PRELIMINARY GEOHYDROLOGICAL ASSESSMENT FOR CEMETERY DEVELOPMENT IN PLETTENBERG BAY

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For:
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SYNOPSIS

Preliminary geohydrological assessment as a specialist study for a proposed cemetery

KEY WORDS:

Geology, geohydrology, hydrocensus, geophysics, groundwater use, groundwater potential, water quality, groundwater, risk, impact and mitigation

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

Verification	Capacity	Name	Signature	Date
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PRELIMINARY GEOHYDROLOGICAL ASSESSMENT FOR CEMETERY DEVELOPMENT IN PLETTENBERG BAY

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1 INTRODUCTION AND TERMS OF REFERENCE

This report presents the results of a specialist geohydrological assessment for proposed cemetery sites on Remainder 3 of Farm 437 and Portion 33 of Farm 437 located in Plettenberg Bay in the Western Cape Province. The site has been reviewed in terms of the geohydrological setting, groundwater use, aquifer vulnerability, strategic value, risk and impact. Geohydrological assessments typically comprise the following phased approach:

Phased Approach to Geohydrological Assessments		
Level of Assessment	Phase	Activity Description
Preliminary Geohydrological Assessment	1	Desktop investigation
	2	Site walkover assessment
	3	Hydrocensus survey
	4	Geophysical investigation
	5	Data interpretation, conceptual model and preliminary report

2 INFORMATION SUPPLIED

The following information has been used in the preparation of this report:

Reports and Documents

- The Department of Water Affairs, First Edition, February 2010. Operational Guideline: Integrated Water and Waste Management Plan
- The Department of Water Affairs and Forestry, Second Edition, 1998. Waste Management Series. Minimum Requirements for Waste Disposal by Landfill
- The Department of Water Affairs and Forestry, Third Edition, 2005. Waste Management Series. Minimum Requirements for Water Monitoring at Waste Management Facilities
- NP Richards and L Croukamp (2004). Geotechnical Investigation Guidelines for Cemetery Site Selection. Council for Geoscience
- The Department of Water Affairs and Forestry, undated. Water quality management policy with regard to the management of and control over cemeteries as a source of water pollution. Internal circular
- World Health Organization, 1998. The Impact of Cemeteries on the Environment and Public Health – An Introductory Briefing.
- Groundwater Africa, 2011. Bitou Municipality Emergency Groundwater Supplies: Borehole Rehabilitation and Drilling
- Parsons and Associates, 2013. Authorizations and Approvals for a Cemetery for the Bitou Municipality: Geohydrological Assessment. Report 327/BCP-D1
- Outeniqua Geotechnical Services, 2013. Geotechnical Report for a Proposed New Cemetery in Plettenberg Bay (Bitou Municipality), Western Cape

- Groundwater Africa, 2018. Bitou Municipality Plettenberg Bay 2018 Drilling Report

Maps and Figures

- Map Sheet titled, "3322 Oudtshoorn", at a scale of 1:250 000, digital version, of the Geological Map Series, supplied by the Department of Mineral and Energy Affairs. CGS 1979.
- Map Sheet titled, "Oudtshoorn 3320", at a scale of 1:500 000, first edition, dated 2000, of the Hydrogeological Map Series of the Republic of South Africa, supplied by the Directorate: Geohydrology, of the Department of Water Affairs and Forestry. DWS 1999.

Data

- National Groundwater Archive (NGA) digital information, as supplied by The Department of Water and Sanitation (DWS) as at October 2020.
- Bitou Municipality borehole data

3 SCOPE OF WORK

Following a Request for Quotation No. SCM/RFQ/2021/009/EDP by Bitou Municipality for the Provision of Geohydrologist Services, JG Afrika (Pty) Ltd submitted a proposal referenced 005324 2017091P01, titled "Provision of Geohydrologist Services", dated 1 August 2020. JG Afrika (Pty) Ltd were requested to proceed with the specialist geohydrological study by Bitou Municipality by means of a Purchase Order No. 390215 received by email on 23 September 2020.

The specific Scope of Works of the Provision of Geohydrologist Services is as follows:

- An intrusive site investigation and water features survey.
- Identification of watercourses, wetlands, boreholes and sensitive targets in the proximity of the site and to determine their distance from or position within the proposed site.
- Aquifer type and classification.
- A hydrocensus (500m radius from the edge of the site) of ground or surface water sources used for drinking.
- The soil profile of the site
- A determination of any fault structures which are concealed beneath overburden.
- Identification of any infrastructure (e.g. metal water mains that would pass beneath the cemetery) that may experience increased acceleration of corrosion.
- Identification and assessment of any artificial drainage with the ground associated with the previous land use.
- Hydrogeological risk assessment including a contamination risk assessment.
- Maps must be compiled depicting the general geology, groundwater flow directions, pollution dispersal and water quality.
- A groundwater monitoring plan be prepared and the baseline groundwater quality documented.

4 LOCALITY

4.1 SITE AND ACTIVITY DESCRIPTION

The proposed sites identified for the cemetery developments are Remainder 3 of Farm 437 and Portion 33 of Farm 437, which are located approximately 4km northwest of the Central Business District of Plettenberg Bay, in the Western Cape Province. The properties can be accessed off the N2 highway between George and Port Elizabeth.

The proposed site is characterised by gentle rolling hill topography. The site elevation ranges between 183 and 170mamsl. The site is currently used as grazing land for cattle and minor recreation (picnic area).

The project area falls on the boundaries of K60F and K60G quaternary catchments, which are primarily drained by the Bietou River and Piesang River, respectively. Both the Bietou and Piesang Rivers flow in an easterly direction into the Indian Ocean. Remainder 3 of Farm 437 mainly slopes towards the east into the catchment area of the Piesang River, whilst Portion 33 of Farm 437 slopes in a north-easterly direction into the catchment area of the Bietou River. A non-perennial stream flows through Portion 33 of Farm 437 in a north-easterly direction and forms a tributary of the Bietou River.

The proposed development comprises the establishment of grave sites within a cemetery development. The extent of the cemetery will be limited to “sub-areas” identified by a recent geotechnical assessment (OGS, 2013).

The location is shown in **Figure 1**.

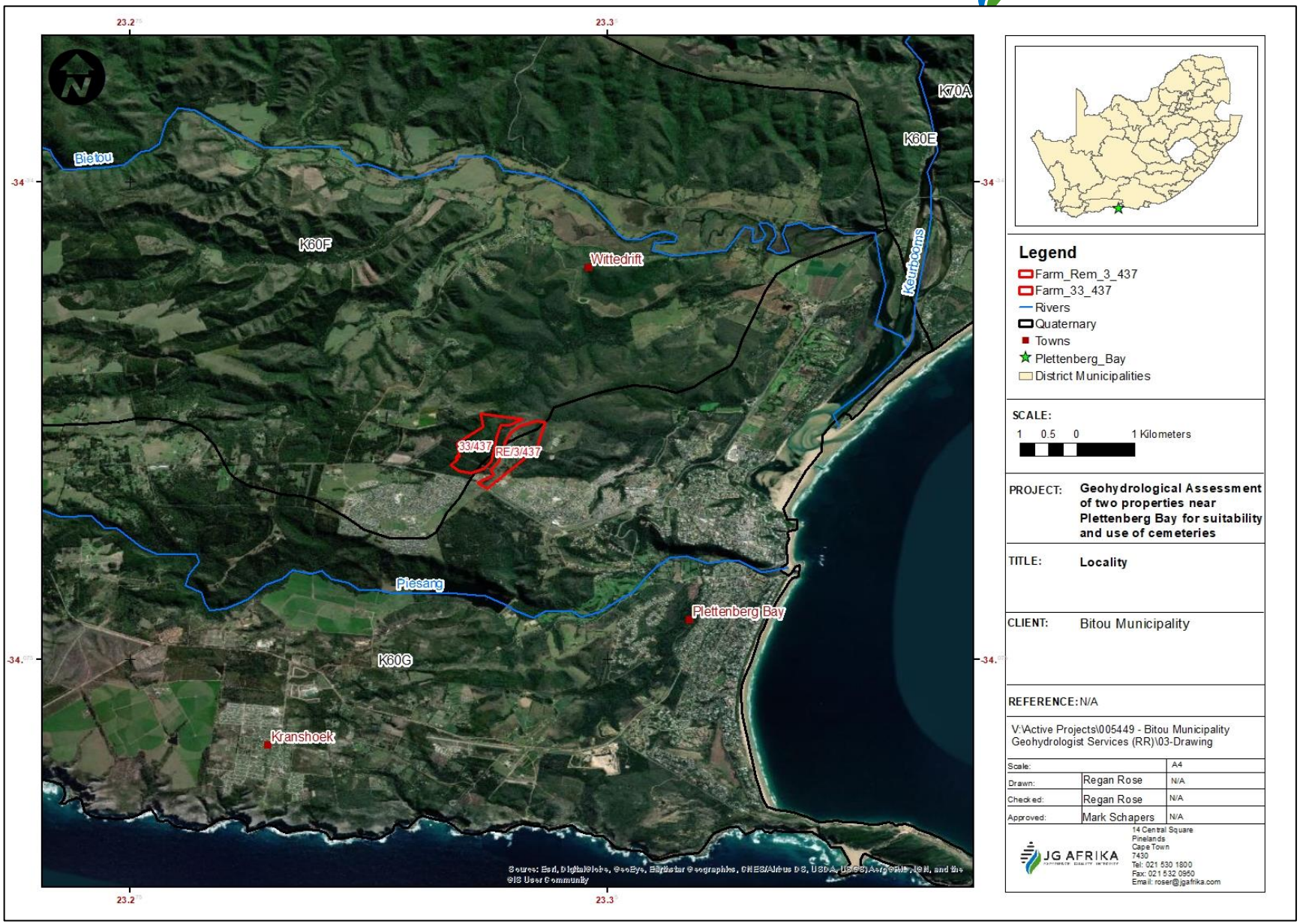

Figure 1: Locality Plan

5 DESKTOP ASSESSMENT

5.1 Regional Geology

The area is underlain by rocks of the Table Mountain Group (TMG), Bokkeveld Group and Uitenhage Group, respectively. The full stratigraphic succession of the TMG is present in the area, which consists mainly of alternating massive quarzitic and feldspathic sandstone formations, separated by shale of the Cedarberg Formation. The basal Bokkeveld Group (Gydo Formation) has limited extent in the north of the project area and consists of shale and siltstone. The Cretaceous aged Enon Formation unconformably overlies the TMG and Bokkeveld Group sediments mainly in the lower lying areas.

Structurally, the TMG and Bokkeveld Group form a syncline as part of the broader Cape Fold Belt. Faulting resulted in small elongated asymmetrical northward tilting half-grabens which was subsequently filled with Cretaceous sediments (Parsons and Associates, 2013). A summary of the geological formations of the site and surrounding area is provided in **Table 1** with the regional geology presented in **Figure 2.**

Table 1: Summary of Geological Formations and Rock Type

Map Symbol	Age	Group	Formation	Lithological Description
Qg	Tertiary			Marine and estuarine terrace gravel and sand
Ke	Cretaceous	Uitenhage	Enon	Conglomerate, sandstone, siltstone, clay
Dg	Devonian	Bokkeveld	Gydo	Shale, siltstone
Sb	Silurian	TMG	Baviaanskloof	Feldspathic sandstone
Sk			Kouga	Whitish weathered quarzitic sandstone, medium to coarse grained, cross-bedded; subordinate shale
St			Tchando	Brownish weathering sandstone, fine to coarse grained; shale
Oc	Ordovician		Cedarberg	Shale, arenaceous shale
Op			Peninsula	Whitish weathered quartzitic sandstone, medium to coarse grained, massive

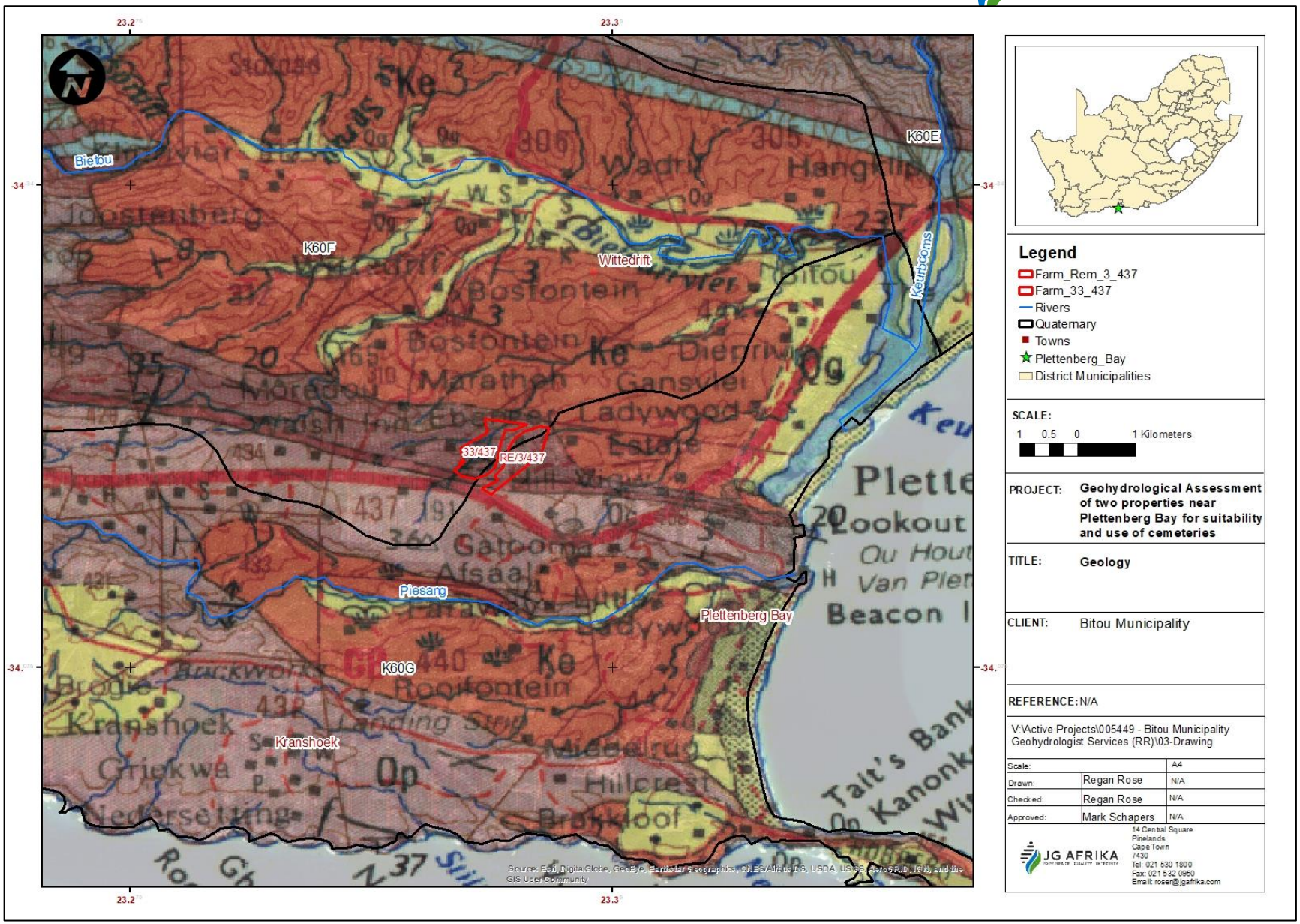

Figure 2: Regional Geology

5.2 Regional Geohydrology

The regional geohydrology of the study area comprises of mainly fractured aquifers; comprising mainly fractured sandstone with the fracturing mainly as a result of joints, fissures, faults, bedding planes, etc. Median borehole yields are in the range of 0.5–2.0l/s. Groundwater quality contoured in the DWAF's publication "Hydrogeological Map Series, Oudtshoorn 3320" indicates the Electrical Conductivity (EC) to be in the range of 70 – 300mS/m. The regional geohydrology is presented in **Figure 3** and the groundwater quality map is presented in **Figure 4**.

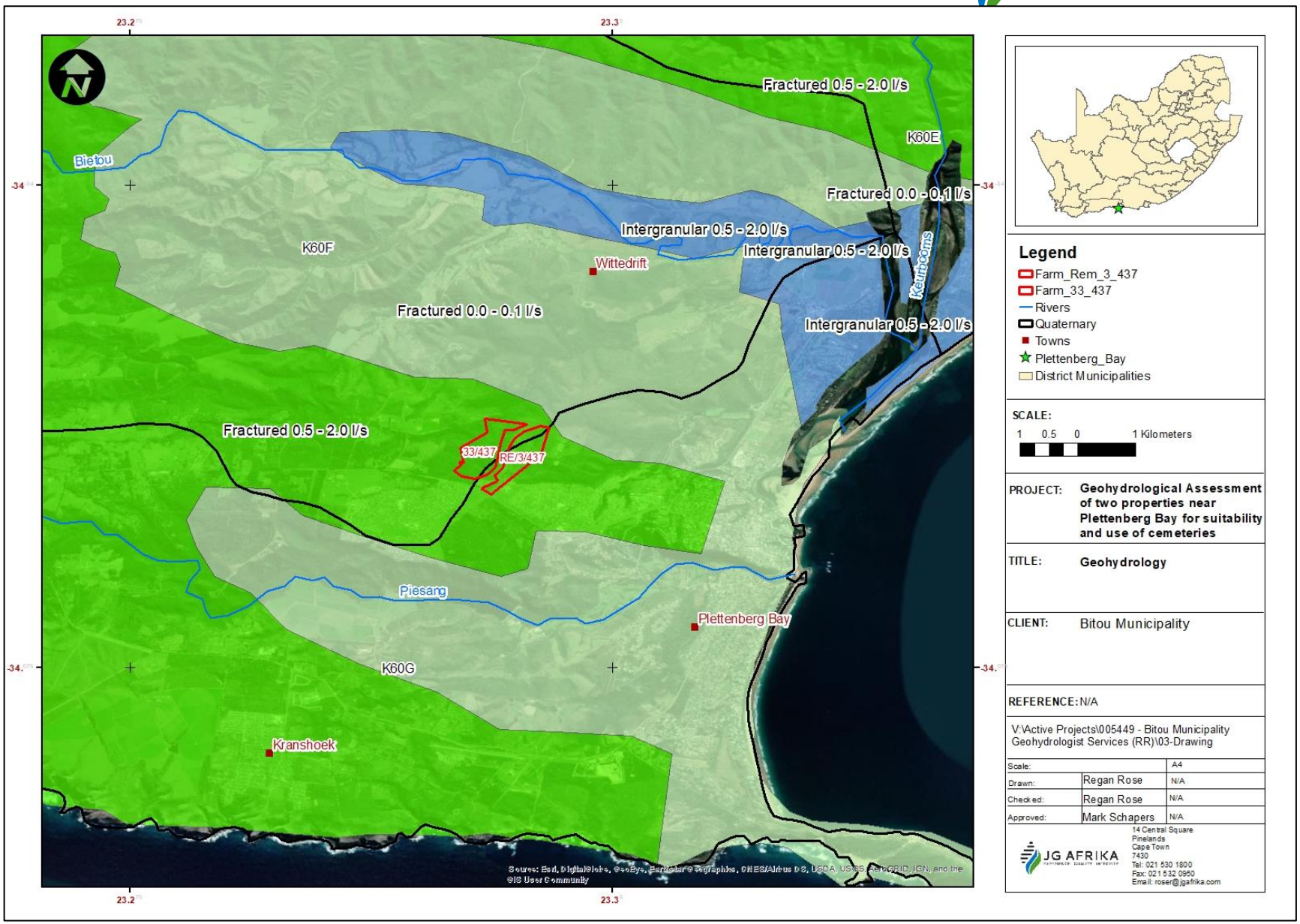

Figure 3: Regional Geohydrology

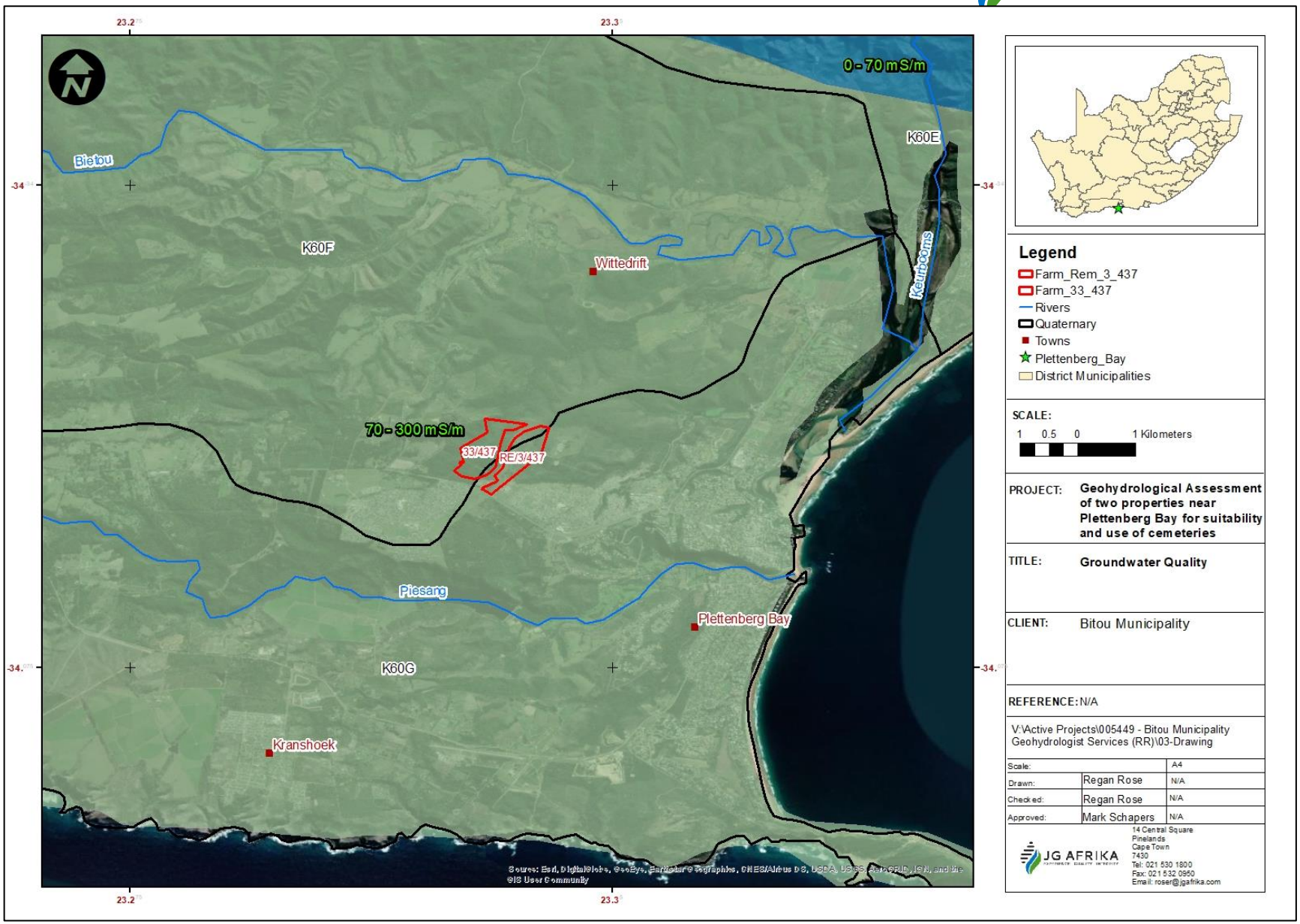

Figure 4: Regional Groundwater Quality

5.3 Recharge

Based on WR2012 data (WRC; Surface Water Resources of South Africa 2012 Study) the Mean Annual Precipitation (MAP) for the quaternary catchment K60G (Remainder 3 of Farm 437) is 806mm/annum and the estimated recharge is 70.5mm/annum, whilst the MAP for the quaternary catchment K60F (Portion 33 of Farm 437) is 860mm/annum and the estimated recharge is 71.3mm/annum. The anticipated recharge for the combined properties of 6.4km^2 is 0.59Mm^3/annum. The results of the first estimate of recharge are presented in Annexure A.

5.4 Surface Water Body Mapping

Portion 33 of Farm 437 and Remainder 3 of Farm 437 are situated along the watershed of K60F and K60G respectively. No major surface water bodies are present on both properties owing mainly to their relative locations on a slight topographical high. A small surface drainage line flows through Portion 3 of Farm 437 and forms a north-easterly flowing non-perennial tributary of the Bietou River. As a result of this localised ponding occur periodically along this drainage line. However small and localised ponding was noted on Remainder 3 of Farm 437 during the site assessment.

5.5 Existing Groundwater Resources

The National Groundwater Archive (NGA) dataset was interrogated in order to establish the existence of groundwater resources with a 2km radius of the site. In addition, municipal borehole data was acquired from Bitou Municipality in the form of technical reports. The municipal borehole dataset includes boreholes not necessarily within the 2km buffer from the properties. The datasets produced a combined twenty-nine (29 No.) groundwater resources of which sixteen (16 No.) groundwater resources are within 2km of the proposed sites. Boreholes have a depth range of 4mbgl to 250mbgl, static water level range of artesian to 133.44mbgl and a yield range of up to 20.00l/s. Median borehole depths (170m) and water levels (67.5mbgl) generally indicate deep groundwater target zones and significantly large unsaturated zones respectively. Further to this, median pumped discharge rates (5.6l/s) and EC (81mS/m) generally indicate excellent borehole yields and groundwater quality (Level 1 in terms of SANS 241:2015 Standards) respectively. The nearest borehole to the two properties is “Bh_New_Horizon”, which has a historic water level of 119mbgl and a pumped discharge rate of 12.0l/s.

The groundwater resource information is summarised in **Table 2** (shaded green indicate NGA data and shaded blue indicate Municipal data). The locations of the boreholes are shown in **Figure 5**.

Table 2: Existing Groundwater resources

Borehole ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Borehole Depth (m)	Water Level (mbgl)	Discharge Rate (l/s)	Electrical Conductivity (mS/m)	pH
GZ00883	-34.06107	23.34722	65	60			80	6.6
GZ00884	-34.06085	23.34793	65	80	40.83			
GZ00885	-34.06045	23.34615	56	47	32.45			
3423AB00018	-34.05180	23.35338	120	170	69.60	10	101	
GZ00880	-34.05173	23.32918	178	250	119.34		44	6.2
GZ00882	-34.05058	23.31275	193	200			94	6.6
GZ00881	-34.04955	23.31775	185	200			120	6.15
GWA 5C	-34.04685	23.30999		292	132	7	68	
GWA 7	-34.08587	23.29258		98	69	1	538	
GWA 8A	-34.06747	23.34445		43	2.4	1		
GWA 8B	-34.06757	23.34420		4	1.8	3.7	65	
GWA 8C	-34.06800	23.34424		109	0	20	54	
GWA 9	-34.06487	23.34424		192	0	20	74	
WTW 1	-34.05601	23.36739		142	56	1.3	81	
WTW 2	-34.05601	23.36739		126	56	1	81	
WTW 3	-34.05602	23.36738		181	56	10	81	
Bh 3	-34.05172	23.31769	184.58			10		
Bh 4	-34.05056	23.35490	124.46	163.4	66.1	2.9		
Bh 6	-34.04953	23.31274	190.06		130	6.1		
Bh New Horizon	-34.04767	23.32919	179.21		119	12		
Bh 2	-34.05428	23.35957	137.81					
Bh Airport	-34.09021	23.33279	134	250	44.69	2.2		
GWA 1A	-34.05392	23.31433	191	205	121.96	5.6		
GWA 1C	-34.05394	23.31437	190	200	125.5	6.9		
GWA A2	-34.08878	23.35606	93	133	52.11	0.8		
GWA A4	-34.05308	23.32292		95				
GWA 5a	-34.04678	23.31003	193	248	133.44	3.4		
GWA 5b	-34.04683	23.30992	193	205	133	3.4		
GWA 6b	-34.05103	23.32611	176	175	113.2	5.9		
		Median		**170.00**	**67.55**	**5.60**	**81.00**	
		Average		**155.20**	**74.68**	**6.16**	**122.21**	

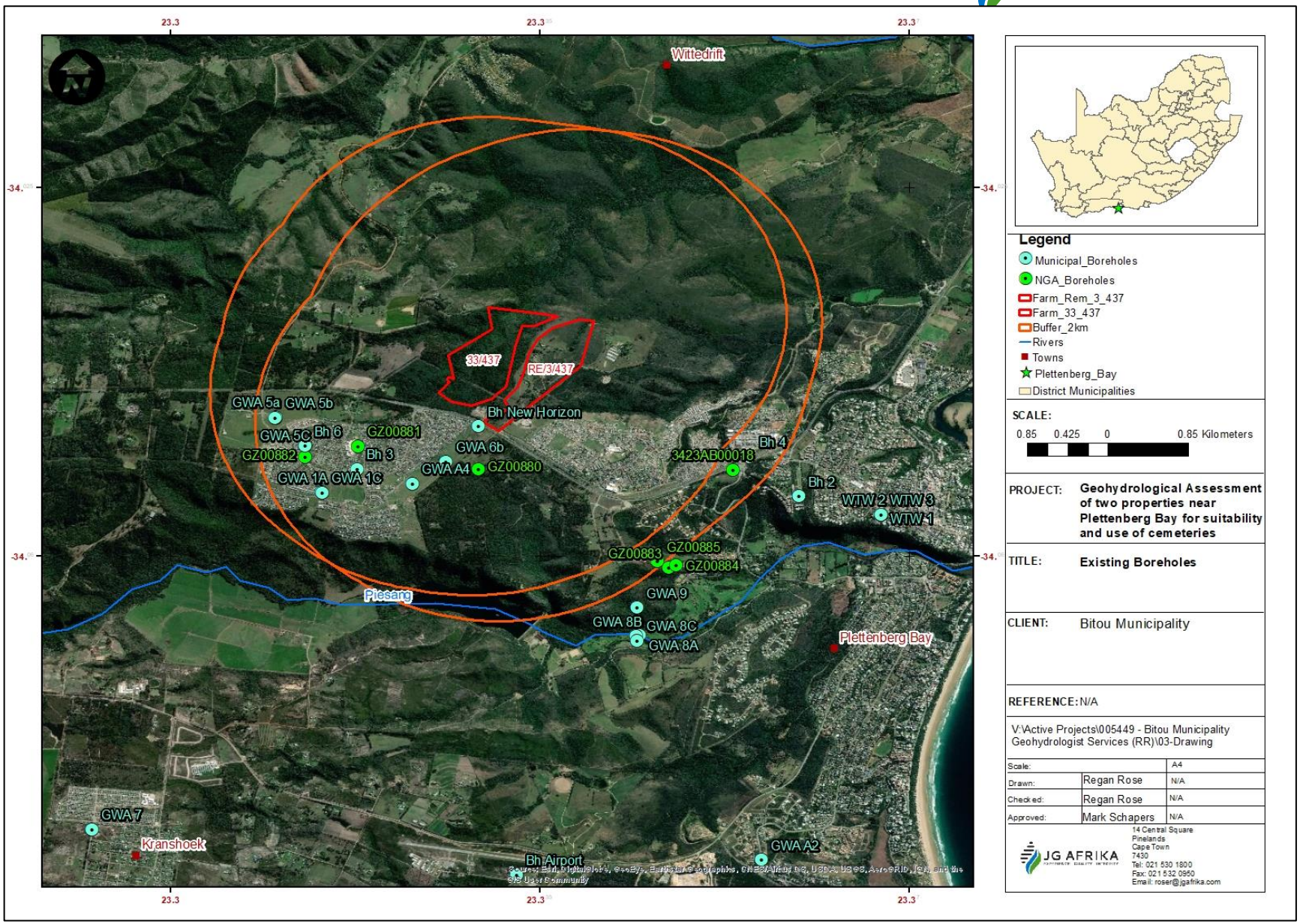

Figure 5: Existing Groundwater Resources

6 SITE ASSESSMENT

6.1 Hydrocensus

A hydrocensus survey was conducted on 5 November 2020 to establish the locations of groundwater resources and to verify the status of groundwater use in proximity to the properties. The hydrocensus focussed mainly on the existing groundwater resources as listed in Table 2, which includes the NGA and municipal groundwater resources. None of the NGA resources could be found during the hydrocensus and several other municipal boreholes are located on privately owned land or required special access. Twelve (12 No.) groundwater resources used for mainly municipal purposes were identified in the area. The field verified resources are presented in **Table 3**. The photographs of the groundwater resource are presented in Annexure B (Refer to Figure 5 for their locations).

Table 3: Summary of Field Verified Groundwater Resources

Borehole ID	Latitude (WGS84)	Longitude (WGS84)	Resource Type	Current Use	Borehole Depth (m)	Water Level (mbgl)
Bh 3	-34.05172	23.31778	Borehole	Not in use	Unable to measure	Unable to measure
Bh 4	-34.05059	23.35490	Borehole	Abandoned	Unable to measure	Unable to measure
Bh 6	-34.04954	23.31275	Borehole	In use	Unable to measure	Unable to measure
Bh Airport	-34.09028	23.33297	Borehole	Not in use	Unable to measure	Artesian
Bh New Horizon	-34.04769	23.32915	Borehole	Abandoned	Unable to measure	Unable to measure
GWA 1A	-34.05391	23.31433	Borehole	In use	Unable to measure	Unable to measure
GWA 1C	-34.05388	23.31437	Borehole	Abandoned	Unable to measure	Unable to measure
GWA 5a	-34.04678	23.30993	Borehole	Abandoned	Unable to measure	Unable to measure
GWA 5C	-34.04684	23.30998	Borehole	Not operational	Unable to measure	Unable to measure
GWA 6b	-34.05106	23.32614	Borehole	In use	Unable to measure	Unable to measure
GWA 7	-34.08605	23.29268	Borehole	Not in use	Unable to measure	Unable to measure
GWA A4	-34.05308	23.32291	Borehole	Abandoned	Unable to measure	Unable to measure

6.2 Geophysical Survey

A geophysical survey was carried out at the site to characterise any geological anomalies around the site. Three (3 No.) traverses, designated T1 to T3, were conducted using the electrical resistivity method. The locations of geophysical traverses are presented in **Figure 6** and the results are presented in Annexure C. A summary review of the interpretation of the geophysical results is presented in **Table 4**.

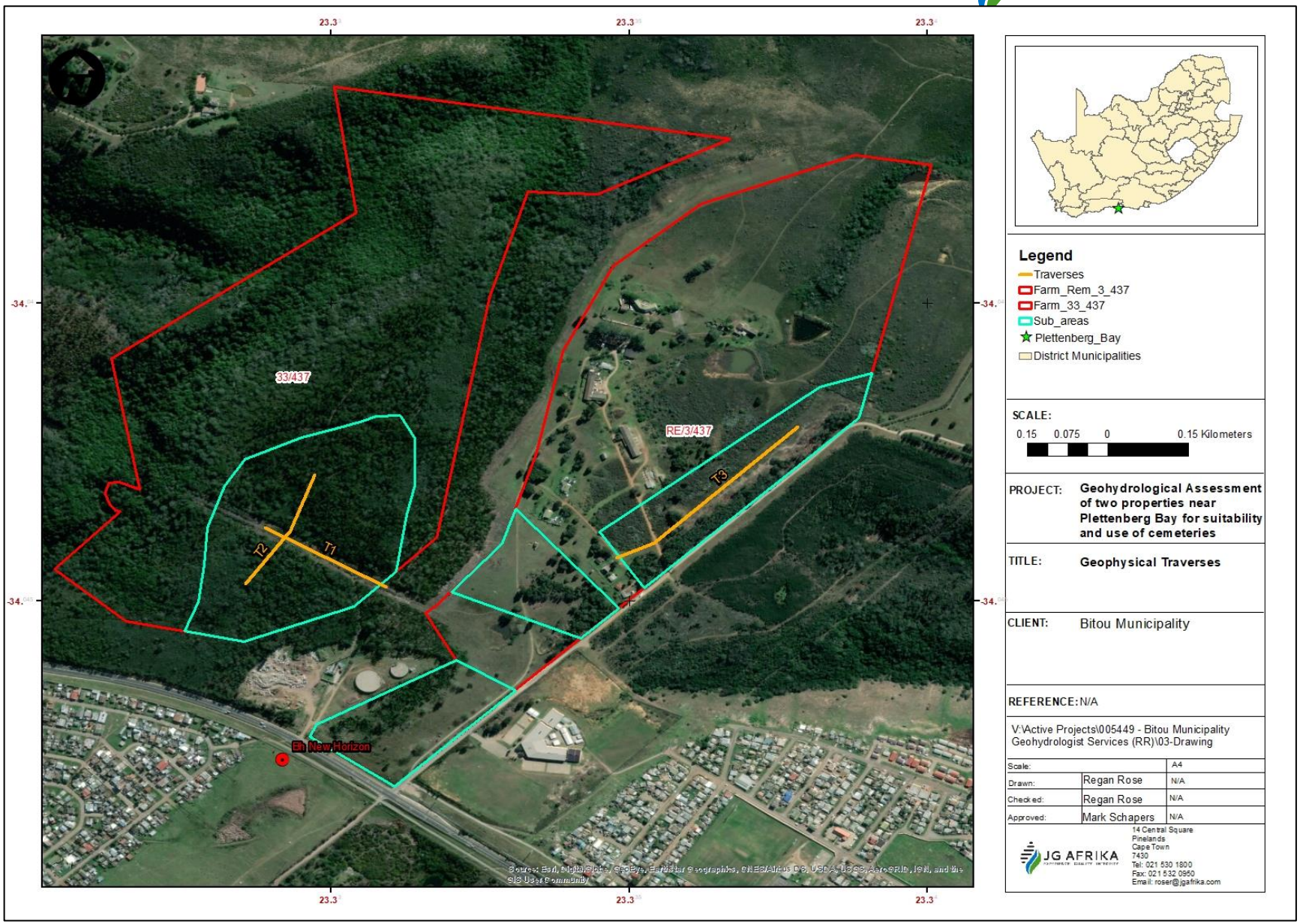

Figure 6: Locations of Geophysical Survey Traverses

Table 4: Summary Interpretation of Geophysical Survey

Traverse No.	Anomaly Position (m)	Traverse Length (m)	Comment
T1	130	220	Shale/Quarzitic sandstone contact zone
T1	150	220	Possible fracturing in the sandstone
T1	180	220	Possible fracturing in the sandstone
T2	180 - 200	230	Thin quarzitic sandstone layer interbedded with shale
T3	140	380	Possible contact zone within mainly shale

7 GEOHYDROLOGICAL IMPACT AND RISK REVIEW

7.1 Impacts

The proposed site will comprise a cemetery development with excavation of graves and burial sites. Listed site developments/activities during construction and operation phases may detrimentally impact on water resources including the underlying aquifer and downstream surface waters. Graves will be constructed throughout the life span of the cemetery and hence the construction phase and operational phase risk merge.

Construction phase impacts include mobilisation of contaminants that may already exist in the soils, and increased turbidity loads associated with high rainfall events on exposed excavation areas. These will increase turbidity loads and associated microbiological loading to water resources. Operational phase impacts are associated with leachate generation from decaying bodies. This may be exacerbated by rainfall recharge and increased surface water infiltration through ponding water, poor stormwater management and high permeability areas. Surface water impacts are likely to be more a concern than groundwater impacts.

Compounds of concern associated with cemetery sites include microbiological and chemical contaminants. Microbiological compounds originating from body decay, or viruses, bacteria and pathogens, include total coliforms, clostridium perfringens and pseudomonas aeruginosa. These may cause diseases such as diarrhoea and dysentery. Chemical compounds originating from body decay and embalming fluids can be both organic and inorganic and include nitrogen, phosphate, calcium and chloride, as well as chemical oxygen demand, dissolved oxygen, lithium, ammonium, and sulphide. Chemical contaminants have a variety of health and aesthetic effects on water quality.

Cemeteries pose a low threat to groundwater due to the very slow rate of decay and the rapid die-off of bacteria and viruses. A human corpse typically decays within 10 years with over half the pollutant load leaching in the first year (World Health Organisation, 1998). Pathogens will die off naturally and rapidly reduce in concentration with increased distance from the grave. Chemical contaminants may be persistent and may chemically alter over time and in certain physical environments. Existing contaminant sources include minor agricultural practices (grazing of stock) and recreational activities from surrounding communities. These activities may already be impacting on the groundwater quality.

7.2 Vulnerability

The project area is underlain by massive quarzitic sandstone and interbedded shale of the TMG, which forms the northern dipping limb of a major synclinal structure. Regional faulting occurred parallel to the strike of the TMG sediments in a graben like manner. Principal groundwater targets include fault and fracture zones, bedding planes and contact zones associated with the TMG, which are generally very deep owing to the extent of folding and faulting in the area. The groundwater potential of the TMG is large due to significant aquifer thickness, favourable recharge, and large storativity. The geophysical survey confirmed potential deep fracture zones within the TMG over a limited section of two of the traverses (T1 and T3).

The median depth to groundwater in the project area is 67.5mbgl, however, the nearest borehole to the properties indicate a depth to groundwater of 119mbgl. A contoured layer, derived from the available historic water levels, indicate the depth to groundwater in the range of 99-122mbgl in the vicinity of the sites (**Figure 7**). Contoured groundwater head data indicates groundwater flow from west (higher head) to east (lower head) (**Figure 8**). In addition to this a geotechnical assessment by Outeniqua Geotechnical Services in 2013 indicates the presence of a shallow perched water level, which roughly coincides with the transported/residual soil contact as groundwater seepage is noted at this contact at an average depth of about 1.0mbgl. Due to the very limited extent of this perched system it is not regarded as an aquifer (more generally accepted as seepage), nor is it likely to be hydraulically linked to the regional TMG aquifer.

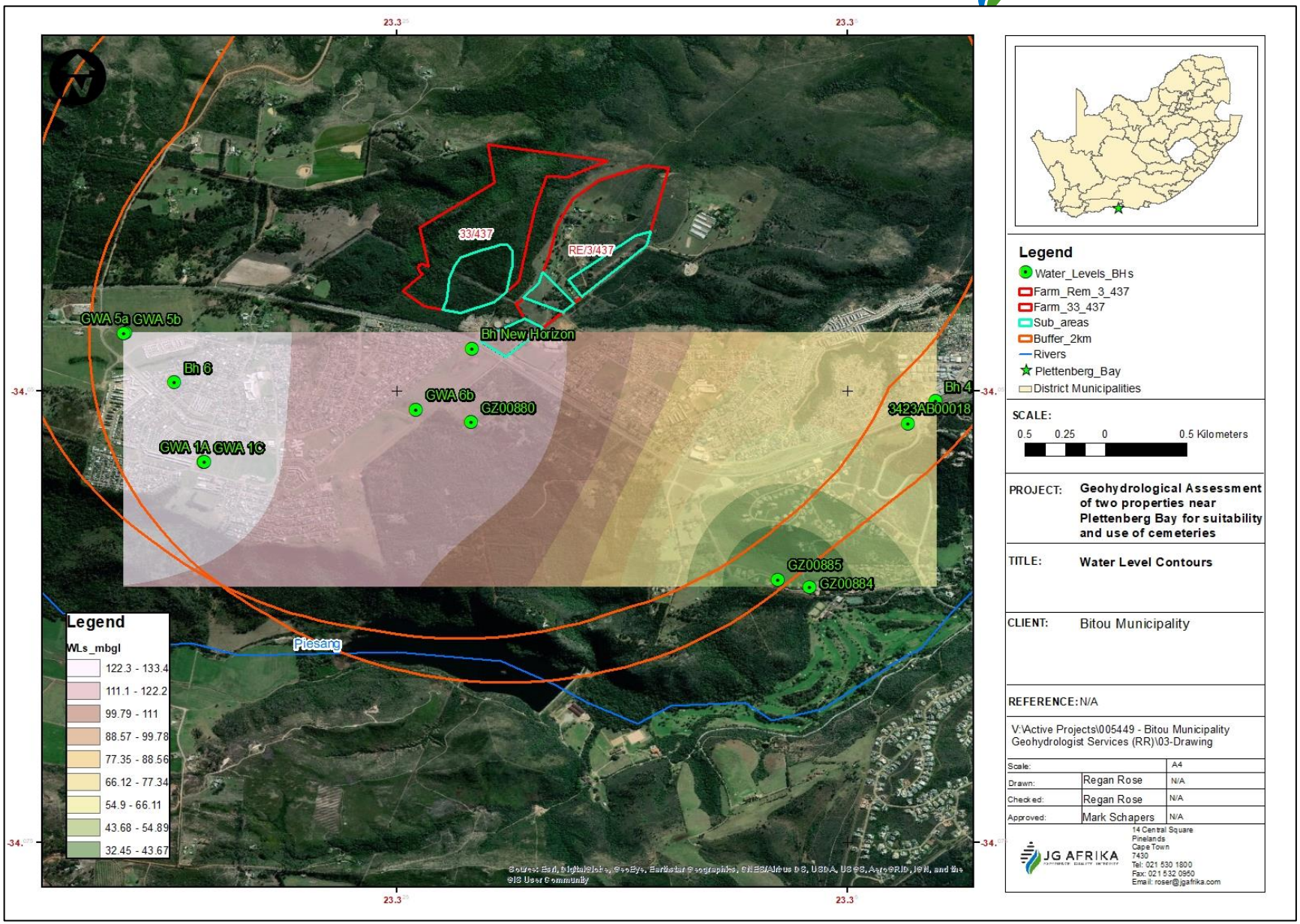

Figure 7: Water Level contours indicating depth to groundwater

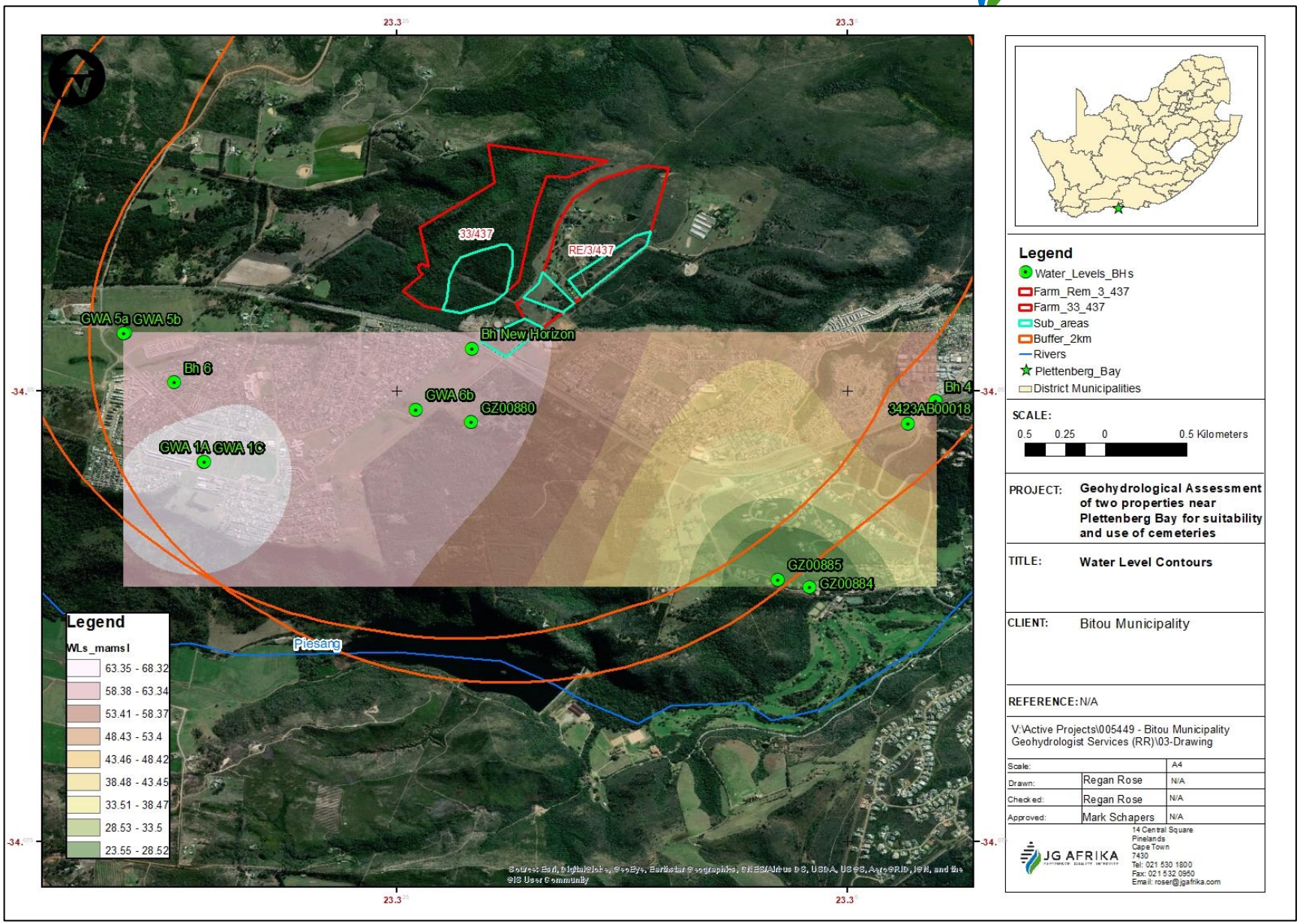

Figure 8: Water Level contours indicating groundwater head

Below the transported soil horizon is the presence of residual clay. The permeability of the residual clay horizon is low in terms of groundwater flow with permeability estimated at 10^{-7}. The vadose zone, comprising of residual clay below the transported soil horizon, could limit groundwater ingress and will act as a natural barrier to micro constituents.

The regional TMG aquifer is classified as a Major aquifer, however, groundwater vulnerability is considered Low due to the presence of deep groundwater targets and large depth to groundwater level. The associated Parsons Groundwater Quality Management System gives the site a Medium Level of Protection index when comparing vulnerability as the second variable (**Table 5**):

Table 5: Groundwater quality management system comparing vulnerability

TABLE A and B: Ratings for the Groundwater Quality Management classification system.			
AQUIFER SYSTEM MANAGEMENT CLASSIFICATION		SECOND VARIABLE CLASSIFICATION	
		AQUIFER VULNERABILITY CLASSIFICATION	
Class	Points	Class	Points
Sole Source Aquifer System	6	High	3
Major Aquifer System	4	Medium	2
Minor Aquifer System	2	Low	1
Non-aquifer System	0		
Special Aquifer System	0 -6		

TABLE C: Appropriate level of groundwater protection required, based on the Groundwater Quality Management classification	
GQM INDEX	LEVEL OF PROTECTION
< 1	Limited protection
01-03	Low level protection
03-06	Medium level protection
06-10	High level protection
> 10	Strictly non-degradation

Variable 1	Variable 2
Aquifer System	Second Variable Description
Major Aquifer System	Vulnerability
	Low
4	1
GQM Index	Level of Protection
4.0	Medium level protection

7.3 Strategic Value

The strategic value of groundwater is based on existing groundwater use. From the hydrocensus survey, groundwater use in the area is evident in the entire area. There is a reliance on both groundwater and surface water resources for municipal and domestic use. Water quality analysis from historic sampling events of surrounding boreholes indicates the groundwater quality to be good and therefore suitable for human consumption.

The strategic value is considered medium to high. Surface water is mainly used for municipal supply although groundwater resources are used to augment shortfall in supply especially in peak demand and drought periods.

Current contaminant sources include minor agricultural practices (grazing of stock) and recreational activities in the project area. These activities may already be impacting to an extent on water quality in the area, particularly the shallow perched condition. The associated Parsons Groundwater Quality Management System gives the site a High Level of Protection index when comparing strategic value as the second variable (**Table 6**).

Table 6: Groundwater quality management system comparing strategic value

TABLE A and B: Ratings for the Groundwater Quality Management classification system.			
AQUIFER SYSTEM MANAGEMENT CLASSIFICATION		SECOND VARIABLE CLASSIFICATION AQUIFER VULNERABILITY CLASSIFICATION	
Class	Points	Class	Points
Sole Source Aquifer System	6	High	3
Major Aquifer System	4	Medium	2
Minor Aquifer System	2	Low	1
Non-aquifer System	0		
Special Aquifer System	0 -6		

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< 1	Limited protection
01-03	Low level protection
03-06	Medium level protection
06-10	High level protection
> 10	Strictly non-degradation

Variable 1	Variable 2
Aquifer System	Second Variable Description
Major Aquifer System	Strategic Value
	Medium High
4	2.5
GQM Index	Level of Protection
10.0	High level protection

7.4 Geohydrological Risk Assessment and Characterisation

The assessment of risk of aquifer contamination is based on aquifer vulnerability and strategic value. Vulnerability is reviewed in terms of geohydrological factors and contaminant load. The summary review of geohydrological risk is as follows:

Stage 1: Assessment of Aquifer Vulnerability	Overall Risk Based on Aquifer Vulnerability and Contaminant Load	
Vulnerability due to flow rate and contaminant load	LOW	LOW
Vulnerability due to geohydrological conditions	LOW	
Stage 2: Strategic Classification of the Groundwater	Strategic Risk	
Strategic value	MEDIUM to HIGH	MEDIUM
Relevance of threats of contaminants	LOW	
Risk Assessment Summary		
Aquifer Vulnerability	LOW	
Aquifer Strategic Value	MEDIUM	

The site is characterised as low risk with conservative offset buffers around geological contacts and existing boreholes (e.g. BH_New_Horizon). These areas are characterised as medium risk areas. A no go exclusion buffer of 200m should be placed around existing boreholes. Although borehole

BH_New_Horizon is not in use, attribute data indicates a good yield and the possibility of a re-drill or rehabilitation in future.

The quantitative environmental risk assessment (ERA) identifies construction and operational phase activities that may impact on the groundwater receiving environments. These phases merge due to the lifespan of the cemetery development. The Significance Points (SP) score is calculated from the following equation using ranking scales:

SP = probability x (duration + scale + magnitude)

The **ERA** is summarised as follows:

Receiving Environment	**Groundwater**						
Significance / Consequence	Construction and Operation Phase						
	quality					quanitity	
Activity	Mobilisation of existing elevated compounds in the soils matrix	Increased turbidity load	Contamination of soils from waste areas and sanitation facilities	Contamination from leachate generation from decaying bodies	Increased infiltration/runoff due to poor stormwater management	Construction and operational requirements	Increased infiltration/runoff due to poor stormwater management
Probability	low	medium to high	medium to high	medium to high	medium to high	low	low
Duration	short	short	medium to long	medium to long	medium	medium to long	medium to long
Scale	site	site	site	site	site	site to local	site to local
Magnitude	low to moderate	low to moderate	low to moderate	moderate to high	moderate to high	low	low
Significance	high negative	medium negative	medium negative	medium high negative	medium high negative	low medium negative	low medium negative
SP SCORE and RATING	2(2+1+5) = **16**	3.5(2+1+5) = **28**	3.5(3.5+1+5) = **33**	3.5(3.5+1+7) = **40**	3.5(3+1+7) = **39**	2(3.5+1.5+4) = **18**	2(3.5+1.5+4) = **18**
>60 indicates high environmental significance <30 indicates low environmental significance	**LOW**	**LOW**	**MODERATE**	**MODERATE**	**MODERATE**	**LOW**	**LOW**

For groundwater quality, contamination from soil from waste areas, leachate from decaying bodies and increased infiltration due to poor stormwater management all score Moderate. Increased infiltration due to poor stormwater management scores low for groundwater quantity. All other activities score Low.

In all instances, the risk to surface water resources for the same review would score higher for all listed activities due to direct runoff. This would be particular significant for high intensity or long duration rain fall events.

7.5 Mitigation

Storm water management and management of excavation areas are standard mitigation options for surface water runoff, ponding and increased turbidity loads. Surface runoff and water ingress should be minimised by limiting excavation areas on a needs bases and implementing erosion control areas in graded areas.

Leachate generation can be minimised using concrete vaults in medium risk areas, particularly where the vadose zone is less defined in low lying areas. Infiltration of rainfall through grave sites can be minimised by appropriate earthworks techniques that promote runoff away from grave sites.

Similar techniques can be implemented to promote the shallow groundwater seepage away from grave sites.

A mandatory exclusion zone should be applied to all existing and new boreholes. Should the existing borehole BH_New_Horizon not be considered for furture production, then the borehole should be converted to a monitoring station for water level and background water quality. Should an environmental authorisation be acquired, an additional on-site or downslope monitoring borehole should be considered to carry out routine monitoring of the groundwater beneath the site and compared to the background monitoring to establish the occurrence of pollution and extent thereof, if any.

The Post mitigation **ERA** is summarised as follows:

Receiving Environment	Groundwater						
Significance / Consequence	Construction and Operation Phase						
	quality					quanitity	
Activity	Mobilisation of existing elevated compounds in the soils matrix	Increased turbidity load	Contamination of soils from waste areas and sanitation facilities	Contamination from leachate generation from decaying bodies	Increased infiltration/runoff due to poor stormwater management	Construction and operational requirements	Increased infiltration/runoff due to poor stormwater management
Probability	low	medium to high	medium to high	medium to high	medium to high	low	low
Duration	short	short	medium to long	medium to long	medium	medium to long	medium to long
Scale	site	site	site	site	site	site to local	site to local
Magnitude	low to moderate	low to moderate	low	low	low	low	low
Significance	high negative	medium negative	medium negative	medium high negative	medium high negative	low medium negative	low medium negative
SP SCORE and RATING >60 indicates high environmental significance <30 indicates low environmental significance	2(2+1+5) = **16**	3.5(2+1+5) = **28**	3.5(3.5+1+4) = **30**	3.5(3.5+1+4) = **30**	3.5(3+1+4) = **28**	2(3.5+1.5+4) = **18**	2(3.5+1.5+4) = **18**
	LOW	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**

8 CONCLUSION

This report presents the results of a geohydrological assessment for a proposed cemetery site on Remainder 3 of Farm 437 and Portion 33 of Farm 437 respectively, near Plettenberg Bay in the Western Cape Province. The aim of the assessment was to characterise the geohydrological setting, and to determine the risk of potential impacts by the activity on the receiving groundwater environment.

The site is underlain by a fractured aquifer comprising quarzitic sandstone with interbedded shale of the TMG. No regional faulting is evident on and near the site. In accordance with DWS (1999), the aquifer is classified as a low to medium yielding aquifer, however, based on municipal borehole data, the aquifer is a high yielding, *major* aquifer. The inferred depth to groundwater in the immediate vicinity of the sites is greater than 100m, and due to this, saturated water bearing fractures are expected deeper than 100mbgl. The aquifer vulnerability is therefore low.

The Parsons Groundwater Quality Management System gives the site a Medium Level of Protection index for the second variable vulnerability, and a High Level of Protection index for the second variable strategic value. Existing potential contaminating sources in the project area include minor agricultural activities and recreational infrastructure. The geohydrological risk assesses the aquifer in terms of vulnerability and strategic value and is summarized as follows.

Aquifer Vulnerability	LOW
Aquifer Strategic Value	MEDIUM

The quantitative environmental risk assessment identified contamination from soil from waste areas, leachate from decaying bodies and increased infiltration due to poor stormwater management scoring Moderate. These scores can generally be reduced with the application of appropriate mitigation measures.

9 RECOMMENDATIONS

Based on the results of the assessment, the following are recommended:

- Mitigate erosion, runoff and ponding water during the lifespan of the cemetery development through appropriate storm water management and earthworks control
- Concrete vaults could be used in medium risk areas in proximity to geological structures
- Exclusion zones around the existing boreholes including BH_New_Horizon should be enforced. This borehole should also be converted to a monitoring station if future abstraction is discontinued
- If an environmental authorisation is acquired, an additional monitoring borehole should be installed in the northern half of the selected property as downslope monitoring points. The borehole would be utilised to profile the geology at depth, to confirm groundwater strikes and levels, and to provide a groundwater monitoring location. Suitable locations identified from the geophysical survey are station 150 on traverse T1 (Portion 33 of Farm 437) or station 140m on traverse T3 (Remainder 3 of Farm 437).

- A groundwater and surface water monitoring plan should be implemented to include routine sampling and analysis of groundwater and surface water locations on or near the site. Analysis should include indicators of potential contamination from cemetery developments (ammonia, nitrate, nitrite, lithium, sulphide, orthophosphate, clostridium perfringens and pseudomonas aeruginosa) as well as standard physical, micro and macro determinants. Bi-annual monitoring is recommended. Base line water quality should be established prior to implementation of any graves
- Careful site management and site operations are basic requirements to ensure the impact on groundwater quality in the area is minimised by the cemetery operations.

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Annexure A: First Estimate of Recharge

Summary of Recharge

MAIN

Remainder 3 of Farm 437

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)
CI			4
SVF: Equal Volume		#DIV/0!	4
SVF: Fit			4
CRD			4
Qualified Guesses :			
Soil	24.2	3.0	3
Geology	40.3	5.0	3
Vegter	95.0	11.8	3
Acru	100.0	12.4	3
Harvest Potential	100.0	12.4	3
Expert's guesses			3
Base Flow (minimum Re)	50.0	6.2	1
^{2} H displacement method			1
Carbon 14 method			1
EARTH Model			1
Groundwater Flow Model			1
Average recharge	70.5	8.8	
Recharge =	70.5	8.8	

= 0.31725 Mm^3/a

= 869.18 m^3/d

= 10.06 L/s

Area (Km^2) =	4.5
Annual Rainfall (mm) =	806

Summary of Recharge

MAIN

Portion 33 of Farm 437

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)
CI			4
SVF: Equal Volume		#DIV/0!	4
SVF: Fit			4
CRD			4
Qualified Guesses :			
Soil	25.8	3.0	3
Geology	43.0	5.0	3
Vegter	95.0	11.0	3
Acru	100.0	11.6	3
Harvest Potential	100.0	11.6	3
Expert's guesses			3
Base Flow (minimum Re)	50.0	5.8	1
^{2} H displacement method			1
Carbon 14 method			1
EARTH Model			1
Groundwater Flow Model			1
Average recharge	71.3	8.3	
Recharge =	71.3	8.3	

=	0.27807	Mm^3/a	
=	761.84	m^3/d	
=	8.82	L/s	

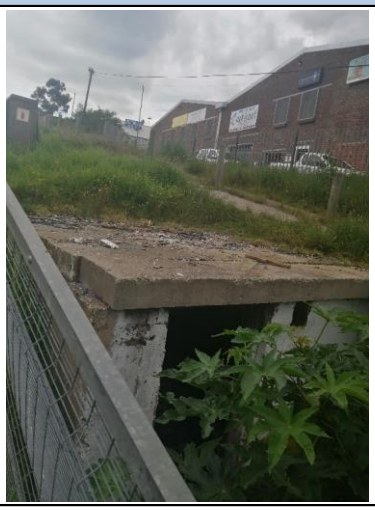
Area (Km^2) =	3.9
Annual Rainfall (mm) =	860

Annexure B: Hydrocensus Survey

GROUNDWATER RESOURCES		
Resource ID	**BH3**	
Latitude	-34.05172	
Longitude	23.31778	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not in use - Equipment Destroyed	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	No	
Equipment	Submersible with control box	
Comments	Rising main joint destroyed, Fence still intact. BH Abandoned	
Resource ID	**BH6**	
Latitude	-34.04954	
Longitude	23.31275	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	In Use, Reported to pump 24/7	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	Yes ~500Kl, 750m away 12m tankstand	
Equipment	Submersible with control box	
Comments	Fenced secured, Slight concern of possible contaimination from residential activity close to the borehole	
Resource ID	**GWA 5A**	
Latitude	-34.04678	
Longitude	23.30993	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Abandoned	
Depth to GW	BH capped could not open to dip	
Final Depth	Could not dip	
Storage	No	
Equipment	None	
Comments	Borehole capped, ~7m away from GWA 5C BH.	

GROUNDWATER RESOURCES		
Resource ID	**GWA 5C**	
Latitude	-34.04684	
Longitude	23.30998	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not operational at the time of visit	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	Yes	
Equipment	Submersible	
Comments	BH enclosed in an uncessible pump-house with no door.	
Resource ID	**GWA 1 C**	
Latitude	-34.05388	
Longitude	23.31437	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not in use	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	None	
Equipment	None	
Comments	Borehole not capped, resulting in it being blocked.	
Resource ID	**GWA 1A**	
Latitude	-34.05391	
Longitude	23.31433	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	In use	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	yes	
Equipment	Submersible	
Comments	Borehole with fence protection	

GROUNDWATER RESOURCES		
Resource ID	**GWA A4**	
Latitude	-34.05308	
Longitude	23.32291	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	not in use	
Depth to GW	unable to measure	
Final Depth	unable to measure	
Storage	none	
Equipment	none	
Comments	Borehole not capped, therefore resulting in borehole being capped	
Resource ID	**GWA 6B**	  Treament plant and booster
Latitude	-34.05106	
Longitude	23.32614	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	In use	
Depth to GW	unable to measure	
Final Depth	unable to measure	
Storage	Yes,~400Kl,350m away,12m tankstand	
Equipment	Submersible	
Comments	Treatment Plant eprational, located 60m away from the BH. Livestock kraal situated next the borehole may be of concern for contaimination leaching to the groundwater	
Resource ID	**BH New Horizon**	
Latitude	-34.04769	
Longitude	23.32915	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not in use - Destroyed	
Depth to GW	unable to measure	
Final Depth	unable to measure	
Storage	no	
Equipment	Submersible	
Comments	Control box and fence vendalised, resulting in borehole being abandoned	

GROUNDWATER RESOURCES		
Resource ID	**BH 4**	
Latitude	-34.05059	
Longitude	23.3549	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not in use - destroyed	
Depth to GW	Unable to measure	
Final Depth	Unable to measure	
Storage	Not in use - destroyed	
Equipment	none	
Comments	Borehole completed vandalised, homeless family living inside the pump house structure.	
Resource ID	**BH Airport**	
Latitude	-34.09028	
Longitude	23.33297	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	Not in use	
Depth to GW	WL on ground level	
Final Depth	unable to dip due to restricted access	
Storage	none	
Equipment	none	
Comments	Box controx box seems destroyed and casing also removed for reasons unknown at time of visit	
Resource ID	**GWA 7**	
Latitude	-34.08605	
Longitude	23.29268	
Resource Type	Borehole	
NGA/GRIP No	-	
Sample No.	-	
Current Use	None	
Depth to GW	Unable to measure due to welded casing	
Final Depth	Unable to measure	
Storage	none	
Equipment	none	
Comments	Borehole capped , and marked of visibly with white paint	

Searched Boreholes	
Borehole ID	Comments
GWA 8A	Boreholes on private property
GWA 8B	
GWA 8C	
WTW 1	Appointed with WTW manager required to enter facility.
WTW 2	
WTW 3	
BH 2	BH on private property
GWA A2	BH on private property
GWA A3	BH >10km from project area
GZ00883	All NGA Boreholes were not found
GZ00884	
GZ00885	
3423AB00018	
GZ00880	
GZ00882	
GZ00881	

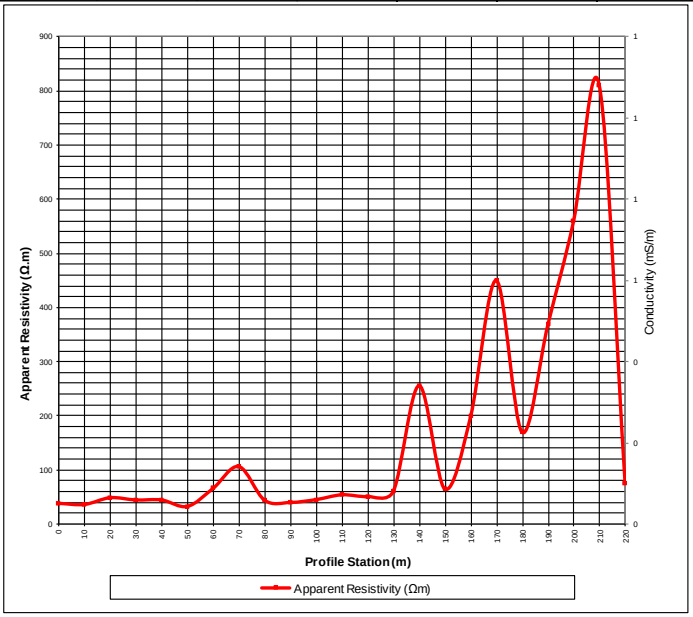
Annexure C: Results of Geophysical Survey

Wenner Profile Fieldsheet

Client :	Bitou Muncipality	Test No:	T1	Ref:	5449	Date:	06-Nov
Project :	Bitou Muncipality Geohydro			Site Description: Parallel 3 phase powerline			

GPS Co-ordinates	Start	End	Spacing:	Orientation:	Test Date:	06-Nov
South	-34.04477	-34.04376	60	NW-SE	Start Time:	
East	23.33092	23.32889			End Time:	

Electrode Spacing					Field Recorded Results		
OA	OM	ON	OB	Station Reading	ΔV (mV)	I (mA)	Apparent Resistivity (Ωm)
-90	-30	30	90	0	14.10	143.9	37.6
-80	-20	40	100	10	10.60	109.3	35.5
-70	-10	50	110	20	3.50	25.0	48.0
-60	0	60	120	30	9.30	85.0	43.8
-50	10	70	130	40	6.00	51.7	43.8
-40	20	80	140	50	5.40	63.9	31.9
-30	30	90	150	60	24.30	146.7	65.4
-20	40	100	160	70	18.60	66.2	105.7
-10	50	110	170	80	5.50	47.9	43.2
0	60	120	180	90	7.00	66.5	39.2
10	70	130	190	100	6.40	77.7	44.5
20	80	140	200	110	9.00	62.5	53.4
30	90	150	210	120	7.50	52.6	50.2
40	100	160	220	130	7.60	46.0	60.0
50	110	170	230	140	26.60	40.4	255.4
60	120	180	240	150	4.00	23.3	64.1
70	130	190	250	160	15.00	28.0	198.2
80	140	200	260	170	38.50	30.9	450.2
90	150	210	270	180	17.00	37.1	168.9
100	160	220	280	190	19.00	18.0	367.8
110	170	230	290	200	35.90	26.9	560.0
120	180	240	300	210	46.00	22.1	810.5
130	190	250	310	220	10.60	55.0	74.6

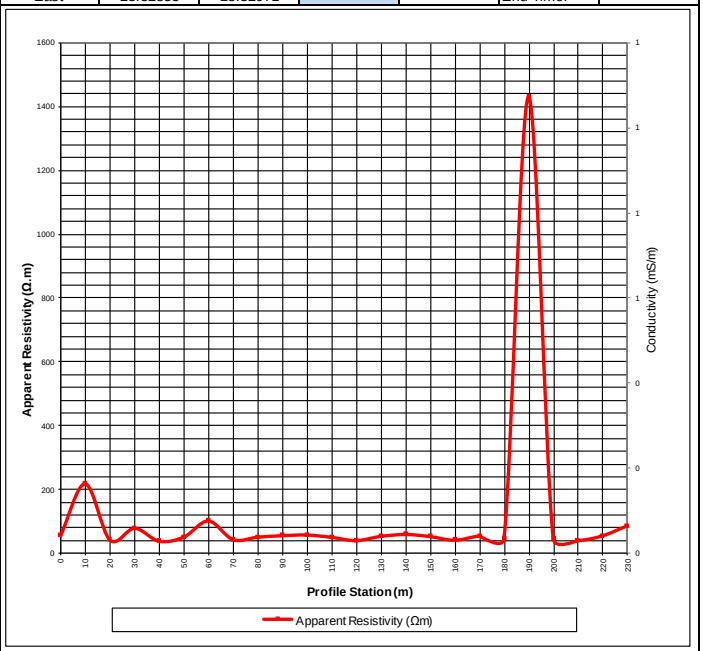


Wenner Profile Fieldsheet

Client :	Bitou Muncipality	Test No:	T2	Ref:	5449	Date:	07-Nov
Project :	Bitou Muncipality Geohydro			Site Description: Perpendicular too 3phase powerline			

GPS Co-ordinates	Start	End	Spacing:	Orientation:	Test Date:	07-Nov
South	-34.04471	-34.04288	60	NE-SW	Start Time:	
East	23.32855	23.32971			End Time:	

Electrode Spacing					Field Recorded Results		
OA	OM	ON	OB	Station Reading	ΔV (mV)	I (mA)	Apparent Resistivity (Ωm)
-90	-30	30	90	0	13.50	89.0	57.0
-80	-20	40	100	10	24.10	42.1	217.9
-70	-10	50	110	20	4.40	41.3	42.0
-60	0	60	120	30	8.80	42.3	78.9
-50	10	70	130	40	3.40	34.1	38.2
-40	20	80	140	50	13.00	91.3	51.3
-30	30	90	150	60	19.40	68.6	101.8
-20	40	100	160	70	9.10	79.2	43.2
-10	50	110	170	80	9.40	69.3	51.1
0	60	120	180	90	5.90	39.7	55.6
10	70	130	190	100	9.70	62.7	57.8
20	80	140	200	110	19.80	147.3	50.5
30	90	150	210	120	3.90	37.0	40.3
40	100	160	220	130	18.00	124.0	53.5
50	110	170	230	140	3.90	31.7	59.5
60	120	180	240	150	4.00	29.0	52.9
70	130	190	250	160	2.60	24.0	41.3
80	140	200	260	170	4.40	36.9	54.1
90	150	210	270	180	8.20	66.0	46.7
100	160	220	280	190	122.00	32.1	1429.0
110	170	230	290	200	3.10	24.9	47.1
120	180	240	300	210	4.00	35.9	40.5
130	190	250	310	220	4.20	28.5	55.2
140	200	260	320	230	13.50	58.4	86.4

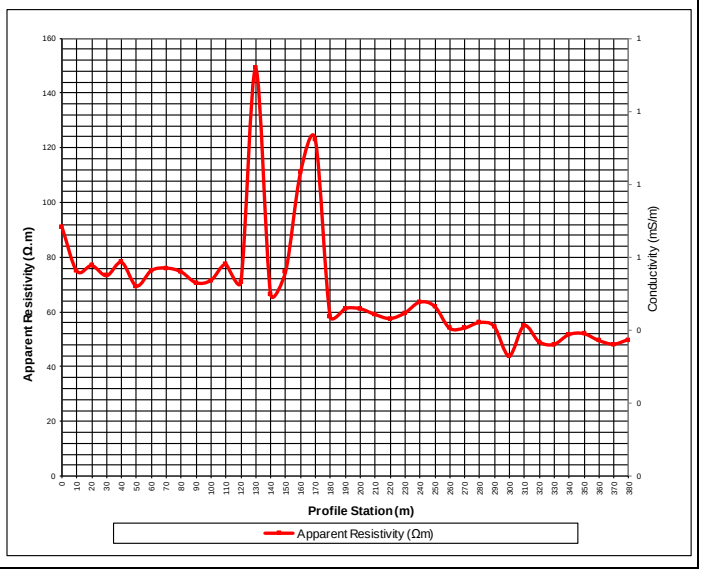


Wenner Profile Fieldsheet

Client :	**Bitou Muncipality**	**Test No:**	**T3**	**Ref:** 5449	**Date:** 08-Nov
Project :	**Bitou Muncipality Geohydro**			Site Description: Open developable area	

GPS Co-ordinates						
Position	Start	End	Spacing:	Orientation:	Test Date:	**08-Nov**
South	-34.04211	-34.04425	**60**	**NE-SW**	Start Time:	
East	23.33781	23.33477			End Time:	

Electrode Spacing					Field Recorded Results		
OA	OM	ON	OB	Station Reading	ΔV (mV)	I (mA)	Apparent Resistivity (Ωm)
-90	-30	30	90	0	7.00	27.4	91.0
-80	-20	40	100	10	15.70	18.9	74.9
-70	-10	50	110	20	14.80	67.6	76.9
-60	0	60	120	30	5.10	26.0	73.2
-50	10	70	130	40	16.80	32.6	78.1
-40	20	80	140	50	4.80	26.7	69.4
-30	30	90	150	60	12.70	63.9	75.1
-20	40	100	160	70	15.00	73.0	76.0
-10	50	110	170	80	20.00	100.0	74.6
0	60	120	180	90	9.60	51.2	70.6
10	70	130	190	100	11.50	60.4	71.5
20	80	140	200	110	11.90	59.5	77.4
30	90	150	210	120	50.80	164.0	70.8
40	100	160	220	130	24.20	63.2	149.0
50	110	170	230	140	9.00	53.2	66.5
60	120	180	240	150	5.10	26.6	74.5
70	130	190	250	160	11.20	36.2	110.9
80	140	200	260	170	13.00	40.0	123.0
90	150	210	270	180	8.70	55.0	58.2
100	160	220	280	190	7.50	46.0	61.2
110	170	230	290	200	14.90	91.8	61.1
120	180	240	300	210	10.90	69.1	59.0
130	190	250	310	220	9.00	58.0	57.5
140	200	260	320	230	7.50	44.0	59.5
150	210	270	330	240	7.10	41.8	63.5
160	220	280	340	250	6.20	37.8	62.0
170	230	290	350	260	4.00	33.0	54.0
180	240	300	360	270	5.60	39.2	54.0
190	250	310	370	280	4.80	32.0	56.0
200	260	320	380	290	2.80	19.5	54.6
210	270	330	390	300	2.90	25.0	43.8
220	280	340	400	310	7.70	50.8	54.9
230	290	350	410	320	8.50	65.0	49.0
240	300	360	420	330	6.50	52.0	48.0
250	310	370	430	340	9.60	68.0	51.6
260	320	380	440	350	8.40	60.0	52.0
270	330	390	450	360	8.20	65.0	49.5
280	340	400	460	370	4.90	40.0	48.1
290	350	410	470	380	6.60	49.0	49.8



Annexure D: Quantitative Environmental Risk Assessment (ERA) Guideline

In terms of a quantitative environmental risk assessment (ERA), the assessment will be based on:

- Probability of occurrence which describes the likelihood of the impact actually occurring and is indicated as:-
  - Improbable, where the likelihood of the impact is very low;
  - Probable, where there is a distinct possibility of the impact to occur;
  - Highly probable, where it very likely that the impact will occur;
  - Definite, where the impact will occur regardless any management measure.
- Consequence of occurrence in terms of:
  - Nature of the impact;
  - Extent of the impact, either local, regional, national or across international borders;
  - Duration of the impact, either short term (0-5 years), medium term (6-15 years) or long-term (the impact will cease after the operational life of the activity) or permanent, where mitigation measures by natural processes or human intervention will not occur;
  - Intensity of the impact, either being low, medium or high effect on the natural, cultural and social functions and processes.
- Significance level of the risk posed by the water use, which is determined through a synthesis of the probability of occurrence and consequence of occurrence.

The applicant will have to rank the risks based on the quantitative assessment as described above into high, medium, or low risks. Management measures need to be identified to mitigate, prevent and /or reduce the risk. These measures will primarily be focussed on the risks identified as high in the ranking matrix, but will also include measures for medium and low risks. The management measures will be taken forward in the IWMP as part of the water use authorisation process.

In order to assess each of the factors for each impact the ranking scales as contained in Table 7-1 could be used. Once the factors had been ranked for each impact, the environmental significance of each impact could be assessed by applying the following formula:

SP = (magnitude + duration + scale) x probability

where SP is defined as significance points.

Table 7-1: Ranking Scales for ERA

PROBABILITY = P 5 – Definite / don't know 4 – High probable 3 – Medium probability 2 – low [probability 1 – Improbable 0 - None	**DURATION** = D 5 – Permanent 4 – Long-term ceases with operational life) 3 – Medium-term (5 – 15 years) 2 – Short-term (0-5 years) 1 - Immediate
SCALE = S 5 – International 4 – National 3 – Regional 2 – Local 1 – Site 0 – None	**MAGNITUDE** = M 10 – Very high / Don't know 8 – High 6 – Moderate 4 – Low 2 – Minor

The maximum value of significance points (SP) is 100. Environmental effects could therefore be rated as either high (H), moderate (M), or low (L) significance on the following basis:

- More than 60 points indicates high (H) environmental significance
- Between 30 – 60 points indicate moderate (M) environmental significance
- Less than 30 points indicates low (L) environmental significance.