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ABBREVIATIONS

ASPT	Average Score per Taxon
EIA	Environmental Impact Assessment
SASS5	South African Scoring System version 5
WUL	Water Use Licence

1. INTRODUCTION

1.1 Background

Middleburg Mine are investigating the feasibility of constructing a wastewater treatment plant to process excess mine water, and to discharge treated water, via pipeline, into the Spookspruit Catchment. The volume of water discharged is expected to be anything between 15 and 25 ML/day, discharged at a constant rate throughout the year. A detailed Environmental Impact Assessment (EIA) and Water Use License Application (WULA) for the proposed development is being conducted by Jones and Wagener Pty (Ltd). Two alternative sites for the proposed treatment plant are under consideration. This report forms part of the EIA and WUL application, and assesses the potential impacts on the receiving aquatic ecosystem of discharging treated water into the Spookspruit Catchment. The report is based on a review of available information and a site visit conducted on 30th July 2008.

1.2 Study Team

This study was conducted by Rob Palmer, aquatic specialist and director of Nepid Consultants CC. Rob has a BSc in zoology from the University of Cape Town, and a PhD in aquatic ecology from Rhodes University, South Africa. He has over 20 years experience in aquatic systems and specialist knowledge of river regulation and river ecology. He has undertaken numerous environmental assessments throughout southern Africa, mostly concerning water resource developments and mining. He is a member of the South African Advisory Committee on the Safety of Dams (Environmental Portfolio), a certified Environmental Assessment Practitioner (No. 0080/06), a registered Natural Scientist (400108/95), as well as a certified biomonitoring practitioner.

1.3 Declaration

Independent Specialist Consultant

I, , declare under oath that I –

- act as an independent specialist consultant in the field of Freshwater Ecology in this application ;
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2006;
- have and will not have no vested interest in the proposed activity proceeding;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Impact Assessment Regulations, 2006; and
- will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.

Signature of specialist consultant

Nepid Consultants cc

Name of company:

13/11/2007

Date:

Signature of the Commissioner of Oaths:

2007 – 11 – 13.

Date:

Constable.

Designation:

Official stamp (below)

SUID AFRIKAANSE POLISIEDIENS
GEMEENSKAPSDIENSSENTRUM
2007 -11- 13
COMMUNITY SERVICE CENTRE
WITRIVIER/WHITE RIVER
SOUTH AFRICAN POLICE SERVICE

2. STUDY AREA

2.1 General Locality

Two alternative sites for the proposed water treatment plant are under consideration (Figure 2-1). All sites are located in the middle reaches of the Spookspruit Catchment, quaternary catchment B11H, in the Olifants Water Management Area. The potential sites are about 15 km south of Middleburg, within the Highveld Ecoregion, Mpumalanga Province.

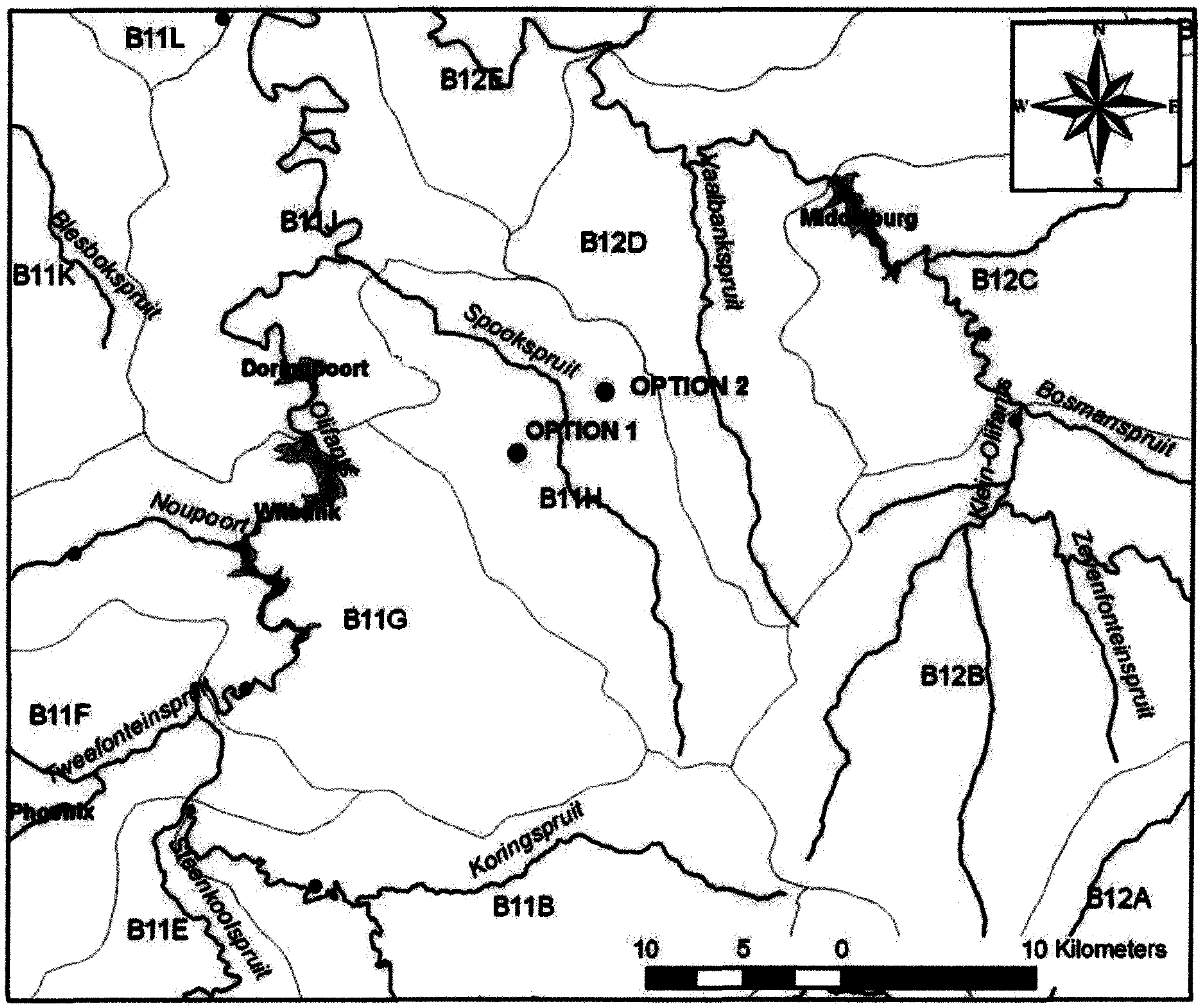

Figure 2-1. General locality map showing the positions of alternative sites for the proposed Middleburg Mine water treatment plant, within the Spookspruit Catchment (B11H).

2.2 Sampling Sites

Details of aquatic sampling sites that were visited in July 2008 are presented in Table 2-1, and sampling locations are shown in Figure 2.2. Photographs of the sites are shown in Appendix A. Three sites were located in the Niekerspruit, and two sites were located in the Spookspruit.

Table 2-1. Details of sites visited during a field survey in July 2008.

[illegible]	[illegible]	[illegible]	[illegible]
AE01	S25 55.001 E29 25.013	1472 m	Niekerspruit: downstream of Pollution Control Dam 5
AE02	S25 54.749 E29 25.199	1493 m	Niekespruit: farm road culvert
AE03	S25 54.709 E29 25.213	1517 m	Niekerspruit: potential discharge point for Option 1
AE04	S25 53.450 E29 25.337	1519 m	Spookspruit: Road crossing at Burnside Farm
AE05	S25 51.540 E29 23.830	1480 m	Spookspruit: R575 road bridge

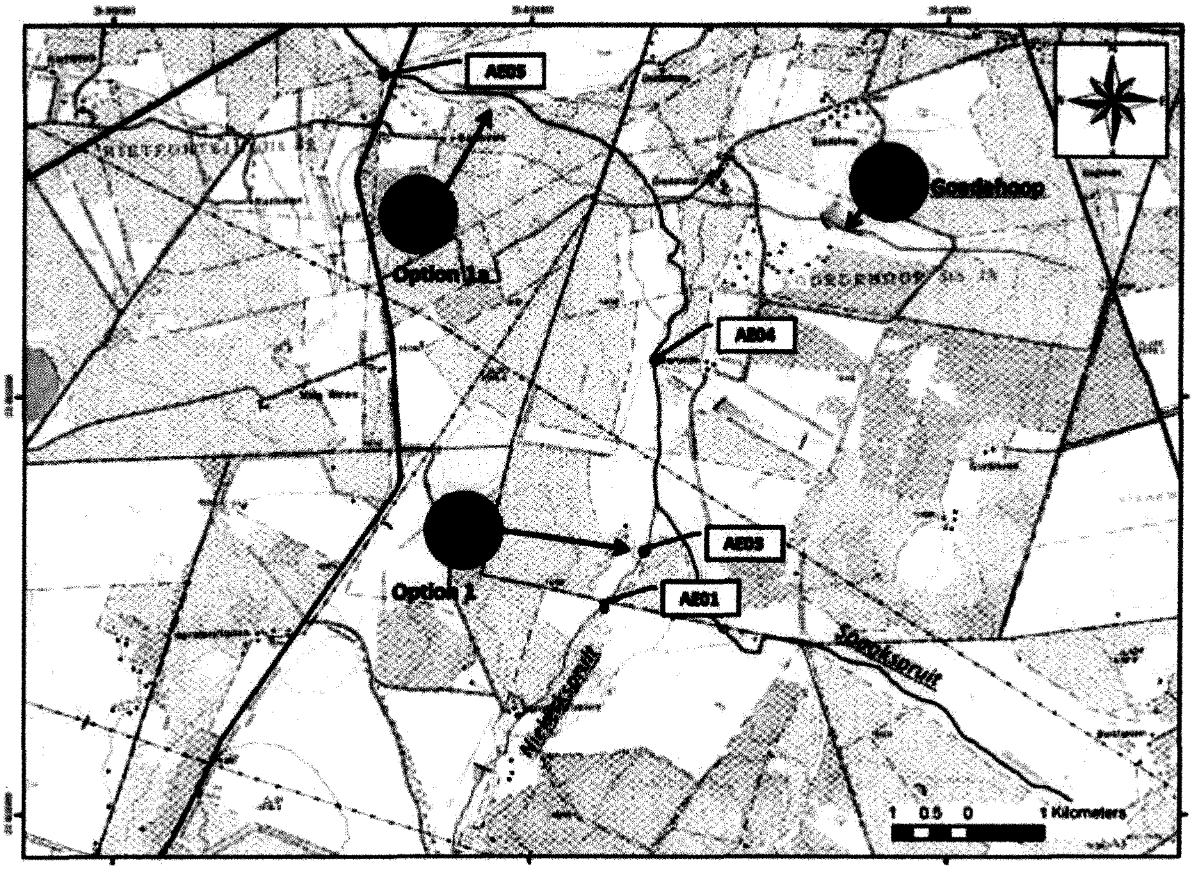

Figure 2-2. Topographical map showing the approximate positions of alternative sites for the proposed Middleburg Mine water treatment plant (red shading), and the aquatic sampling sites visited during this study (AE01 to AE05).

2.3 Alternative Locations

2.3.1 Option 1

Option 1 is located in a Eucalyptus plantation alongside the R575 road. The nearest surface water to the site is the Niekerspruit, a tributary of the Spookspruit, which is about 2 km from the proposed site at its nearest point. The Niekerspruit is a historical seasonal, non-channelled, valley-bottom riparian wetland, which would have naturally risen about 5 km upstream of the proposed point of discharge. However, most of the catchment has been transformed by surface coal mining. There are five pollution control dams located upstream of the proposed point of discharge, and a 90°V-notch weir is located on the lower, larger dam (Dam 5).

2.3.2 Option 2

Option 2 is located on the farm Goedehoop, about 5 km north-east of Option 1. This option will discharge into an impounded, unnamed tributary of the Spookspruit.

3. METHODS

3.1 Review

The National River Health Database was queried for biomonitoring records for the Spookspruit Catchment, but no historical biomonitoring data were available. The Department of Water Affairs and Forestry: Resource Quality Services (Christa Thirion, pers. comm.), as well as the Mpumalanga Parks Board (Johan Engelbrecht, pers. comm..) were contacted for ecological information on the Spookspruit, but neither organisations were aware of any biomonitoring data for the catchment.

3.2 Field Survey

A field survey was undertaken on 30th July 2008. The survey focussed on the Present Ecological State of the Spookspruit Catchment that could be affected by the proposed development, based mainly on the composition and abundance of aquatic invertebrates.

3.3 Cross-sectional Profiles

One of the key considerations of the proposed development is the potential for erosion because of elevated flows. Cross-sectional profiles and local gradients of the receiving stream were therefore surveyed with a dumpy level to assess the potential risks of erosion. The surveys were undertaken at two sites that were considered representative of the two receiving streams: the Niekerspruit at Site AE03, and the Spookspruit at Site AE04.

3.4 Flow

Flows during the field survey in July 2008 were used to indicate the approximate winter baseflows. Flows were measured as follows:

- Site AE01, based on depth at a 90°V-notch weir;
- Site AE05, based on velocity-area method at three pipe culverts at the R575 road bridge (pipe diameter each 0.6 m)
- B1H002, based on stage height over sharp-crested weir and associated discharge table, downloaded from the DWAF website (www.dwaf.gov)

3.5 Water Quality

Field measurements were made of conductivity, pH and spot water temperature.

3.6 Aquatic Invertebrates

Aquatic invertebrates were sampled and identified using the standard SASS5 biomonitoring method (Dickens and Graham 2002). The method was applied at sites AE04 and AE05 only. The method could not be applied at other sites because flows were too low and biotopes were unsuitable for the application of the method.

The SASS5 results were classified into one of six categories, ranging from *Excellent* (Category A), to *Very Poor* (Category F). The classification was based on professional judgement and historical biomonitoring data collected from the Highveld Ecoregion and analysed by the Institute for Water Quality Studies (Table 3-1). This system was used in preference to the guidelines for the interpretation of SASS results, which have recently been published (Dallas 2007). The reason for this is that the guidelines do not address the problem of low SASS scores, other than warning that these should "treated with caution".

Table 3-1. Guide used to classify SASS5 biomonitoring results. [SASS4 data collected in the Highveld Ecoregion by the Institute for Water Quality Studies.]

Category	Condition		SASS4	ASPT
[illegible]	Excellent	Unimpaired. High diversity of taxa with numerous sensitive taxa.	>120	>6
[illegible]	Very Good	Slightly impaired. High diversity of taxa, but with fewer sensitive taxa.	91-120	5-6
C	Good	Moderately impaired. Moderate diversity of taxa.	71-90	4.5-5.5
[illegible]	Fair	Considerably impaired. Mostly tolerant taxa present.	56-70	4.5-5.5
[illegible]	Poor	Severely impaired. Only tolerant taxa present. Low diversity.	30-55	Variable
[illegible]	Very Poor	Very severely impaired. Very few tolerant taxa present. Very low diversity	<30	Variable

3.7 Fish

Sampling of fish was undertaken using a portable, battery operated electro-fisher (Samus 725M).

3.8 Impacts Evaluation

The likely environmental impacts of the proposed development were evaluated using the following criteria:

M = Magnitude or Severity: 1=minor; 2= low; 3=moderate; 4=high; 5=very high or don't know.

R = Reversibility: 1=naturally reversible; 3=reversible with human input; 4= difficult; 5=irreversible.

D = Duration or Frequency: 1=immediate and/or unique impact; 2=short-term (0 to 5 years) and/or infrequent impact; 3=medium-term (5 to 10 years) and/or frequent impact; 4=long-term (impact ceases after operational life) and/or very frequent impact; 5=permanent and/or continuous impact.

E = Spatial Extent: 1=site only; 2=local; 3=regional; 4=national; 5=international.

P = Probability: 1=improbable; 2= low probability; 3=medium probability; 4=high probability; 5=definite or don't know.

S = Significance: The overall significance of each impact was determined by combining the consequence of the impact and the probability of occurrence i.e.: Significance = Consequence (magnitude + reversibility + duration + spatial extent + environmental context) x Probability. The scores were interpreted as follows:

Total Score	Significance
>100	Very High
76-100	High
51-75	Moderate
26-50	Low
<26	Very Low

3.9 Assumptions and Limitations

It is assumed that the quality of the discharged water will consistently meet the water quality targets that have been set by DNWRP (2009) for Management Unit 26 (Appendix E). The expected quality of water discharged from the plant is unknown, but it is certain to be better than the quality of water that is currently in the Niekerspruit and Spookspruit.

4. BASELINE ASSESSMENT

4.1 Cross-Sectional Profiles

Niekerkspruit

The Niekerkspruit at the proposed discharge point (Site AE03) comprises a non-channelled valley-bottom wetland that is about 80 m wide (see Appendix D). The regional and local stream slope is gentle (0.005). The addition of 15 to 25 ML/day of water to this wide stream channel is unlikely to increase the risks of erosion.

Spookspruit

The Spookspruit at Site AE04 comprises a channelled valley-bottom wetland, where the main channel is 3 m wide, but the riparian zone is about 300 m wide in total (see Appendix D). The regional gradient is gentle (0.008), but there are erosion nick-points where the local gradient is steep (0.02). Current speeds of up to 0.8 m/s were recorded in one of the erosion nick points during the field visit in July 2008. The addition of 15 to 25 ML/day of water to this stream channel therefore has the potential to increase the risks of erosion at a few existing erosion nick points.

4.2 Flow

Flow in the Niekerkspruit at Site AE01 during the field survey in July 2008 comprised little more than a trickle (1.8 L/s). Although flows in this catchment are highly altered because of upstream mining activities and impoundments, it is probable that this flow approximates natural baseflow for this time of the year. The proposed discharge is expected to be between 174 and 289 L/s (i.e. 160 times the flows measured in July 2008).

Flow in the Spookspruit at Site AE05 during the field survey in July 2008 was moderate, and calculated to be about 237 L/s. Further downstream, at gauging weir B1H002, the flow was recorded to be 228 L/s. The proposed flows are in the same order of magnitude, which means that the flows seen in July 2008 would be roughly doubled. Flows recorded at gauge B1H002 in the month of July during the late 1950's and early 1960's, when development of the catchment is presumed to have been limited, varied between 69 and 144 L/s. The available information therefore indicates that current winter flows are significantly higher than they may have been under natural conditions.

4.3 Surface Water Quality

Water quality in the Spookspruit Catchment is seriously compromised. Spot readings of conductivity recorded during the field survey in July 2008 were consistently and excessively high (>200 mS/m) (Table 4.1). These values are equivalent to a Total Dissolved Salt concentration in excess of 1,300 mg/L. A noticeable smell of sulphide was recorded at Site AE04. The pH of the Niekerkspruit (Site AE01) was acidic (6.4), while the Spookspruit was alkaline (7.4 to 7.6). Water at all sites was clear (Secchi depth >1 m), and these conditions are typically associated with elevated salt levels which promotes sedimentation of clays.

Table 4-1. Field measurements of selected water quality variables recorded at selected sites in July 2008.

[illegible]	[illegible]	[illegible]	[illegible]
AE01	6.4	7.7	216
AE04	7.6	10.7	207
AE05	7.4	11.9	214

4.4 Aquatic Invertebrates

Data on aquatic invertebrates collected at two sites during this study are shown in Appendix B, and summary results are shown in Table 4-2. The fauna was "Severely Impaired" (Category E), and characterised by a few (10 to 13), hardy SASS taxa, and low population numbers, despite the generally good quality of biotopes available. The Total SASS5 Scores were very low (54 and 56), and the Average Score per Taxon was also very low (4.3 and 5.4). The only taxa that were considered common (>10 in sample) at were non-biting midges (Chironomidae) and whirligig beetles (Gyrinidae). Mayflies and snails were notably absent at both sites, although an empty shell of *Lymnaea* was found at Site AE04. The highest SASS5 score at Site AE04 was for aeshnid dragonflies (SASS5 Score = 8), while the highest scoring taxa at Site AE05 comprised three species of hydropsychid caddisflies (SASS5 Score = 12). The results indicate that poor water quality is the main reason for the low diversity and abundance of invertebrates.

Table 4-2. Summary results of SASS5 biomonitoring data recorded at selected site in July 208.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AE04	56	13	4.3	E
AE05	54	10	5.4	E

4.5 Fish

No fish were recorded during the field survey in July 2008. Six species of indigenous fish are expected to occur in the Spookspruit under natural conditions, namely *Barbus anoplus;*

B. paludinosus; B. trimaculatus; Chiloglanis pretoriae; Pseudocrenilabrus philander and *Tilapia sparrmanii* (Kleynhans *et al.* 2007). It is therefore concluded that the Present Ecological State of the Spookspruit in terms of fish is "Critically Impaired" (Category F). There are no impoundments that could restrict the movement of fish in the middle and lower reaches, apart from the gauging weir B1H002. The absence of fish in the Spookspruit is therefore attributed to poor quality water. No fish are expected under natural conditions in the Niekerkspruit because there is insufficient habitat.

4.6 Functional Values

The wetlands in the catchment have a number of important functional attributes, including:

- ***Flood Attenuation.*** The valleybottom wetlands cover a significant portion of the catchment, and the gradient is gentle, so the potential influence on flood attenuation is high.
- ***Water Quality Enhancement.*** Water quality improvement within the lateral seepage wetlands and the valleybottom wetlands is likely to be significant, as the contact with vegetation is high. However, natural wetlands are unlikely to serve any significant role in processing high concentrations of salt.
- ***Biodiversity Support.*** The wetlands provide moderate diversity of habitat for flora and fauna, although this has been severely compromised by deterioration in water quality.

5. POTENTIAL ENVIRONMENTAL IMPACTS

This section details the expected environmental impacts of the proposed development on aquatic ecosystems. Impacts are arranged in order of increasing overall significance. A summary and rating of the main impacts is provided in Table 6-1.

5.1 Planning and Construction Phases

The Planning and Construction Phases of the proposed development are not expected to have any impacts on the receiving aquatic environment.

5.2 Operational Phase

5.2.1 Improved Water Quality

The proposed development is certain to improve the quality of the water in the receiving stream because of dilution. The improvement will be most apparent in the Niekerspruit (Option 1). The improvement is expected to be immediate, of moderate magnitude, of local extent, and easily reversible. The impact is positive, and the overall significance is rated as **Low (+ve)**.

5.2.2 Increased Biodiversity

Improved water quality and elevated baseflows (and therefore increased habitat availability), is expected to improve the faunal biodiversity of the receiving stream, irrespective of which option is developed. The improvement is expected to be immediate, of high magnitude, of local extent, and easily reversible. The impact is positive, and the overall significance is rated as **Low (+ve)**.

5.2.3 Reed Encroachment

Elevated constant baseflows could lead to the proliferation of reeds, particularly bulrush (*Typha capensis*), irrespective of which option is developed. This could lead to a single-species dominance; a reduction in wetland plant diversity and wetland habitat diversity; an increase in evapotranspiration losses; and an increase in the risk of fire during dry periods. The changes are expected to take a number of years to develop, and are likely to be of local extent, and moderately difficult to control once established. The overall significance of this impact is rated as ***Low (-ve)***.

5.2.4 Increased Erosion

Erosion is anticipated in the receiving channel during the operational phase, particularly at the point of discharge, and in areas where the flows are constricted, or the gradients steep. The Niekerkspruit has a wide channel with gentle gradient, and is therefore unlikely to be affected, except at the point of discharge. However, there are sections of the Spookspruit that could be moderately susceptible to erosion. In particular, the spillway of the dam located 1.6 km downstream of Site AE04 may be at risk to erosion. The overall significance of this impact is rated as ***Low (-ve)***.

5.3 Options

There is no major difference between the various options in terms of impacts on the receiving aquatic environments. However, Option 1 would have the advantage of significantly improving the water quality, and therefore the ecological functioning and biodiversity support, of the Niekerkspruit to its confluence with the Spookspruit, a distance of about 600 m. Furthermore, the proposed point of discharge for this option has a hillslope that lends itself for creating an artificial hillslope seepage wetland.

Table 5-1. Summary and rating of the main impacts of the proposed Water Treatment Plant on the receiving aquatic ecosystems, before and after mitigation. The overall significance of detrimental impacts is highlighted in colour.

Potential Impact	**Environmental significance before mitigation**									**Environmental significance after mitigation**							
	M	R	D	E	C	P	**TOTAL**	**S**	**MITIGATION**	M	R	D	E	C	P	**TOTAL**	**S**
Operational Phase																	
Improved Water Quality	4	1	1	2	2	5	**50**	**+ Low**	Monitor	3	1	1	2	2	5	**45**	**+ Low**
Increased Biodiversity	4	1	1	2	2	4	**40**	**+ Low**	Biomonitor	4	1	1	2	2	4	**40**	**+ Low**
Reed Encroachment	3	3	3	2	2	-3	**-39**		Nothing	3	3	3	2	2	-3	**-39**	
Increased Erosion	3	4	5	2	2	-3	**-48**		Monitor; Aquifer Recharge	2	4	5	2	2	-2	**-30**	

M=Magntitude or Severity; R=Reversibility; D=Duration; E=Extent; C=Context; P=Probability; S=Significance

6. RECOMMENDED MITIGATION MEASURES

Recommendations for mitigating the detrimental impacts of the proposed water treatment plant on aquatic ecosystems are detailed below.

6.1 Pre-Construction

6.1.1 Aquifer Recharge

Water discharged from the proposed treatment plant could be used to recharge aquifers adjacent to the receiving stream, instead of discharging it directly into the stream channel. This will reduce the risks of erosion at the point of discharge, and is expected to create a new, artificial hillslope seepage wetland area that could mitigate any potential negative impacts of the proposed development. The left bank of the Niekerkspruit at the point of discharge for Option 1 (Site AE03), has a moderate slope (0.073) that lends itself for creating an artificial hillslope seepage wetland (See Appendix D). However, a specialist geohydrological study of the feasibility of doing this at the selected point of discharge is recommended.

6.2 Operational Phase

6.2.1 Monitor Erosion

The applicant should be responsible for undertaking regular checks of the structural stability of the receiving stream, and correct any problems of erosion as soon as they are noticed. This should be done immediately after any significant rainfall event. Digital photographs of key areas should be kept and maintained as a record of how the stream channel is responding to the changes in flow. Areas of particular concern are:

- the point of discharge;
- existing erosion nick points, and;
- the spillway of the existing dam located 1.6 km downstream of Site AE04.

6.2.2 Monitor Water Quality

Monthly monitoring of the quality of discharged water as well as the receiving stream is recommended. Key variables should include conductivity and pH. Annual monitoring of a comprehensive suite of variables is recommended. Appropriate steps should be taken if levels exceed target levels.

6.2.3 Biomonitoring

Annual SASS5 biomonitoring is recommended at two sites in the Spookspruit, downstream of the selected point of discharge.

6.2.4 Re-introduce Indigenous Fish

Introduction of indigenous fish into the Spookspruit upstream of gauging weir B1H002 should be considered if the water quality and SASS5 biomonitoring results indicate significant improvement, as expected.

6.2.5 Monitor Wetlands in Recharge Zone

The proposed artificial wetland that is expected to be formed near the recharge zone should be monitored in terms of its size, ecological state and plant biodiversity.

7. REFERENCES

Dallas, H. F. 2007. River Health Programme: South African Scoring System (SASS) data interpretation guidelines. Report prepared by the Freshwater Consulting Group and the Freshwater Research Unit, University of Cape Town. Report prepared for the Institute of Natural Resources, Pietermaritzburg, and the South African Department of Water Affairs and Forestry.

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Directorate National Water Resource Planning (DNWRP) Department of Water Affairs and Forestry, South Africa, July 2009. Integrated water resource management plan for the upper and middle Olifants Catchment: Integrated Water Resource Management Plan. Report Number: P WMA 04/000/00/7007.

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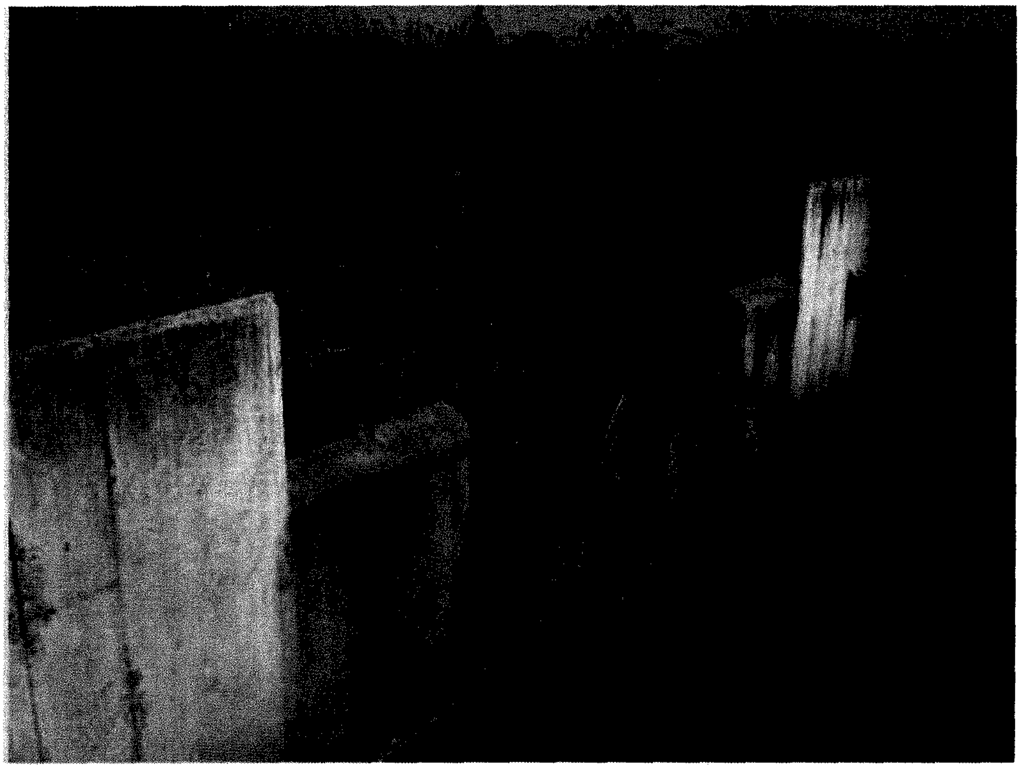
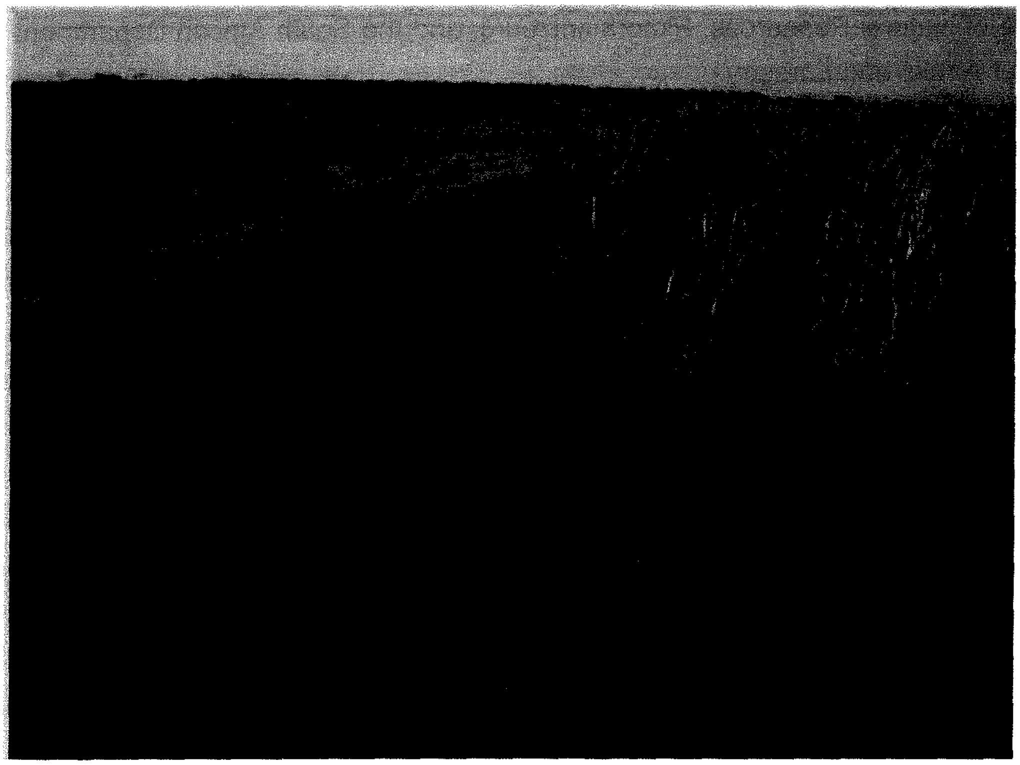
8. APPENDICES

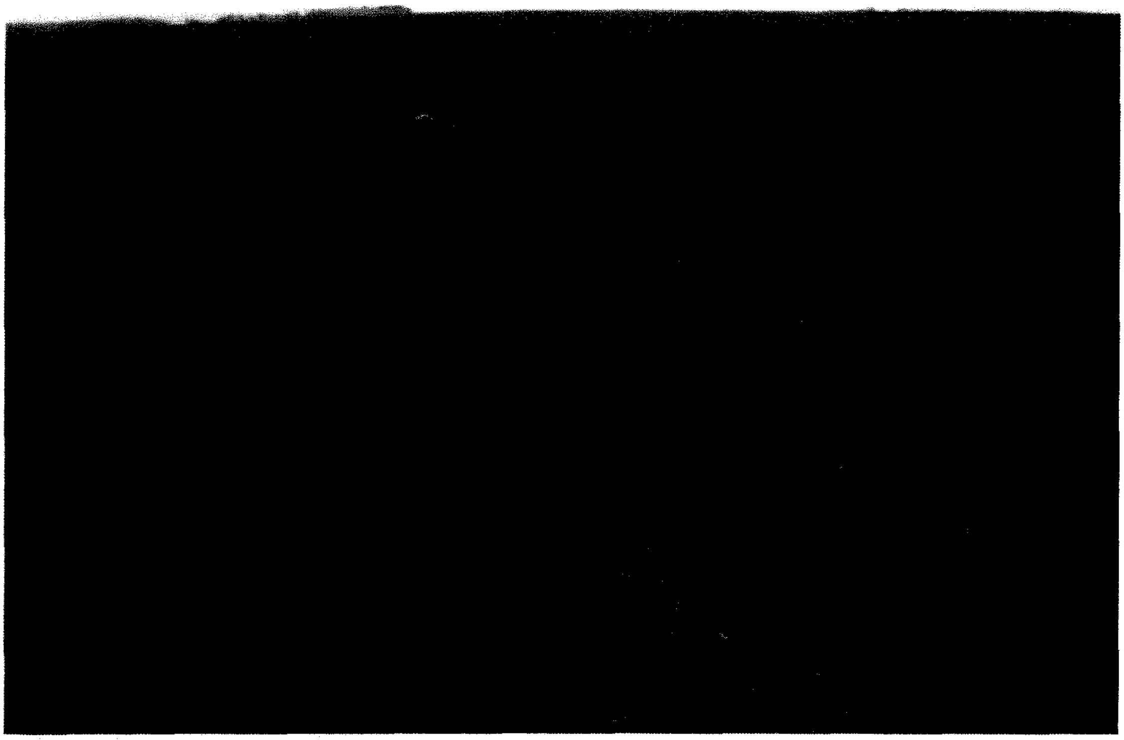
8.1 Appendix A: Photographs



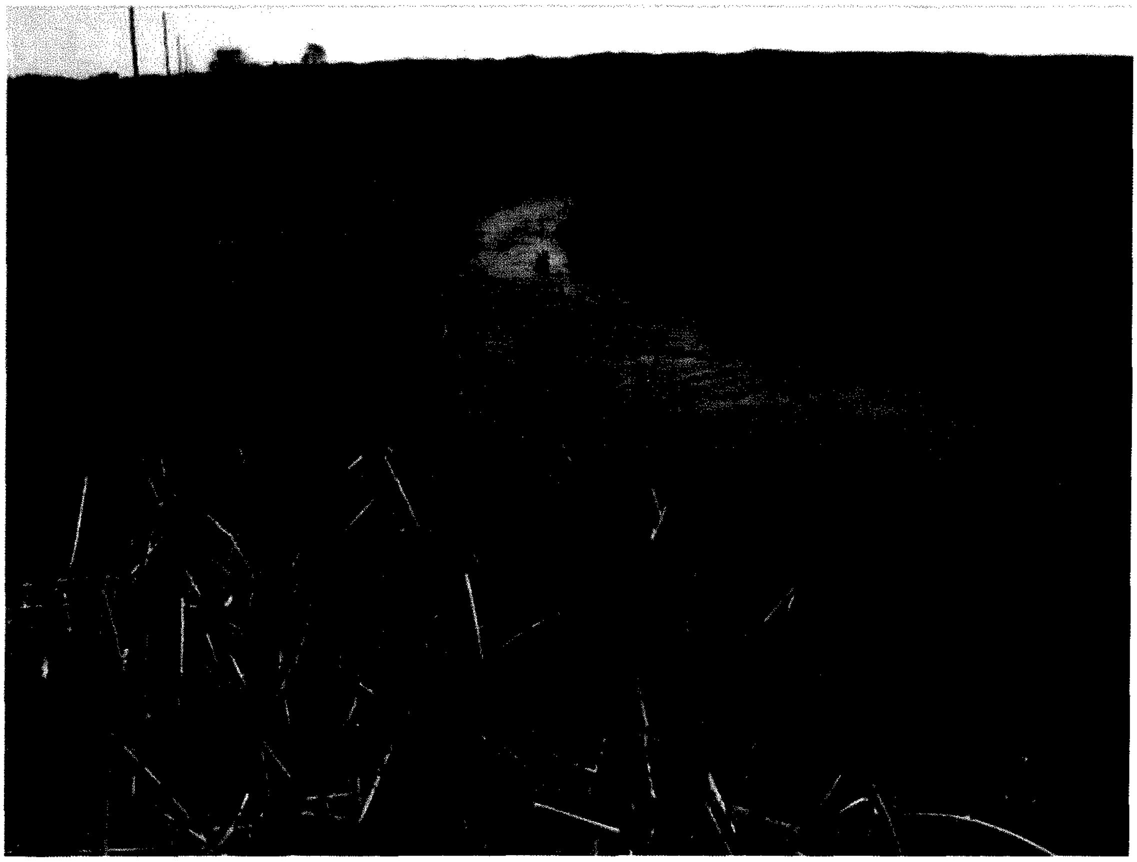
Photograph A: V-notch flow gauge in the Niekespruit, downstream of pollution control dams (Site AE01)



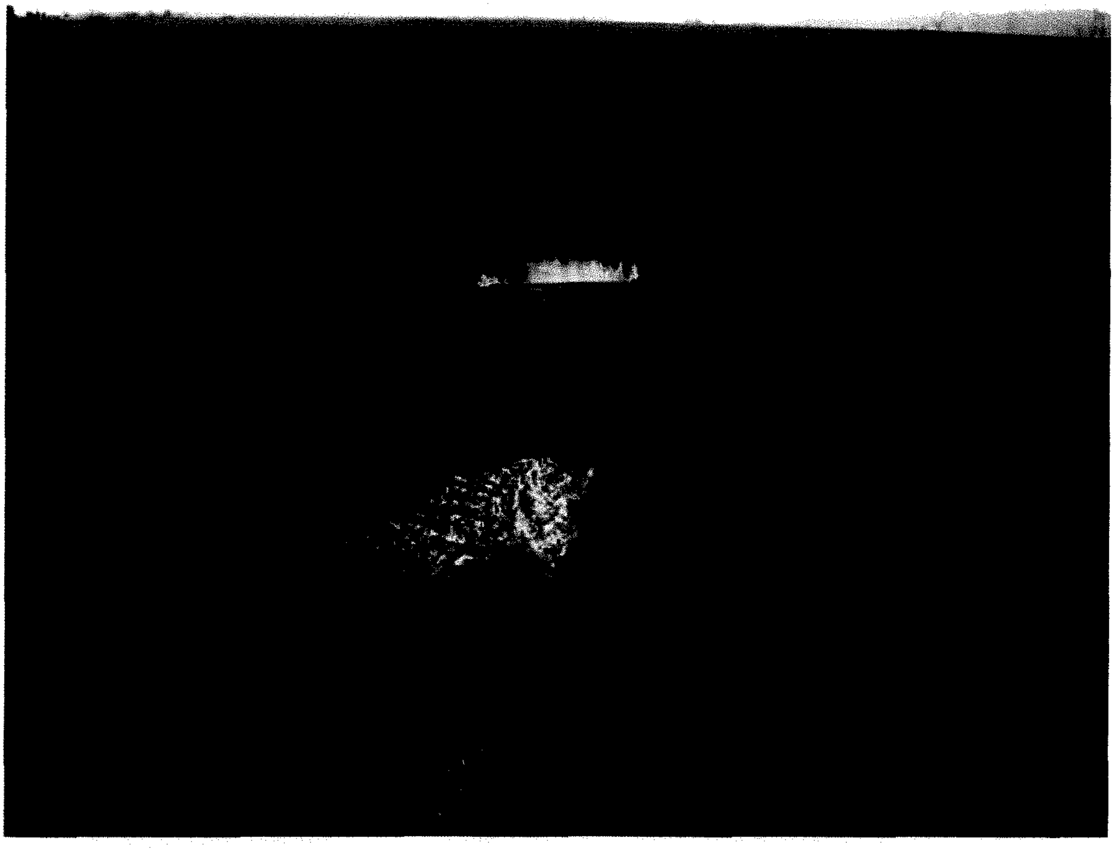
Photograph B: Niekerkspruit and road crossing (Site AE02)



Photograph C: Niekerkspruit and proposed discharge point for Option 1 (Site AE03)



Photograph D: Spookspruit on the farm Burnside (Site AE04)



Photograph E: Spookspruit immediately downstream of the R575 road bridge (Site AE05)

8.2 Appendix B: Detailed Results - Aquatic Invertebrates.

30-Jul-08
AE04
Rob Palmer
Spookspruit
11: HIGHVELD
B11H

Road crossing on Jaap Visser's farm (Burnside)

10.7
7.6
-
207

Routine or Project? (circle one)
Project Name:
Middleburg Mine - Proposed Water Treatment Plant

Lat: 25 53 27.4
Long: 29 25 20.0
WGS84
1519
E: Lower Foothills

Low
>1m
V Low
Normal Transparent

	3
	4
	0
	3
	0
	4
	0
	2
	1
	yes

Taxon	QV	S	Veg	GSM	TOT
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1			1	1
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	1			1
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A			A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6			1	1
Libellulidae (Darters/Skimmers)	4		1		1
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		1		1
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A	1		A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6		1		1
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		B		B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5	1			1
Chironomidae (Midges)	2		A	A	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A			A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					56
No. of Taxa					13
ASPT					4.3

Other biota:

Empty shell - Lymnaea
Cheumatopsyche afra

Comments/Observations:

Sulphide smell

Date (dd/mm/yy):	30-Jul-08
Site Code:	AE05
Collector/Sampler:	Rob Palmer
River:	Spookspruit
Level 1 Ecoregion:	11: HIGHVELD
Quaternary Catchment:	B11H
Temp (°C):	11.9
pH:	7.4
DO (mg/L):	-
Cond (mS/m):	214

Site Description:
R575 road bridge

Routine or Project? (circle one)

Project Name:
Middleburg Mine - Proposed Water Treatment Plant

Grid reference (dd mm ss.s) Lat:	S	25 51 32.6
Long:	E	29 23 49.7
Datum (WGS84/Cape):		WGS84
Altitude (m):		1480
Zonation:		E: Lower Foothills
Flow:		Medium (237 L/s)
Clarity (cm):		>1m
Turbidity:		V Low
Colour:		Normal Transparent

Biotopes Sampled	
[illegible]	4
[illegible]	4
[illegible]	0
Aquatic Veg	4
[illegible]	4
[illegible]	4
[illegible]	4
Sand	0
[illegible]	3
[illegible]	yes

[illegible]					
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
[illegible]					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
[illegible]					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	A		1	A
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
[illegible]					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
[illegible]					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	1			1
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4	A			A
[illegible]					
Crambidae (Pyralidae)	12				

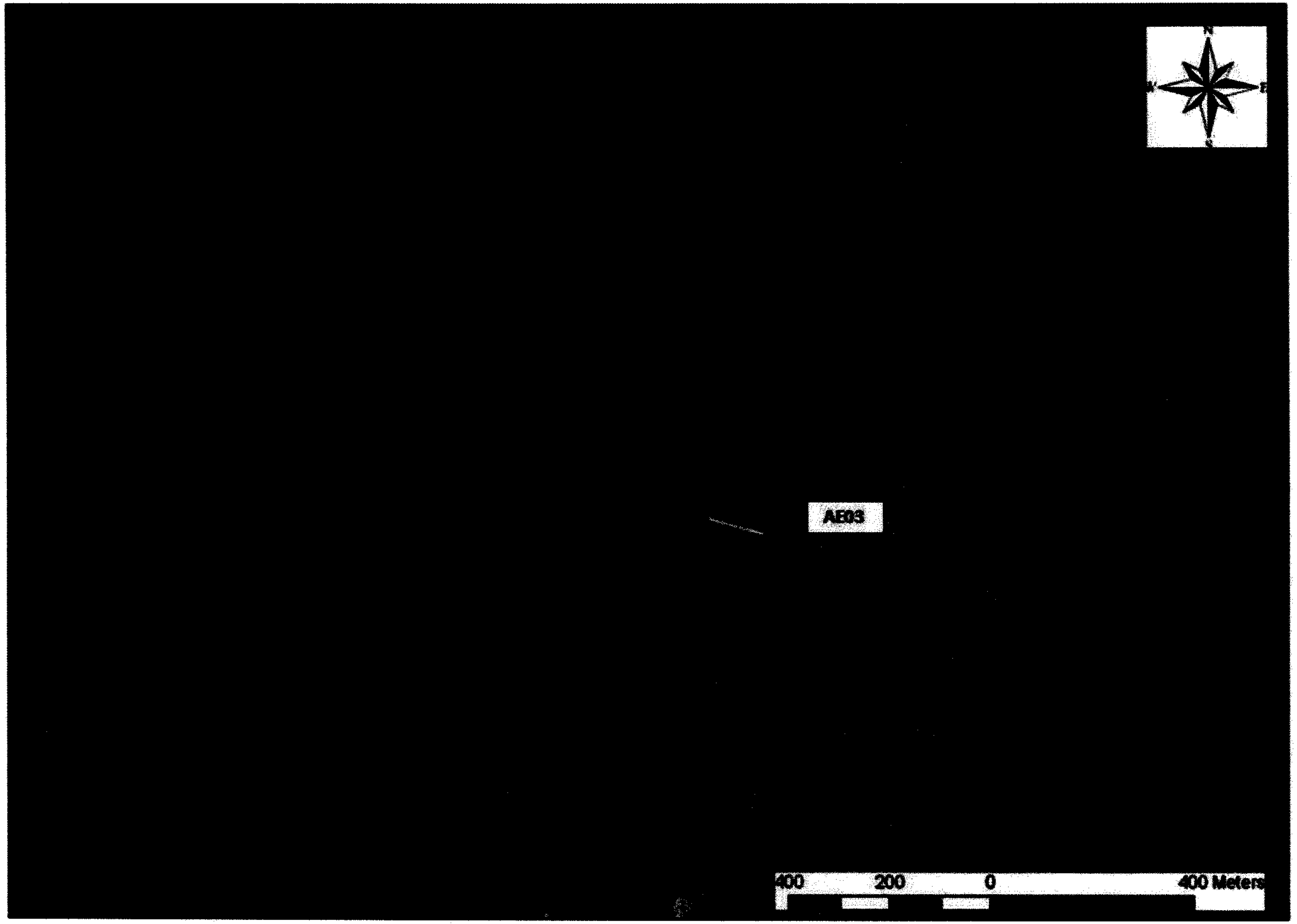
[illegible]					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12	A			A
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6		1		1
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5		A		A
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	A		A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

[illegible]					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2			A	A
Culicidae* (Mosquitoes)	1	A	A	A	B
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
[illegible]					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
[illegible]					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					54
No. of Taxa					10
ASPT					5.4

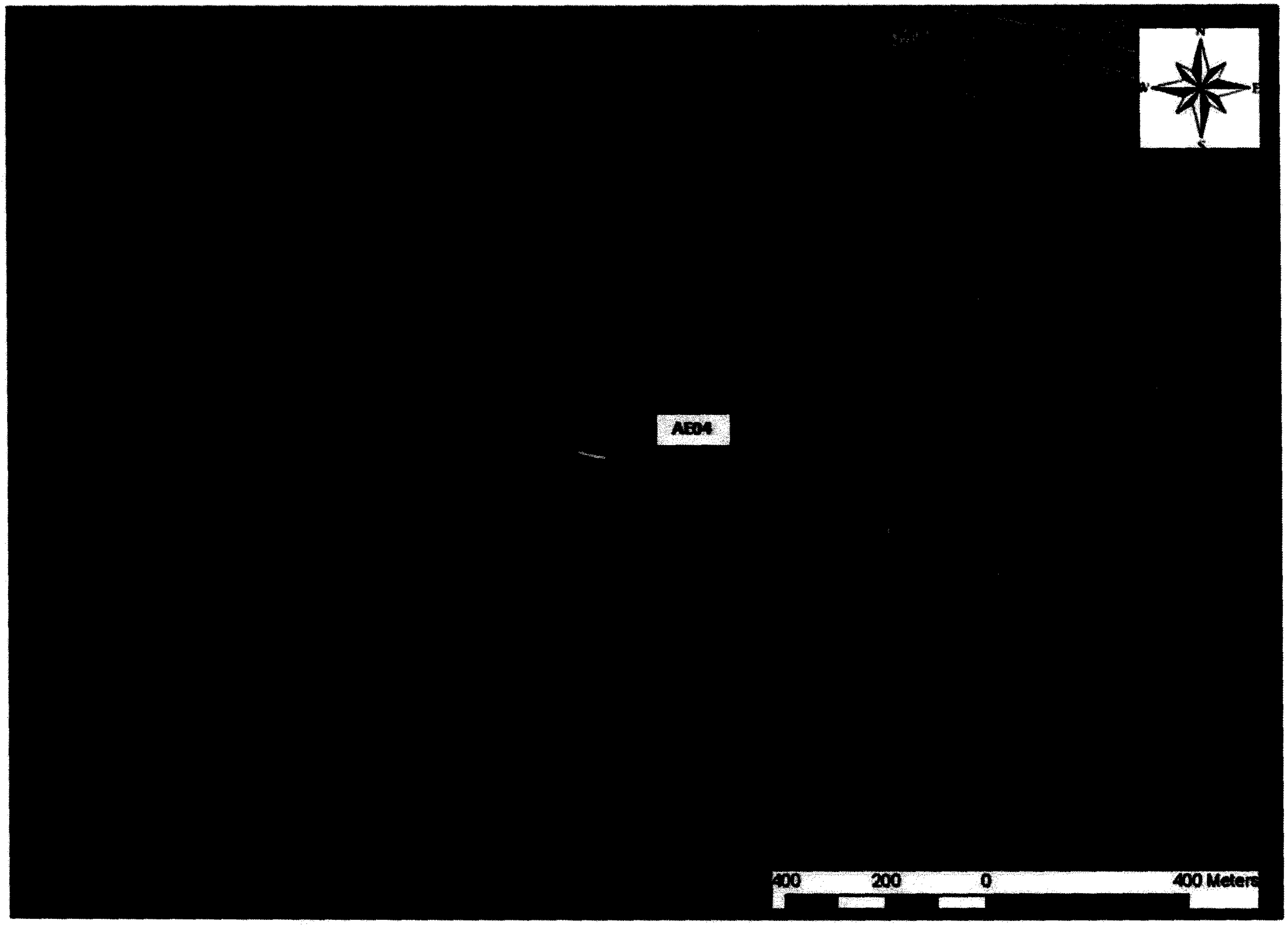
Other biota:
Cheumatopsyche tomasetti; Chuematopsyche afra; Macrostemum capense

Comments/Observations:
Tadpole present; Current speed over Potamogeton pectinatus about 0.68 m/s

8.3 Appendix C: Aerial Photographs

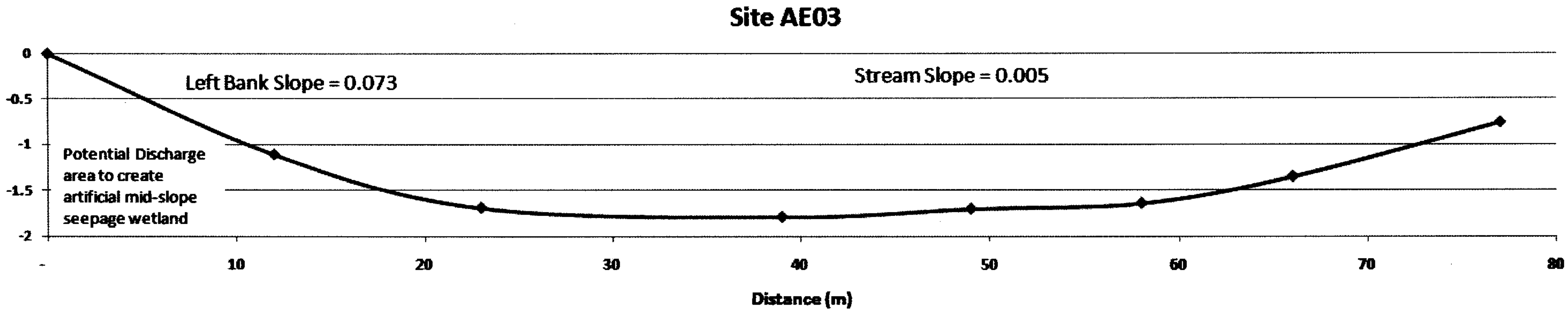


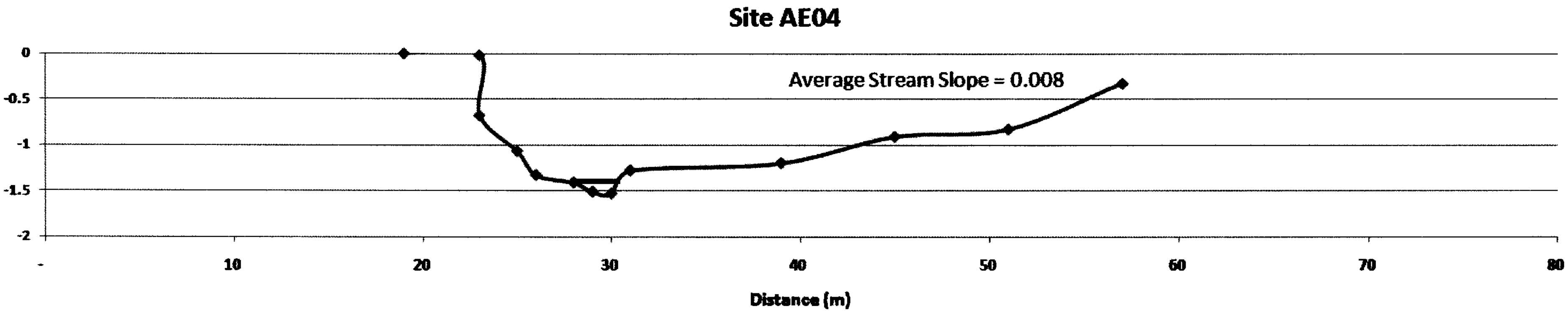
Aerial Photograph A: Site AE03



Aerial Photograph B: Site AE04

Appendix D: Cross-sectional Profiles





Appendix E: Target Water Quality Guidelines

Target water quality guidelines applicable to the Spookspruit, located in Management Unit 26, extracted from DNWRP (2009).

Water quality Variables	Units	Management Units			
		16, 17, 18	26	27, 28, 29, 30	Loskop Dam
PHYSICAL					
Conductivity	mS/m	120 (PRWQ)	90 (IMS)	90 (IMS)	40 (PS)
Dissolved Oxygen	% Sat	70 (AER)	70 (AER)	70 (AER)	70 (AER)
pH	-	6.0-9.0 (PRWQ)	6.5-8.4 (IMS)	6.5-8.4 (IMS)	6.5-8.4 (IMS)
Suspended solids	mg/ℓ	-	-	-	-
Turbidity	NTU	-	-	-	-
CHEMICAL, INORGANIC					
Alkalinity	mg $CaCO_3$/ℓ	120 (PS)	120 (PS)	120 (PS)	85 (PS)
Boron	mg/ℓ	0.5 (IMS)	0.5 (IMS)	0.5 (IMS)	0.5 (IMS)
Calcium	mg/ℓ	150 (DI)	150 (DI)	150 (DI)	32 (PS)
Chloride	mg/ℓ	60 (PS)	20 (PS)	175 (IMS)	25 (PS)
Fluoride	mg/ℓ	0.75 (AET)	0.75 (AET)	0.75 (AET)	0.75 (PS)
Magnesium	mg/ℓ	100 (DI)	100 (DI)	70 (AET)	20 (PS)
Potassium	mg/ℓ	50 (DI)	20 (PS)	50 (DI)	10 (PS)
Sodium	mg/ℓ	115 (IMS)	70 (PS)	70 (AET)	25 (PS)
SAR	meql$^{0.5}$	2.0 (IMS)	2.0 (IMS)	2.0 (IMS)	1.5 (PS)

Appendix E. continued...

Water quality Variables	Units	Management Units			
		16, 17, 18	26	27, 28, 29, 30	Loskop Dam
Sulphate	mg/ℓ	500 (PRWQ)	400 (DI)	120 (AET)	120 (PS)
Total Dissolved Solids	mg/ℓ	820 (PRWQ)	650 (IMS)	650 (PS)	260 (PS)
CHEMICAL, ORGANIC					
Dissolved Organic Carbon	mg/ℓ	10 (DI)	10 (DI)	10 (DI)	10 (DI)
METALS, DISSOLVED					
Iron	mg/ℓ	1.0 (PRWQ)	1.0 (DI)	1.0 (DI)	1.0 (DI)
Manganese	mg/ℓ	1.0 (PRWQ)	0.4 (AER)	0.4 (AER)	0.18 (AER)
Aluminium	mg/ℓ	0.2 (PRWQ)	0.02 (AER)	0.02 (AER)	0.02 (AER)
Chromium (VI)	mg/ℓ	0.05 (DF)	0.05 (DF)	0.05 (DF)	0.05 (DF)
PLANT NUTRIENTS					
Ammonia*	mg/ℓ as N	0.007 (AER)	0.007 (AER)	0.007 (AER)	0.007 (AER)
Nitrate	mg/ℓ as N	6 (DF)	6 (DF)	6 (DF)	6 (DF)
Phosphate	mg/ℓ as P	0.05 (AER)	0.05 (AER)	0.05 (AER)	0.02 (AER)
Total Phosphorus	mg/ℓ as P	0.25 (AER)	0.25 (AER)	0.25 (AER)	0.05 (AER)
Total Inorganic Nitrogen	mg/ℓ as N	2.5 (AER)	2.5 (AER)	2.5 (AER)	0.2 (AER)
MICROBIOLOGICAL					
E Coli	# per 100mℓ	130 (RFC)	130 (RFC)	130 (RFC)	130 (RFC)
Chlorophyll a	mg/ℓ	0.02 (RIC)	0.02 (RIC)	0.02 (RIC)	0.02 (RIC)

**Free unionised* NH_3

D.3 Biodiversity Impact Assessment (Ecological, Floral, Fauna and Wetlands)

MIDDELBURG WATER RECLAMATION PROJECT: COMBINED SUMMARY ECOLOGICAL REPORT

SEF Ref No. 504105

Prepared for:

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S.E.F
STRATEGIC ENVIRONMENTAL FOCUS

June 2011

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Acronym / Abbreviation	Meaning
BECSA	BHP Billiton Energy Coal South Africa
DEA	Department of Environmental Affairs
DTJV	Douglas Tavistock Joint Venture
DWA	Department of Water Affairs
EMPR	Environmental Management Program Report (MPRDA)
EMPr	Environmental Management Program (NEMA)
GIS	Geographic Information Systems
ha	hectares
HSECO	Health, Safety and Environmental Control Officer
MDEDET	Mpumalanga Department of Economic Development, Environment and Tourism
MM	Middelburg Mines
MPRDA	Mineral and Petroleum Resources Development Act
MBCP	Mpumalanga Biodiversity Conservation Plan
MWRP	Middelburg Water Reclamation Project
NEMA	National Environmental Management Act
NWA	National Water Act
RWQO	Resource Water Quality Objectives
SEF	Strategic Environmental Focus
WTP	Water Treatment Plant
XCSA	Xstrata Coal South Africa

1. INTRODUCTION

1.1 Background

Middelburg Mines (now known as Middelburg Colliery), located near Middelburg Mpumalanga, generates excess impacted mine water and intends constructing a water treatment plant, called the Middelburg Water Reclamation Project (MWRP) to treat excess impacted mine water from the Hartbeesfontein, Goedehoop and Klipfontein sections to a suitable standard for release into the Spookspruit catchment, a tributary of the Upper Olifants River catchment. The MWRP is a joint venture between BHP Billiton Energy Coal South Africa (BECSA) and Tavistock Collieries, called the Douglas Tavistock Joint Venture (DTJV).

The DTJV has conducted a pre-feasibility study to determine the viability of constructing and operating a water treatment plant located on Middelburg Mines' North Section. The project is now at a definition phase study to determine its ultimate feasibility. If feasible and the plant becomes operative, the final product of the Water Treatment Plant (WTP) will be treated water complying with the Department of Water Affairs (DWA) interim Resource Water Quality Objectives (RWQO). The envisaged point of discharge of this water will be in the Niekerkspruit, a tributary of the Spookspruit.

As part of the study, it was necessary to determine the environmental impacts associated with the implementation of this project to ultimately determine the feasibility thereof. Strategic Environmental Focus (Pty) Ltd was tasked by Jones & Wagener (Pty) Ltd to undertake an ecological assessment on the locality of the WTP Option 1 and Option 2 as well as the proposed pipeline routes (Figure 1).

The ecological assessments for the WTP Option 1 and WTP Option 2 as well as some of the proposed pipeline routes were undertaken during 2008. As different alternatives for the pipelines became likely, these were also ecologically assessed over the period 2009-2010. The ecological assessments included three reports namely floral assessments, faunal assessments and wetland assessments. The relevant findings of the ecological reports produced for the MWRP are summarised in this combined summary report.

1.2 Locality and Alternatives

1.2.1 Water Treatment Plant

During the site alternative selection process only sites located on Middelburg Mine properties were considered for the proposed development. Additionally areas where no coal seams or undermining was present were considered.

Two alternative sites were assessed namely:

- **Option 1:** This site is located to the east of the R575 and the Naledi Village. Access to the site will have to be established from the R575. The plant and infrastructure will be located on a portion of the farm Hartbeesfontein 339 JS, Portion 9.
- **Option 2:** This site is located on a portion of the farm Goedehoop 315 JS, near Dam 10 and to the south of the N4 national road. Access to the site is from a tertiary road that links the R575 with south western parts of Middelburg.

The location of the sites was based on the fact that both the areas would not be mined due to them not being underlain with economically viable coal reserves.

In conclusion regardless of which WTP site alternative is authorised three pipelines are required to be constructed to transport untreated water to the treatment plant, with one pipeline being located within the treatment plant footprint.

1.2.2 Pipeline routes

WTP Option 1: Pipeline corridor alternatives

For Option 1 three pipelines are required (Figure 1). Due to the distance from Dam 5 abstraction point to the WTP-Option 1 site and since the pipeline between these two points is within the WTP-Option 1 footprint, no pipeline alternatives have been considered for this portion of the pipeline.

From Rondeboschje Dam

From the Rondeboschje abstraction dam to WTP-Option 1 site, *only one* pipeline with no alternatives was considered. This is a result of the decision made by the mine to ensure that the pipeline remains on mine owned property and to avoid areas with coal seams and undermined areas. This pipeline is described as follows: From the starting point, that is Rondeboschje Dam, the pipeline would travel in a north westerly direction for approximately 1.5 km over the Klipfontein Section of the mine. On exiting the Klipfontein Section the pipeline would turn westward and run parallel to an existing road for approximately 7 km, crossing over the R35 and the Spookspruit River on the North Section of the mine. The pipeline would then deviate slightly south of a water body and continue north westwards to the proposed WTP-Option 1. This proposed pipeline would run predominantly parallel to existing roads and is approximately 11 km in length.

From Goedehoop Dam

Two alternatives are being assessed to transport untreated mine water from Goedehoop abstraction dam to the north of the study area to WTP-Option 1. These alternatives are geographically represented in Figure 1 and explained in Table 1 below.

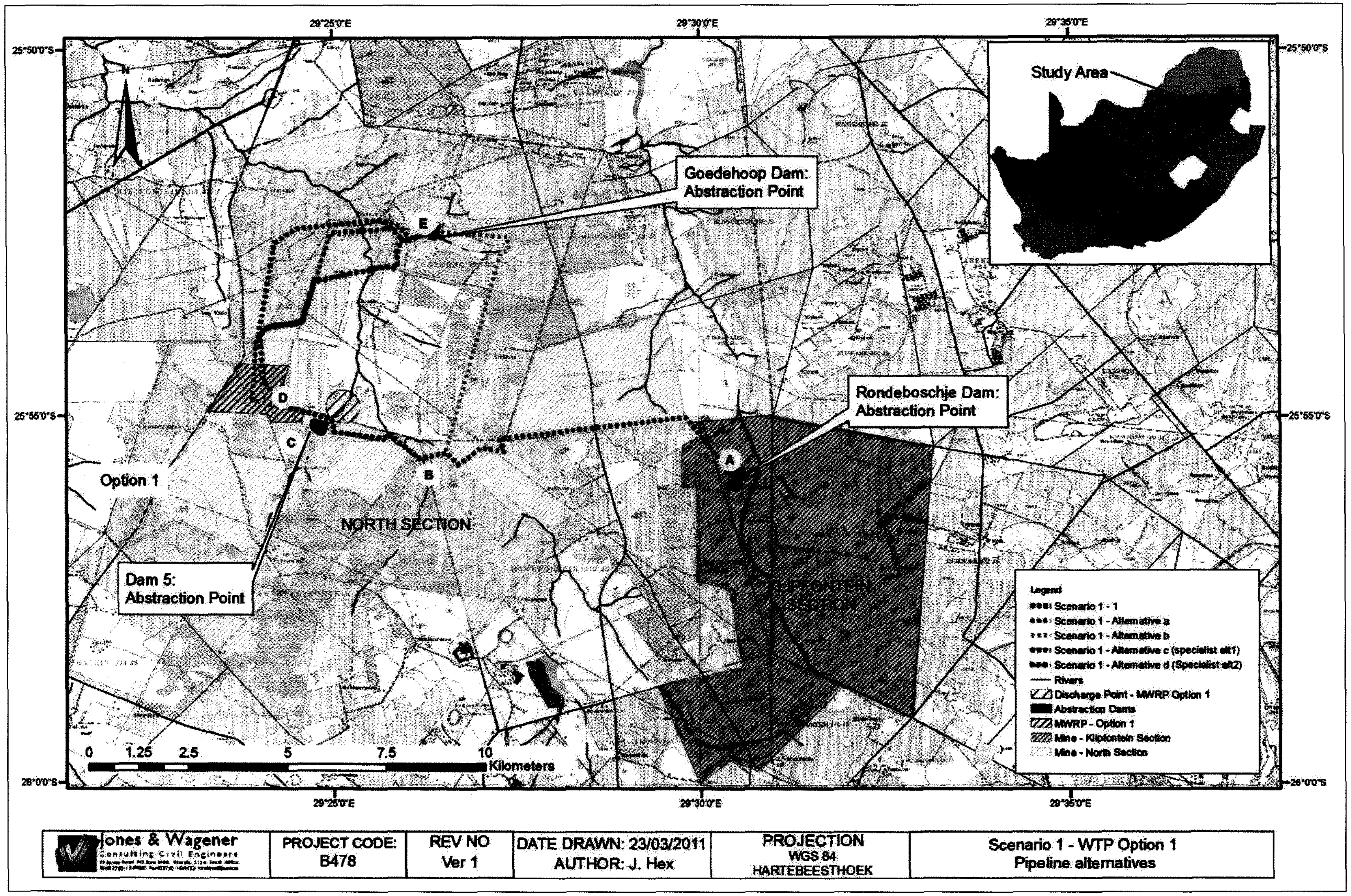


Figure 1: Locality WTP Option 1 and pipeline routes

Table 1: Pipeline route alternatives 1.1 a and 1.1b

Alternatives Option 1.1-a	Alternatives Option 1.1-b
Alternative 1.1-a starts at the Goedehoop Dam (point E) and heads in a westerly direction for approximately 2 km crossing over the Spookspruit river. Alternative 1.1-a then turns in a southerly direction and continues south for approximately 2.5 km until it reaches the pan. The route then deviates westerly around the pan and then enters the proposed WTP (Option 1) from the north. This alternative is approximately 8 km in length	Alternative 1.1-b starts at the Goedehoop Dam (point E) and heads in an easterly direction for approximately 1.5 km before turning southwards along the mine boundary for approximately 5.5 km before turning westwards along an existing road. Alternative 1.1-b continues for 4 km along the road crossing over the Spookspruit before entering the proposed WTP (Option 1) from the east of the site. This alternative is approximately 11 km in length.

WTP Option 2: Pipeline corridor alternatives

For Option 2, three pipelines are required. As with Option 1, due to the distance from Goedehoop abstraction dam to the WTP-Option 2 site and since the pipeline between these two points is within the WTP-Option 2 footprint, no pipeline alternatives have been considered for this portion of the pipeline.

From Rondeboschje

Two alternatives are being assessed to transport untreated mine water from Rondeboschje abstraction dam to the east of the study area to WTP-Option 2 namely Option 2.1 and Option 2.2. These alternatives are explained in Table 2 below and geographically represented in Figure 2.

Table 2: Pipeline route alternatives for WTP Option 2

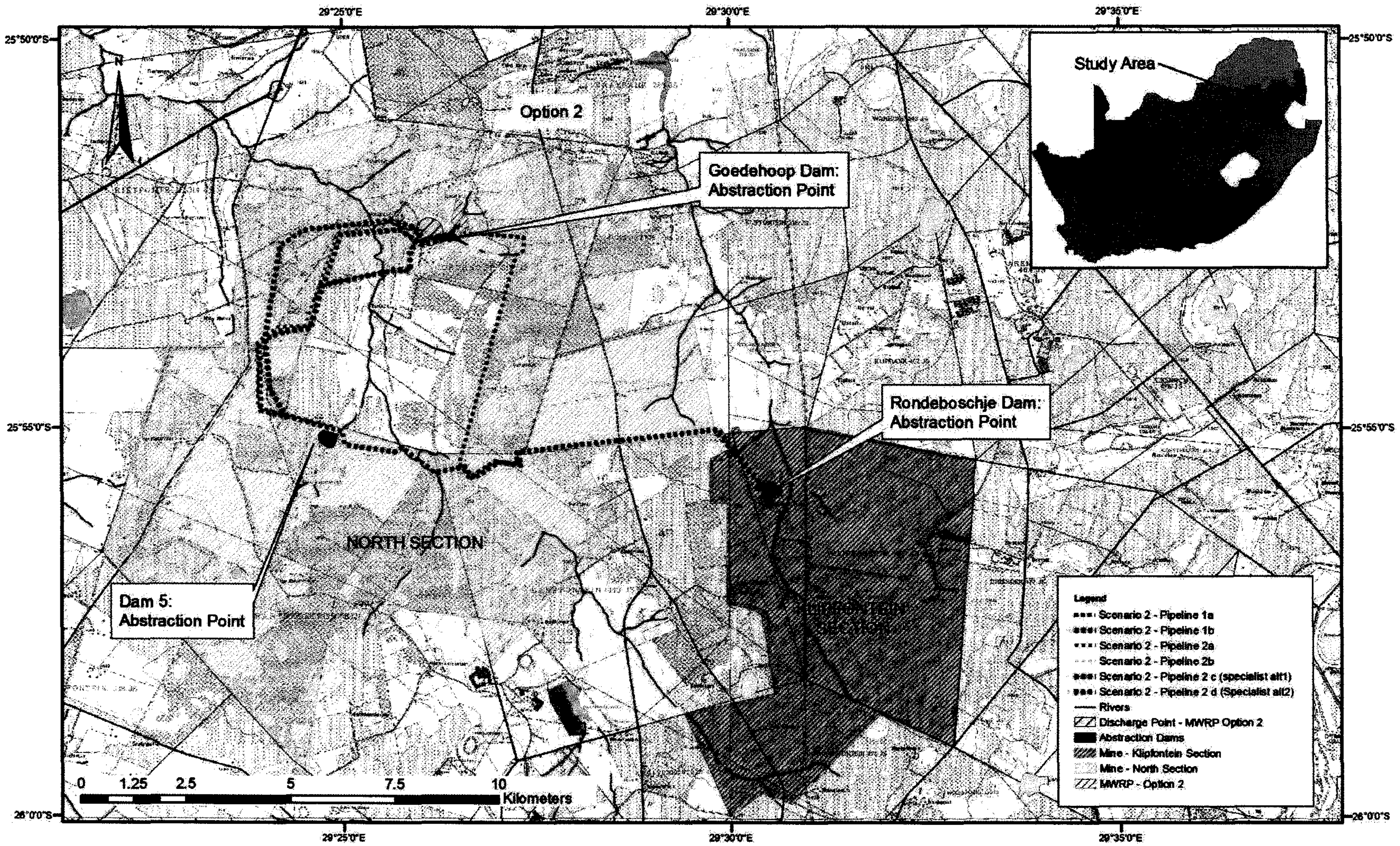
Alternatives Option 2.1-a	Alternatives Option 2.1-b
Alternative 2.1-a starts at the Rondeboschje abstraction Dam (point A) and heads in a north westerly direction for approximately 1.5 km over the Klipfontein Section of the mine. On exiting the Klipfontein Section the pipeline would turn westward and run parallel to an existing road for approximately 7 km, crossing over the R35 and the Spookspruit River on the North Section of the mine. Thereafter the alternative turns north north-eastwards for approximately 5.5 km before turning westwards and entering the proposed WTP (Option 2, point E).	Alternative 2.1-b similarly to Alternative 2.1-a starts at the Rondeboschje Dam (point A) and travels the same route as Alternative 2.1-a for 8.5km and then continues along the same path as Alternative 1.1-a until it reaches the proposed WTP (Option 2, point E).
Alternatives Option 2.2a	**Alternatives Option 2.2-b**
From Dam 5, this pipeline continues north westwards past the proposed WTP-Option 1 locality and then head northwards deviating around the pan before turning eastwards crossing the Spookspruit river and entering WTP-Option 2.	Alternative 2.2-b starts at Dam 5 (point C) and follows the same route as Alternative 1.1-b but in an opposite direction. This alternative is approximately 11 km in length

1.3 Study approach

This report is compiled as a summary of the following reports:

1. Middelburg Mines Water Treatment Plant: Flora Assessment (SEF, 2008a);
2. Middelburg Mines Water Treatment Plant: Fauna Assessment (SEF, 2008b);
3. Middelburg Mines Water Treatment Plant: Wetland Delineation Assessment (SEF, 2008c);
4. Middelburg Mines Water Treatment Plan: Ecological Assessment New Site (SEF, 2009);
5. Middelburg Water Reclamation Project: Flora Assessment (SEF, 2011a);
6. Middelburg Water Reclamation Project: Fauna Assessment (SEF, 2011b); and
7. Middelburg Water Reclamation Project: Wetland Delineation Assessment (SEF, 2011c).

Please refer to each report for the methodologies used during the studies as well as comprehensive species lists.



Jones & Wagener Consulting Civil Engineers	PROJECT CODE: B478	REV NO Ver 1	DATE DRAWN: 23/03/2011 AUTHOR: J. Hex	PROJECTION WGS 84 HARTEBEESTHOEK	Scenario 2 - WTP Option 2 Pipeline alternatives

Figure 2: Locality WTP Option 2 and pipeline route alternatives

2. BIOPHYSICAL DISCRIPTION

2.1 Climate

Mpumalanga Province experiences summer rainfall and dry winters with frost. Temperature ranges between an average high of 34 ℃ and a low of 8℃. Rainfall is on average 710 mm per year.

2.2 Regional Vegetation and Listed Ecosystems

Regional Vegetation

The study area falls within the Grassland Biome (Rutherford & Westfall, 1994) wherein high summer rainfall characteristics combined with dry winters with night frost and marked diurnal temperature variations are unfavourable to tree growth. The Grassland Biome therefore comprises mainly of grasses and plants with perennial underground storage organs, for example bulbs and tubers and less trees. The majority of Rare and Threatened plant species in the summer rainfall regions of South Africa are restricted to high-rainfall grasslands, making this the vegetation type in most urgent need of conservation. It is not generally acknowledged that the majority of plant species in grasslands are non-grassy herbs (forbs), most of which are perennial plants with large underground storage structures.

Frost, fire and grazing maintain the herbaceous grass and forb layer and prevent the establishment of thickets (Tainton, 1999). Fire is a natural disturbance caused by lightning, and regular burning is therefore essential for maintaining the structure and biodiversity of this biome. However, if prevented due to activities such as agriculture and mining, alien species eventually dominate the natural vegetation and place an additional burden on already scarce resources such as water. Currently, within South Africa, there are over 1.5 million hectares of alien tree plantations, mostly composed of *Eucalyptus* species, *Pinus* species and *Acacia mearnsii* (Black Wattle).

The Grassland Biome can be divided into smaller units known as vegetation types. Three dominant vegetation types occur within the study area (Mucina & Rutherford 2006) namely (Figure 3):

1. Eastern Highveld Grassland;
2. Rand Highveld Grassland; and
3. Eastern Temperate Freshwater Wetlands.

Eastern Highveld Grassland occurs on moderately undulating plains and includes low hills and pan depressions. This grassland comprises short grassland dominated by grass species such as *Themeda triandra* (Red Grass), *Aristida* -and *Eragrostis* species. Only a small portion of this grassland is statutory conserved (Mucina & Rutherford, 2006).

Transformation is mainly due to cultivation, mining and the invasion by the alien *Acacia mearsnii* (Black Wattle).

Rand Highveld Grassland occurs on variable landscapes and includes species-rich sour grassland and low shrubland on rocky outcrops. The dominant grasses are mainly *Themeda triandra* (Red Grass), *Eragrostis* species, *Heteropogon contortus* (Spear Grass) and *Elionorus muticus* (Copper Wire Grass). Rocky areas can include *Protea caffra* or *P. welwitchii, Acacia caffra* and *Celtis africana* (White Stinkwood). The Rand Highveld Grassland vegetation type is poorly conserved with much of its area transformed by cultivation, grazing, and mining. Where disturbances occur, the invasive exotic tree *Acacia mearnsii* (Black Wattle) can become dominant and displace the natural vegetation. Due to the extensive usage of the areas once covered by the Rand Highveld Grassland vegetation type, the remaining portions are of high conservation value and sensitivity and are thus classified as an endangered vegetation type (Mucina & Rutherford, 2006).

The Eastern Temperate Freshwater Wetlands occur in flat landscapes or shallow depressions filled with water. The water bodies contain aquatic zones and outer parts with hygrophilous vegetation of temporary flooded grasslands (Mucina & Rutherford, 2006).

The regional vegetation is an indication of the vegetation composition prior to adverse anthropogenic disturbances. Where the vegetation on the study site resembles the regional vegetation, it is assessed to be in a largely primary state.

Listed Ecosystems

Nationally, each vegetation unit has been assigned a conservation status in order to identify those ecosystems in critical need of conservation. In addition, the South African Biodiversity Act (Act 10 of 2004) provides for the listing of threatened or protected ecosystems. These ecosystems are grouped into Critically Endangered-, Endangered-, Vulnerable- and Protected Ecosystems (Government Gazette, 2009). The purpose of listing ecosystems is primarily to reduce the rate of ecosystem and species extinction, including the prevention of further degradation and loss of structure, function and composition of threatened ecosystems. Although Geographic Information System (GIS) layers are not yet available for the listed ecosystems, they correspond largely to the associated vegetation units.

All three vegetation units that could be impacted by the proposed pipeline route alignment are listed as Vulnerable Ecosystems in terms of Section 52 of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (Government Gazette, 2009). However, it is essential to determine the state of these vegetation units in the light of the past and present land uses along the proposed pipeline route.

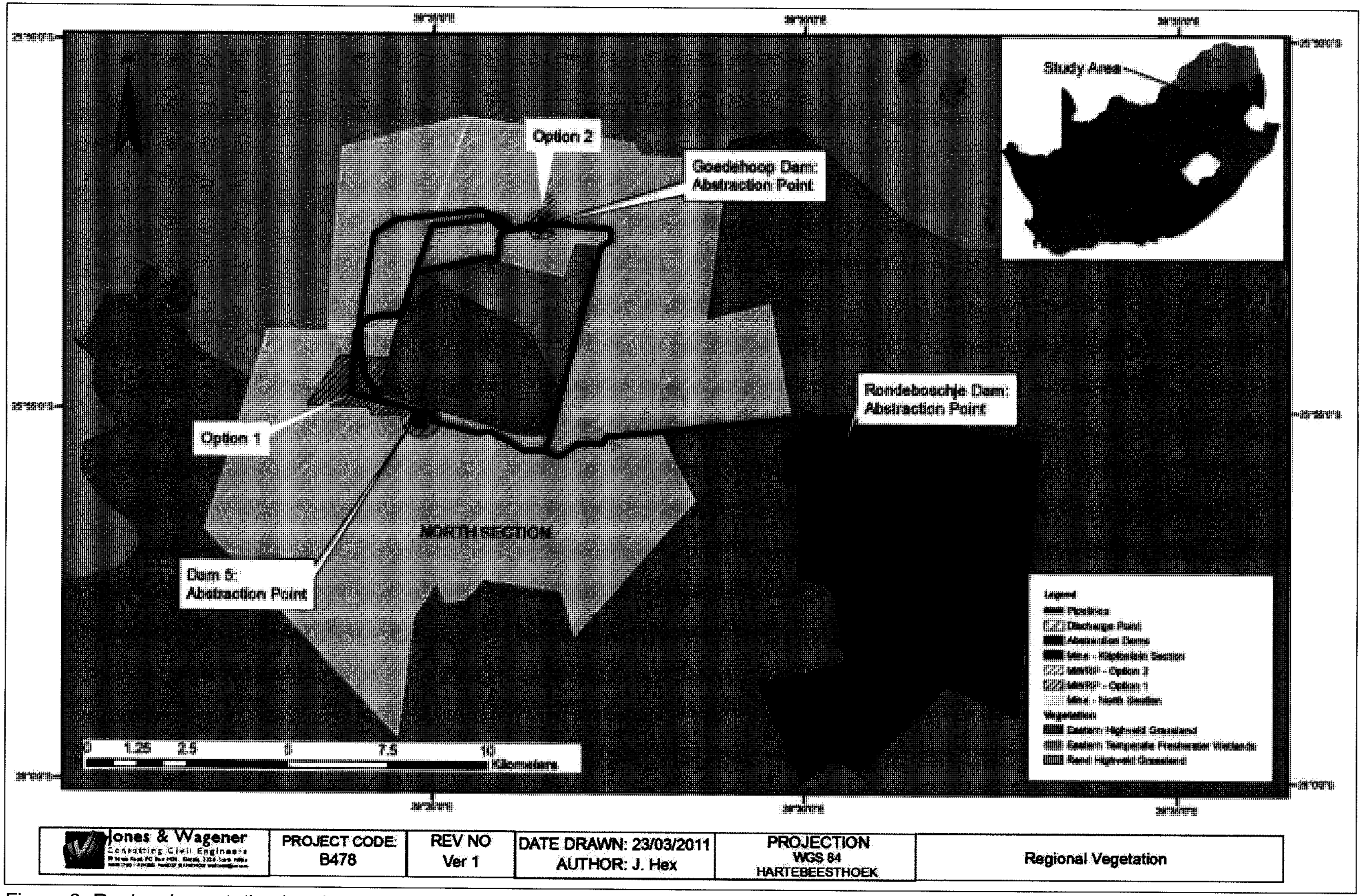


Figure 3: Regional vegetation in relation to the proposed MWRP

2.3 Mpumalanga Biodiversity Conservation Plan

The Mpumalanga Province developed the Mpumalanga Biodiversity Conservation Plan (MBCP), which is a comprehensive environmental inventory and spatial plan that is intended to guide conservation and land-use decisions in support of sustainable development (Lötter & Ferrar, 2006). The MBCP maps the distribution of the Province's known biodiversity into six categories. These are ranked according to ecological and biodiversity importance and their contribution to meeting the quantitative targets set for each biodiversity feature:

1. Areas with No Natural Habitat Remaining (areas with development options);
2. Areas of Least Concern with development options;
3. Important and Necessary ecosystems (protection needed);
4. Ecological Corridors;
5. Highly Significant; and
6. Irreplaceable Ecosystems.

Areas that have already been transformed are classified as "No Natural Habitat Remaining" or areas of "Least Concern", while most of the remnant patches of indigenous vegetation, including those within the study area, have been classified as "Highly Significant" and "Important and Necessary" in the MBCP. The MBCP is accompanied by land-use planning guidelines to guide planning and development within each of the biodiversity conservation categories throughout the Province. In each category, there are different land uses and development consequences. The biodiversity conservation categories that will be impacted by the proposed MWRP and their respective land-use planning guidelines are geographically represented in Figure 4 and described below.

Although the MBCP indicates certain areas as being of Least Concern in terms of the provincial conservation targets, this does not imply that national laws e.g. the National Water Act does not apply within these areas. Due to fragmentation and the current impacts and edge effects of land uses such as mining, an area might not be able to contribute to the conservation of ecosystems on a provincial level, but they may display local sensitivities and contribute to the ecosystem functioning at a local level.

2.3.1 Areas with No Natural Habitat Remaining

Much of the proposed pipeline routes are situated within areas with "No Natural Habitat Remaining", as well as a small portion of WTP Option 1. According to the MBCP, this category has already lost most of its biodiversity and consequently its ecological functioning too.

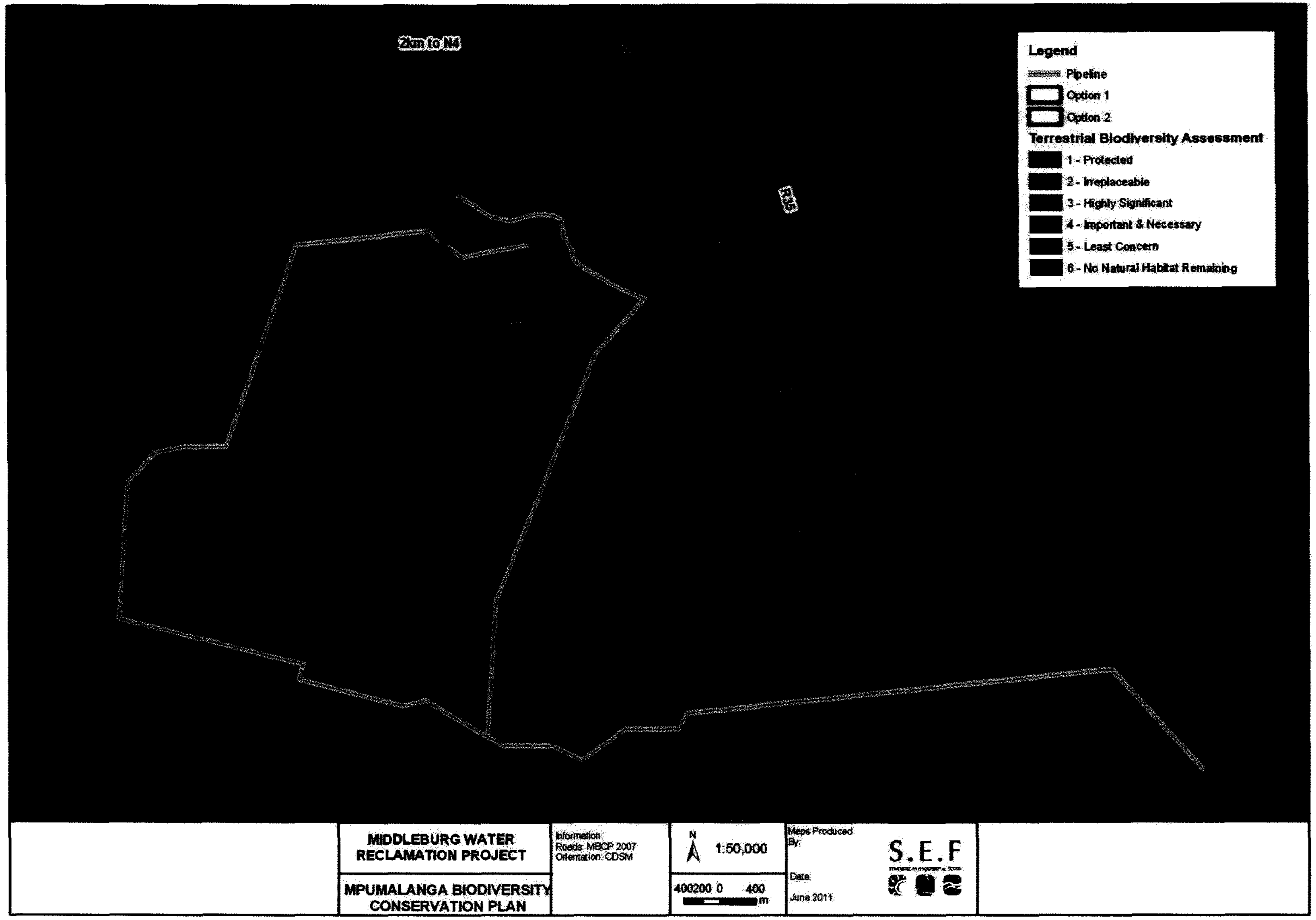


Figure 4: The general study area of the Middelburg Water Reclamation Project in relation to the Mpumalanga Biodiversity Conservation Plan

In the remnants of natural habitat that occur between cultivated lands and along river lines and ridges, residual biodiversity features and ecological processes do survive. However, these disconnected remnants are biologically impoverished, highly vulnerable to damage and have limited likelihood of being able to persist. The more transformed a landscape becomes the more value is placed on these remnants of natural habitat (Ferrar & Lötter, 2007).

2.3.2 Areas of Least Concern

WTP Option 1 includes areas of "Least Concern", while WTP Option 2 is wholly situated within it. The various proposed pipeline routes will also cross through portions of "Least Concern". Biodiversity assets in areas of "Least Concern" contribute to natural ecosystem functioning, ensure the maintenance of viable species populations and provide essential ecological and environmental goods and services across the landscape. Although these areas contribute least to reaching biodiversity targets they have significant environmental, aesthetic and social values and should not be viewed as wastelands or carte-blanche development zones (Lötter & Ferrar, 2006). Development options are widest in these areas. At the broad scale, these areas, and those where natural habitat has been lost, serve as preferred sites for all forms of development. However, land-use planners are still required to consider other environmental factors such as socio-economic efficiency, aesthetics and the sense-of-place in making decisions about development.

2.3.3 Important and Necessary Areas;

These areas are represented on the site by the moist grasslands and grasslands that were identified west of the pan on WTP Option 1 as well as along the east-west pipeline route which is largely impacted on by current mining activities (Figure 4). According to the MBCP, "Important and Necessary" areas are areas of natural vegetation that play an important role in meeting biodiversity targets. Their designation as important and necessary seeks to minimise conflict with competing land uses and represents the most efficient selection of areas to meet biodiversity targets (Ferrar & Lötter, 2007).

2.3.4 Highly Significant Ecosystems

WTP Option 1 as well as the east-west pipeline route alignments will impact on "Highly Significant Ecosystem". However, the portions along the east-west pipeline route are transformed by current mining activities. "Highly Significant Ecosystems" contribute to conservation within Mpumalanga as well as support the ecological function of "Irreplaceable" sites. These areas must be maintained as natural vegetation cover. Permissible land uses should be limited to those that are least harmful to biodiversity, and are conservation orientated. No agriculture or other land transformation activities should be allowed.

3. RESULTS: WTP LOCALITIES

The proposed localities for the WTP were assessed during April 2008. Since then, the Option 1 site boundary was extended eastward and additional ecological studies for the extended site were undertaken during March 2009. The vegetation sensitivities for WTP Option 1 are geographically represented in Figure 5 and that of WTP Option 2 in Figure 6.

3.1 Floral Assessment

3.1.1 WTP Option 1

Grassland and moist grassland

The majority of the site comprised grassland. Although this grassland has been subjected to disturbances such as grazing, exotic tree plantation and a quarry in the past, some pockets of intact grassland still remained on the site wherein a great number of forbs were still present. The high number of forbs encountered through much of the grassland signifies that these grassland portions were still in a healthy state and was considered to be Primary Grassland. The primary grassland comprised at least twenty seven (27) grass species and a minimum of forty (40) herbaceous species. The various forb species that were found on WTP Option 1 are indicative of the presence of Rand Highveld Grassland and Eastern Highveld Grassland. Forbs identified included *Dianthus mooienis* (Frilly Dianthus), *Aster harveyanus* (Bloublommetjie), the protected *Protea welwitschii, Boopane distichia* (Poison Bulb), *Gladiolus crassifolius* and the medicinal *Hypoxis hemerocallidea*. The primary grassland stretched from the west of the WTP Option 1 site north-westwards and was classified as being of **high sensitivity** (Figure 5; SEF, 2008a).

The moist grasslands associated with the pan and wetland housed the grass orchid, *Habenaria nyikana*. All plants from the family Orchidaceae are protected in Mpumalanga (Mpumalanga Nature Conservation Act, 1998). The grassland also plays an important role in the health and functioning of the wetlands and housed protected plants. This area is indicated as being of **high sensitivity** and should not be impacted upon by the proposed project.

Secondary Grassland

WTP Option 1 included a portion of secondary grassland within the southern portion of the study site that was indicative of the presence of Rand Highveld Grassland and Eastern Highveld Grassland. This grassland included forbs such as *Erica drakensbergensis* (Drakensberg Heath), *Strigea elegans* (Large Witchweed), *Pollichia campestris* (Waxberry) and *Hypoxis rigidula* (Kaffirtulp). This grassland portion was small and not in a primary state. The basel cover was reasonably low and overgrazing evident; however, protected plants such as *Gladiolus* cf. *crassifolius*, *Boophane distichia* (Poison

Bulb) and a *Crinum* species occurred here. The function of this grassland is important around the moist grassland / wetland areas as well as where it includes protected plants and it is classified as **medium sensitivity** (Figure 5; SEF, 2008a).

Overgrazed grassland and alien bush clumps

The disturbed portions include the secondary, overgrazed grassland and alien bush clumps. The disturbance on the site increased towards the eastern, southern and south-eastern boundary of the site, where the grasslands displayed signs of severe overgrazing. The pioneer shrub, *Seripheum plumosum* (Bankruptbush) grew abundantly with very few forbs and grass species present. The disturbed, and consequently low sensitivity areas, are of sufficient dimension to contain the WTP and its associated activities, provided that the WTP is situated as far as possible from the areas of high sensitivity (pan, wetlands and primary vegetation). No threatened or protected plant species were encountered within this vegetation community and none were expected to grow here. Due to the disturbances, this vegetation community is regarded as being of **low sensitivity** and low conservation concern (Figure 5). The disturbance gradient increases towards the south-eastern corner of the site where alien bush clumps were established. The alien invasive bush clumps were dominated by *Eucalyptus* species (Bluegum) and *Acacia mearsnii* (Black Wattle). Although an eradication plan seemingly fell and burned the Bluegum and Wattle trees, most of the trees have re-sprouted and are growing profusely.

East of the alien bush clumps, a large stretch of *Eragrostis chlormelas-Eragrostis curvula* grassland was found. This grassland was planted as grazing and little or no herbaceous plants were found growing here. This reduces the ecological importance of this vegetation community and it is thus regarded as being of **low sensitivity**.

3.1.2 WTP Option 2

At the time of the assessment, Option 2 comprised relatively homogenous rocky grassland and a small patch of invasive bush clumps. The grassland supported more than fifteen (15) different grass species as well as a minimum of thirty (30) different herbaceous species. A number of patches within the grassland contained the pioneer shrub *Seripheum plumosum* (Bankrupt Bush), but severe disturbances were not apparent. The rocky grasslands characteristically have higher biodiversity and were regarded as sensitive vegetation (Ferrar & Lötter, 2007). Furthermore, the Rand Highveld Grassland is an endangered vegetation community which leads to Option 2 being regarded as being of Medium to High Sensitivity (Figure 6). Although there were some disturbances to the vegetation on Option 2, they are generally contained and too small to be considered as a suitable position for the WTP. In addition, this site would necessitate additional infrastructure such as access roads which would have greater impact on the mainly open habitat. .

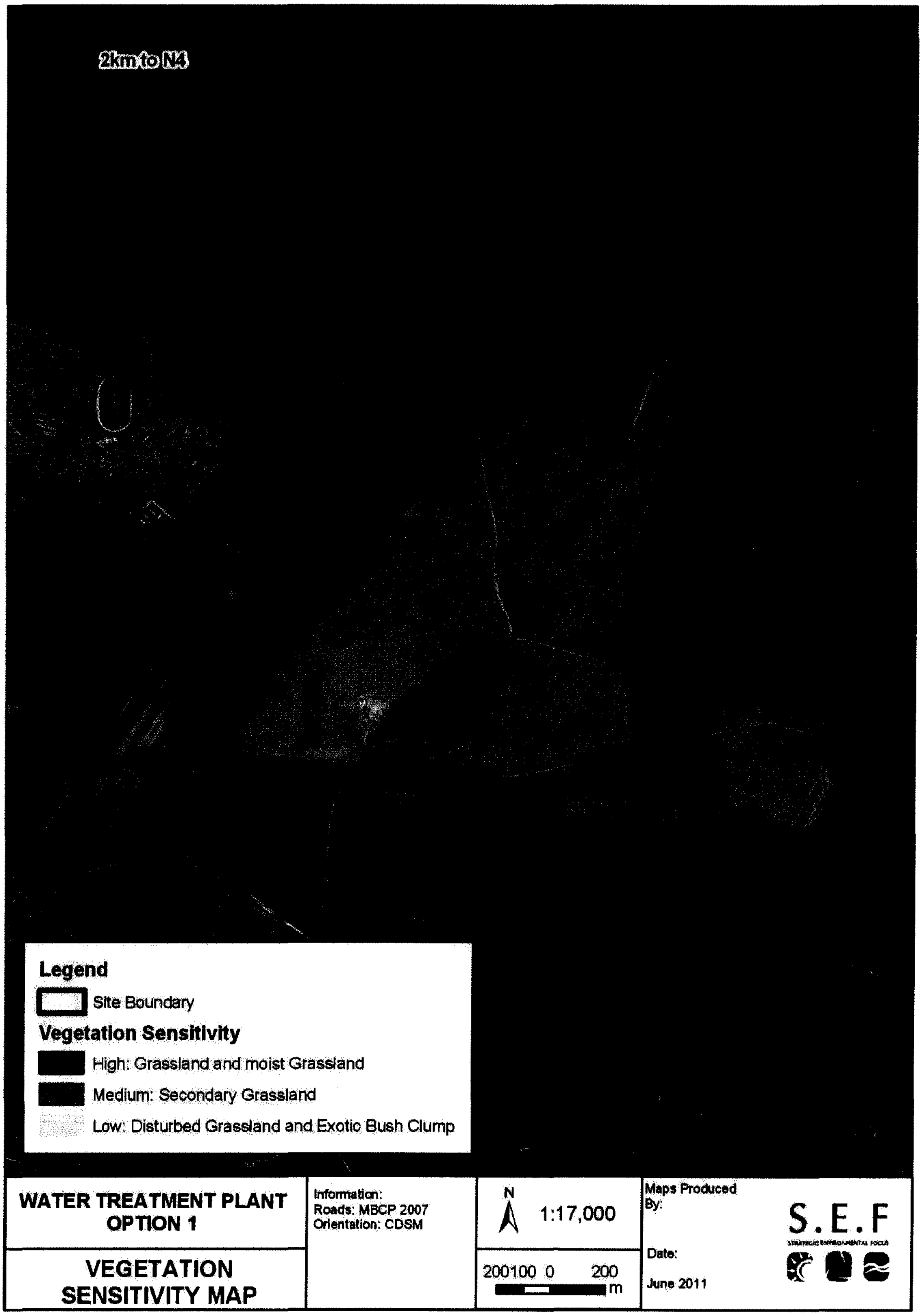


Figure 5: WTP Option 1 Vegetation Sensitivity

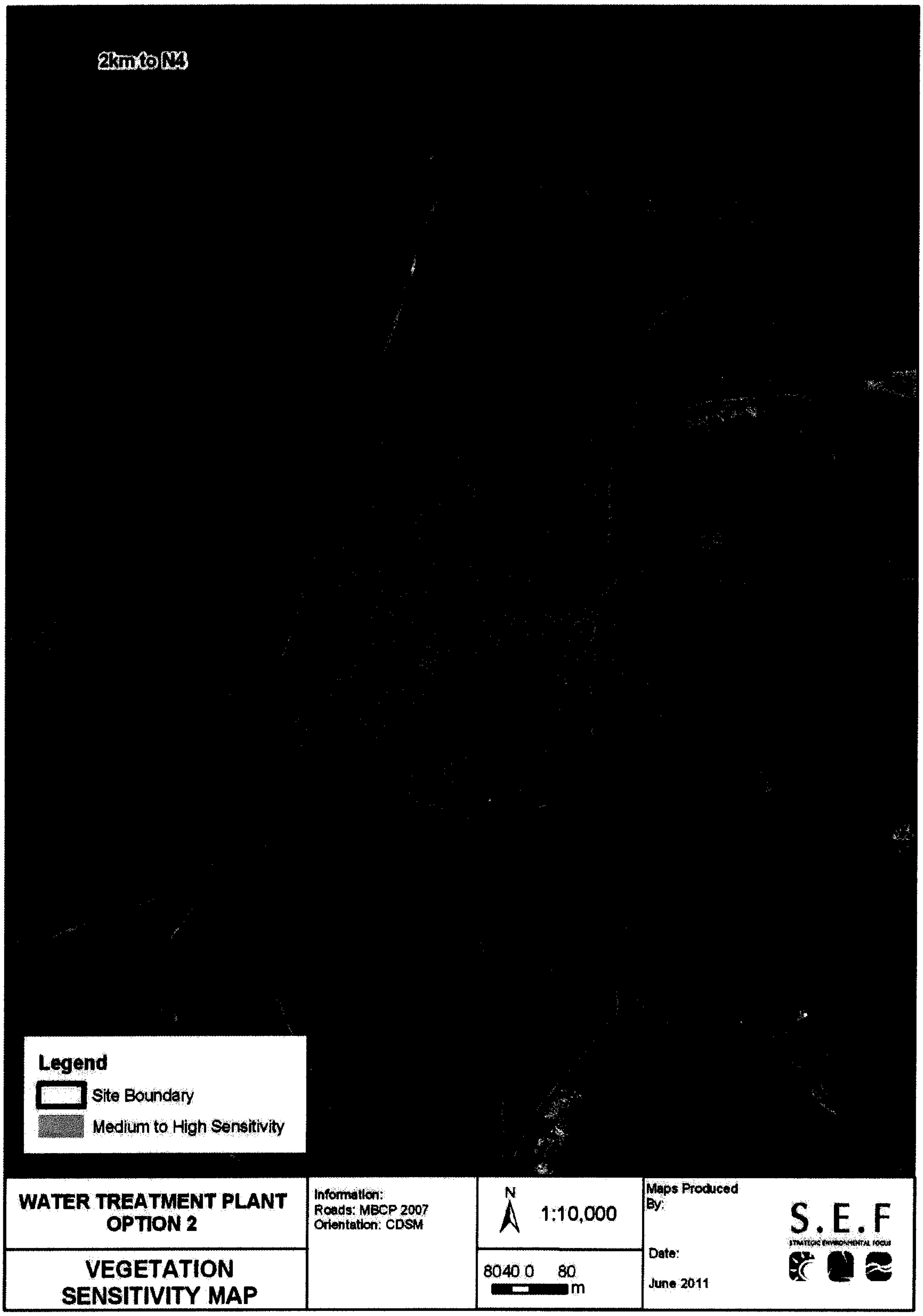


Figure 6: WTP Option 2 Vegetation Sensitivity

3.1.3 Conclusion

Due to the homogenous sensitivity of WTP Option 2, as well as the largely open and un-fragmented surroundings, this site was assessed as not ideal for the WTP. Rather, the floral report recommended that the disturbed areas of low sensitivity on WTP Option 1 are utilised for the construction of the WTP. However, the disturbed portion was found to be in close proximity of highly sensitive areas and if construction takes place within the disturbed areas, it should be subjected to stringent mitigation measures as set out by the floral report as well as the faunal and wetland delineation report.

3.2 Faunal Assessment

3.2.1 WTP Option 1

Option 1 was found to be highly sensitive with five Red Data species and/or habitat recorded at this site. Four faunal habitat types were delineated at WTP Option 1 and comprised the Wetland/Pan Areas, Degraded Grassland, Rocky Grassland and Alien Invasive Bush clumps. The Wetlands, Pans and Rocky Grassland which provide habitat to these species were therefore also deemed to be highly sensitive. Highly sensitive faunal areas perform important ecological functions offering burrowing habitat, migration corridors and forage areas to animals, and therefore warrant conservation. WTP Option 1 was found to be highly sensitive as a result of Red Data individuals and Red Data habitat recorded on site (Figure 7).

The following Red Data individuals were recorded within WTP Option 1:
- *Geronotus calvus* (Bald Ibis); and
- *Ourebia ourebi* (Oribi).

Habitat for the following Red Data individuals was recorded within WTP Option 1:
- *Pyxicephalus adspersus* (Giant Bullfrog);
- *Dingana fraternal* (Stoffberg Widow Butterfly); and
- *Metisella meninx* (Marsh Sylph).

These species are all of Red Data status and therefore pose constraints to a development. Legislation also stipulates that areas supporting these species warrant conservation.

The Alien Invasive Bush Clumps were regarded as an area of medium sensitivity with sampling revealing three species of small mammals inhabiting this area. As the Alien Bush Clumps are an exotic and invasive vegetation community which do not naturally occur on site; less ecological value and conservational importance is assigned to this community. Though faunal inhabitants were recorded, these species are opportunistic and have colonised the Alien Bush Clumps for the moist soil conditions and shelter from predators offered by the tree cover. It is therefore expected that just as these animals moved into the Alien Bush Clumps, they will again move out of the community, if a disturbance arose within this community.

3.2.2 WTP Option 2

WTP Option 2 was found to comprise two habitat types, Rocky Outcrop Grassland and Alien Bush Clumps. Sampling yielded no mammal taxa, and only common invertebrates and avifaunal taxa were recorded on site. WTP Option 2 was deemed to be of lower sensitivity with regards to faunal diversity than WTP Option 1. No species of conservation importance were recorded on WTP Option 2 and it is therefore characterised as of medium sensitivity, although the habitat is intact and may support species of conservation importance (Figure 8).

3.2.3 Conclusion

As a result of the sensitivities at WTP Option 1, WTP Option 2 is more preferred for the development of the WTP from a faunal perspective. Placing the development at WTP Option 2 would confine the disturbance to a currently disturbed area of the Middelburg Mine. Furthermore sensitive aquatic habitats would not be affected and the displacement and disturbance of faunal taxa would be minimal.

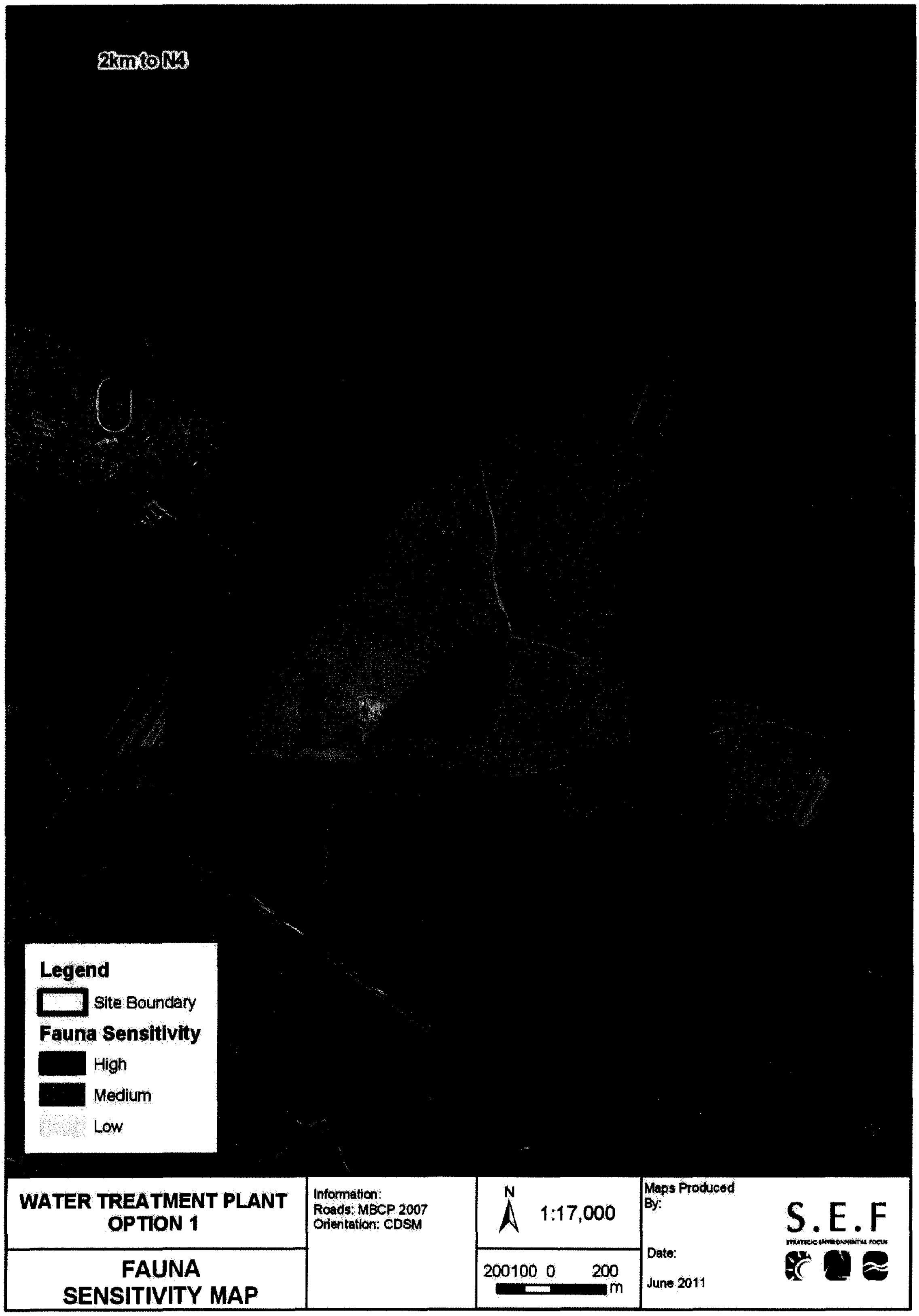


Figure 7: WTP Option 1 Fauna Sensitivity

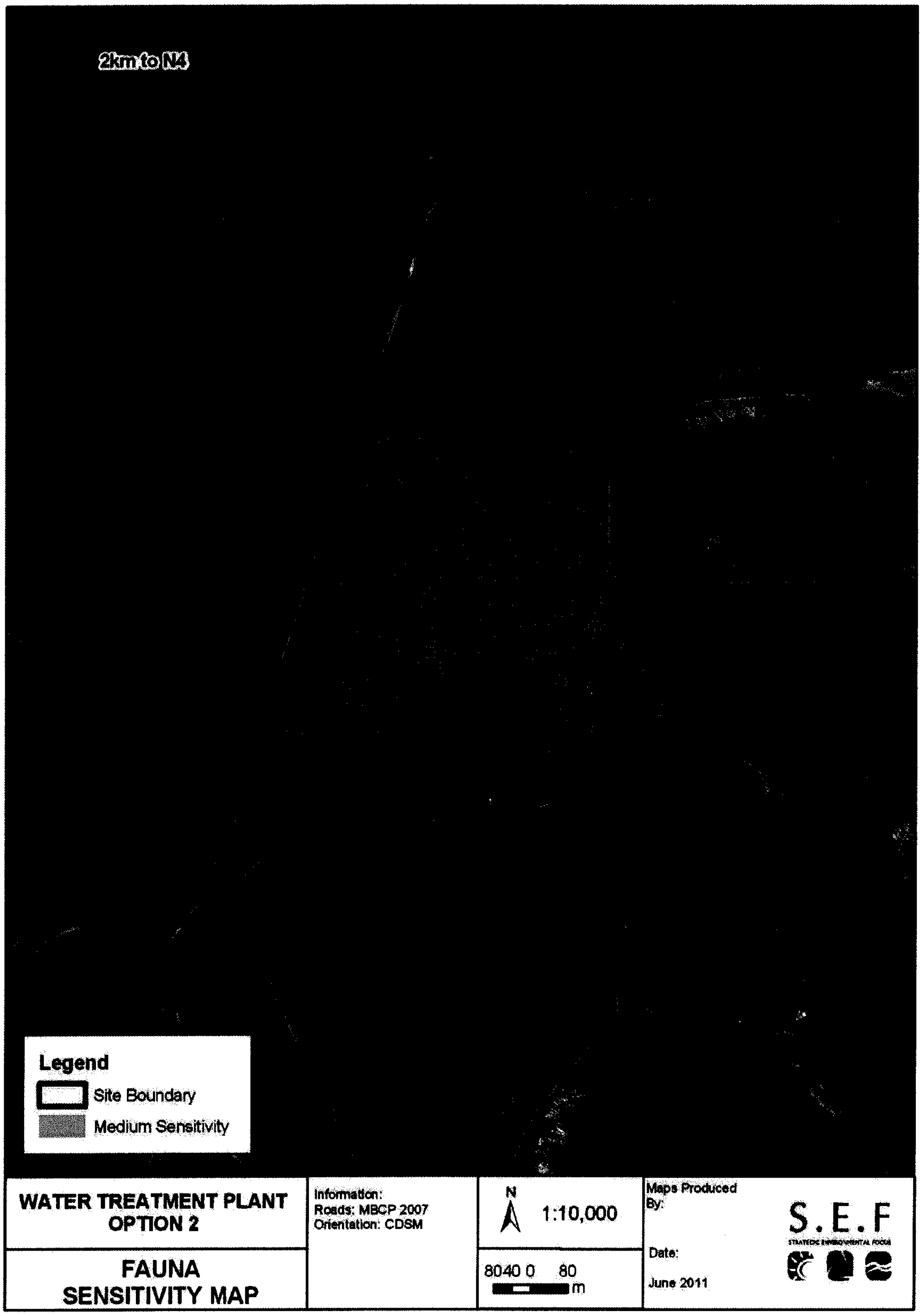


Figure 8: WTP Option 2 Fauna Sensitivity

3.3 Wetland Assessment

3.3.1 WTP Option 1

Four hydro-geomorphic (HGM) units were identified within the Option 1 site of the study area. These include a valley bottom wetland without a channel, a secondary wetland, a hillslope seepage not feeding a watercourse and an Endorheic Pan wetland. All of the wetlands have been impacted to various degrees as a result of human activities. The most sensitive hydro-geomorphic unit within Option 1 is the isolated Endorheic Pan wetland system located in the northern portion of the site. The largest portion of the pan is comprised of a permanent zone, fringed by a seasonal zone and only a fraction of the surface area comprising of a temporary zone (mostly confined to seepage areas). The large percentage of permanent zonation suggests a higher hydrological functionality compared to the other wetlands within Option 1. Further, the wetland supports important biodiversity, which include protected species under Schedule 11 (Nature Conservation Ordinance No. 12 of 1983), such as *Habaneria nyikana* and *Eulophia* species.

3.3.2 WTP Option 2

Specimens of facultative wetland species such as *Imperata cylindrica* and *Berkeya setifera* do occur within terrestrial areas but the soils do not contain any signs of redoximorphic features. It is likely that the presence of these facultative species is supported through seepage events occurring from the dirty water holding facilities.

Hydro-geomorphic unit 5 is located along the western border of the study area. This seep was most likely connected or could still be hydrologically connected to a seepage linking with the valley bottom wetland system further west. This upper reaches of this seep was dissected perpendicularly by a road, but still display a wetland with temporary zonation within the study area.

3.4 Conclusion

From a wetland perspective, both Options 1 and Option 2 sites are viable as long as wetland habitats or its associated buffer zones are not impacted upon.

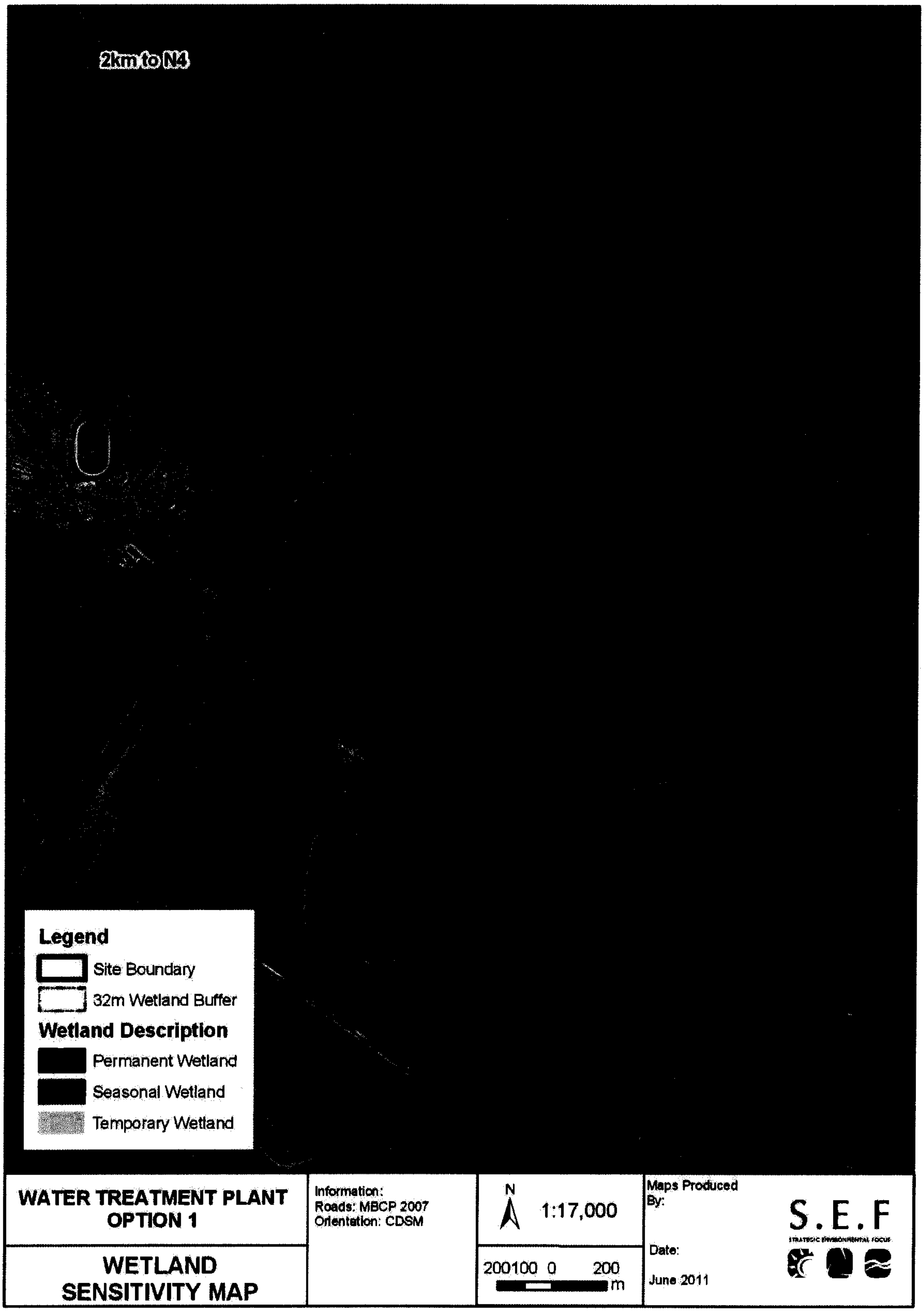


Figure 9: Wetland Sensitivity Option 1

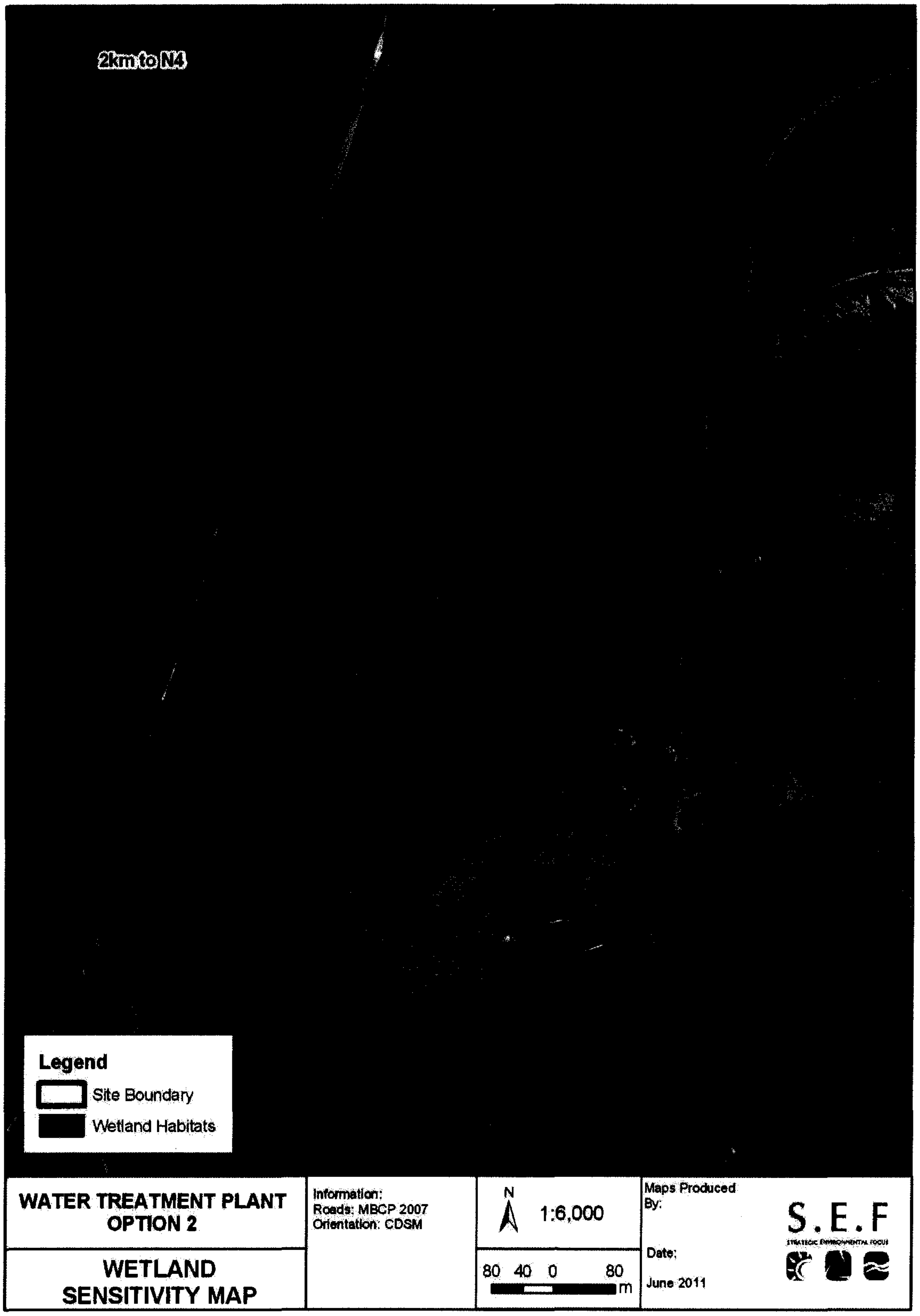


Figure 10: Wetland Sensitivity Option 2

3.5 Preferred WTP Option

The three reports indicate that wetlands and primary grassland vegetation on WTP Option 1 are most sensitive and must be avoided during the placement of the water treatment plant. However, the Alien Bush Clumps present on WTP Option 1 are of low floral sensitivity and could be a potential site for the plant. Although the faunal report indicated that construction on WTP Option 1 should ideally be avoided, it also indicates that the faunal species that currently inhabit the areas of low floral sensitivity on WTP Option 1 are opportunistic and should be able to relocate in response to disturbances.

WTP Option 2 comprises of primary Rocky Grassland which from a floral perspective are of high conservation importance and sensitivity. However, no mammal species were trapped here. The surrounding disturbances of the mining activities and construction of the Goedehoop Dam could thus limit the faunal diversity on WTP Option 2 and thereby lower its sensitivity from a faunal perspective.

Concluding these findings, it was recommended that the water treatment plant be placed on WTP Option 1 within the area classified as low floral sensitivity. This recommendation is based on the provision that the water treatment plant locality is contained within the areas of low sensitivity. The WTP should be built as far south as possible in order to steer clear of the catchments area of the pan, thus in the event of a spill the integrity of the pan would therefore have less chance of being affected. In addition, the access road must be placed in the southern section of the site. This will ensure that disturbances and construction activities do not impact on the highly sensitive sections of WTP Option 1 as dust and erosion form the access road can severely impact on the functionality of the water systems, while noise from construction vehicles will disturb faunal activities on the site and could possibly result in fatalities.

However, since these areas were investigated in 2008, the project scope has evolved and the associated alternative pipeline routes (Option 1.1a) are infringing on areas of high sensitivity. Therefore, if the project scope and associated impacts can not be contained within the areas of low sensitivity (Figure 5), then WTP Option 2 should be re-considered. WTP Option 2 did not contain areas delineated as high sensitivity but at the time the paradigm was to rather utilise the areas of low sensitivity on WTP Option 1.

4. RESULTS: PIPELINE OPTIONS FOR WTP OPTION 1

For Option 1 three pipelines are required (Figure1 and Figure 11). Due to the distance from Dam 5 abstraction point to the WTP-Option 1 site and since the pipeline between these two points is within the WTP-Option 1 footprint, no pipeline alternatives have been considered for this portion of the pipeline. From the Rondeboschje abstraction dam to WTP-Option 1 site, *only one* pipeline with no alternatives was considered. This is a result of the decision made by the mine to ensure that the pipeline remains on mine owned property and to avoid areas with coal seams and undermined areas. However, t*wo* alternatives are being assessed to transport untreated mine water from Goedehoop abstraction dam to the north of the study area to WTP-Option 1, namely Option 1.1a and Option 1.1b (Figure 11).

4.1 Pipeline from Rondeboschje Dam

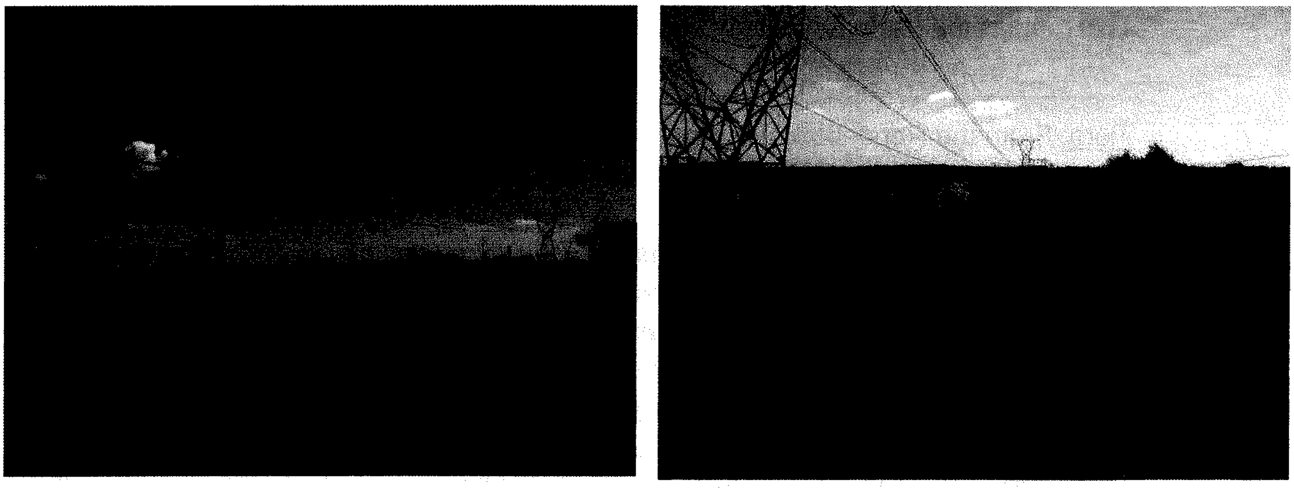
This route is the same for Option 1.1a and 1.1b.

Flora: From the Rondeboschje Dam, the pipeline route is proposed to be situated within the coal conveyer servitude as well as along an existing dirt road. The coal conveyer servitudes are regularly mowed and are unlikely to house any plants species of conservation concern. Portions of this line will pass through rehabilitated land that is dominated by *Hyparrhenia hirta* (Common Thatching Grass) which is unlikely to house any threatened species. The pipeline continues west and passes through the much disturbed Niekerk- and Spookspruit until it reaches WTP Option 1. The Niekerkspruit is degraded and the surrounding grasslands are inhabited by grasses such *Hyparrhenia hirta* (Common Thatching Grass), *Digitaria eriantha* (Common Finger Grass) and *Melinis repens* (Natal Red Top). From here the pipeline will cross through a wetland area where no plants of conservation concern were observed at the time of the assessment (SEF, 2009). The adjacent grasslands were found to be degraded and included Acacia mearsnii (Black Wattle) bush clumps up to the proposed locality for WTP Option 1.

Fauna: A number of wetland and river crossings are proposed along the pipeline route and are the main areas of fauna concern. As the interface between aquatic and terrestrial environments, the highest biodiversity of plant, invertebrate, amphibian and small mammal taxa are located here. They are therefore areas of high forage potential for fauna and provide wildlife habitat as a result of the unique soil and microclimatic conditions, nesting sites and shaded areas. The Niekerkspruit flows adjacent to a rocky outcrop that is as yet undisturbed. The pipeline is proposed to follow in already disturbed areas and should not impact on the rocky outcrop.

Wetland: This route will cross a non-channelled valley bottom wetland called the Spookspruit. The pipeline is assumed to cross the Spookspruit twice along the existing conveyor route. The pipeline is to be placed on the existing embankment of the conveyor and thereby impacting less on the wetland. Wherever the conveyor is bridged the same should be done for the pipeline. If the pipeline can't be aligned along the existing conveyor route with minimal impact, the pipeline should be placed next to the dirt road located just to the south of the conveyor.

This route will also cross a non-channelled valley bottom wetland called the Niekerkspruit (at Dam 5). The pipeline is to cross the wetland via an old access road with built in weir or along the conveyor crossing. Immediately south of the conveyor the wetland is highly disturbed consisting of a serious of dirty water dams. North of the weir the wetland is still intact and provide a number of ecological services, including flood attenuation, stream flow regulation, sediment trapping, phosphate trapping, nitrate removal, carbon storage, etc. Due to the existing crossing points the pipeline is not foreseen to have any impact upon the wetland system.



Photograph 1: Niekerkspruit crossing point for pipeline route (Left) and existing conveyor route passing through Spookspruit (right)

Just before this pipeline route reaches WTP Option 1, it will traverse a wetland area. This hydro-geomorphic unit consists of a hillslope seep which is not connected to a watercourse. The northern extent of this wetland is disturbed through cultivated fields (where the pipelines are proposed to align) while evidence of numerous historic surface mining activities persist throughout the rest of this hydro-geomorphic unit. These disturbances have potentially reduced the temporary and seasonal zones in the northern section of the wetland by approximately 20m as indicated by hydric soils which correspondingly don't carry hydrophilic vegetation. The south western boundary of the temporary zone extends relatively far in a westerly direction, this is most likely the effect of seepage from the two slimes dams located towards the south-west. From here the pipeline will skirt around the pan where the temporary zonation was more diverse and harboured provincially protected species such as the orchid *Habenaria nyikana* (SEF, 2008c). Further north, the largest majority of wetlands consisted of seepage wetlands with temporary zonation.

4.1.1 Option 1.1a (from Goedehoop Dam)

Flora: The results obtained during this study indicated that at least two areas of high vegetation sensitivity existed along the pipeline route, namely the moist grasslands that exist along the route, as well as the natural grassland west of the pan. The vegetation in and around the Spookspruit, pan and moist grassland play an important role in water catchments, assimilation of phosphates, nitrates and toxins as well as a possible role in flood attenuation The natural grasslands that were observed to the west of the pan were inhabited by two plants classified nationally as declining (*Boophane distichia* and *Hypoxis hemerocallidea*), protected plants, such as the *Protea welwitschii,* and plays a role as catchment area to the pan. In addition, the plant species composition of the grassland corresponded to that of the regional Rand Highveld Grassland, which is an Endangered vegetation type (Mucina and Rutherford, 2006) and listed as a Vulnerable ecosystem in terms of Section 52 of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (Government Gazette, 2009). This grassland, along with the natural rocky grassland north of the pan is classified as being of high sensitivity and should the pipeline be routed through a portion of this grassland, strict mitigation measures as set out in this report should apply. However, it is recommended that the pipeline be aligned directly west and north of the existing dirt roads in this section of the route. This is expected to limit the impacts on the moist grassland and pan so that disturbances that occurred along the existing dirt roads be utilised for the pipeline route.

Fauna: This proposed pipeline route crossed a variety of faunal habitat types that were of varying sensitivity. The most sensitive habitats included the pan and the immediate surrounding vegetation as well as some wetlands identified along the Spookspruit. The riverine habitats encountered along the Spookspruit can also be regarded as sensitive, especially the short dense grass sward adjacent to the spruit. These habitats can support distinct faunal communities and are of special conservation concern. For instance, the presence of wetland or riverine vegetation suggests the possible occurrence of threatened species known to associate closely with these habitats. Similarly these habitats support a high diversity of birds and amphibian species - some which are of special conservation concern. Habitats of low sensitivity included ploughed and overgrazed grassland, as well as some bush clumps primarily made up of the invasive *Acacia mearnsii* (Black Wattle). These habitats could support a number of faunal species; however most of these are likely to be common and widespread species that are not of conservation concern. During the present assessment, two bird species of conservation concern were encountered on the study site, namely the Near Threatened

Phoenicopterus roseus (Greater Flamingo) and the Vulnerable *Geronticus calvus* (Southern Bald Ibis). The Greater Flamingos were confined to the pan and are expected to only occur within close proximity of the pan, whereas the Southern Bald Ibises were observed to be foraging in dense moist grassland adjacent to the proposed pipeline route. The pan and its surrounding habitats were considered to be highly sensitive faunal habitat primarily due to the occurrence of Flamingos, but also because it provides habitat for a wide array of other bird species within the area. For the pan to be maintained as a viable feeding and water point for fauna, the catchment of the pan must be maintained.

Wetland: A wide variety of hydric soil types were present within the study area due to the relatively large extent of the study area and its associated geographical variance. Soils with higher clay content such as Rensburg, Katspruit and Kroonstad were characteristic of the permanent and seasonal wetland zones associated with valley bottom wetlands and depressions while the more sandy soils such as Avalon were associated with hillslope seepage wetlands. Numerous areas associated with vigorous plant growth, particularly valley bottom areas, also displayed a dark organic layer at ground surface. The build up of organic carbon content in topsoil was indicative of water preventing breakdown of organic matter, as would typically occur within a wetland.

The largest majority of wetlands in the northern section of this proposed pipeline consisted of seepage wetlands with temporary zonation and was dominated by a rather homogenous graminoid layer with very few herbaceous species present. However, the temporary zonation in the southern section of the study area was more diverse and harboured provincially protected species such as the orchid *Habenaria nyikana* (SEF, 2008c). Seasonal wetland zones included some of the above mentioned species but were dominated by the graminoids *Agrosits lachnanta, Andropogon eucomus* and *Paspalum dilatum,* while the forbs included *Hypericum lalandii, Monopsis decipiens, Cycnium tubulosum* and *Verbena bonariensis.*

The dominant species associated with the permanent zone of valley bottom wetlands and an endorheic pan within the study site was the obligatory wetland species *Leersia hexandra, Phragmites australis* and *Typha capensis. Agrosits lachnanta,* an obligatory wetland species was present in all three wetland zones but flourished more abundantly in the seasonal zones. Other species associated with wetlands within the study area included obligated hydrophytes such as *Schoenoplectus corymbosus* and *Persicaria lapathifolia,* while facultative hydrophytes included *Berkheya radula, Berkheya speciosa, Eragrsotis plana* and *Hyparrhenia tamba* .

Six different types of wetland areas were classified within the study area and were categorised into hydro-geomorphic (HGM) units. These include valley bottom wetlands without a channel, valley bottom wetlands with a channel, depressions, hillslope seepage wetlands feeding a watercourse, secondary wetlands and hillslope seepage wetlands not feeding a watercourse. A total of 8 hydro-geomorphic units were delineated and classified within the study area.

4.2 Option 1.1b (from Goedehoop Dam)

Flora: The pipeline from the Goedehoop Dam passes through areas disturbed by the building of the Goedehoop Dam and past current mining activities along a haul road. From here the pipeline trails through alien invasive *Acacaia mearsnii* (Black Wattle) plantations and crosses over the Spookspruit, just north of a decant dam. The area was highly disturbed and included exotic plants such as *Arundo donax* (Spanish Reed) and *Cortaderia jubata* (Pampas Grass). The pipeline amalgamates with the pipeline that originates at Rondeboschje Dam in an area that was dominated by invasive species such as the naturalised *Bidens formosa* (Cosmos). No plant species of conservation concern were identified here and due to the largely degraded habitat, none were expected to occur here.

Fauna: The wetland at Dam 6 was the main area of fauna concern. As the interface between aquatic and terrestrial environments, the highest biodiversity of plant, invertebrate, amphibian and small mammal taxa are located here. They are therefore areas of high forage potential for fauna and provide wildlife habitat as a result of the unique soil and microclimatic conditions, nesting sites and shaded areas. However, this wetland area was largely degraded and was not thought to provide habitat to species of conservation concern.

Wetland: From the Goedehoop Dam, the pipeline crosses a tributary of the Spookspruit (at Dam 6). This is also a non-channelled valley bottom wetland with a pollution control dam built within the macro channel of the wetland. It is recommended that the pipeline make use of the existing dam wall / access road that runs across the wetland, if this option is approved. From here, the pipeline turns west and follows the same route as the pipeline from Rondeboschje Dam, through the Niekerkspruit as well as a wetland area before it arrives at WTP Option 1. This hydro-geomorphic unit consists of a hillslope seep which is not connected to a watercourse. The northern extent of this wetland is disturbed through cultivated fields while evidence of numerous historic surface mining activities persists throughout the rest of this hydro-geomorphic unit. These disturbances have potentially reduced the temporary and seasonal zones in the northern section of the wetland by approximately 20m as indicated by hydric soils which correspondingly don't carry hydrophilic vegetation. The south western boundary of the temporary zone extends relatively far in a westerly direction, this is most likely the effect of seepage from the two slimes dams located towards the south-west.

4.3 Preferred pipelines for WTP Option 1

The proposed route from the Rondeboschje Dam to WTP Option 1 is fixed and was found to comprise wetland crossings and largely degraded fauna and flora habitat. Existing road crossings over these wetlands should be utilised to support the pipeline so as to minimise impacts on these functional wetlands.

From Goedehoop Dam, Option 1.1a and Option 1.1b were assessed. From an ecological point of view, Pipeline Option 1.1a will impact on sensitive, natural environments such as moist grasslands, wetlands and primary grasslands with confirmed protected fauna and flora species. Option 1.1b is therefore the preferred route as this proposed option will trail through already impacted and transformed environments and align with the fixed route form the Rondeboschje Dam. The wetland that occurs along this route assisted in water purification and it is recommended that the pipeline make use of the existing dam wall / access road that runs across the wetland, to minimise impact on this wetland area.

In the event that Option 1.1a is approved

If Option 1.1b is not an option due to engineering or other concerns and Option 1.1a proven to be the only viable option, then the potential impacts that Option 1.1a would have on the wetlands and moist grasslands in the northern portion of this alternative must be minimised. With the purpose of minimising environmental impacts, two additional alternatives were proposed. These alternatives are indicated in Figure 11 and described as Alternative Option 1.1c and Alternative Option 1.1d. Please note that these alternatives were not ground-truthed and were based largely on wetland delineation and aerial imagery. Alternative Option 1.1c will cross the Spookspruit and is proposed to align with an existing dirt road. Alternatively, Option 1.1d will cross the Spookspruit and then traverse through cultivated land instead of moist grassland / wetlands as Option 1.1a and 1.1c. Option1.1d will therefore limit the impact on moist grasslands and the Spookspruit. Therefore, if Option1.1a is unavoidable, then the route must be amended to include Option 1.1d as the preferred route.

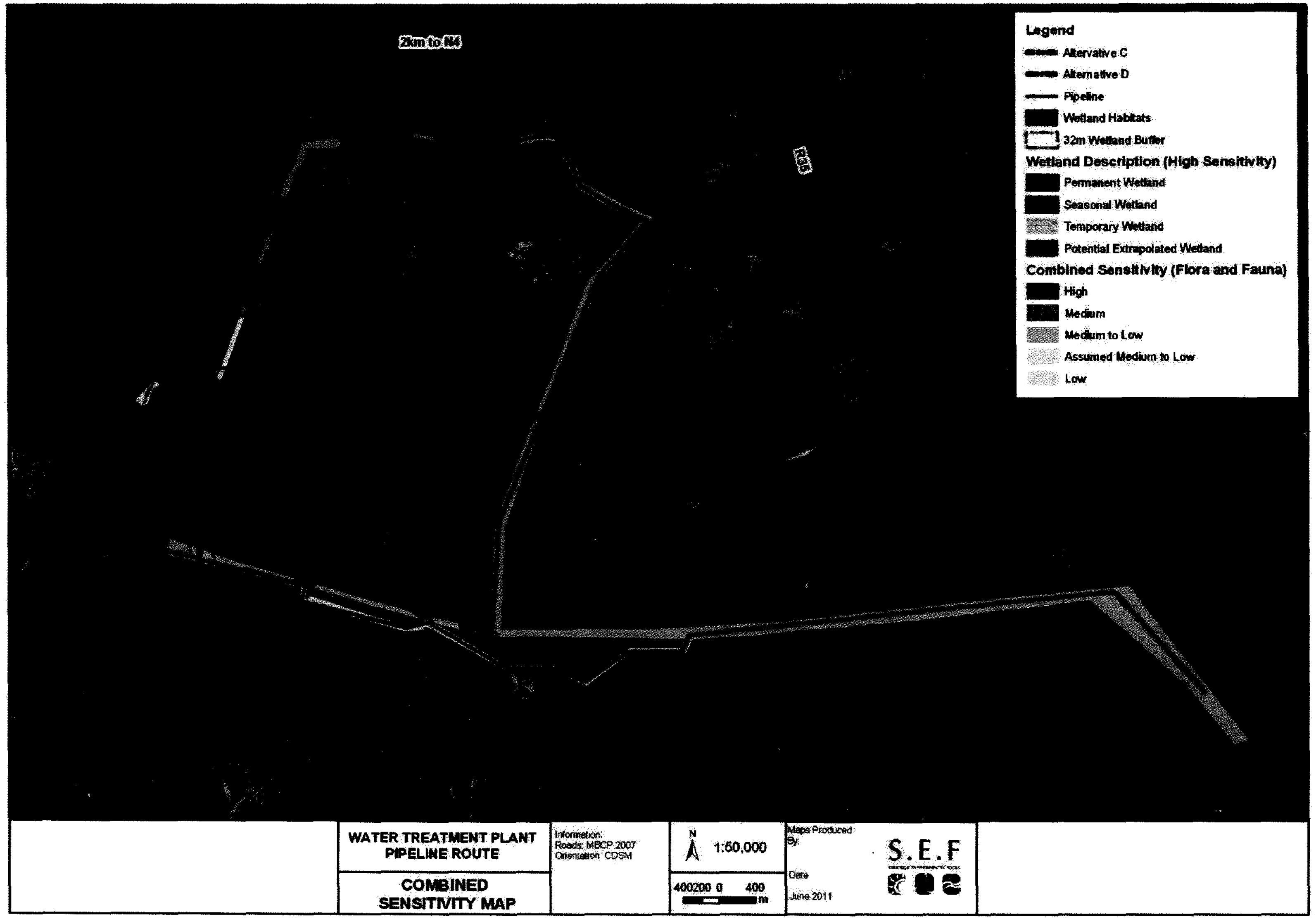


Figure 11 Pipeline route combined sensitivities

5. RESULST: PIPELINE OPTIONS FOR WTP OPTION 2

For WTP Option 2, three pipelines are required. As with Option 1, due to the distance from Goedehoop abstraction dam to the WTP-Option 2 site and since the pipeline between these two points is within the WTP-Option 2 footprint, no pipeline alternatives have been considered for this portion of the pipeline. Two alternatives were assessed to transport untreated mine water from Rondeboschje abstraction dam in the east of the study area to WTP-Option 2 namely Option 2.1a and 2.1b. In addition, two alternatives to pump untreated water from Dam 5 to WTP Option 2 were assessed namely Option 2.2a and Option 2.2b.

5.1 Pipeline comparison: Option 2.1 (from Rondeboschje Dam)

5.1.1 Option 2.1a

Flora: From the Rondeboschje Dam, the pipeline route is proposed to be situated within the coal conveyer servitude as well as along an existing dirt road. The coal conveyer servitudes are regularly mowed and are unlikely to house any plants species of conservation concern. Portions of this line will pass through rehabilitated land that is dominated by *Hyparrhenia hirta* (Common Thatching Grass) which is unlikely to house any threatened species. The pipeline continues west and will cross the Spookspruit upstream from the area that was assessed on 2008. However, the area is also contained within the current mining activities and degraded from a floral perspective. In addition, due to the disturbances and transformation of habitat here, it is unlikely that plant species of conservation concern will occur here. From here the route turns northwards and passes through degraded mining areas, an *Acacia mearsnii* (Black Wattle) plantation and areas disturbed by the construction of the Goedehoop Dam. On route to the *Acacia mearsnii* plantation the pipeline crosses a tributary of the Spookspruit (at Dam 6). This is also a non-channelled valley bottom wetland with a pollution control dam built within the macro channel of the wetland (SEF, 2008c). No plants of conservation concern were identified along this route alignment.

Fauna: A number of wetland and river crossings are proposed along the pipeline route and are the main areas of fauna concern. As the interface between aquatic and terrestrial environments, the highest biodiversity of plant, invertebrate, amphibian and small mammal taxa are located here. They are therefore areas of high forage potential for fauna and provide wildlife habitat as a result of the unique soil and microclimatic conditions, nesting sites and shaded areas. No species of conservation concern was observed to occur along this proposed pipeline option at the time of this assessment.

Wetland: This east-west alignment from the Rondeboschje Dam route will impact on the Spookspruit where the pipeline turns northwards towards the WTP Option 2. The exact area where the Spookspruit will be crossed is unknown. However, the area assessed in 2008 (approximately 500m downstream from the proposed crossing) aligned with an existing conveyor and indicated that the Spookspruit comprised a non-channelled valley bottom wetland here. If the pipeline is placed on the existing embankment of the conveyor it will impact less on the wetland. Wherever the conveyor is bridged the same should be done for the pipeline. From here the proposed pipeline crosses a tributary of the Spookspruit (at Dam 6). This was also assessed to be a non-channelled valley bottom wetland with a pollution control dam built within the macro channel of the wetland. It is recommended that the pipeline make use of the existing dam wall / access road that runs across the wetland.

5.1.2 Option 2.1b

Flora: From the Rondeboschje Dam, the pipeline route is proposed to be situated within the coal conveyer servitude as well as along an existing dirt road. The coal conveyer servitudes are regularly mowed and are unlikely to house any plants species of conservation concern. Portions of this line will pass through rehabilitated land that is dominated by *Hyparrhenia hirta* (Common Thatching Grass) which is unlikely to house any threatened species. The pipeline continues west and passes through the much disturbed Niekerk- and Spookspruit until it reaches WTP Option 1. The Niekerkspruit is degraded and the surrounding grasslands are inhabited by grasses such *Hyparrhenia hirta* (Common Thatching Grass), *Digitaria eriantha* (Common Finger Grass) and *Melinis repens* (Natal Red Top). From the proposed locality of WTP Option 1 the pipeline will traverse though sensitive grassland vegetation, moist grasslands and wetlands. However, some degraded grasslands were also identified along the proposed route. The sensitive primary grasslands and moist grasslands included plants species nationally classified as Declining as well as protected plants (as per Option 1.1a). It is recommended that the pipeline be aligned directly west and north of the existing dirt roads in this section of the route. This is expected to limit the impacts on the moist grassland and pan so that disturbances that occurred along the existing dirt roads be utilised for the pipeline route.

Fauna: A number of wetland and river crossings are proposed along the pipeline route and are the main areas of fauna concern. As mentioned above, they are therefore areas of high forage potential for fauna and provide wildlife habitat as a result of the unique soil and microclimatic conditions, nesting sites and shaded areas. The Niekerkspruit flows adjacent to a rocky outcrop that is as yet undisturbed. The pipeline is proposed to follow in already disturbed areas and should not impact on the rocky outcrop. From the WTP Option 1 locality, the pipeline turns northwards and will cross a variety of faunal habitat types that were of varying sensitivity. The most sensitive habitats included the pan and the immediate surrounding vegetation as well as some wetlands identified along the. The riverine habitats encountered along the Spookspruit can also be regarded as sensitive, especially the short dense grass sward adjacent to the spruit. These habitats can support distinct faunal communities and are of special conservation concern. For instance, the presence of wetland or riverine vegetation suggests the possible occurrence of threatened species known to associate closely with these habitats. Similarly these habitats support a high diversity of birds and amphibian species - some which are of special conservation concern. Habitats of low sensitivity included ploughed and overgrazed grassland, as well as some bush clumps primarily made up of the invasive *Acacia mearnsii* (Black Wattle). These habitats could support a number of faunal species; however most of these are likely to be common and widespread species that are not of conservation concern. During the present assessment, two bird species of conservation concern were encountered on the study site, namely the Near Threatened *Phoenicopterus roseus* (Greater Flamingo) and the Vulnerable *Geronticus calvus* (Southern Bald Ibis). The Greater Flamingos were confined to the pan and are expected to only occur within close proximity of the pan, whereas the Southern Bald Ibises were observed to be foraging in dense moist grassland adjacent to the proposed pipeline route. The pan and its surrounding habitats were considered to be highly sensitive faunal habitat primarily due to the occurrence of Flamingos, but also because it provides habitat for a wide array of other bird species within the area. For the pan to be maintained as a viable feeding and water point for fauna, the catchment of the pan must be maintained.

Wetland: From the Rondeboschje Dam, this route included a non-channelled valley bottom wetland called the Spookspruit. The pipeline is to cross the Spookspruit along the existing conveyor route. The pipeline is to be placed on the existing embankment of the conveyor and thereby impacting less on the wetland. Wherever the conveyor is bridged the same should be done for the pipeline. If the pipeline can't be aligned along the existing conveyor route with minimal impact, the pipeline should be placed next to the dirt road located just to the south of the conveyor. In addition, this route will cross a non-channelled valley bottom wetland called the Niekerkspruit. The pipeline is to cross the wetland via an old access road with built in weir or along the conveyor crossing. Immediately south of the conveyor the wetland is highly disturbed consisting of a serious of dirty water dams. North of the weir the wetland is still intact and provide a number of ecological services, including flood attenuation, stream flow regulation, sediment trapping, phosphate trapping, nitrate removal, carbon storage, etc. Due to the existing crossing points the pipeline is not foreseen to have any impact upon the wetland system. From here the pipeline will cross through a wetland area which consists of a hillslope seep which is not connected to a watercourse. The northern extent of this wetland is disturbed through cultivated fields while evidence of numerous historic surface mining activities persists throughout the rest of this hydro-geomorphic unit. These disturbances have potentially reduced the temporary and seasonal zones in the northern section of the wetland by approximately 20m as indicated by hydric soils which correspondingly don't carry hydrophilic vegetation. The south western boundary of the temporary zone extends relatively far in a westerly direction, this is most likely the effect of seepage from the two slimes dams located towards the south-west.

The pipeline continues to the proposed WTP Option 1 locality from where it will turn northwards, around a pan and along the Spookspruit towards the WTP Option 2 where it will need to cross the Spookspruit and wetlands. A largest majority of wetlands in this northerly section of Option 2.1b proposed pipeline consisted of seepage wetlands with temporary zonation (as per Option1.1a). Six different types of wetland areas were classified within the study area and were categorised into hydro-geomorphic (HGM) units. These include valley bottom wetlands without a channel, valley bottom wetlands with a channel, depressions, hillslope seepage wetlands feeding a watercourse, secondary wetlands and hillslope seepage wetlands not feeding a watercourse. A total of 8 hydro-geomorphic units were delineated and classified within this northerly portion of the proposed Option 2.1b

5.1.3 Preferred alternative for Option 2.1

Option 2.1a is situated in areas that were largely transformed by mining and associated activities. Although this option will traverse wetland areas, existing infrastructure such as the conveyers could be used to raise the pipeline from the wetland areas and minimise its impact. On the contrary, Option 2.1b could impact on areas where natural vegetation still occur as well as on the pan and wetlands in its northerly alignment. Therefore, from an ecological perspective, Option 2.1a is most preferred.

In the event that Option 2.1b is approved

If for any other reason Option 2.1a is not viable, then Option 2.1b **must** be amended to limit the impact on wetlands and the Spookspruit in its most northerly section of this portion of the pipeline route. From an environmental perspective, alternatives Alternative Option 2.1c or Option 2.1d were proposed (Figure 11) to limit the impact on the Spookspruit. However, Alternative Option 2.1d is the preferred as this alternative will limit impacts through wetland areas (see Section 4.3). Please note that these alternatives were based on wetland delineation and aerial images and were not ground truthed.

5.2 Pipeline comparison: Option 2.2 (from Dam 5)

5.2.1 Option 2.2a

From Dam 5, this proposed pipeline option continue north westwards past the proposed locality of WTP-Option 1, from where it heads northwards deviating around the pan before turning eastwards crossing the Spookspruit River and entering the proposed WTP-Option 2. This route corresponds largely with Option 1.1a.

Flora: The results obtained during this study indicated that at least two areas of high vegetation sensitivity existed along this proposed pipeline option, namely the moist grasslands that exist along the route, adjacent to the Niekerkspruit and Spookspruit, as well as the natural grassland west of the pan. The vegetation in and around the Niekerkspruit, Spookspruit, pan and moist grassland play an important role in water catchments, assimilation of phosphates, nitrates and toxins as well as a possible role in flood attenuation The natural grasslands that were observed to the west of the pan were inhabited by two plants classified nationally as Declining, as well as protected plants. In addition, the plant species composition of the grassland corresponded to that of the regional Rand Highveld Grassland, which is an Endangered vegetation type (Mucina and Rutherford, 2006) and listed as a Vulnerable ecosystem in terms of Section 52 of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (Government Gazette, 2009). This grassland, along with the natural rocky grassland north of the pan is classified as being of high sensitivity and should the pipeline be routed through a portion of this grassland, strict mitigation measures as set out in this report should apply. However, it is recommended that the pipeline be aligned directly west and north of the existing dirt roads in this section of the route. This is expected to limit the impacts on the moist grassland and pan so that disturbances that occurred along the existing dirt roads be utilised for the pipeline route.

Fauna: This proposed pipeline route crossed a variety of faunal habitat types that were of varying sensitivity. The most sensitive habitats included the pan and the immediate surrounding vegetation as well as some wetlands identified along the. The riverine habitats encountered along the Niekerkspruit and Spookspruit can also be regarded as sensitive, especially the short dense grass sward adjacent to the spruit. These habitats can support distinct faunal communities and are of special conservation concern. For instance, the presence of wetland or riverine vegetation suggests the possible occurrence of threatened species known to associate closely with these habitats. Similarly these habitats support a high diversity of birds and amphibian species - some which are of special conservation concern. Habitats of low sensitivity included ploughed and overgrazed grassland, as well as some bush clumps primarily made up of the invasive *Acacia mearnsii* (Black Wattle). These habitats could support a number of faunal species; however most of these are likely to be common and widespread species that are not of conservation concern. During the present assessment, two bird species of conservation concern were encountered on the study site, namely the Near Threatened *Phoenicopterus roseus* (Greater Flamingo) and the Vulnerable *Geronticus calvus* (Southern Bald Ibis). The Greater Flamingos were confined to the pan and are expected to only occur within close proximity of the pan, whereas the Southern Bald Ibises were observed to be foraging in dense moist grassland around the Spookspruit, adjacent to the Goedehoop Dam. The pan and its surrounding habitats were considered to be highly sensitive faunal habitat primarily due to the occurrence of Flamingos, but also because it provides habitat for a wide array of other bird species within the area. For the pan to be maintained as a viable feeding and water point for fauna, the catchment of the pan must be maintained.

Wetland: The pipeline route will impact on the Niekerkspruit west of Dam 5, as well as moist grasslands south east of the proposed WTP Option 1 locality. This hydro-geomorphic unit consist of a hillslope seep which is not connected to a watercourse. The northern extent of this wetland is disturbed through cultivated fields (where the pipeline are proposed to align) while evidence of numerous historic surface mining activities persist throughout the rest of this hydro-geomorphic unit. These disturbances have potentially reduced the temporary and seasonal zones in the northern section of the wetland by approximately 20m as indicated by hydric soils which correspondingly don't carry hydrophilic vegetation. The south western boundary of the temporary zone extends relatively far in a westerly direction, this is most likely the effect of seepage from the two slimes dams located towards the south-west. From here the pipeline will skirt around the pan where the temporary zonation was more diverse and harboured provincially protected species such as the orchid *Habenaria nyikana* (SEF, 2008c). Further north, the largest majority of wetlands consisted of seepage wetlands with temporary zonation.

Six different types of wetland areas were classified within the study area and were categorised into hydro-geomorphic (HGM) units. These include valley bottom wetlands without a channel, valley bottom wetlands with a channel, depressions, hillslope seepage wetlands feeding a watercourse, secondary wetlands and hillslope seepage wetlands not feeding a watercourse.

5.2.2 Option 2.2b

Option 2.2b starts at Dam 5 and follows the same route as Option 1.1b but in an opposite direction. Thus, from Dam5 the route travels eastwards for approximately 2 km where after it turns northwards towards WTP Option 2.

Flora: The pipeline will impact on the Niekerkspruit and Spookspruit as it travels eastwards from Dam 5. The vegetation around the Niekerkspruit and Spookspruit was largely disturbed. Reeds included the indigenous *Phragmites australis* but also the invasive *Arundo donax* (Spanish Reed) and *Cortaderia jubata* (Pampas Grass). In addition a wetland system was observed at Dam 6. No plant species of conservation concern were identified here and due to the largely degraded habitat, none were expected to occur here. From here the pipeline turns northwards through past and current mining activities along a haul road and trails through alien invasive *Acacia mearsnii* (Black Wattle) to the WTP option 2.

Fauna: The Niekerkspruit and Spookspruit as well as the wetland area at Dam 6 were the main areas of fauna concern. As the interface between aquatic and terrestrial environments, the highest biodiversity of plant, invertebrate, amphibian and small mammal taxa are located here. They are therefore areas of high forage potential for fauna and provide wildlife habitat as a result of the unique soil and microclimatic conditions, nesting sites and shaded areas. However, the wetland area was largely degraded and was not thought to provide habitat to species of conservation concern.

Wetland: From Dam 5, the pipeline will impact on across a non-channelled valley bottom wetland called Niekerkspruit. The pipeline is to cross the wetland via an old access road with built in weir or along the conveyor crossing. Immediately south of the conveyor the wetland is highly disturbed consisting of a serious of dirty water dams. North of the weir the wetland is still intact and provide a number of ecological services, including flood attenuation, stream flow regulation, sediment trapping, phosphate trapping, nitrate removal, carbon storage, etc. Due to the existing crossing points the pipeline is not foreseen to have any impact upon the wetland system. In addition, the pipeline is to cross the Spookspruit along an existing conveyor route. The pipeline is to be placed on the existing embankment of the conveyor and thereby impacting less on the wetland. Wherever the conveyor is bridged the same should be done for the pipeline. If the pipeline can't be aligned along the existing conveyor route with minimal impact, the pipeline should be placed next to the dirt road located just to the south of the conveyor. After the pipeline turns northwards, a non-channelled valley bottom wetland with a pollution control dam built within the macro channel of the wetland was observed. It is recommended that the pipeline make use of the existing dam wall / access road that runs across the wetland, if this option is approved.

5.2.3 Preferred alternative for Option 2.2

Alternative Option 2.2a will impact on a larger number of sensitivities including wetlands, riverine habitat and protected and declining plant species than option 2.2b. Although Alternative Option 2.2b will traverse the Niekerkspruit, Spookspruit and wetland systems, the impacts could be mitigated by placing the pipeline along existing infrastructure such as the conveyer and roads. In addition, the vegetation and habitats surrounding Alternative Option 2.2b is largely degraded and therefore alternative Option 2.2b is the most preferred pipeline from an ecological perspective.

In the event that Option 2.2a is approved

If for any other reason Option 2.2b is not viable, then Option 2.2a **must** be amended to limit the impact on wetlands and the Spookspruit in its most northerly portion of the proposed route. From an environmental perspective, alternatives proposed for this portion of the pipeline, is Alternative Option 2.1c and Option 2.1d (Figure 11). Of these, Alternative Option 2.1d is the preferred (see Section 4.3). Please note that these alternatives were based on wetland delineation and aerial images and were not ground-truthed.

5.3 Pipeline alternative summary: WTP Option1

Table 3 summarises the ecological findings for the alternative pipelines for WTP Option 1. Preferred routes are shaded in green.

Table 3: WTP Option 1 pipeline alternatives summary

Ecological sensitivity	**Fixed route from Rondeboschje Dam**	**Alternative from Goedehoop Dam**		**Proposed amendments to alternative 1.1a** (please not that these were not ground-truthed. and are extrapolated form aerial images)	
		Option 1.1a	[redacted]	**Option 1.1c**	**Option 1.1d**
Primary Vegetation	Limited	Yes	[redacted]	Limited to the proximity with Goedehoop Dam	Limited
Plants species of conservation concern	None observed	Yes *Boophane distichia* (D) *Hypoxis hemerocallidea* (D) *Habernarya nyika* (P) *Protea welwitchii* (P) *Gladiolus crassifolius* (P)	[redacted]	Likelihood of *Habenarya nyika* (P) and *Crinum* species (D) in moist grasslands around the Spookspruit	Likelihood of *Habenarya nyika* (P) and *Crinum* species (D) in moist grasslands surrounding the Spookspruit
Fauna habitat	Limited	Yes Pan, wetland and riverine habitat as well as primary grassland	[redacted]	Yes Wetlands and Spookspruit	Yes Wetlands and Spookspruit
Fauna species of conservation concern	None observed	Yes *Phoenicopterus roseus* (Greater Flamingo) (NT) *Geronticus calvus* (Southern Bald Ibis) (V)	[redacted]	Yes *Geronticus calvus* (Southern Bald Ibis) (V)	Yes *Geronticus calvus* (Southern Bald Ibis) (V)
Spruit and wetland crossings	Spookspruit and associated wetlands	Spookspruit, Niekerkspruit, as well as a minimum of six different wetland systems.	[redacted]	Spookspruit and associated wetlands	Spookspruit and associated wetlands. Will impact on less wetland habitats than 1.1a
Preferred Alternative	**Fixed**	**Not preferred**	[redacted]	**Not preferred**	**Preferred amendment if 1.1a is approved**

NT=Near Threatened P=Provincially protected
V=Vulnerable D=Declining

In the event that Option 1.1a is approved

If Option 1.1b is not an option due to engineering or other concerns and Option 1.1a proven to be the only viable option, then the potential impacts that Option 1.1a would have on the wetlands and moist grasslands in the northern portion of this alternative must be minimised. With the purpose of minimising environmental impacts, two additional alternatives were proposed. These alternatives are indicated in Figure 11 and described as Alternative Option 1.1c and Alternative Option 1.1d. Please note that these alternatives were not ground-truthed and were based largely on wetland delineation and aerial imagery. Alternative Option 1.1c will cross the Spookspruit and is proposed to align with an existing dirt road. Alternatively, Option 1.1d will cross the Spookspruit and then traverse through cultivated land instead of moist grassland / wetlands as option 1.1a and 1.1c. Option1.1d will therefore limit the impact on moist grasslands and the Spookspruit. Therefore, if Option1.1a is unavoidable, then the route must be amended to include Option 1.1d as the preferred route.

5.4 Pipeline alternative summary for WTP Option 2

Table 4 lists the ecological findings for the alternative pipelines for Option 2.1 and Option 2.2. Preferred routes are shaded in green.

In the event that Option 2.1b is approved

If for any other reason Option 2.1a is not viable, then Option 2.1b **must** be amended to limit the impact on wetlands and the Spookspruit in its most northerly section of this portion of the pipeline route. From an environmental perspective, alternatives proposed are Alternative Option 2.1c and Option 2.1d (Figure 12), whereas Alternative Option 2.1d is the preferred (see Section 4.3). Please note that these alternatives were based on wetland delineation and aerial images and were not ground-truthed.

In the event that Option 2.2a is approved

If for any other reason Option 2.2b is not viable, then Option 2.2a **must** be amended to limit the impact on wetlands and the Spookspruit in its most northerly portion of the proposed route. From an environmental perspective, alternatives proposed for this portion of the pipeline, is Alternative Option 2.1c and Option 2.1d (Figure 12), whereas Alternative Option 2.1d is the preferred (see Section 4.3). Please note that these alternatives were based on wetland delineation and aerial images and were not ground-truthed.

Table 4: WTP Option 2 pipeline alternatives summary

Ecological Sensitivity	**Alternative from Rondeboschje Dam**		**Alternative from Dam 5**		**Proposed amendments to alternative 2.1b and 2.2a** (please not that these were not ground-truthed. and are extrapolated form aerial images)	
	[redacted]	**Option 2.1b**	**Option 2.2a**	**Option 2.2b**	**Alternative c**	**Alternative d**
Primary Vegetation	[redacted]	Yes	Yes	[redacted]	Limited to the proximity with Goedehoop Dam	Limited
Plants species of conservation concern	[redacted]	Yes *Boophane distichia* (D) *Hypoxis hemerocallidea* (D) *Habernarya nyika* (P) *Protea welwitchii* (P) *Gladiolus crassifolius* (P)	Yes *Boophane distichia* (D) *Hypoxis hemerocallidea* (D) *Habernarya nyika* (P) *Protea welwitchii* (P) *Gladiolus crassifolius* (P)	[redacted]	Likelihood of *Habenarya nyika* (P) and *Crinum* species (D) in moist grasslands around the Spookspruit	Likelihood of *Habenarya nyika* (P) and *Crinum* species (D) in moist grasslands surrounding the Spookspruit
Fauna habitat	[redacted]	Yes Pan, wetland and riverine habitat as well as primary grassland	Yes Pan, wetland and riverine habitat as well as primary grassland	[redacted]	Yes Wetlands and Spookspruit	Yes Wetlands and Spookspruit
Fauna species of conservation concern	[redacted]	Yes *Phoenicopterus roseus* (Greater Flamingo) (NT) *Geronticus calvus* (Southern Bald Ibis) (V)	Yes *Phoenicopterus roseus* (Greater Flamingo) (NT) *Geronticus calvus* (Southern Bald Ibis) (V)	[redacted]	Yes *Geronticus calvus* (Southern Bald Ibis) (V)	Yes *Geronticus calvus* (Southern Bald Ibis) (V)
Spruit and wetland crossings	[redacted]	Spookspruit, Niekerkspruit, pan as well as a minimum of six different wetland systems.	Spookspruit, Niekerkspruit, as well as a minimum of six different wetland systems.	[redacted]	Spookspruit and associated wetlands	Spookspruit and associated wetlands. Will impact on less wetland habitats than alternative c
Preferred Alternative	[redacted]	**Not preferred**	**Not preferred**	[redacted]	**Not preferred**	**Preferred amendment if 2.1b or 2.2a is approved**

NT=Near Threatened
V=Vulnerable

P=Provincially protected
D=Declining

6. IMPACT AND MITIGATION MEASSURES

Any developmental activity in a natural system will impact on the surrounding environment, usually in a negative way. The purpose of this phase of the study was therefore to identify and assess the significance of the impacts likely to arise during the construction and the operational phases of the MWRP, and provide a description of the mitigation required so as to limit the impact of the proposed development on the natural environment.

6.1 Assessment Criteria

The environmental impacts are assessed with mitigation measures (WMM) and without mitigation measures (WOMM) and the results presented in impact tables which summarise the assessment. Mitigation and management actions are also recommended with the aim of enhancing positive impacts and minimising negative impacts.

In order to assess these impacts, the proposed development has been divided into two project phases, namely the construction and operation phase. The criteria against which these activities were assessed are discussed below.

6.1.1 Nature of the Impact

This is an appraisal of the type of effect the project would have on the environment. This description includes what would be affected, how and whether the impact is expected to be positive or negative.

6.1.2 Extent of the Impact

A description of whether the impact will be local (extending only as far as the site/servitude), limited to the study area and its immediate surroundings, regional, or on a national scale.

6.1.3 Duration of the Impact

This provides an indication of whether the lifespan of the impact would be short term (0-5 years), medium term (6-10 years), long term (>10 years) or permanent.

6.1.4 Intensity

This indicates the degree to which the impact would change the conditions or quality of the environment. This was qualified as low, medium or high.

6.1.5 Probability of Occurrence

This describes the probability of the impact actually occurring. This is rated as improbable (low likelihood), probable (distinct possibility), highly probable (most likely) or definite (impact will occur regardless of any prevention measures).

6.1.6 Degree of Confidence

This describes the degree of confidence for the predicted impact based on the available information and level of knowledge and expertise. It has been divided into low, medium or high.

6.2 Impact Assessment

The possible impacts of the proposed development on the study area are divided into two phases of activities: Construction phase and Operational phase of the development. Table 5 and Table 6 list a *summary* of the possible risks that could occur within the two phases and focus on the worst case scenario with the highest ecological sensitivities. For comprehensive mitigation measures, please refer to the site specific reports (SEF, 2008; SEF, 2009; SEF, 2011).

Table 5: Potential Impacts during the Construction Phase of the proposed pipeline.

Possible Risks	Source of the Risk	Site to be affected
Destruction of natural vegetation and subsequent loss of ecological function	Construction workers and construction vehicles	Natural grassland at WTP Option 1 and WTP Option 2, pipeline routes 1.1a, 2.1b and 2.2a. Moist grasslands at WTP Option 1 and pipeline routes 1.1a, 2.1b and 2.2a as well as alternatives c and d
Exposure of the site to erosion	Construction activity, which includes site clearance, trenching, pipe placement, and backfilling and levelling.	All possible alternatives.
Destruction and harvesting of protected plants and plants of conservation concern	Construction activity	Grassland and moist grasslands areas around the pan on WTP Option 1 and WTP Option 2.as well as pipeline routes 1.1a, 2.1b and 2.2a. Limited likelihood at alternative c and d pipeline alternatives
Destruction of faunal habitat	Construction activity	All alternatives
Faunal interactions with personnel	Construction workers and Construction activity	All alternatives
Loss of the ecological function of wetlands, Niekerkspruit,	Construction activity	WTP Option 1 and all alternative pipeline routes

Possible Risks	Source of the Risk	Site to be affected
Spookspruit and pan		
Destruction of wetland habitat	Reshaping and construction activities of pipeline within or close to wetland habitat	WTP Option 1 and WTP Option 2 as well as all alternative pipeline routes
Surface water pollution	Flooding of construction area; construction vehicles; construction camp within wetland habitat or wetland catchments	WTP Option 1 and WTP Option 2 as well as all alternative pipeline routes.

Table 6: Potential impacts during the Operational Phase of the proposed pipeline

Possible Risks	Source of the Risk	Site to be affected
Deterioration of the natural vegetation, faunal habitat and the subsequent loss of the ecological function of the vegetation	Possible malfunction of the pipeline e.g. burst pipeline Maintenance work to the pipeline	Natural grassland at WTP Option 1 or WTP Option 2, pipeline routes 1.1a, 2.1b and 2.2a. Limited for alternative c and d pipeline routes Moist grasslands at WTP Option 1 and pipeline routes 1.1a, 2.1b and 2.2a as well as c and d.
Possible increase in exotic vegetation	Alien invasive plants (in specific *Acacia mearsnii*) spreading to disturbed soils where construction took place	All alternatives
Reduction of natural migratory routes and faunal dispersal patterns.	Fragmented landscape	All alternatives
Reduction in faunal biodiversity	Modification of natural habitat by landscaping	WTP Option 1 or WTP Option 2 as well as pipeline routes 1.1a, 2.1b, 2.2a as well as alternatives c and d.
Disturbance of fauna in sensitive vegetation	Human activity within the development could disturb fauna that depend on the sensitive vegetation (wetland)	Natural grassland at WTP Option 1 and WTP Option 2, pipeline routes 1.1a, 2.1b and 2.2a. Limited for alternative c and d pipeline routes Moist grasslands at WTP Option 1 and pipeline routes 1.1a, 2.1b and 2.2a as well as c and d
Environmental degradation of the study site, particularly sensitive areas	Surface area containing the pipeline not rehabilitated	Natural grassland at WTP Option 1 and WTP Option 2, pipeline routes 1.1a, 2.1b and 2.2a. Moist grasslands at WTP Option 1 and pipeline routes 1.1a, 2.1b and 2.2a as well as c and d. Seepage wetlands, habitats within close

Possible Risks	Source of the Risk	Site to be affected
		proximity to the Spookspruit, Niekerkspruit & habitats nearby the pan
Increased erosion and loss of wetland functionality	Increased surface runoff & canalisation of flow due to lack of proper rehabilitation	All alternatives

6.2.1 Construction Phase

6.2.1a Destruction of Natural Vegetation

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Destruction of natural vegetation	Natural vegetation along the proposed pipeline route as well as WTP locality	Development footprint and edge effects into riparian and wetland area	Short term	Medium	Definite	High	Medium to Low	High

Description of Impact

The proposed MWRP will impact on natural vegetation and although portions of the vegetation are transformed, the impact may spread out to the areas of high sensitivity and deter pollinators and small mammals from the site. In addition, the vehicles and construction workers could trample natural vegetation and threaten the survival of sensitive vegetation.

Mitigation Measures

- Ideally, the moist grasslands should not be disturbed. If this is inevitable, mitigation measures as set out in the Wetland Delineation and Functionality Assessment should be adhered to (SEF, 2008c; SEF, 2009; SEF, 2011).
- Cordon off the construction footprint to prevent any disturbances into the surrounding natural grasslands or any area assessed to be of high sensitivity.
- Protected plants and plants of conservation concern that will be directly affected by the pipeline must be removed prior to commencement of construction. Please note that the removal or destruction of these plants can only take place once the relevant permits for removal are obtained from the Mpumalanga Tourism and Parks Agency (MTPA). In addition, some of these plants (e.g. *Protea* spp and *Habenaria* spp) are

difficult, if not impossible to relocate and therefore every effort should be made to conserve these plants *in situ*.

- Prior to construction, remove sods from the natural grassland where the pipeline route and likely impacted areas will be. Remove the sods to about 30-50cm depth (including any other herbaceous species other than the grasses) and keep in a suitable position (e.g. construction nursery) for later use to re-vegetate the soil disturbed by the construction. These sods should not be watered but kept in conditions as natural as possible within the construction nursery (or other suitable facility). In addition, seeds from the surrounding grasses could be harvested for sowing in soils disturbed by the pipeline construction.
- Retain vegetation and soil in position for as long as possible, removing it immediately ahead of construction / earthworks in that area (DWAF, 2005). Stockpiles should not be placed on top of natural vegetation that should be cordoned off by this stage.
- Make use of existing roads and tracks, rather than creating new routes through vegetated areas.
- Avoid routes through drainage lines and riparian zones. Where access through drainage lines and riparian zones is unavoidable, only one road should be constructed, perpendicular to the drainage line. Avoid roads that follow drainage lines within the floodplain.
- Implement an Environnemental Management Programme.
- A Health, Safety and Environmental Control Officer (HSECO) must be appointed to oversee mitigation measures during construction and will be responsible for the monitoring and auditing of contractor's compliance with the conditions of the Environmental Management Program.
- In the event that pipeline 1.1a is approved for WTP Option1 OR in the event that pipeline 2.1b and 2.2a are approved for WTP Option 2, the proposed alternative 1.1d or 2.1d/2.2d must be followed to minimise impacts on the Spookspruit and surrounding wetlands (Figure 11 and Figure 12). Also, where the pipeline aligns between pan and natural grassland, the pipeline should be placed as far as possible from the pan and surrounding moist grasslands. In addition, impacts to the adjacent natural grasslands should also be limited. Therefore the following amendments are recommended to the proposed pipeline route:
    - *West of the pan:* the pipeline should be placed immediately west of the existing dirt road, within this roads disturbance footprint;
    - *North*-west of the pan: the pipeline should be placed through the degraded grasslands and within the disturbance footprint of the existing dirt road. The pipeline should closely follow this existing dirt road on its northern side (i.e. furthest from the pan).

6.2.1b Exposure of the site to erosion

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Exposure of the whole route to erosion	All alternatives	Local	Short term	Medium	Probable	High	Medium to low	High

Description of Impact

The removal of the surface vegetation will cause exposed soil conditions where rainfall and high winds can cause mechanical erosion. The sediments could wash down into wetlands, Niekerkspruit and Spookspruit causing sedimentation. In addition, indigenous vegetation communities are unlikely to colonise eroded soils successfully and seeds from proximate alien bush clumps can spread easily into these eroded soils.

Mitigation Measure

- Plan construction to take place during the dry season (winter), where possible.
- Make use of existing roads and tracks where feasible, rather than creating new routes through vegetated areas.
- Retain vegetation and soil in position for as long as possible, removing it immediately ahead of construction / earthworks in that area (DWAF, 2005). The vegetation and soil should not be placed in areas cordoned off as natural vegetation.
- Runoff from roads must be managed to avoid erosion and pollution problems.
- An ecologically sound, storm water management plan must be implemented during construction; and
- Remove only the vegetation where essential for construction of the pipeline to continue and do not allow any disturbance to the adjoining natural vegetation cover.

6.2.1c Destruction of protected plants and plants of conservation concern.

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Destruction of protected plants and plants of conservation concern	Moist grasslands and natural grassland at WTP Option 1 and pipeline routes 1.1a, 2.1b and 2.2a.	Site	Short term	Medium	Probable	Medium	Low	High

Description of Impact

The proposed pipeline could impact on the habitat, pollinators and inevitably the survival of protected plants and plant species of conservation concern which will put further strain on the already declining populations.

Mitigation Measure

- Construction workers may not tamper or remove these plants and neither may anyone collect seeds from the plants without permission from the MPTA.
- Cordon off the sensitive vegetation that house the protected plant species and the plants of conservation concern and protect from construction activities and vehicles.
- Slight deviations of alignment must be permitted, so as to avoid plant populations of conservation concern (DWAF, 2005).
- Implement a Plant Rescue and Rehabilitation Plan: Where the plants of conservation concern and protected plants are deemed to be under threat from the construction activity, the plants should be removed by a suitably qualified specialist and replanted as part of vegetation rehabilitation after the construction (**Note, these plants may only be removed or destroyed with the permission of the MPTA**). In addition the following is recommended (DWAF, 2005):
    - Aloes and bulbous plants may be transplanted at any time of the year, although the winter months are preferred.
    - Minimise disturbance of the soil and the remaining roots in the rootball during the lifting, moving and or transportation of all species.
    - Wrap the rootball in Hessian or in plastic sheeting to retain the soil and to keep the rootball moist.
    - Plant aloes and bulbs in similar soil conditions and to the same depth as in their original position.
    - Water aloes and bulbs once directly after transplanting to settle the soil.
- Some plants such as the *Protea welwitschii* as well as the *Habenaria* species generally do not survive relocation and therefore these plants should be conserved *in situ.* The roots of *Protea* species are susceptible to the *Phytophtera* fungi in soils, therefore, the trench for the proposed pipeline should also avoid a buffer area of at least 4m from the Proteas.
- An HSECO must be appointed to oversee mitigation measures during the construction and will be responsible for the monitoring and auditing of contractor's compliance with the conditions of the Environmental Management Program.

6.2.1d Destruction of faunal habitat

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Destruction of faunal habitat	All alternatives, especially areas delineated as sensitive	Site	Short term	Medium	Probable	Medium	Low	High

Description of the impact

Heavy motor vehicle usage and construction activities over the study area and adjacent land could result in damage to the habitat as well as exposing the soils in the area to erosion and compaction. This will have a negative effect on the ecosystem habitat fragmentation could occur. However, with the appropriate mitigation measures, this impact is considered to be of medium significance.

Mitigating Measures

- Construction vehicles should be restricted to the existing road network that services the various sections of the site.
- Construction areas should be inspected for any occurrence of erosion. Appropriate remedial action (rehabilitation) must be undertaken should any eroded areas be identified.
- Prior to construction, fences should be erected in such a manner to prevent access and damage to any sensitive areas identified.
- Areas designated as sensitive should be incorporated into an open space system which must be managed in accordance with an Environmental Management Programme.
- All stormwater structures should be designed so as to block faunal access to road surfaces and other bulk services which may be entered.

6.2.1e Faunal interactions with personnel

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Destruction of faunal habitat	All alternatives, especially areas delineated as sensitive	Site	Short term	Medium	Probable	Medium	Low	High

Description of impact

Harassing, snaring and killing of mammal species may occur when construction personnel and visitors are on the site. This is especially important where species of conservation concern are involved. In addition, the loud noise associated with the construction phase may frighten mammal species away but this is considered of medium significance and it can be expected for many of the smaller faunal species to return when construction ends provided suitable habitat remains.

Mitigation measures

- No wild animal may under any circumstance be hunted, snared, captured, injured or killed. This includes animals perceived to be vermin.
- Regularly undertake checks of the surrounding vegetation, in fences and along game paths to ensure that no traps have been set. Remove and dispose of any snares or traps found on or adjacent to the site.
- No wild animal may be fed on site.
- The construction staff should be educated about the value of wildlife and environmental sensitivity.
- Construction personnel should be informed of the Animal Protection Act no. 71 of 1962 and encouraged not to harm any wildlife.
- Access should be restricted to the sections of the study area where construction activities are occurring.

6.2.1f Loss of ecological functions of wetlands, Niekerkspruit, Spookspruit and pan.

Impact	**Site**	**Extent**	**Duration**	**Intensity**	**Probability of occurrence**	**Significance**		**Confidence**
						WOMM	WMM	
Loss of the ecological function of the potential wetland	Moist grasslands, wetlands, Spruit crossings and pan	Local	Permanent	High	Highly probable	High	Medium	High

Description of impact

Construction will inevitably alter the landscape and influence the drainage processes on the site. This in turn, will influence the drainage and status of the pan and wetland area.

Mitigation measures

- The demarcated buffer zones must be fenced during the construction using permeable fencing;
- Plan construction to avoid any impact on the natural drainage of the site and wetland functionality;

- The water treatment plant must be designed in such a way that no spillages can flow from the water treatment plant into the wetlands;
- To avoid accidental spillages or emergencies that could contaminate the wetlands on the site, the water treatment plant must be constructed as far as possible from the wetlands;
- No surface water generated as a result of the activities may be discharged directly into any natural drainage system or the wetlands;
- No activities should take place in a buffer of at least a 30m from the edge of wetlands (Mpumalanga Tourism and Parks Agency, 2008);
- A comprehensive surface water runoff management plan, indicating the management of all surface runoff generated as a result of the activities prior to stormwater entering any natural drainage system or wetland, must be submitted (e.g. stormwater and flood retention ponds if relevant); and
- No activity such as temporary housing, temporary ablution, disturbance of natural habitat, storing of equipment or any other use of the buffer/flood zone whatsoever, may be permitted.

6.2.1g Destruction of wetland habitat through excavation and pipeline construction activities

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Destruction of wetland habitat	WTP option 1, WTP Option 2 as well as alternative pipeline routes	Site	Permanent	High	Probable	High	Medium - Low	High

Description of Impact

Footprint of pipeline could infringe or destroy wetland habitat and associated biota through removal of hydrophytic vegetation and or hydric soils. The disturbance of hydric soils and hydrophytic vegetation could potentially negatively affect the functionality of the wetlands. There is therefore also the risk of increased sediment loads entering wetlands.

Specific Mitigation Measures

- Avoid wetland habitat as far as possible. The proposed route which will affect the least amount of wetland habitat is Option d as per Figure 11 and Figure 12.
- Where it is not possible to avoid wetland habitat, the area of disturbance must be kept to a minimum and not exceed 6m in width.
- Sequential construction strategy i.e. phasing the construction of the site and rehabilitating the soil with indigenous plants immediately after each phase. Soils

must be replaced in same sequence as excavated. Therefore soils must be excavated and stored in sequence.

- Where the pipeline is crossing the Spookspruit, the bridging or borrowing method with the least amount of impact should be employed.
- Implement sound storm water management measures and time construction so that construction takes place outside the rainy seasons where possible, thus reducing opportunities for erosion from rainfall events
- Do not leave soil surfaces open to erosion for lengthy time periods
- Re-vegetation of disturbed areas must be undertaken with site indigenous species and in accordance with the instructions issued by the HSECO. The following species should be utilised in each of the different wetland zones for rehabilitation:

  Temporary seeps: *Aristida junciformis; Conyza ulmifolia; Eriocaulon dregei; Fingerhuthia sesleriiformis; Gunnera perpensa; Helichrysum mundii; Imperata cylindrica; Miscanthus capensis; Miscanthus junceus; Paspalum scrobiculatum; Pennisetum macrourum; Pennisetum sphacelatum; Ranunculus meyeri; Ranunculus multifidus* and *Setaria sphacelata.*
  Seasonal wetlands: Andropogon appendiculatus; Arundinella nepalensis; Carex acutiformis; Carex cognata; Cladium mariscus; Cyperus digitatus; Cyperus latifolius; Cyperus longus; Eriocaulon dregei; Fimbristylis complanata; Fimbristylis dichotoma; Fingerhuthia sesleriiformis; Gunnera perpensa; Helichrysum mundii; Isolepis costata; Juncus dregeanus; Juncus exsertus; Juncus oxycarpus; Juncus punctorius; Kniphofia linearifolia; Limosella longiflora; Ludwigia palustris; Paspalum scrobiculatum; Pennisetum macrourum; Pycreus mundii; Pycreus nitidus; Ranunculus meyeri; Ranunculus multifidus; Sacciolepis chevalieri; Schoenoplectus decipiens; Scleria welwitschii; Setaria sphacelata; Xyris capensis; Agrosits lachnanta and *Xyris congensis.*

  Permanent zone: *Arundinella nepalensis; Carex acutiformis; Carex cognata; Cladium mariscus; Cyperus digitatus; Cyperus latifolius; Fimbristylis dichotoma; Gunnera perpensa; Isolepis costata; Juncus dregeanus; Juncus exsertus; Juncus oxycarpus; Juncus punctorius; Kniphofia linearifolia; Limosella longiflora; Ludwigia palustris; Phragmites australis; Leersia hexandra, Typha capensis; Agrosits lachnanta, Pycreus mundii; Pycreus nitidus; Ranunculus meyeri; Ranunculus multifidus; Sacciolepis chevalieri; Schoenoplectus decipiens* and *Scleria welwitschii.*

General Mitigation Measures

- Avoid construction activities in wetlands at all cost through proper demarcation and appropriate environmental awareness training. The Contractor has a responsibility to inform all staff of the need to be vigilant against any practice that will have a harmful effect on wetlands. This information shall form part of the Environmental Education Programme to be effected by the Contractor.

- No construction shall take place in areas of high sensitivity i.e. "no-go areas". All no-go areas must be demarcated with red tape under guidance of the HSECO.
- Any proclaimed weed or alien species that germinates during the contract period shall be cleared by hand before flowering.
- Infilling, excavation, drainage and hardened surfaces (including buildings and asphalt) should not occur in any of the wetland zones (i.e. permanent, seasonal or temporary), or within 32m of a wetland. Any such activities are subjected to a water use license and the conditions stipulated within the water use license. This 32m buffer zone should be extended in areas where slope in combination with rainfall will potentially provide conditions for the transportation and deposition of materials within wetland areas.
- Caution must be taken to ensure building materials are not dumped or stored within the delineated wetland buffer zone of 32m.
- The construction of surface stormwater drainage systems during the construction phase must be done in a manner that would protect the quality and quantity of the downstream system. The use of swales is recommended as the swales would attenuate run-off water.
- Imported fill material should be monitored during and after construction for the presence of any alien species. Any such species should be removed immediately.
- Emergency plans must be in place in case of spillages into wetland systems.
- All stockpiles must be protected from erosion, stored on flat areas where run-off will be minimized, and be surrounded by bunds. Stockpiles should also only be stored for the minimum amount of time necessary.
- Erosion control of all banks must take place so as to reduce erosion and sedimentation into river channels or wetland areas.
- Weather forecasts from the South African Weather Bureau of up to three days in advance must be monitored on a daily basis to avoid exposing soil or building works or materials during a storm event and appropriate action must be taken in advance to protect construction works should a storm event be forecasted.
- Littering and contamination of water sources during construction must be mitigated by effective construction camp management
- All construction materials including fuels and oil should be stored in a demarcated area (outside of wetlands or wetland buffer zones) that is contained within a bunded impermeable surface to avoid spread of any contamination
- Cement and plaster should only be mixed within mixing trays. Washing and cleaning of equipment should also be done within a bermed area, in order to trap any cement or plaster and avoid excessive soil erosion. These sites must be rehabilitated prior to commencing the operational phase.

6.2.1h Surface water pollution

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Surface Water Pollution	WTP Option 1 and WTP Option 2 as well as all alternative pipelines	Regional	Short	Low	Probable	Low	Low	High

Description of Impact

Hydrocarbon-based fuels or lubricants spilled from construction vehicles, construction materials that are not properly stockpiled, and litter deposited by construction workers may be washed into wetlands and surface water bodies. Should appropriate toilet facilities not be provided for construction workers at the construction crew camps, the potential exists for surface water resources and surrounds to be contaminated by raw sewage. While it is acknowledged that the impacts associated with the proposed activities will be negligible, every effort should still be taken so as to limit additional contributions.

Mitigation Measure

- Construction vehicles are to be maintained in good working order, to reduce the probability of leakage of fuels and lubricants.
- A walled concrete platform, dedicated store with adequate flooring or bermed area should be used to accommodate chemicals such as fuel, oil, paint, herbicide and insecticides, as appropriate, in well-ventilated areas.
- Storage of potentially hazardous materials should be above any 100-year flood line, or as agreed with the HSECO. These materials include fuel, oil, cement, bitumen, etc.
- Sufficient care must be taken when handling these materials to prevent pollution.
- Surface water draining off contaminated areas containing oil and petrol would need to be channelled towards a sump which will separate these chemicals and oils.
- Oil residue shall be treated with oil absorbent such as Drizit or similar and this material removed to an approved waste site.
- Concrete, if used, is to be mixed on mixing trays only, not on exposed soil.
- Concrete and tar shall be mixed only in areas which have been specially demarcated for this purpose.
- All concrete and tar that is spilled outside these areas shall be promptly removed by the Contractor and taken to a licensed waste disposal site;
- After all the concrete / tar mixing is complete all waste concrete / tar shall be removed from the batching area and disposed of at an licensed waste disposal site.

- Stormwater shall not be allowed to flow through the batching area. Cement sediment shall be removed from time to time and disposed of in a manner as instructed by the Consulting Engineer.
- All construction materials liable to spillage are to be stored in appropriate structures with impermeable flooring.
- Portable septic toilets are to be provided and maintained for construction crews. Maintenance must include their removal without sewage spillage.
- Portable septic toilets are to be located outside of the 1-100 year floodline.
- Under no circumstances may ablutions occur outside of the provided facilities;
- At all times care should be taken not to contaminate surface water resources.
- No uncontrolled discharges from the construction crew camps to any surface water resources shall be permitted. Any discharge points need to be approved by the relevant authority.
- In the case of pollution of any surface or groundwater, the Regional Representative of the Department of Water Affairs (DWA) must be informed immediately.
- Where construction in close proximity to sewer lines is unavoidable then excavations must be done by hand while at all times ensuring that the soil beneath the sewer lines is not destabilised.
- Store all litter carefully so it cannot be washed or blown into any of the water courses within the study area;
- Provide bins for construction workers and staff at appropriate locations, particularly where food is consumed.
- The construction site should be cleaned daily and litter removed.
- Conduct ongoing staff awareness programs so as to reinforce the need to avoid littering.
- Backfill must be compacted to form a stabilised and durable blanket; and the current load above the sewer lines must at no time be exceeded.

6.2.2 Operational Phase

6.2.2a Deterioration of the natural vegetation, fauna habitat and the subsequent loss of the ecological function of the vegetation

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Deterioration of the natural vegetation and sub-sequent loss of the ecological function thereof	WTP Option 1, WTP Option 2 and pipeline 1.1a / 2.1b / 2.2a	Local	Medium term	Medium	Probable	Medium	Medium to low	High

Description of impact

The natural vegetation could degrade over time if suitable rehabilitation of the disturbed soils does not take place. In addition, possible malfunction of the MWRP (e.g. burst pipeline) as well regular or emergency maintenance work to the pipeline could damage the vegetation along the route which could lead to soil erosion, habitat modification, trampling of vegetation as well as the destruction of protected plants and plants of conservation concern.

Mitigation Measures

- After construction, the land must be cleared of rubbish, surplus materials, and equipment, and all parts of the land shall be left in a condition as close as possible to that prior to use.
- Ensure that work does not take place haphazardly, but, according to a fixed plan, from one area to the next.
- Planting and re-planting of plants removed prior to commencement of the pipeline construction should preferably be done during the rainy season.
- Allow for a maintenance period of one year following practical completion, unless otherwise specified.
- Cordon off areas that are under rehabilitation as no-go areas. If necessary, these areas should be fenced off to prevent vehicular, pedestrian and livestock access.
- Delay the re-introduction of livestock to all rehabilitation areas until an acceptable level of re-vegetation has been reached.
- In case of emergencies or unforeseen events (e.g. burst pipeline), the problem must be remediated immediately and any spillage into any watercourses be reported to the DWA. In addition, the soil must be stabilised (recover lost topsoil and import additional topsoil from reputable sources if necessary) and re-vegetated as soon as possible. Re-vegetation should include seeds from the adjacent grassland and any rescued protected plants and/or plants of conservation concern that might have been impacted upon by the emergency.
- Maintenance workers may not trample natural vegetation and work should be restricted to previously disturbed footprint. In addition, mitigation measures as set out for the construction phase should be adhered to.

6.2.2b Possible increase in exotic vegetation

Impact	**Site**	**Extent**	**Duration**	**Intensity**	**Probability of occurrence**	**Significance**		**Confidence**
						WOMM	WMM	
Possible increase in exotic vegetation on the site	All alternatives	Local	Medium to long term	Medium to High	Probable	Medium	Medium to low	High

Description of impact

Alien invasive plants (specifically *Acacia mearsnii*) could spread into the soils disturbed by the construction of the proposed pipeline route. In addition, the invasive species could out-compete natural vegetation, displace natural grassland and lead to a species poor transformed landscape.

Mitigation measures

- Compile and implement an alien invasive monitoring plan to prevent the colonisation and spread of alien invasive plant species.
- Monitor all sites disturbed by construction activities for colonisation by exotics or invasive plants and control these as they emerge.
- Follow manufacturer's instruction when using chemical methods, especially in terms of quantities, time of application etc.
- Ensure that only properly trained people handle and make use of chemicals.
- Dispose of the eradicated plant material at a licensed waste disposal site. If no toxic sprays or persistent poisons were used during eradication, then the wood may be sold or donated.
- Rehabilitate all identified areas as soon as practically possible, utilising specified methods and species.
- In addition, only indigenous plant species naturally occurring in the area should be used during the rehabilitation of the areas affected by the construction activities.

6.2.2c Reduction of natural migratory routes and fauna dispersal patterns

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Reduction of faunal migratory routes and faunal dispersal patterns	Fragmented landscape	Regional	Permanent	Medium	High	High	Medium - high	High

Description of impact

The grassland, wetlands and spruit-areas on site provide habitat for faunal species and links the area with other areas of open space. They are therefore able to provide important migration corridors and dispersal patterns for faunal species by linking various sections of open land that would otherwise be fragmented from one another. Should construction occur, the possibility that the connectivity between areas of open space and therefore the migration corridor, would be lost, is high.

Mitigation measures

- Leave as much of the natural vegetation intact in order to maintain ecological corridors for the movement of faunal species.
- All areas designated as sensitive should be incorporated into an open space plan which is managed according to an Environmental Management Program.
- All open spaces should be incorporated and linked to provide corridors for faunal movement within the development.
- No development or activities allowed to impact or alter the remainder of the natural vegetation.

6.2.2d Reduction in faunal biodiversity

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Reduction in indigenous fauna species	Site and surroundings	Regional	Permanent	Medium	Probable	High	Medium	High

Description of impact

The development will modify the natural habitat of various faunal species. These species may no longer be able to find suitable habitat on the site or surrounding land. This could possibly lead to a decline in species numbers and ultimately extinction.

Mitigation measures

- Create open, natural space within the development.
- All open spaces should be incorporated to provide corridors for faunal movement within the development.

6.2.2e Disturbance of fauna in sensitive vegetation

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Disturbance of fauna in sensitive vegetation	Areas delineated as sensitive	Local	Permanent	medium	Probable	Medium	Low	Medium

Description of impact

Human activity within the development could disturb faunal species that depend on the natural, sensitive vegetation on the site.

Mitigation measures

- A management plan to prevent the occupants of the development from disturbing or harassing any faunal species.
- Implement a monitoring program to regularly assess the presence of faunal species within the sensitive vegetation.

6.2.2f Environmental degradation of the study site, particularly sensitive areas

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Environmental degradation of the site	Wetlands, habitats within close proximity to Niekerkspruit, Spookspruit and near the pan	Local	Medium to long term	Medium to High	Probable	Medium	Medium to low	High

Description of impact

Environmental degradation is the process where the natural environment of an area is degenerated to such an extent that the general health and biodiversity of an area is subjected to drastic reduction. After construction has taken place, the effects of the impacts may contribute to the continued environmental degradation of the study site. This could be attributed to a variety of human activities such as health and sanitation activities, storage of hazardous materials, use of pesticides, frequent and unnatural fires, etc.

Mitigation measures

- Implement an alien invasive monitoring plan to prevent the colonisation and spread of alien invasive plant species.
- Ensure that the ecological rehabilitation plan that was compiled and implemented during the construction phase is continued.

6.2.2g Increased erosion and loss of wetland functionality

Impact	Site	Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
						WOMM	WMM	
Increased erosion and loss of wetland functionality	All alternatives	Regional	Permanent	medium	Possible	High	Low	medium

Description of impact

Improper rehabilitation measures after completion of construction activities could lead to an increase in impermeable surfaces and an associated increase in flow velocities and erosion potential within affected wetland habitats. Runoff from the affected surface may enter into the associated watercourse and wetlands, resulting in an unnaturally high catchment runoff, wetland scouring and increased flooding of downstream areas. Increased runoff could potentially also affect existing erosion processes within catchments to such an extent that the newly constructed pipeline itself is threatened in the medium to long term.

Mitigation measures

After completion of the construction phase and appropriate rehabilitation, a wetland monitoring program must be initiated to ensure that rehabilitation measures are successful. The monitoring program should be initiated as soon as the pipeline is operational with site visits after the first three major storm events.

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D.4 Flow rates

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NOTE

DESCRIPTION	MIDDELBURG WATER RECLAMATION PLANT IMPACT OF DISCHARGE ON FLOW RATES	JOB NO.	B478
FILE NAME	B478mp2_NTE_InterimReport.doc	DATE	3 December 2010

INITIAL REPORT ON THE IMPACT OF THE PROPOSED DISCHARGE OF TREATED WATER ON THE FLOW REGIME OF THE SPOOKSPRUIT

As and input to the environmental processes for the proposed Middelburg Water Reclamation Project, it is necessary to determine the impact of the proposed discharge of clean water on the receiving watercourses.

It is currently planned to discharge treated mine water from the proposed water treatment plant into the Niekerkspruit at Dam 5 at Middelburg Mine North Section. A short distance downstream of the discharge point, the Niekerkspruit discharges into the Spookspruit, which in turn discharges into the Olifants River some 16.5 km downstream.

As an initial indication of the magnitude of the impact that the proposed discharge will have on the flow regime in the Spookspruit, the proposed discharge quantities have been compared with the recorded flows in the Spookspruit, just upstream of the confluence with the Olifants River (Department of Water Affairs (DWA) stream flow gauging station No. B11H002). This station has recorded monthly flow volumes at this location since November 1956 and has a substantially complete flow record spanning 54 years.

The use of this station is motivated on the basis that it is located at the downstream end of the are of interest and therefore has the largest catchment and consequently is expected to have the greatest flow volumes. If a significant impact is noted here, then it follows that the impact will become more severe as one moves upstream towards the discharge point.

The catchment area to this station is recorded on the DWA database as 252 km^2. The flow record indicates a mean annual runoff (MAR) of 10.1x10^6 m^3, translating to a MAR depth of 40.1 mm. This is in agreement with the Water Research Commission's "*Surface Water Resources of South Africa 1990*" (*WR90*), which indicates a MAR range for this catchment of 20 to 50 mm.

The discharge rates used in the assessment are as follows:

- Phase 1: 16.1 Ml/day
- Phase 2: 30.0 Ml/day

Comparison of the proposed discharge rates with the average monthly flow volumes are shown in Table 1 and Figure 1 below.

Table 1 – Comparison of natural stream flow volumes with proposed discharge

Flow volumes ($m^3 \times 10^6$)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average	0.36	0.94	1.40	2.64	1.73	1.21	0.75	0.32	0.24	0.22	0.15	0.14	10.10
Max on record	2.71	6.02	8.41	20.90	22.50	9.71	6.06	3.23	1.58	1.07	0.71	1.13	56.10
Min on record	0.00	0.01	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.41
Phase 1 discharge (16.1 Ml/day)	0.50	0.48	0.50	0.50	0.45	0.50	0.48	0.50	0.48	0.50	0.50	0.48	5.88
Phase 2 discharge (30 Ml/day)	0.93	0.90	0.93	0.93	0.84	0.93	0.90	0.93	0.90	0.93	0.93	0.90	10.95
Phase 1 proportion of natural	1.40	0.52	0.36	0.19	0.26	0.41	0.64	1.55	2.02	2.29	3.23	3.39	0.58
Phase 2 proportion of natural	2.61	0.96	0.66	0.35	0.49	0.77	1.20	2.89	3.77	4.26	6.02	6.31	1.08

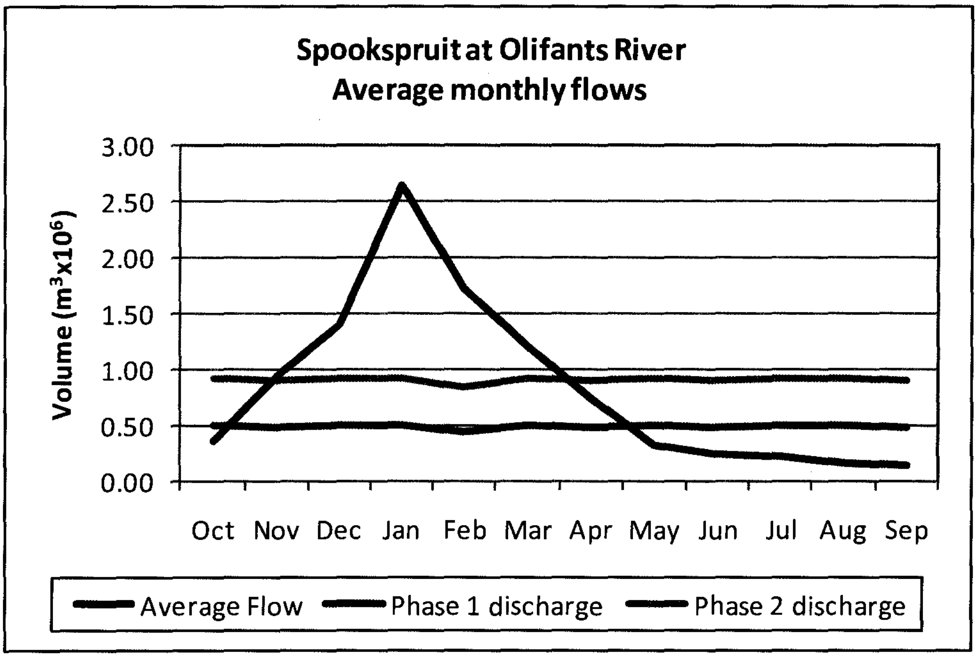

Figure 1 – Proposed discharge volumes vs monthly natural flow volume

The table and figure above illustrate that the proposed discharge would result in a significant increase in flow volumes in the Spookspruit. On an annual basis, the Phase 1 and Phase 2 flows will increase the MAR by 58% and 108% respectively, i.e. the Phase 2 flow will essentially double the mean annual runoff in the Spookspruit.

For the driest month (September) the increase would be 340% and 630% for Phase 1 and Phase 2 respectively.

For the wettest month (January) the increase in flow remains significant at 19% and 35% for the two respective phases.

Based on these findings, it is recommended that runoff modelling be carried out to determine the expected natural flow volumes at key locations along the watercourse so that the impact on the flow regime in terms of volume and additional inundation can be assessed.

Michael Palmer MSc Eng

For Jones & Wagener

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D.5 Geophysical Survey

Orpheus Hydrogeophysics

FOLLOW-ON GEOPHYSICAL SURVEY:

Middelburg Mine – Water Reclamation Project

10 April 2009

Report compiled for

The Institute for Groundwater Studies

IGS

Report number: OHGP2009/04/MWRP.2

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10 April 2009
Our ref.: OHGP2009/04/MWRP.2

The Institute for Groundwater Studies
The University of the Free State
PO Box 339
BLOEMFONTEIN
9300

FOR ATTENTION: Dr. Danie Vermeulen

Dear Sir,

REPORT ON THE FOLLOW-ON GEOPHYSICAL SURVEY CONDUCTED AT THE EXTENSION OF THE PREFERRED SITE CONSIDERED FOR THE DEVELOPMENT OF A WATER TREATMENT PLANT, MIDDELBURG MINE

It is our pleasure to include two copies of the report OHGP2009/04/MWRP.2 "Follow-on Geophysical Survey: Middelburg Mine – Water Reclamation Project". We trust that the report will meet your expectations.

Please feel free to contact me should you have any queries or suggestions.

Yours sincerely,

F.D. Fourie
(Ph.D., Pr.Sci.Nat.)

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Copies: One (1) electronic copy to the IGS

Executive Summary

Orpheus Hydrogeophysics conducted geophysical investigations at an extension of the preferred site considered for the development of a Water Treatment Plant at Middelburg Mine after it was suggested that this extension may be more suitable for the proposed development than the preferred site itself. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. As part of the geophysical investigations, the following actions were taken:

- *A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.*
- *Ortho-photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions.*
- *An airborne magnetics map covering the area of interest was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.*
- *A site visit was conducted to allow familiarisation with the site layout and orientation.*
- *Ground magnetic and electromagnetic data were recorded on seventeen traverses across and in the vicinity of the selected site.*
- *All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.*
- *Targets for the drilling of investigative and monitoring boreholes were identified.*

The geophysical investigations revealed the presence of a zone of high magnetic variability to the south-east of the extension of the preferred site. Although other minor magnetic anomalies were observed on some of the traverses, none of these anomalies were consistent with the presence of a prominent geological feature in the vicinity of the site. The EM data also did not reveal the presence of prominent zones of high conductivity which could be indicative of faults or highly weathered zones along which preferential groundwater migration may take place.

Since the origin of the zone of high magnetic variability warrants further investigation, a drilling target was selected within this zone. Another drilling target was sited to the north-west of the site. Boreholes drilled at these positions could provide information on the geological conditions in the vicinity of the site and could later serve as groundwater monitoring boreholes during the construction, operational, decommissioning and post-closure phases of the project.

After drilling of the investigative and monitoring boreholes, it is recommended that geohydrological investigations be undertaken to study the hydraulic properties of the geological units in the vicinity of the site before any conclusions are drawn on the suitability of the site for the proposed development.

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1 Introduction

1.1 Project Description

During May 2008 Orpheus Hydrogeophysics was commissioned by the Institute for Groundwater Studies (IGS) to conduct geophysical investigations at a site proposed for the development of a Water Treatment Plant (WTP) at Middelburg Mine. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. Such features could include intrusive magmatic bodies, fault zones and zones of higher weathering. The results of the geophysical investigations were used to site investigative and monitoring boreholes at positions appropriate to the geohydrological studies that were to follow the geophysical survey (refer to report OHGP2008/06/MWRP.1)

During February 2009 Orpheus Hydrogeophysics conducted follow-on geophysical investigations at an extension of the preferred site after it was suggested that this extension may be more suitable for the development.

1.2 Approach to the Geophysical Investigations

As part of the geophysical investigations, the following actions were taken:

- A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.
- Ortho-photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions. Such features could include visible changes in the vegetation, the presence of rock outcrops and prominent topographical changes.
- An airborne magnetics map covering the area of interest was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.
- A site visit was conducted to allow familiarisation with the site layout and orientation.
- Ground magnetic and electromagnetic data were recorded on selected traverses across and in the vicinity of the site considered for the development.
- All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.

- Based on the results of the geophysical investigations, targets for the drilling of investigative and monitoring boreholes were identified.

2 Regional setting

The sites (preferred and extension) considered for the development of the WTP and associated infrastructure are located approximately 16 km south-south-west from the town of Middelburg in the Mpumalanga Province of South Africa (refer to Figure 1 and Map M008MWRP in **Appendix A**). From Middelburg the site may be reached via the R575 (Vandijksdrif) main road.

Both the preferred site and its extension are situated on open land with little surface infrastructure. This land was used for farming purposes prior to acquisition by Middelburg Mine. The land is bordered on the east by another farm on which maize production takes place. A high voltage power line extends in an approximately north-west/south-east direction near the southern perimeter of the preferred site and the northern perimeter of its extension. Mining infrastructure (a slurry dam and associated infrastructure) of Middelburg Mine occurs at a distance of approximately 250 m to the south of the extension.

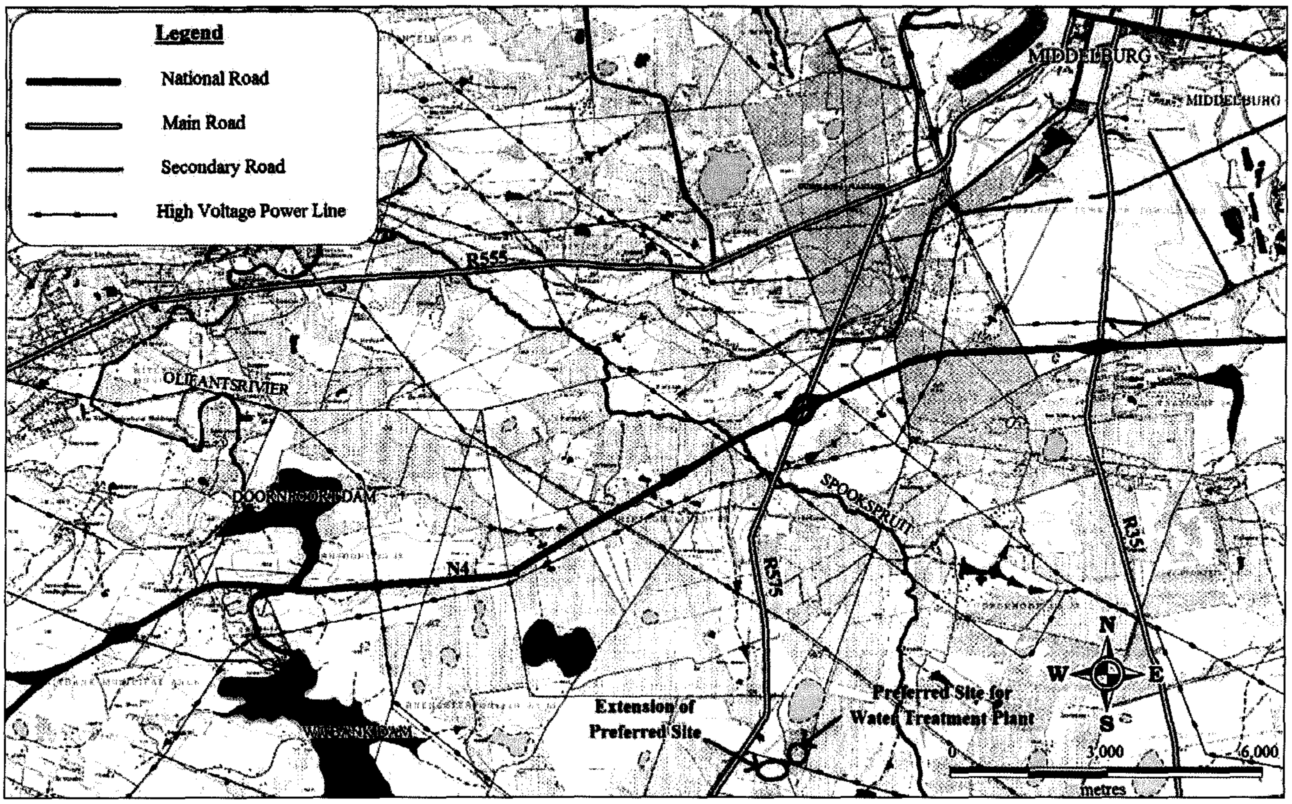

Figure 1. Regional setting of the sites considered for the development of the Water Treatment Plant.

3 Geological setting

The 1:250,000 geological map presented in this section is the intellectual property of the Council for Geoscience and is used by permission. Copyright and all rights are reserved by the said Council.

The selected site is located in an area underlain by rocks of the Karoo Supergroup, represented locally by rocks of the Ecca Group. These rocks are all of a sedimentary origin and consist of shales, sandstones, grits, conglomerates and coal beds in places (refer to the 1:250,000 geological maps presented in Figure 2 and in Map M009MWRP of **Appendix A**).

Outcrops of diabase intrusives are known to occur within 1.5 km to the north and north-east of the preferred site, but no large-scale intrusive magmatic bodies or prominent fault zones have been mapped in the immediate vicinities of either the preferred site or its extension.

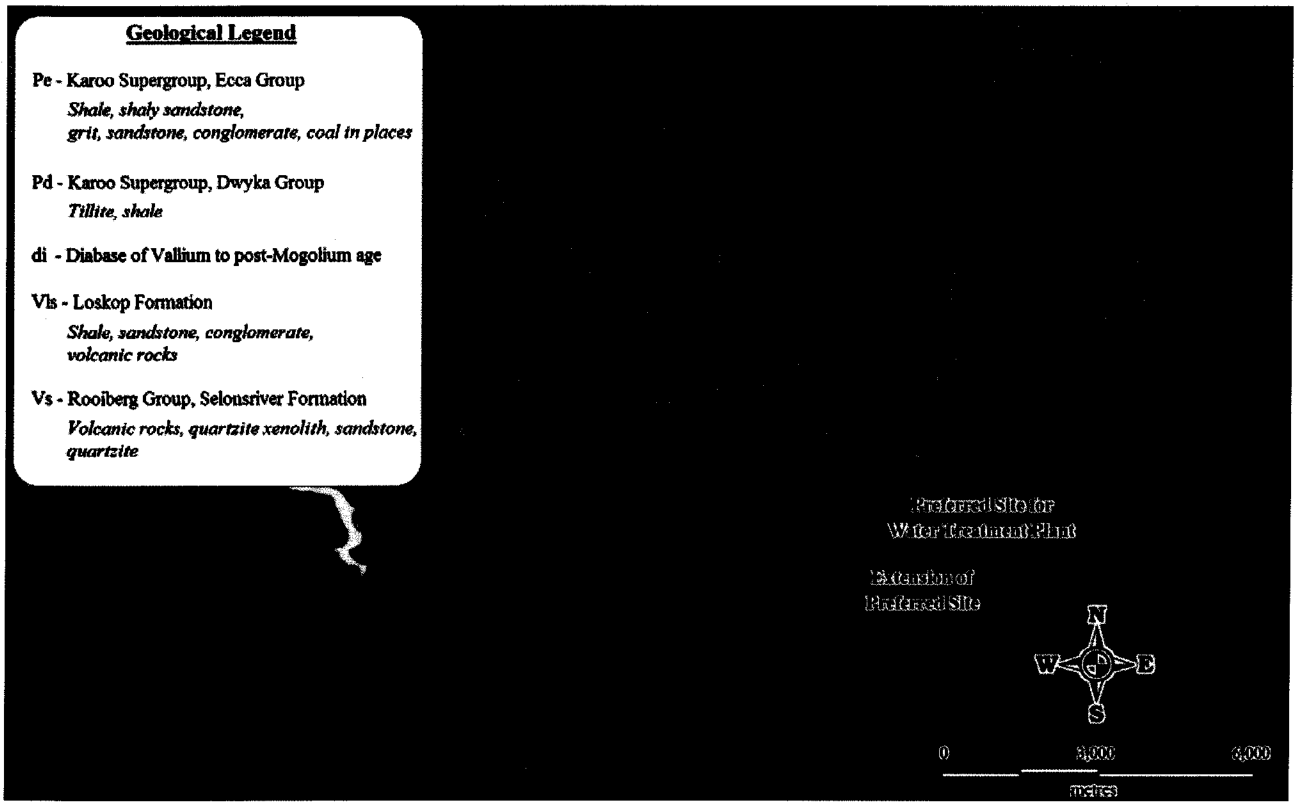

Figure 2. Geological setting of the sites considered for the development of the Water Treatment Plant.

4 Topography and drainage

The extension of the preferred site considered for the development of the WTP occurs in an area that displays gentle slopes to the north-west, north, and south-east. These slopes are generally smaller than 1:25 to the south-east and 1:36 to the north and north-west. The average topographic elevation of the site is approximately 1,557 metres above mean sea level (mamsl) (refer to Figure 3 and Map M010MWRP in **Appendix A**).

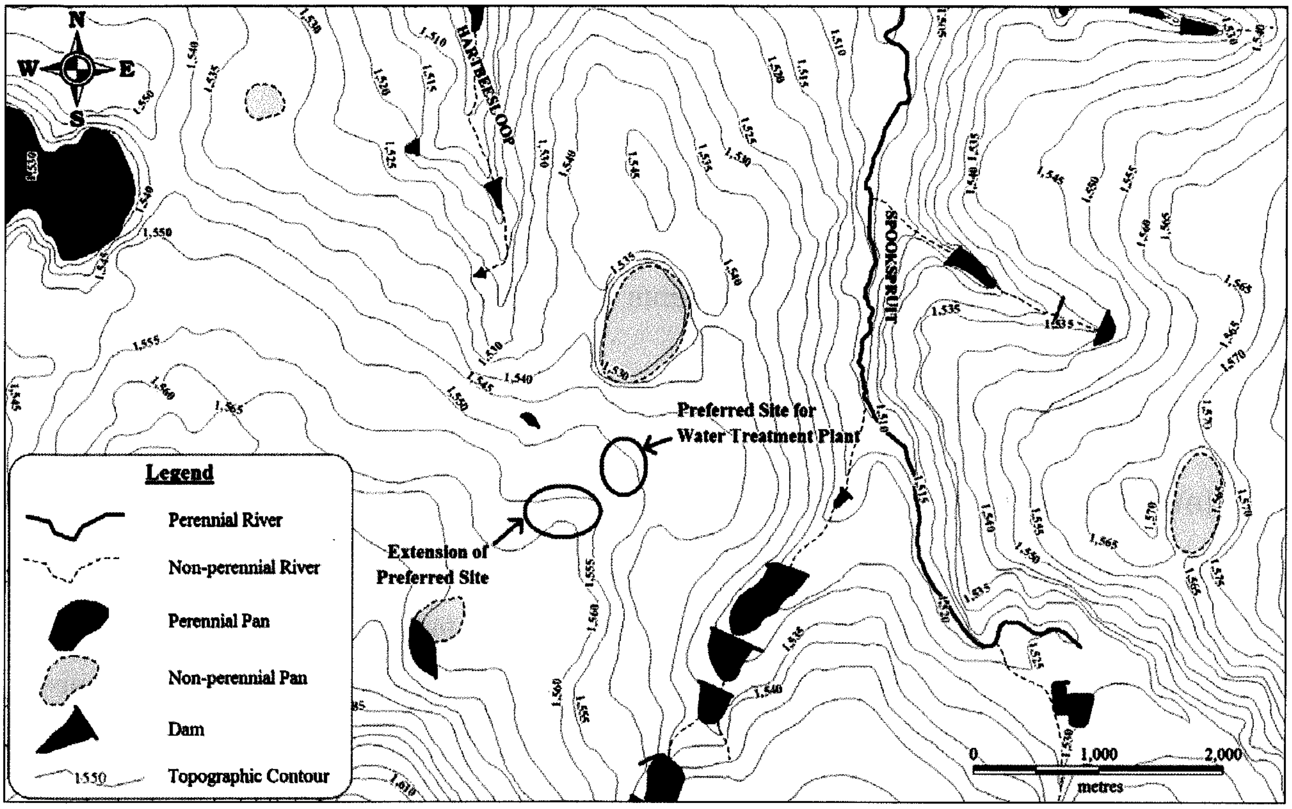

Figure 3. Surface topography and surface water bodies in the vicinity of the sites considered for the proposed development.

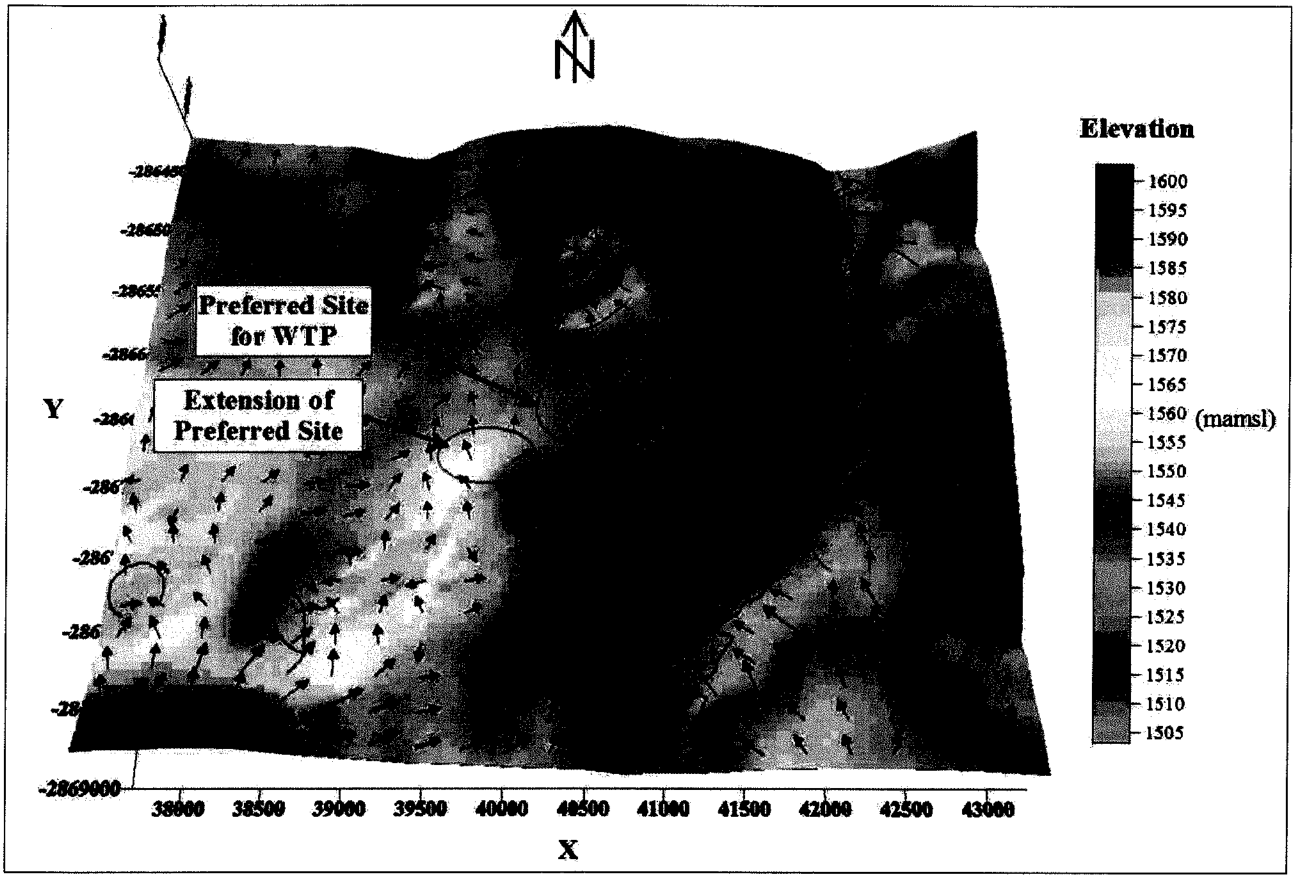

Figure 4. Surface topography and drainage in the vicinity of the preferred site (and extension) considered for the proposed development. Blue arrows indicate the direction and relative magnitude of surface runoff flow.

The extension of the preferred site occurs on a local watershed. Drainage from the north-western and western portions of the extension is expected to take place in a northerly and north-westerly direction towards the upper catchment areas of the Hartbeesloop. Runoff from the north-eastern portions could drain towards a non-perennial pan situated at a distance of approximately 900 m from the site. Runoff from the south-eastern portions of the extension will drain towards the south-east in the direction of a tributary of the Spookspruit (see Figure 4).

5 Geophysical investigations

5.1 Introduction

The purpose of the geophysical investigations was to identify and delineate geological features that could potentially influence the groundwater environment by forming preferential pathways or barriers to groundwater flow and contaminant transport. Such geological features include intrusive magmatic bodies and fault zones.

Due to the high pressures and temperatures generated when magma intrudes the host rock, extensive fracturing and weathering of the host rock often occur in the vicinity of the intrusive bodies. These fractured and weathered zones generally have enhanced permeabilities and thus may form preferential pathways to groundwater flow in directions parallel to the strikes of the intrusives. The intrusive bodies themselves may furthermore be dense enough to form barriers to groundwater flow in directions perpendicular to these bodies, thereby compartmentalising the aquifer systems intersected.

Fault zones are also generally associated with extensive fracturing and increased permeabilities. Groundwater flow rates along these fault zones may be orders of magnitude higher than through the undisturbed host rock.

Two ground geophysical techniques, namely the magnetic and electromagnetic (EM) methods, were employed during the investigations. These reasons for selecting these techniques and the physical principles of which they operate are briefly described below:

Magnetic method

Many earth materials contain magnetic minerals such as magnetite, ilmenite and pyrrhotite. When geological units contain such magnetic minerals, these units may become magnetised by the earth's magnetic field, and may then have magnetic fields associated with them. These local magnetic fields that are due to the magnetised geological units will be superimposed on the earth's regional magnetic field. Measurements taken in the vicinity of magnetised geological units will therefore show local variations or departures from the undisturbed magnetic field of the earth (called the regional field). These departures are referred to as anomalies. The shapes of the anomalies are dependent on a number of factors regarding the physical properties and dimensions of the magnetised geological units. By incorporating existing knowledge on the geological conditions at the site being surveyed, the magnetic anomalies recorded during a survey may be interpreted in terms of the local geological conditions.

Since outcrops of diabase intrusives are known to occur within 1.5 km from the site under investigation, and since diabase is generally very magnetic, the magnetic method was used to the detect the possible presence of diabase dykes and/or sills in the near vicinity of the site. The magnetic survey was conducted using the G5 proton magnetometer manufactured by Geotron Systems (Pty) Ltd.

Electromagnetic (EM) method

EM methods make use of the fact that electromagnetic waves travelling through conductive media generally induce electrical current flows in these media. The behaviour of these electrical currents and their associated magnetic fields contains information about the conductivities of the media in which the currents flow.

In active EM methods, a time-varying source (primary) current is made to flow in a source loop. Associated with the primary current is a primary time-varying magnetic field. The time-varying magnetic field causes a time-varying magnetic flux through a body (geological unit) in the vicinity of the source. This time-varying magnetic flux sets up a time-varying emf in the geological unit. The time-varying emf drives electrical current flows (eddy currents) through the geological unit.

The behaviour of the induced eddy currents and their associated (secondary) magnetic fields is dependent on a number of parameters, including the conductivity of the geological unit. The emf induced in a receiver loop by the time-varying magnetic flux of the secondary magnetic field through the loop, may be measured. The measured emf contains information on the conductive properties of the geological unit. The subsurface conductivity distribution, as determined from the EM survey, may now be interpreted in terms of the local geological conditions by incorporating known information on the geology of the site.

The EM survey at the extension of the preferred site was conducted using the Geonics EM34-4 instrument. This instrument is an active, frequency domain system that calculates an apparent conductivity of the earth by measuring the quadrature (out-of-phase) component of the secondary magnetic field at low induction numbers. Since fault zones are often associated with elevated electrical conductivities, such zones could lead to detectable EM anomalies. Measurements are generally taken with two dipole orientations. Horizontal dipole (HD) orientations investigate at shallower depths and give good coupling with vertical structures while vertical dipole (VD) orientations investigate at deeper depths and give good coupling with horizontal structures.

An inter-coil spacing of 20 m was used for the EM survey at the extension. This separation allows investigation to depths of 20 – 30 m, depending on the conductivities of the earth materials. These depths of investigation were deemed adequate for the detection of near-surface fault zones that could act as preferential pathways for seepage from the proposed WTP and associated infrastructure.

5.2 Study of ortho-photographs

As part of the geophysical investigations overlapping ortho-photographs of the area under investigation were studied to identify any natural features that could indicate the presence of variations in the local geological conditions. Such features could include visible changes in the vegetation, the presence of rock outcrops and prominent topographical changes. The overlapping ortho-photographs of the study area are displayed in Figure 5 and Map M011MWRP of **Appendix A**.

No prominent changes in the natural features are discernible in the immediate vicinity of the preferred site or its extension. Surface activities to the east, south and west of the site (including farming, mining and housing infrastructure) have significantly disturbed the natural environment, making the identification of large-scale geological features that manifest themselves at surface very difficult.

5.3 Study of airborne magnetics map

The airborne magnetics map presented in this section is the intellectual property of the Council for Geoscience and is used by permission. Copyright and all rights are reserved by the said Council.

An airborne magnetics map covering the area of interest was studied to investigate the presence of large-scale magnetic features in the vicinity of the WTP site. Such magnetic features could indicate the presence of large-scale intrusives that could significantly alter the groundwater environment.

In Figure 6 it can be seen that both the preferred site and its extension are located in an area of relatively low magnetic activity with little lateral variation in the measured magnetic field strength, although large-scale low-amplitude features with north-east and north-west strikes may be identified. These features are, however, dwarfed by a ring-like structure to the south of the sites of which the northern perimeter occurs at a distance of approximately 2 km from the southern perimeter of the extension. The ring-like feature is in all likelihood due to the presence of an intrusive magmatic body, such as a diabase ring-dyke. The geological feature responsible for the large magnetic response is, however, adequately remote from the WTP sites to have an insignificant influence on the aquifer system underlying the sites.

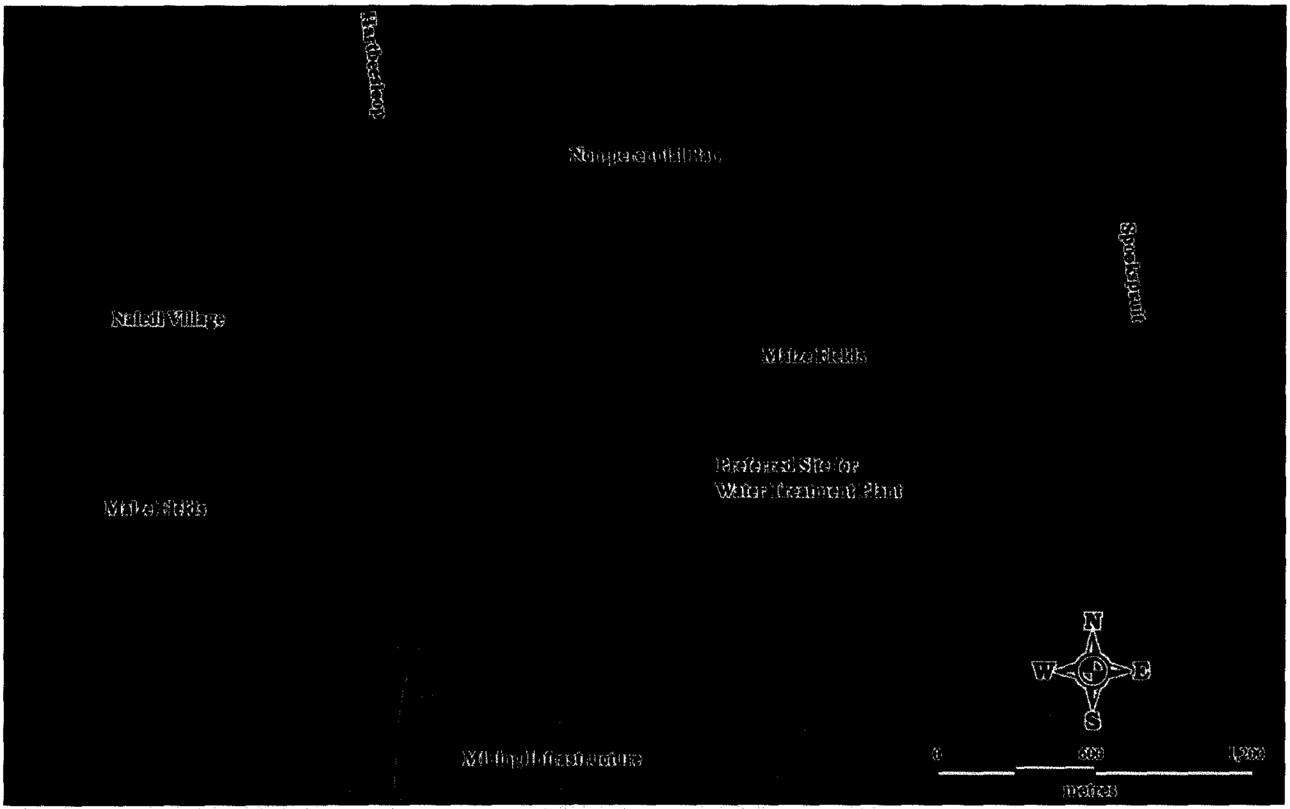

Figure 5. Overlapping ortho-photographs of the area under investigation.

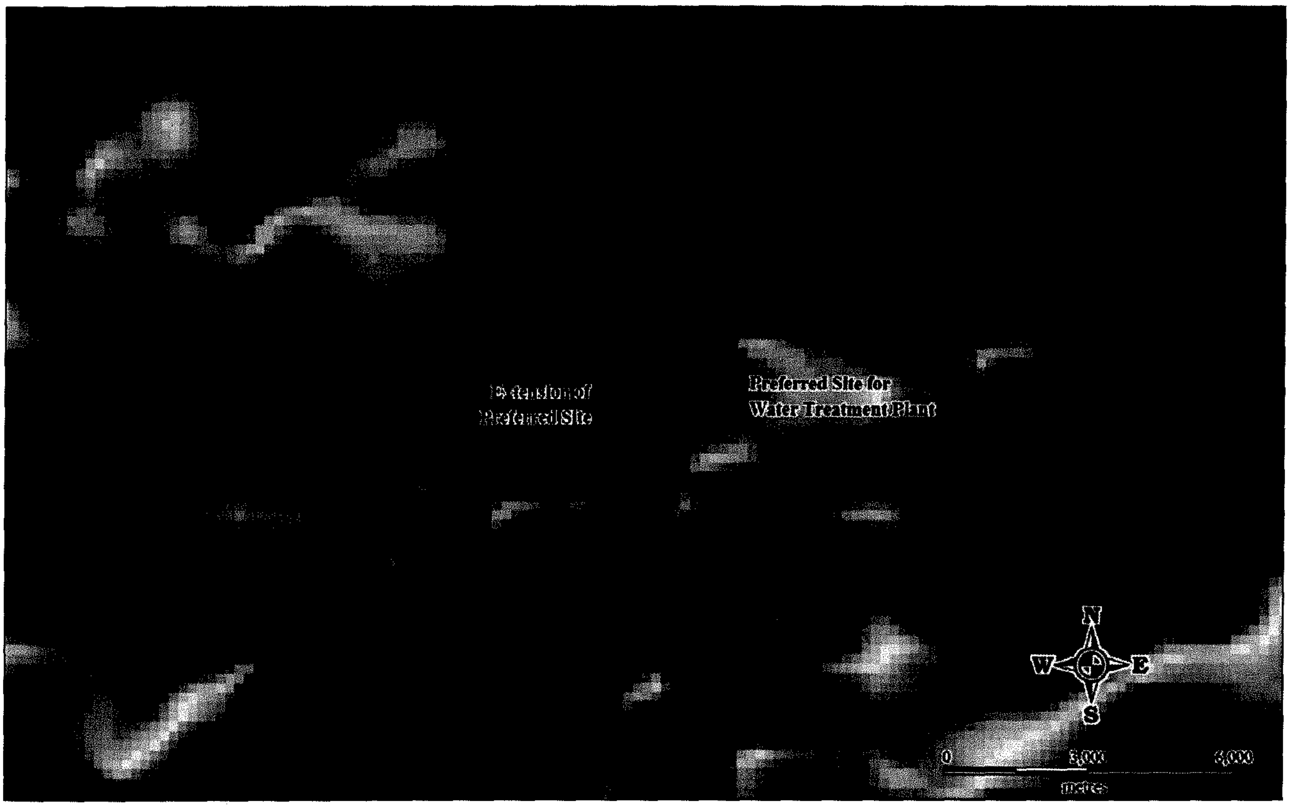

Figure 6. Airborne magnetics map covering the area under investigation.

5.4 Ground geophysical investigations

Geophysical data were recorded on 17 traverses across the extension of the preferred site and at positions to the west and south-east of the extension. The reason for extending the geophysical survey to these positions was to allow different locations to be considered for the WTP should the both the preferred site and its extension for some reason be found to be unsuitable for the proposed development. The positions and orientations of the 17 geophysical traverses relative to extension and surface infrastructure are shown in Figure 7. Also shown in Figure 7 are the positions and orientations of the 15 traverses on which geophysical data were recorded during May 2009 as part of the investigations at the preferred site.

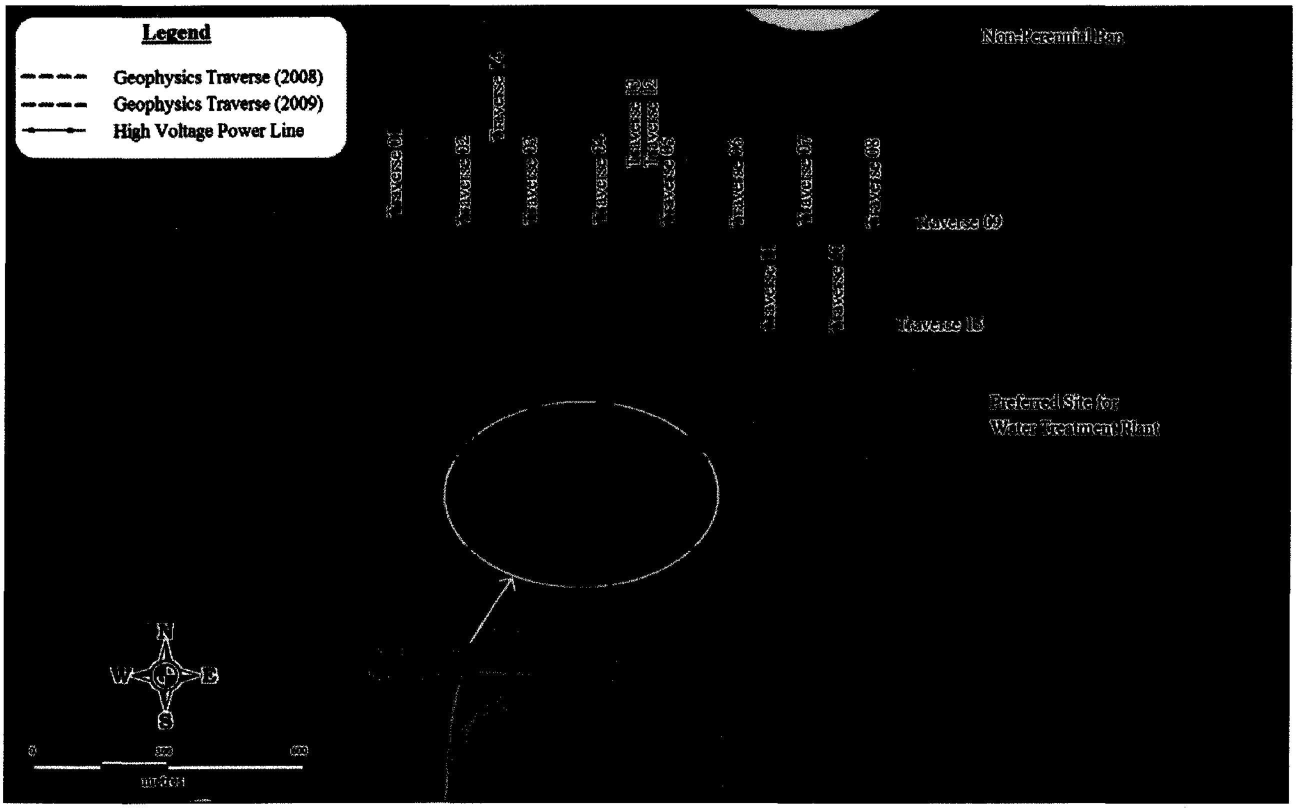

Figure 7. Positions and orientations of the ground geophysics traverses relative to the preferred site (and extension) and existing surface infrastructure.

5.4.1 Results of the ground geophysical investigations

During the geophysical survey, surface infrastructure in the form of high voltage power lines and wire fences acted as sources of noise that influenced both the magnetic and EM surveys and limited the lateral extent of the geophysical traverses on which high-integrity data could be recorded. Especially the high voltage power lines were a prominent source of noise. The results of the ground geophysical investigations are presented as profile plots in **Appendix B** and discussed below:

Traverses 16-29

Magnetic data were recorded on all 14 of these south/north striking traverses, while EM data were recorded over the footprint of the extension on Traverses 19 to 22, as well as on the part of Traverse

05 south of the high voltage power line. The line spacing between the traverses was approximately 150 m, while magnetic and EM data were recorded at station spacings of approximately 10 m.

After subtraction of the estimated regional field, prominent magnetic anomalies with amplitudes greater than 20 nT were only observed on six of the 14 traverses, namely on Traverses 16, 21, 22, 24, 26 and 29 (refer to **Appendix B**).

A broad negative anomaly with amplitude of 60 nT and spatial wavelength of approximately 120 m was detected on Traverse 16. This anomaly was, however, in all likelihood caused by the presence of overhead electrical wires that crossed the traverse at an oblique angle.

Two single-point anomalies with amplitudes of approximately 20 nT were recorded on Traverse 21, 63 m and 266 m from the start of the traverse. The southern anomaly is in all likelihood due to the presence of overhead electrical wires that run adjacent to the dirt road south of the extension (refer to Figure 7). The anomaly near the centre of the traverse is unlikely to be due to a geological structure and may have been caused by near-surface sources of noise, such as metal objects at surface or buried at shallow depths. A broad anomaly with amplitude of approximately 35 nT was recorded at the northernmost stations on Traverse 21. This anomaly may, however, also be related to the presence of surface infrastructure in the form of the high voltage power lines to the north of the extension and the large pylons that support them.

Magnetic anomalies with amplitudes as large as 600 nT occur along the southern parts of Traverse 22, extending over a distance of approximately 120 m. Although the overhead electrical wires that occur to the south of the traverse may have contributed to the observed anomalies, the magnitude and spatial extent of the anomalies suggest other sources. The anomalies could possibly be due to a geological structure, but may also be due to buried infrastructure from past farming or mining related activities.

The magnetic anomalies at the northernmost stations of Traverses 24 and 26 (amplitudes of approximately 33 nT and 23 nT, respectively) are in all likelihood due to the presence of the high voltage power lines that occur near these positions.

A broad magnetic anomaly with amplitude of approximately 28 nT was recorded on Traverse 29. The anomaly does not extend to the adjacent traverses and is therefore unlikely to be due to a prominent geological feature. Since Traverse 29 was located adjacent to mining infrastructure in the form of a conveyor belt, the observed anomaly may have been due the manmade noise.

The EM survey was negatively impacted on by the presence of high voltage power lines to the north and overhead electrical wires to the south of the extension. Especially the vertical dipole (VD) orientation was very sensitive to EM noise from these manmade sources and high integrity data could only be recorded at positions removed by more than 150 m from the power lines. The horizontal dipole (HD) orientation was less severely impacted on by these manmade sources of noise.

The EM responses measured on Traverses 19, 21 and 22 are typical of layered earth response, and suggests near horizontal layering of the sedimentary units underlying the extension. Since the VD orientation allows investigation of materials at greater depths than the HD orientation, it appears that deeper geological units are more conductive than the shallower units, possibly due to a larger degree of saturation. The conductivities of both the shallower and deeper geological units appear to gradually decrease to the north, although a broad zone of increased conductivities was observed on Traverse 22.

Elevated conductivities were recorded on Traverse 20 within a disused sand quarry. The increased conductivities observed in this area may be explained by the exposure of the deeper, more saturated geological units within the quarry. Standing water occurred within the quarry at the time of the survey and prohibited measurement at certain positions within the quarry.

No EM anomalies that clearly suggest the presence of prominent geological structures were recorded on Traverses 19 to 22.

Traverses 30 to 32

Traverses 30, 31 and 32 extended along west/east strikes. Magnetic data were recorded on all three traverses to investigate the possible presence of magnetic structures with south/north strikes that were not intersected by Traverses 16 to 29. Another purpose of these three traverses was to tie in the south/north striking traverses in order to adjust the estimated regional magnetic fields recorded on these traverses to the same reference level.

The only significant magnetic anomaly observed on the west/east striking traverses occurred near the start of Traverse 31. This anomaly is thought to have the same origin as the prominent anomaly recorded on Traverse 22.

EM data were recorded on Traverses 30 and 31. No significant anomalies were observed on Traverse 30. A zone of high variability in the recorded EM data is observed along Traverse 31, in the vicinity of station 600. The anomalous zone corresponds to the position of the disused quarry and the observed apparent conductivities were in all likelihood caused by the presence of discarded metal objects within the quarry.

A minor EM anomaly is observed towards the end of Traverse 31. However, the EM data recorded on Traverses 30 and 31 suggest the absence of zones of high conductivity, such as fault zones or highly weathered zones, along which preferential groundwater migration may take place.

A contour map of the estimated regional magnetic field intensity in the vicinity of the WTP site is displayed in Figure 8. The regional field displays spatial wavelengths in the order of a couple of hundred metres to kilometres, indicating that the regional field has its origin in magnetic materials that occur at great depth. The regional field is relatively consistent (variations <60 nT) at the position of the extension, although an area of higher regional magnetic field intensities is observed near the north-western perimeter of the site.

The "anomalous" magnetic field intensity, obtained after removal of the regional field, is shown as a contour map in Figure 9. To allow the investigation of possible linear magnetic features of small amplitude, the prominent magnetic anomalies observed on Traverses 16 and 22 were removed from the data prior to contouring. No magnetic anomaly consistent with a linear intrusive magmatic body can be observed in the contour map of the anomalous magnetic field. The anomalies that are observed along the northern perimeter of the contour map appear to be associated with the surface infrastructure (pylons and high voltage power lines) that occurs in this area. It therefore seems that the area under investigation is free of magnetic intrusives such as diabase or dolerite.

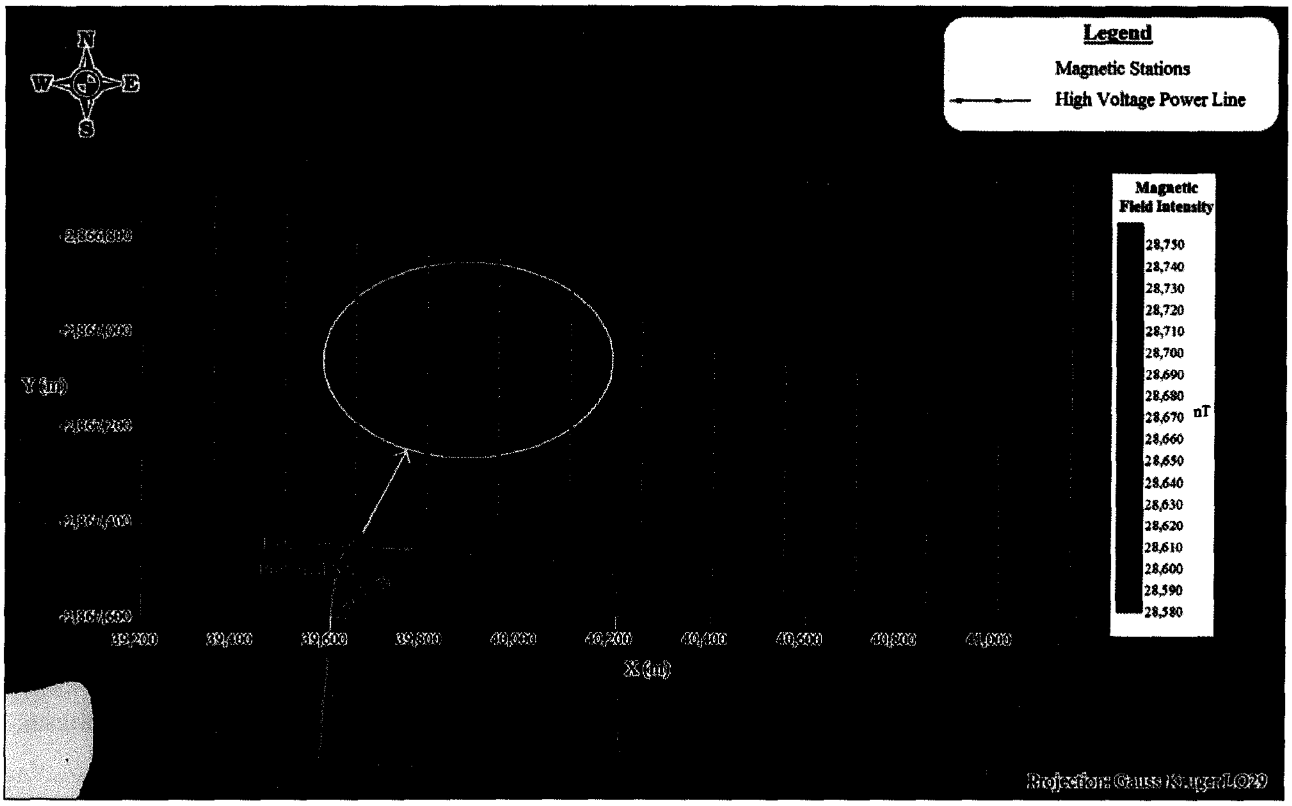

Figure 8. Contour map of the estimated regional magnetic field intensity.

Figure 9. Contour map of the magnetic field intensity after removal of the estimated regional field.

5.5 Proposed drilling targets

Investigative and monitoring boreholes were sited by considering the results of the geophysical investigations as well as the local topographic gradients in the vicinity of the site. The boreholes that are to be drilled at the sites could serve to:

- Obtain information on the background groundwater conditions prior to the development of the WTP, including water quality and water table elevation,
- Investigate the hydraulic properties of the intersected aquifer systems by means of different hydraulic tests, and,
- Act as monitoring boreholes to evaluate impacts of the development on the groundwater environment during the construction, operational, decommissioning and post-closure phases of the project.

One drilling target (BH04) was selected at a position where large magnetic anomalies were observed on Traverses 22 and 31. The borehole drilled at this position could provide information on the source of the observed magnetic anomalies, and whether this source has a manmade or geological origin. Once development of the WTP commences and during the operational and post-closure phases of the project, this borehole could further serve as a monitoring borehole to allow investigation of possible impacts on the groundwater environment along the south-eastern drainage.

A second drilling target (BH05) was selected north-west of the extension. A borehole installed at this position will provide information on the geological conditions and could serve as a monitoring borehole to investigate possible contaminant transport in north-westerly directions.

Borehole BH01, drilled after the 2008 geophysical investigations, may be used to monitor impacts on the groundwater environment at positions to the north-east of the extension.

The positions of the existing and proposed investigative and monitoring boreholes are shown in Figure 10 while the coordinates of the proposed boreholes are listed in Table 1.

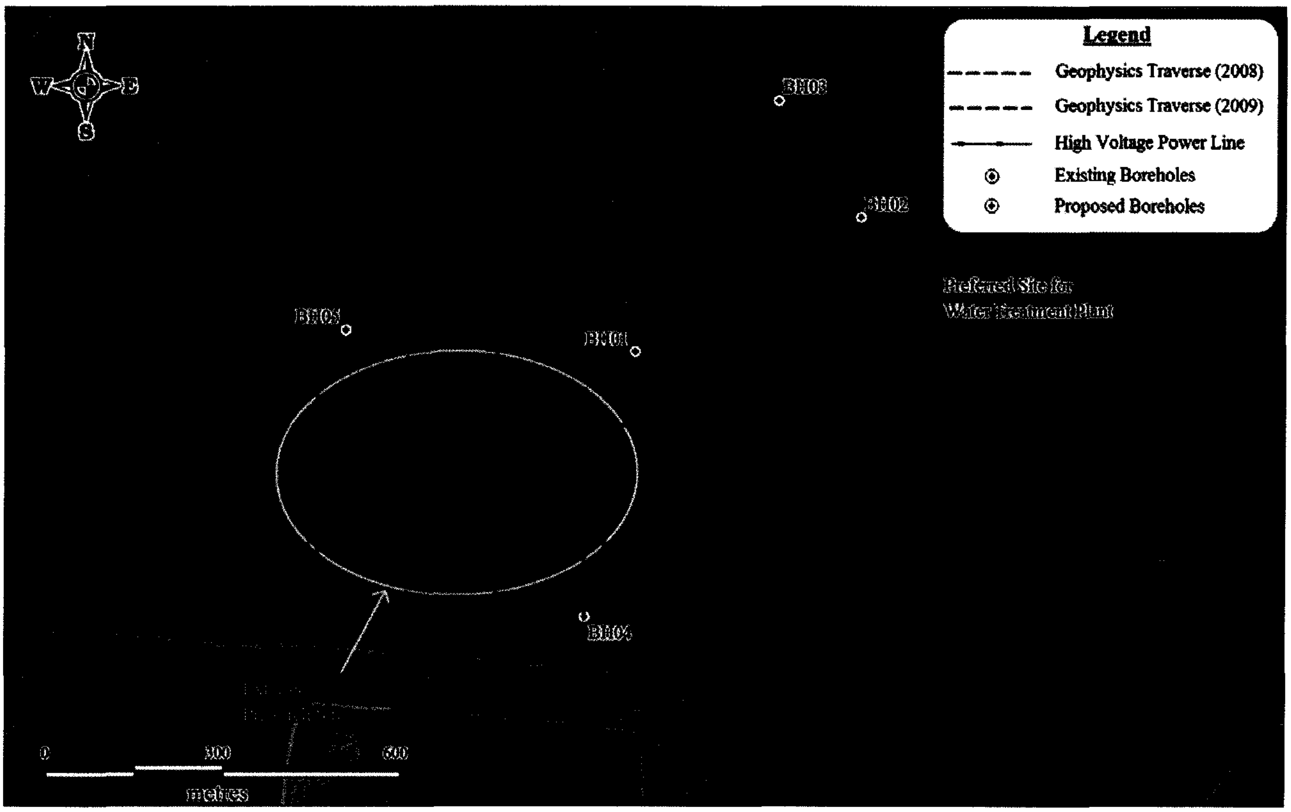

Figure 10. Proposed drilling targets for the installation of investigative and monitoring boreholes.

Table 1. Coordinates of the proposed positions for the drilling of investigative and monitoring boreholes.

BH #	Coordinates					
	WGS 84		WGS 84, LO29		Gauss-Kruger LO29	
	Lat (°S)	Long (°E)	X (m)	Y (m)	X (m)	Y (m)
BH04	25.91609	29.40000	40,075.69	-2,867,599.66	40,104.35	-2,867,303.43
BH05	25.91175	29.39597	39,673.19	-2,867,117.39	39,701.84	-2,866,821.16

6 Summary and Conclusions

This report summarizes findings made during the geophysical investigations conducted by Orpheus Hydrogeophysics at an extension of the preferred site considered for the development of a Water Treatment Plant at Middelburg Mine after it was suggested that this extension may be more suitable for the proposed development than the preferred site itself. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. As part of the geophysical investigations, the following actions were taken:

- A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.
- Ortho-photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions.
- An airborne magnetics map covering the area of interest was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.
- A site visit was conducted to allow familiarisation with the site layout and orientation.
- Ground magnetic and electromagnetic data were recorded on seventeen traverses across and in the vicinity of the selected site.
- All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.
- Targets for the drilling of investigative and monitoring boreholes were identified.

The geophysical investigations revealed the presence of a zone of high magnetic variability to the south-east of the extension. Although other minor magnetic anomalies were observed on some of the traverses, none of these anomalies were consistent with the presence of a prominent geological feature in the vicinity of the site. The EM data also did not reveal the presence of prominent zones of high conductivity which could be indicative of faults or highly weathered zones along which preferential groundwater migration may take place.

Since the origin of the zone of high magnetic variability warrants further investigation, a drilling target was selected within this zone. Another drilling target was sited to the north-west of the extension. Boreholes drilled at these positions could provide information on the geological conditions in the vicinity of the site and could later serve as groundwater monitoring boreholes during the construction, operational, decommissioning and post-closure phases of the project.

After drilling of the investigative and monitoring boreholes, it is recommended that geohydrological investigations be undertaken to study the hydraulic properties of the geological units in the vicinity of the extension before any conclusions are drawn on the suitability of the site for the proposed development.

FD Fourie
(Ph.D. Pr.Sci.Nat.)

10 April 2009
Date

Orpheus
Hydrogeophysics

GEOPHYSICAL SURVEY:

Middelburg Mine - Water Reclamation Project

11 June 2008

Report compiled for

The Institute for Groundwater Studies

Report number: OHGP2008/06/MWRP.1

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11 June 2008
Our ref.: OHGP2008/06/MWRP.1

The Institute for Groundwater Studies
The University of the Free State
PO Box 339
BLOEMFONTEIN
9300

FOR ATTENTION: Dr. Brent Usher

Dear Sir,

REPORT ON THE GEOPHYSICAL SURVEY CONDUCTED AT A SITE PROPOSED FOR THE DEVELOPMENT OF A WATER TREATMENT PLANT, MIDDELBURG MINE

It is our pleasure to include two copies of the report OHGP2008/06/MWRP.1 "Geophysical Survey: Middelburg Mine – Water Reclamation Project". We trust that the report will meet your expectations.

Please feel free to contact me should you have any queries or suggestions.

Yours sincerely,

F.D. Fourie
(Ph.D., Pr.Sci.Nat.)

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Copies: Two (2) copies to the IGS

Executive Summary

Orpheus Hydrogeophysics conducted geophysical investigations at a site proposed for the development of a Water Treatment Plant at Middelburg Mine. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. As part of the geophysical investigations, the following actions were taken:

- *A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.*
- *Aerial photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions.*
- *An airborne magnetic map covering the area of interest was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.*
- *A site visit was conducted to allow familiarisation with the site layout and orientation.*
- *Ground magnetic and electromagnetic data were recorded on fifteen traverses across and in the vicinity of the selected site.*
- *All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.*
- *Targets for the drilling of investigative and monitoring boreholes were selected.*

The geophysical investigations did not identify any prominent geological feature in the vicinity of proposed WTP site. This observation suggests that the site selected for the development of the WTP poses no problems in terms of the presence of major geological features that could influence the groundwater environment by forming preferential pathways to groundwater flow and contaminant migration. However, additional geohydrological investigations are still required to evaluate the hydraulic properties of the geological units underlying the site before any conclusions can be drawn on the suitability of the site for the proposed development.

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1.1 Project Description

Orpheus Hydrogeophysics was commissioned by the Institute for Groundwater Studies (IGS) to conduct geophysical investigations at a site proposed for the development of a Water Treatment Plant (WTP) at Middelburg Mine. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. Such features could include intrusive magmatic bodies, fault zones and zones of higher weathering. The results of the geophysical investigations were to be used to site investigative and monitoring boreholes at positions appropriate to the geohydrological studies that are to follow the geophysical survey.

1.2 Approach to the Geophysical Investigations

As part of the geophysical investigations, the following actions were taken:

- A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.
- Aerial photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions. Such features could include visible changes in the vegetation, the presence of rock outcrops and prominent topographical changes.
- An airborne magnetic map covering the area of interest was purchased from the Council for Geoscience. This map was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.
- A site visit was conducted to allow familiarisation with the site layout and orientation.
- Ground magnetic and electromagnetic data were recorded on selected traverses across and in the vicinity of the selected site.
- All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.
- Based on the results of the geophysical investigations, targets for the drilling of investigative and monitoring boreholes were identified.

2 Regional setting

The site proposed for the development of the WTP and associated infrastructure is located approximately 16 km south-south-west from the town of Middelburg in the Mpumalanga Province of South Africa (refer to Figure 1 and Map M002MWRP in **Appendix A**). From Middelburg the site may be reached via the R575 main road.

The proposed site is situated on open land with little surface infrastructure. This land was used for farming purposes prior to acquisition by Middelburg Mine. The land is bordered on the east by another farm on which maize production takes place. A high voltage power line extends in an approximately north-west/south-east direction near the southern perimeter of the selected site. Mining infrastructure of Middelburg Mine occurs at a distance of approximately 700 m to the south of the site.

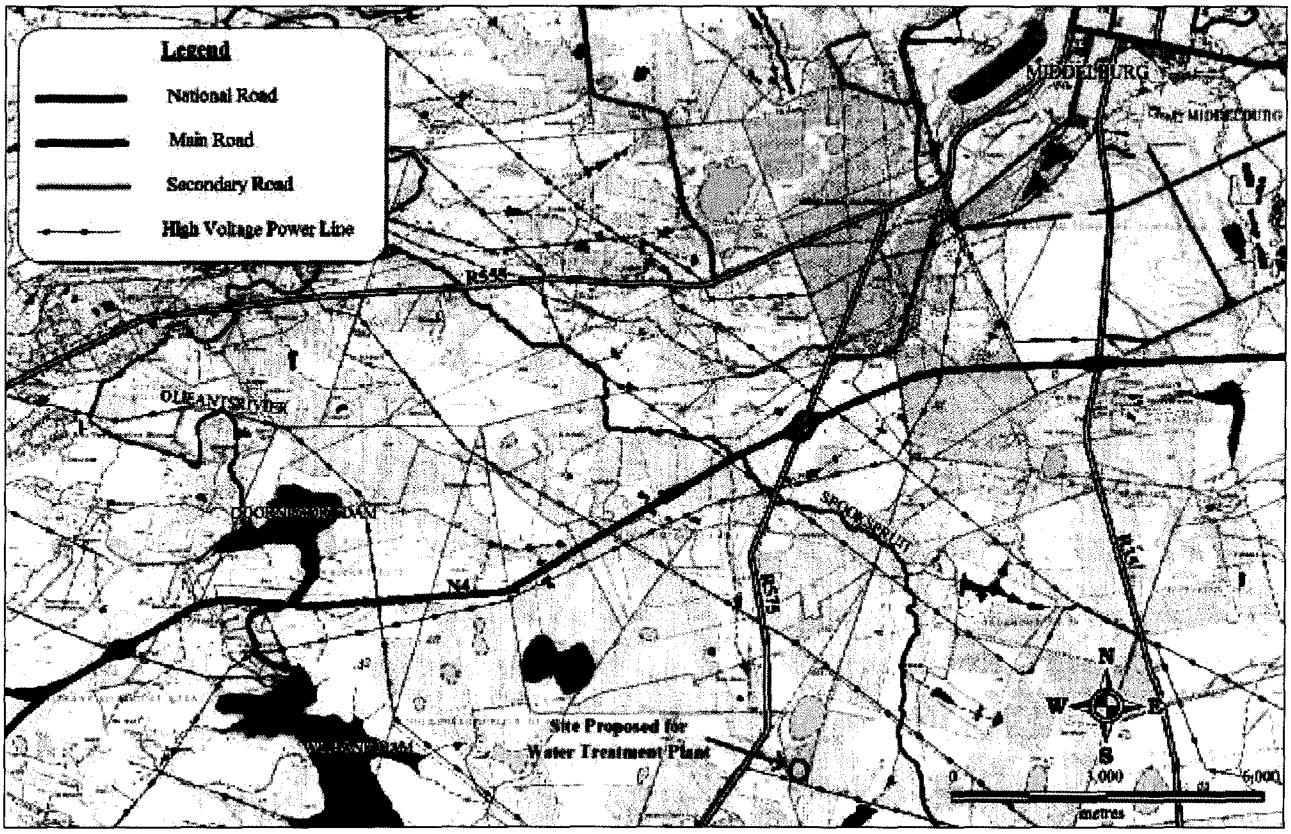

Figure 1. Regional setting of the site proposed for the development of the Water Treatment Plant.

3 Geological setting

The selected site is located in an area underlain by rocks of the Karoo Supergroup, represented locally by rocks of the Ecca Group. These rocks are all of a sedimentary origin and consist of shales, sandstones, grits, conglomerates and coal beds in places (refer to the 1:250,000 geological maps presented in Figure 2 and in Map M002MWRP of **Appendix A**).

Outcrops of diabase intrusives are known to occur within 1.5 km from the site, but no large-scale intrusive magmatic bodies or prominent fault zones have been mapped in the immediate vicinity of the site.

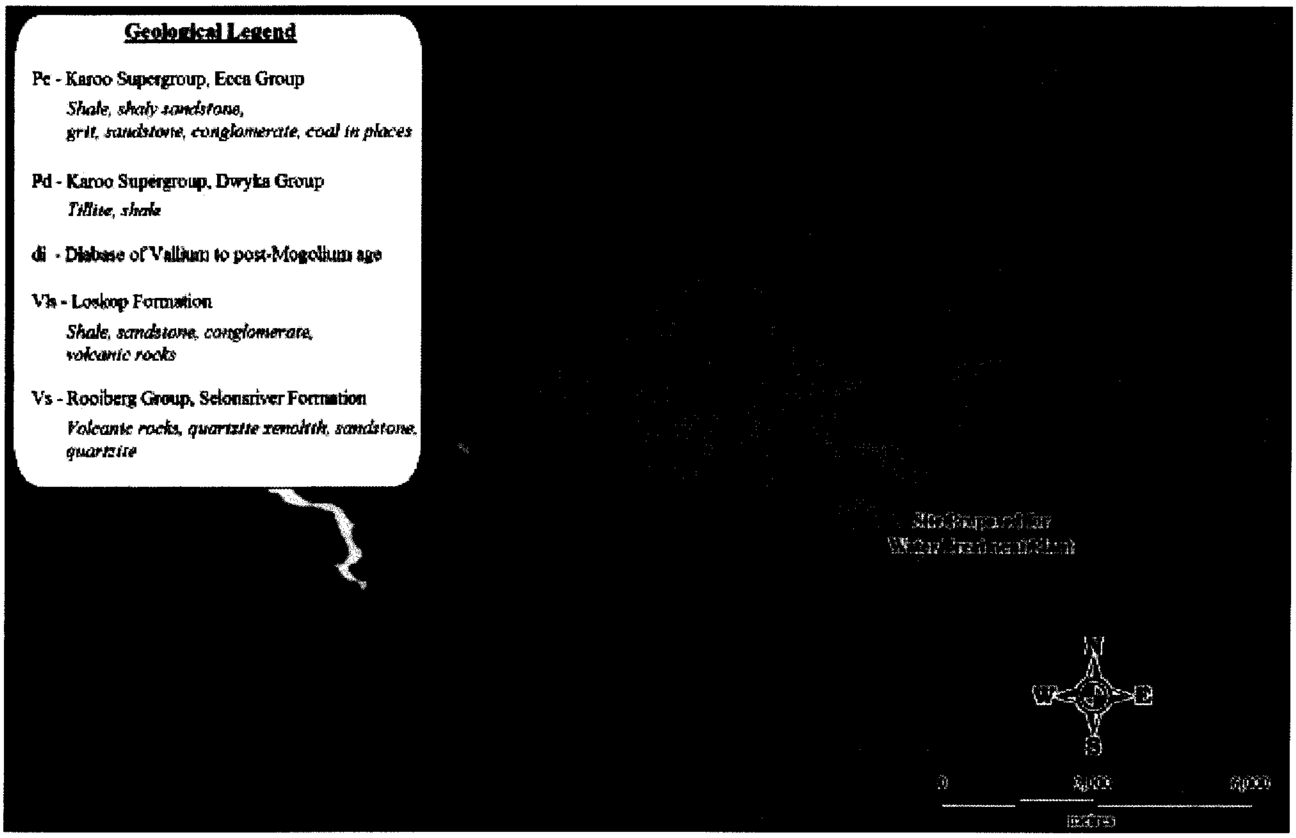

Figure 2. Geological setting of the site proposed for the development of the Water Treatment Plant.

4 Topography and drainage

The site proposed for the development of the WTP occurs in an area that displays gentle slopes to the east and north-east. These slopes are generally smaller than 1:8. The average topographic elevation of the site is approximately 1,550 metres above mean sea level (mamsl) (refer to Figure 3 and Map M003MWRP in **Appendix A**).

Drainage from the site is expected to take place predominantly in a north-north-easterly direction towards a non-perennial pan situated at a distance of less than 500 m from the site. Runoff from the site could also drain in north-easterly direction towards the Spookspruit which occurs at a distance of approximately 1.8 km. It is also possible that runoff form the site could eventually reach a non-perennial tributary of the Spookspruit that occurs south-west of the site (see Figure 4).

A watershed is present near the western perimeter of the site and extends in a northerly direction past the western shores of the non-perennial pan. At positions west of this watershed drainage takes place in a north-westerly direction towards the Hartbeesloop.

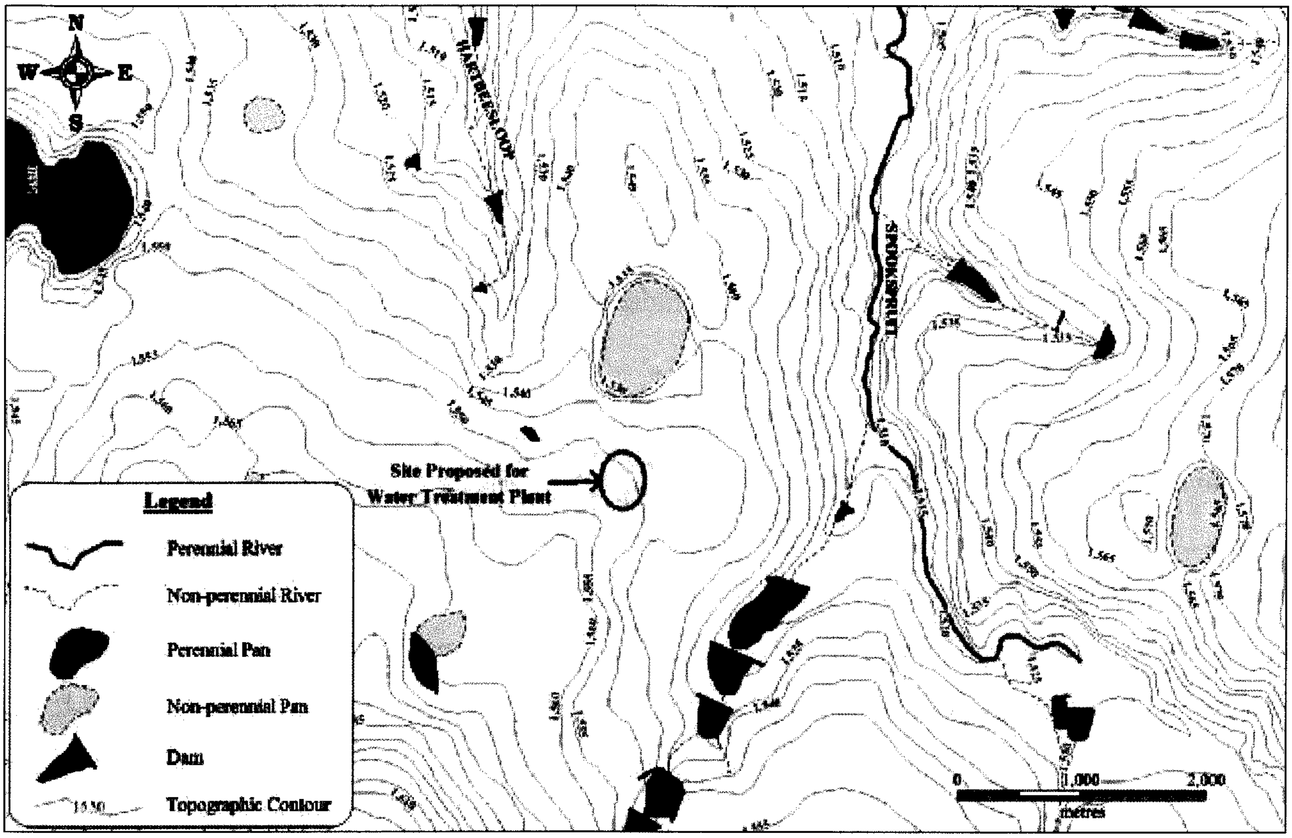

Figure 3. Surface topography and surface water bodies in the vicinity of the proposed development.

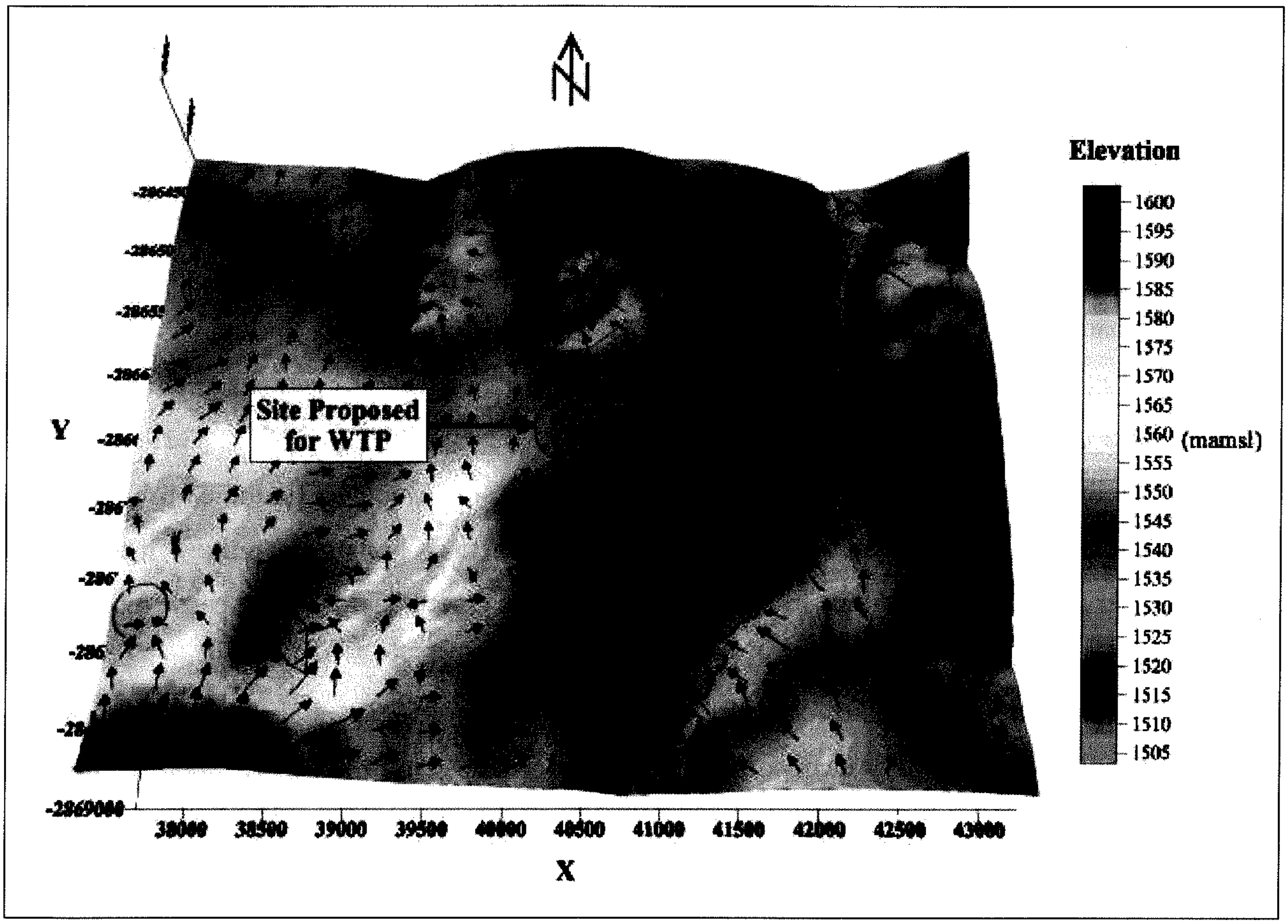

Figure 4. Surface topography and drainage in the vicinity of the proposed development. Blue arrows indicate the direction and relative magnitude of surface runoff flow.

5 Geophysical investigations

5.1 Introduction

The purpose of the geophysical investigations was to identify and delineate geological features that could potentially influence the groundwater environment by forming preferential pathways or barriers to groundwater flow and contaminant transport. Such geological features include intrusive magmatic bodies and fault zones.

Due to the high pressures and temperatures generated when magma intrudes the host rock, extensive fracturing and weathering of the host rock often occur in the vicinity of the intrusive bodies. These fractured and weathered zones generally have enhanced permeabilities and thus may form preferential pathways to groundwater flow in directions parallel to the strikes of the intrusives. The intrusive bodies themselves may furthermore be dense enough to form barriers to groundwater flow in directions perpendicular to these bodies, thereby compartmentalising the aquifer systems intersected.

Fault zones are also generally associated with extensive fracturing and increased permeabilities. Groundwater flow rates along these fault zones may be orders of magnitude higher than through the undisturbed host rock.

Two ground geophysical techniques, namely the magnetic and electromagnetic (EM) methods, were employed during the investigations. These reasons for selecting these techniques and the physical principles of which they operate are briefly described below:

Magnetic method

Many earth materials contain magnetic minerals such as magnetite, ilmenite and pyrrhotite. When geological units contain such magnetic minerals, these units may become magnetised by the earth's magnetic field, and may then have magnetic fields associated with them. These local magnetic fields that are due to the magnetised geological units will be superimposed on the earth's regional magnetic field. Measurements taken in the vicinity of magnetised geological units will therefore show local variations or departures from the undisturbed magnetic field of the earth (called the regional field). These departures are referred to as anomalies. The shapes of the anomalies are dependent on a number of factors regarding the physical properties and dimensions of the magnetised geological units. By incorporating existing knowledge on the geological conditions at the site being surveyed, the magnetic anomalies recorded during a survey may be interpreted in terms of the local geological conditions.

Since outcrops of diabase intrusives are known to occur within 1.5 km from the site proposed for the WTP, and since diabase is generally very magnetic, the magnetic method was used to the detect the possible presence of diabase dykes and/or sills in the near vicinity of the site. The magnetic survey was conducted using the G5 proton magnetometer manufactured by Geotron Systems (Pty) Ltd.

Electromagnetic (EM) method

EM methods make use of the fact that electromagnetic waves travelling through conductive media generally induce electrical current flows in these media. The behaviour of these electrical currents and their associated magnetic fields contains information about the conductivities of the media in which the currents flow.

In active EM methods, a time-varying source (primary) current is made to flow in a source loop. Associated with the primary current is a primary time-varying magnetic field. The time-varying magnetic field causes a time-varying magnetic flux through a body (geological unit) in the vicinity of the source. This time-varying magnetic flux sets up a time-varying emf in the geological unit. The time-varying emf drives electrical current flows (eddy currents) through the geological unit.

The behaviour of the induced eddy currents and their associated (secondary) magnetic fields is dependent on a number of parameters, including the conductivity of the geological unit. The emf induced in a receiver loop by the time-varying magnetic flux of the secondary magnetic field through the loop, may be measured. The measured emf contains information on the conductive properties of the geological unit. The subsurface conductivity distribution, as determined from the EM survey, may now be interpreted in terms of the local geological conditions by incorporating known information on the geology of the site.

The EM survey at the site proposed for the development of the WTP was conducted using the Geonics EM34-4 instrument. This instrument is an active, frequency domain system that calculates an apparent conductivity of the earth by measuring the quadrature (out-of-phase) component of the secondary magnetic field at low induction numbers. Since fault zones are often associated with elevated electrical conductivities, such zones could lead to detectable EM anomalies. Measurements are generally taken with two dipole orientations. Horizontal dipole (HD) orientations investigate at shallower depths and give good coupling with vertical structures while vertical dipole (VD) orientations investigate at deeper depths and give good coupling with horizontal structures.

An inter-coil spacing of 20 m was used for the EM survey at the WTP site. This separation allows investigation to depths of 20 – 30 m, depending on the conductivities of the earth materials. These depths of investigation were deemed adequate for the detection of near-surface fault zones that could act as preferential pathways for seepage from the WTP and associated infrastructure.

5.2 Study of aerial photographs

As part of the geophysical investigations overlapping aerial photographs of the area under investigation were studied to identify any natural features that could indicate the presence of variations in the local geological conditions. Such features could include visible changes in the vegetation, the presence of rock outcrops and prominent topographical changes. The overlapping aerial photographs of the study area are displayed in Figure 5 and Map M004MWRP of **Appendix A**.

No prominent changes in the natural features are discernible in the immediate vicinity of the site proposed for the development of the WTP. Surface activities to the east, south and west of the site (including farming, mining and housing infrastructure) have significantly disturbed the natural environment, making the identification of large-scale geological features that manifest themselves at surface very difficult.

North-west of the WTP site, at a distance of approximately 250 m, a circular area of lighter coloured vegetation (marked A in Figure 5) may be identified from the aerial photographs. This area appears to be the remnants of past farming activities.

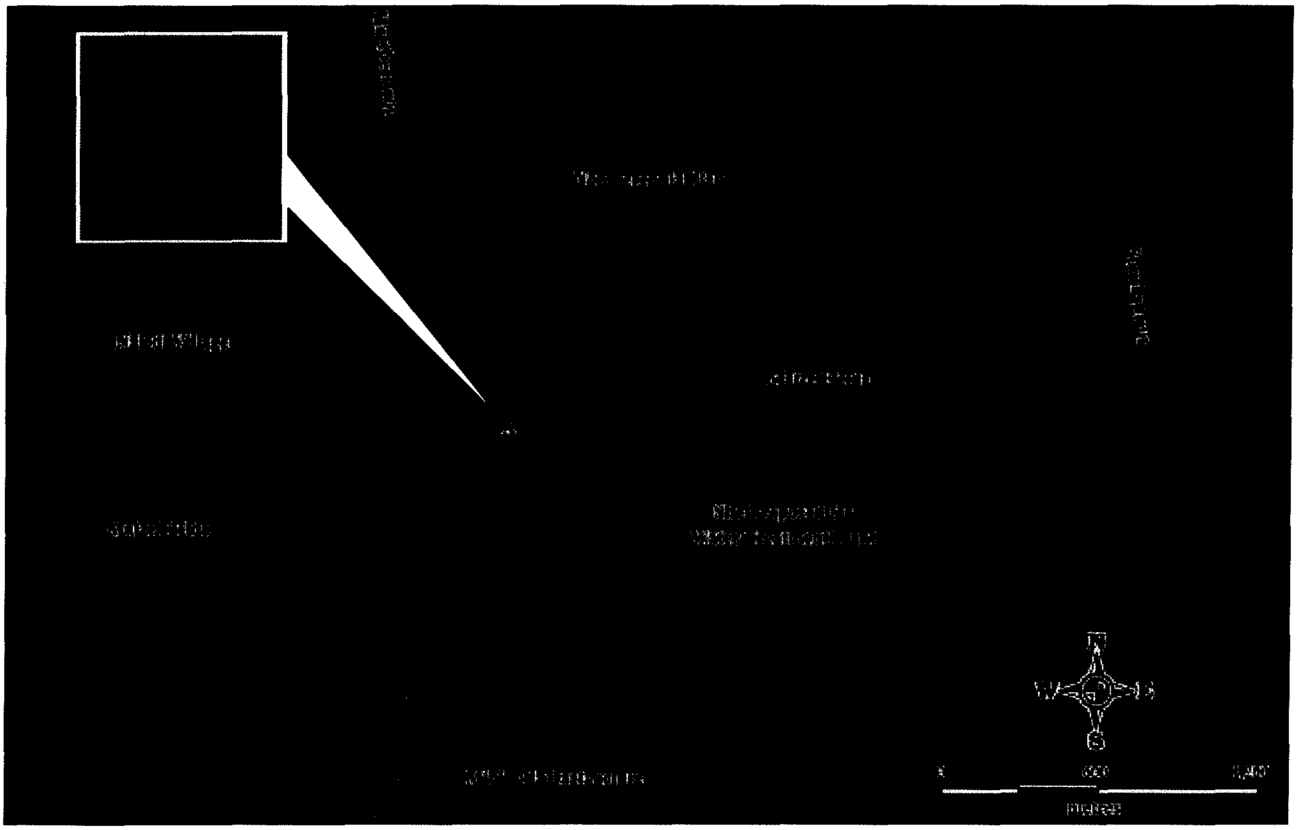

Figure 5. Aerial photograph of the area under investigation.

5.3 Study of airborne magnetics map

An airborne magnetics map covering the area of interest was obtained from the Council for Geoscience. This map was studied to investigate the presence of large-scale magnetic features in the vicinity of the WTP site. Such magnetic features could indicate the presence of large-scale intrusives that could significantly alter the groundwater environment.

In Figure 6 it can be seen that the WTP site is located in an area of relatively low magnetic activity with little lateral variation in the measured magnetic field strength, although large-scale low-amplitude features with north-east and north-west strikes may be identified. These features are, however, dwarfed by a ring-like structure to the south of the WTP site of which the northern perimeter occurs at a distance of approximately 3 km from the site. The ring-like feature is in all likelihood due to the presence of an intrusive magmatic body, such as a diabase ring-dyke. The geological feature responsible the large magnetic response is, however, adequately remote from the WTP site to have an insignificant influence on the aquifer system underlying the site.

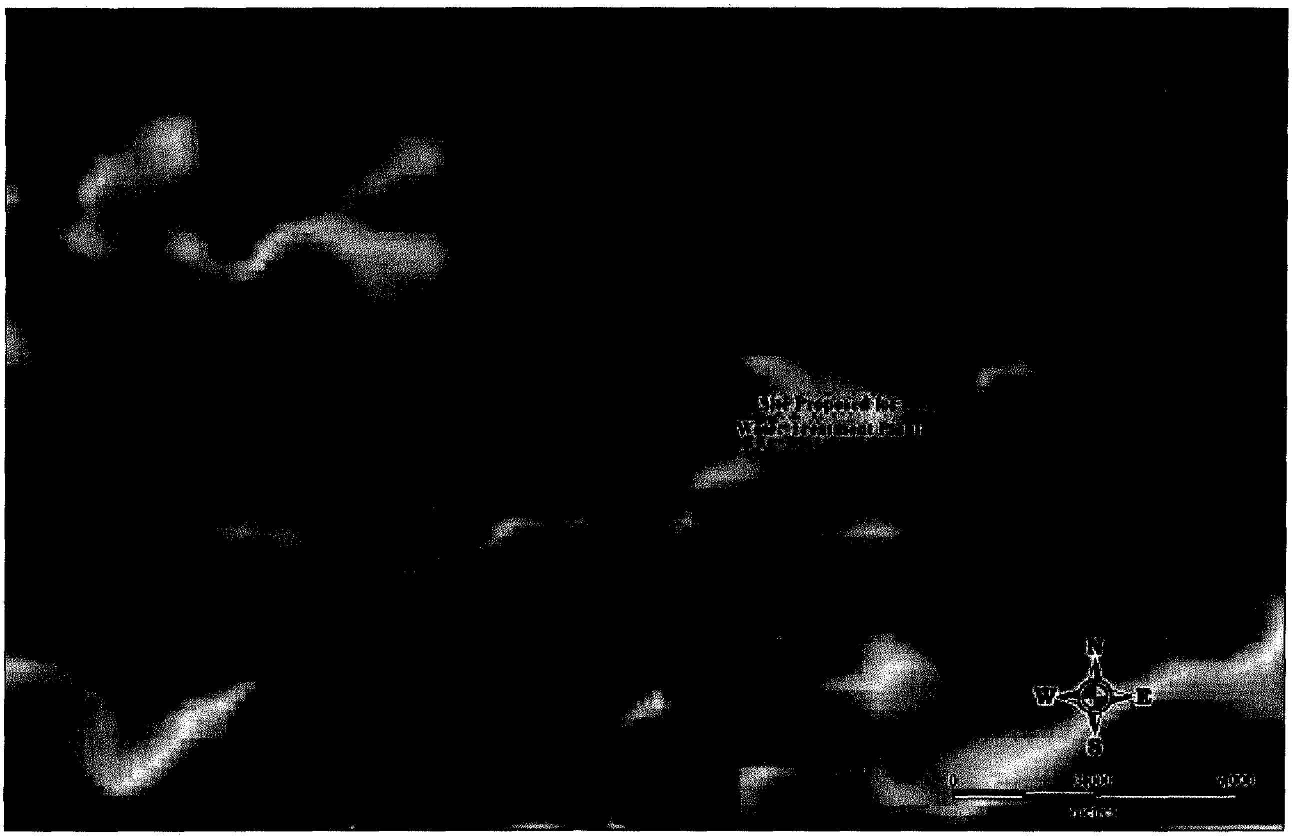

Figure 6. Airborne magnetic map covering the area under investigation.

5.4 Ground geophysical investigations

Geophysical data were recorded on 15 traverses across the proposed WTP site and at positions to the west, north and north-west of the site. The reason for extending the geophysical survey to these positions was to allow alternative locations to be considered for the WTP should the preferred location for some reason be found to be unsuitable for the proposed development. The positions and orientations of the 15 geophysical traverses relative to WTP site and surface infrastructure are shown in Figure 7.

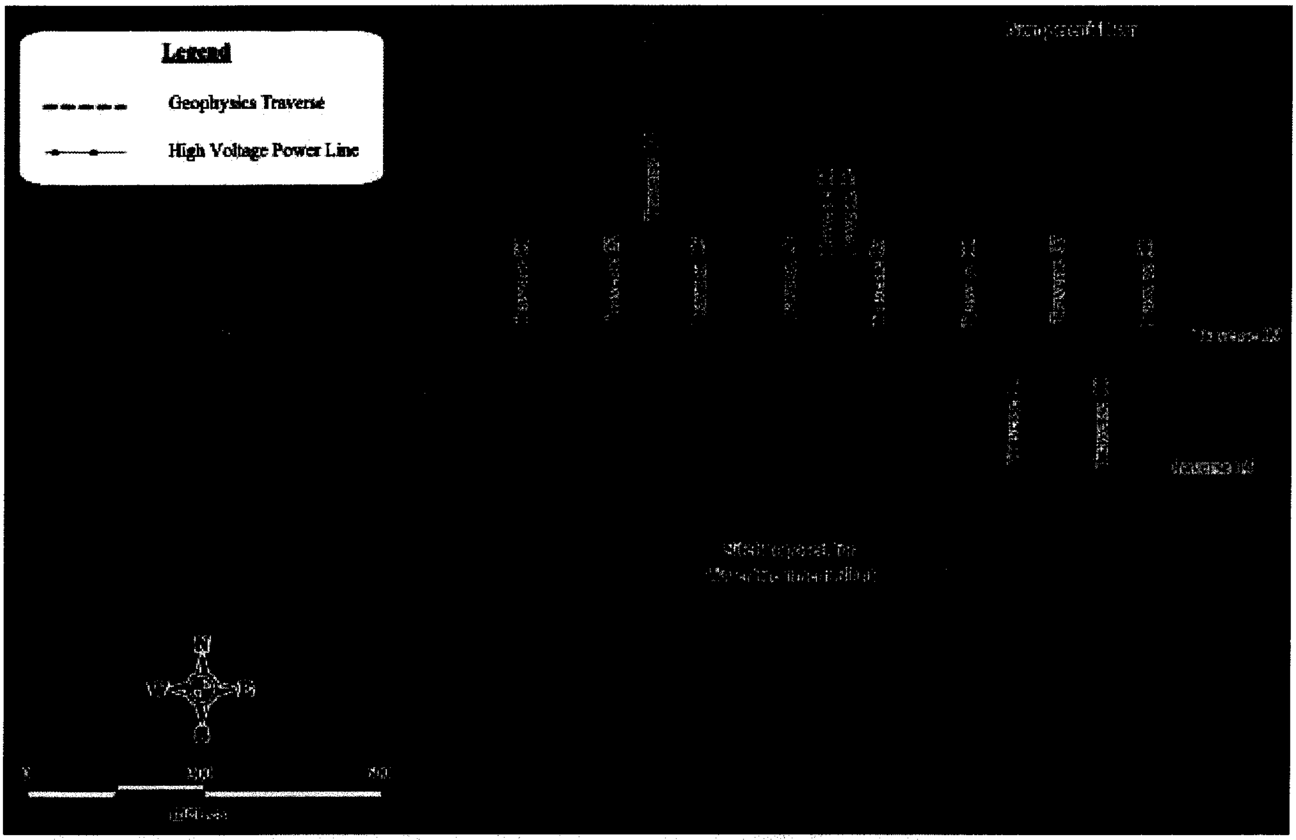

Figure 7. Positions and orientations of the ground geophysics traverses relative to the proposed WTP site and existing surface infrastructure.

5.4.1 Results of the ground geophysical investigations

During the geophysical survey, surface infrastructure in the form of high voltage power lines and wire fences acted as sources of noise that influenced both the magnetic and EM surveys and limited the lateral extent of the geophysical traverses on which high-integrity data could be recorded. Especially the high voltage power lines were a prominent source of noise. The results of the ground geophysical investigations are presented as profile plots in **Appendix B** and discussed below:

__Traverses 01-08__

These traverses formed part of the initial recognisance survey aimed at detecting prominent magnetic features in the vicinity of the WTP site. EM data were also recorded on Traverses 06 and 07. All the traverses had south/north strikes and with line spacings of approximately 150 m. Data were recorded at station spacings of approximately 10 m.

After subtraction of the estimated regional field, prominent magnetic anomalies were only observed on four of the eight traverses, namely on Traverses 02, 04, 05 and 07 (refer to **Appendix B**). A large negative anomaly with amplitude of 95 nT was detected on Traverse 02. This anomaly was, however, in all likelihood due to the presence of overhead electrical wires that crossed the traverse at an oblique angle. A large magnetic anomaly with an amplitude of more than 2,000 nT was recorded on Traverse 04 at the position of the circular area of lighter vegetation as observed in the aerial photographs (refer to Figure 5). The large magnitude and short spatial wavelength of the anomaly suggested the presence of near-surface magnetic materials. This observation further suggests that the circular area is due to past farming activities of which metallic infrastructure has been left in the subsurface. The magnetic anomalies observed along Traverses 05 and 07 are in all likelihood due to the presence of the high voltage power lines crossed by these traverses.

No prominent EM anomalies were observed on either Traverse 06 or 07. The EM response measured on these two traverses is a typical layered earth response, and suggests near horizontal layering of the sedimentary units underlying the proposed WTP site. Since the vertical dipole (VD) orientation allows investigation of materials at greater depths than the horizontal dipole (HD) orientation, it appears that deeper geological units are more conductive than the shallower units, possibly due to larger degrees of saturation. The VD orientation was very sensitive to EM noise from the high voltage power lines and high integrity data could only be recorded at positions removed by more than 150 m from the power lines.

Traverse 09

Magnetic data were recorded on Traverse 9 to allow investigation of the possible presence of magnetic intrusives with south/north strikes that were not detected on Traverses 01 to 08. Traverse 09 also served as a tie-line to allow the magnetic data recorded on the south/north traverses to be calibrated with respect to a common base value for the regional field.

The only prominent magnetic anomaly recorded on Traverse 09 corresponded to the position of the circular area of lighter vegetation thought to be due to the remnants of farming infrastructure. A negative anomaly with amplitude of approximately 800 nT was observed at this position.

Traverse 10 and 11

Magnetic and EM data were recorded on Traverses 10 and 11 in order to increase the spatial density of the geophysical data at the position of the proposed WTP site. No magnetic or EM anomalies consistent with the presence of linear magmatic intrusives or fault zones were observed on either of these traverses. A small anomaly with amplitude of approximately 23 nT was recorded along Traverse 11, but this anomaly does not extend to the two adjacent traverses (Traverses 06 and 07) and may be due to the presence of metal objects at surface or in the shallow subsurface.

Traverse 12 and 13

Traverses 12 and 13 extended across the circular area of lighter vegetation that occurs north-west of the WTP site. Magnetic data were recorded on Traverses 12 while both magnetic and EM data were recorded on Traverse 13. The purpose of these two traverses was to further investigate the circular area to confirm that the large magnetic responses observed on Traverses 04 and 09 were indeed due to subsurface materials that remained after the removal of surface farming infrastructure and not due to some geological feature that manifests itself at surface.

Large magnetic and EM anomalies were recorded on Traverses 12 and 13. These anomalies display large amplitudes and short spatial wavelengths consistent with the presence of near-surface metallic objects. The anomalies also coincide very well with the lateral extent of the circular area. All the above observations suggest that this area is indeed due to metallic objects left behind when farming on the property ceased.

Traverse 14

The purpose of Traverse 14 was to confirm that the magnetic anomaly observed on Traverse 02 was due to the overhead electric wires crossed by this traverse and not some geological feature. The absence of prominent magnetic anomalies on Traverse 14 indicated that the anomaly observed on Traverse 02 was in fact due to manmade noise in the form of the overhead electric wires.

Traverse 15

Traverse 15 extended across the site proposed for the WTP along a west/east strike. EM data were recorded on this traverse to investigate the possible presence of conductive zones with south/north strikes that were not intersected by Traverses 06, 07, 10 or 11. No prominent EM anomalies were, however, observed on Traverse 15, suggesting the absence of zones of high conductivity, such as fault zones or highly weathered zones.

A contour map of the estimated regional magnetic field intensity in the vicinity of the WTP site is displayed in Figure 8 while the "anomalous" magnetic field intensity, obtained after removal of the regional field, is shown as a contour map in Figure 9. The regional field displays spatial wavelengths in the order of a couple of hundred metres to kilometres, indicating that the regional field has its origin in magnetic materials that occur at great depth. The regional field is relatively consistent at the position of the proposed WTP site.

No magnetic anomaly consistent with a prominent intrusive magmatic body can be observed in the contour map of the anomalous magnetic field. It therefore seems that the area under investigation is free of magnetic intrusives such as diabase or dolerite.

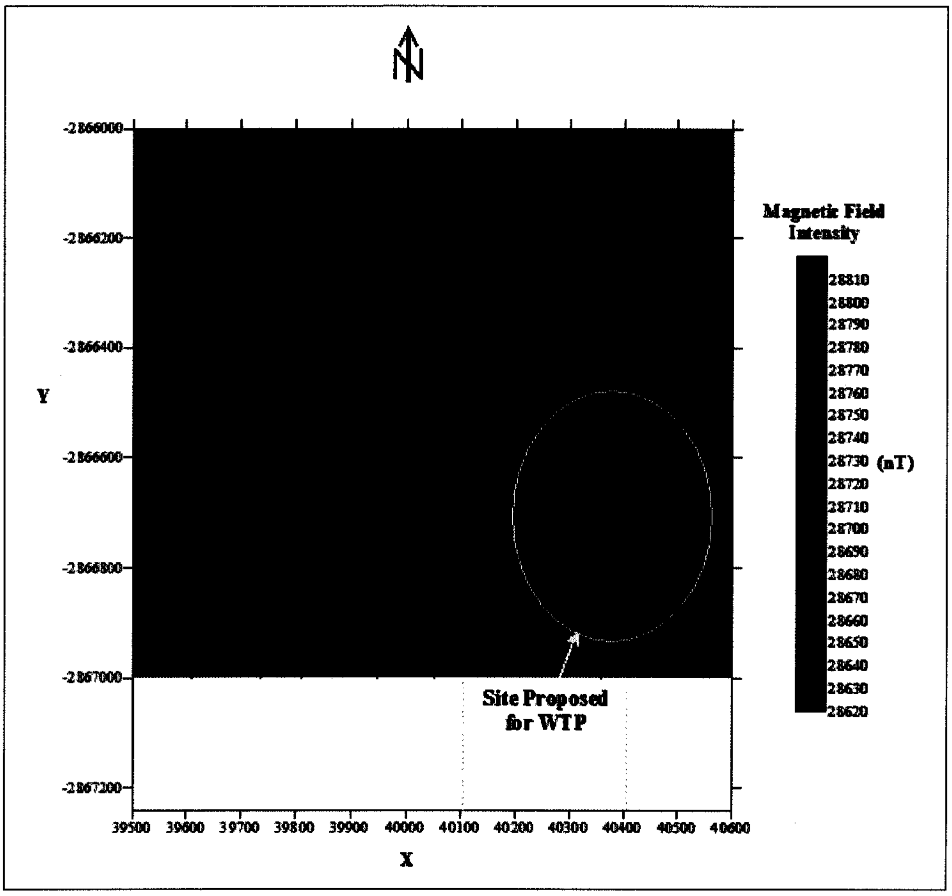

Figure 8. Contour map of the estimated regional magnetic field intensity.

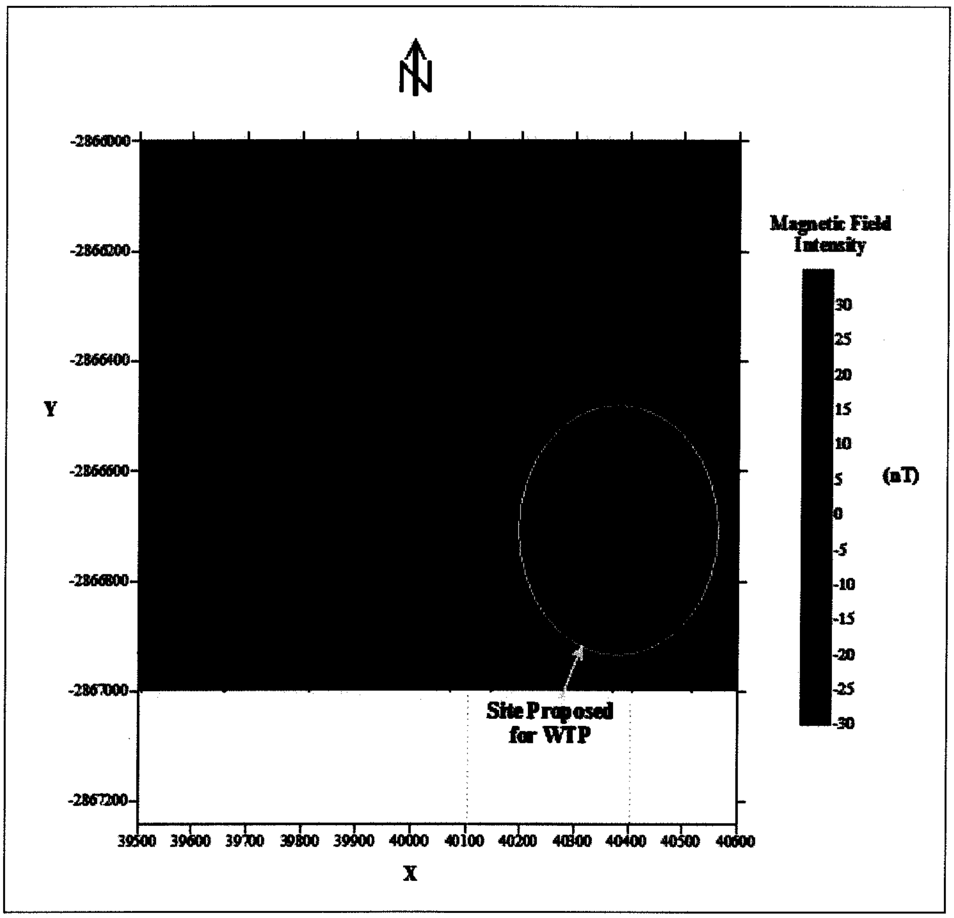

Figure 9. Contour map of the magnetic field intensity after removal of the estimated regional field.

5.5 Proposed drilling targets

Since the geophysical investigations did not identify any prominent geological feature in the vicinity of proposed WTP site, investigative and monitoring boreholes were sited by considering the local topographic gradient. Since the groundwater table generally emulates the surface topography, groundwater flow is expected to take place in directions parallel to the local topographic gradient. One borehole (BH01) was sited up-gradient (south-west) of the proposed site, while the other two boreholes (BH02 and BH03) were sited at down-gradient positions to the north-east and north of the proposed site. The boreholes that are to be drilled at the sites could serve to:

- Obtain information on the background groundwater conditions prior to the development of the WTP, including water quality and water table elevation,
- Investigate the hydraulic properties of the intersected aquifer systems by means of different hydraulic tests, and,
- Act as monitoring boreholes to evaluate impacts of the development on the groundwater environment during the construction, operational and decommissioning phases of the project.

The positions of the proposed boreholes are shown in Figure 10 while their coordinates are listed in Table 1.

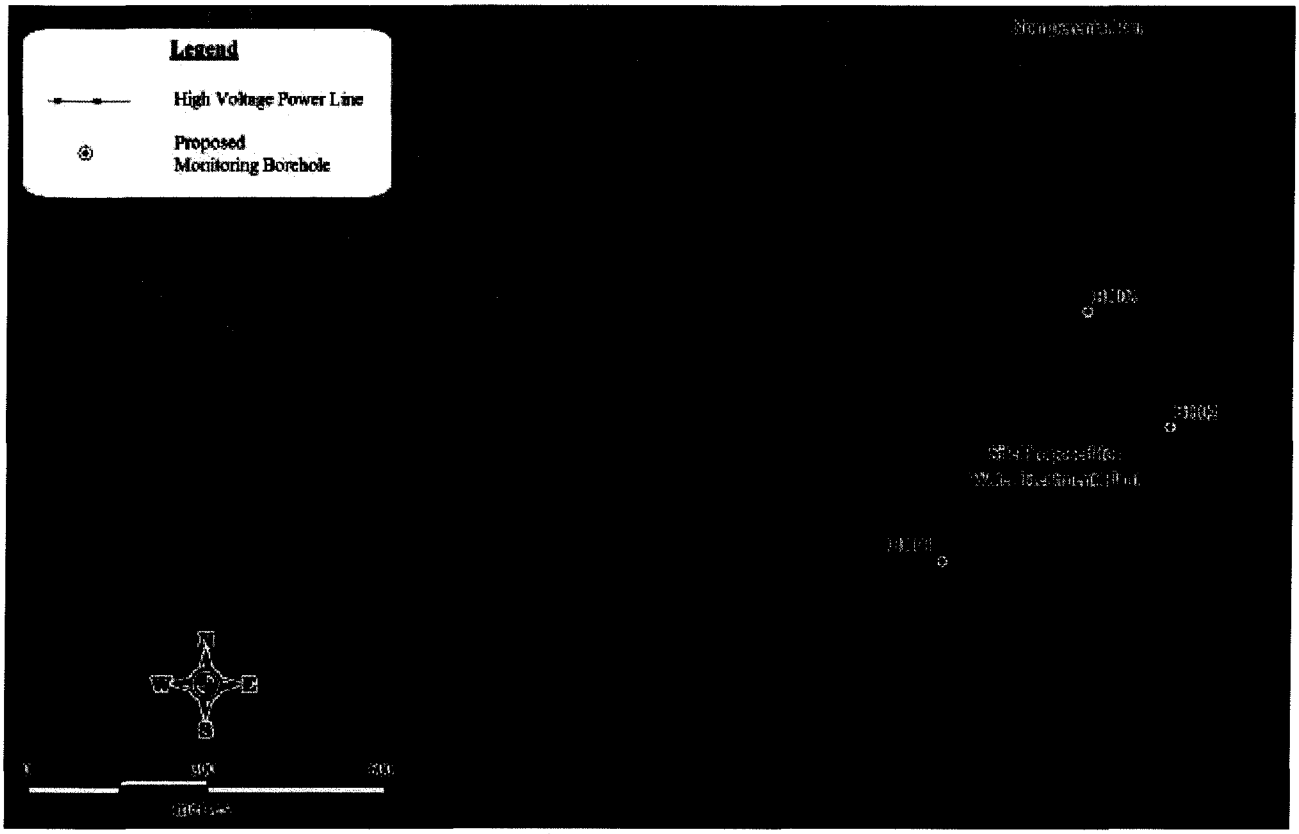

Figure 10. Proposed drilling targets for the installation of investigative and monitoring boreholes.

Table 1. Coordinates of the proposed positions for the drilling of investigative and monitoring boreholes.

Borehole #	WGS 84		WGS 84, LO29		Cape Datum, LO29	
	Latitude (°S)	Longitude (°E)	X	Y	X	Y
BH01	25.91207	29.40083	40,160.31	-2,867,154.10	40,188.98	-2,866,857.87
BH02	25.91003	29.40463	40,541.25	-2,866,929.04	40,569.92	-2,866,632.81
BH03	25.90827	29.40323	40,402.07	-2,866,734.28	40,430.74	-2,866,438.05

6 Summary and Conclusions

This report summarizes findings made during the geophysical investigations conducted by Orpheus Hydrogeophysics at a site proposed for the development of a Water Treatment Plant at Middelburg Mine. The main purpose of the geophysical survey was to detect and delineate geological features that could potentially influence the groundwater environment. As part of the geophysical investigations, the following actions were taken:

- A geological map covering the area under investigation was studied to determine the geological conditions that can be expected and to ascertain whether any large-scale geological features have been mapped in the immediate vicinity of the selected site.
- Aerial photographs of the area under investigation were studied in order to identify any natural features that could indicate the presence of variations in the local geological conditions.
- An airborne magnetic map covering the area of interest was studied to identify large-scale magnetic features that could indicate the presence of intrusive magmatic bodies.
- A site visit was conducted to allow familiarisation with the site layout and orientation.
- Ground magnetic and electromagnetic data were recorded on fifteen traverses across and in the vicinity of the selected site.
- All the geophysical data recorded during the survey were processed and interpreted in terms of the local geological and geohydrological conditions.
- Targets for the drilling of investigative and monitoring boreholes were identified.

The geophysical investigations did not identify any prominent geological feature in the vicinity of proposed WTP site. This observation suggests that the site selected for the development of the WTP poses no problems in terms of the presence of major geological features that could influence the groundwater environment by forming preferential pathways to groundwater flow and contaminant migration. However, additional geohydrological investigations are still required to evaluate the hydraulic properties of the geological units underlying the site before any conclusions can be drawn on the suitability of the site for the proposed development.

FD Fourie
(Ph.D. Pr.Sci.Nat.)

11 June 2008
Date

D.6 Geotechnical and Land Capability Assessment

MIDDELBURG MINE SERVICES

FEASIBILITY GEOTECHNICAL EVALUATION OF TWO PROPOSED WATER TREATMENT PLANTS MIDDELBURG MINE, MIDDELBURG

Report No.: JW107/08/B478 - Rev 0

October 2008

Jones & Wagener
Consulting Civil Engineers
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Prepared	Geologist	B. Antrobus	16 July 2008	
Reviewed	Scientist	B. Candy	September 2008	
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July 2008	Rev. A	Draft report	Beth Candy	Word document	1
September	Rev. A	Draft report	Client	Electronic	1
October	Rev. 0	Final report	Client	Hard copy Electronic copy on CD	1 1

SYNOPSIS

This report details the findings of a feasibility study undertaken to evaluate the founding conditions of two sites selected for the proposed Water Treatment Plant.

The Preferred Site is characterised predominantly by a flat to gently convex crestal area. A pan and drainage zone are present in the north east and south west areas respectively.

A dense to very dense ferruginised horizon is present from a depth of approximately 0,8m. This horizon is suitable for foundations but bearing pressures should not exceed 300 kPa.

The Alternate Site is generally characterised by a rough, convex sideslope. Boulder dolerite outcrop is present in the northern portions of the site. The residual dolerite comprises dolerite boulders (spheroids) in a soft residual silt matrix.

The major portion of the site is underlain by a dense to very dense residual sandstone from a depth of approximately 500mm.

The residual sandstone is suitable for foundations but bearing pressures should not exceed 350 kPa.

The feasibility study evaluated general shallow founding conditions at the two sites. Once the final site selection is made, a detailed geotechnical investigation should be undertaken for the defined area. Investigation procedures will be determined by the structures (i.e. loads, sensitivity, etc) but would include auger drilling, rotary core drilling, etc.

Founding conditions at the Preferred Site and Alternate Site (sandstone section) are similar but at the Alternate Site, more extensive earthworks and site preparation is likely.

The agricultural review of the two areas has indicated that although arable land is present, it is probably better suited to grazing as soils exhibit a poor ability to retain and supply nutrients for plant growth. Soil Form and capability maps of the areas are provided.

MIDDELBURG MINE SERVICES

FEASIBILITY GEOTECHNICAL EVALUATION OF
TWO PROPOSED WATER TREATMENT PLANTS
MIDDELBURG MINE, MIDDELBURG REPORT NO: JW107/08/B478 - Rev 0

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APPENDICES

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MIDDELBURG MINE SERVICES

FEASIBILITY GEOTECHNICAL EVALUATION OF
TWO PROPOSED WATER TREATMENT PLANTS
MIDDELBURG MINE, MIDDELBURG

REPORT NO: JW107/08/B478 - Rev 0

1. INTRODUCTION

The geotechnical investigation forms a section of an Environmental Impact Assessment report for the proposed Water Treatment Facility at Middelburg Mine.

The investigation was undertaken under Order No. 4300153009 requested by BHP Billiton Energy Coal SA Ltd.

1.1 Definitions and Abbreviations

1.1.1 Commercial

J&W	Jones & Wagener (Pty) Ltd - Geotechnical consultant

1.1.2 Technical

Survey & Coordinates:

m amsl	metres above mean sea level
NGL	Natural Ground Level
WGS84	World Geodetic System 1984, in latitude and longitude

Investigations:

TLB	Tractor-mounted Loader / Backhoe
TPxx	Test Pit position

Soils Classification:

Hw	Hillwash
Fe	Ferruginised
Gw	Gullywash
Trans	Transition
Res	Residual
Dol	Dolerite
SS	Sandstone
G1 - G10	Standard classification of natural road building materials according to

	TRH14[1]
CBR	**C**alifornian **B**earing **R**atio
MDD	**M**aximum **D**ry **D**ensity
Mod AASHTO	**Mod**ified **AASHTO** test for determining MDD and OMC
OMC	**O**ptimum **M**oisture **C**ontent
PI	**P**lasticity **I**ndex
SG	**S**pecific **G**ravity

2. NATURE AND SCOPE OF THE STUDY

The feasibility geotechnical investigation was to evaluate, compare the geotechnical conditions, founding options and agricultural capability of the two potential sites identified as the preferred site and the alternate site. The investigation also included an evaluation of profile conditions along approximately 90 kilometres of proposed water pipelines related to the mining areas and water treatment location. The review for the pipeline will be discussed in a separate report and is therefore excluded from this report.

3. METHOD OF INVESTIGATION

An air photo interpretation (API) to identify different terrain units and identify potential test hole sites was undertaken.

The test holes were positioned to ensure that the different terrain units identified in the API were adequately investigated. All test pits were excavated either to reach or refusal of the TLB. All test pits were logged by an engineering geologist according to recognised standards[2].

Laboratory testing included grading and indicators, Mod. AASHTO and CBR on samples taken from representative horizons.

4. SITE DESCRIPTION

The locations of the two sites are shown on Figure 1.

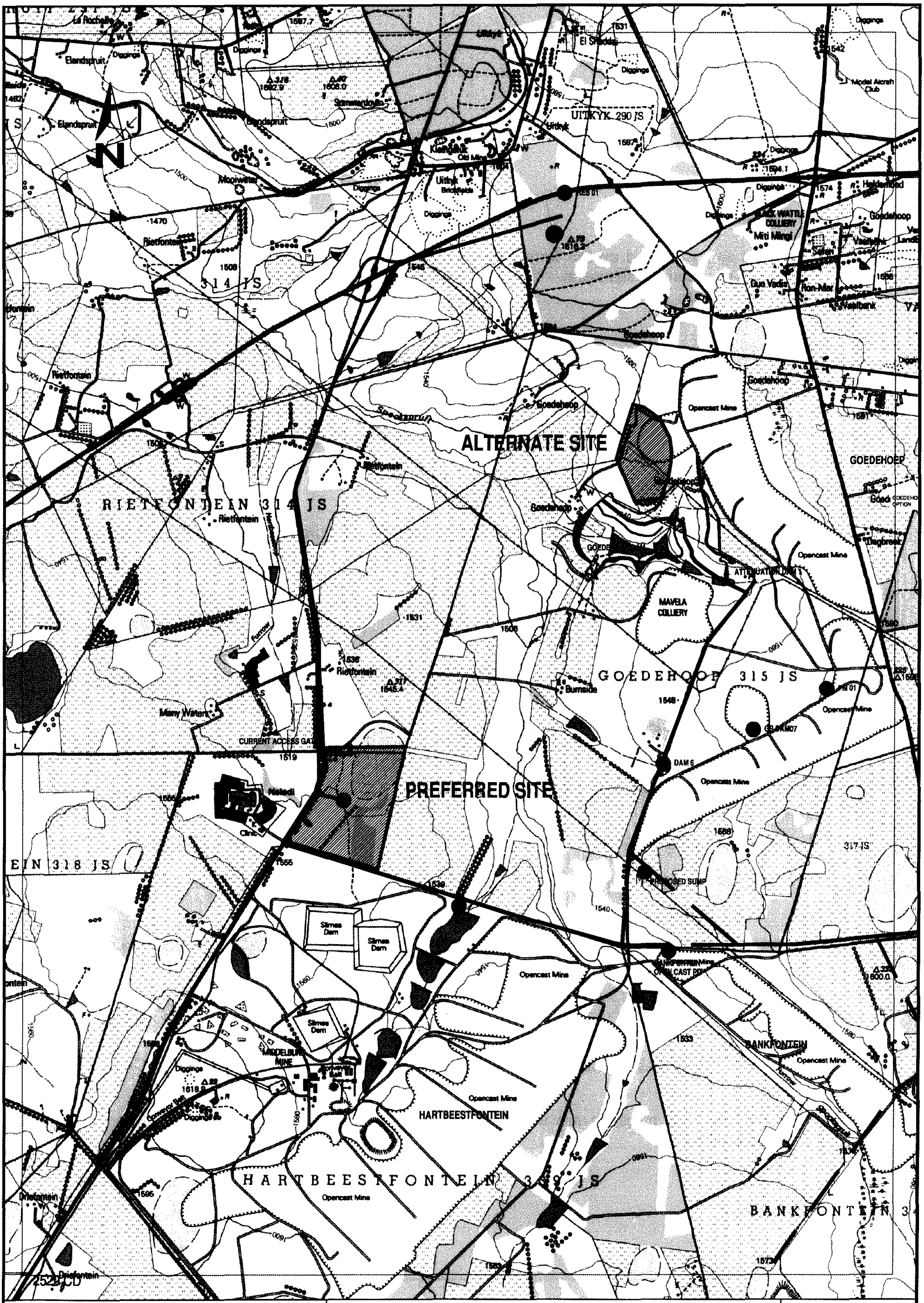
4.1 Preferred site

The preferred site is located on the farm Hartebeesfontein 339IS, opposite Naledi Village. The area is characterised by a broad convex crestal area at an approximate elevation of 1540 m amsl. In the north, a well defined pan is present and along the western boundary, a poorly defined drainage depression is present.

---

[1] **TRH14:1985. Guidelines for Road Construction Materials.** Committee for State Road Authorities, Department of Transport, Pretoria.

[2] Brink A.B.A. and Bruin R.M.H. (eds) (1990) **Guidelines for Soil and Rock Logging in South Africa,** 2nd Impression 2002. Proc. Geoterminology Workshop. SAIEG - AEG - SAICE 1990.



Scale 1 : 100 000

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MIDDELBURG MINE - Water Treatment Plant

Locality Plan

Figure 1

Job No B478

4.2 Alternate site

This site is located on the farm Goedehoop 315JS and is characterised rough convex crestal to convex sideslope. The elevation across the site ranges from 1560 mamsl to 1540 mamsl.

5. GEOLOGY

The study area is underlain by sedimentary rocks of the Karoo Sequence. Locally these include shales and sandstones of the Vryheid Formation, Ecca Group. Dolerite intrusions are common within the Karoo Sequence. A sill intrusion was noted at the alternate site.

6. GEOTECHNICAL CONSIDERATIONS

This section details the profiles, the founding conditions and recommendations for each of the potential sites.

6.1 Preferred site

6.1.1 Soil profiles

The soil profile encountered on the site is controlled by the topographic expressions on site and consequently consists of:

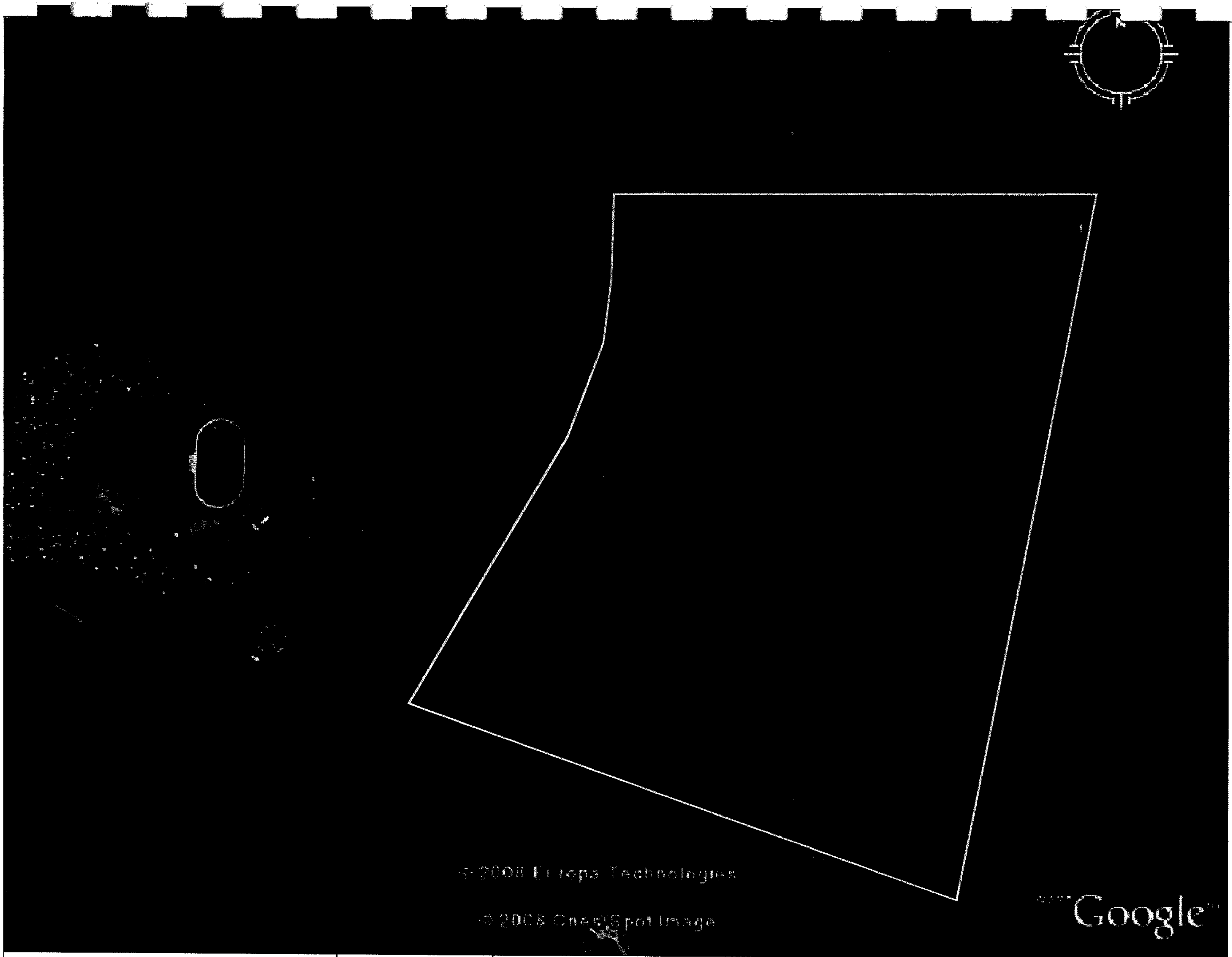
- A crestal profile.
- A gully profile.
- A pan profile.

Crestal profile:

The typical profile for the Crestal Area that characterised most of the site comprises:

- Hillwash: 800mm of moist, yellow-brown, loose, silty sand on
- Ferruginised hillwash: relatively closely packed ferricrete nodules in above matrix. This horizon extends to 1,2m and overlies a
- Ferruginised transition: moist, yellow-brown mottled grey, dense to very dense, moderately cemented and ferruginised clayey sand with ferricrete nodules. Below a depth of 2,2m, this horizon grades into
- Residual siltstone: this is a moist, yellow-brown streaked grey, stiff, clayey silt.

The test hole positions are shown in Figure 2 and detailed soil profiles are given in Appendix A1.



COORDINATES - (MSS Local grid Lo29)

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PTP02	-40156	2866794
PTP03	-39861	2866674
PTP04	-39607	2866610
PTP05	-39535	2866266
PTP06	-39957	2866404
PTP07	-40362	2866446
PTP08	-40596	2866195
PTP09	-40490	2866048
PTP10	-40475	2865990
PTP11	-40313	2866104
PTP12	-39961	2866004
PTP13	-39789	2865755
PTP14	-40135	2865853
PTP15	-40190	2865714
PTP16	-40007	2865598
PTP17	-40172	2865482
PTP18	-39855	2865469

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MIDDELBURG MINE - Water Treatment Plant
Preferred Site - Test Hole Positions

Scale 1 : 12 500

Figure 2

Job No B478

Gullywash profile:

This profile is located along the south-western portion of the property and comprises:

- 800mm wet, grey-brown, loose, silty sand on
- moist, dark orange-brown mottled grey, very dense, moderately cemented and ferruginised, silty sand (ferruginised transition).

Pan profile:

The profile encountered around the pan present in the north east corner of the site comprised a thin (300mm) grey, leached hillwash on a well cemented to hardpan ferricrete around the sides of the pan while in the pan basin approximately 700mm of wet, mottled grey, sandy clay on a wet clay-silt was present.

6.1.2 *Soil Properties*

The transported soils are sandy in nature and pinhole voided and consequently consolidation / collapse characteristics rather than heave will dominate.

The ferruginised hillwash and transition are clayey sands and the laboratory tests indicate that these soils although clayey will exhibit a low heave potential. These soils are generally moderately to well ferruginised and cemented.

The residual soils are typically sandy silts and also exhibit low heave potentials.

Table 1 summarises main soil properties.

Table 1: Soil Properties

HORIZON	HILLWASH	GULLYWASH	FER TRANS	RESIDUAL
PROPERTY				
Gravel	50	1	10 - 3	9
Sand	30 - 77	47	40 - 45	44
Silt	11 - 14	19	18 - 34	29
Clay	9	34	9 - 12	19
PI	NP - 12	8	4 - 12	9
LL	NP - 24	37	25 - 32	22
LS	0 - 5.5	9	2 - 7	4
Heave	Low	Low	Low	Low
AASHTO Classification	SC - SM	CL	SC/SM	-
Mod	-	-	2000 - 2100	-
CBR @ 95%	-	-	32 - 41	-
TRH14 Classification	-	-	G5	-

6.1.3 *Founding recommendations*

The hillwash horizon is not considered suitable for foundations due to the potential for both collapse and consolidation settlements that could occur.

The well cemented and ferruginised hillwash to transition horizon generally encountered at a depth of approximately 0,8m is suitable for founding purposes.

Figure 3 illustrates likely settlement magnitudes for different spread footing sizes and bearing pressures up to 350 kPa. Should the structures be either heavily loaded or settlement sensitive, a piled foundation will have to be considered. A detailed investigation of founding conditions would have to be evaluated once the final position of the proposed Treatment Plant is selected.

6.2 Alternate site

6.2.1 *Soil profiles*

The area is characterised by a crestal and sideslope topography. The crestal area is underlain by a dolerite sill while the sideslope is underlain by Karoo Sediments.

The typical profiles recorded can be summarised as follows:

- Sideslope profile.
- Crestal profile.

Detailed soil profiles are provided in Appendix A2 and test hole positions are provided in Figure 4.

Sideslope:

This profile represents the bulk of the area and is characterised by:

- a colluvium / hillwash horizon of 400mm of brown silty sand with relatively closely packed gravels and ferricrete nodules. This overlies
- a residual sandstone of slightly moist, reddish brown streaked yellow-brown, dense, silty sand with fine residual gravels. Locally residual siltstone encountered. Below a depth of approximately 1,4m this grades into a dense to very dense residual sandstone.

The material from 0,4m to 1,4m is locally ferruginised and may extend to 0,7m.

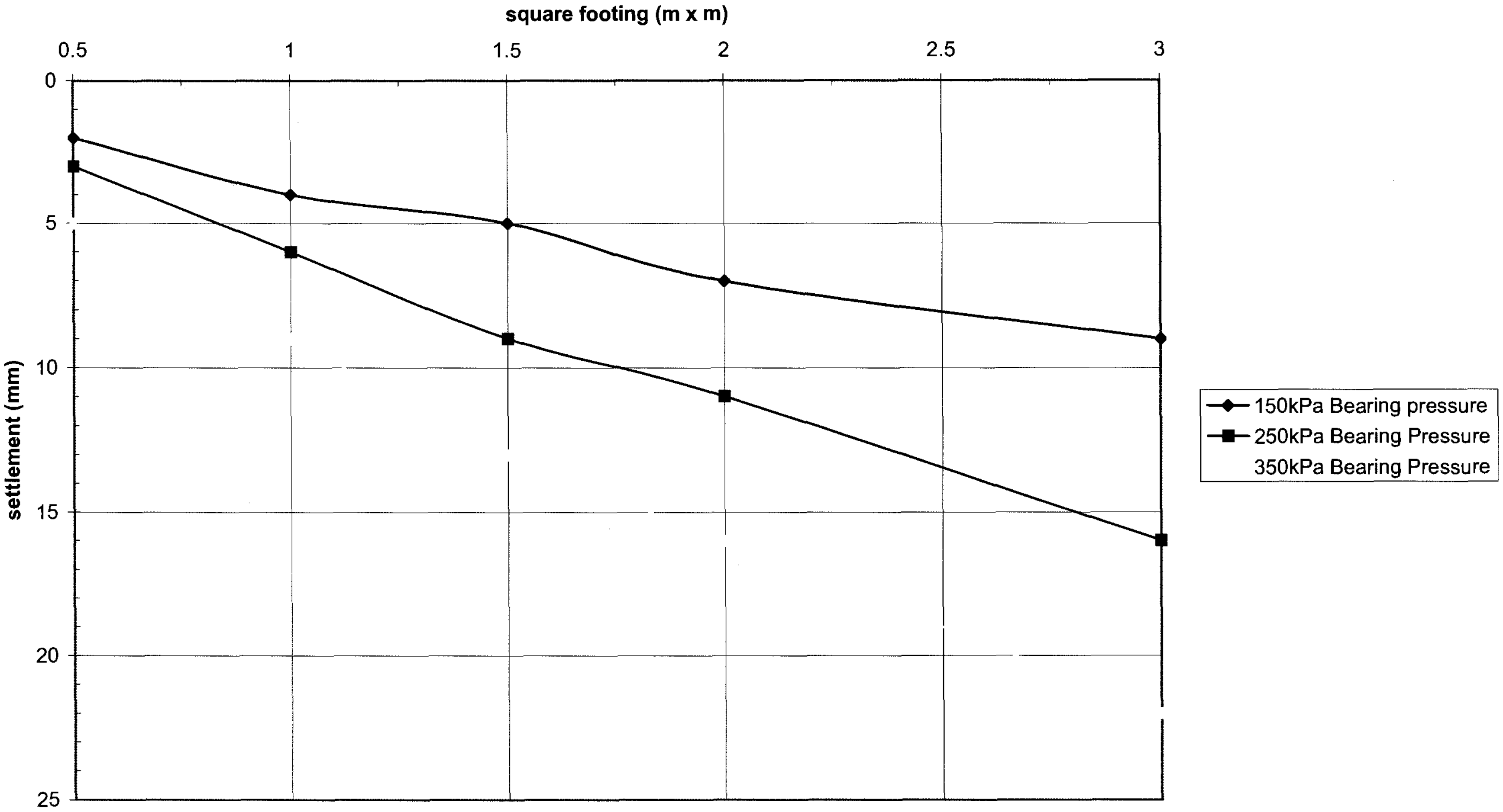
Crestal profile:

This profile is located in the north western section of the site and is characterised by:

- 700mm thick boulder dolerite in a brown clayey sand matrix with ferricrete nodules on
- a residual dolerite of moist, reddish brown, soft to firm, silty clay with scattered hard rock dolerite boulders.

The dolerite boulders encountered on surface and within the profile are highly variable in size.

FIGURE 3 : **Estimated Settlement for different bearing pressures. Founding on dense Ferricrete or Residual Sandstone**



COORDINATES - (MSS Local grid Lo29)		
	-Y	+X
ATP01	-43872.7	2861255.7
ATP02	-43880.6	2861047.4
ATP03	-43933.7	2861305.7
ATP04	-43685.7	2861501.7
ATP05	-43873.7	2861616.7
ATP06	-44169.7	2861715.7
ATP07	-43903.7	2861857.7
ATP08	-43666.7	2861741.7
ATPT1	-44009.7	2862376.7
ATPT2	-43750.7	2862358.7

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MIDDELBURG MINE - Water Treatment Plant
Alternate Site - Test Hole Positions

Scale 1 : 10 000

Figure 4

Job No B478

6.2.2 *Profile properties*

The residual dolerite comprises a clayey silt to silty clay and exhibits a moderate heave potential. The consistency of the matrix is, however, soft to firm and consequently consolidation settlement would also occur.

A summary of soil properties is provided in Table 2.

Table 2: Soil Properties

HORIZON	HILLWASH	RESIDUAL SANDSTONE	RESIDUAL DOLERITE
PROPERTY			
Gravel	2-50	37	0-5
Sand	30-64	40	20-23
Silt	11-24	17	35-46
Clay	9-10	7	33-41
PI	11-12	10	23-25
LL	24-26	31	50-55
LS	5-5.5	5	11-12
Heave	Low	Low	Medium
AASHTO Classification	Sc	Sc	MH/CH

6.2.3 *Founding recommendations*

The residual dolerite is not considered a suitable founding horizon. Figure 5 summarises expected settlement magnitudes for light, flexible structures located on the dolerite.

The residual sandstone, however, would provide suitable founding conditions. Likely settlement magnitudes for different spread footings sizes and bearing pressures up to 350 kPa are shown in Figure 3.

A detailed investigation of founding conditions would have to be evaluated once the final position of the proposed Treatment Plant is selected.

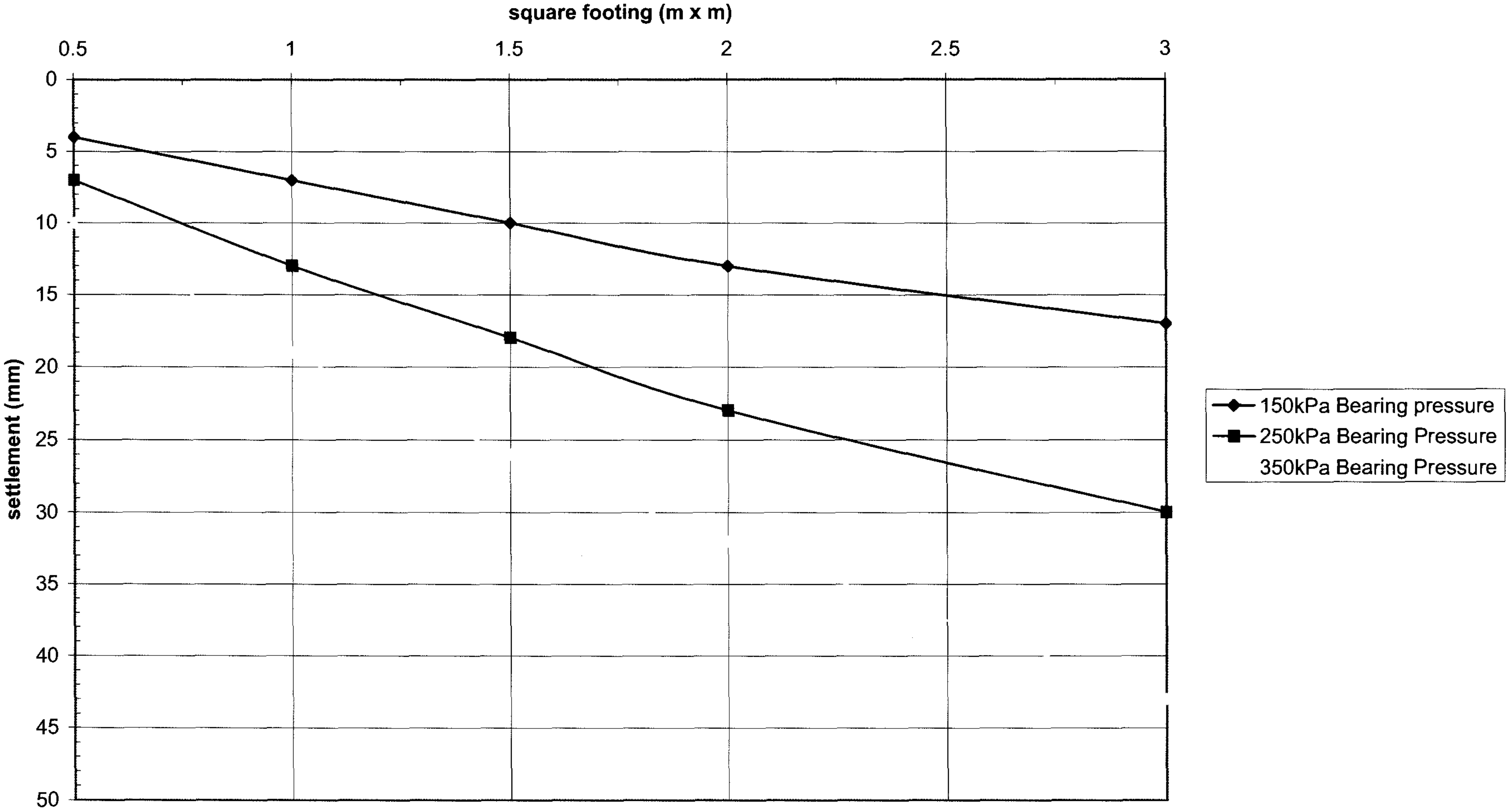
6.2.4 *Site comparison*

The feasibility investigation has indicated that suitable founding conditions are present at the Preferred Site (crestal area) and on the Alternate Site (sideslope profile).

At the Alternate Site, due to the site gradient, moderate terracing could be expected while at the Preferred Site only slight terracing will be required.

The above preliminary assessment is pertinent to light flexible structures. A detailed investigation will be required once the final site is selected.

FIGURE 5 : Estimated Settlement for different bearing pressures.
Foundations on Residual Dolerite



7. AGRICULTURAL EVALUATION

7.1 General

The identification and classification of the soils was carried out using the Taxonomic Soil Classification System[3]. As the study was of a feasibility nature only the soil form and general soil conditions (pH, grading, extractable cations, etc) were assessed.

The land capability has been classified according to the Chamber of Mines Guidelines[4] that include:

Wetlands:	wet areas where vegetation and soil processes determined by water.
Arable land:	permeable soils to a depth of at least 750mm. pH value between 4 and 8.4, <10% fragments greater than 100mm.
Grazing:	does not quality as arable or wetlands. Must be capable of supporting grass species, permeable soils at least 250mm thick with < 50% by volume of fragments >100mm.
Wilderness:	all land not qualified by above.

The soils encountered in the area are summarised below.

7.2 Preferred site

7.2.1 Soil forms

The soil forms encountered on the preferred site included

- Avalon (Av)
- Glencoe / Wasbank (Gc/Wa)
- Westleigh (We)
- Katspruit (Ka)

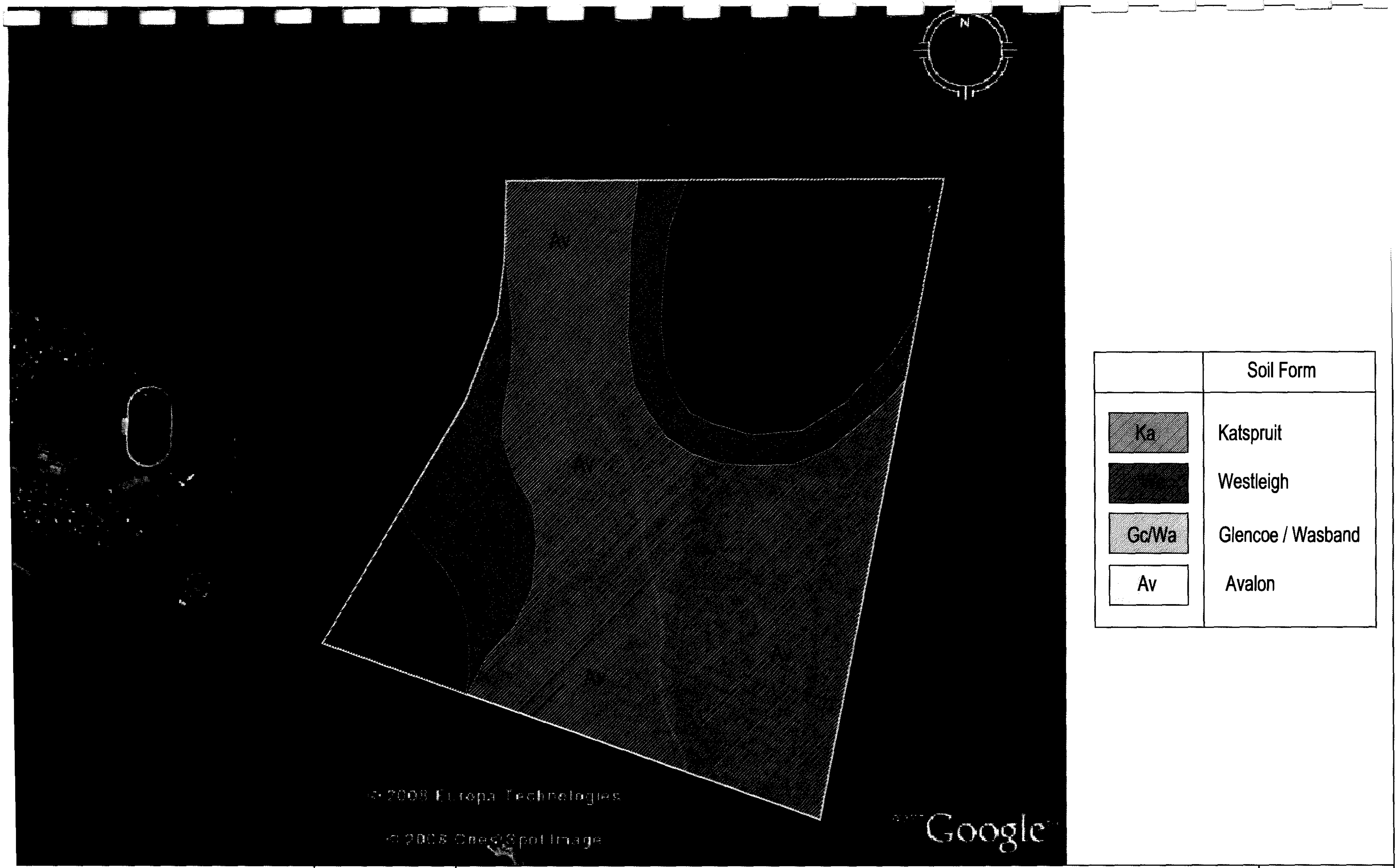
Localised Cartref Formation were noted around pan sideslope. The dominant Soil Forms are shown in Figure 6.

The Avalon Form characterises most of the site and is defined by a thin topsoil (Orthic A) horizon overlying a yellow-brown silty sand (yellow brown Apedal B horizon) on a ferruginised silty sand (soft Plinthic B) horizon. The thickness of and depth to the soft plinthic B horizon is variable and can be encountered from as shallow as 600mm (i.e. above the effective rooting depths of soil). This could result in saturated conditions at this depth and adversely affecting crop. Consequently this soil form is only considered to exhibit a moderate potential for crops and arable requirements.

---

[3] Macvicar C N, de Villiers J M 1991 Soil Classification: **A taxonomic System for South Africa soil classification working group**, Department of Agricultural Development, Pretoria 1991.

[4] Chamber of Mines of S A, 1981. **Handbook of Guidelines for Environmental Protection,** Vol 3 / 1981: **The Rehabilitation of Land Disturbed by Surface coal Mining in South Africa.**



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MIDDELBURG MINE - Water Treatment Plant
Preferred Site - Soil Classification

Scale 1 : 12 500

Figure 6

Job No B478

The Glencoe Form is typically encountered in the sideslopes of the drainage features (drainage channel in south west and pan in north east). This is typically characterised by a thin topsoil (Orthic A horizon) on yellowish brown to brown hillwash of silty sand (yellow brown Apedal B horizon) on a very dense ferruginised hillwash to transition (Hard Plinthic B horizon). Locally the hillwash is limited and hard Plinthic B will occur and the soil form tends to the Wasbank Form.

The soil in the poorly defined drainage channel in the south west is represented by the Westleigh Form where a very moist to wet, silty sand to sandy silt (Orthic A horizon) overlies a clayey sand with poorly developed ferricrete nodules (Soft Plinthic B) horizon.

The pan deposit soils in the north east comprises a very moist silty sand (Orthic A) overlying a very moist mottled orange brown sandy clay (G horizon). The Katspruit Form is associated mainly with the pan feature.

The distribution of the Soil Forms and capability is shown on Figures 6 and 7 and summarised in Table 3.

Table 3: Soil Form Coverage

SOIL FORM	AREA (Ha)	PERCENT OF WHOLE AREA	LAND CAPABILITY
Katspruit (Ka)	36.1	22.4	Pan
Westleigh (We)	9.1	5.6	Wetlands
Glencoe / Wasband (Gc / Wa)	28.8	17.8	Grazing
Avalon (Av)	90.8	56.2	Arable

7.2.2 *Soil properties*

The main agricultural properties of the soils encountered in the units are summarised in Table 4.

Table 4: Agricultural Soil Properties

	TESTPIT AND SOIL FORM						
DEPTH	0.4	0.3	1.3	0,6	0,4	1.6	0.4
HORIZON	Apedal B	Orthica A	Soft plinthic B	Apedal B	E	G	G
TP (Soil Form)	2(Av)	4 (We)	(We)	7 (Av)	9 (Gc)	9 (Gc)	15 (Ka)
PROPERTY							
Sand %	87	86	61	83	84	69	
Silt	6	7	12	7	6	6	
Clay	7	7	27	10	10	25	
Na (ppm)	0.01	0.01	0.10	0.06	0.01	5.66	
K (ppm)	0.02	0.02	0.03	0.03	0.03	0.23	
Ca (ppm)	0.10	0.09	0.10	0.10	0.20	1.35	
Mg (ppm)	0.30	0.40	0.55	0.20	0.15	1.20	
S Value	0.43	0.52	0.78	0.39	0.39	8.44	

CEC/100gm clay	13	16	7	8	8	34	
pH	4.6	4.2	5.2	4.4	4.4	9.8	

pH values in the 6 to 7 range promote the availability of plant nutrients, while values ≤3 or ≥9 adversely affect nutrient uptake. Site values are in the range of 4 to 5 and consequently are not ideal for nutrient uptake and therefore not ideal for arable requirements unless modified.

The low CEC values are indicative of soils low in organic matter and clay and consequently characterise soils with a poor ability to retain and supply nutrients for plant growth.

A detailed analysis of the soil properties has not been undertaken as the study is a feasibility assessment but the basic properties indicate that although a reasonable rooting depth (± 750mm) is present in the Avalon Form that represents most of the site, the soil will only be ideally suited for crops with addition of fertiliser, lime, etc. Under its current state it is more suited to grazing.

7.2.3 Land capability

The land capability of the area is shown on Figure 7. The plan illustrates that of the total available area

Potential arable land comprises	56.2
Grazing	18.3
Wetland	25.5

Although 56% is potentially arable, it is expected to be only fair unless treated and consequently considered better suited to grazing.

7.3 Alternate site

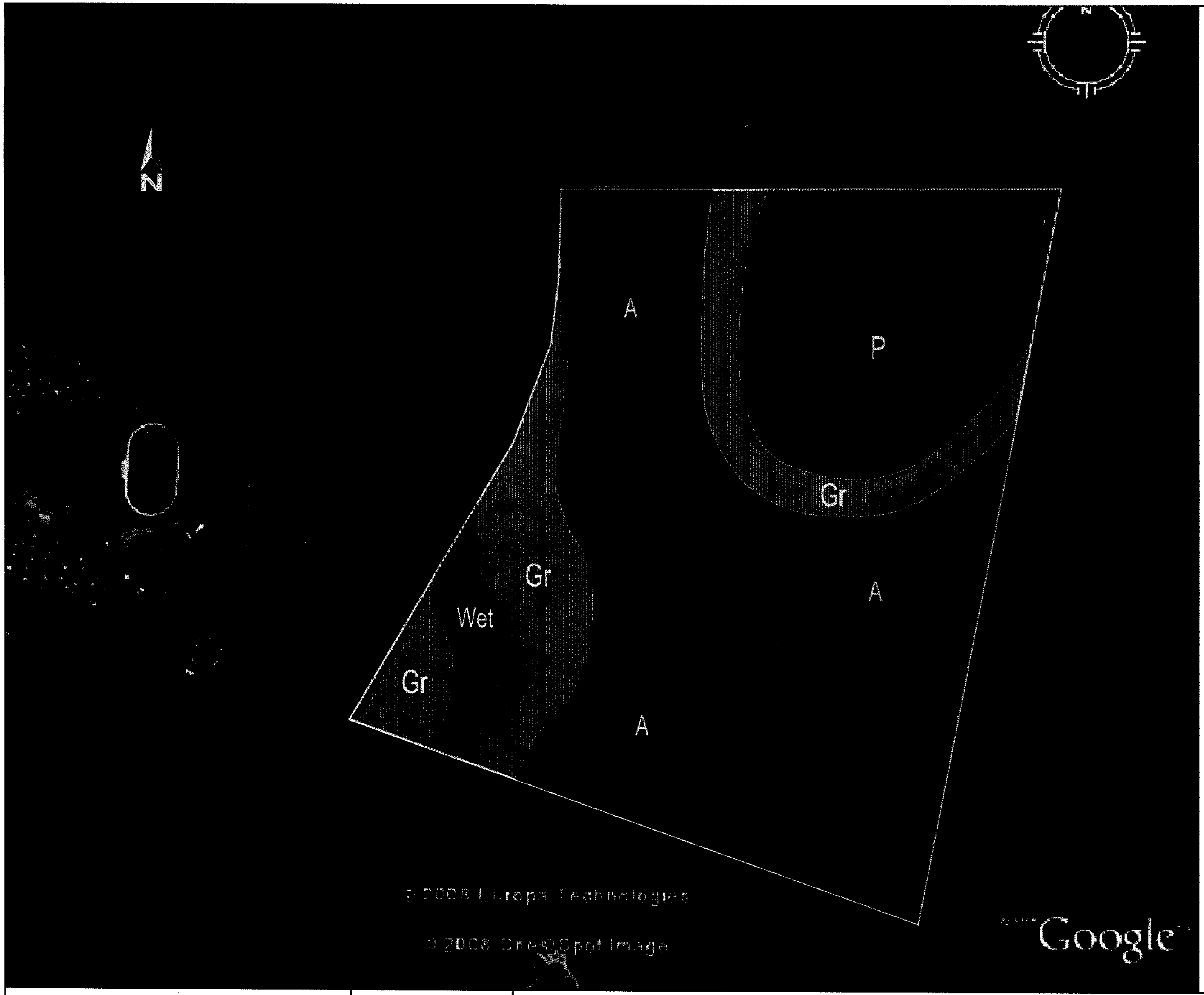
7.3.1 Soil forms

The site is characterised by two dominant soil forms and their distribution is shown on Figure 8

- Glenrosa Form (Gs)
- Bloemdal Form (Bd)

The Glenrosa Form is encountered in the area underlain by the sedimentary rocks of the Karoo Sequence and comprises a thin sandy soil with pebble marker (Orthic A) that merges into the underlying weathered bedrock that comprises a residual sandstone of reddish brown silty sand (Lithocutanic B horizon). The contact between the Orthic A and Lithocutanic B horizon is often irregular as runnels of the overlying transported horizon extend into the residual material.

Along the western boundary of the Glenrosa Form an isolated Glencoe Form was recorded (TP8). The Glenrosa Form covers 40.04 Hectares that represents 58.7% of the site area.



	Land Type
▇	Arable
▨	Wetlands
Gr	Grazing

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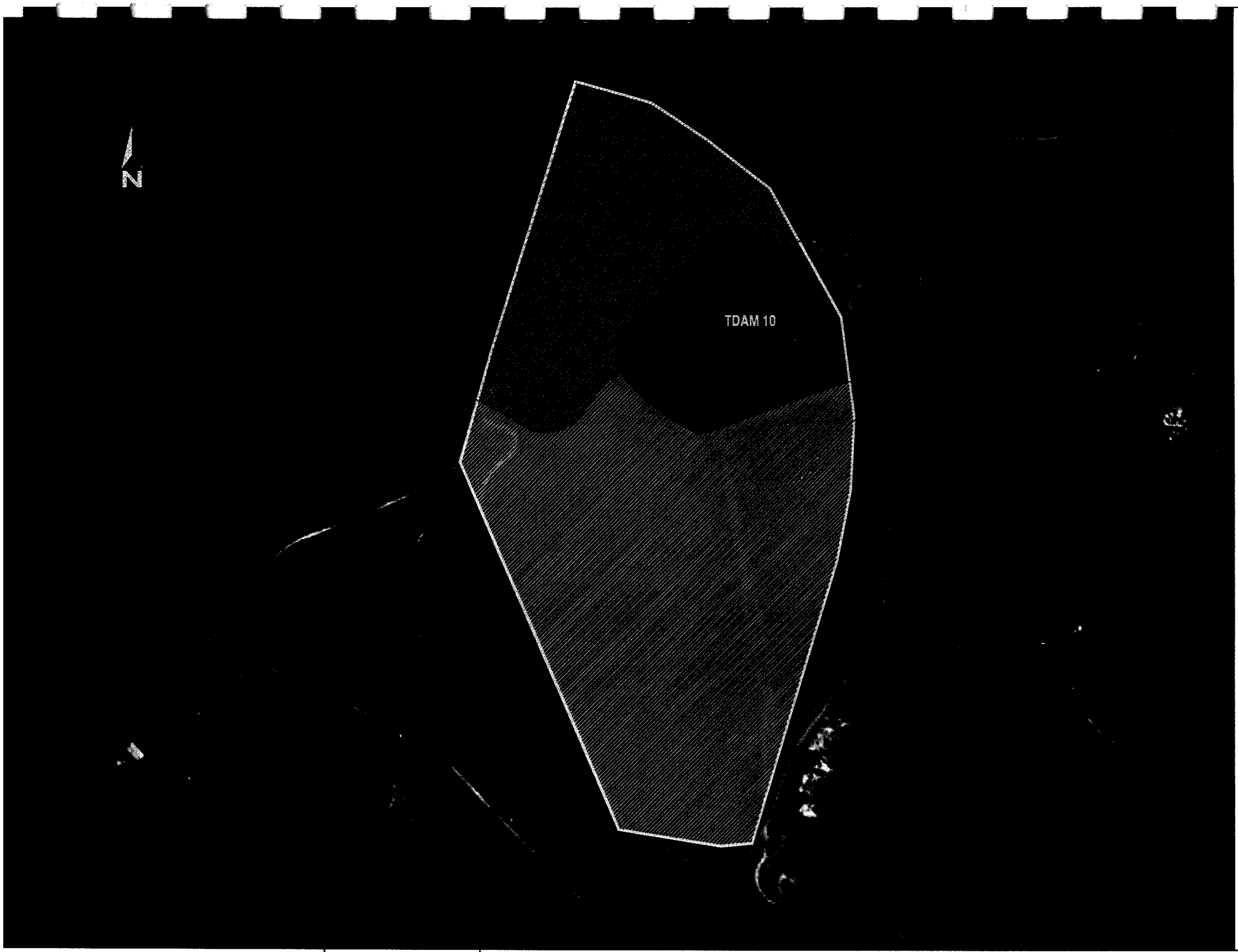
MIDDELBURG MINE - Water Treatment Plant
Preferred Site - Land Capability

Scale 1 : 12 500

Figure 7

Job No B478



	Soil Form
Gs	Glenrosa
Bd	Bloendal

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Rivonia 2128

bhpbilliton

MIDDELBURG MINE - Water Treatment Plant
Alternate Site - Soil Classification

Scale 1 : 10 000

Figure 8

Job No B478

The Bloemdal Form is encountered in the north-western area of the site. This section is underlain by a dolerite intrusive and the area is characterised by a rough boulder strewn surface. The soils encountered basically comprise an Orthic A horizon of brown silty sand with roots overlying an irregularly developed repapedal B horizon comprising a red brown to brown silty fine sand with dolerite boulders. This horizon overlies an orange brown to reddish brown flecked orange and grey clayey silt. This soil form occurs over 17.23 Ha and represents 25.3% of the site. Dam 10 occupies 10.97 Ha (16.1%) of the area.

The properties of the soil horizons are summarised below.

Table 5: Soil Properties: Alternate site

TESTPIT (Soil Form)	2 (Bd)	4 (Bd)	4 (Bd)	8 (Gs)
DEPTH	0.3	0.2	1.1	0.4
HORIZON	Orthic A	Orthic A	Residual	Apedal B
PROPERTY				
Sand %	67	75	52	77
Silt	12	9	16	12
Clay	21	16	32	11
Na (ppm)	0.04	0.03	0.06	0.01
K (ppm)	0.17	0.27	0.10	0.06
Ca (ppm)	2.5	0.5	0.35	0.35
Mg (ppm)	0.55	2.7	0.4	0.45
S Value	3.26	3.5	0.91	0.87
CEC/100gm clay	18	26	.5	13
pH	5.8	3.0	5.1	4.7

The pH values are generally low and consequently uptake of nutrients by plants would be limited and not typically suited for crops. The low CEC values per 100g clay also indicate soil poor in organic matter and therefore a poor ability to retain and supply nutrients for plant growth.

The rooting depth for both soil types is also limited to a depth of about 300mm to 400mm.

7.3.2 *Land capability*

The land capability of the area is shown on Figure 9 and summarised below:

Arable land	56.6%
Grazing	25.3%
Wetland	20.1%

The Glenrosa Form although potentially arable is characterised by a shallow effective depth and probably, therefore, more suited to grazing.

The area of Glenrosa immediately south of Dam 10 has been classified as a Wetland. This is artificial wetland resulting from leakage from Dam 10.

8. GENERAL CONSIDERATIONS

The feasibility study of the area has identified the general geotechnical and agricultural aspects of the two areas identified as potential sites for the water treatment plant. This review has shown that there are no near surface geotechnical aspects that would adversely affect development either site.

Other considerations (e.g. undermining, major faulting, lithology, groundwater etc) have also been assessed with regard to likely potential flaws.

A detailed study of underground plans is beyond the scope of this study but preliminary indications are that the area is not undermined. **The Preferred Site** is underlain primarily by Karroo rocks and consequently, if coal reserves are present, the site may be affected by mining regulations. The restrictions may limit either the extent of mining up to or below the proposed development but they are unlikely to prohibit development unless the area is already undermined at shallow depth. However it is assumed that as the area was identified by MMS as a preferred site, any potential or existing mining in the area was addressed and not considered problematic.

The general lithology at the **Alternate Site** comprises Karoo rocks, a diabase intrusion and basement rhyolites. It is probable that this area is representative of a basement high and therefore it is likely that any coal reserves are limited in thickness or extent and probably not economically viable.

No major faults or lineaments were noted on either sites and the presence of rock types (e.g. dolomite) that also could constitute fatal flaws were not identified.

9. CONCLUSION

This report has reviewed both the geotechnical and agricultural properties of the two possible sites proposed for the Water Treatment Plant.

A preliminary review of lithology, undermining and structural features indicate that there are no obvious reasons to prevent development of either site.

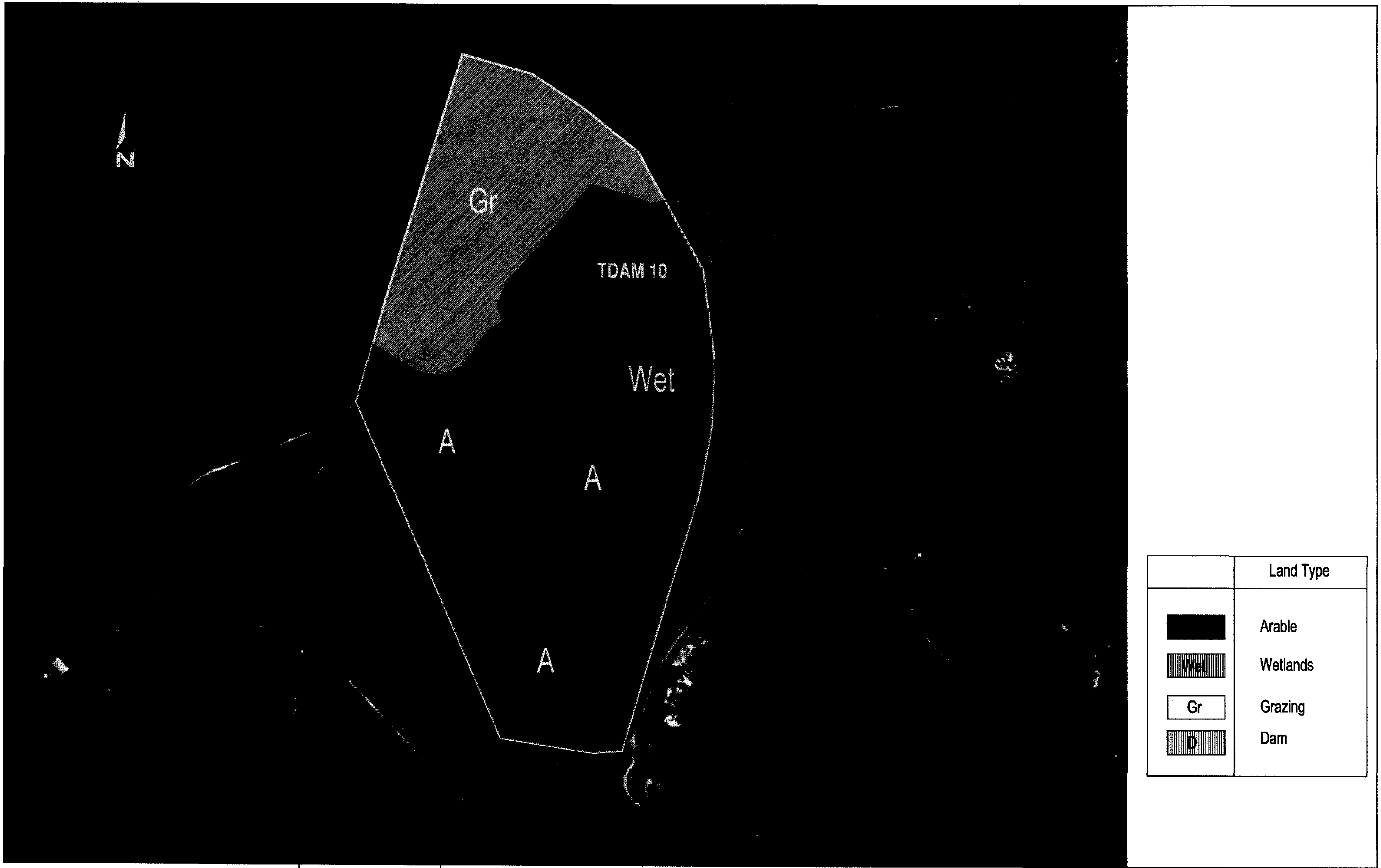
The conditions at both sites are fairly similar but the Preferred Site does have the advantage of location (more readily accessible) and is characterised by a more gentle gradient that would require less earthworks than the Alternate Site.

BRYAN ANTROBUS PrSciNat
Jones & Wagener

CHRIS WAYGOOD PrEng

24 July 2008

Document source: C:\Alljobs\B478_Middelburg\B478ba04_TreatmentPlant_report.doc
Document template: Report Geotech_tem_RevA_Feb08.dot



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Rivonia 2128

bhpbilliton

MIDDELBURG MINE - Water Treatment Plant
Alternate Site - Land Capability

Scale 1 : 10 000

Figure 9

Job No B478

MIDDELBURG MINE SERVICES

FEASIBILITY GEOTECHNICAL EVALUATION OF
TWO PROPOSED WATER TREATMENT PLANTS
MIDDELBURG MINE, MIDDELBURG

Report: JW107/08/B478 - Rev 0

APPENDIX A

TEST PIT PROFILES

A.1 Preferred Site Profiles

A.2 Alternate Site Profiles

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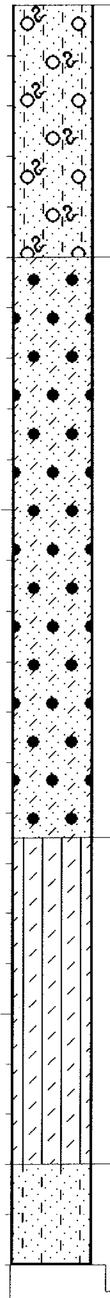
MMS
WATER TREATMENT PLANT

Hole No: PTP01
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:15



0.00

Moist, yellow-brown, <u>loose</u>, silty, medium and fine SAND. **HILLWASH** and roots.

<u>Note</u>:
1. Scattered gravels.

0.50

Moist, dark reddish brown mottled pale brown, <u>dense</u>, slightly friable, very closely packed, subrounded ferricrete nodules (<10mm) in a slightly clayey SAND matrix. **MODERATELY FERRUGINISED HILLWASH TO TRANSITION**.

1.65

Moist, banded yellow-brown and dark purple-brown, <u>stiff</u>, clayey SILT. **RESIDUAL SLIGHTLY FERRUGINISED SILTSTONE**.

<u>Note</u>:
1. At 1,7m to 1,75m purple, very dense, fine grained ferruginous sandstone.
2. Slight seep at 2,3m.

2.30

Slightly moist, pale grey to off-white, <u>very dense</u>, relict bedded, silty, coarse, medium and fine SAND. **RESIDUAL SANDSTONE TO DIAMICTITE**.

2.50

NOTES

1) Slow excavation.

2) Slight general seepage at 2,3m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

ELEVATION :
x-coord : 2866875
y-coord : -40469

Hole No: PTP01

dot.PLOT 5003 J&W

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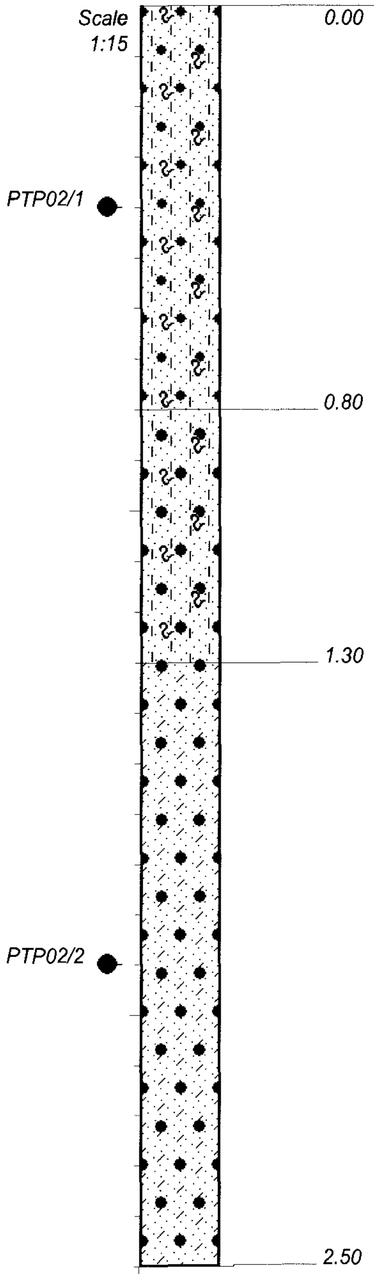
MMS
WATER TREATMENT PLANT

Hole No: PTP02
Sheet 1 of 1

JOB NUMBER: B478



Very moist, light yellow-brown, very loose, silty, medium and fine SAND with scattered fine ferricrete nodules and fine roots. **HILLWASH**.

As above but wet, loose, friable but with relatively closely packed fine ferricrete nodules and ferruginised hillwash.

Note:
1. Moisture at base.

Moist, dark red-brown mottled light brown and grey, dense, intact, closely packed, subrounded ferricrete nodules (<10mm) in a matrix of weakly ferruginised and cemented clayey fine SAND. **FERRUGINISED TRANSITION**.

Note:
1. Slight sidewall seep at 1,9m and general moderate seepage below 2,4m.

NOTES

1) TLB near limit of reach.

2) Sidewalls vertical and stable.

3) Slight seepage at 1,9m and 2,4m.

4) Profiled insitu to 2,5m.

5) Disturbed sample PTP02/1 taken at 0,4m and PTP02/2 at 1,9m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866794
y-coord : -40156

Hole No: PTP02

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
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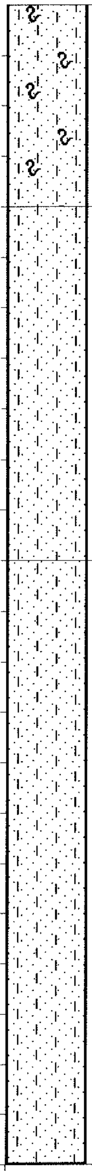
Hole No: PTP03
Sheet 1 of 1

JOB NUMBER: B478

Scale 1:15



0.00	Moist, pale brown, <u>loose</u>, slightly silty fine and medium SAND with fine roots. **TOPSOIL**.
0.40	Moist, pale yellow-brown, <u>loose</u>, slightly silty fine and medium SAND with scattered fine rootlets. **HILLWASH**. <u>Note</u>: 1. Scattered fine ferricrete nodules at base of horizon. 2. Fine rootlets to 1,3m.
1.10	Moist to wet, dark red-brown mottled pale grey and yellow-brown, <u>dense</u> to <u>very dense</u> from 2,0m, moderately ferruginised and cemented, silty fine SAND with scattered, soft rock, ferricrete nodules to 10mm. **FERRUGINISED TRANSITION**. <u>Note</u>: 1. Slight sidewall seepage at 2,0m.
2.30	

NOTES

1) Slow excavation.

2) Slight seepage at 2,0m.

3) Profiled insitu.

4) Sidewall vertical and stable during profiling.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866674
y-coord : -39861

Hole No: PTP03

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
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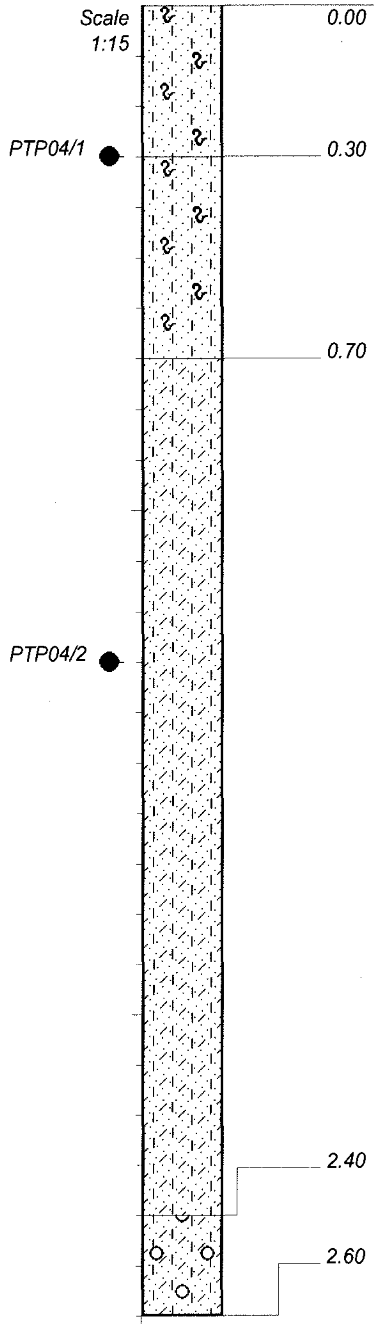
WATER TREATMENT PLANT

Hole No: PTP04
Sheet 1 of 1

JOB NUMBER: B478



Very moist, dark brown, <u>loose</u>, silty, medium and fine SAND with fine roots. **TOPSOIL.**

Very moist, brown mottled orange-brown, <u>loose</u>, pinhole voided, silty, medium and fine SAND with fine roots. **GULLYWASH.**

Very moist, grey mottled orange-brown, <u>medium dense</u>, clayey silty fine SAND with poorly developed ferruginised runnels. **GULLYWASH.**

<u>Note</u>:
1. General sidewall seep below 1,2m.

As above but <u>dense</u> to <u>very dense</u>, moderately cemented and ferruginised with scattered quartz gravels. **FERRUGINISED GULLYWASH.**

NOTES

1) TLB excavating slowly – requested to stop.

2) Sidewall vertical and stable.

3) General sidewall seep at 1,2m.

4) Profiled insitu to 2,6m.

5) Disturbed samples PTP04/1 at 0,3m and PTP04/2 at 1,3m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866610
y-coord : -39607

Hole No: PTP04

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
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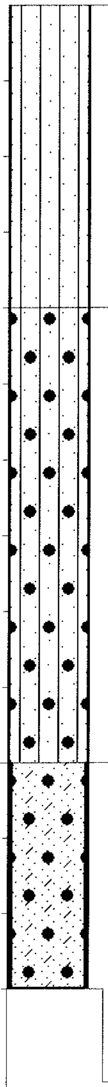
WATER TREATMENT PLANT

Hole No: PTP05
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Wet, dark grey, soft, intact, slightly sandy SILT. **GULLYWASH.**

0.40

As above but with relatively closely packed ferricrete nodules. **FERRUGINISED GULLYWASH.**

1.00

Moist, orange-brown mottled yellow-brown and grey, dense to very dense, well cemented and ferruginised, slightly clayey fine SAND with closely packed ferricrete nodules. **FERRUGINISED TRANSITION.**

Note:
1. Moderate to strong seep below 0,9m.
2. Below 0,6m and 0,8m, scattered, subrounded sandstone and quartz gravels from 15mm to 300mm.
3. Test hole excavated in general well defined drainage area.

1.30

NOTES

1) TLB requested to stop.

2) Unstable sidewall due to seepage.

3) Strong sidewall seep below 0,9m.

4) Profiled from surface spoil.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866266
y-coord : -39535

Hole No: PTP05

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
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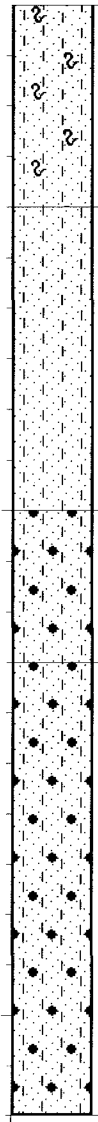
MMS
WATER TREATMENT PLANT

Hole No: PTP06
Sheet 1 of 1

JOB NUMBER: B478

Scale 1:15



0.00	Moist, pale brown, <u>loose</u>, slightly silty fine and medium SAND with fine roots. **TOPSOIL**.
0.40	Very moist, pale yellow-brown, <u>loose</u>, pinhole voided, slightly silty fine SAND with scattered fine roots. **HILLWASH**.
1.00	Wet, pale yellowish brown mottled red-brown, <u>loose</u>, silty fine SAND with scattered ferricrete nodules to 20mm and scattered fine roots. **FERRUGINISED HILLWASH**.
1.30	Moist, dark red-brown mottled grey and orange-brown, <u>dense</u>, moderately cemented and ferruginised silty fine SAND with scattered ferricrete nodules and concretions to 30mm. **FERRUGINISED TRANSITION**. <u>Note</u>: 1. Very slight sidewall seep at 1,4m.
2.20	

NOTES

1) Slow excavation - near refusal.

2) Very slight seepage at 1,4m.

3) No samples taken.

4) Sidewall vertical and stable.

5) Profiled in situ.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866404
y-coord : -39957

Hole No: PTP06

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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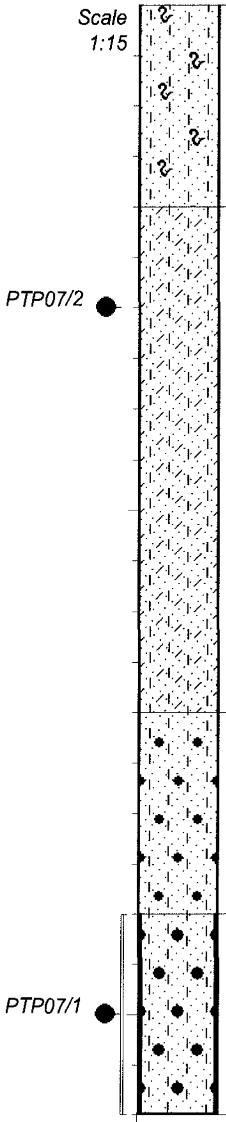
MMS
WATER TREATMENT PLANT

Hole No: PTP07
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:15



0.00	Moist, brown to dark brown, very loose, silty fine SAND with abundant fine roots. **TOPSOIL**.
0.40	Moist, yellow-brown, loose, pinhole voided, slightly clayey, silty fine SAND with scattered fine roots. **HILLWASH**.
1.40	Wet, yellow-brown blotched reddish brown, loose, silty fine SAND with scattered fine (10mm) ferricrete nodules. **FERRUGINISED HILLWASH**.
1.80	Moist, dark red-brown mottled orange-brown, dense to very dense, well cemented and ferruginised, silty, medium and fine SAND with closely packed ferricrete nodules. **FERRUGINISED TRANSITION**.
2.20	

NOTES

1) Moderate general sidewall seep below 1,7m.

2) Slow excavation – near refusal.

3) Sidewall vertical and stable showing signs of instability.

4) Profile insitu.

5) Disturbed and agricultural sample PTP07/2 taken at 0,6m.

6) Bulk sample PTP07/1 from 1,8--2,2m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

ELEVATION :
x-coord : 2866446
y-coord : -40362

Hole No: PTP07

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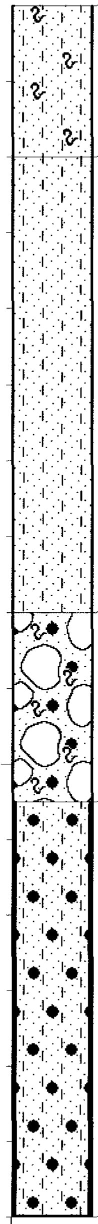
WATER TREATMENT PLANT

Hole No: PTP08
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00	Moist, dark brown to pale brown with depth, <u>loose</u>, slightly silty fine and medium SAND with abundant roots. **TOPSOIL**.
0.20	Moist, pale yellow-brown, <u>loose</u>, silty fine and medium SAND with scattered fine rootlets. **HILLWASH**.
0.80	Wet, pale yellow-brown blotched red-brown, <u>very loose</u>, sitly fine SAND with relatively closely packed ferricrete nodules to 20mm and fine roots. **FERRUGINISED HILLWASH** with isolated angular and subrounded sandstone boulders to 200mm.
1.05	Moist, dark red-brown mottled grey and yellow-brown, <u>dense</u> becoming <u>very dense</u> below 1,4m, well ferruginised and cemented, silty fine and medium SAND with relatively closely packed ferricrete nodules and concretions. **FERRUGINISED TRANSITION**. <u>Note</u>: 1. Tends to hardpan at 1,6m.
1.60	

NOTES

1) TLB near refusal.

2) Sidewall vertical and stable.

3) Slight sidewall seepage from 1,1m.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866195
y-coord : -40596

Hole No: PTP08

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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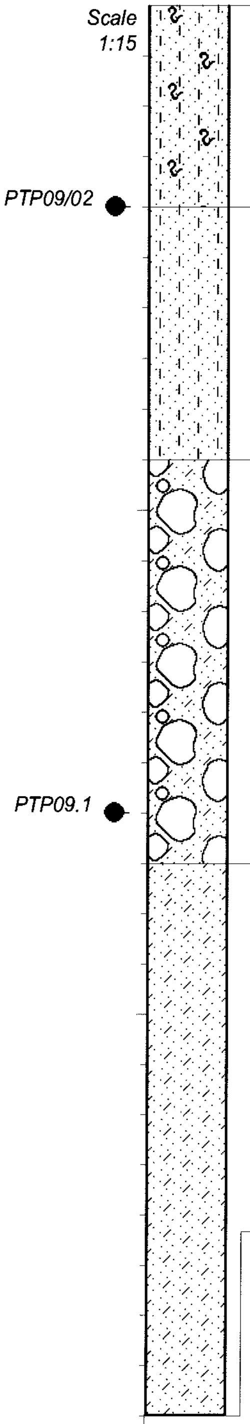
MMS
WATER TREATMENT PLANT

Hole No: PTP09
Sheet 1 of 1

JOB NUMBER: B478



0.00	Moist, brown, loose, silty, medium and fine SAND with roots. **TOPSOIL.**
0.40	Moist to very moist, pale grey, loose, pinhole voided, slightly silty, medium grained SAND. **LEACHED HILLWASH.** Note: 1. Very moist at 0,9m.
0.90	Moist, pale grey mottled yellow-brown, firm, clayey medium grained SAND with scattered gravels and boulders from 1,5m to 1,7m.
1.70	Moist, mottled orange-brown and grey, firm, slightly clayey medium grained SAND with orange-brown silt lenses. Origin uncertain possibly **RESIDUAL LEACHED TILLITE**. Note: 1. Scattered subrounded gravels evident.
2.80	

NOTES

1) TLB requested to stop.

2) Sidewalls vertical and stable (likely to be unstable in long trenches).

3) No seepage.

4) Profiled insitu.

5) Agricultural sample PTP09/02 at 0,4m and disturbed sample PTP09.1 at 1,6m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J.Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2866048
y-coord : -40490

Hole No: PTP09

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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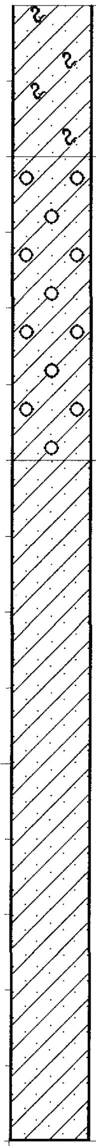
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

MMS
WATER TREATMENT PLANT

Hole No: PTP10
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00 Very moist, dark grey, soft, sandy CLAY. **PAN DEPOSIT** with fine roots.

0.20 Very moist, pale grey, soft, sandy CLAY with scattered gravels. **PAN DEPOSIT**.

0.60 Moist, orange-brown mottled reddish brown and grey, firm, fissured, slightly sandy CLAY with reddish brown clayey silt zones. Origin uncertain possibly **RESIDUAL** material.

1.50

NOTES

1) Slight sidewall seep from 0,8m.

2) No refusal, TLB requested to stop.

3) Sidewalls vertical - long excavations probably unstable.

4) Profiled from surface spoil.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865990
y-coord : -40475

Hole No: PTP10

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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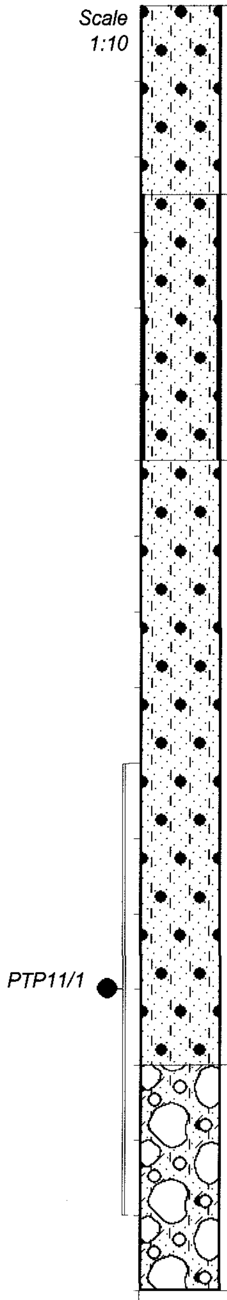
MMS
WATER TREATMENT PLANT

Hole No: PTP11
Sheet 1 of 1

JOB NUMBER: B478



0.00	Slightly moist, pale brown, medium dense, silty fine SAND with relatively closely packed ferricrete nodules to 15mm and isolated angular gravels to 40mm. **HILLWASH**.
0.25	Yellow-brown mottled grey and reddish brown, well ferruginised and cemented, silty fine and medium SAND with relatively closely packed ferricrete nodules and isolated runnels of silty fine sand. **HARDPAN FERRICRETE**. Overall consistency very soft rock.
0.60	Relatively closely packed ferricrete nodules and concretions to 80mm in a matrix of slightly moist, pale brown, silty fine and medium SAND. Overall consistency dense with scattered fine rootlets. **FERRUGINISED HILLWASH**.
1.40	Moist, red-brown mottled pale grey and yellow-brown, dense, moderately ferruginised and cemented, slightly clayey silty fine and medium SAND with scattered ferricrete nodules and subrounded and angular quartzitic sandstone boulders and gravels. **FERRUGINISED / TRANSPORTED**. Note: 1. Becomes very dense with depth.
1.70	

NOTES

1) TLB near refusal - requested to stop.

2) No seepage or water table.

3) Profiled insitu.

4) Sidewalls vertical and stable.

5) Bulk sample PTP11/1 from 1,0m--1,6m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

ELEVATION :
x-coord : 2866104
y-coord : -40313

Hole No: PTP11

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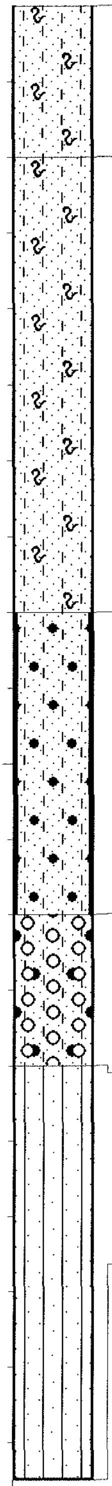
MMS
WATER TREATMENT PLANT

Hole No: PTP12
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Moist, brown, <u>loose</u>, silty fine SAND with fine roots. **TOPSOIL**.

0.20

Moist, yellow-brown, <u>loose</u>, pinhole voided, silty fine SAND with fine roots. **HILLWASH**.

<u>Note</u>:
1. Closely packed ferricrete nodules from 0,7m to 0,8m.

0.80

Slightly moist, dark reddish brown mottled yellow-brown and black, <u>very dense</u>, well cemented and ferruginised silty SAND with closely packed ferruginised concretions. **FERRUGINISED HILLWASH**.

<u>Note</u>:
1. Tends to hardpan.

1.20

Slightly moist, dark reddish brown mottled pale red and black, <u>dense</u>, moderately cemented and ferruginised silty SAND with relatively closely packed (<10mm) ferricrete nodules and sandstone gravels up to 80mm. **FERRUGINISED TRANSITION**.

1.40

Moist, yellow-brown banded pale grey, <u>stiff</u>, relict laminated, fine sandy SILT. **RESIDUAL SILTSTONE**.

<u>Note</u>:
1. Below 1,8m becomes very stiff to very soft rock.

1.95

NOTES

1) TLB near refusal.

2) Sidewalls vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

ELEVATION :
x-coord : 2866004
y-coord : -39961

Hole No: PTP12

dot.PLOT 5003 J&W

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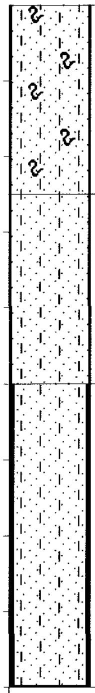
MMS
WATER TREATMENT PLANT

Hole No: PTP13
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00	Moist, pale grey-brown, loose, silty fine SAND with fine roots. **TOPSOIL**.
0.25	Moist, pale grey to pale yellow-grey, medium dense, silty fine SAND. **GULLYWASH**.
0.50	Slightly moist, reddish brown mottled orange-brown and grey, very dense, well cemented and ferruginised, silty SAND with isolated runnels of material from above extending to 0,7m. **FERRUGINISED TRANSPORTED**. Note: 1. Tending to hardpan from 0,7m.
0.90	

NOTES

1) Excavated to refusal on hardpan.

2) No seepage or water table.

3) Sidewall vertical and stable.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865755
y-coord : -39789

Hole No: PTP13

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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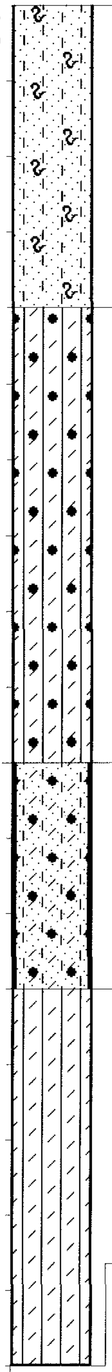
MMS
WATER TREATMENT PLANT

Hole No: PTP14
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Moist, dark yellow-brown, loose, silty fine SAND with fine roots and isolated fine ferricrete nodules. **TOPSOIL**.

0.40

Relatively closely packed, subrounded, ferruginised concretions from 5mm to 20mm and isolated subrounded quartz gravels in a matrix of moist, yellow-brown, clayey SILT. Overall consistency medium dense but friable. **FERRUGINISED HILLWASH**.

1.00

Slightly moist, orange-brown mottled grey and occasionally black, very dense, well cemented and ferruginised, silty to clayey fine SAND with relatively closely packed ferruginised concretions. **FERRUGINISED TRANSITION**.

1.30

Slightly moist, banded yellow-brown and reddish brown, stiff, indistinctly relict laminated, clayey SILT. **RESIDUAL SILTSTONE**.

Note:
1. Base of hole on purple, very soft rock, ferruginised sandstone.

1.80

NOTES

1) TLB excavating slowly – requested to stop.

2) No seepage or water table.

3) Sidewalls vertical and stable.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR: Vanalls Plant Hire
MACHINE: Case 580 G
DRILLED BY: Steyn
PROFILED BY: J. Rapp

TYPE SET BY: Beth
SETUP FILE: STANDARD.SET

INCLINATION: Vertical
DIAM: Trench
DATE: 27 May 2008
DATE: 27 May 2008

DATE: 01/10/08 10:49
TEXT: ..\B478_M~1\B478BA~1.DOC

ELEVATION:
x-coord: 2865853
y-coord: -40135

Hole No: PTP14

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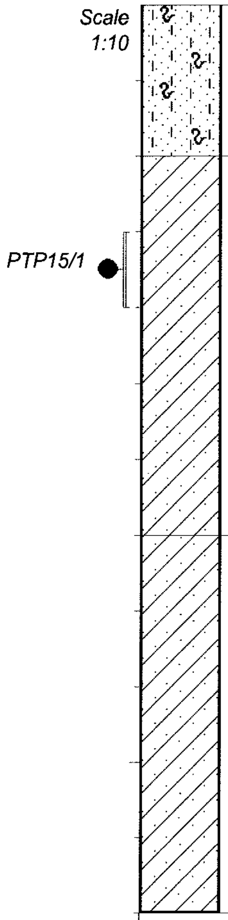
MMS
WATER TREATMENT PLANT

Hole No: PTP15
Sheet 1 of 1

JOB NUMBER: B478

Scale 1:10



0.00	Wet, dark brown, <u>loose</u>, silty fine SAND with fine roots. **TOPSOIL**.
0.20	Very moist, brown mottled orange-brown and grey, <u>firm</u>, sandy CLAY with occasional fine roots. **PAN DEPOSIT**.
0.70	Slightly moist, pale grey flecked off-white and orange-brown, <u>stiff</u>, fissured to shattered, sandy CLAY with powder calcrete on fracture zones. **REWORKED SILTSTONE**. <u>Note</u>: 1. Thin clayey sand lense 80mm at top of horizon. 2. Ferruginised sandstone lense at base of horizon (irregularly developed).
1.20	

NOTES

1) TLB requested to stop.

2) Sidewalls vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) Agricultural sample PTP15/1 from 0,3m--0,4m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865714
y-coord : -40190

Hole No: PTP15

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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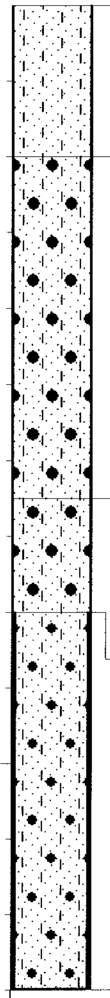
MMS
WATER TREATMENT PLANT

Hole No: PTP16
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Slightly moist, brown, <u>loose</u>, slightly silty fine SAND with fine rootlets. **TOPSOIL**.

0.20

Moist, pale yellow-brown, <u>loose</u>, silty fine SAND with relatively closely packed, fine (5mm) ferricrete nodules. **FERRUGINISED HILLWASH**.

0.65

Closely packed ferricrete nodules and concretions to 50mm in a matrix of slightly moist, pale yellow-brown and red-brown, silty fine SAND with isolated fine roots. Overall consistency <u>medium dense</u>. **FERRUGINISED HILLWASH**.

0.80

Slightly moist, dark red-brown mottled yellow-brown and grey, moderately to well cemented and ferruginised with depth, silty fine and medium SAND with scattered ferricrete nodules. **FERRUGINISED HILLWASH**.

<u>Note</u>:
1. Becomes very dense from 1,1m. Tending to hardpan ferricrete at base of hole.

1.30

NOTES

1) TLB at refusal.

2) Sidewall vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) FIND PTP16/1 taken at 0,5m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865598
y-coord : -40007

Hole No: PTP16

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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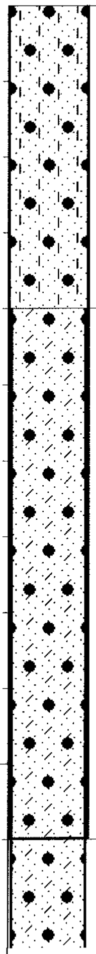
MMS
WATER TREATMENT PLANT

Hole No: PTP17
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Closely packed, fine (5 to 15mm) ferricrete nodules in a matrix of slightly moist, brown, silty fine SAND. Overall consistency <u>medium dense</u> but friable. **FERRUGINISED HILLWASH**.

0.40

Closely packed ferricrete nodules and concretions from 5mm to 25mm on a matrix of slightly moist, yellow-brown, well cemented and ferruginised, clayey fine SAND. Overall consistency <u>very dense</u>. **FERRUGINISED HILLWASH**.

1.10

As above, pale yellow-brown mottled grey, possibly ferruginised transition.

NOTES

1) TLB near refusal - requested to stop.

2) Sidewalls vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865482
y-coord : -40172

Hole No: PTP17

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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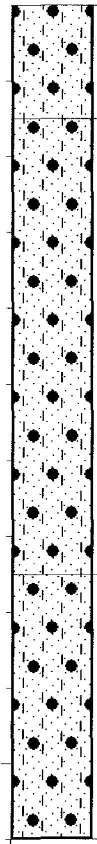
MMS
WATER TREATMENT PLANT

Hole No: PTP18
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Slightly moist, pale brown, medium dense, silty fine SAND with relatively closely packed ferricrete nodules (to 15mm) and scattered fine roots. **TOPSOIL**.

0.15

Closely packed, fine ferricrete nodules to 10mm in a matrix of slightly moist, pale brown to pale yellow-brown, silty fine SAND with fine rootlets. Overall consistency loose and friable. **FERRUGINISED HILLWASH**.

0.75

Relatively closely packed ferricrete nodules and concretions in a matrix of slightly moist, dark red-brown mottled grey and pale yellow-brown, moderately ferruginised silty fine and medium SAND. Overall consistency dense becoming very dense. **FERRUGINISED HILLWASH**.

Note:
1. Isolated subrounded sandstone boulders to 150mm.

1.10

NOTES

1) Near refusal.

2) No seepage or water table.

3) Sidewall vertical and stable.

4) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 27 May 2008
DATE : 27 May 2008

ELEVATION :
x-coord : 2865469
y-coord : -39855

Hole No: PTP18

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:49
TEXT : ..\B478_M~1\B478BA~1.DOC

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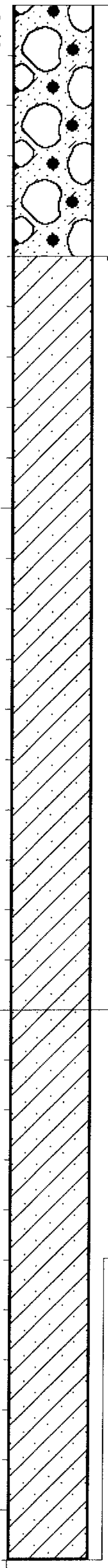
MMS
WATER TREATMENT PLANT

Hole No: ATP01
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:15



0.00	Slightly moist, brown, <u>stiff</u>, clayey SAND with relatively closely packed, medium weathered, subrounded, medium hard rock to hard rock, dolerite boulders and fine ferricrete nodules. <u>Note</u>: 1. Soil has a granular texture with abundant fine roots. 2. Characterised by closely packed boulder outcrop on surface.
0.50	Moist, dark reddish brown occasionally flecked orange-brown, <u>stiff</u>, fissured, granular textured, sandy CLAY. **REWORKED RESIDUAL DOLERITE**.
2.00	Moist to very moist, mottled yellow-brown and dark reddish brown flecked black, <u>soft</u>, fissured, sandy CLAY. **RESIDUAL DOLERITE**. <u>Note</u>: 1. Below 2,6m scattered hard rock spheroids up to 300mm x 500mm. 2. Sidewall seepage below 2,4m.
3.10	

NOTES

1) HOLE NO: TLB near limit of reach.

2) Sidewalls vertical and stable.

3) Sidewall seepage below 2,4m.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861256
y-coord : -43873

Hole No: ATP01

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

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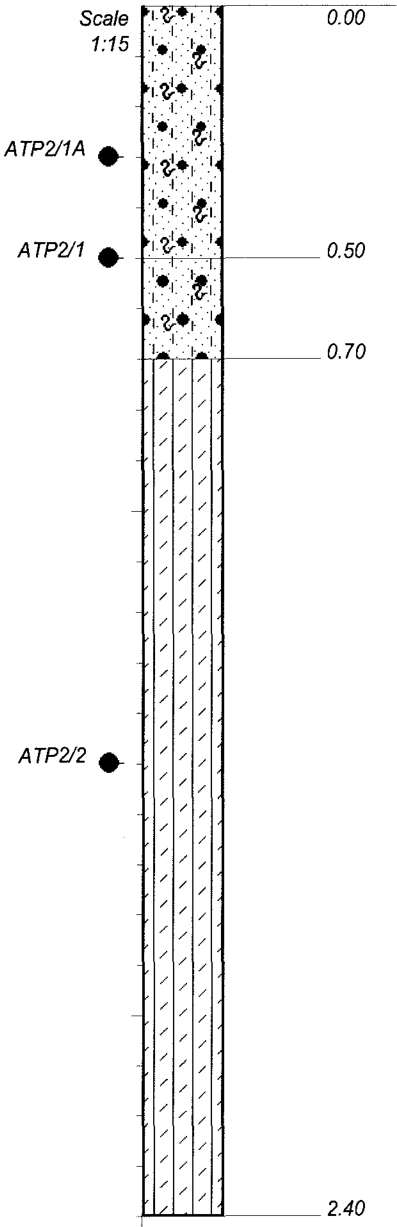
MMS
WATER TREATMENT PLANT

Hole No: ATP02
Sheet 1 of 1

JOB NUMBER: B478



Slightly moist, reddish brown, medium dense, silty fine SAND with scattered ferricrete nodules to 5mm and fine roots. **TOPSOIL**.

Relatively closely packed ferricrete nodules to 10mm in a matrix as above. Overall consistency medium dense. **FERRUGINISED HILLWASH**.

Moist, khaki brown speckled off-white blotched orange-brown and pale grey, soft, clayey SILT. **RESIDUAL DOLERITE**.

NOTES

1) No refusal.

2) Sidewalls vertical and stable.

3) Indicator samples ATP2/1A taken at 0,3m; ATP2/1 at 0,5m and ATP2/2 at 1,5m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

ELEVATION :
x-coord : 2861047
y-coord : -43881

Hole No: ATP02

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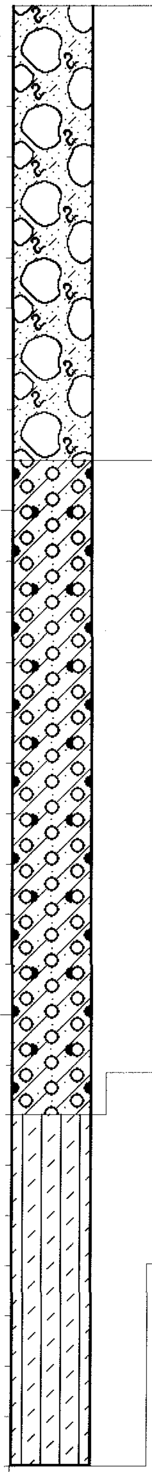
MMS
WATER TREATMENT PLANT

Hole No: ATP03
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:15



0.00

Closely packed dolerite boulders up to 500mm x 300mm in a matrix of slightly moist, reddish brown, clayey fine SAND with roots. Overall consistency stiff. **BOULDER DOLERITE**.

0.90

Moist, dark reddish brown, firm, granular textured, sandy CLAY with relatively closely packed fine ferricrete nodules and diabase gravels. **REWORKED DIABASE**.

2.20

Very moist to wet with depth, orange-brown mottled dark brown, soft, clayey SILT with scattered dolerite spheroids.

Note:
1. General sidewall seep at 2,4m.

2.90

NOTES

1) TLB near limit of reach – requested to stop.

2) Sidewall irregular due to boulders but stable.

3) Sidewall seep at 2,4m.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861306
y-coord : -43934

Hole No: ATP03

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

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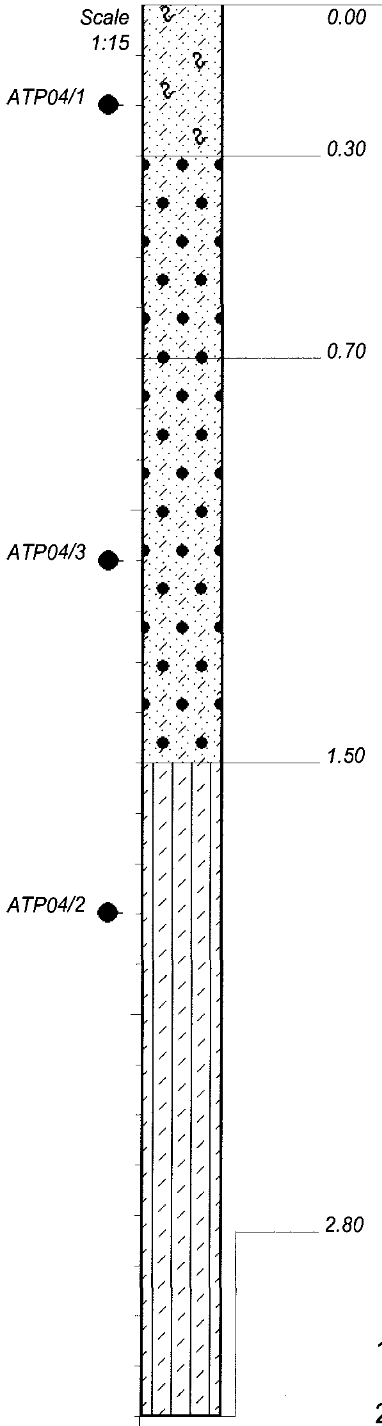
MMS
WATER TREATMENT PLANT

Hole No: ATP04
Sheet 1 of 1

JOB NUMBER: B478



0.00 Slightly moist, brown, medium dense, clayey fine SAND and roots. **TOPSOIL**.

0.30 Moist, dark reddish brown, clayey fine SAND with closely packed, fine (<10mm) ferricrete nodules and isolated sandstone boulders. **HILLWASH**.

0.70 Moist, dark reddish brown, firm, fissured, clayey SAND with relatively closely packed fine ferricrete nodules. **FERRUGINISED REWORKED DIABASE**.

1.50 Moist, dark reddish brown mottled light brown and orange-brown, firm, clayey SILT. **REWORKED DOLERITE**.

2.80

NOTES

1) TLB requested to stop.

2) Sidewalls vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) Agricultural sample ATP04/1 at 0,2m; disturbed sample ATP04/2 at 1,8m and agricultural sample ATP04/3 at 1,1m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861502
y-coord : -43686

Hole No: ATP04

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

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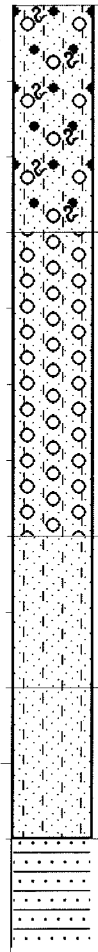
MMS
WATER TREATMENT PLANT

Hole No: ATP05
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00	Moist, pale brown, <u>medium dense</u>, silty fine and medium SAND with scattered, fine, ferricrete nodules to 10mm and isolated fine grained sandstone gravels with fine roots. **TOPSOIL**.
0.30	Closely packed, angular ine grained sandstone gravels in a matrix of moist, pale brown, slightly silty fine SAND with scattered fine roots. Overall consistency <u>dense</u>. **FERRUGINISED REWORKED SANDSTONE**.
0.70	Pale purple banded yellow-brown, relict jointed, thinly bedded, <u>very dense</u> to <u>very soft rock</u>, silty SAND. **RESIDUAL SANDSTONE**. <u>Note</u>: 1. Stained black on bedding.
0.90	but soft rock.
1.10	Pale purple, highly weathered, jointed and thinly bedded, fine grained, <u>soft rock</u>, **SANDSTONE**.

NOTES

1) TLB near refusal.

2) No seepage or water table.

3) Profiled in situ.

4) Hole vertical and stable.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : B. Antrobus

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861617
y-coord : -43874

Hole No: ATP05

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

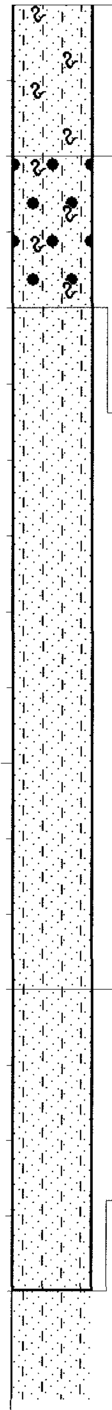
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

MMS
WATER TREATMENT PLANT

Hole No: ATP06
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00	Very moist, brown, loose, silty, coarse, medium and fine SAND with roots. **TOPSOIL**.
0.20	Closely packed, subrounded ferricrete nodules in a matrix as above. Overall consistency medium dense but friable. **SLIGHTLY FERRUGINISED HILLWASH**. Note: 1. Isolated gravels up to 75mm. 2. Very moist at lower contact.
0.40	Very moist, banded reddish brown to pale yellowish brown, dense, relict bedded, silty, coarse, medium and fine SAND. **RESIDUAL SANDSTONE**. Note: 1. Irregular ferruginised lenses up to 50mm.
1.30	Moist, pale grey, relict laminated, stained brown, very stiff, silty fine SAND. **RESIDUAL SANDY SILTSTONE.** Note: 1. Moderate sidewall seepage at contact.
1.70	As above but highly weathered very soft rock.

NOTES

1) TLB refused on very soft rock siltstone.

2) Vertical and stable sidewalls.

3) Moderate sidewall seep at 1,3m.

4) Profiled insitu.

5) No samples taken.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861716
y-coord : -44170

Hole No: ATP06

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

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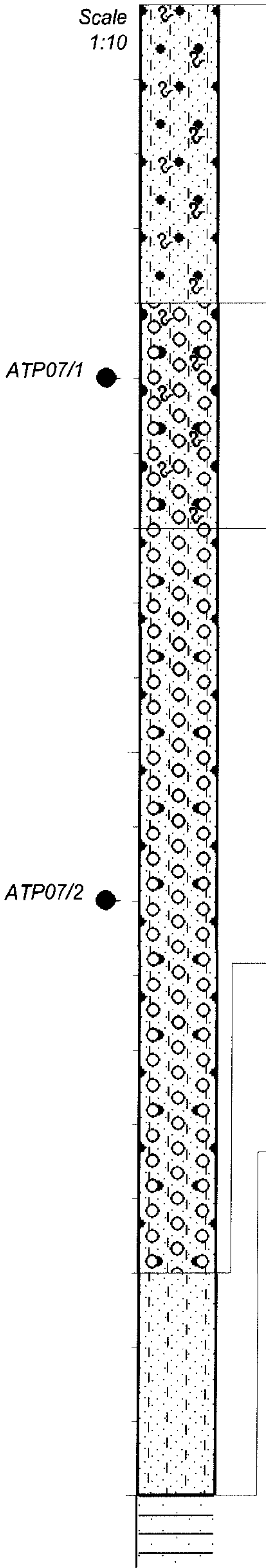
MMS
WATER TREATMENT PLANT

Hole No: ATP07
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00

Slightly moist, pale brown, <u>medium dense</u>, slightly silty, fine and medium SAND with scattered ferricrete nodules and fine roots. **TOPSOIL.**

0.40

Relatively closely packed quartz gravels and ferricrete nodules to 30mm in a matrix as above with scattered fine roots. Overall consistency <u>medium dense</u> but friable. **HILLWASH.**

0.70

Relatively closely packed fine gravels to 15mm and scattered ferricrete nodules in a matrix of slightly moist, red-brown blotched and streaked pale yellow-brown, slightly ferruginised silty fine SAND. Overall consistency <u>dense</u> becoming <u>very dense</u> with depth. **REWORKED RESIDUAL SANDSTONE.**

<u>Note</u>:
1. Continuous 150mm lense of very soft rock sandstone at 1,4m.
2. Indistinctly relict bedded.

1.70

Slightly moist, pale purple stained and streaked red-brown, <u>very dense</u>, relict jointed and bedded, silty fine SAND. **RESIDUAL SANDSTONE.**

<u>Note</u>:
1. Tending to very soft rock with depth.

2.00

Highly weathered, jointed and bedded, <u>very soft rock</u>, **SANDY SILTSTONE.**

NOTES

1) TLB near refusal - requested to stop.

2) Sidewalls vertical and stable.

3) No seepage or water table.

4) Profiled insitu.

5) Indicator sample ATP07/1 at 0,5m and ATP07/2 at 1,2m.

CONTRACTOR :	Vanalls Plant Hire	*INCLINATION :*	Vertical	*ELEVATION :*	
MACHINE :	Case 580 G	*DIAM :*	Trench	*x-coord :*	2861858
DRILLED BY :	Steyn	*DATE :*	28 May 2008	*y-coord :*	-43904
PROFILED BY :	J. Rapp	*DATE :*	28 May 2008		

Hole No: ATP07

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET
DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

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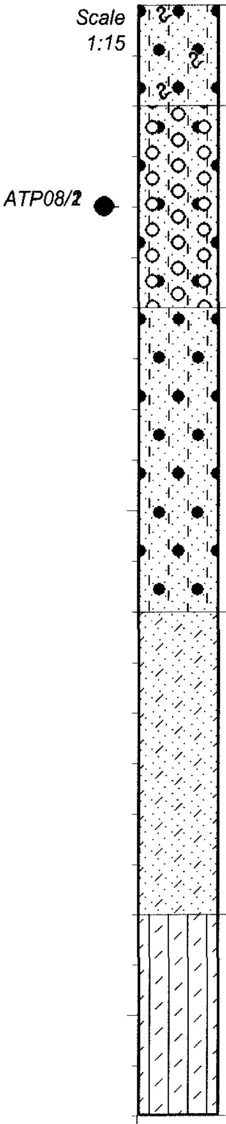
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

MMS
WATER TREATMENT PLANT

Hole No: ATP08
Sheet 1 of 1

JOB NUMBER: B478



0.00

Slightly moist, dark yellow-brown, medium dense, silty, medium grained SAND with scattered fine (<5mm) ferricrete nodules with fine roots. **TOPSOIL**.

0.20

Closely packed, subrounded ferricrete nodules (from 5mm to 15mm) and quartz gravels (<10mm) in a matrix of moist, yellow-brown, silty fine SAND. Overall consistency medium dense but friable.

0.60

Closely packed ferricrete concretions (from 10mm to 35mm) in a matrix of slightly moist, yellow-brown, silty fine SAND. Overall consistency dense. **WELL CEMENTED AND FERRUGINISED HILLWASH**.

1.20

Moist, red-brown mottled yellow-brown, clayey fine SAND to sandy CLAY with closely packed, slightly ferruginised shale fragments. **POORLY FERRUGINISED AND CEMENTED REWORKED SILTSTONE**.

1.80

Slightly moist, pale pinkish red, stiff, relict laminated, clayey SILT. **RESIDUAL SILTSTONE**.

Note:
1. Becomes very stiff to very soft rock below 2,1m.
2. General sidewall seepage at 2,17m.

2.20

NOTES

1) TLB excavating slowly - requested to stop.

2) Sidewalls vertical and stable.

3) General sidewall seep at 2,17m.

4) Profiled in situ.

5) Agricultural sample ATP08/1 at 0,4m. Disturbed sample ATP08/2 at 0,4m.

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

ELEVATION :
x-coord : 2861742
y-coord : -43667

Hole No: ATP08

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

Jones & Wagener
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MMS
WATER TREATMENT PLANT

Hole No: ATPT1
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10

0.00	Slightly moist, light brown, <u>medium dense</u>, silty, medium and fine SAND with fine ferricrete nodules and generally gravels. <u>Note</u>: 1. Basal closely packed pebble marker horizon.
0.45	Moist, banded red-brown and yellow-brown, <u>stiff</u>, finely bedded (indistinct) sandy SILT. **RESIDUAL SILTSTONE**. <u>Note</u>: 1. Poorly ferruginised.
1.30	As above but dark reddish brown streaked grey with isolated boulders up to 300mm. <u>Note</u>: 1. Profile sidewall of existing drainage trench.
1.70	

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

ELEVATION :
x-coord : 2862377
y-coord : -44010

Hole No: ATPT1
TRENCH S1

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Consulting Civil Engineers
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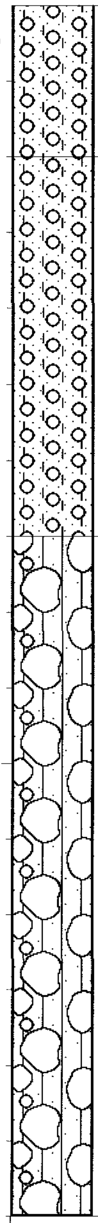
MMS
WATER TREATMENT PLANT

Hole No: ATPT2
Sheet 1 of 1

JOB NUMBER: B478

Scale
1:10



0.00	Slightly moist, brown, <u>medium dense</u>, silty fine SAND with relatively closely packed, subrounded gravels and isolated boulders from 5mm to 150mm. **COLLUVIUM**.
0.20	Slightly moist, red-brown streaked yellow-brown, <u>stiff</u>, indistinctly laminated, weakly ferruginised, silty fine SAND with isolated gravels in upper 100mm of horizon. **POORLY FERRUGINISED RESIDUAL SILTSTONE**.
0.70	Moist, brownish purple banded yellow-brown and grey, <u>very stiff</u>, relict laminated, sandy SILT with scattered, subrounded, mixed gravels and boulders from 50mm to 150mm. **RESIDUAL DIAMICTITE (TILLITE).**
1.60	

CONTRACTOR : Vanalls Plant Hire
MACHINE : Case 580 G
DRILLED BY : Steyn
PROFILED BY : J. Rapp

TYPE SET BY : Beth
SETUP FILE : STANDARD.SET

INCLINATION : Vertical
DIAM : Trench
DATE : 28 May 2008
DATE : 28 May 2008

DATE : 01/10/08 10:45
TEXT : ..\B478_M~1\B478BA~2.DOC

ELEVATION :
x-coord : 2862359
y-coord : -43751

Hole No: ATPT2
TRENCH S2

dot.PLOT 5003 J&W

MIDDELBURG MINE SERVICES

FEASIBILITY GEOTECHNICAL EVALUATION OF
TWO PROPOSED WATER TREATMENT PLANTS
MIDDELBURG MINE, MIDDELBURG

Report: JW107/08/B478 - Rev 0

APPENDIX B

LABORATORY TEST RESULTS

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: (011) 519-0200 Fax: (011) 803-1456 email: post@jaws.co.za

Client:	**Middelburg Mine Services**
Job:	**Middelburg Mine Water Treatment Plant**
Lab:	**Civilab**
Tests:	

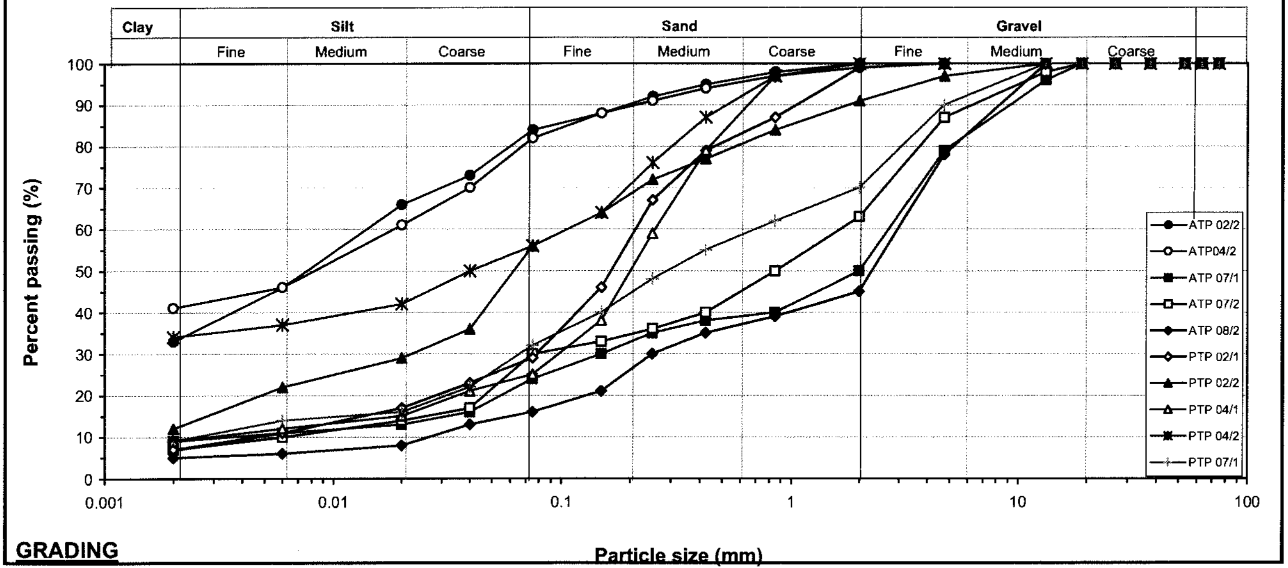
Our Ref:	**B478**
Set no.:	**1/2**
Made by:	**MT**
Date:	**16 June 2008**

Classification Data

Hole no.			**ATP 02**	**ATP 04**	**ATP 07**	**ATP 07**	**ATP 08**	**PTP 02**	**PTP 02**	**PTP 04**	**PTP 04**	**PTP 07**
Sample Name			**ATP 02/2**	**ATP04/2**	**ATP 07/1**	**ATP 07/2**	**ATP 08/2**	**PTP 02/1**	**PTP 02/2**	**PTP 04/1**	**PTP 04/2**	**PTP 07/1**
Depth		m	**1.5**	**1.8**	**0.5**	**1.2**	**0.4**	**0.4**	**1.9**	**0.3**	**1.3**	**1.8-2.2**
Description												
Specific Gravity:	G_s											
Grading:												
		75.0	100	100	100	100	100	100	100	100	100	100
		63.0	100	100	100	100	100	100	100	100	100	100
		53.0	100	100	100	100	100	100	100	100	100	100
		37.5	100	100	100	100	100	100	100	100	100	100
		26.5	100	100	100	100	100	100	100	100	100	100
		19.0	100	100	100	100	100	100	100	100	100	100
		13.2	100	100	96	98	100	100	100	100	100	100
	No 4	4.75	100	100	79	87	78	100	97	100	100	90
	No 10	2.00	100	99	50	63	45	99	91	100	100	70
	No 20	0.850	98	97	40	50	39	87	84	97	97	62
	No 40	0.425	95	94	38	40	35	79	77	79	87	55
	No 60	0.250	92	91	35	36	30	67	72	59	76	48
	No 100	0.150	88	88	30	33	21	46	64	38	64	40
	No 200	0.075	84	82	24	30	16	29	56	25	56	32
	Hydrometer	0.040	73	70	16	17	13	23	36	21	50	22
		0.020	66	61	13	14	8	17	29	15	42	16
		0.006	46	46	11	10	6	11	22	12	37	14
		0.002	33	41	9	7	5	7	12	9	34	9
Grading Properties												
D_{10}		mm			0.003	0.006	0.026	0.005		0.003		0.002
D_{30}		*mm*			0.150	0.075	0.250	0.078	0.022	0.098		0.066
D_{60}		*mm*	0.014	0.018	2.695	1.642	2.963	0.211	0.106	0.257	0.106	0.697
Coefficient of Uniformity	CU				778.0	273.6	112.3	46.3		89.0		279.9
Coefficient of Curvature	CC				2.4	0.6	0.8	6.3		12.9		2.5
Grading Modulus	**GM**		**0.21**	**0.25**	**1.88**	**1.67**	**2.04**	**0.93**	**0.76**	**0.96**	**0.57**	**1.43**
Gravel	G	%	0	1	50	37	55	1	9	0	0	30
Sand	S	%	22	23	30	40	31	73	45	77	47	43
Silt	M	%	46	35	11	17	10	19	34	14	19	18
Clay	C	%	33	41	9	7	5	7	12	9	34	9
Fines	M+C	%	79	76	20	24	15	26	46	23	53	27
Total		%	100	100	100	100	100	100	100	100	100	100
Matrix		%	100	99	50	63	45	99	91	100	100	70
Matrix Sand		%	22	23	60	63	68	74	49	77	47	61
Matrix Silt		%	46	35	22	26	21	19	37	14	19	26
Atterberg Limits												
Liquid Limit	LL	%	54	50	24	31	19	18	32		37	26
Plastic Limit	PL	%	31	25	12	21	12	13	20		19	16
Shrinkage Limit	SL	%										
Linear Shrinkage	LS	%	11.0	12.0	5.5							
Plasticity Index	PI	%	23	25	12	10	7	5	12		18	10
PI Whole Sample		%	22	24	5	4	2	4	9		16	6
Liquidity Index	LI		0.3 Plastic									0.1 Plastic
Clay Activity	A		0.70 Inactive	0.61 Inactive	1.33 Active	1.43 Active	1.40 Active	0.71 Inactive	1.00 Normal		0.53 Inactive	1.11 Normal
Vd Merwe Swell		%	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low
Brackley Swell												
Natural Moisture Content	w	%	38.1									16.8
Dry Density	ρ_d	*kg/m³*										
Saturation	S	%										
Swell @ p(kPa)	50	%										
	125	%										
	250	%										
Classification												
			Silty	**Silty**	**Silty**	**Silty**			**Silty**	**Silty**	**Sandy**	**Silty**
Matrix Description			**CLAY**	**CLAY**	**SAND**	**SAND**	**SAND**	**Silty SAND**	**SAND**	**SAND**	**CLAY**	**SAND**
British			**MH**	**CI**	**GCL**	**GCL**	**GCL**	**SML**	**CLS**	**SML**	**CIS**	**SCL**
AASHTO			**A-7-5[16]**	**A-7-6[16]**	**A-2-6[0]**	**A-2-4[0]**	**A-2-4[0]**	**A-2-4[0]**	**A-6[5]**	**A-2-4[0]**	**A-6[7]**	**A-2-4[0]**
Unified			**MH/OH**	**CH**	**SC**	**SC**	**SC**	**SC-SM**	**CL**	**SM**	**CL**	**SC**

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: (011) 519-0200 Fax: (011) 803-1456 email: post@jaws.co.za

Client:	**Middelburg Mine Services**	**Our Ref:**	**B478**
Job:	**Middelburg Mine Water Treatment Plant**	**Set no.:**	**1/2**
Lab:	**Civilab**	**Made by:**	**MT**
Tests:		**Date:**	**16 June 2008**



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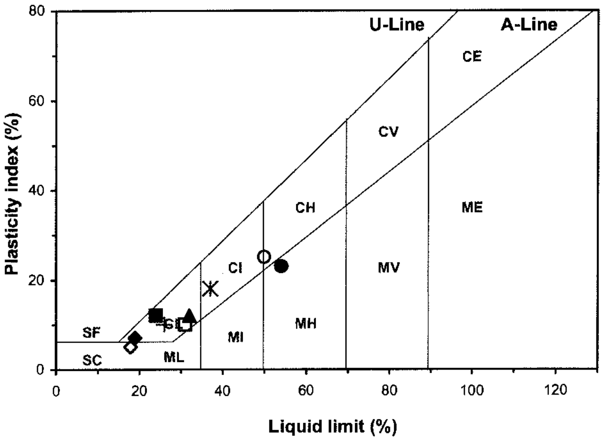
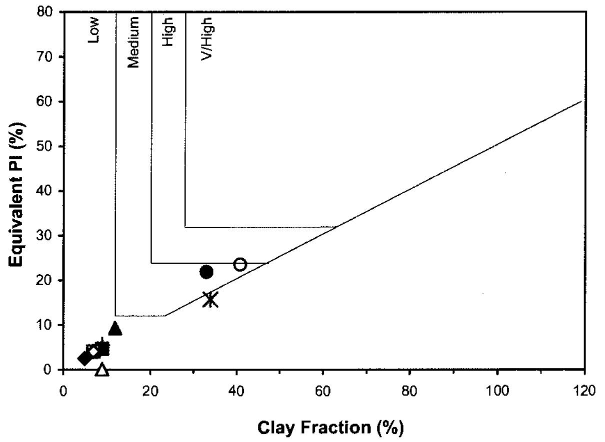


CASAGRANDE CHART



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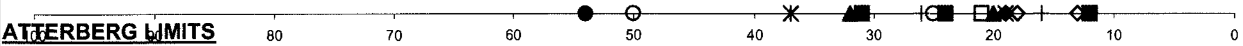
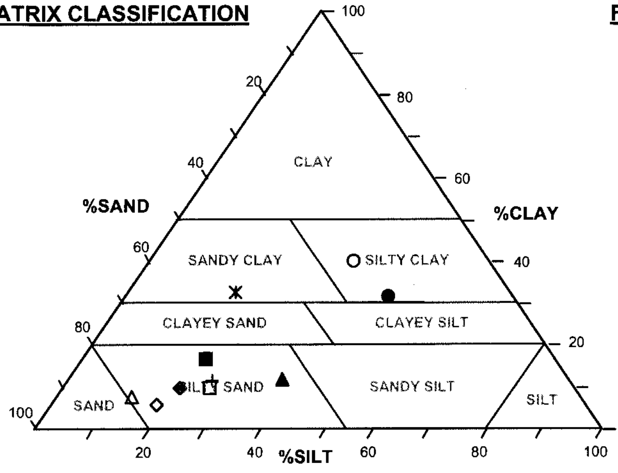
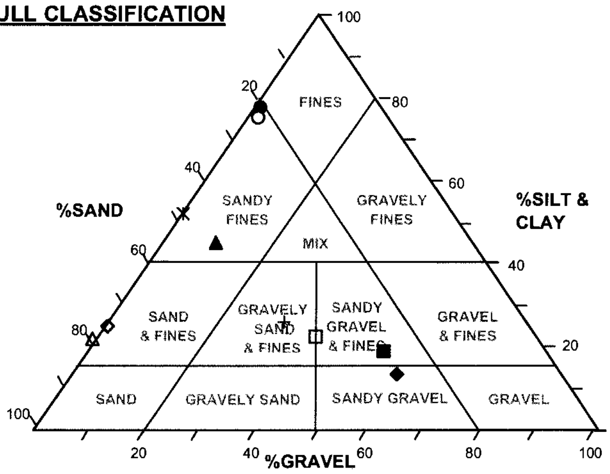


ATTERBERG LIMITS

MATRIX CLASSIFICATION



FULL CLASSIFICATION



Groundwater Assessment for the Middelburg Water Treatment Project

Middelburg Mine, Middelburg

Compiled by
Sakhile Mndaweni, Brent Usher and Danie Vermeulen

Report number: 2008/ 33/PDV

January, 2009

Institute for Groundwater Studies
University of the Free State, P.O. Box 339, Bloemfontein 9300
Phone: 051-401 2482 – Fax: 051-444 6538 – http://www.uovs.ac.za/igs

Executive Summary

Jones and Wagener approached the Institute for Groundwater Studies to conduct an investigation at the proposed Middelburg Mine Water Treatment Plant.

The aim of the study is to:

- Briefly overview the geohydrology of the site indicating potential fatal flaws,
- Drill upstream and downstream boreholes at the site,
- Model the potential impacts of leaks from the brine pond and sludge areas, and
- Indicate possible mitigation measures should leaks be detected.

From this:

- A conceptual understanding of the groundwater/geology of the area is determined.
- Pathways by which possible receptors might be affected by the leachate are identified.
- A risk assessment to determine the risk that the leachate and/ or impact thereof have on human receptors, the ecosystem and surface and groundwater is conducted.

Geophysical work was executed by the use of magnetic and electromagnetic methods. The results of the magnetic survey in the immediate western regions of the Middelburg Mine Water Treatment Plant area indicate that no major structural features were encountered in those regions.

Prior to the pump test, slug tests were performed on all boreholes and piezometers to estimate the hydraulic conductivity. The initial estimations of the transmissivity values, obtained from the borehole blow yields information, for the region are in the range of 0.069 - 0.486 m^2/day. All tested boreholes have a low transmissivity (T-value) of 1.3 m^2/day.

All boreholes show that all compounds tested are within the acceptable (Class I) SANS 241:2006 water quality standards.

From the numerical modeling exercise, the developed simulated plume after twenty years is indicative of slow plume migration, with the plume more concentrated in the immediate vicinity of the site.

The results of the Middelburg Mine Water Treatment Plant site risk assessment indicate that the site poses very low pollution risk to the area, with no associated health risks due to the non existent groundwater use in the area.

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UNIVERSITEIT VAN DIE VRYSTAAT
UNIVERSITY OF THE FREE STATE

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🖷: +27-(0)51-444 6538

1. Introduction

1.1 Project Description

Jones and Wagner Consulting Engineers approached the Institute for Groundwater Studies to conduct a groundwater specialist study as an input into the EIA, EMP, IWWMP and IWULA process on the potential impact on the groundwater by the proposed Middelburg Mine Water Treatment Plant.

Contaminated water from the mines will be treated and used by the local communities. Sludge and brine wastes will have to be disposed off, and it is anticipated that the brine residue will be stored in brine evaporation ponds, and the sludge disposal facility adjacent to the brine evaporation ponds, or discharged into the Olifants River Catchment. These facilities must be permitted as a hazardous waste disposal site (DWAF, 1998) and also be constructed according to the Department of Water Affairs and Forestry (DWAF, 1998) guideline for construction of hazardous waste disposal sites.

1.2 Legal Framework

Currently, the South African water resource environment is protected by several important pieces of legislation. The three most important include:

- The Constitution of the Republic of South Africa (Act 108 of 1996), which states that it is a fundamental right of every person to have an environment which is not detrimental to his/her health or wellbeing and to have an environment protected for the benefit of present and future generations,
- The Environmental Conservation Act (ECA Act 73 of 1989), which governs the protection and control of the environment and the National Environmental

Management Act (NEMA Act 107, 1998), which promotes the cooperative management of issues pertaining the environment, and

- The National Water Act (NWA Act 36 of 1998), providing the necessary framework within which to protect, use, develop, conserve, manage and control South African water resources.

The Waste Bill (Government Gazette No. 30142, 2007) is aimed at reforming the laws regulating waste management for the protection from pollution and ecological degradation.

More than half of South Africa's land is underlain by the sediments of the Karoo Stratigraphic Sequence, characterised by fractured hard rock aquifers (Botha, *et al.*, 1998). These aquifers can be described as the most important source of potable water for many of the South Africa's rural communities, and they should therefore be protected against any contamination.

1.3 Scope of Work

1.3.1 Objectives

- Brief overview of the geohydrology of the site indicating potential fatal flaws,
- Drilling of upstream and downstream boreholes at the site,
- Model the potential impacts of leaks from the brine pond and sludge areas,
- Indication of possible mitigation measures should leaks be detected, and
- Broad review of the likely long term water chemistry to be fed into the water treatment plant.

1.3.2 Deliverables

- Review all existing geological information and geophysical investigations to indicate potential fatal flaws (if any).
- Development of the initial site conceptual model and establishment of initial groundwater monitoring network.
- Identify the pathway by which possible receptors might be affected by the potential leaks and also identify the receptor(s) (groundwater, streams, etc), which may be affected in future affected by the leaks.

- Conduct a risk assessment to determine the risk that the leaks and/ or impact thereof has on human receptors, the ecosystem and surface and groundwater.

1.3.3 Methodology

The steps followed to meet these objectives are as follows:

- Study all the available data,
- Geophysical Investigations,
- Drilling Investigations,
- Aquifer Parameter Estimation,
- Numerical Flow and Mass Transport Modelling and,
- Risk Assessment.

2. Description of the Study Area

2.1 Overview

Middelburg mine is an opencast coal mining operation located at about 20 km south-southwest of the Middelburg town and 20 km southeast of the Witbank town (Figure 1) in the Mpumalanga province of South Africa. The mine area can be accessed via road R575 from Middelburg town. The proposed Mine Water Treatment Plant is located at about 3 km north of the mine (Figure 1) at coordinates (S25.910703, E29.402680) on the farm HARTBEESFONTEIN339JS.

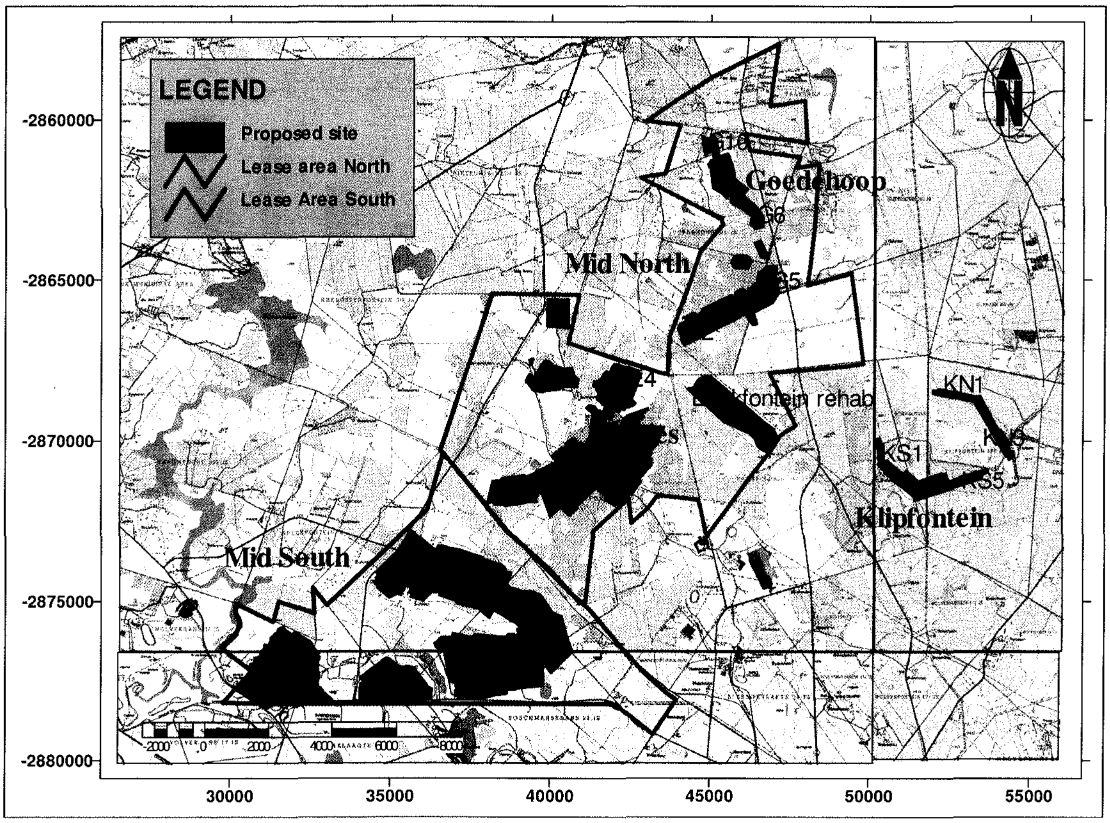

Figure 1: Locality Map showing Middelburg Mine and the Proposed Mine Water Treatment Plant site.

2.2 Physiography

2.2.1 Climate

The Middelburg mine area is located in the Highveld Climatic Zone, a temperate climate with hot summers and cool to cold winters associated with frost. Average maximum daily temperatures range in the vicinity of 26°C in December-January to an average minimum of 1°C in June -July.

The region is a summer (October - March) rainfall region, with 89% of rain occurring during these months (SA Weather Services). Most of the heavy rain in the region is associated with thunderstorms. The average annual rainfall (MAP) for the area is 700 mm per annum. The mean annual evaporation (MAE) of the region is 1566 mm, and the mean annual run-off (MAR) 50mm (Figure 2).

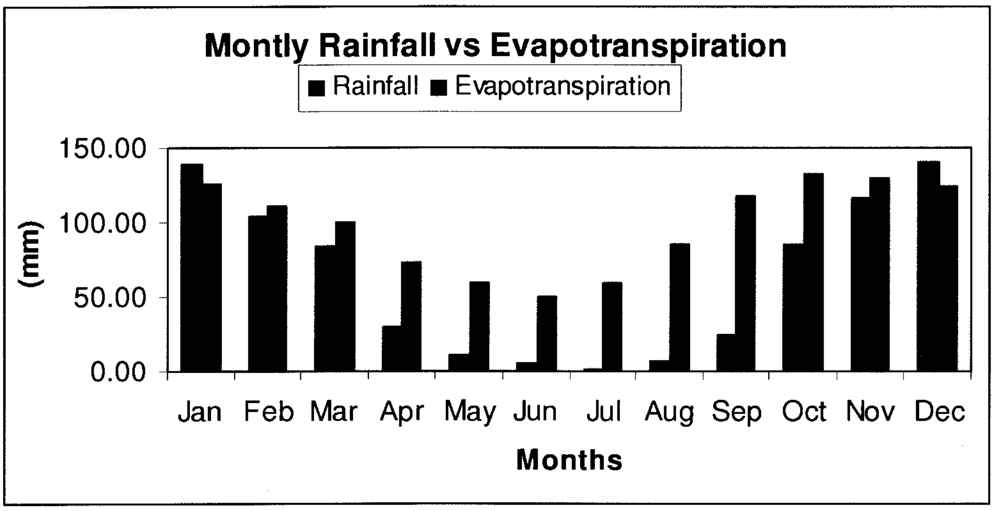

Figure 2: Plot of monthly rainfall vs evapotranspiration in the Witbank Dam (DWAF, 2008).

2.2.2 Topography and Drainage

The region is relatively flat characterised by gently rolling hills that are broken by drainage lines, with an average elevation of 1550 metres above mean sea level (mamsl). The Middelburg mine area falls within quaternary catchment B11H, all of which fall within the Limpopo-Olifants primary drainge region, with the Spookspruit River the main tributary in the area draining towards north northwest to the Olifants River. The landscape is characterised by low-gradient streams meandering over small alluvial plains.

2.3 Geology and Geohydrology

2.3.1 General Geology

Regionally, the area is wholly underlain by rocks of the Karoo Supergroup, mainly comprising clastic sediments of the Permian age Ecca Group. In South Africa, the

Ecca Group occurs between the lower late Carboniferous Dwyka Group and the upper late Permian-Middle Triassic Beaufort Group, attaining a maximum depth of about 3000m in the south (foreland), and diminishing outward. In the northern part of the Karoo Basin, the Ecca Group is subdivided from the bottom up into the Pietermaritzburg, Vryheid and Volkrust formations, conformably overlying the Dwyka tillite that represents the basal unit of the Karoo sequence.

The Middelburg mine area forms the northern part of the Karoo basin, falling within the Witbank Coalfied and the area is predominantly underlain by rocks of the Vryheid formation, and these are shallow marine and fluvio-deltaic sediments, consisting predominantly of a series of vertically stacked, upward-coarsening and upward-fining facies assemblages of interbedded sandstone, siltstone, shale, minor conglomerates and several coal seams. The depths below the surface of the coal seams is relatively shallow, with the underground workings seldom deeper than 200m.

Throughout South Africa, the Jurassic age dolerites have intruded into the Karoo Supergroup and the underlying gneissic basement in the form of horizontal to sub-horizontal transgressive sills and near-vertical dykes in the region. The dolerite sills range in thickness from 30-300m and the dolerite dykes range from 1-50m. Most of sediments in the vicinity were recrystallised during intrusion. Quaternary deposits are found along the rivers and streams, consisting mainly of gravels that comprise cobbles and boulders.

2.3.2 General Geohydrology

The Karoo Supergroup mainly consists of fractured-rock aquifers characterised by sediments with low permeability. This implies that groundwater movement occurs mostly along secondary structures such as fractures, cracks and joints in the sediments. The Karoo aquifers are the most extensive type of aquifers in South Africa.

There are two distinct and superimposed groundwater systems in the Highveld Coalfields area;

- The upper weathered Ecca aquifer system, and
- The lower fractured rock Ecca aquifer system.

The upper weathered Ecca aquifer system is associated with the uppermost weathered horizon, mainly comprising weathered Ecca sediments and quaternary deposits, weathered to depths between 5-12 metres below surface, and sometimes perched. This aquifer is directly recharged by rainfall infiltrating through the weathered zone until it reaches the underlying impermeable solid rock. Thereafter groundwater movement occurs on the contact zone between the weathered part and the underlying consolidated sediments following their slope. Where barriers exist (dykes, sill, etc.), obstructing the flow, this water is discharged on surface as fountains or springs. The aquifer has low yields (+/- 0.1 l/s) with shallow water tables. Most of the groundwater from this aquifer is discharged into surrounding rivers and streams.

Immediately below the upper weathered horizon is the lower fractured Ecca aquifer system, which is mainly composed of well-cemented sediments with little or no groundwater movement. All groundwater movement is associated with secondary structures (fractures, faults, dykes, etc.). Borehole yields in Karoo aquifers are generally low (+/- 1 l/s), with regional flow resembling flow in the porous medium (i.e. obeying Darcy's law). This implies that formations contain large quantities of water that cannot be released readily on a small scale.

3. Field Investigations and Data Analysis

3.1 Geophysical Investigations

The DWAF (1998) minimum requirements clearly indicate that waste disposal sites should not be sited on unstable ground (e.g. fault zones, seismic zones and where sinkholes and subsidence are likely to occur). The proposed site for the Middelburg Water Treatment Plant area is located within the Witbank Coalfields, but no underground mining or opencast mining underlies the area of the site.

Geophysical techniques are useful in the assessment of physical and chemical properties of soils, rocks and groundwater. In groundwater contamination studies, they are useful in the preliminary characterisation of soils, geologic stratigraphy and subsurface structures, and the further characterisation of the extent and direction of the contaminant plume.

Appendix 1 has a geophysical report on geophysical investigations conducted on the Middelburg Water Treatment Plant site.

3.2 Borehole Drilling

Drilling incorporates the collection of all site-related information on subsurface conditions, i.e. geology, hydrogeology and the extent of contamination with depth. Percussion drilling method was utilised for the full site characterisation, in order to obtain information about the geology (rock types, physical and chemical properties and water quality) of the site. Three pairs (shallow and deep) of boreholes were drilled during June 2008 at strategic locations, with one up-gradient and two down-gradient of the proposed site. Figure 3 shows the positions of all the boreholes at the proposed site.

The shallow boreholes were drilled to 11 m, cased with 165 mm slotted steel casing and further installed inside with slotted HPDE pipe piezometers. The deep boreholes were drilled to 30 - 40 m, with solid only steel casing installed only in the soil and weathered part of upper formations. This was done to study the flow of groundwater in the shallow and deeper aquifers.

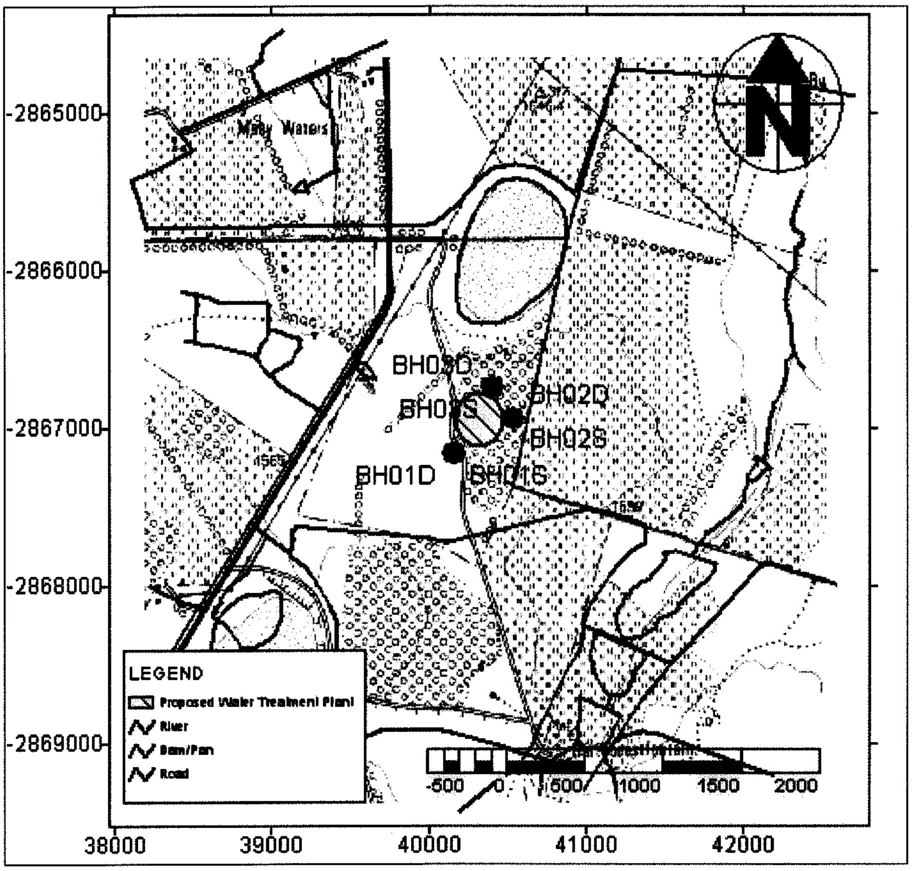

Figure 3: Map showing the proposed site with monitoring boreholes.

The general lithology obtained from borehole drilling at the site is mainly composed of alternating layers of sandstones and shales below the soil clay layer. The coordinates of the boreholes and their blow yields are depicted in Table 1.

Table 1: Coordinates of boreholes at the proposed site.

BH No	Y-Coord	X-Coord	Elevation (mamsl)	Collar Height (m)	Blow Yield (L/hr)	Strike Depth (m)	BH Depth (m)	Water Level (mbgl)
BH01D	-2867155	40159	1558	0.54	200	38	39	6.04
BH01S	-2867158	40165	1558	0.53	50	-	12	2.28
BH02D	-2866931	40543	1553	0.34	50	32	34.62	2.57
BH02S	-2866931	40533	1554	0.55	-	-	12	3.1
BH03D	-2866736	40401	1552	0.43	350	27	27.87	2.4
BH03S	-2866735	40409	1552	0.59	-	-	12	1.93

The photographs (Figure 4, Figure 5 and Figure 6) below show all boreholes that were drilled at the site.

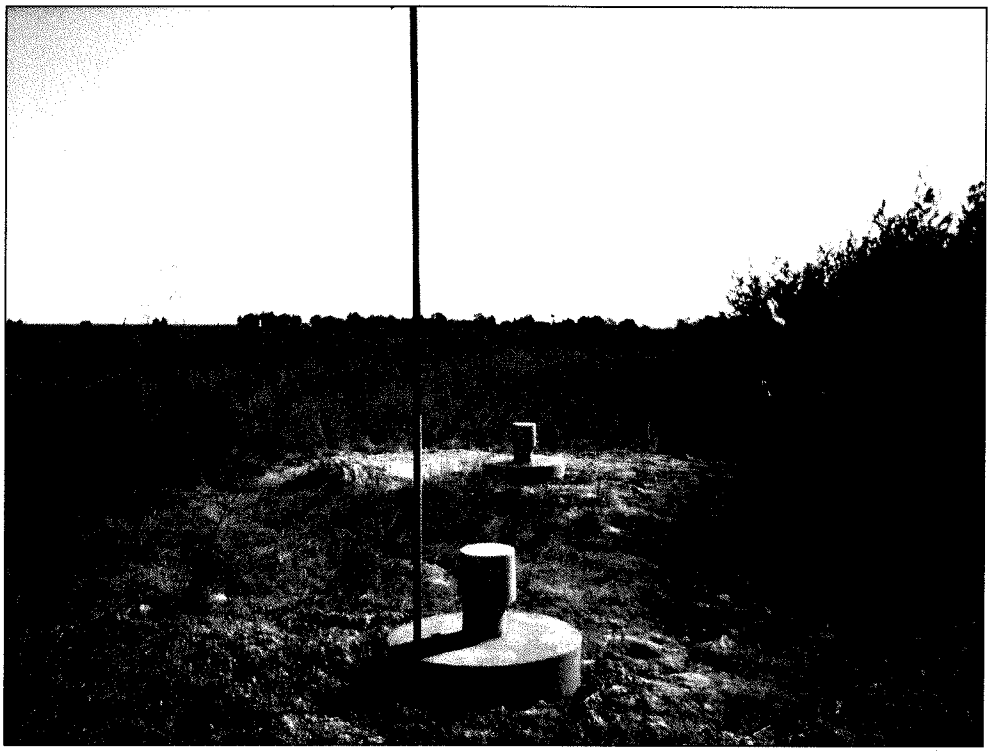

Figure 4: BH01 (shallow - near and deep - distant).

Figure 5: BH02 (shallow - near and deep - distant).

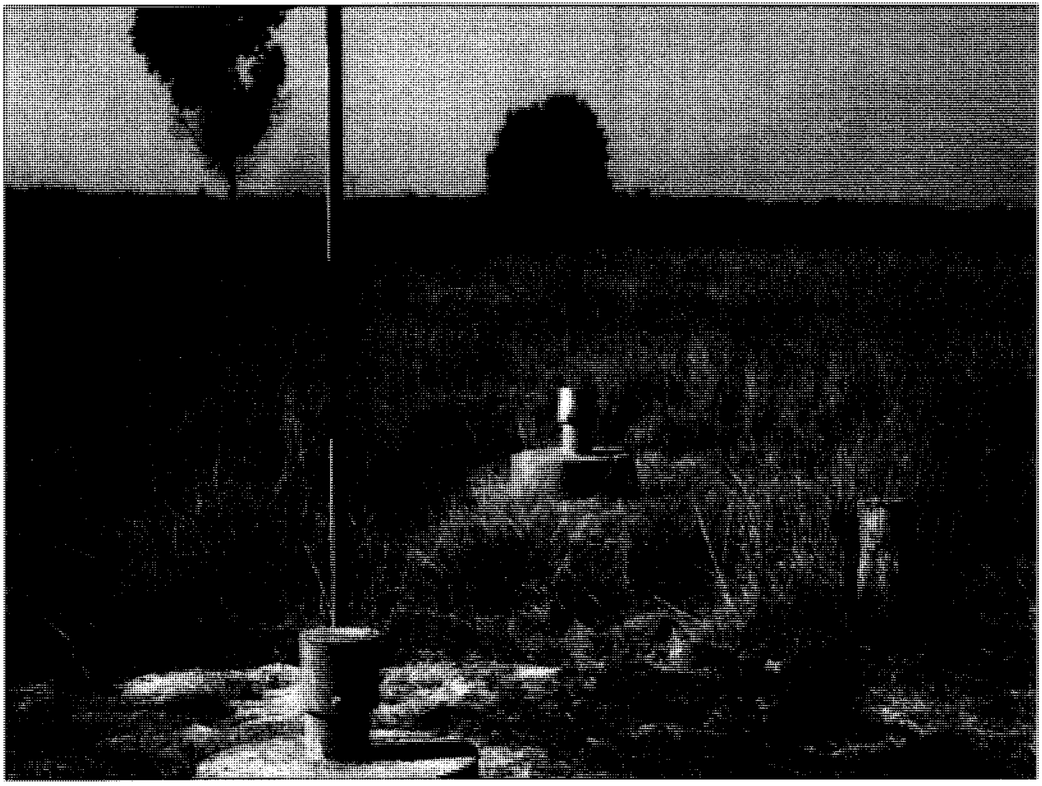

Figure 6: BH03 (deep - near and shallow - distant).

3.3 Hydrochemical Borehole Logging

An YSI multi-parameter Sonde probe was used to obtain geochemical profiles for all three deep boreholes, measuring electrical conductivity (EC), Temperature (T), Oxidation Reduction Potential (ORP) and pH with depth, to study the effects of the various lithologies on the chemistry. These profiles are obtained in situ and changes in any of the above parameters with depth will indicate changes in aquifer conditions, i.e. hydraulic (fracture) or/and chemical (contaminant plume) conditions. Figure 7, Figure 8 and Figure 9 below illustrates the geochemical logging data from the boreholes.

Profile of BH01D:

- This borehole is 38 m deep, with a water level of 6.04mbgl.
- The chemical profiling (Figure 7) indicated no major stratifications/existence of major fractured zone with only minor difference observed in ORP with depth.

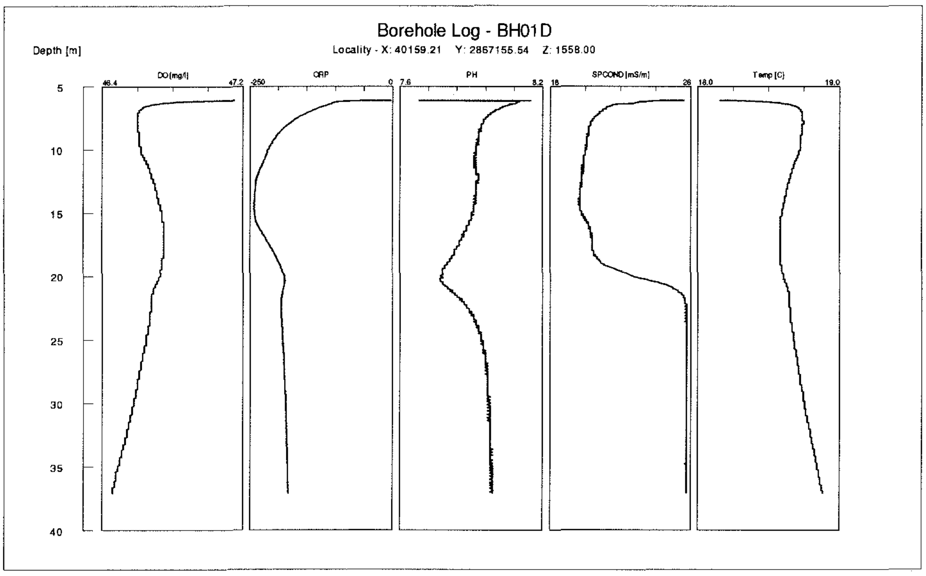

Figure 7: Chemical profiling of BH01D.

Profile of BH02D:

- This borehole is 32 m deep, with a water level of 2.57mbgl.
- The chemical profiling (Figure 8) indicated no major stratifications/existence of major fractured zone with only minor difference observed in ORP with depth.

Profile of BH03D:

- This borehole is 27 m deep, with a water level of 2.40mbgl.
- The chemical profiling (Figure 9) indicated no major stratifications/existence of major fractured zone with only minor difference observed in ORP with depth.

Therefore, all three boreholes indicate no major changes in aquifer conditions with depth, indicating similar aquifer conditions except for the ORP. The ORP from all of the boreholes changes from the positive values at the top and become negative with depth and the similar trend is observed with the DO, but at lesser extent. The implication is that the reducing conditions are increasing with depth.

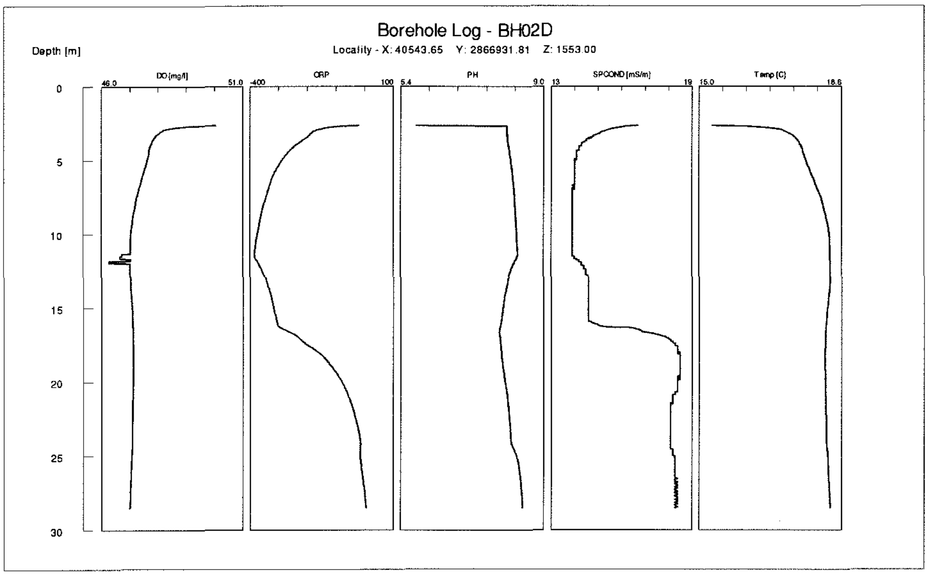

Figure 8: Chemical profiling of BH02D.

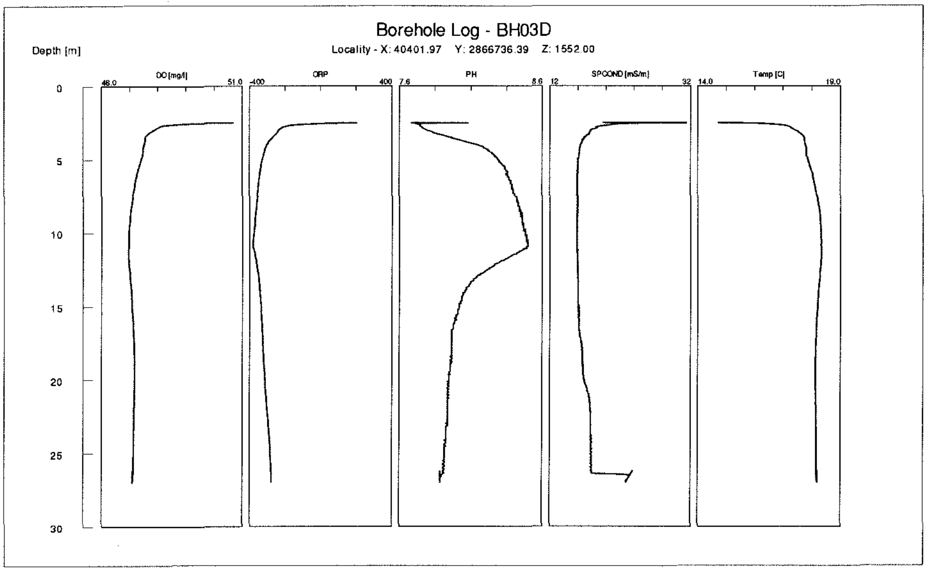

Figure 9: Chemical profiling of BH03D.

3.4 Aquifer Testing

3.4.1 Blow yields

The blow yield gives an early indication of the yield of a borehole. From the data in Table 2, it is clear that all boreholes have very low yields, with the strike deeper down at 27-38m in the shale. The initial blow yield for a borehole could provide an early estimate of the transmissivity/T-values (Van Tonder *et al.*, 2002).

$T\ (m^2/d) = 5 \times Q$ where Q is in L/s.

Table 2: Estimated T-vaues obtained from blow yield information.

Site Name	Blow Yield (l/h)	Strike Depth (m)	Estimated T (m^2/d)
BH 01D	200	38	0.277
BH 02D	50	32	0.069
BH 03D	350	27	0.486

3.4.2 Slug Test

Prior to the pump test, slug tests were performed on all three deep boreholes to estimate the hydraulic conductivity. The slug test is applicable for the *in-situ* determination of the saturated hydraulic conductivity in unconfined and confined aquifers, and is applied in partially to fully penetrating boreholes to determine the horizontal hydraulic conductivity in the borehole. This method consists of inserting (falling head) or removing (rising head) a slug instantaneously in a borehole and measuring the recovery of the water in the borehole. The equilibrium in the water level is altered, and the water level will then recover to its initial water level. The analysis was then made using the Bouwer-Rice (1976) method in the FC-program (Van Tonder *et al.*, 2002), and based on the equation below.

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2d} \frac{1}{t} \ln \frac{h_0}{h_t}$$

Where:

r_c = radius of the unscreened part of the borehole where the head is rising

r_w = horizontal distance from the borehole centre to the undisturbed aquifer

R_e = Radial distance over which the difference in head h_0 is dissipated in the flow system of the aquifer

d = length of the borehole screen or open section of the borehole

h_0 = head in the borehole at time t_0

h_t = head in the borehole at time t

The results of major interest are, and most importantly, values of hydraulic conductivity for the boreholes tested, and therefore the hydraulic conductivity of the area surrounding the borehole. Table 3 shows the estimated hydraulic conductivities (K-values) from the three boreholes at the Middelburg Mine Water Treatment Plant area. The average horizontal hydraulic conductivity in the immediate vicinity of the borehole or piezometer was estimated with the above equation.

Table 3: Hydraulic conductivity from slug test.

Borehole Number	K-value (m/d)
BH01D	0.17
BH02D	0.03
BH03D	0.167

3.4.3 Pumping Test (Aquifer Test)

A constant rate test is "performed in order to assess the productivity of the aquifer according to its response to the abstraction of water". This response can be analysed to provide information with regard to the hydraulic properties of the groundwater system (Van Tonder *et al*, 2002). The duration of the constant rate test depends on the objectives of the test results.

Constant rate discharge tests were performed to determine the transmissivity of the aquifer; thus information with regard to the hydraulic properties of the groundwater system. Constant discharge tests were performed on Boreholes BH01D, BH02D and BH03D. The transmissivity (T-values) were estimated by means of the Cooper - Jacob method. The Cooper - Jacob Method, also known as the Jacob Method, was developed in 1946 (Krusemann and De Ridder, 2000). It is based upon the Theis Method. The Cooper-Jacob equation is as follows:

$$s = \frac{2.30Q}{4\pi KD}\log\frac{2.25KDt}{r^2S}$$

Also, the recovery tests were conducted in order to allow the transmissivity of the aquifer to be calculated using Theis recovery method (Krusemann and De Ridder, 2000), thereby providing an independent check on the results of the pumping test. The analysis of a recovery test is based on an assumption that after the pump has been shut down, the borehole continues to be pumped at the same discharge rate as before, and that an imaginary recharge equal to the discharge is injected into the borehole.

$$s'=\frac{2.30Q}{4\Pi KD}\log t/t'$$

s' - residual drawdown

From a plot of s' versus t/t', the slope Δs' can be estimated.

$$\Delta s'=\frac{2.30Q}{4\Pi KD}$$

The Cooper - Jacob and the Theis equations were also used for the analysis of the constant rate pump tests. The hydraulic conductivity values are linked to the transmissivity values (T-value), as transmissivity is a product of the hydraulic conductivity and the aquifer thickness (T=KD). Table 4 present the T-values obtained from the tests.

Table 4: Transmissivity values form pumping tests.

Borehole Number	T-value (Cooper - Jacob) (m^2/d)	T-value (Theis's Recovery) (m^2/d)
BH01D	0.3	1.3
BH02D	0.3	1.6
BH03D	1.5	1.5

All tested boreholes have a low transmissivity (T-value) of approximately approx 1.3 m^2/day. The transmissivity values obtained represent the T-values for the upper aquifer in the region, also taking into consideration the K-values obtained from slug test.

4. Water Quality Analysis

A specific depth sampler was used to sample at positions indicated by probing of the boreholes. All water samples collected from the six boreholes were analysed for the dissolved inorganic parameters at the Institute for Groundwater Studies laboratory using spectrophotometer, ion chromatograph (anions) and Inductively Coupled Plasma Atom Emission Spectrophotometer (cations).

The chemistry data were interpreted by means of the WISH software package (Lukas, 2008) for water quality standards and plotting of specialised diagrams. The criteria used for inorganic analysis is the **SANS 241:2006** standards. The inorganic water samples are classified as follows:

- Class I - acceptable (colour coded green, but not illustrated in the table)
- Class II - allowable (colour coded)
- Above - not allowable (colour coded red)

(This is the most stringent standard and is commonly used to evaluate the quality of the water).

Table 5 show water quality analysis results from all six (three pairs) boreholes. All boreholes show that all compounds tested are within the acceptable (Class I) SANS 241:2006 water quality standards.

Table 5: Results of the chemical analyses for the sampled boreholes -July 2008.

BH No	pH	EC	Ca	Mg	Na	K	PAlk	MAlk
		mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BHM 01D	9.02	19.6	6.2	9.2	17.2	7.76	11	99
BHM 01S	6.59	5.01	2.0	1.3	10.1	3.10	0	20
BHM 02D	8.83	13	5.4	5.9	12.0	6.25	7	68
BHM 02S	6.56	7.6	5.0	2.6	6.3	4.03	0	30
BHM 03D	8.59	11.9	5.4	5.3	15.1	5.63	3.85	60
BHM 03S	6.81	11.1	7.5	3.8	9.1	5.25	0	43
BH No	**F**	**Cl**	**NO2(N)**	**Br**	**NO3(N)**	**PO4**	**SO4**	
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
BHM 01D	0.26	2.92	0.01	0.01	0.17	<0.10	5.44	
BHM 01S	0.12	6.58	0.00	0.05	0.84	<0.10	6.47	
BHM 02D	0.15	3.26	0.01	0.02	0.32	<0.10	4.14	
BHM 02S	0.09	5.53	0.00	0.03	0.20	<0.10	5.74	
BHM 03D	0.12	7.94	0.01	0.01	0.74	<0.10	7.51	
BHM 03S	0.13	10.70	0.01	0.03	0.67	<0.10	7.77	

4.1 Hydrochemical Characterisation using Interpretive Diagrams

When gathering raw data, it is important to interpret these data in a manner that would make geohydrological relationships understandable. The use of interpretive diagrams for understanding the nature and origin of different water qualities is well established. Trilinear diagrams are generally used for such water classification. Examples of these diagrams are the Piper, Durov and Expanded Durov diagrams.

Water can be classified with Piper diagrams and a Piper diagram was used to classify the water type by plotting the percentages of major cations (Ca, Mg, Na and K) and anions (Cl, SO_4 and HCO_3+CO_3) as two points in a trilinear diagram. These points are then extended to the main diamond-shaped field of the Piper diagram to plot as one point. The water is classified, depending on the position of this point.

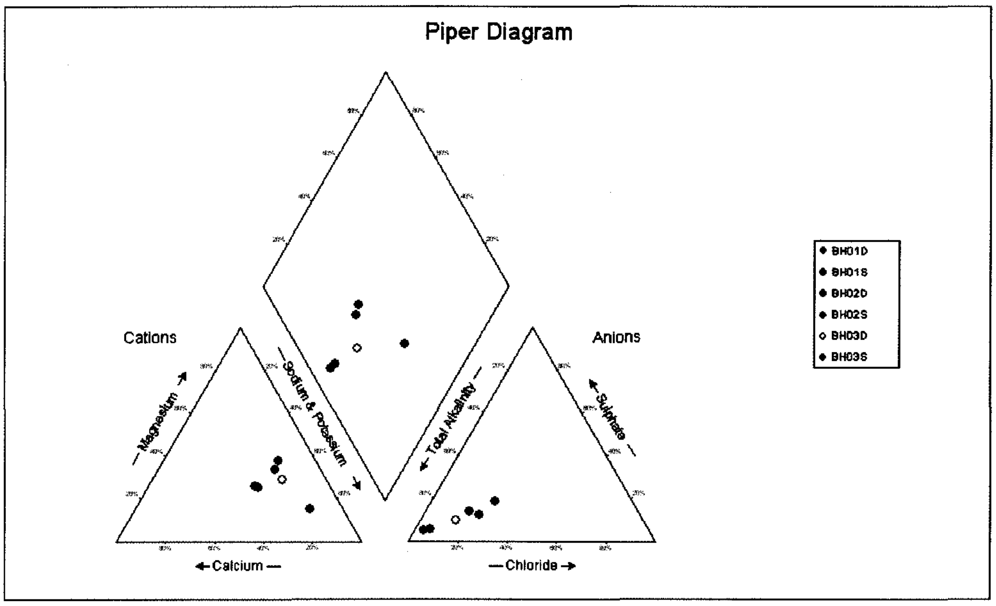

Figure 10: Piper Diagram.

Figure 10 illustrates a Piper Diagram of the groundwater samples collected at the preferred Middelburg Water Treatment Plant site. As can be seen from this diagram, there is no dominant cations (although BH01S show slight high Na-K content), with total alkalinity dominant in the anions.

An Expanded Durov Diagram is similar to a Piper Diagram in that relative percentages of the anions and cations are plotted, namely three for the anions and three for the cations. The Expanded Durov Diagram consists of nine plots for the anions and cations.

Figure 11 below, an Expanded Durov Diagram is illustrated representing the groundwater samples taken in the Middelburg Water Treatment Plant area. As can be seen, there is a dominance of magnesium-alkalinity waters some sodium-potassium-alkalinity waters are also present. This is an indication of recently recharged waters.

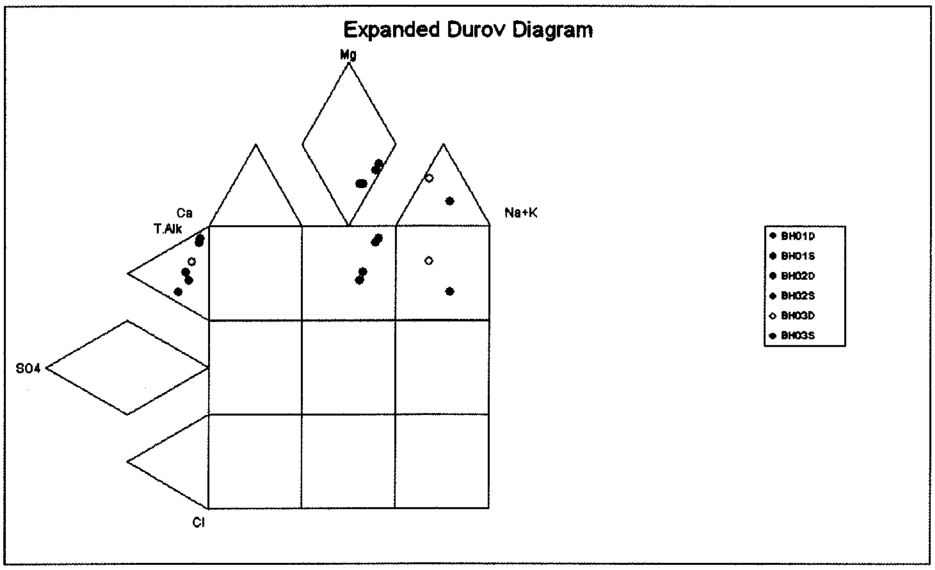

Figure 11: Expanded Durov Diagram.

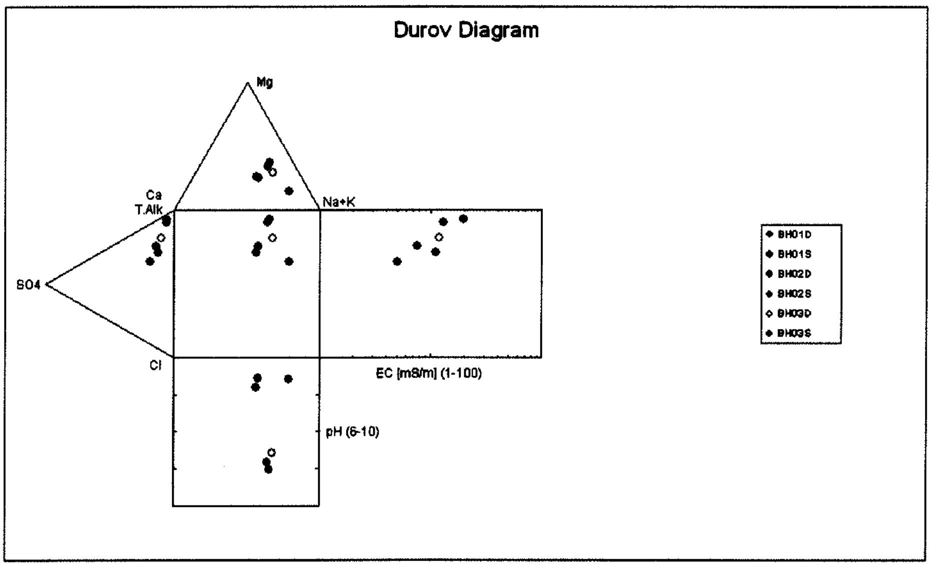

Figure 12: Durov Diagram.

The Durov diagrams (Figure 12) show no variations in the electrical conductivity, but the pH varies between the deeper and shallow boreholes (i.e. shallow boreholes have lower pH-values and the deeper boreholes have higher pH-values).

Stiff diagrams are useful in making an instant visual distinction between water from different sources or that have been impacted by pollution. Figure 13 below show the Stiff diagrams for all the boreholes, with the majority of the Stiff diagrams illustrating relatively high alkalinity anions, and high sodium-potassium and also variable magnesium cations.

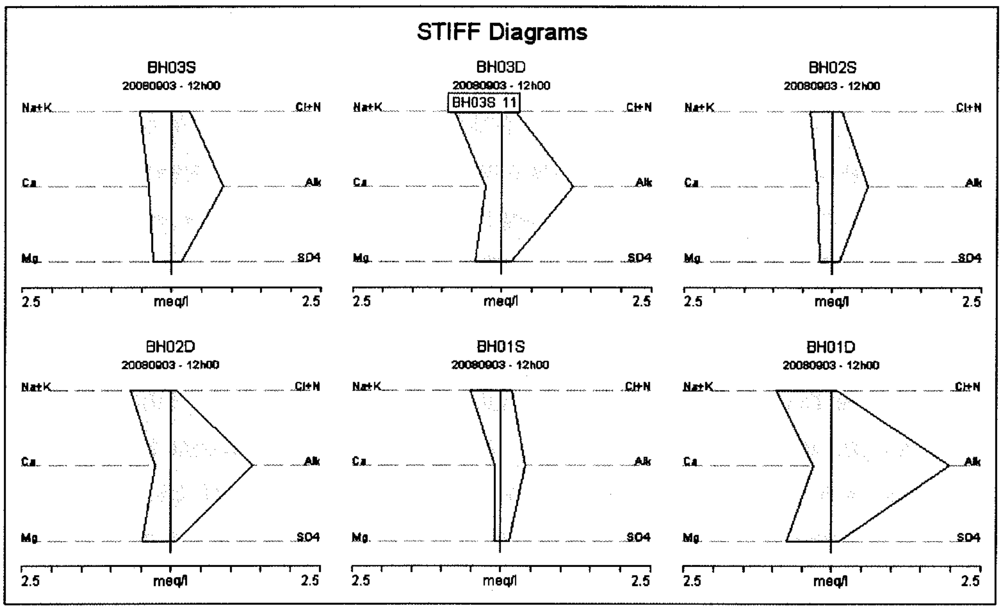

Figure 13: Stiff Diagrams.

The conclusion that can be drawn from the interpretive diagrams is that there is negligible difference in water quality (different signatures) collected in the region. These mostly indicate that this is recently recharged groundwater entering the groundwater regime.

5. Numerical Model

5.1 Overview

The use of numerical models has become widespread in the study of groundwater to investigate a wide variety of hydrogeologic conditions. Numerical models are useful for visual description of hydrogeological processes taking place at the site and furthermore to predict the future behaviour of the groundwater system. They are useful in solving both complex and simple groundwater problems and further, to predict the transport of contaminants for risk evaluation.

Groundwater flow models describe the flow and transport processes using mathematical equations based on simplifying hypothesises that involve aquifer geometry, flow direction, sediment's anisotropy or heterogeneity, contaminant transport mechanisms and chemical reactions. For Middelburg Water Treatment Plant site the purpose of a groundwater flow and transport simulation model is to compute the concentration of a dissolved chemical species in an aquifer at any specified time and place in an event of leaks.

5.2 Conceptualisation of the Groundwater System

In every model the system under investigation is represented by a conceptual model. A conceptual model includes designing and constructing equivalent but simplified conditions for a real world problem that are acceptable in terms of the objectives of the modelling and the associated management problems. Transferring the real world situation into an equivalent model system, which can then be solved using existing software, is a crucial step in groundwater modelling. The following information is needed for a conceptual model:

- The known geological and geohydrological features and characteristics of the area.
- The static water levels/piezometric heads of the study area.
- The effects of the geology and geohydrology on the boundary of the study area.
- A description of the processes and interactions taking place within the study area that will influence the movement of groundwater and,

- Any simplifying assumptions necessary for the development of a numerical model and the selection of a suitable numerical code.

5.2.1 Proposed Hydrogeological Conceptual Model

The hydrogeological conceptual model is constructed based on the available data, with the main objective to promote a qualitative understanding of the site in terms of hydrology and hydrogeology. From the data analysis, the following site conceptual model could be constructed:

- The Middelburg Water Treatment site is located in a relatively flat area bounded by a stream in the east,
- The area forms a topographic high (1552 mamsl),
- The area is wholly underlain by sedimentary rocks of the Karoo Stratigraphic Sequence comprising of sandstones and shale,
- The groundwater flow direction follows the topography in the direction of the site drainage (water levels),
- The transmissivity T-values obtained from the pump test indicate a low transmissivity value of 1.3 m^2/day, representing the T-value for the whole formation,

5.3 Numerical Modelling

Numerical models are approximations that describe real systems or processes using mathematical equations; they are not exact descriptions of the actual system. For the Middelburg Mine Water Treatment Plant site, a groundwater flow simulation model was created to be used as the flow field for particle tracking and solute transport simulation, in order to identify the pathways and receptors for leachate derived from the site. This exercise can assist in the identification of the sources of contamination and provide estimates of the time, magnitude and the location of the contaminant occurrence/plume.

5.3.1 Modelling Software Selection

A modular three-dimensional finite difference groundwater flow model MODFLOW developed by United States Geological Survey (USGS), in the PMWIN programme, has been adopted for simulating the saturated groundwater flow in the vicinity of the site and furthermore to predict future contaminant loading at the site. MODFLOW was chosen because it is simple to use (especially for USGS codes), widely used internationally, can simulate steady- and transient-state flow in an irregularly shaped flow system in which the aquifer layers can be either confined, unconfined, or both confined and unconfined, and is mathematically efficient.

The simulation model (MODFLOW) used in this modelling study is based on three-dimensional groundwater flow and may be described by the following equation:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t}$$

Where,

K_{xx}, K_{yy} and K_{zz} = hydraulic conductivity along the x,y and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T),

h = potentiomatric head (L)

W = volumetric flux per unit volume and represent sources and/or sinks of water (1/T)

S_s = specific storage (1/L), and

t = time (T)

The K and S_s are allowed to be heterogeneous and anisotropic, and this equation describes non-equilibrium groundwater flow.

5.3.2 Assumptions and Limitations

For the appropriate model development of an aquifer system, certain assumptions are necessary. The following assumptions were made to develop the model:

- The aquifer system can be represented by a simplified system, consisting of one layer. The geometry and thickness of this layer is obtained from geological and hydrogeological data collected in the field,
- The hydraulic conductivity (K-values), transmissivity (T-values) and storativity used were measured from the field data,
- The dispersivity values were estimated from literature (Spitz and Moreno, 1996),
- Recharge was derived from literature (Vegter, 1995),
- Rivers are treated as Dirichlet boundaries,

- The Karoo formation is represented as one layer (i.e. fractures and/or stratification were not taken into consideration), and
- There are no groundwater extraction/abstraction zones.

5.3.3 Model Input Parameters

The quality of a groundwater numerical model output depends largely on the quality of the data used for input into the model.

5.3.3.1 Discretisation

A grid network was constructed for the area with number of columns (240 x 20m) and number of rows (246 x 20m), with the X_0Y_0=(38005, -2864467), X_1Y_1= (38005, -2869385) and X_2Y_2= (42799, -2864467). The network extends over a larger area covering the stream in the east of the site and the pan north of site. The model network extends over a larger area than the area under investigation, to ensure that the model boundaries do not affect simulated results.

5.3.3.2 Layers and Layer Construction

A one-layer system was constructed for the model with the top of the layer represented by the ground surface (topography), with the bottom of the layer assigned at 1450 mamsl. This one layer is formed by a confined aquifer (type 0) and comprises of the Karoo system with user defined transmissivity values.

5.3.3.2.1 Boundary Conditions

A model boundary is the interface between the model area and the surrounding environment. Boundaries in groundwater models can be specified as:

- Dirichlet (also known as constant head or constant concentration) boundary conditions
- Neuman (or specified flux) boundary conditions
- Cauchy (or a combination of Dirichlet and Neuman) boundary conditions

A constant head (Dirichlet) boundary was defined for the river east of the site and the other locations over the river were assigned as inactive cells.

5.3.3.2.2 Initial Hydraulic Heads

Point values for geohydrological parameters (e.g. T, S and water levels) are obtained from boreholes, which are usually sparsely spread over an area of interest. To obtain estimates for these parameters at other points where no boreholes exist, an interpolation technique must be used.

Usually Kriging is used for the interpolation of T and S values to unknown points of interest. Because the water level in an aquifer usually tends to mimic the topography, this extra information could be used for interpolation to unknown points (with the method of Bayesian estimation or co-Kriging, where other information is used as qualified guesses for the water levels).

The data for x-, y-, z- and water levels are provided for each borehole at the site, and Bayesian estimation is achieved using Tripol and estimations could be made of areas where no information on water levels is obtained. The initial hydraulic heads for the model simulation used the actual water levels measured in the area, combined with Bayesian Interpolation and applied to the model area using the Field Interpolator function in PMWIN. Figure 14 show the Bayesian estimated initial hydraulic heads for the Middelburg Water Treatment Plant area.

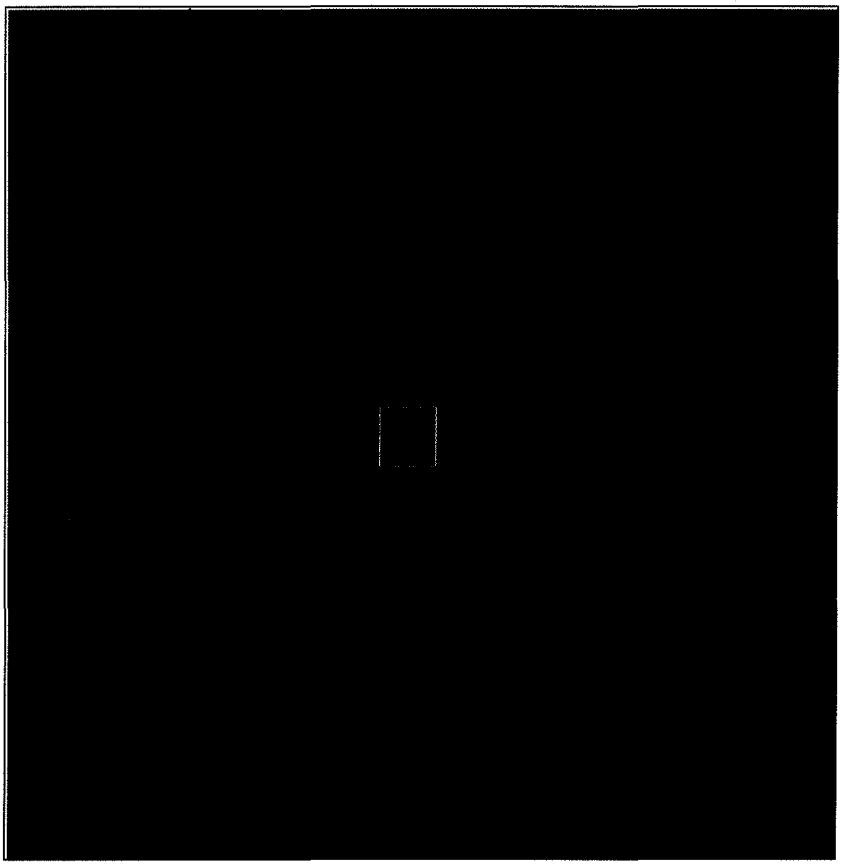

Figure 14: Interpolated Initial Starting Heads.

5.3.3.2.3 Aquifer Parameters

The model demands that for each aquifer parameter for the layer are defined depending on the type of aquifer system each layer represents. It should be noted that MODFLOW uses the assigned parameters according to the layer types (i.e. type 0-confined and type 2-confined/unconfined uses constant transmissivity throughout the modelling process and the type 1-unconfined and type-3 unconfined/confined uses the hydraulic conductivity with transmissivity values varying depending on the saturated thickness of the aquifer, (Chiang and Kinzelbach, 1998).

A value of 1.3 m^2/d for transmissivity obtained from the pumping test analysis was initially assigned to a layer, representing the modelled aquifer. The initial horizontal hydraulic conductivity was assigned to the layer at 0.17 m/day.

5.3.3.3 Mass Transport Parameters and Modelling

Mass transport modelling refers to the simulation of water contamination or pollution plume due to deteriorating water quality in response to man's disturbance of the natural conditions. The MT3DMS Mass Transport model package in the PMWIN modelling programme was used to simulate the movement of pollutants from the source. The initial input requirements are the initial contaminant concentration, transmissivity values, porosity values, longitudinal and transverse dispersivities and the hydraulic heads in the aquifer over time.

The initial concentration of 100% (Orange) was assigned for the Middelburg Mine Water Treatment Plant Waste Disposal area (assuming brine ponds as 100% (e.g. 20 000 mg/L)). One of the biggest uncertainties encountered during the transport modelling of pollutants is the kinematic/effective porosity of the aquifer. An effective porosity value of 0.02 was assigned to the model.

The transmissivity value of 1.3 m^2/d was utilised during mass transport modelling and the longitudinal dispersivity value of 50 m was assigned for simulation (Spitz and Moreno, 1996). Bear and Verruijt (1992) estimated the average transverse dispersivity to be 10 to 20 times smaller than the longitudinal dispersivity; therefore a transverse dispersivity value of 4 m was used for the model. The hydraulic heads were assigned as constant heads throughout the mass transport simulation. The results of the mass transport model are shown in the figures below.

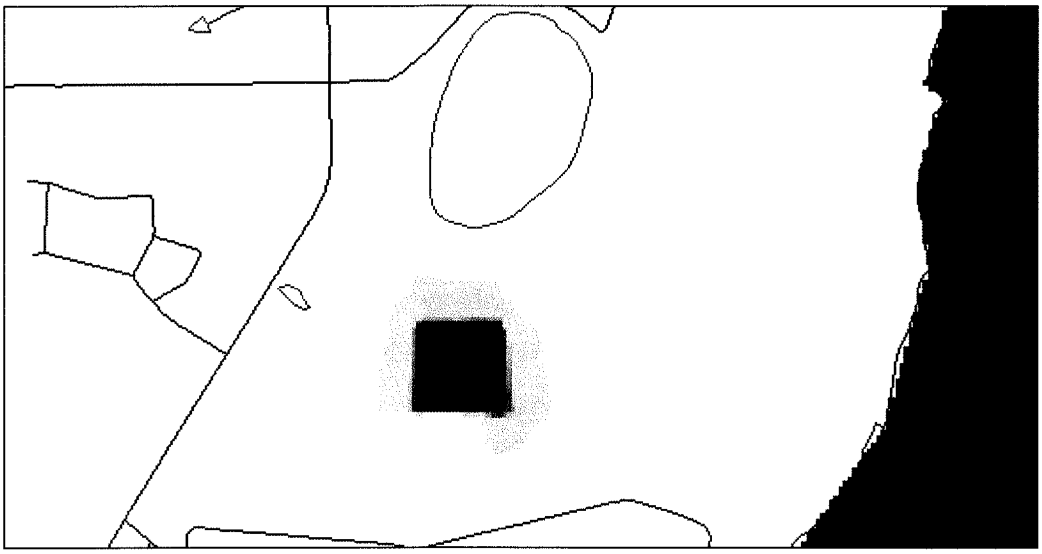

Figure 15: Plume development after twenty years.

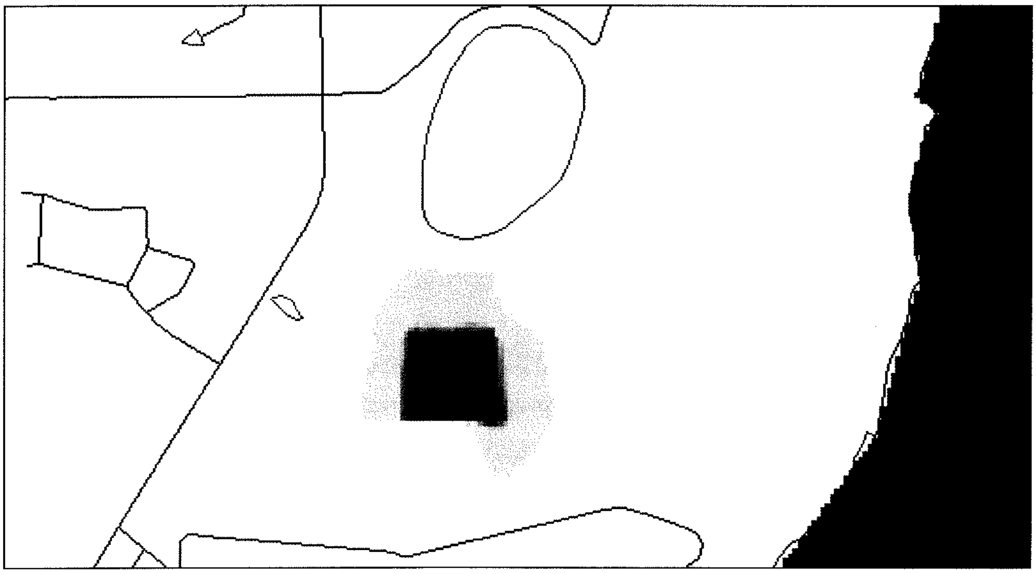

Figure 16: Plume development after forty years.

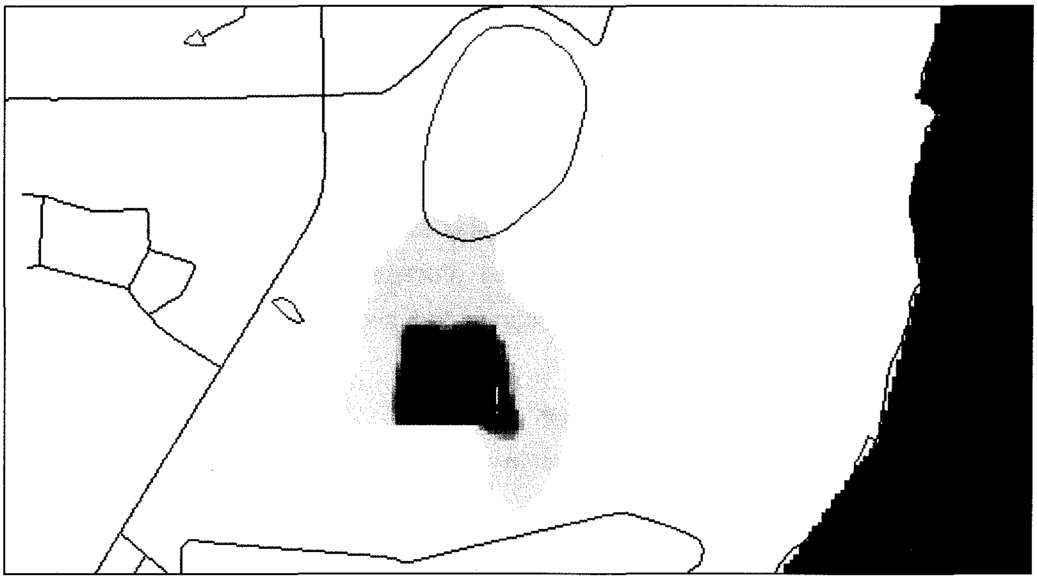

Figure 17: Plume development after one hundred years.

Figure 15, Figure 16 and Figure 17 show the simulated plume development from the Middelburg Mine Water Treatment Plant Waste Disposal area over the period from year 20 to year 100. The grey areas represent TDS concentration of less than 1% of the brine (i.e. less than 200 mg/L). This indicates that lateral movement from the site is very slow, with very low concentration of TDS (<200 mg/L) reaching the north pan only after one hundred years. The model illustrated very slow lateral contaminant migration, with less than 500 m of movement over 100years, and only in very low concentrations (as illustrated with the grey-coloured plume areas in the figures above).

6. Risk Assessment

6.1 Overview

Risk - is a probability that an adverse event will occur in specified circumstances. Risk Analysis - is the technique that provides information to a manager, to facilitate complex and integrated decisions. Quantifying the real risk rather than allowing perceived risk to dominate decision-making processes would enable more cost-effective and targeted response to contaminated site problems. Pollution risk is based on two elements:

- The time period of pollution or risk
- Position of the pollution source in relation to the monitoring or potential affected sites

Risk assessment is a process for estimating the potential of impact of a chemical, biological or physical agent on humans, plants animals and the ecology and it is a site assessment technique useful in determining the intensity of monitoring at waste disposal facilities in terms of time and space (DWAF, 2005). Further, DWAF states that *it is a minimum requirement to determine the risk of groundwater becoming polluted, before installation of monitoring system.*

According to minimum requirements (DWAF, 2005), the decision on the requirement of detail risk assessment for waste disposal sites can be related to the table below (Table 6).

Detailed quantitative risk assessment - detailed quantification of relevant parameters including variability, mass transport modelling including probabilities of failure.

Semi-quantitative risk assessment - estimation and limited field testing of relevant parameters, including variability.

Professional opinion - limited field observation and prediction is based on one-dimensional flow without attenuation.

No risk assessment required - indicate the applicable classes in the table below.

Table 6: Risk Assessment Procedures, (DWAF, 2005).

Risk	**High**	**Medium**	**Small**	**Negligible**
Waste site rating	H:H and H:h	G:L and G:M	G:S	G:C
Distance to nearest borehole	<100 m	100 - 400 m	400 - 1000 m	>1000 m
Distance to nearest stream	<100 m	100 - 400 m	400 - 1000 m	>1000 m
Underlying soil type	Sand	Loam	Clayey loam	Clay
Thickness of soil	<1 m	1 - 4 m	4 - 10 m	>10 m
Underlying rock type	Sand	Fractured rock	Dense rock	Impermeable rock
Leachate generation potential	High	Medium	Low	Negligible
Outcome (highest category in tow or more scores have been recorded)	**Detailed quantitative risk assessment**	**Semi-quantitative risk assessment**	**Professional opinion**	**No risk assessment required**

The detailed-quantitative risk assessment was conducted for the Middelburg Water Reclamation Project area in order to determine its influence of the site on the surrounding environment. The locality, geology, hydrology and geohydrology of the area are the main controlling factors. Further, there is no groundwater usage in the area (i.e. all drilled boreholes will be used for monitoring purposes only) and the more regional surrounding area is used for farming (crop and stock).

6.2 South African Groundwater Decision Tool (SAGDT)

The groundwater risk-based decision tool for managing and protecting groundwater had been developed for South African conditions. It provides methods and tools to assist groundwater professionals and regulators in making informed decisions concerning groundwater use, management and protection. The SAGDT is a spatially-based software allowing problem solving at a regional or local scale, depending on the problem at hand. It employs fuzzy logic for risk assessment for groundwater sustainability, pollution, health and ecological environment.

In sustainability risk assessment, factors such as recharge and aquifer type are taken into consideration to determine the risk of borehole failure (i.e. relates to groundwater abstraction). For contaminant risk assessment, aquifer vulnerability (establishing the tendency of contaminant reaching a specified position in the groundwater system) and type of pollutant (establishing the frequency, duration and the potential impacts of contamination) are considered. The health risk assessment considers the pathways of exposure (ingestion, inhalation and dermal exposure), body weight, duration of exposure, ingestion rate and the contaminant property (toxin, carcinogenic, micro-organism and radiation). The ecosystem risk assessment considers both quantity and quality dependency of the ecosystem on the aquifer system.

6.3 Middelburg Mine Water Treatment Plant Site Risk Assessment

The detailed -quantitative risk assessment was conducted for the Middelburg Mine Water Treatment Plant site in order to determine the influence of the waste disposal site on the surrounding environment.

6.3.1 Assumptions

The following assumptions are made regarding the area to be modelled based on the available information:

- Water levels,
- One aquifer system is used for the area with average thickness of 40m,
- Transmissivity value of 1.3 m^2/day for the aquifer,
- Storativity value of 0.001 for the aquifer,
- Recharge of 4.5% (30mm/annum),
- Average rainfall of 700mm/annum,
- Site unlined (modelled unlined in order to determine the maximum contamination extent if there are leaks in the liner system),
- Effective porosity of 0.02, and
- Data confidence of all objects of 60-70%.

6.3.2 Modelling Methodology

The methodology in simulating the scenario will include the following:

- Elevation data obtained from the topographic maps of the area is used together with the Tripol generated (using Bayesian Interpolation) groundwater levels obtained from boreholes.
- The waste disposal site is simulated with the pollution site whose area is used as a constant pollution source to determine the impact on the neighbouring boreholes.
- The groundwater levels, water strikes and blow yields obtained from boreholes were used for risk assessment.
- No pumping in the vicinity of the waste disposal site.

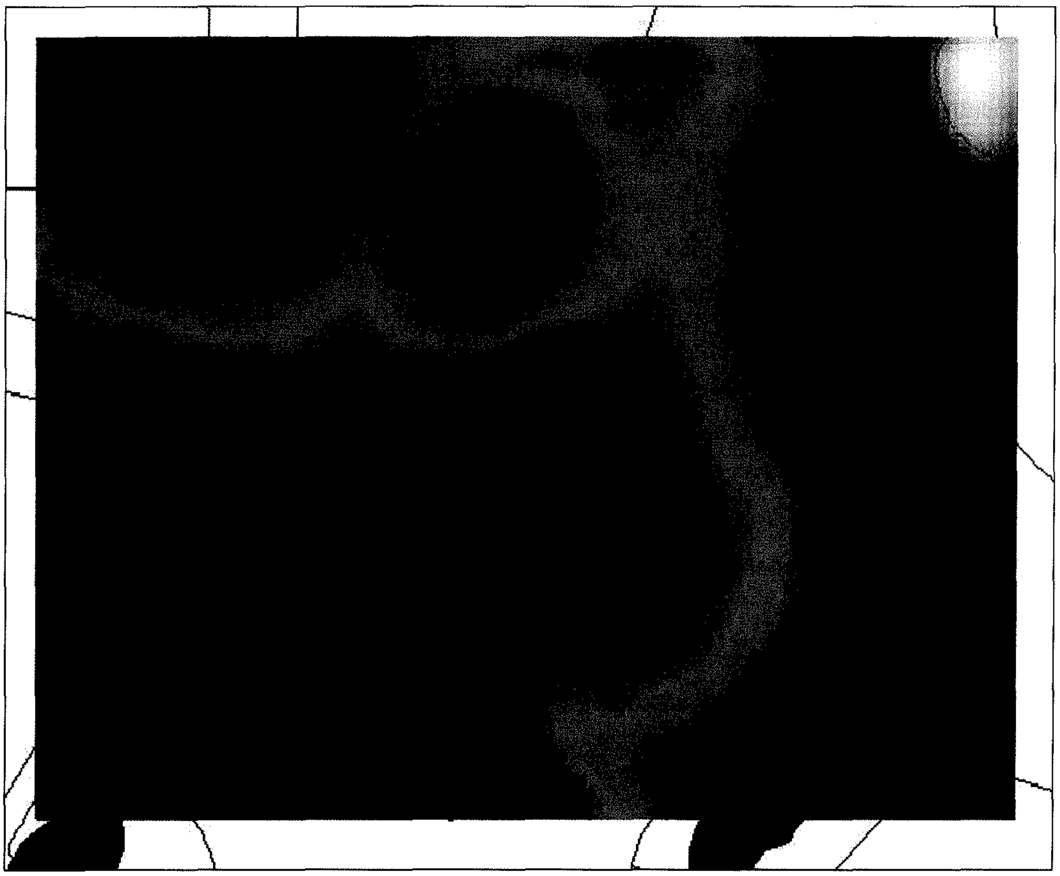

Figure 18: Interpolated hydraulic head contours in the SAGDT.

6.4 Results

The results of the assessment indicate the **aquifer vulnerability** of 67.2% (it is based on the **DRASTIC** model for evaluating **ground water** pollution - DRASTIC is an acronym for Depth to water, net Recharge, Aquifer media, Soil Topography (slope), Impact of the vadose zone, and hydraulic Conductivity) with a sensitivity of 6.4%. Due to the fact that the inputs to the DRASTIC method are of a static nature the aquifer vulnerability will not likely change with time. There is *no groundwater usage* in close vicinity of the waste disposal site, thus the **sustainability risk** is low 9.6% with sensitivity of 0.7% and further, the health risks for the area are not quantified. The presence of the waste disposal site poses a 100% **pollution risk** to the underlying aquifer. (On a pollution site a 100% pollution risk will always be assigned to a site over time).

Pollution risk is both a function of position a time due to the fact that a pollution plume moves with time and concentration attenuates with distance. Thus at the point of pollution the water quality guidelines may be exceeded indicating a 100% risk at the point. Some distance from the pollution source, the risk might be minimal due to the fact that the pollution plume concentrations are very low or has not reached the point yet. It is therefore important to run various scenarios over different time periods to describe the pollution movement.

The waste site pollution plume was run for 20 years with the results shown in Figure 19. The pollution risks to each individual borehole were quantified, indicating pollution risk of 100% due to the fact that the water quality guidelines are exceeded at those points. This result is mainly attributed to the locality of the boreholes with respect to the waste disposal site.

One cannot ignore the fact that pollution occurs at the indicated borehole positions and a 100% pollution risk is associated with these sites. However should a borehole be drilled outside the extent of the pollution a 0% pollution risk will be achieved. Due to the fact that it is impossible to assign a single pollution risk value to the study area (variability with position and time) the direct impact on human life is considered. In this case no groundwater use takes place and the pollution plume stays fairly localised, hence the low risk assigned to the study area concerning pollution.

The different levels of concentrations indicate that the plume is mainly moving towards the north side of the waste disposal site.

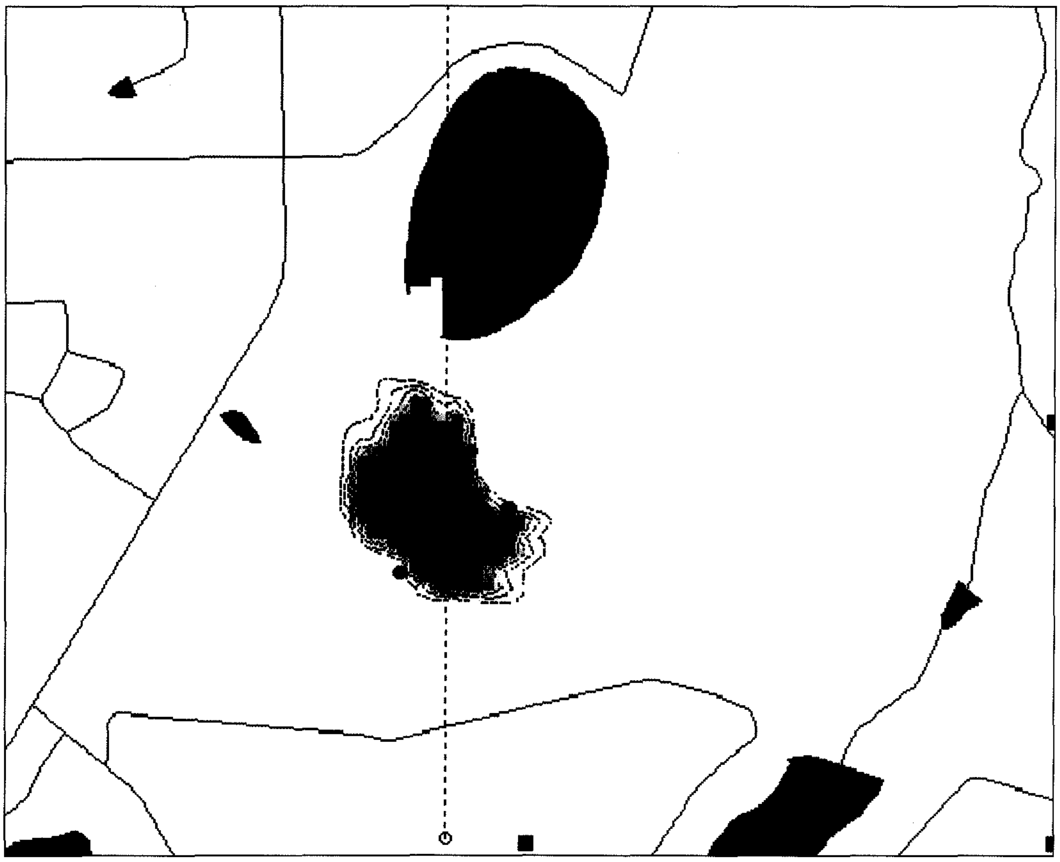

Figure 19: SAGDT risk assessment for 20 year period.

6.4.1 Conclusions

The results of the Middelburg Mine Water Treatment site risk assessment indicate that the site poses a very low pollution risk to the area, with no associated health risks due to the non existent groundwater use in the area.

7 Conclusions and Recommendations

7.1 Conclusions

The primary objectives were to investigate the potential impacts that the Middelburg Water Reclamation Project (MWRP) has on the underlying aquifer, thus enabling prediction of the degree of future contamination. The above objectives have been achieved by applying various field and laboratory experiments to assemble and evaluate information of the site in terms of its geological, geohydrological, and chemical properties.

The geophysical investigations did not identify any prominent geological feature in the vicinity of proposed MWRP. This observation suggests that the site selected for the development of MWRP the poses no problems in terms of the presence of major geological features that could influence the groundwater environment by forming preferential pathways to groundwater flow and contaminant migration.

The general lithology obtained from borehole drilling at the site is mainly composed of alternating layers of sandstones and shales below the soil clay layer. The physical properties of soils in the area adjacent to the site indicate that it has high clay content; therefore retardation (by biochemical reactions, sorption, cation-exchange etc.) of contaminants will occur with only very small quantities reaching the groundwater. Further, in-situ borehole profiling indicated that all three deeper boreholes indicate no major changes in aquifer conditions with depth, indicating similar aquifer conditions except for the ORP.

All tested boreholes have a low transmissivity (T-value) of approximately approx 1.3 m^2/day. The transmissivity values obtained represent the T-values for the upper aquifer in the region, also taking into consideration the K-values obtained from slug test.

All boreholes show that all compounds tested are within the acceptable (Class I) SANS 241:2006 water quality standards. Further, the interpretive diagrams indicate that there is negligible difference in water quality (different signatures) collected in the region. These mostly indicate that this is recently recharged groundwater entering the groundwater regime.

The model illustrated very slow lateral contaminant migration, with less than 500 m of movement over 100years. This is due to the fact that no structure exist in the area (as determined by the geophysics) that will serve as conduits for faster flow.

The risk assessment for all boreholes at the site showed that the boreholes located at low elevation to the landfill are susceptible to pollution, with a 100% pollution risks, but the site poses low/no threat to the human health due to *no groundwater usage* in the area (no groundwater in the area is being extracted for human or animal use) and low concentration of health impacting substances in groundwater. The surface receptors are not affected by the presence of the landfill, and as is observed with groundwater modelling, the contaminant plume is migrating very slowly with very small quantities (MODELLING) reaching the surface rivers and streams in 100 year period.

7.2 Recommendations

The groundwater assessment into the preferred locality for the Middelburg Water Reclamation Plant (Figure 3) indicates that the site poses little threat to the groundwater regime in the region; a hydrocensus done by the IGS in 2006 indicates that there is no groundwater abstraction in the immediate vicinity of the proposed site, and an investigation done during this investigation indicated no additional boreholes drilled since then (APPENDIX III). But, for protection of the countries water resources (i.e. groundwater), the sludge and brine ponds facilities should be constructed according to the Department of Water Affairs and Forestry (**DWAF, 1998**) guideline for construction of hazardous waste disposal sites.

8 References

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APPENDIX I

Geophysical Report

APPENDIX II

Risk Assessment

Report generated by the SAGDT

Aquifer Vulnerability [%] = 67.8% ± 7.2
Sustainability Risk [%] = 9.6% ± 0.7
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

ASSESSMENT AREA

Aquifer Vulnerability [%] = 67.2% ± 6.4
Sustainability Risk [%] = 9.6% ± 0.7
Pollution Risk [%] = 0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

POLLUTION (AREA)

Aquifer Vulnerability [%] = 67.2% ± 100.0
Sustainability Risk [%] = 9.6% ± 1.6
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH1D

Aquifer Vulnerability [%] = 63.6% ± 3.6
Sustainability Risk [%] = 1% ± 100.0
Pollution Risk [%] = 0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH1S

Aquifer Vulnerability [%] = 67.6% ± 6.8
Sustainability Risk [%] = 1% ± 100.0
Pollution Risk [%] = 0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH2D
Aquifer Vulnerability [%] = 67.3% ± 6.8
Sustainability Risk [%] = 1% ± 100.0
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH2S
Aquifer Vulnerability [%] = 66.9% ± 6.2
Sustainability Risk [%] = 1% ± 100.0
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH3D
Aquifer Vulnerability [%] = 67.5% ± 6.8
Sustainability Risk [%] = 9.6% ± 10.2
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

BH3S
Aquifer Vulnerability [%] = 67.8% ± 7.2
Sustainability Risk [%] = 1% ± 100.0
Pollution Risk [%] = 100% ± 0.0
Ecological Risk [%] = 0
Waste Site Impact [%] = 0
Toxicity Risk = 0
Carcinogenic Risk = 0
Radiogenic Risk = 0
Microbial Risk = 0

ASSESSMENT AREA
X Reference [m] = 0
Y Reference [m] = 0
Assessment Time [days] = 7200
Total Area [km^2] = 20.3
Total Baseflow [Mm^3/a] = 0.0000
Total Population = 0
Recharge [mm/a] = 53 {Sensitivity: 2.9%}
Rainfall [mm/a] = 696
Rainfall Cl [mg/l] = 0.53
Groundwater Level [mbgl] = 2.8 {Sensitivity: 0.5%}
Groundwater Use [Mm^3/a] = 0.0000
Slope [%] = 0.881 {Sensitivity: 0.2%}
S = 0.04000 {Sensitivity: 0.1%}

T [m²/d] = 1.3
Aquifer Thickness [m] = 40
Aquifer Media = Weathered/Fractured {Sensitivity: 1.3%}
Soil Media = SaLm-SaCl {Sensitivity: 0.6%}
Vadose Zone = Karoo(southern) {Sensitivity: 6.4%}
Percentage Recharge [%] = 7.6 {Sensitivity: 0.7%}
Data Confidence [%] = 70

POLLUTION (AREA)
Area [km²] = 0.1
Concentration [mg/l] = 20000 {Sensitivity: 0.0%}
Acceptable [mg/l] = 1000
Unacceptable [mg/l] = 2400
Data Confidence [%] = 80

BH1D
X [m] = 40159.0
Y [m] = -2867156.0
S = 0.04000 {Sensitivity: 0.0%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 100.0%}
Blow Yield [l/s] = 0.06
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.0
Groundwater Level [mbgl] = 6.04 {Sensitivity: 1.1%}
Main Strike [mbgl] = 38
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1557
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 17.0 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1551.0
Water Level [mamsl] = 1551.0 {Sensitivity: 0.0%}
Water Strike [mamsl] = 1519.0
Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

BH1S
X [m] = 40165.0
Y [m] = -2867159.0
S = 0.04000 {Sensitivity: 0.0%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 100.0%}
Blow Yield [l/s] = 0.01
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.0
Groundwater Level [mbgl] = 2.28 {Sensitivity: 0.4%}
Main Strike [mbgl] = 10
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1558
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 136.8 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1555.7
Water Level [mamsl] = 1555.7 {Sensitivity: 0.0%}
Water Strike [mamsl] = 1548.0

Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

BH2D
X [m] = 40544.0
Y [m] = -2866932.0
S = 0.04000 {Sensitivity: 0.0%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 100.0%}
Blow Yield [l/s] = 0.01
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.0
Groundwater Level [mbgl] = 2.57 {Sensitivity: 0.5%}
Main Strike [mbgl] = 32
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1552
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 4174.0 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1549.4
Water Level [mamsl] = 1549.4 {Sensitivity: 0.0%}
Water Strike [mamsl] = 1520.0
Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

BH2S
X [m] = 40534.0
Y [m] = -2866932.0
S = 0.04000 {Sensitivity: 0.0%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 100.0%}
Blow Yield [l/s] = 0
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.0
Groundwater Level [mbgl] = 3.1 {Sensitivity: 0.6%}
Main Strike [mbgl] = 10
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1552
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 4174.0 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1548.9
Water Level [mamsl] = 1548.9 {Sensitivity: 0.0%}
Water Strike [mamsl] = 1542.0
Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

BH3D
X [m] = 40402.0
Y [m] = -2866736.0

S = 0.04000 {Sensitivity: 0.1%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 0.5%}
Blow Yield [l/s] = 0.1
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.1
Groundwater Level [mbgl] = 2.4 {Sensitivity: 0.4%}
Main Strike [mbgl] = 27
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1552
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 7619.8 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1549.6
Water Level [mamsl] = 1549.6 {Sensitivity: 10.2%}
Water Strike [mamsl] = 1525.0
Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

BH3S
X [m] = 40410.0
Y [m] = -2866735.0
S = 0.04000 {Sensitivity: 0.0%}
T [m²/d] = 1.3
Abstraction [l/s] = 0 {Sensitivity: 100.0%}
Blow Yield [l/s] = 0
Favourable Q [l/s] = 0.0
Unfavourable Q [l/s] = 0.0
Groundwater Level [mbgl] = 1.93 {Sensitivity: 0.4%}
Main Strike [mbgl] = 10
Borehole Chloride [mg/l] = 10
Elevation [mamsl] = 1552
Drawdown [m] = 0.0
Borehole Drawdown [m] = 0.0
Concentration [mg/l] = 7619.8 {Sensitivity: 0.0%}
Static Water Level [mamsl] = 1550.1
Water Level [mamsl] = 1550.1 {Sensitivity: 0.0%}
Water Strike [mamsl] = 1542.0
Toxic Risk = 0.000000 {Sensitivity: 0.0%}
Carcinogenic Risk = 0.000000 {Sensitivity: 0.0%}
Radiogenic Risk = 0.000000 {Sensitivity: 0.0%}
Microbial Risk = 0.000000 {Sensitivity: 0.0%}
Data Confidence [%] = 70

APPENDIX III

Hydrocensus Report

MIDDELBURG MINE

HYDROCENSUS STUDY

by

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and
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Report number: 2006/13/PDV

June 2006

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1. Introduction and Scope of Investigation

The importance of groundwater in the health of many communities cannot be overstated. The quality and quantity of these resources are constantly under pressure from the activities of human existence and development. It is therefore of vital importance that adequate measures are taken to preserve valuable groundwater resources.

A hydrocensus is a task that involves gathering information on water features, water supply sources and sources of potential water pollution in a particular site or area. The Institute for Groundwater Studies conducted a hydrocensus study between the 9th and 24th of May, at the request of Middelburg Mine Services.

The aim was to:

- Identify all the boreholes and springs in the vicinity of the mining area that are currently in use by the community for domestic and other purposes.
- To determine the use for each borehole, and
- To analyze the water quality of some of the boreholes located close to the mining area that are likely to be influenced by mining activities.

Figure 1 is a graphic representation of the mining area with the boreholes surrounding the area. The boreholes lie within a five kilometer range around the mine lease area.

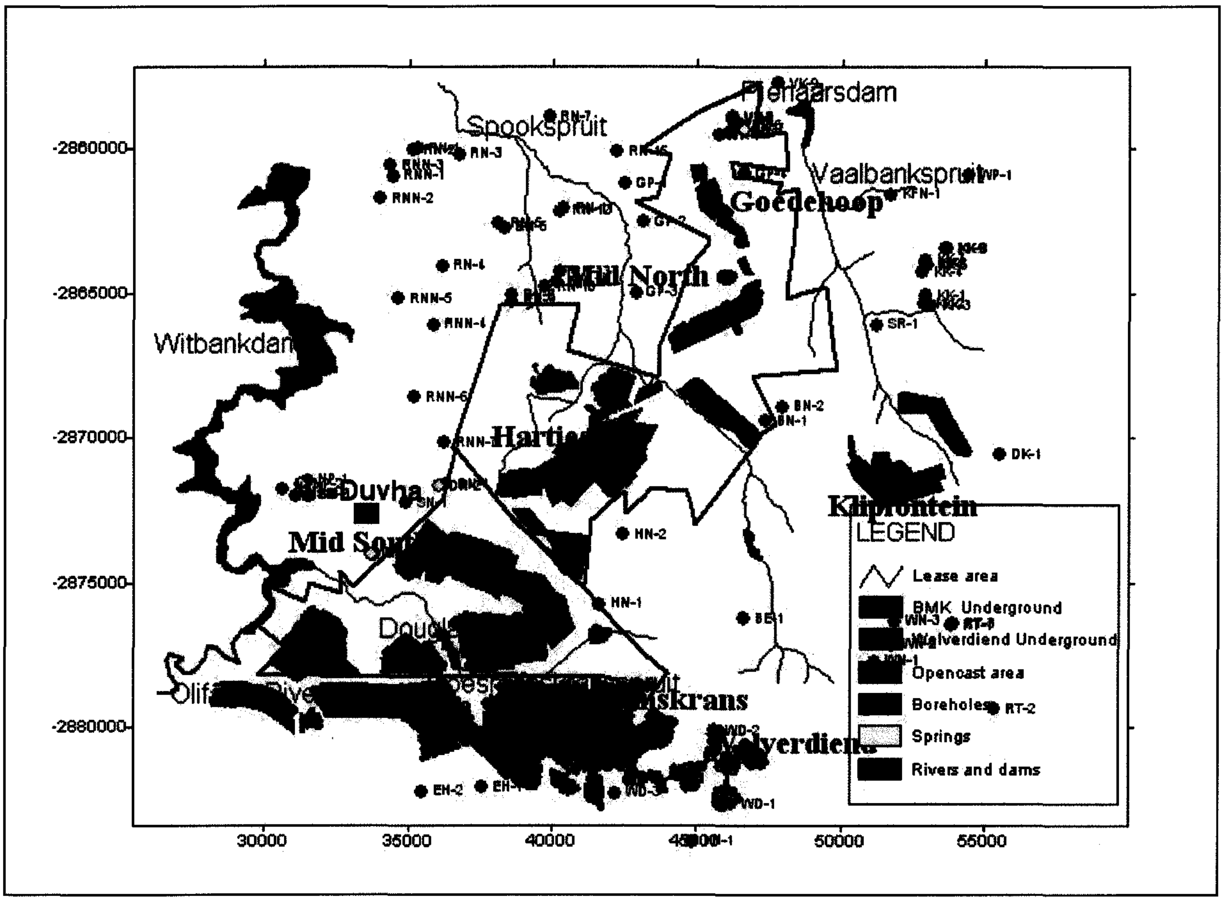


Figure 1: Boreholes identified in the vicinity of Middelburg Mine

Information gathered during a hydrocensus is useful for:

- Planning development in a rural community that is reliant on groundwater abstraction points for its water supply.
- Planning new groundwater abstraction points for an existing rural community.
- Assessing an existing situation (e.g. animal kraals and pit latrines in the vicinity of an existing or disused groundwater abstraction point (borehole).
- Planning alternative or back-up water supplies where the current resources may become unsustainable or contaminated.

2. Locality and Physiography

The Middelburg Mine is situated some 15 kilometres south of Middelburg and 20 kilometres east of Witbank. The mine is drained by three distinct drainage systems. The Spook Spruit runs through the North Section, while the Boesmans Spruit runs through the South Section into the Witbank Dam. The Klipfontein section is situated in the upper reaches of the Vaalbank Spruit, which eventually ends up in the Pienaars Dam. It is evident from the topographic figure below that the direction of surface water drainage is towards the north.

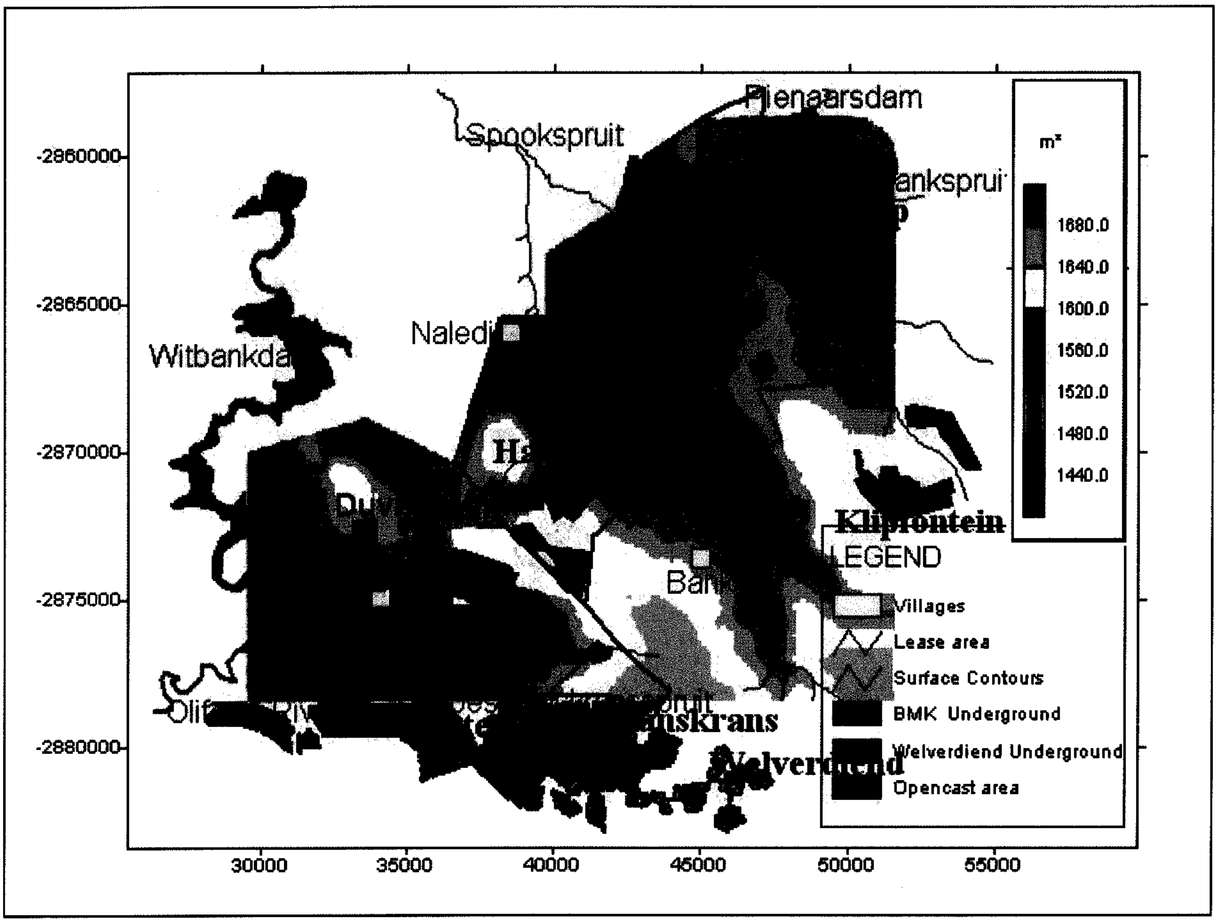


Figure 2: Surface elevation and drainage system around the study area

Table 1 indicates the monthly rainfall averages for Middelburg Mine and Figure 3 shows a graph of the yearly rainfall averages (in mm) as measured at Middelburg Mine.

Table 1: Monthly rainfall (mm) and averages at Middelburg Mine for the past 27 years (1979 - 2005)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1979	48	30	37	15	7	7	6	27	17	62	123	85	464
1980	162	66	39	35	4	0	0	0	7	8	177	99	597
1981	161	118	54	25	0	14	6	12	40	62	35	64	591
1982	115	35	76	19	0	1	12	0	8	19	19	47	351
1983	135	44	33	21	14	12	20	40	3	51	224	102	699
1984	69	29	74	0	0	0	0	8	12	93	63	57	405
1985	73	150	47	0	12	0	0	0	34	65	124	121	626
1986	126	69	67	24	34	0	0	4	10	63	160	128	685
1987	92	110	183	17	12	0	0	52	122	108	205	110	1011
1988	88	111	100	47	0	21	0	12	17	104	87	102	689
1989	99	191	69	21	16	56	0	0	10	52	252	223	989
1990	107	142	124	103	40	0	7	10	0	54	79	212	878
1991	314	64	187	0	20	48	0	11	0	74	49	162	929
1992	129	95	77	25	0	0	0	31	3	63	63	214	700
1993	123	228	139	48	10	0	0	0	41	162	160	101	1012
1994	120	168	56	0	0	0	0	0	15	81	49	133	622
1995	69	43	121	63	17	0	0	0	5	123	154	164	759
1996	154	344	122	30	24	0	21	11	0	103	49	137	995
1997	105	15	59	33	43	0	4	1	29	94	105	132	620
1998	66	33	48	28	0	0	0	0	76	30	111	126	518
1999	63	40	29	19	34	10	0	0	25	27	106	239	592
2000	179	142	126	18	10	0	0	0	20	122	90	56	763
2001	60	79	31	7	36	0	0	0	0	77	181	99	570
2002	43	83	24	32	12	16	0	35	9	74	48	154	530
2003	125	47	0	0	0	0	0	0	0	73	64	79	388
2004	185	136	112	33	0	0	16	0	0	42	73	142	739
2005	141	38	30	0	0	0	0	0	0	0	40	59	308
Total	3151	2650	2064	663	345	185	92	254	503	1886	2890	3347	18030
Average	117	98	76	25	13	7	3	9	19	70	107	124	668

The average rainfall for the Middelburg Mine was 668 mm/a over a period of 27 years (1979 - 2005). Data were collected from the South Section of Middelburg Mine.

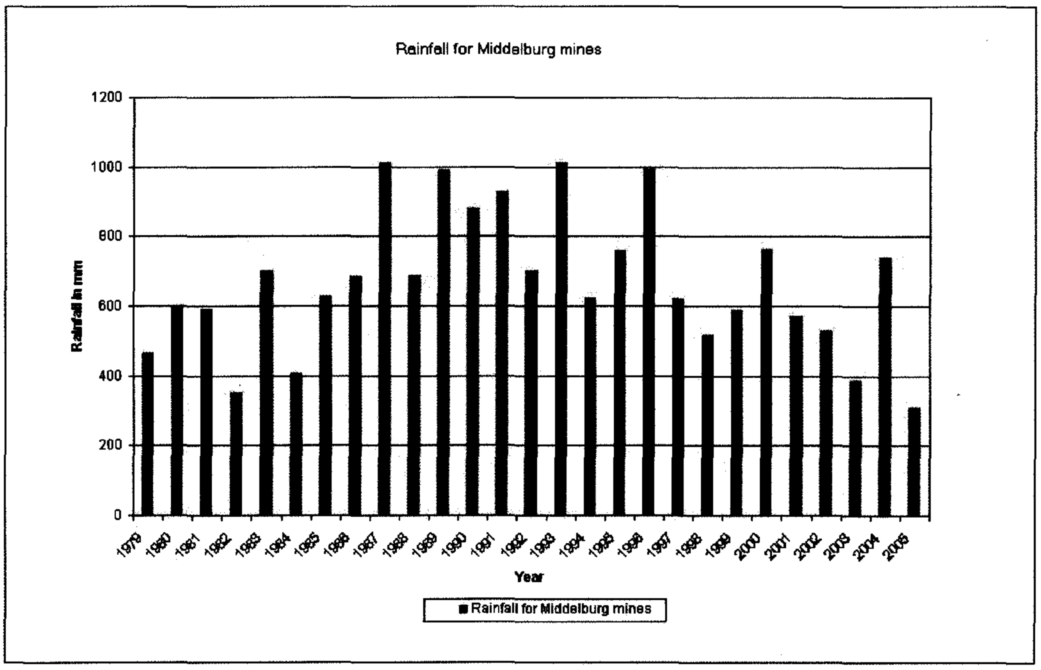


Figure 3: Rainfall (mm) at Middelburg Mine for the past 27 years (1979 - 2005)

3. Geology and Geohydrology

The geology in the area consists of typical Karoo rocks from the Ecca Group. The main lithological units comprise soil, weathered sediments, sandstone, mudstone and coal. The No. 2 and No. 4 Seams are nearby the surface and their extraction mostly involves opencast operations. Underground mining took place to the south at the Boschmanskrans and Welverdiend section. Remining of the pillars is taking place through opencast operations at Boschmanskrans.

The top 3 - 10 metres of the sedimentary sequence are usually weathered. The water-bearing strata are mainly sandstones above the coal seams, with the major flow path on the contact point between the sandstone and coal strata.

The two geohydrological units of significance are (Hodgson and Grobbelaar, 1997):

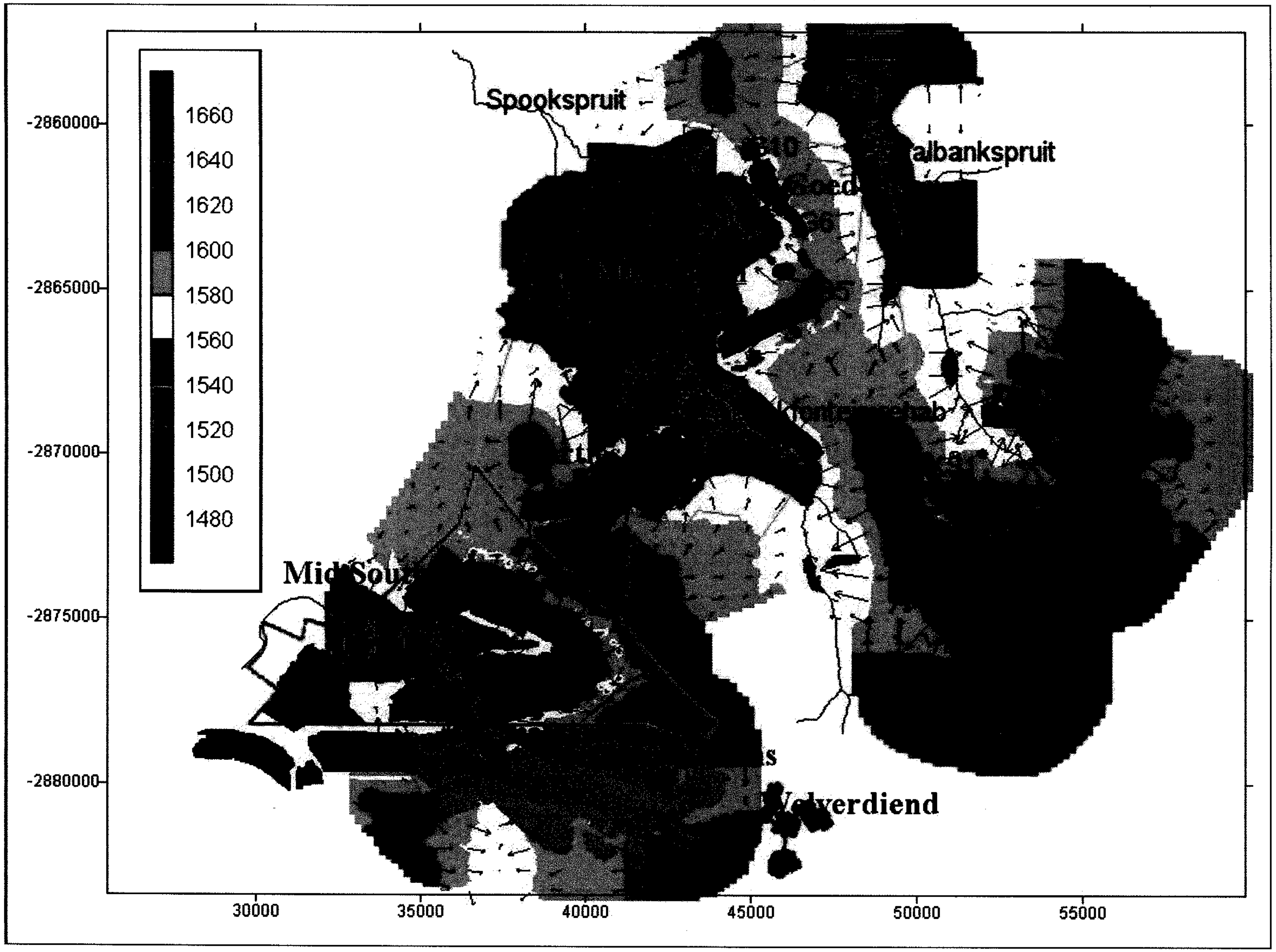
- The weathered zone.
- The coal.

Of lesser significance is the occasional occurrence of groundwater within fractures in the sandstone

The flow of the natural groundwater is mainly in the direction of the topographic slope. Influx into the pits from downstream groundwater resources is therefore limited to a small area.

The coalfield floor contour rises between the boundary of the North and South Sections, forming a groundwater divide between the two (Figure 4). There should therefore not be any groundwater interaction between the two sections. On the southern boundary of the South Section, lies the Ogies Dyke, which is impermeable. Thus no groundwater interaction can take place on the southern boundary (Hodgson, FDI and Grobbelaar, R., 1997).

Figure 4: Groundwater flow directions



4. Hydrosensus study

4.1 General

From the 9th until the 24th of May 2006 a hydrosensus study was conducted on the area surrounding the Middelburg Mine. The area included the following farms (See Figure 1).

- Bankfontein
- Boschmanskrans
- Blesbokvlakte
- Driefontein
- Driehoek
- Elandslaagte
- Enkeldebosch
- Goedhoop
- Hartbeestfontein
- Klipfontein
- Klipbank
- Koornfontein
- Naauwpoort
- Noodhulp
- Rhenosterfontein
- Rietfontein
- Roodepoort
- Speekfontein
- Sterkwater
- Vaalbank
- Vlaklaagte
- Wanhoop
- Welverdiend
- Wolwefontein
- Wolwekrans

Each farm is subdivided into smaller farms and/or plots. Only a few families are still living on the surrounding farms, mostly to the western side of the mine. They are dependent on the abstraction of borehole water for domestic and agricultural use. A few springs occur in the area (see Figure 5), some of which are also in use for domestic purposes (see Table 2).

The area is mainly covered by grassland. Mixed farming is practiced in the area. Cattle (beef and dairy), sheep, pork, poultry, maize, wheat, vegetables, beans and potatoes are produced. Three large farming groups (C.J. Schoeman, Kanhym, and the SIS Farming Group) are situated on the eastern side of the Middelburg Mine.

Kanhym and the SIS Farming Group have huge feedlots on the farms (cattle and pork). Their water for agricultural use is mostly drawn from surface water bodies and from the Middelburg municipality. Water abstracted from the boreholes is used only for domestic purposes, supplying villages, farmhouses and offices situated on the premises. No water from boreholes is used for irrigation purposes. Pivots on the eastern side of the mines receive their water from surface water bodies.

According to C.J. Schoeman, the boreholes on his premises (Blesbokvlakte and Wolwefontein) have dried up. The water supply for this farm is received from the mine. Enkeldebosch (owner Mr. Neels van Dyk), south of the Douglas section, also receives its water from the mine. Borehole water is abstracted only for agricultural use.

The yields of most of the boreholes are unknown, but according to the farmers, they are all roughly between 1500 and 3000 litres per hour.
Due to the high precipitation during the last summer, the water levels are relatively high, between 1m and 20m below surface (see Table 2).

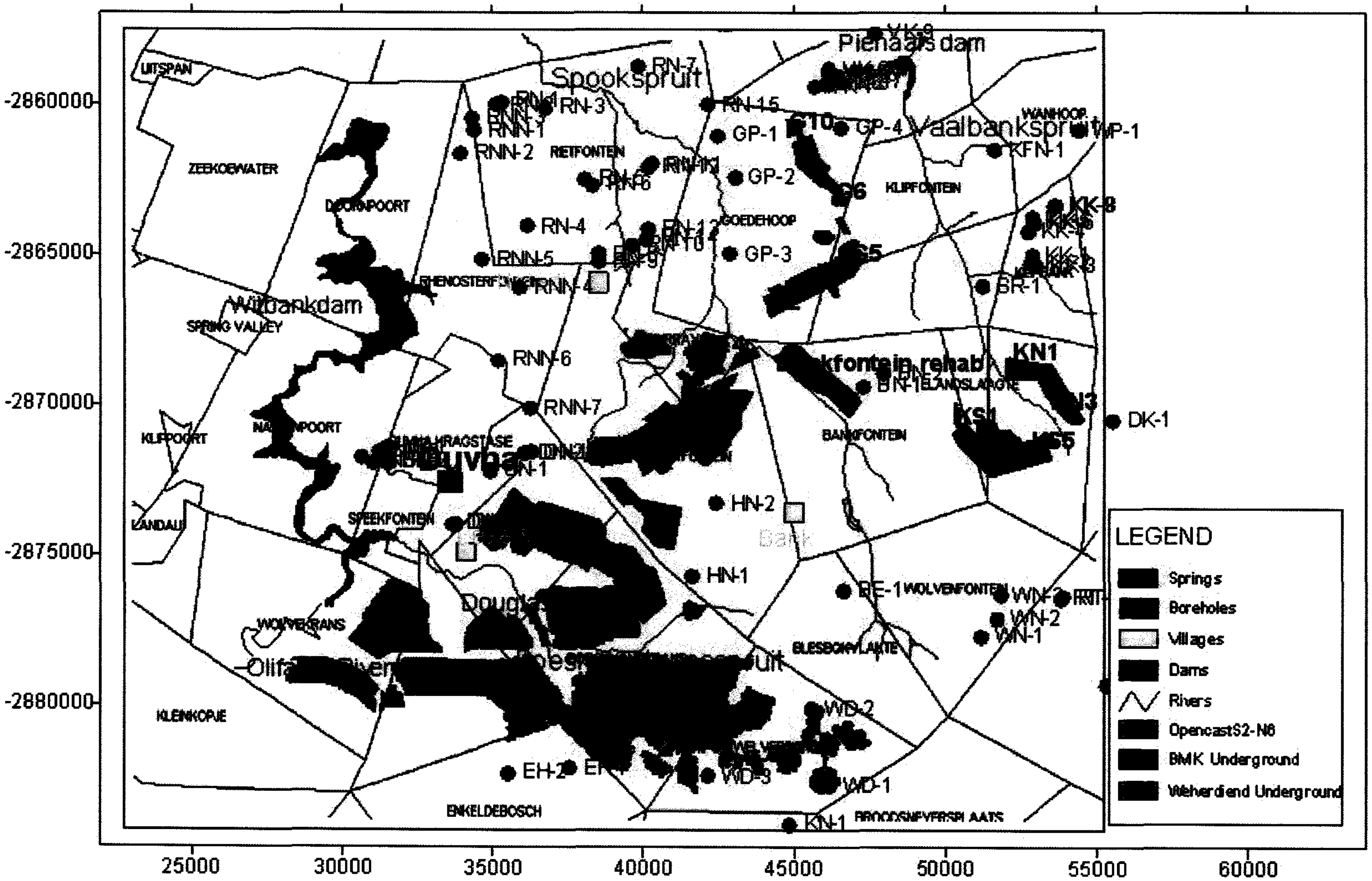


Figure 5: Study area (farms, mining area, surface water bodies, springs and boreholes)

4.2 Results

Table 2: Hydrocensus results

[illegible]	Jannie Schoeman/Sancor		BN-2	25.92805	29.47841	1609	Not measured	Unknown	Agricultural	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Jannie Schoeman/Sancor		BN-1	25.93219	29.47237	1588	Not measured	Unknown	Domestic	Handpump is sealed - No waterlevel	Y	Y
[illegible]	CJ Schoeman	0823884456	BE-1	25.99375	29.46553	1597	1.67	Unknown	Not in use	No Pump	Y	Y
[illegible]	Chris Gouws	0824957517	DN-1	25.95226	29.36241	1576	1.66	0.3	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Chris Gouws	0824957518	DN-2	25.95295	29.35978	1507			Not in use	Spring	Y	Y
[illegible]	Neels van Dyk	0832291948	DN-3	25.97451	29.33761	1578	9.8	0.4	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Neels van Dyk	0832291948	DN-4	25.9746	29.33629	1571			Domestic	Spring	Y	Y
[illegible]	Kanhym		DK-1	25.94238	29.55405	1634	7.34	Unknown	Domestic	Submercible pump	Y	Y
[illegible]	Neels van Dyk	0832291948	EH-1	26.0469	29.37528	1590	Not measured	0.4	Agricultural	Submercible pump	Y	N
[illegible]	Neels van Dyk	0832291948	EH-2	26.04862	29.35481	1617	4.49	Unknown	Not in use	No Pump	Y	Y
[illegible]	LS Viljoen	0827792484	GP-4	25.85514	29.46484	1588	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y
[illegible]	Francois Hattingh	0828077600	GP-1	25.85798	29.42401	1538	5.11	Unknown	Not in use	No Pump	Y	Y
[illegible]	CJ Schoeman	0823884456	GP-2	25.87025	29.4301	1524	19.74	Unknown	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Jaap Visser	0824572395	GP-3	25.89275	29.42778	1526	14.12	0.9	Domestic and Agricultural	WL taken while pump is switched on	Y	Y
[illegible]	Michael Allen	0823883200	HN-2	25.9676	29.42375	1606	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y
[illegible]	Phillip Schoeman		HN-1	25.98986	29.41572	1615	20.45	0.4	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302176	KK-7	25.88188	29.528	1637	Not measured	Unknown	Not in use	No Pump - Sealed	N	N
[illegible]	Ingwe/Jopie Sauerman	0836302174	KK-5	25.88313	29.52792	1646	Not measured	Unknown	Domestic and Agricultural	Submersible pump is sealed - No waterlevel	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302175	KK-6	25.88331	29.52841	1643	Not measured	Unknown	Not in use	Handpump is sealed - No waterlevel	N	Y
[illegible]	Ingwe/Jopie Sauerman	0836302173	KK-4	25.88561	29.52656	1635	1.91	Unknown	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302170	KK-1	25.89302	29.5279	1602	30.23	Unknown	Domestic	Submercible pump	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302171	KK-3	25.89573	29.52941	1605	Not measured	Unknown	Domestic	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302172	KK-2	25.89561	29.52707	1606	10.72	Unknown	Domestic	Submercible pump	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302177	KK-8	25.87793	29.53544	1633	5.11	Unknown	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Ingwe/Jopie Sauerman	0836302178	KK-9	25.8783	29.53475	1635	Not measured	Unknown	Domestic and Agricultural	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Kanhym		KFN-1	25.86164	29.51546	1590	2.36	Unknown	Domestic	Submercible pump	Y	Y
[illegible]	Gideon De klerk		KN-1	26.06397	29.44845	1605	16.03	Unknown	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Andries Hums	0829249847	NP-1	25.95133	29.3144	1578	Not measured	Unknown	Domestic and Agricultural	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Andries Hums	0829249847	NP-2	25.95248	29.3121	1566		Unknown	Not in use	Spring	Y	Y
[illegible]	Andries Hums	0829249847	NP-4	25.95409	29.30586	1543	Not measured	Unknown	Domestic	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Andries Hums	0829249847	NP-3	25.95601	29.31013	1547	Not measured	Unknown	Domestic and Agricultural	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Jannie Du Plessis	0832318282	RNN-3	25.85254	29.34268	1528	Not measured	0.4	Domestic	Submersible pump is sealed - No waterlevel	Y	Y
[illegible]	Jannie Du Plessis	0832318282	RNN-1	25.85634	29.34336	1525	5.76	0.4	Domestic	Submercible pump	Y	Y
[illegible]	Jannie Du Plessis	0832318282	RNN-2	25.86319	29.33873	1488	3.32	0.4	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Neels van Dyk	0832291948	RNN-5	25.89458	29.34568	1561	Not measured	0.7	Agricultural	Windpump is sealed - No waterlevel	Y	Y
[illegible]	Neels van Dyk		RNN-4	25.90296	29.35811	1554	Not measured	Unknown	Agricultural	Monopump is sealed - No waterlevel	Y	Y
[illegible]	Neels van Dyk	0832291948	RNN-6	25.92526	29.35103	1543	1.72	Unknown	Domestic and Agricultural	Submercible pump	Y	Y
[illegible]	Neels van Dyk	0832291948	RNN-7	25.93941	29.36164	1577	Not measured	Unknown	Domestic and Agricultural	Submersible pump is sealed - No waterlevel	Y	Y

[illegible]	Lukas de Klerk	0832681222	RN-7	-2860000.1	35286.9152	1514	20.21	Unknown	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Chrisjan Coetzer	0132434961	RN-1	-2860071.4	42181.8062	1589	Not measured	0.4	Domestic	Submersible pump is sealed - No waterlevel	Y	N	N
[illegible]	Francois Hattingh	0828077600	RN-15	-2860064	35122.3377	1518	Not measured	Unknown	Domestic and Agricultural	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Chrisjan Coetzer	0132434961	RN-2	-2860189.2	36758.036	1483	Not measured	0.4	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Francois Rossouw	0828027554	RN-3	-2862037.7	40347.2447	1515	1.32	0.4	Domestic	Submercible pump	Y	Y	N
[illegible]	Dif De Villiers	0837877798	RN-11	-2862190.1	40208.4566	1525	10.45	Unknown	Domestic and Agricultural	WL taken while pump is switched on	Y	Y	N
[illegible]	Dif De Villiers	0837877798	RN-12	-2862561.6	38083.4597	1520	2.87	Unknown	Not in use	No Pump	Y	Y	N
[illegible]	Martin Jordaan	0728292371	RN-5	-2862782.7	38313.3433	1511	2.15	Unknown	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Martin Jordaan	0728292371	RN-6	-2864104	36186.8905	1557	Not measured	Unknown	Agricultural	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Dolph Rossouw	0828064785	RN-4	-2864250.8	40213.1834	1554	8.73	0.4	Domestic	Submercible pump	Y	Y	N
[illegible]	Johan Lombaard	0823883103	RN-13	-2864584	40126.9825	1549	21.86	0.4	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Johan Lombaard	0823883103	RN-14	-2864786.5	39684.4269	1542	32.75	0.4	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Andre van Dyk		RN-10	-2865049	38539.2308	1543	7.67	0.4	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Nick De Wet	0829211983	RN-8	-2865300.5	38532.4811	1552	16.03	Unknown	Domestic and Agricultural	Submercible pump	Y	Y	N
[illegible]	Nick De Wet	0829211983	RN-9	-2876409.3	53879.0446	1641	1.18	Unknown	Not in use	No Pump	Y	Y	N
Roodepoort	SIS Farming group		RT-3	-2876463.4	53831.7628	1642	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
Roodepoort	SIS Farming group		RT-1	-2879332.6	55354.5504	1625	7.32	Unknown	Domestic	Submercible pump	Y	Y	N
Roodepoort	SIS Farming group		RT-2	-2872015.6	31547.8737	1558	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Corobrick/B. Taljaardt	0721257931	SN-3	-2872026.6	31512.7925	1557	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Corobrick/B. Taljaardt	0721257931	SN-2	-2872261.3	34927.5034	1594	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Chris Gouws	0824957517	SN-1	-2866103.9	51244.93	1560	5.46	0.4	Domestic	Submercible pump	Y	Y	N
[illegible]	CJ Schoeman	0823884456	SR-1	-2859012.4	46204.5085	1572	Artesian	Unknown	Domestic	No Pump	Y	Y	N
Vaalbank Plot 11	Rassie Erasmus	0828221031	VK-4	-2859046.8	46216.4188	1573	6.98	0.6	Domestic	Submercible pump	Y	Y	N
Vaalbank Plot 11	Rassie Erasmus	0828221032	VK-5	-2858882.7	46173.8831	1579	6.46	0.6	Domestic	Submercible pump	Y	Y	N
Vaalbank Plot 13	Francois Nel	0132822308	VK-8	-2859411.1	46148.9733	1578	Not measured	0.4	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
Vaalbank Plot 16	Piet Wilson		VK-3	-2859450.7	46062.6161	1578	12.73	0.6	Domestic	Submercible pump	Y	Y	N
Vaalbank Plot 17	TJ Lourens	0766563831	VK-2	-2859159.6	46479.6976	1564	15.88	0.8	Domestic	Submercible pump	Y	Y	N
Vaalbank Plot 21	Patrick Lee	0132431545	VK-6	-2859344	46610.3815	1560	Not measured	0.5	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
Vaalbank Plot 23	Unknown		VK-7	-2859489.5	45750.6909	1593			Domestic	Spring	Y	N	N
Vaalbank Plot 28	Black Wattle Colliery		VK-1	-2857739.3	47726.0159	1550	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	N	N
Vaalbank Plot 37	JJ Coetzee	0826521147	VK-9	-2860916.1	54407.7995	1598	Not measured	0.8	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	Kanhym		WP-1	-2880108.2	45606.7927	1646	3.06	Unknown	Domestic	Submercible pump	Y	Y	N
[illegible]	Potgieter	0825548119	WD-2	-2882324.7	42188.3561	1618	Not measured	0.2	Domestic and Agricultural	Submersible pump is sealed - No waterlevel	Y	Y	Y
[illegible]	Rudolph Schoeman	0823883105	WD-3	-2882676.1	46164.2624	1630	3.24	Unknown	Domestic and Agricultural	Submercible pump	Y	Y	Y
[illegible]	Phillip Opperman		WD-1	-2876362.4	51871.703	1638	Not measured	Unknown	Domestic and Agricultural	Submersible pump is sealed - No waterlevel	Y	Y	N
[illegible]	SIS Farming group		WN-3	-2877131.9	51738.4966	1636	Not measured	Unknown	Domestic	Submersible pump is sealed - No waterlevel	Y	Y	Y
[illegible]	SIS Farming group		WN-2	-2877744.5	51177.4287	1631	2.56	Unknown	Domestic	Submercible pump	Y	Y	N
[illegible]	SIS Farming group		WN-1	26.00731	29.5112	1631	9.85	Unknown	Domestic	Submercible pump	Y	Y	N

*Yield based on farmers estimate

1. Borehole BN-1 is situated next to a maize field on the farm Bankfontein, owned by Mr. Jannie Schoeman (Sancor). A hand pump is installed at the borehole and this water is used for domestic purposes only. The borehole is situated next to the Bankfontein opencast rehabilitation section (south-east).

2. DN-3 is situated less than 1 km west of the N2 opencast section on the farm Driefontein. The farm is owned by Mr. Neels van Dyk. The water is abstracted through a submersible pump and used for domestic and agricultural purposes.

3. Borehole EH-1 is on the farm Enkeldebosch (also owned by Mr. Neels van Dyk), south of the Boschmanskrans section. The water is abstracted by a submersible pump and used for agricultural purposes. Domestic water is supplied by the mine.

4. GP-2 is situated on the farm Goedehoop, ± 2 km east of the G6 to G10 opencast rehabilitated sections. The farm is owned by Mr. Jannie Schoeman (Sancor). Water is abstracted by a submersible pump and used for domestic and agricultural purposes.

5. GP-3 is also on the farm Goedehoop, owned by Mr. Jaap Visser. The borehole is situated ± 2km east of the G2 to G5 opencast sections. Water is abstracted by a submersible pump and used for domestic and agricultural purposes.

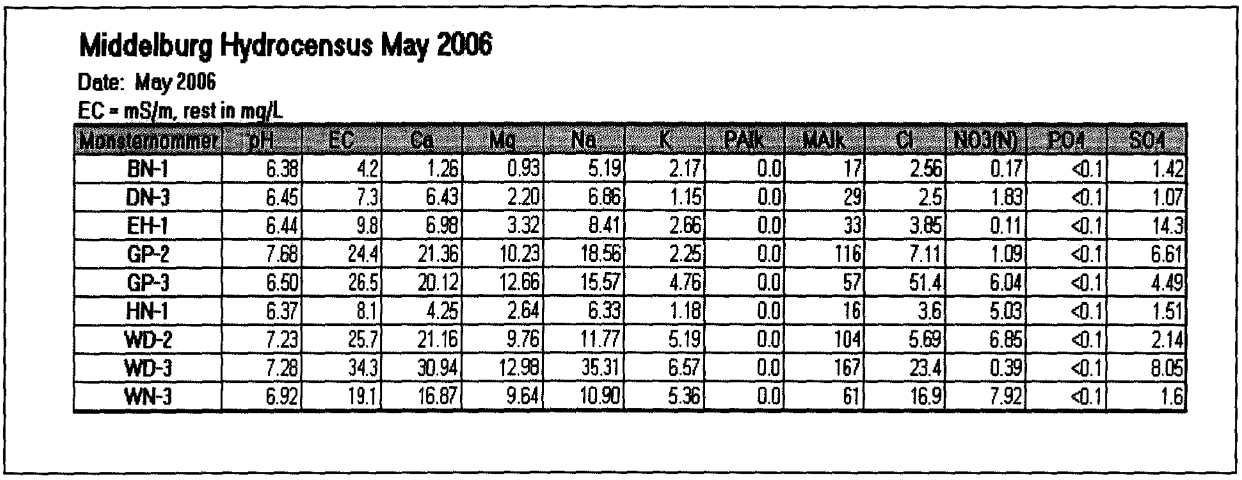
6. HN-1 is situated ± 1.8 km east of opencast sections N7 and S5, on the farm Hartbeestfontein. The farm is owned by Mr. Phillip Schoeman and water is abstracted for domestic and agricultural purposes. A submersible pump is installed at the borehole.

7. WD-2 is situated north of the Welverdiend underground section on the farm Welverdiend. Water is abstracted for agricultural and domestic purposes by a submersible pump.

8. WD-3 is also on the farm Welverdiend, owned by Mr. Rudolph Schoeman. The position of the borehole is ± 800 m south of the Boschmanskrans underground section. Water is abstracted for agricultural and domestic use via a submersible pump.

9. WN-3 is on the farm Wolwefontein ± 4.3 km south of the Klipfontein south opencast section. The farm is owned by the SIS Farming Group and water is abstracted for domestic use by a submersible pump.

Table 3: Chemistry results



Middelburg Hydrocensus May 2006

Date: May 2006

EC = mS/m, rest in mg/L

Monsternommer	pH	EC	Ca	Mg	Na	K	PAlk	MAlk	Cl	NO3(N)	PO4	SO4
BN-1	6.38	4.2	1.26	0.93	5.19	2.17	0.0	17	2.56	0.17	<0.1	1.42
DN-3	6.45	7.3	6.43	2.20	6.86	1.15	0.0	29	2.5	1.83	<0.1	1.07
EH-1	6.44	9.8	6.98	3.32	8.41	2.66	0.0	33	3.85	0.11	<0.1	14.3
GP-2	7.68	24.4	21.36	10.23	18.56	2.25	0.0	116	7.11	1.09	<0.1	6.61
GP-3	6.50	26.5	20.12	12.66	15.57	4.76	0.0	57	51.4	6.04	<0.1	4.49
HN-1	6.37	8.1	4.25	2.64	6.33	1.18	0.0	16	3.6	5.03	<0.1	1.51
WD-2	7.23	25.7	21.16	9.76	11.77	5.19	0.0	104	5.69	6.85	<0.1	2.14
WD-3	7.28	34.3	30.94	12.98	35.31	6.57	0.0	167	23.4	0.39	<0.1	8.05
WN-3	6.92	19.1	16.87	9.64	10.90	5.36	0.0	61	16.9	7.92	<0.1	1.6

Slightly high concentrations of nitrates occur at the Boreholes GP-3, WD-2 and WN-3, but this involves no health risk. The reason for the high concentrations might relate to fertilisers farmers are using in the maize fields. The three boreholes are also down-gradient from the maize fields and are next to or near surface water reservoirs and streams, where high levels of nitrates can be expected.

The sulphate concentrations in all the boreholes are very low and therefore it can be concluded that the mine has no effect on the water quality in the boreholes. The boreholes are drilled into virgin rock and soils, and there is no mine water seepage towards the boreholes in use by the community.

The electrical conductivity and all the other macro- and trace elements in the water are far below the maximum acceptable concentrations, indicating that there is no pollution in the boreholes (see Figure 9).

The inorganic water samples are classified according to the South African drinking water standards:

- Class 0 - ideal
- Class I - acceptable
- Class II - allowable
- Above - not allowable

The water can be classified as Class 0. Therefore the water poses no threat and is of ideal quality for domestic and agricultural use.

According to the Stiff diagrams (Figure 7) and the Piper diagram (Figure 8) the water are all Ca, Mg, Na-bicarbonate water, with some chloride enrichment in a few of the boreholes. This is "normal" water, while the chloride enrichment is geology related.

The water also has a low sodium and salinity hazard, and is therefore suitable for irrigation (see Figure 10).

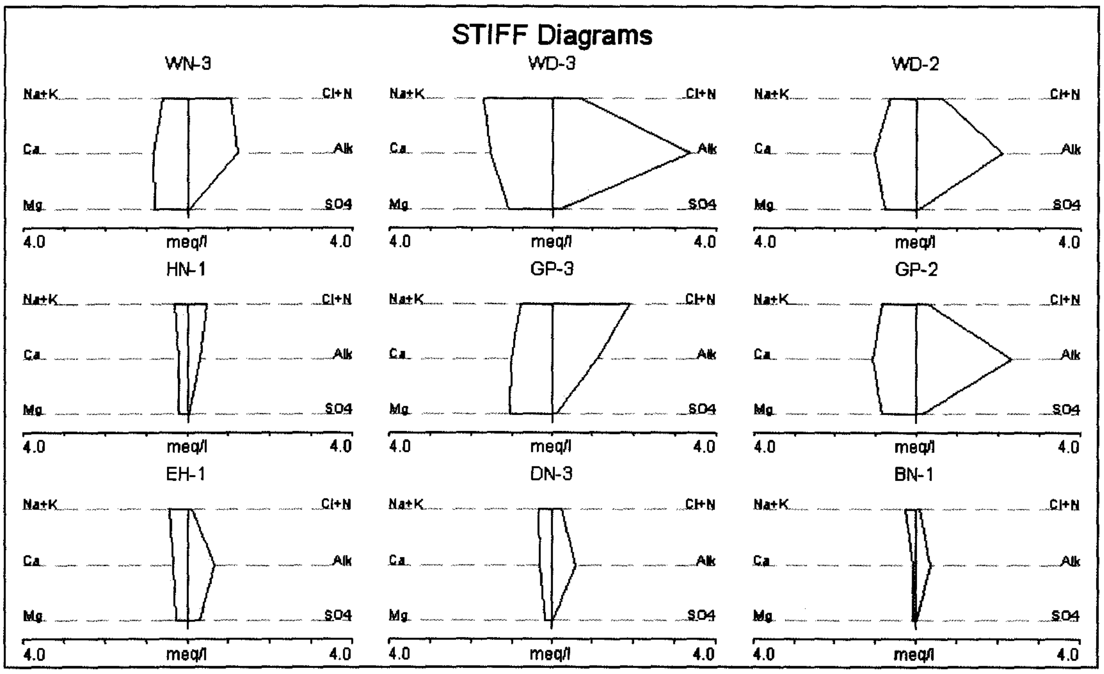


Figure 7: Stiff diagrams

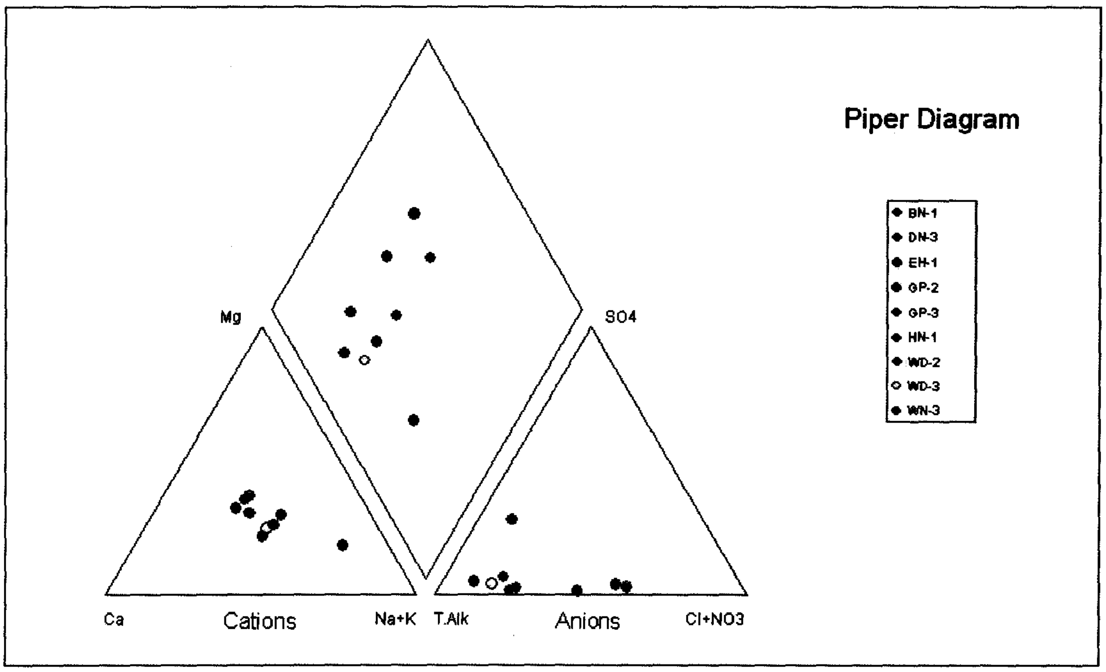


Figure 8: Piper diagram

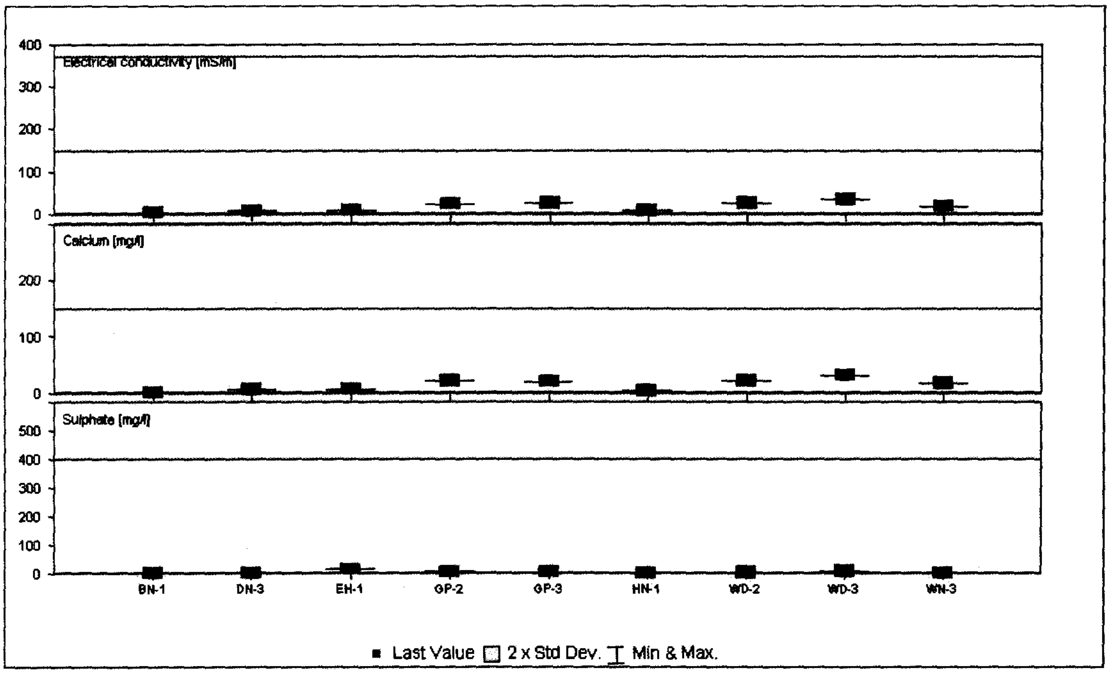


Figure 9: Box-and-whiskers plot for sulphate, calcium and electrical conductivity

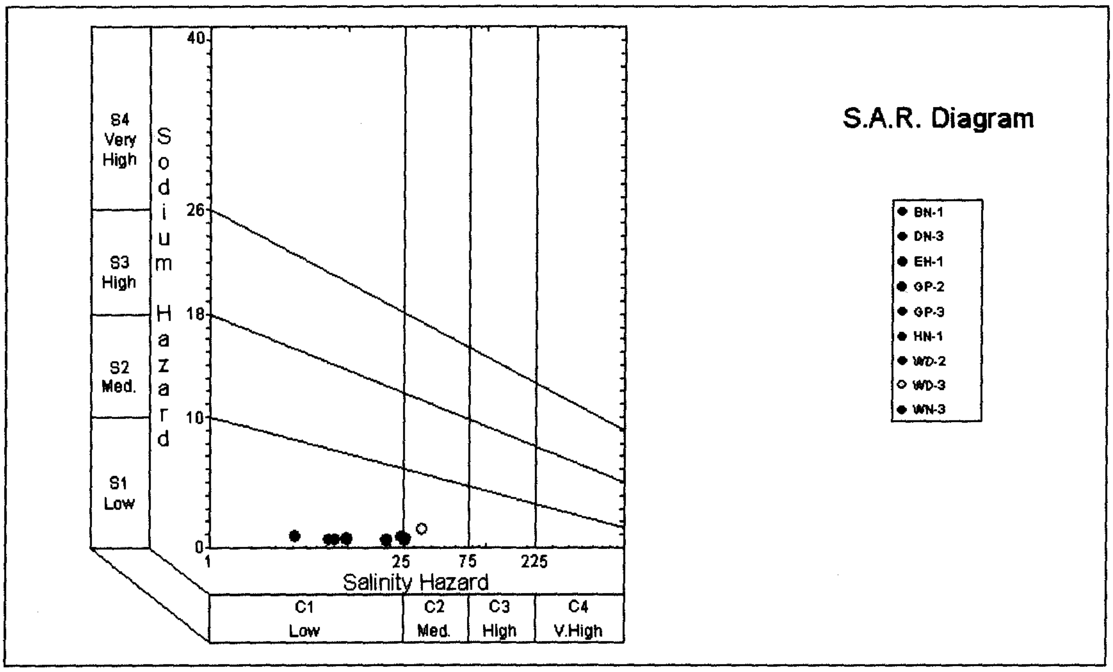


Figure 10: S.A.R. diagram

5. Conclusions

- Slightly high concentrations of nitrates in boreholes GP-3, WD-2 and WN-3 might be the result of fertiliser use up-gradient from the boreholes.
- The boreholes are also nearby or next to surface water bodies where high concentrations of nitrates can accumulate.
- The sulphate concentrations in the boreholes are low, and no mine water is seeping through the strata towards the boreholes.
- The macro- and trace elements are far below the maximum acceptable concentrations.
- According to the South African drinking water standards, the water can be classified as Class 0. The water quality therefore poses no threat to the community and is ideal for domestic and agricultural use.
- There is also a low sodium and salinity hazard, and the water is therefore suitable for irrigation.

The main conclusion that can be drawn is that the mine has no effect on the water quality of the boreholes selected for sampling.

6. References

DWAF (1996). South African water quality guidelines. Domestic use. Volume 1. Second edition.

Hodgson, FDI and Grobbelaar, R (1997). Current and long-term water and salt balances for Middelburg Colliery.

Van Tonder, GJ, Vermeulen PD and Lukas, E (2006). Middelburg mines groundwater assesment. Report no 08/MC/GvT.

Appendix A

Boreholes and springs in Study Area

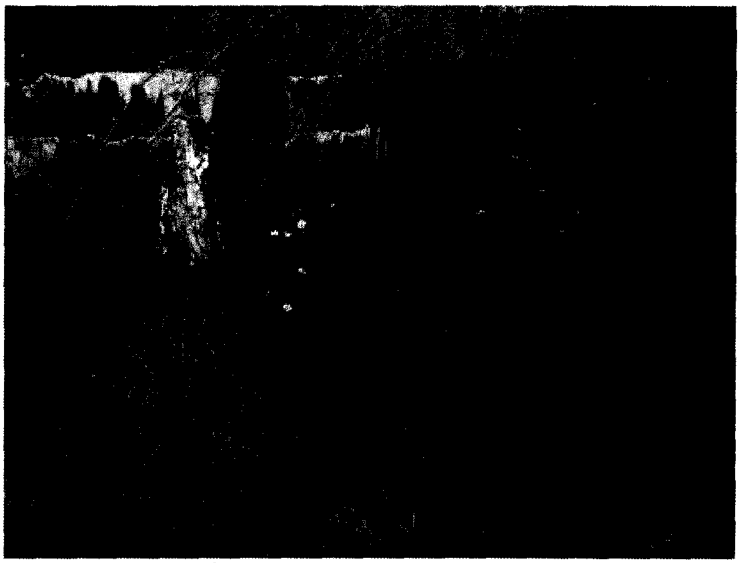
During the Hydrocensus study, four springs and 73 boreholes were recorded in the study area on the farms and plots around the Middelburg Mine. Samples were taken from the boreholes and water levels measured where possible. The boreholes can be seen in the figures below:

<u>BE-1</u>

Borehole 1: BE-1

Farm:	Blesbokvlakte
Water level:	1.67 m
Yield:	Unknown
Use:	Not in use

BN-1



Borehole 2: BN-1

Farm:	Bankfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

BN-2

Borehole 3: BN-2

Farm:	Bankfontein
Water level:	Not measured
Yield:	Unknown
Use:	Agricultural

DK-1

Borehole 4: DK-1

Farm:	Driehoek
Water level:	7.34m
Yield:	Unknown
Use:	Domestic

DN-1

Borehole 5: DN-1

Farm:	Driefontein
Water level:	1.66 m
Yield:	0.3 l/s
Use:	Domestic and Agricultural

DN-2

Spring 1: DN-2

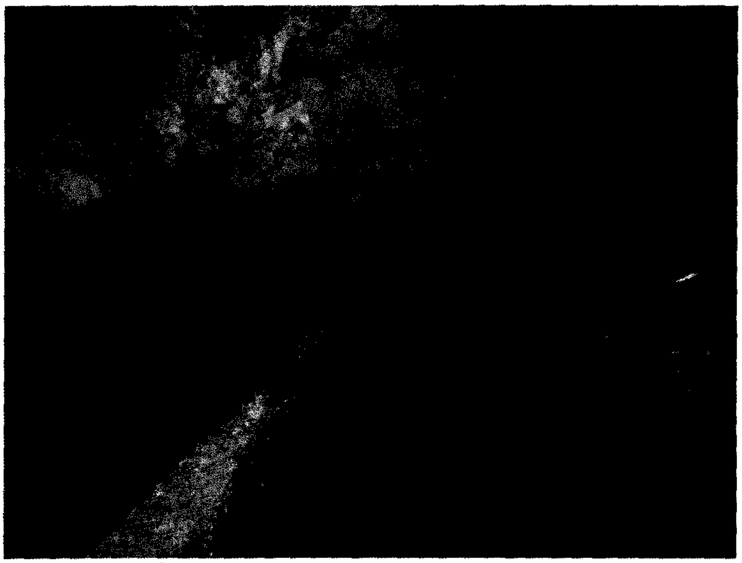
Farm:	Driefontein
Water level:	-
Yield:	-
Use:	Not in use

DN-3

Borehole 6: DN-3

Farm:	Driefontein
Water level:	9.8 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

DN-4



Spring 2: DN-2

Farm: Driefontein
Water level: -
Yield: -
Use: Domestic

EH-1

No photo taken. Borehole not accessible

Borehole 7: EH-1

Farm: Enkeldebosch
Water level: Not measured
Yield: 0.4 l/s
Use: Agricultural

EH2

Borehole 8: EH-2

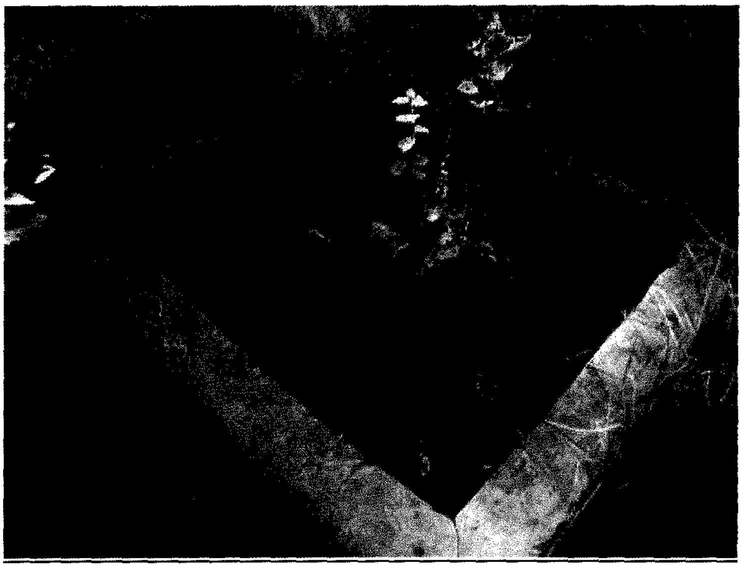
Farm:	Enkeldebosch
Water level:	4.49 m
Yield:	0.4 l/s
Use:	Not in use

GP-1

Borehole 9: GP-1

Farm:	Goedehoop
Water level:	5.11 m
Yield:	Unknown
Use:	Not in use

GP-2



Borehole 10: GP-2

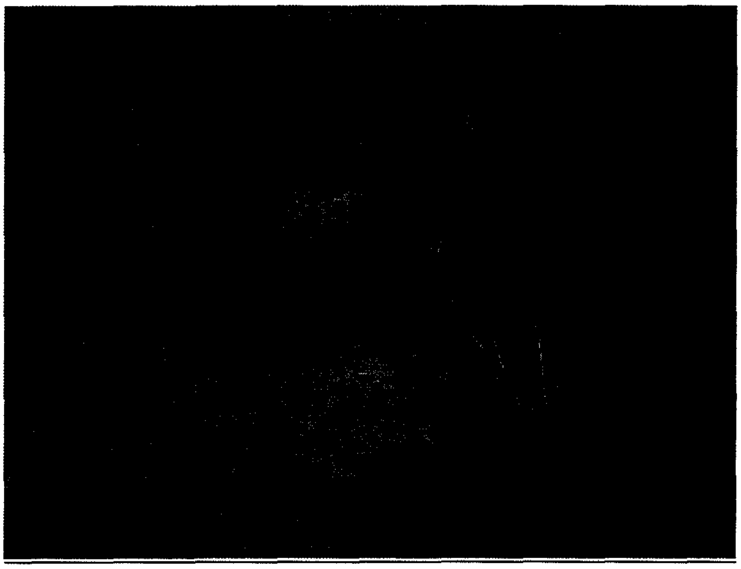
Farm:	Goedehoop
Water level:	19.74 m
Yield:	Unknown
Use:	Domestic and Agricultural

GP-3

Borehole 11: GP-3

Farm:	Goedehoop
Water level:	14.12 m
Yield:	0.9 l/s
Use:	Domestic and Agricultural

GP-4



Borehole 12: GP-4

Farm:	Goedehoop
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

HN-1

Borehole 13: HN-1

Farm:	Hartbeestfontein
Water level:	20.45 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

HN-2

Borehole 14: HN-2

Farm:	Hartbeestfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

KFN-1

Borehole 15: KFN-1

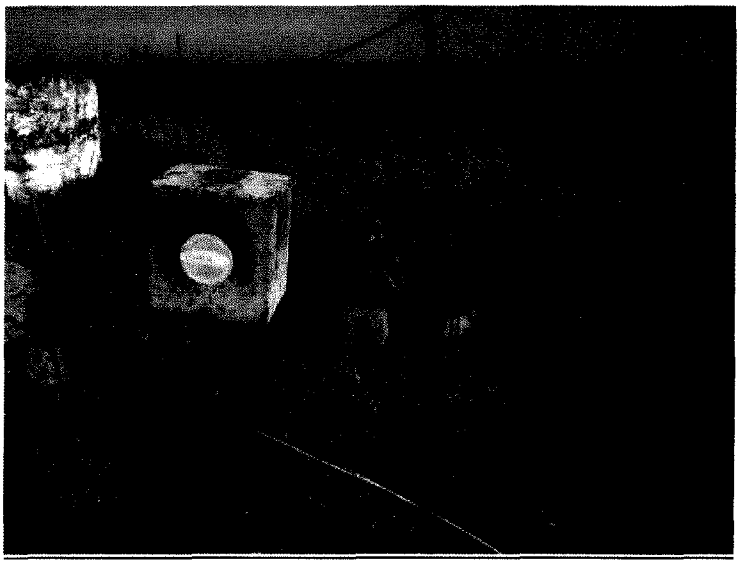
Farm:	Klipfontein
Water level:	2.36 m
Yield:	Unknown
Use:	Domestic

KK-1

Borehole 16: KK-1

Farm:	Klipbank (Plot 15)
Water level:	30.23 m
Yield:	Unknown
Use:	Domestic

KK-2



Borehole 17: KK-2

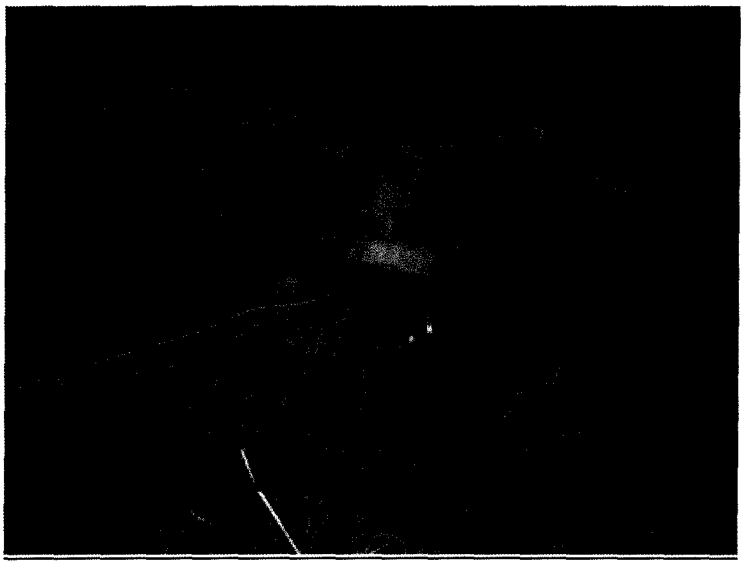
Farm:	Klipbank (Plot 16)
Water level:	10.72 m
Yield:	Unknown
Use:	Domestic

KK-3

Borehole 18: KK-3

Farm:	Klipbank (Plot 15)
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

KK-4



Borehole 19: KK-4

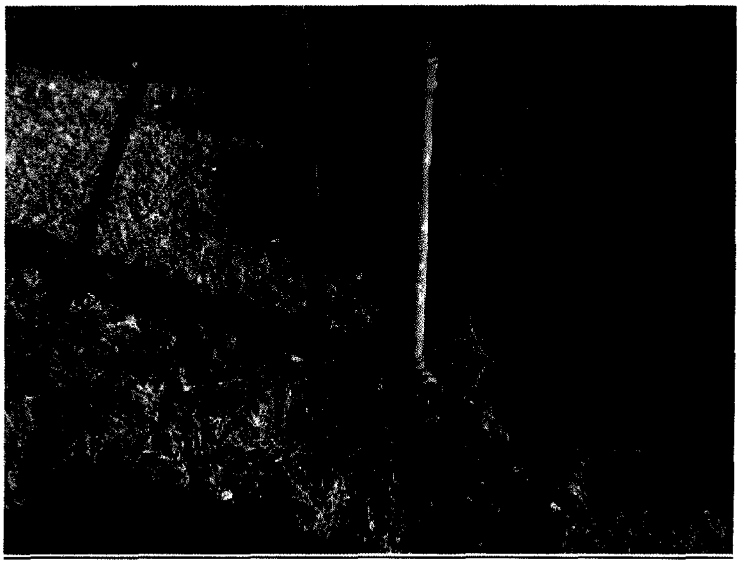
Farm:	Klipbank (Plot 12)
Water level:	1.91 m
Yield:	Unknown
Use:	Domestic and Agricultural

KK-5

Borehole 20: KK-5

Farm:	Klipbank (Plot 11)
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

KK-6



Borehole 21: KK-6

Farm:	Klipbank (Plot 11)
Water level:	Not measured
Yield:	Unknown
Use:	Not in use

KK-7

No photo taken

Borehole 22: KK-7

Farm:	Klipbank (Plot 11)
Water level:	Not measured
Yield:	Unknown
Use:	Not in use

KK-8

Borehole 23: KK-8

Farm:	Klipbank (Plot 8)
Water level:	5.11 m
Yield:	Unknown
Use:	Domestic and Agricultural

KK-9

Borehole 24: KK-9

Farm: Klipbank (Plot 8)
Water level: Not measured
Yield: Unknown
Use: Domestic and Agricultural

KN-1

Borehole 25: KN-1

Farm: Koornfontein
Water level: 16.03 m
Yield: Unknown
Use: Domestic and Agricultural

NP-1

Borehole 26: NP-1

Farm:	Naauwpoort
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

NP-2

Spring 3: NP-2

Farm:	Naauwpoort
Water level:	-
Yield:	-
Use:	Not in use

NP-3

Borehole 27: NP-3

Farm:	Naauwpoort
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

NP-4

Borehole 28: NP-4

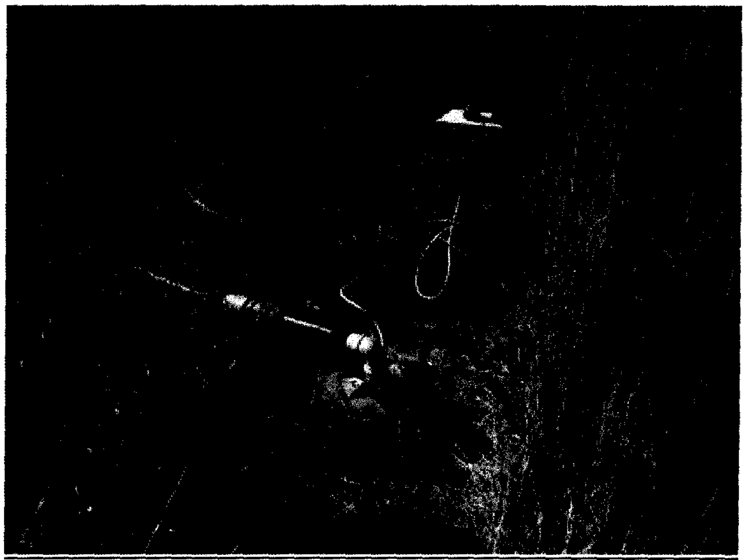
Farm:	Naauwpoort
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

RNN-1

Borehole 29: RNN-1

Farm:	Rhenosterfontein
Water level:	5.76 m
Yield:	0.4 l/s
Use:	Domestic

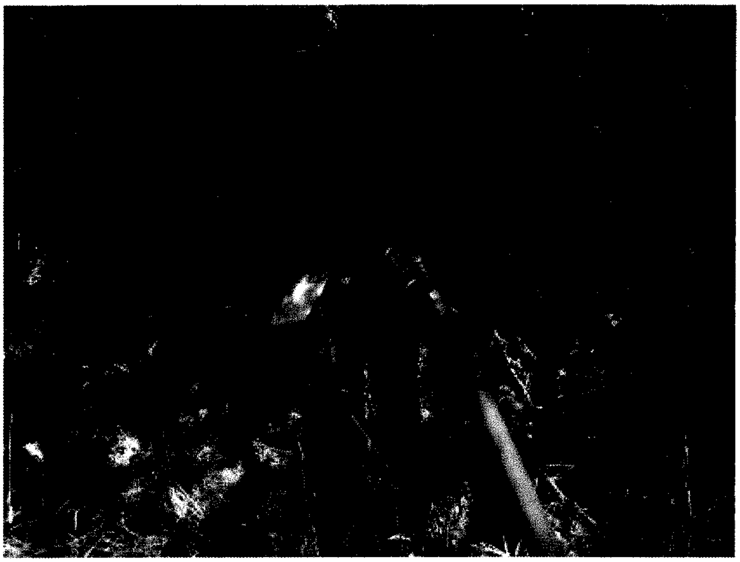
RNN-2



Borehole 30: RNN-2

Farm:	Rhenosterfontein
Water level:	3.32 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

RNN-3



Borehole 31: RNN-3

Farm:	Rhenosterfontein
Water level:	Not measured
Yield:	0.4 l/s
Use:	Domestic

RNN-4

Borehole 32: RNN-4

Farm:	Rhenosterfontein
Water level:	Not measured
Yield:	Unknown
Use:	Agricultural

RNN-5

Borehole 33: RNN-5

Farm:	Rhenosterfontein
Water level:	Not measured
Yield:	0.7 l/s
Use:	Agricultural

RNN-6

Borehole 34: RNN-6

Farm:	Rhenosterfontein
Water level:	1.72 m
Yield:	Unknown
Use:	Domestic and Agricultural

RNN-7

Borehole 35: RNN-7

Farm:	Rhenosterfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

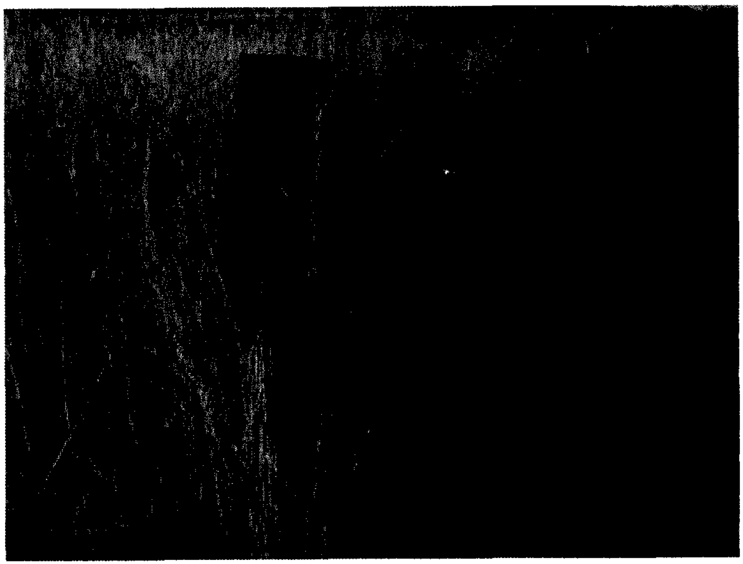
RN-1

No photo taken

Borehole 36: RN-1

Farm:	Rietfontein
Water level:	Not measured
Yield:	0.4 l/s
Use:	Domestic

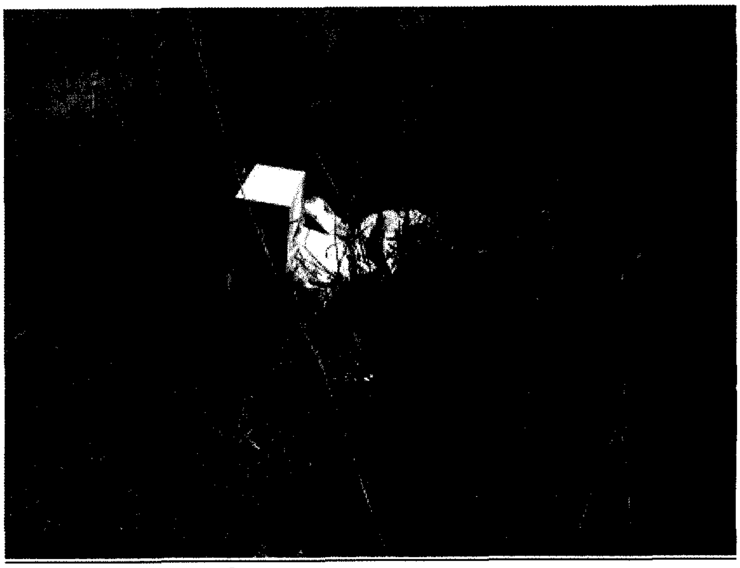
RN-2



Borehole 37: RN-2

Farm:	Rietfontein
Water level:	Not measured
Yield:	0.4 l/s
Use:	Domestic

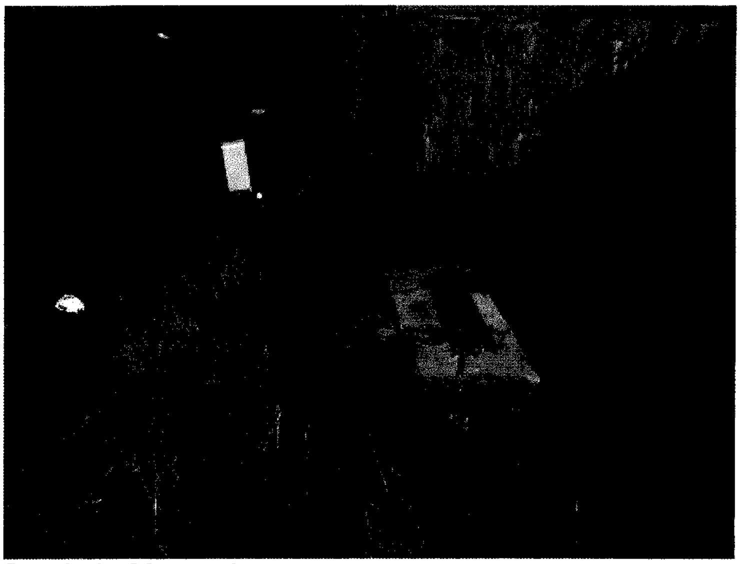
RN-3



Borehole 38: RN-3

Farm:	Rietfontein
Water level:	1.32 m
Yield:	0.4 l/s
Use:	Domestic

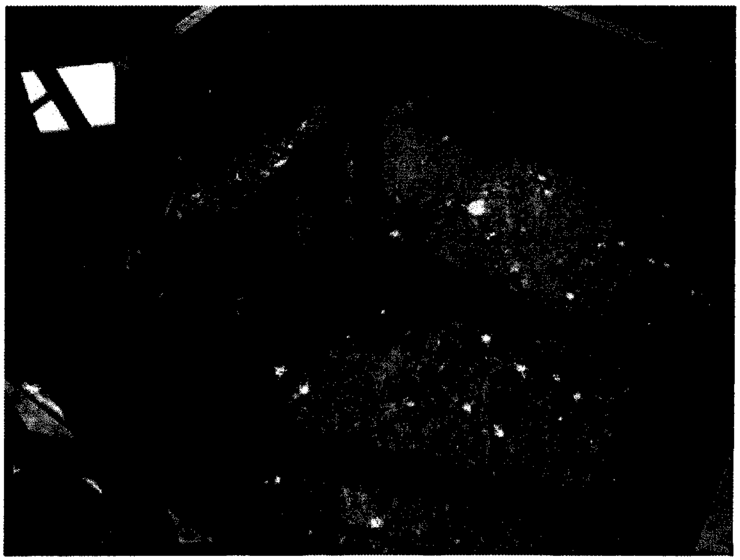
RN-4



Borehole 39: RN-4

Farm:	Rietfontein
Water level:	8.73 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

RN-5



Borehole 40: RN-5

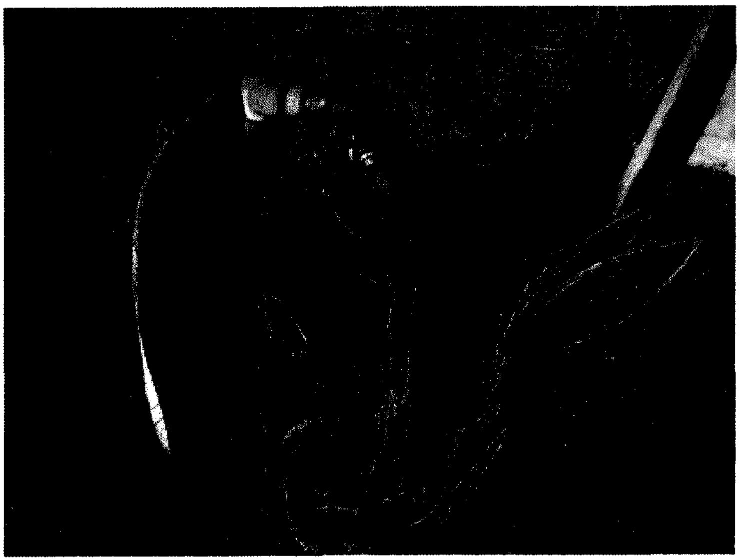
Farm:	Rietfontein
Water level:	2.15 m
Yield:	Unknown
Use:	Domestic and Agricultural

RN-6

Borehole 41: RN-6

Farm:	Rietfontein
Water level:	Not measured
Yield:	Unknown
Use:	Agricultural

RN-7



Borehole 42: RN-8

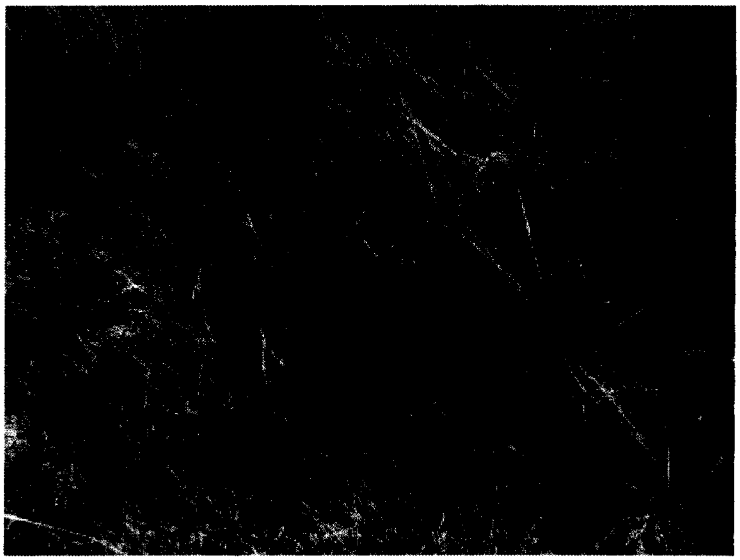
Farm:	Rietfontein
Water level:	20.21 m
Yield:	Unknown
Use:	Domestic and Agricultural

RN-8

Borehole 43: RN-8

Farm:	Rietfontein
Water level:	16.03
Yield:	Unknown
Use:	Domestic and Agricultural

RN-9



Borehole 44: RN-9

Farm:	Rietfontein
Water level:	1.18 m
Yield:	Unknown
Use:	Not in use

RN-10

Borehole 45: RN-10

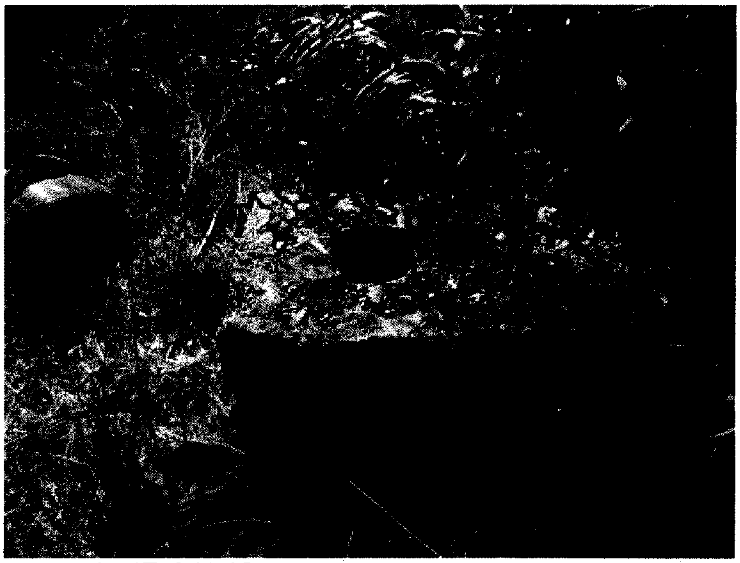
Farm:	Rietfontein
Water level:	7.76 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

RN-11

Borehole 46: RN-11

Farm:	Rietfontein
Water level:	10.45 m
Yield:	Unknown
Use:	Domestic and Agricultural

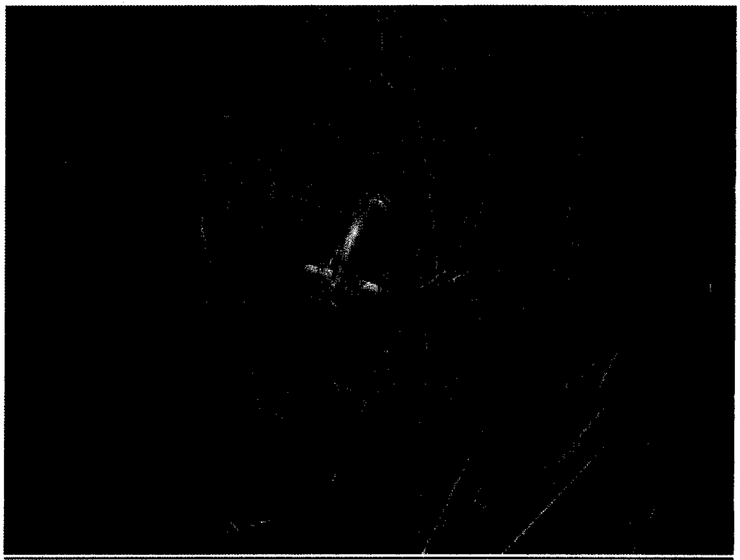
RN-12



Borehole 47: RN-12

Farm:	Rietfontein
Water level:	2.87 m
Yield:	Unknown
Use:	Not in use

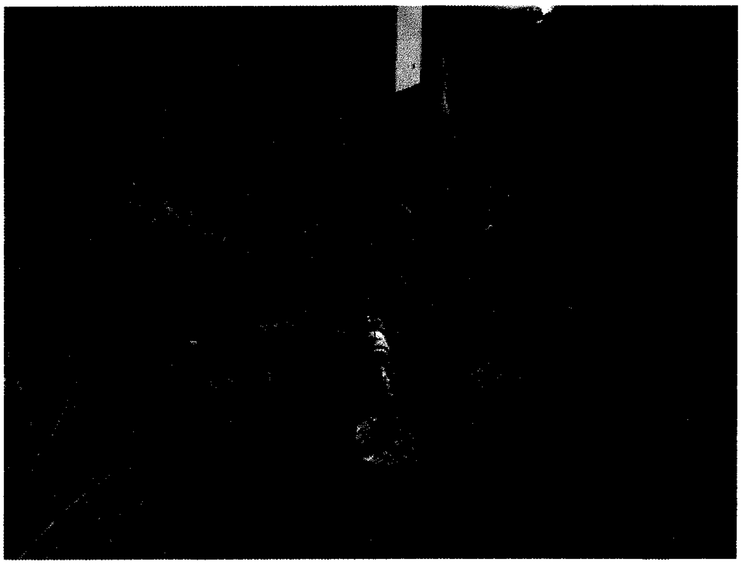
RN-13



Borehole 48: RN-13

Farm:	Rietfontein
Water level:	21.86
Yield:	0.4 l/s
Use:	Domestic and Agricultural

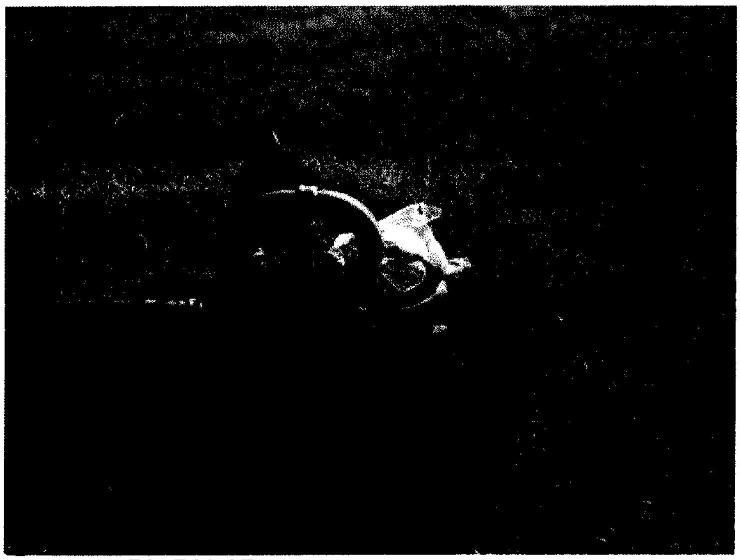
RN-14



Borehole 49: RN-14

Farm:	Rietfontein
Water level:	32.75 m
Yield:	0.4 l/s
Use:	Domestic and Agricultural

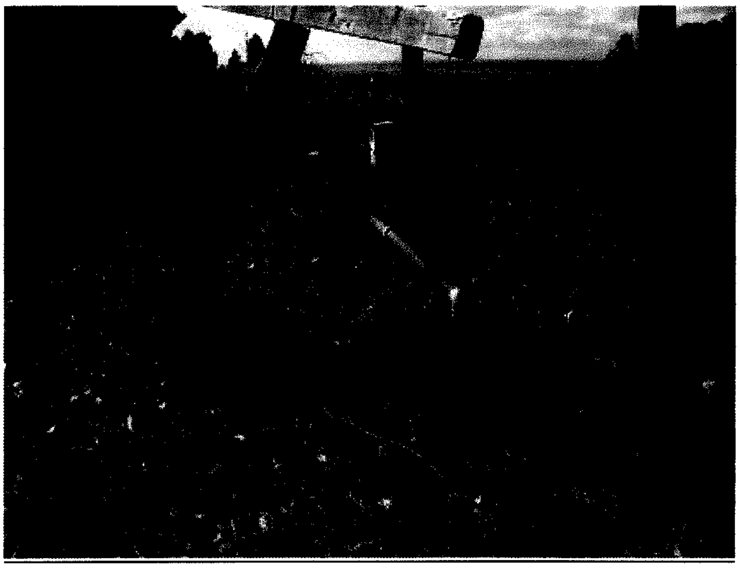
RN-15



Borehole 50: RN-15

Farm:	Rietfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

RT-1



Borehole 51: RT-1

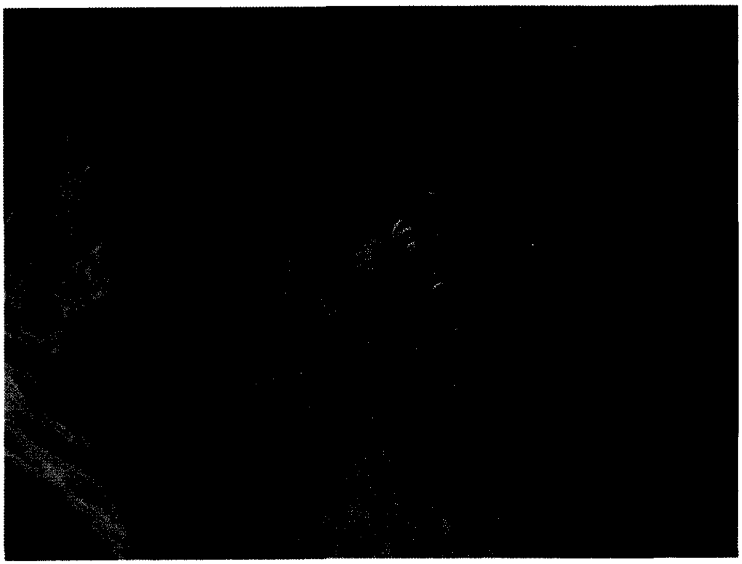
Farm:	Roodepoort
Water level:	7.32 m
Yield:	Unknown
Use:	Domestic

RT-2

Borehole 52: RT-2

Farm:	Roodepoort
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

RT-3



Borehole 53: RT-3

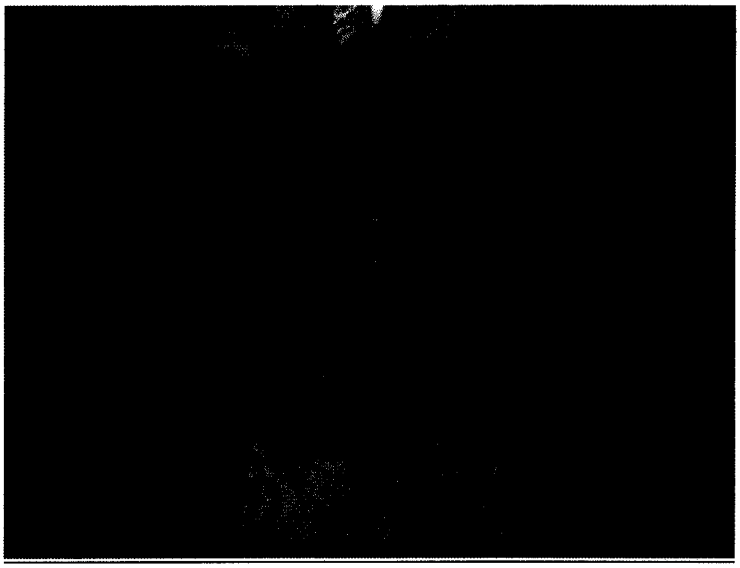
Farm:	Roodepoort
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

SN-1

Borehole 54: SN-1

Farm:	Speekfontein
Water level:	5.46 m
Yield:	0.4 l/s
Use:	Domestic

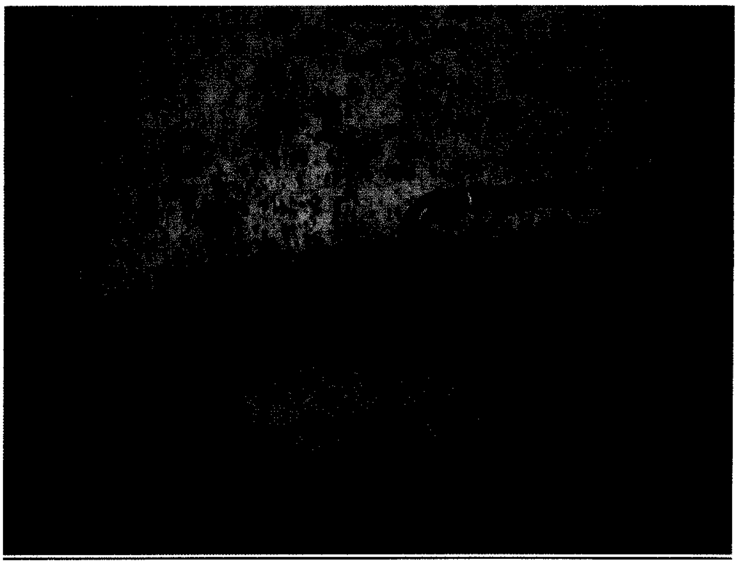
SN-2



Borehole 55: SN-2

Farm:	Speekfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

SN-3



Borehole 56: SN-3

Farm:	Speekfontein
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

SR-1

Borehole 57: SR-1

Farm:	Sterkwater
Water level:	Artesian
Yield:	Unknown
Use:	Domestic

VK-1

No photo taken

Borehole 58: VK-1

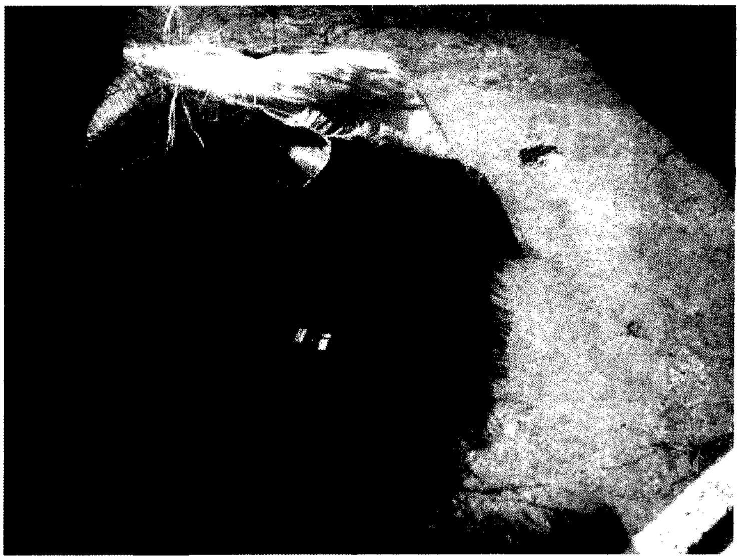
Farm:	Vaalbank (Plot 28)
Water level:	Not measured
Yield:	Unknown
Use:	Domestic

VK-2

Borehole 59: VK-2

Farm: Vaalbank (Plot 17)
Water level: 15.88 m
Yield: 0.8 l/s
Use: Domestic

VK-3



Borehole 60: VK-3

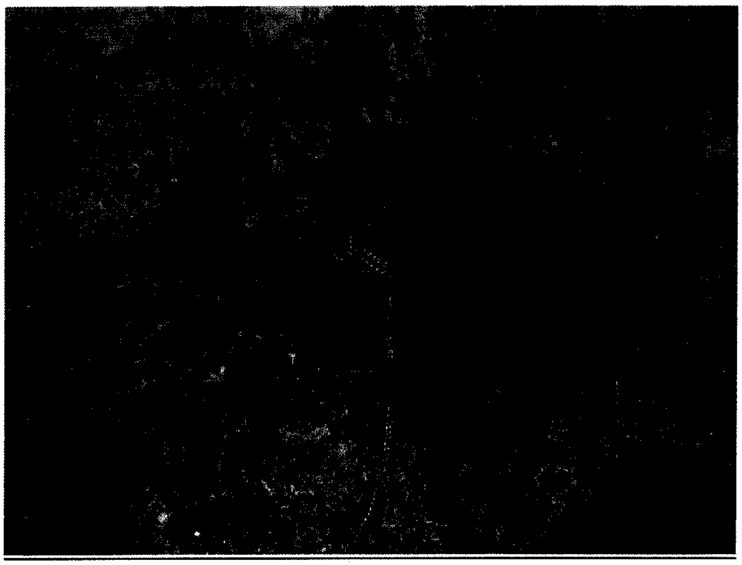
Farm: Vaalbank (Plot 17)
Water level: 12.73 m
Yield: 0.6 l/s
Use: Domestic

VK-4

Borehole 61: VK-4

Farm:	Vaalbank (Plot 11)
Water level:	6.98 m
Yield:	0.6 l/s
Use:	Domestic

VK-5



Borehole 62: VK-5

Farm:	Vaalbank (Plot 11)
Water level:	6.46 m
Yield:	0.6 l/s
Use:	Domestic

VK-6

Borehole 63: VK-6

Farm:	Vaalbank (Plot 21)
Water level:	Not measured
Yield:	0.5 l/s
Use:	Domestic

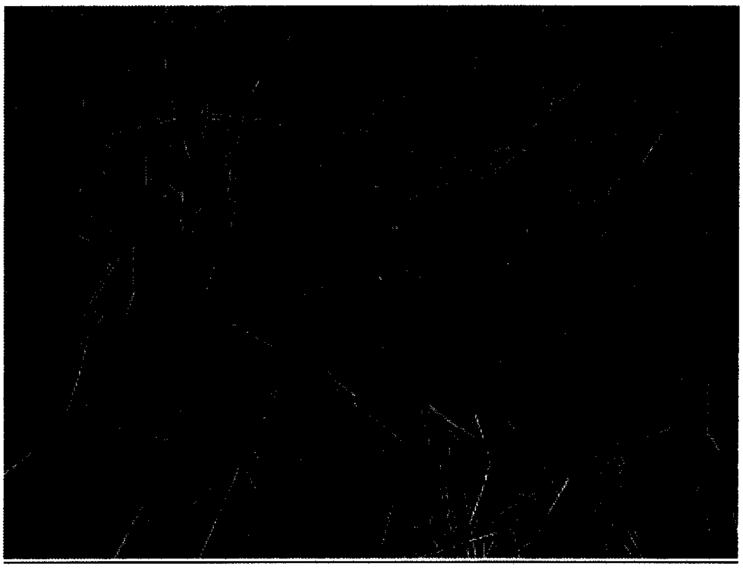
VK-7

No photo taken (spring)

Spring 4: VK-7

Farm:	Vaalbank (Plot 23)
Water level:	-
Yield:	-
Use:	Domestic

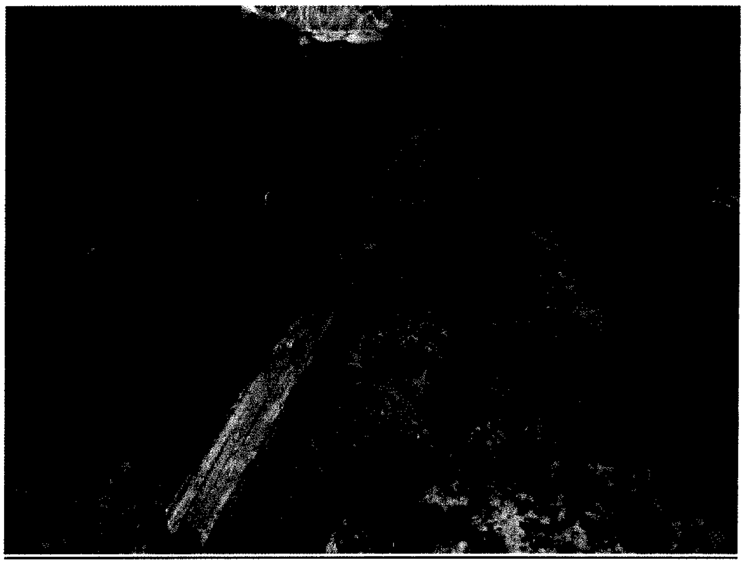
VK-8



Borehole 64: VK-8

Farm:	Vaalbank (Plot 13)
Water level:	Not measured
Yield:	0.4 l/s
Use:	Domestic

VK-9



Borehole 65: VK-9

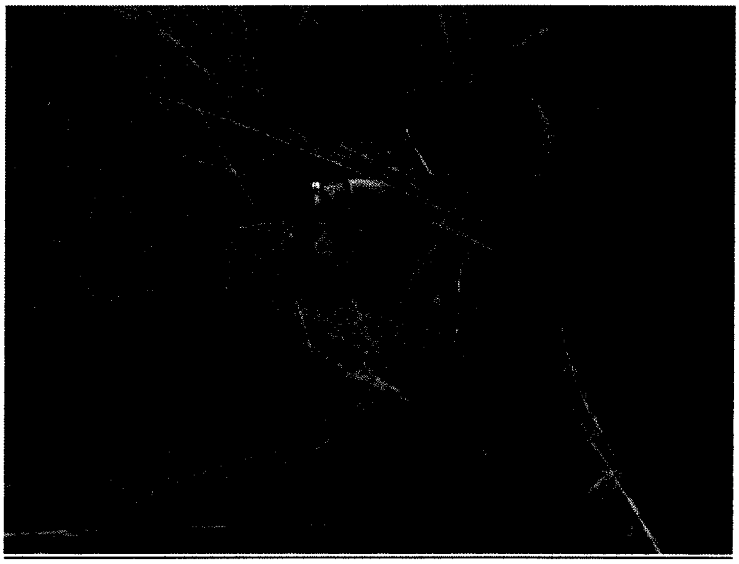
Farm:	Vaalbank (Plot 37)
Water level:	Not measured
Yield:	0.8 l/s
Use:	Domesti

WP-1

Borehole 66: WP-1

Farm:	Wanhoop
Water level:	3.06 m
Yield:	Unknown
Use:	Domestic

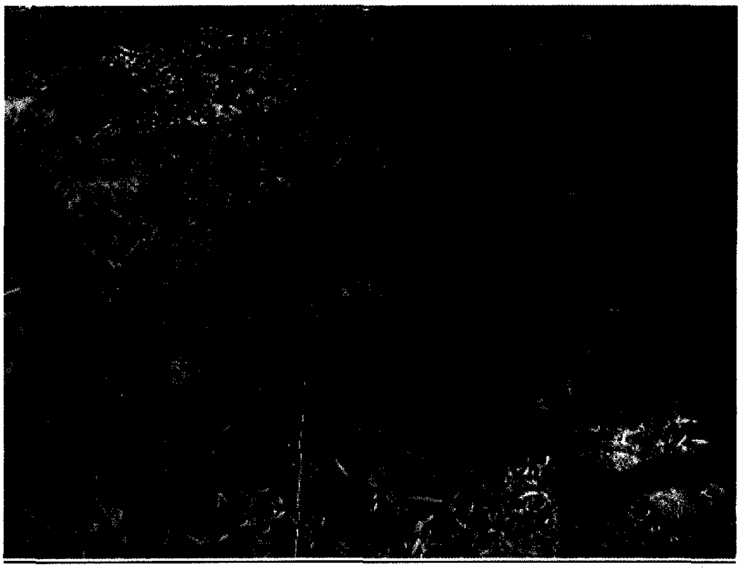
WD-1



Borehole 67: WD-1

Farm:	Welverdiend
Water level:	Not measured
Yield:	Unknown
Use:	Domestic and Agricultural

WD-2



Borehole 68: WD-2

Farm: Welverdiend
Water level: Not measured
Yield: 0.2 l/s
Use: Domestic and Agricultural

WD-3

Borehole 69: WD-3

Farm: Welverdiend
Water level: 3.24 m
Yield: Unknown
Use: Domestic and Agricultural