; Feeds into lower dam; stocked with bass etc.	
Dam 10	Bospoort 450-KR	-24.84466	28.29458								Retention dam and game watering point, stocked with fish; fishing and power boats used on dam	
Water Treatment tanks	Bospoort 450-KR	-24.84630	28.29567								3 x 5000l tanks; chlorine added before used for domestic purposes	
BH17	Buiskop 464-KR	-24.86079	28.31278	In Use	70				E-Sub	285l per day	Was previously used to provide water for pigs, but currently only used for domestic use at office; the current owners is looking to sell property; Used for back-up	
BH18	Buiskop 464-KR	-24.86072	28.31454	Not in use	80		17.85		Not Equiped		Was previously used for pigs; currently filled with sand	
BH19	Buiskop 464-KR	-24.85941	28.31550	In Use	110		6.95		E-Sub	2500l per day	Used for domestic and irrigation vegetables in tunnes, approximately 1 ha under drip irrigation	sample L1219
BH20	Buiskop 464-KR	-24.85896	28.32147	Not in use	18		2		Not Equiped		Previously used for the irrigation of crop; Overlfowed during the 2002 floods	
BH21	Buisfontein 451-KR	-24.83189	28.34294	In Use	45		2.7		E-Sub	1200l per day	Used for domestic purposes	Not submitted
BH22	Buiskop 464-KR	-24.85075	28.31122	In Use					E-Sub	Used for domestic purposes for 2 households and the irrigation of 10 ha of grazing fields	Tank re-filled automatically; Waterfall along north-western border of site; Water also used to provide water to game	
BH23	Buiskop 464-KR	-24.85105	28.31148	Not in use	eeper than 50 m		11.25		Not Equiped		Borehole will be used as a back-up in the future	
BH24	Buiskop 464-KR	-24.85105	28.34683	In Use	96		27.9		E-Sub		Max. Capacity at Marula is 800 beds, swimming pool and restaurant facilities	
Dam 11	Buisfontein 451-KR	-24.81173	28.33915								Build by the Italian prisoners; cement dam with overflow; still in good condition; used as a retention dam and as a game watering point	
BH25	Buisfontein 451-KR	-24.80933	28.33870	In Use		90	6.75		E-Sub		All boreholes are combind for domestic and the irrigation of gardens at different overnight facilities, lodge and restaurant; Automatic re-fill of tanks; 2 x 30 000l and 2 x 20 000l tanks; Very strong flow	
BH26	Buisfontein 451-KR	-24.80750	28.32922	In Use			28.1				Primary borehole	
Dam 12	Buisfontein 451-KR	-24.81218	28.32255								Used for Game watering	
Dam 13	Buisfontein 451-KR	-24.81655	28.32749								Retention dam, Stocked with fish and used as a game watering point, concrete dam wall with overflow.	
BH27	Buisfontein 451-KR	-24.82379	28.32394	In Use	130		14.35		E-Sub	Approximately 1 500l per day	Used for Domestic and garden purposes at smallholding; Various new trees planted at and along the household	
BH28	Buisfontein 451-KR	-24.82412	28.32591	In Use			12.85		E-Sub	Approximately 1 200l per day	Used for Domestic and garden purposes at smallholding	
BH29	Buisfontein 451-KR	-24.82664	28.34218	In Use			8.42		E-Sub	Approximately 1800l per day	Was previously used for the irrigation of 0.5 ha sitrus trees; Currently in the process of new owners that will not be utilized the farm for agricultural purposes	
BH30	Buisfontein 451-KR	-24.85616	28.33352	Not in use	150		12.75		Not equiped		Was previously drilled to be used for the irrigation of crops	
BH31	Buisfontein 451-KR	-24.85387	28.32674	Not in use	12				Not equiped		Was previously used for the irrigation of crops, is currently still sealed, was not able to determine a static water level	
BH32	Buisfontein 451-KR	-24.85279	28.32679	Not in use	17				Not equiped		Was previously used for the irrigation of crops, is currently still sealed, was not able to determine a static water level	
BH33	Buisfontein 451-KR	-24.85294	28.32670	Not in use	16.35		8.35		Not equiped		Was previously used for crop cultivation	
BH34	Buisfontein 451-KR	-24.85294	28.32670	Not in use					Not equiped		Was previously used for the irrigation of crops, is currently still sealed, was not able to determine a static water level	
BH35	Buisfontein 451-KR	-24.85295	28.32660	Not in use	6		No Water		Not equiped		Was previously used for crop cultivation	
BH36	Buisfontein 451-KR	-24.85314	28.32671	Not in use					Not equiped		Was previously used for the irrigation of crops, is currently still sealed, was not able to determine a static water level	
BH37	Buisfontein 451-KR	-24.85429	28.32421	In Use	21		9.85		E-Sub	Approximately 2 500l per day	Used for Domestic purposes and watering for cattle	
BH38	Buisfontein 451-KR	-24.85422	28.32401	Not in use					Not equiped		Was previously used for the irrigation of crops, is currently still sealed, was not able to determine a static water level	
BH39	Buisfontein 451-KR	-24.85435	28.32396	Not in use	11		8.87		Not equiped		Was previously used for crop cultivation	
BH40	Tweefontein 463-KR	-24.82900	28.35564	In Use	120		12.5		E-Sub	All the boreholes together BH40, 41, 42 and 4	No Photo	
BH41	Tweefontein 463-KR	-24.82828	28.35632	In Use	140		8.03		E-Sub		No Photo	
BH42	Tweefontein 463-KR	-24.81741	28.35123	In Use	60		5.1		E-Sub		3rd photo	
BH43	Tweefontein 463-KR	-24.82075	28.35108	In Use	60		4.75		E-Sub		4th photo	
BH44	Tweefontein 463-KR	-24.82639	28.35855	Not in use	120		2.65		Not equiped		1st photo	
BH45	Tweefontein 463-KR	-24.81615	28.35020	In Use	60		2.3		E-Sub	Approximately 2000l per day	Water used for Domestic purposes; 2nd photo	
Sewage Treatment Plant	Klein Kariba	-24.85105	28.33077	In Use							Photos taken in 8 compass directions; the water from the sewage plant will be re-used for the irrigation of the mini-gholf course; In peak times the excess water will be pumped to the evaporation Dam 14	
BH46	Buiskop 464-KR	-24.85290	28.33202	In Use	80				E-Sub	126 000l per day	Used for domestic use for approximately 140 staff members living permanently at Klein Kariba	Sample L699
Dam 14	Buiskop 464-KR	-24.85184	28.33279								Evaporation dam for treated sewage during peak periods, less than 70m from domestic water resource BH46; Alternative must be investigated	
BH47	Buiskop 464-KR	-24.84888	28.33352	In Use	80		7.85		E-Sub	82 500l per day for both BH47 and 48	Back-up resource - Used for domestic and garden purposes, approximately 55 units with gardens	
BH48	Buiskop 464-KR	-24.84594	28.33151	In Use	80		53.9		E-Sub	In combination with BH47	Primary resource - Used for domestic and garden purposes, approximately 55 units with gardens	
Dam 15	Buiskop 464-KR	-24.84809	28.32934								Retention dam for Spring water and perennial stream	
Spring 1	Buiskop 464-KR	-24.83744	28.32926	In Use					Mono-pump	414 000l per day	The spring is the main water resource of Klein Kariba; The water does not have a good taste and must be treated before use (Cl); This resource almost went dry during the previous dry season in 2007-2008, an alternative or back-upsource were therefore investigated, it was decided on BH50; These resources BH50 and Spring 1 supplies water to approximately 276 units with gardens.	Sample L695
BH49	Buiskop 464-KR	-24.83498	28.33038	In Use		50	10.92		E-Sub	30 000l per day	This borehole provides water for approximately 25 tent units with between 6-12 children per tent during peak periods	
BH50	Valencia 449-KR	-24.82916	28.32217	In Use	250		19.85		E-Sub	In combination with Spring 1	This borehole will be lost to Klein Kariba if the development is to take place	
BH51	Valencia 449-KR	-24.83008	28.31643	In Use	65		39.9		E-Sub	Water for approximately 250 people	This borehole will be lost to Klein Kariba if the development is to take place	Sample L698
Main Tank	Buiskop 464-KR	-24.83331	28.33173								1 x 350 000l steel tank which will be used for both Spring 1 and BH50.	
Dam 16	Buiskop 464-KR	-24.83653	28.33202								Retention dam above waterval and restaurant	
BH52	Buiskop 464-KR	-24.856333	28.317917	Not in use	36				Mono-pump	0	Piet Lubbe 2 - estimated at >50 000L/hr, previous used for irrigation	
BH53	Buiskop 464-KR	-24.854817	28.315967	Not in use	38				Not equiped	0	Piet Lubbe 1 - borehole from old homestead, very good WQ, >50 years	V. GOOD
BH54	Buiskop 464-KR	-24.856750	28.317767	Not in use					Not equiped	0	Piet Lubbe 3 - under the fig tree, sealed	
BH55	Buiskop 464-KR	-24.852883	28.321133	In Use			23.8		E-Sub	2500 l/day	DR Wessels - low yielding, but dependant on the water	
BH56	Buiskop 464-KR	-24.854550	28.324000	Not in use			7.5		Not equiped	0	Anton - drilled 02/03/1983, previously used for irrigation	
BH57	Buiskop 464-KR	-24.866167	28.323100	Not in use				closed	Windpump	0	Ronvil 1 - very old windpump	
BH58	Buiskop 464-KR	-24.864483	28.321450	In Use				obstructed	E-Sub	15 000l/day	Ronvil 2	
BH59	Buiskop 464-KR	-24.868317	28.322300	Destroyed						0		
BH60	Buiskop 464-KR	-24.864017	28.315200	In Use					E-Sub	2 500 l/day	Domestic water use - Humpreys Pig Farming	
BH61	Buiskop 464-KR	-24.868083	28.315333	In Use			10.84		E-Sub	2 500 l/day	Steve Horen - Domestic and garden use	
BH62	Buiskop 464-KR	-24.868350	28.314717	In Use				obstructed	E-Sub	10 000 l/day	Ice making in the summer months	
BH63	Buiskop 464-KR	-24.876333	28.316217	In Use			8.9		E-Sub	2 500 l/day	Cattle watering with new domestic dwelling planned	

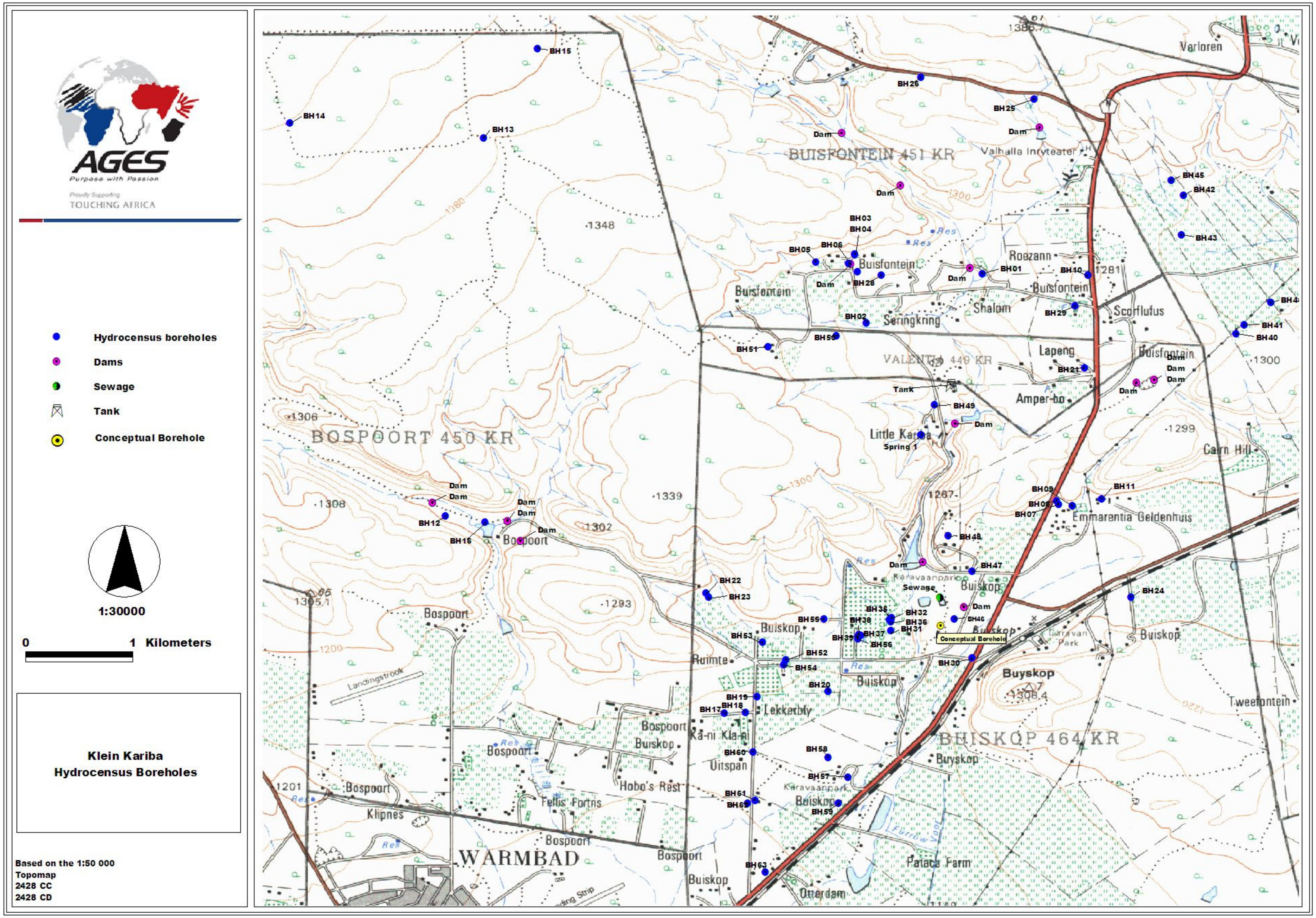

Figure 1: Summary of Borehole Census Results

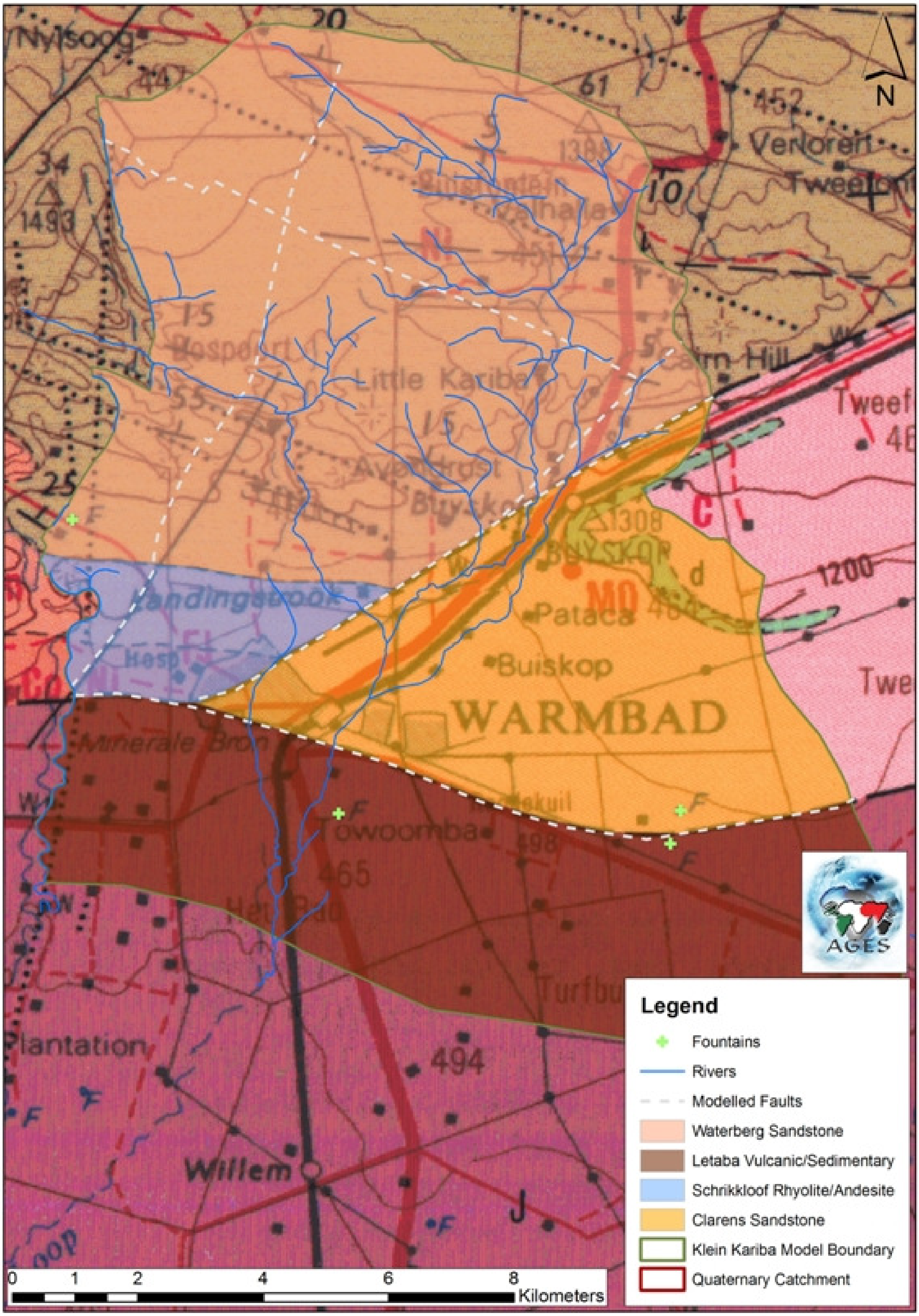

Figure 2: Regional Geological Setting

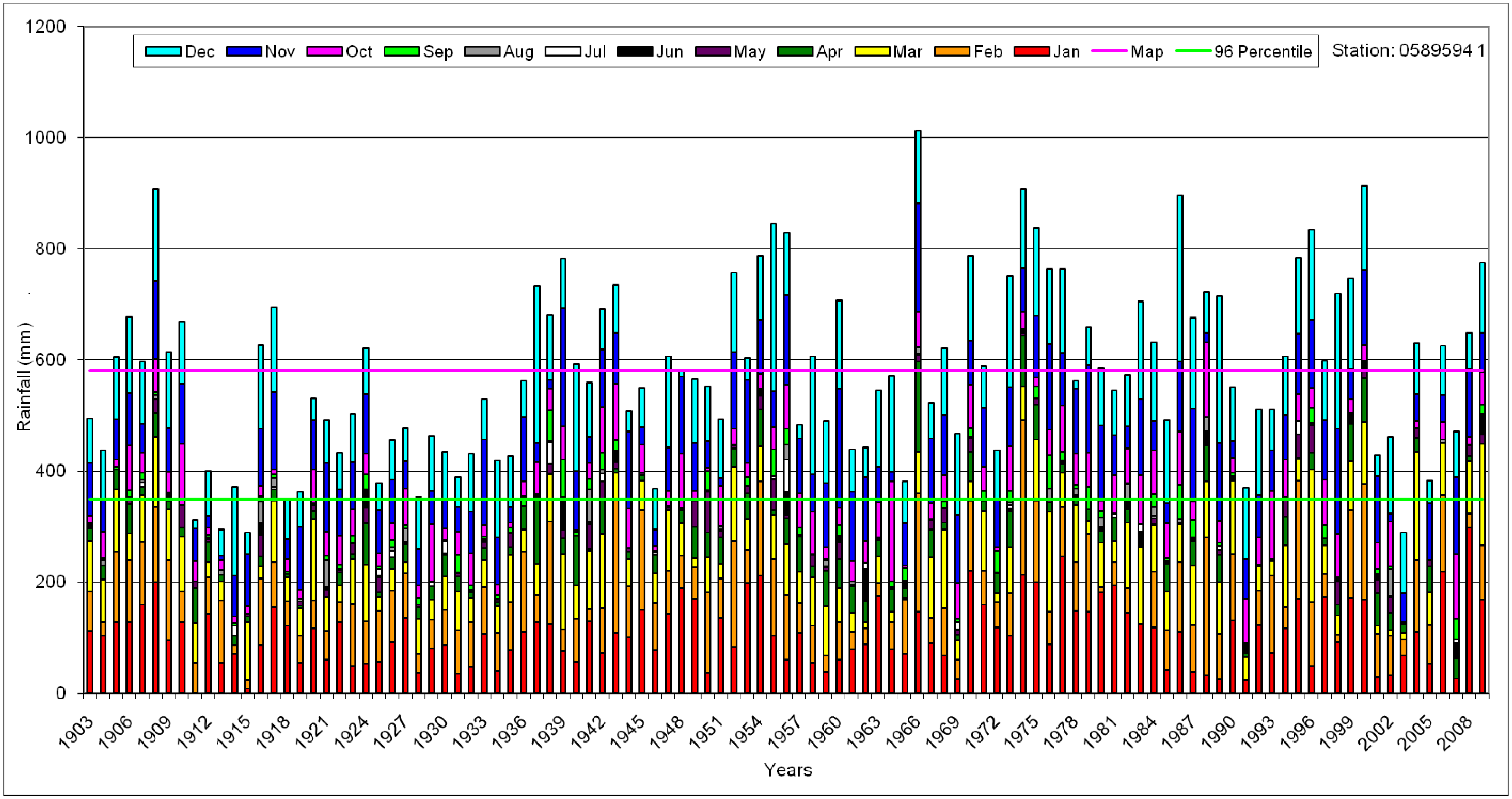

Figure 3: Rainfall Data for station 0589594

3 RESOURCE EVALUATION

3.1 Existing Information

In 2008 a geohydrological investigation was completed where a number of boreholes were identified, and tested to provide water for a proposed development on portion 1 of Valencia 449-KR. (See unpublished Geo-Logic report G2007/149 attached as appendix A).

Although both the area and the scope of the development are redefined, the two boreholes (BH01, and BH02) were successfully tested, and recommended for groundwater abstraction. Based on the current water levels (comparable with the initial findings), the yield tests are deemed valid, and thus the boreholes were not re-tested as part of this investigation.

Utilization recommendations are made with the aim of providing a **sustainable** water supply, even during prolonged periods when the annual rainfall is below average.

It should be noted that the boreholes evaluated are **existing boreholes**, and Messrs AGES can take no liability for borehole stability during long-term use. Borehole stability is related to the correct installation of sufficient, suitable casing to ensure that zones of weathering and fracturing are adequately protected for sidewall failure. Lower pumping yields over longer pumping schedules reduces the water level fluctuations in the borehole, and may reduce the chance of sidewall collapse in unstable boreholes.

During the current study, and in this report, the existing boreholes are re-numbered as follows:

- BH01 (static water level was 32.7m) is now – BH51 (water level 39.9m)
- BH02 (static water level was 12.3m) is now – BH50 (water level 19.8m)

It is noted that when the boreholes were initially tested in 2008, they were not in use, but were equipped based on the recommendations and have been in use since.

The following table is an extract from report G2007/149 and summaries the utilisation recommendations for the two boreholes located on Valencia.

Borehole Number	Previous Borehole Number (G2007/149)	Latitude	Longitude	Rec Abstraction Rate (l/sec)	Duty Cycle (hr/day)	Max Daily Abstraction (m^3/day)	Dynamic Water Level	Water Level (mbdl)
BH 51	BH01	24.83008	28.31643	1.4	24	121	53	Was 32.7m, now 39.9m
BH 50	BH02	24.82916	28.32217	1.2	24	104	47	Was 12.3m, now 19.8m
					TOTAL	225		

Table 3: Borehole Utilisation Recommendations

3.2 Regional Water Quality

Six regional water samples were collected during the initial investigation:

- Sample 1 – (L695) - The spring water currently used by Klein Kariba
- Sample 2 – (L696) - BH07 at Emmarentia Resort (east of the development)
- Sample 3 – (L697) - BH12 Bospoort Smallholdings (west of the development)
- Sample 4 – (L698) - BH51 Valencia portion 1 (development area)
- Sample 5 – (L699) - BH46 Borehole on the Zebediela Fault
- Sample 6 – (L701) - BH02 Valencia Smallholdings

A seventh water sample was collected for background water quality based on the concerns raised by water users on the Bospoort Smallholdings southwest of Klein Kariba.

- Sample 7 – (L1219) - BH19 Bospoort Smallholdings (southwest of the development)

The results of the water quality assessment (attached as appendix C) are plotted on a Stiff Diagram (Figure 4) presenting a simplified plot to illustrate the possible relationship of the water on site.

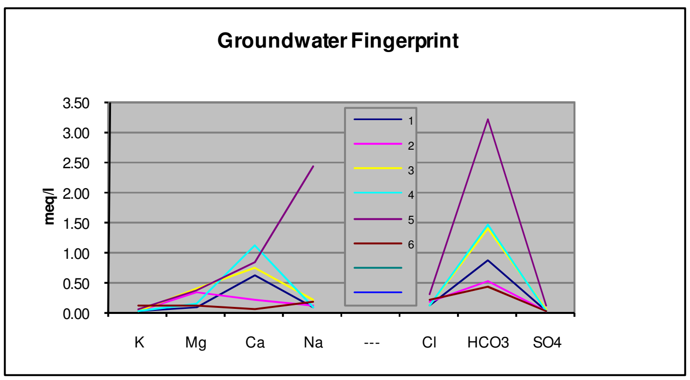

Figure 4: Groundwater Fingerprint

Based on the water quality results, the following is noted:

- The water sampled at BH46, along the Zebediela Fault has a different groundwater fingerprint
    - The local geological setting thus has a significant influence on the groundwater quality
- The water in all cases is deemed to be of Good Quality (class 1), and suitable for domestic use
- The groundwater (with the exception of BH46) has a **low pH**, and may be aggressive (corrosive) to geysers, metal pipes, and cement

The chemical character of the groundwater samples is deemed to be consistent with the local geology of the area, with Magnesium and Calcium being the prominent cations present in the water.

BH19 (sample 7) and BH12 (sample 3), both collected on the Bospoort Smallholdings southwest of Klein Kariba have the same fingerprint, and a very similar water chemistry composition (see appendix C). The results of the water quality analysis do support comments by local water users that the water is indeed of a very good quality (Ideal water quality for domestic use). The TDS of groundwater collected at BH19 is less than 80mg/ℓ, total hardness less than 45mg/ℓ, and a nitrate concentration falling below the minimum detection limits of the laboratory.

4 REGIONAL GROUNDWATER POTENTIAL

4.1 General

To ensure the sustainability of a groundwater resource, one needs to gain an understanding of regional flow patterns, groundwater - surface water interactions and variations in groundwater quantity in time and space.

4.2 Scale of the Abstraction

Based on the requirements of the Department of Water Affairs, the initial regional assessment is required to determine the necessary information required to assess a new water use license application. Study area parameters are summarised in Table 4 below.

Table 4: Summary of the scale of Abstraction

Available Groundwater (m3/day) based on various models			
		Study Area	DWA Category of Abstraction
Area (m^2)	Factor	6293983	
Resource Potential (m)	0.037	**638.0**	**127%**
Resource Potential (m)	0.050	**862.2**	**94%**
Harvest Potential (m^3/km/a)	10000	**172.4**	**469%**
Harvest Potential (m3/km/a)	15000	**258.7**	**313%**
GA	75	**129.3**	**626%**
GRA 11 (recharge - m)	0.022	**379.4**	**213%**
Wet Season Exploitation (m^3/m^2/a)	0.0273848	**472.2**	**171%**
Dry Season Exploitation (m^3/m^2/a)	0.0249116	**429.6**	**188%**
Comments		Easy to justify	Based on a total water demand of 809m3/day

Size of the Property	=	6 293 983 m^2
Recharge	=	various (based on different models)
Existing Water Use	=	326 m^3/day (at the existing resort)
New Use	=	111 m^3/day (437 m^3/day after upgrade at the existing resort
	=	372 m^3/day (at the new development)
Scale of Abstraction	=	with all recharge scenarios >100%
		Category C

Since with all recharge scenarios the abstraction ratio exceeds 100% (**category C**), a detailed geohydrological study is required. A numerical model was initiated based on the high abstraction ratio for a development that requires water for **primary domestic application**.

4.3 Water Demand

A joint water demand is used for the study based on the relationship between the proposed development and the existing Klein Kariba Resort (currently two of the water supply boreholes for Klein Kariba are located on the proposed development area).

The water demand for the existing resort (including planned future expansion) is calculated at 437 648 ℓ/day (existing use is estimated at 326 012 ℓ/day), and the proposed development has an estimated water demand of some 371 815 ℓ/day. These volumes are combined to define the joint water demand (**in the order of 809m^3/day**) which is used as the maximum water demand for the study.

4.4 Groundwater Model

A **conceptual groundwater model** was developed to determine and predict the regional groundwater flow based on an understanding of the regional geological and geohydrological setting. A **numerical groundwater model** was then developed. Using measured groundwater levels, and existing groundwater abstraction values, the model was calibrated to reflect and geohydrological conditions on site.

Based on the results of the calibrated numerical model, various **abstraction scenarios** are simulated, and the influence on the regional geohydrology is calculated, and used to predict the sustainability of the proposed abstraction. It is noted that when assumptions are made in the model, or where reference values are used, a conservative approach is followed, hence the groundwater sustainability is underestimated rather than overestimated resulting in a **high degree of assurance.**

The groundwater model was developed, and initially five abstraction scenarios were successfully simulated based on a total additional expected abstraction of 4.3ℓ/sec (375m^3/day) at the new development. A sixth scenario was then simulated based on the total water demand (809m^3/day) of not only the new development, but also the proposed upgrades at the existing resort. Details of the modelling process are reported fully in the unpublished AGES report AS-R-2010-03-15 attached as appendix B.

4.5 Model Scenarios

The following five model scenarios were initially simulated:

1. Scenario 1: The pumping of BH50 and BH51 at the maximum recommended rate (24h cycle) by GeoLogic (Kruidenier, 2008). BH50 pumps at 104m^3/d and BH51 at 121m^3/d.
2. Scenario 2: The pumping of BH50 and BH51 at the reduced 12h rate recommended by GeoLogic (Kruidenier, 2008) BH50 pumps at 73m^3/d and BH51 at 86m^3/d.
3. Scenario 3: The development of a deep production borehole on the Zebediela Fault near the Klein Kariba entrance to augment the supply to the proposed development. This borehole will augment supply with 216m^3/d to supply the total water demand from groundwater alone.
4. Scenario 4: The total volume of 375m^3/d is abstracted from the proposed new borehole on the Zebediela Fault.
5. Scenario 5: The initial total water demand for both Klein Kariba and the proposed development was 701m^3/d. Klein Kariba currently depends on the water from Spring 1 to a large extent for their water demand. Should the spring dry up due to extended periods of below average groundwater recharge, Klein Kariba would experience severe water shortages. Therefore this scenario models the total demand of 701m^3/day from a proposed well field on the Zebediela Fault.

6. A sixth scenario was simulated based on the revised combined water demand of the proposed development and the upgrading of the existing facilities. A total water abstraction of **809m^3/day** was simulated from a proposed well field on the Zebediela Fault.

4.6 Hydraulic Parameters

The hydraulic zones and the parameters used in the numerical model are summarised in Table 5 below.

Table 5: Hydraulic zones in the calibrated model

No	Hydraulic zone	Layer	Horizontal Conductivity Kx,y (m/d)	Saturated Thickness (m)	Transmissivity (m²/d)	Recharge (% of MAP)	Recharge (mm/year)	Recharge (m/d)
1	Waterberg plateau	1	0.028	250	7	3%	0.075	4.7671E-5
2	Waterberg outcrop	1	0.028	250	7	2.5%	0.0625	3.9726E-5
3	Waterberg valley	1	0.08	250	20	2.5%	0.0625	3.9726E-5
4	Schrikkloof formation	1	0.08	250	20	2.5%	8.75	3.9726E-5
5	Clarens formation	1	0.16	250	40	2.5%	14.5	3.9726E-5
6	Letaba formation	1	0.16	250	40	2.5%	45	3.9726E-5

4.7 Modelling results

4.7.1 Scenario 1

From the results of the transient modelling (simulated for a period of 25 years) for scenario 1, it can be seen that the modelled effect at the springs is a drawdown in hydraulic head of between 1.0 and 1.5 m after 25 years. During the first five years very little impact should be experienced, but after 25 years a slight reduction in the spring flow might be expected as a result of the pumping of boreholes BH50 and 51 at the maximum recommended rate.

The water balance indicates that all of the boreholes combined (including the proposed abstraction of scenario 1) would total a volume of 394m^3/d. It is noted that the spring outflow used by Klein Kariba is not included as borehole use in the model. The conservative recharge estimates used totals a groundwater recharge volume of 5,556m^3/d. The total water balance factoring in all of the in and outflows indicates a positive water balance exists after 25 years with the total inflows exceeding the total outflows by 28m^3/d.

4.7.2 Scenario 2

From the results of the transient scenario (simulated for a period of 25 years), it can be seen that the springs could be impacted by a decrease in the water table of around 1.0 m after 25 years. The impact expected after 25 years of pumping would be a drawdown of less than one metre. Similar to scenario 1, the first five years will see very little impact on the hydraulic head at the springs.

Compared to the total groundwater abstraction in scenario 1 of 568m^3/d, during scenario 2 the abstraction would reduce to 328m^3/d. This is a reduction of 66m^3/d just by decreasing the proposed pumping rates of BH50 and 51. The total water balance reflects a positive balance of 28m^3/d, which is similar to scenario 1. This can be ascribed to the balance of the groundwater abstraction that is now being lost through drains (springs) to reach the same equilibrium.

4.7.3 Scenario 3

The transient results for scenario 3 indicate a slight increase in the effect that would be realised at the springs when compared to scenario 2. The final impact that is modelled is a drawdown in hydraulic head at the springs of 1.0 m after 25 years of pumping.

Scenario 3 assumes that the total water demand for the proposed development (375m^3/d) will be abstracted from groundwater, bringing the total volume of groundwater abstraction for the modelled area to 544m^3/d. This has the effect that less water is available to escape through drains and other outflows. The total water balance after 25 years indicates that the total inflows exceed the total outflows by 27m^3/d.

4.7.4 Scenario 4

The impact on the hydraulic heads near the springs would be less than 0.5 m after an estimated 25 years. This scenario is deemed to be sustainable based on the conservative variables used in the model calibration.

According to the water balance for scenario 4 the total groundwater abstraction is 569m^3/d which is 25m^3/d more than in scenario 3 since the 25m^3/d that is currently being abstracted from BH51 (used in the calibrated model) is included in the total volume of groundwater abstraction for BH51 as per the yield recommendations used in scenarios 2 and 3. The water balance indicates that a positive water balance exists after 25 years with the total inflows exceeding the total outflows by 26m^3/d.

4.7.5 Scenario 5

Although the abstraction is almost doubled compared to scenario 4, the impact on the hydraulic heads near the springs would be less than 0.8 m after an estimated 25 years. This scenario is thus deemed to be sustainable based on the conservative variables used in the model calibration.

The total groundwater abstraction from wells increased from 569 m^3/d in scenario 4 to 894m^3/d in scenario 5. Even after this significant increase the water balance remains positive with total inflows exceeding outflows by 26m^3/day.

4.7.6 Scenario 6

Groundwater abstraction of some 809m^3/day is simulated from a proposed well field developed on the Zebediela Fault. This water is used as the primary water source for not only the upgrading of the existing resort, but also as the primary water supply to the proposed new development.

Based on the model, after 25 years, BH19, located on the Bospoort smallholdings will show a 4.2 meter loss in water level due to the proposed abstraction along the Zebediela fault. A borehole located on Dr Wessels' smallholding (BH55), will show a water level drop of some 4.8m, while the borehole (BH53), on Mr Lubbe's property will show a water level drop of some 4.6m after 25 years (transient flow).

Based on the results of the model, the hot water spring at Bela Bela Forever Resorts will experience less than 0.5m of head loss after 25 years due to the proposed abstraction at the Klein Kariba Resort.

4.8 Groundwater Potential

The results from the numerical model are positive for the abstraction of groundwater for water supply to both the proposed development and the existing resort.

The various scenarios do however indicate that the abstraction of groundwater should be focused along the Zebidelia Fault to the south of the site, rather than from boreholes located to the north of the site, close to the springs as abstraction from these boreholes in the north will have the greatest impact on the springs.

The abstraction of 809m^3/day, deemed to be the total water requirement of both the proposed development and the resort is thus deemed to be sustainable with a positive water balance.

5 CONTAMINATION RISK ASSESSMENT

5.1 Possible sources of contamination

The possible groundwater contamination sources on the site are limited to the disposal of on-site sanitation effluent, and the temporary storage of solid waste.

5.2 Risk Assessment

The risk of contamination to the local aquifer was determined during the previous geohydrological assessment (see report G2007/149 attached as appendix A).

The following extracts from the report summarise the findings:

- The aquifer is classed as a **minor aquifer** region and can be described as a moderately yielding aquifer system of variable water quality
- A **moderate tendency** or likelihood does exist for contamination to reach a specific position in the groundwater system after introduction at some location above the uppermost aquifer
- The aquifer is rated to have a **medium susceptibility** to contamination
- The **GQM index of the area is rated at 4**, with medium protection level needed
- The hydraulic flow time for water to reach the groundwater table is approximately 2 days. This is not regarded as enough for the attenuation of bacteria and viruses, thus the use of French drains or simplistic septic tanks cannot be recommended.

6 CONCLUSIONS

- The total study area is defined by the extent of the groundwater model boundary, and is approximately 138km^2 in extent.
- The proposed development is restricted to portion 1, 2, 3, and 4 of the cadastral farm Valentia 449-KR covering an area of approximately 1km^2.
- The existing water demand will increase at the existing resort due to the upgrading of the facilities.
- Due to the relationship between the proposed development, and the Klein Kariba Resort, the area of the resort (portion 87 of Buiskop 464-KR) of some 5.3km^2 is included in the investigation for the development of proposed boreholes.
- The study area falls within the Limpopo Catchment Management Area (CMA), within Quaternary Catchment Area (QCA) **A23G**.
- Natural vegetation covers the majority of the study area, with the development of wildlife smallholdings to the north of the area. Small scale agriculture, with isolated incidence of irrigation is noted to the south west of the area.
- The area is located in the summer rainfall region. The data yielded an average rainfall of 581 mm/a, but the annual rainfall is very erratic, with annual figures ranging from less than 300 mm to over 1 000 mm.
- The region experiences evaporation figures between 1 700 and 1 800 mm/a
- The prominent sandstone outcrops to the north is predominantly medium to coarse grained sandstone, pebble sandstone and conglomerate from the Swaershoek Formation of the Waterberg Group sediments. Finer grained sedimentary rocks like shale and siltstone also occur in this formation.
- The flat lying areas to the south are fine grained red to cream coloured sandstone of the Clarens Formation of the Karoo Super Group.
- A regionally significant fault, the **Zebediela Fault** that extents for many kilometres defines the contact between the Waterberg Group, and the Karoo Super Group.
- Further south the Clarens Formation is bound by the overlying by volcanic and sedimentary rocks of the Letaba Formation of the Karoo Super Group.
- The underlying aquifer is described as a Fractured Type Aquifer underlying the Waterberg sandstone and an Intergranular and Fractured Type aquifer underlying the Clarens and Letaba Formations.
- In and around the area of investigation a borehole yield median of between 0.5 and 2.0 L/s can be expected based on existing borehole data.
- According to the hydrogeological map, the Letaba Formation further to the south can yield in excess of 5.0 L/s.
- The Zebediela Fault is deemed to be a significant geohydrological feature, with Transmissivity an order of magnitude greater than the surrounding lithology. Borehole yields of greater than 5 ℓ/sec can be expected
- A numerical model was initiated based on the high abstraction ratio (abstraction/recharge > 100%) for a development that requires water for **primary domestic application**.
- Based on the relationship between the proposed development and the existing Klein Kariba Resort (currently two of the water supply boreholes for Klein Kariba are located on the proposed development area), the water demand for the existing

Resort is calculated at 437 648 ℓ/day (including planned future expansion), and the proposed development 371 815 ℓ/day are combined to define the joint water demand of **809m^3/day.**

- The following six model scenarios were simulated:

  a. Scenario 1: The pumping of BH50 and BH51 at the maximum recommended rate (24h cycle) by GeoLogic (Kruidenier, 2008). BH50 pumps at 104m^3/d and BH51 at 121m^3/d.

  b. Scenario 2: The pumping of BH50 and BH51 at the reduced 12h rate recommended by GeoLogic (Kruidenier, 2008) BH50 pumps at 73m^3/d and BH51 at 86m^3/d.

  c. Scenario 3: The development of a deep production borehole on the Zebediela Fault near the Klein Kariba entrance to augment the supply to the proposed development. This borehole will augment supply with 216m^3/d to supply the total water demand from groundwater alone.

  d. Scenario 4: The total volume of 375m^3/d is abstracted from the proposed new borehole on the Zebediela Fault.

  e. Scenario 5: The total water demand for both Klein Kariba and the proposed development is 701m^3/d. Klein Kariba currently depends on the water from Spring 1 to a large extent for their water demand. Should the spring dry up due to extended periods of below average groundwater recharge, Klein Kariba would experience severe water shortages. Therefore this scenario models the total demand of 701m^3/day from a proposed well field on the Zebediela Fault.

  f. Scenario 6: The revised combined water demand of the proposed development and the upgrading of the existing facilities with a total water abstraction of **809m^3/day** was simulated from a proposed well field on the Zebediela Fault.

- Although the two existing boreholes (previously tested) located on the development area are deemed suitable for groundwater abstraction to a daily maximum of 225m^3, the greater impact on the springs (1m – 1.5m over a 25 year period) should limit the utilisation of these boreholes in preference to proposed boreholes along the Zebediela fault where the impact on the springs is far less (less than 0.8m over 25 years)
- The abstraction of 809m^3/day, deemed to be the total water requirement of both the proposed development and the resort is deemed to be sustainable with a positive water balance
- The local groundwater gradient is from the north-west towards the south.
- The water sampled at BH46, along the Zebediela Fault has a different groundwater fingerprint, confirming that the groundwater reflects the different geological setting
- The water in all cases is deemed to be of Good Quality (class 1), and suitable for domestic use

- The groundwater (with the exception of BH46) has a **low pH**, and may be aggressive (corrosive) to geysers, metal pipes, and cement
- The chemical character of the groundwater samples is deemed to be consistent with the local geology of the area, with Magnesium and Calcium being the prominent cations present in the water
- Results of analysis of groundwater collected on the Bospoort Smallholdings southwest of Klein Kariba supports comments by local water users that the water is indeed of a very good quality (Ideal water quality for domestic use). The TDS of groundwater collected at BH19 is less than 80mg/ℓ, total hardness less than 45mg/ℓ, and a nitrate concentration falling below the minimum detection limits of the laboratory.
- The aquifer is classed as a **minor aquifer** region and can be described as a moderately yielding aquifer system of variable water quality
- A **moderate tendency** or likelihood does exist for contamination to reach a specific position in the groundwater system after introduction at some location above the uppermost aquifer
- The aquifer is rated to have a **medium susceptibility** to contamination
- The **GQM index of the area is rated at 4**, with medium protection level needed
- The hydraulic flow time for water to reach the groundwater table is approximately 2 days. This is not regarded as enough for the attenuation of bacteria and viruses, thus the use of French drains or simplistic septic tanks cannot be recommended.

7 RECOMMENDATIONS

7.1 Groundwater Development

7.1.1 Existing Boreholes

- The existing boreholes should be numbered in the field according to the specifications of DWA in Limpopo, so that information can be entered on the National Groundwater Database, and that data can be managed on a regional basis.
- The existing boreholes BH50, and BH51 should only be used as a water supply for a limited period of no more than 5 years, while further groundwater development along the Zebediela fault takes place.
- Groundwater abstraction from borehole BH49 which currently abstracts 30m^3/d (peak season) should be stopped. Borehole BH49 should be developed as a monitoring borehole for critical groundwater water level management near to spring 2. The information on the water level can be used to manage the abstraction from boreholes BH50, and BH51 to protect the springs.
- Water levels of water supply boreholes should be measured on a quarterly basis and archived for trend analysis.
- Water abstraction should be licensed with the DWA - (21a-taking water from a resource)
- Existing boreholes on the Klein Kariba Resort should be tested to confirm the aquifer properties, and to determine the sustainable groundwater yield
- Existing boreholes on the Klein Kariba Resort should be maintained as standby emergency water supply to the resort
- Although **seasonal**, the existing spring, and well point abstraction will continue to be an important water supply to the resort

7.1.2 New Boreholes

- All new boreholes should be numbered in the field according to the specifications of DWA in Limpopo, so that information can be entered on the National Groundwater Database, and that data can be managed on a regional basis.
- Valencia 449-KR
  - No additional boreholes should be developed on the proposed development area, with management and restricted abstraction for the two existing boreholes.
- Klein Kariba Resort
  - A detailed geophysical investigation should be initiated to determine the orientation and inclination of the Zebediela Fault
  - Suitable drilling positions for exploration drilling should be targeted along the Zebediela Fault
  - A borehole well-field should be developed along the Zebediela Fault to a cumulative maximum of 810m^3/day (provision should be made for a standby borehole)
  - The well field should target both deep water strikes, and more shallow water strikes.

- Should the fault be targeted at depth, there is a high possibility that heated water will be encountered, this in turn may supplement other recreational water demands at the resort
- Should the fault be targeted at more shallow depths, the potential groundwater yield from the well-field will meet the full water demand of 809m^3/day.

7.1.3 Return Waste Water

- Treated water from sanitation systems may be used for the irrigation of gardens. Irrigation with waste or water containing waste should meet strict discharge requirements, and be licensed with the DWA (21e-irrigation with water containing waste as a controlled activity)

7.2 Water Quality

- It is recommended that water with low pH be treated with lime to elevate the pH to approximately 7.
  - The sodium and calcium concentrations are sufficiently low so as not to have a negative effect on water salinity.
  - The taste of the water will improve from slightly sour to a more palatable taste
- Mixing water from the proposed Zebediela well-field will also have a positive effect on water quality of groundwater abstracted from the Waterberg Sandstones.

7.3 On Site Sanitation

- A well head protection area (WHPA) is established to protect a borehole or spring from contact with pathogenic micro-organisms and chemical contaminants which can emanate from a source (e.g. septic system, etc). It is designed to protect the borehole or spring from chemical contaminants that may migrate to the borehole and typically includes a major portion of the recharge area or the capture zone (radius of 200m). It is therefore recommended that:

1. No waste storage facility to be located within 200 m from any borehole or spring.
2. No irrigation of water containing waste takes place within a 200 m radius from any borehole or spring.
3. On-site sanitation systems that do <u>not</u> rely on seepage for the disposal of liquids must be used.

7.4 Monitoring and Management

- G<u>roundwater levels</u> (rest and pump levels) must be monitored on a quarterly basis. Should the water level drop to within **2 metres** of the pump intake during regular pumping, the pumping rate should be reduced. Results of recorded abstraction rates, abstraction volumes, and water levels may then be re-evaluated.
- **Totalling flow meters** must be installed on all production boreholes in order to monitor monthly <u>abstraction volumes</u>.
- An **annual** assessment of the **groundwater quality,** both microbial and macro-chemical**,** should be conducted to ensure that the water is potable, and suitable for domestic use.

8 REFERENCES

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Klein Kariba Water Supply: Groundwater Flow Modelling Report (AS-R-2010-03-15)

Appendix A

Geohydrological Report
G 2007/149

Appendix B

Groundwater Modelling Report
AS-R-2010-03-15

Appendix C

Water Quality Results

V0014

CAPRICORN VETERINARY LABORATORIES cc

VETERINARY PRECISE ANALYTICAL & DIAGNOSTIC LABORATORY SERVICES

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Fax: +27(15) 297-6666
E-mail: caprivet@telkomsa.net

LABORATORY TEST REPORT

WATER CHEMISTRY:

Your reference:	**220-ATKVKlein Kariba**
Our reference:	**10/01/143**
Enquiries:	**015 297-6666**
Date:	**2010/01/29**

Sender/ Client:	Ages Group Limpopo	**Owner:**	Ref sender
Person sent:	Miss. Magderie Botha	**Sample origin:**	On site – Not specified
Postal:	P.O. Box 2526 Polokwane 0700	**Postal:**	Ref sender Ref sender Ref sender
Tel:	015 291-1577	**Tel:**	Ref sender
Fax:	015 291-1577	**Fax:**	Ref sender
E-mail:	limpopo@ages-group.com	**E-mail:**	Ref sender

Ground water

1. Samples received:
7 x ground water sample(s) as indicated in Table 1.

1.1 Date sample(s) received:	2010/01/20
1.2 Time sample(s) received:	14h30
1.3 Date test(s) started:	2010/01/27
1.4 Date test completed:	2010/01/28

2. Required test(s):
2.1 Water chemistry

3. Test method
The sample(s) were tested in accordance with:

3.1 Refer to Appendix A

4. Sample and condition/…

4. Sample and condition :

4.1 Date of sampling: 2010/01/19
4.2 Date sample submitted: 2010/01/20
4.3 Temp. upon sample reception: 27.5°C
4.4 Sample defects noted: None

5. Sub contractor:

5.1 Sub contractor: Labserve
5.2 Submission date to sub-contractor: 2010/01/26
5.3 Submission method: EPX courier services on ONX.

.

6. Results:

<u>Table 1:</u>
Refer to 2.1

Determinand	Unit	1. 1-10/143	2. 2-10/143	3. 3-10/143	4. 4-10/143
		L695	L696	L697	L698
Physical and aggregate properties					
pH @ 25°C	pH units	6.0	6.0	6.8	6.9
Conductivity @25°C	mS/m	9.1	8.4	14.8	14.2
*Total dissolved solids (calculated)	mg/l	60.7	54.5	103.8	92.8
Alkalinity					
*Bicarbonate alkalinity as $CaCO_3$	mg/l	52	32	84	88
*Carbonate alkalinity as $CaCO_3$	mg/l	0	0	0	0
Hardness					
*Total hardness as $CaCO_3$	mg/l	34.2	26.7	56.6	63.2
*Ca hardness as $CaCO_3$	mg/l	30.5	9.5	36.5	55.8
*Mg hardness as $CaCO_3$	mg/l	3.7	17.2	20.1	7.4
Metals					
*Calcium as Ca (**)	mg/l	12.2	3.8	14.6	22.3
*Iron as Fe (**)	mg/l	<0.01	<0.01	<0.01	<0.01
*Magnesium as Mg (**)	mg/l	0.9	4.2	4.9	1.8
*Manganese as Mn (**)	mg/l	0.01	<0.01	<0.01	0.02
*Potassium as K (**)	mg/l	0.22	1.1	1.2	0.47
*Sodium as Na (**)	mg/l	1.3	2.4	5.1	1.4
Inorganic non-metallic constituents					
Chloride as Cl	mg/l	3.3	6.4	4.5	3.8
Fluoride as F	mg/l	<0.1	<0.1	<0.1	<0.1
Nitrogen					
Nitrate as NO_3-N	mg/l	<1.4	<1.4	<1.4	<1.4
*Nitrite as NO_2-N	mg/l	<0.01	<0.01	<0.01	<0.01
Sulphur					
*Sulphate as SO_4 (**)	mg/l	0.61	0.68	2.7	0.63

Table 1/…

Table 1 (continued):
Refer to 2.1

Determinand	Unit	5. 5-10/143	6. 6-10/143	7. 7-10/143
		L699	L700	L701
Physical and aggregate properties				
pH @ 25°C	pH units	7.9	5.8	6.0
Conductivity @25°C	mS/m	35.4	2.6	4.6
*Total dissolved solids (calculated)	mg/l	233.1	32.7	43.7
Alkalinity				
*Bicarbonate alkalinity as $CaCO_3$	mg/l	195	22	26
*Carbonate alkalinity as $CaCO_3$	mg/l	0	0	0
Hardness				
*Total hardness as $CaCO_3$	mg/l	58.7	14.3	8.5
*Ca hardness as $CaCO_3$	mg/l	41.5	10.3	1.5
*Mg hardness as $CaCO_3$	mg/l	17.2	4.0	7.0
Metals				
*Calcium as Ca (**)	mg/l	16.6	4.1	0.6
*Iron as Fe (**)	mg/l	0.01	2.5	0.17
*Magnesium as Mg (**)	mg/l	4.2	0.97	1.7
*Manganese as Mn (**)	mg/l	<0.01	<0.01	0.05
*Potassium as K (**)	mg/l	1.8	1.8	0.23
*Sodium as Na (**)	mg/l	55.7	1.0	3.7
Inorganic non-metallic constituents				
Chloride as Cl	mg/l	10.7	<1.5	6.9
Fluoride as F	mg/l	0.35	<0.1	<0.1
Nitrogen				
Nitrate as NO_3-N	mg/l	<1.4	<1.4	<1.4
*Nitrite as NO_2-N	mg/l	<0.01	0.03	<0.01
Sulphur				
*Sulphate as SO_4 (**)	mg/l	5.8	1.9	0.6

Key:
(**) - Sub contracted analysis
* - Not a SANAS accredited method

Disclaimer: Comments and Interpretations expressed herein are not within the scope of SANAS accreditation.

7. Comments:
7.1None

8. Interpretations:
8.1 None

.... Analyst
.... Head of Section
.... Technical Manager

(END OF REPORT)

CAPRICORN VETERINARY LABORATORIES cc

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E-mail: caprivet@telkomsa.net

LABORATORY TEST REPORT

WATER CHEMISTRY:		**Your reference:**	L10-081H
		Our reference:	10/12/2588
		Enquiries:	015 297-6666
		Date:	2010/12/30
Sender/ Client:	Ages Group Limpopo	**Owner:**	Ref sender
Person sent:	Miss. M. Botha	**Sample origin:**	On site – Nico Espach
Postal:	P.O. Box 2526 Polokwane 0700	**Postal:**	Ref sender Ref sender Ref sender
Tel:	015 291-1577	**Tel:**	Ref sender
Fax:	015 291-1577	**Fax:**	Ref sender
E-mail:	limpopo@ages-group.com	**E-mail:**	Ref sender

Water

1. **Samples received:**
1 x ground water sample(s) as indicated in Table 1.

1.1 Date sample(s) received:	2010/12/09
1.2 Time sample(s) received:	11h20
1.3 Date test(s) started:	2010/12/09
1.4 Date test completed:	2010/12/21

2. **Required test(s):**
2.1 Water chemistry

3. **Test method**
The sample(s) were tested in accordance with:

3.1 Refer to Table 1.

4. Sample and condition/...

4. Sample and condition :
4.1 Date of sampling: 2010/12/03
4.2 Date sample submitted: 2010/12/09
4.3 Temp. upon sample reception: 26.0°C
4.4 Sample defects noted: Prolonged sample submission period

5. Sub contractor:
5.1 None
.
6. Results:

Table 1:
Refer to 2.1

Determinand	Test Method Reference	Unit	1. 1-10/2588 L1219
pH @ 25°C	CH-METH-001	pH units	6.3
Conductivity @25°C	CH-METH-002	mS/m	12.2
*Total dissolved solids (calculated)	CH-METH-038	mg/l	79.3
Alkalinity			
*Bicarbonate alkalinity as $CaCO_3$	CH-METH-006	mg/l	47.2
*Carbonate alkalinity as $CaCO_3$		mg/l	0
Hardness:			
*Total hardness as $CaCO_3$	CH-METH-039	mg/l	44.54
*Ca hardness as $CaCO_3$		mg/l	28.50
*Mg hardness as $CaCO_3$		mg/l	16.04
Metals			
*Calcium as Ca	CH-METH-020	mg/l	11.40
*Iron as Fe	CH-METH-020	mg/l	<0.01
*Magnesium as Mg	CH-METH-020	mg/l	3.91
*Manganese as Mn	CH-METH-020	mg/l	0.01
*Potassium as K	CH-METH-020	mg/l	2.09
*Sodium as Na	CH-METH-020	mg/l	7.81
Inorganic non-metallic constituents			
Chloride as Cl	CH-METH-012	mg/l	8.3
Fluoride as F	CH-METH-013	mg/l	0.11
Nitrogen			
Nitrate as NO_3-N	CH-METH-010	mg/l	<1.4
*Nitrite as NO_2-N	CH-METH-011	mg/l	<0.01
Sulphur			
*Sulphate as SO_4	CH-METH-020	mg/l	2.05

Key:
* - Not a SANAS accredited method

Disclaimer: Comments and interpretations expressed herein are not within the scope of SANAS accreditation.

7. Comments/...

7. Comments:
7.1 The sample(s) have deviated from the norm, in which the maximum preservation period allowed for certain chemical determinands has been exceeded prior to sample submission. The prolonged sample submission period does have an impact with regards to the outcome of the test results.

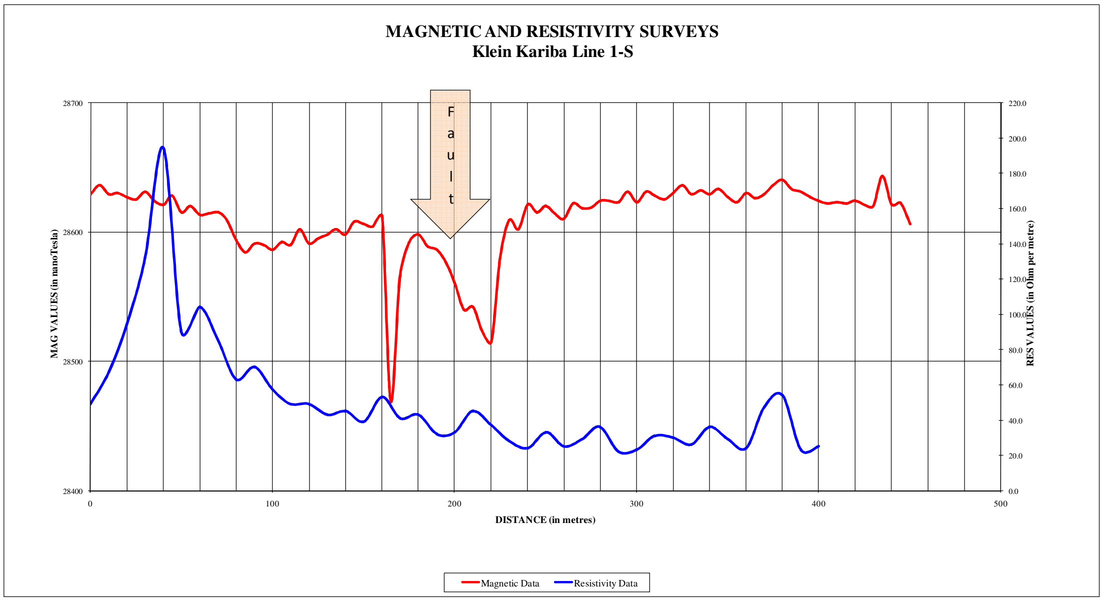
8. Interpretations:
8.1 None

…………………………
Technical Signatory

(END OF REPORT)

Appendix D

Geophysical Survey Results


MAGNETIC AND RESISTIVITY SURVEYS
Klein Kariba Line 1-S
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MAG VALUES (in nanoTesla)
RES VALUES (in Ohm per metre)
DISTANCE (in metres)
28700
28600
28500
28400
0
100
200
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220.0
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180.0
160.0
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60.0
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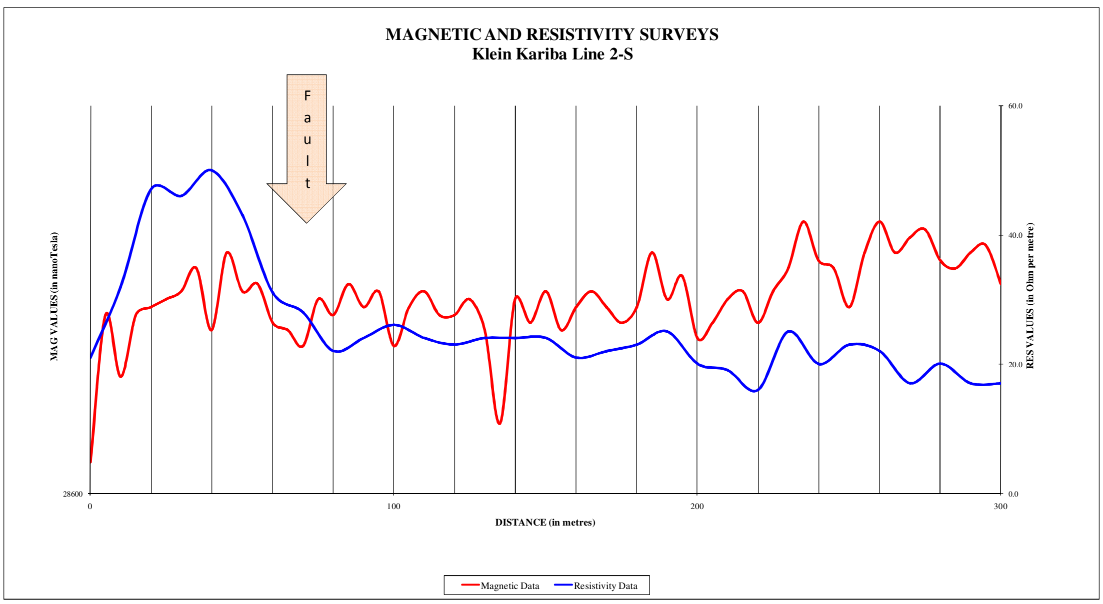
Magnetic Data
Resistivity Data


MAGNETIC AND RESISTIVITY SURVEYS
Klein Kariba Line 2-S
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MAG VALUES (in nanoTesla)
RES VALUES (in Ohm per metre)
DISTANCE (in metres)
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Magnetic Data
Resistivity Data