Appendix H: Geohydrology

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/
NEAS Reference Number:	DEAT/EIA/
Date Received:	

Application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2010

PROJECT TITLE

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED CONTINUOUS ASH DISPOSAL FACILITY FOR THE MATIMBAPOWER STATION IN LEPHALALE, LIMPOPO PROVINCE

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4.2 The specialist appointed in terms of the Regulations_

I, Claudia du Plessis. , declare that --

General declaration:

I act as the independent specialist in this application
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of section 24F of the Act.

CduPlessis.

Signature of the specialist:

GCS Water & Environmental Consultants.

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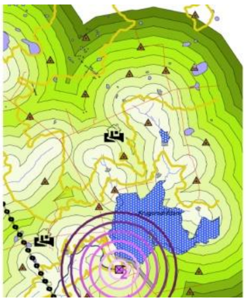
HYDROGEOLOGICAL STUDY: ASH DISPOSAL FACILITY FOR THE MATIMBA POWER STATION AND CONVEYER BELT IMPACT ASSESSMENT

Report

Version - 1
May 2014

Royal HaskoningDHV
GCS Project Number: 12-204




Hydrogeological Study - Ash Disposal Facility for the Matimba Power Station and Conveyer Belt Impact Assessment

Report
Version - 2

May 2014

Royal HaskoningDHV

14-065

DOCUMENT ISSUE STATUS

Report Issue	Version 2		
GCS Reference Number	GCS Ref – 14-065		
Title	Hydrogeological Study: Ash Disposal Facility for the Matimba Power Station and Conveyer Belt Impact Assessment		
	Name	**Signature**	**Date**
Author	Marlese Nel		April 2014
Document Reviewer	Kobus Troskie		April 2014
Document Authorisation	Alkie Marias		April 2014

EXECUTIVE SUMMARY

Introduction

GCS undertook hydrogeological studies, including an initial desktop study, followed by detailed site investigations of both non-intrusive, intrusive and characterisation nature for the proposed continuous ash disposal facility for Matimba Power Station. All studies were conducted in order to comply with the EIA (Environmental Impact Assessment) and Waste Management Licensing (WML) process.

GCS assessed all available geological and hydrogeological data as part of the hydrogeological investigation within the study area (8km radius with the Matimba Power Station as the centre point). All existing groundwater data obtained from previous GCS projects, data provided by the client as well as government data was reviewed and included as part of the assessment.

Topography & Hydrology

The general topography of the area slopes in an easterly direction towards the Sandloop River, which is a non-perennial river flowing in a north easterly direction towards the Mokolo River. The Mokolo River is a large perennial river, which is a tributary of the Limpopo River. The Sandloop River was highlighted as a sensitive receptor. It is situated within the eastern portion of the 8km buffer zone.

Geological Setting

The existing Matimba Ash disposal facility and southern portions of the 8km buffer is underlain by the Mogalakwena Formation of the Waterberg Group. The Formation is comprised of coarse grained purplish brown sandstone.

The Eenzaamheid Fault separates the Waterberg Group in the south from the Karoo Supergroup sediments underlying the remainder of the 8km buffer area to the north. The Swartrant and Grootegeluk Formations (Ecca Group) of the Karoo Supergroup are located in the central, western and eastern portions of the 8km buffer. The Swartrant Formation consists of sandstone, gritstone, mudstone and coal and the Grootegeluk Formation consists of mudstone, carbonaceous shale and coal. The Daarby Fault separates the Swartrant Formation from the Clarens Formation (Stormberg Group) to the north of the buffer area. The Clarens Formation consists of fine grained cream coloured sandstone.

An overview of the structural geology indicates the presence of several faults, namely Eenzaamheid fault, Daarby fault and Zoetfontein fault, located north of the existing Ash disposal facility.

The geological structures can either enhance or impede the groundwater potential in the area by increasing the permeability and transmissivity of the host rock. Secondary processes, such as faulting and fracturing may be associated with enhanced aquifer conditions.

Hydrogeological Setting

According to the 1:500 000 Hydrogeological Map of Polokwane 2326 (2003), the southern portion of the study area, south of the Eenzaamheid fault as well as the Grootegeluk Formation is mostly associated with fractured aquifers based on the geology. The average groundwater yields associated with these aquifers, range from 0.5-2 l/s. Numerous faults transect the study area. Lithology north of the Eenzaamheid fault consists of intergranular and fractured aquifers associated with the Swartrant and Clarens Formations with yields ranging from 0.5-2.0 l/s for the Swartrant Formation and 0.1-0.5l/s for the Clarens Formation.

Groundwater occurs within the joints, bedding planes, and along dolerite contacts within the Waterberg Group sediments. Groundwater potential is generally low in these rocks, with 87% of borehole with yields less than 3 l/s.

The desktop study conducted revealed the presence of numerous NGA (National groundwater archive) boreholes (data obtained from the Department of Water Affairs) and monitoring boreholes that are currently included within the overall Matimba Power Station and Grootegeluk Mine monitoring program.

A review of the existing groundwater quality and groundwater monitoring programs currently implemented at Matimba Power Station indicated high concentrations of the indicator parameters (electrical conductivity, sodium, chloride and sulphate) within most boreholes located downgradient of the current ash disposal facility. The water quality was compared to the SANS (South African National Standard) 241-1:2011 water quality standards for drinking water as well as the target values of the South African Water Quality Guidelines for Domestic Water Use (SAWQG) as published by the Department of Water Affairs (DWA) which is used as a guideline. Two boreholes, B29 and B31 indicate anomalous concentrations of the indicator elements when compared with up-gradient monitoring boreholes. The non-compliance of the water quality confirm the impact of the existing ash disposal facility on the water quality, however in certain boreholes, the ambient water quality is non-compliant with several parameters. Boreholes further downgradient indicated better water quality and were more compliant with the standards indicating the pollution plume is localised.

Detailed Hydrogeological Investigation

Two site alternatives were considered during the EIA Phase, namely Alternative 1 located south of the Matimba Power Station (adjacent to the existing ash disposal facility) and Alternative 2 located north of the Matimba Power Station located on portions of farm Vooruit 449 LQ, Droogeheuvel 447LQ, Ganzepan 446 LQ and Appelvlakte 448 LQ (refer to Figure 4.1).

Site Alternative 1

A detailed hydrocensus was conducted as part of the hydrogeological investigation whereby properties within a 2km radius of Alternative 1 were visited. During the visit, details which were recorded included water use type, volumes of abstraction, water levels and coordinates were obtained.

Majority of the boreholes identified surrounding Alternative 1 during the hydrocensus were Matimba monitoring boreholes. In total 10 water levels were recorded in these boreholes. The water levels ranged from 5.63mbgl to 21.47mbgl. Only one of the 12 boreholes identified, was a production boreholes, the remainder were Matimba monitoring boreholes. The production borehole is used for domestic purposes as well as stock watering.

In total, four new monitoring boreholes surrounding Alternative 1 were drilled in order to expand the existing groundwater monitoring program. MA1 was drilled upgradient and MA2, MA3 and MA4 were drilled downgradient with depths which ranged from 15m to 40m.

The groundwater flow direction for site Alternative 1 is generally in an easterly direction. The flow direction contours were based on water levels collected from 10 boreholes. The flow direction associated with the eastern portion of the current ash disposal area is somewhat different to the general easterly direction. This is most likely due to potential seepage occurring from the ash disposal facility resulting in shallower water levels immediately downgradient of the ash disposal facility.

Short duration constant discharge tests were performed to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters. Aquifer testing was conducted on MA1 & MA2, which indicated relatively low transmissivities which ranged from 0.04 to 0.06 m^2/day.

A review of the chemistry of the Matimba Power Station monitoring boreholes sampled, indicated a general trend with similar parameters which generally exceeded the SANS 241-1:2011 water quality standards. Most of these parameters indicated concentrations which exceeded the relevant standards. Indicator elements as identified using the pollution index include; TDS; chloride; sulphate; calcium; sodium; manganese and magnesium.

Majority of the boreholes indicated poor water quality with high concentrations of indicator elements. This was with the exception of the newly drilled upgradient borehole MA1, P03 and P20. The chemistry results of the remaining boreholes indicated the effect of the current ash disposal facility on the groundwater environment.

Based on the risk rating of the site, Alternative 1 is identified as the most suitable site for the ash disposal facility and will have the smallest impact due to the following reasons:

- Depth to water level – Slightly deeper when compared with Alternative 2;
- Presence of intrusive lithologies – Further distance to intrusive lithologies in comparison to Alternative 2;
- Proximity of production boreholes – Only 1 production borehole was identified in the 2km radius of the site compared to the 13 production boreholes in use surrounding Alternative 2.
- The risk rating of Alternative 1 is reduced by placing the ash disposal facility adjacent to the existing ash disposal facility where a contamination plume already exists and which was confirmed to be localised during the investigation.

The following boreholes are currently being monitored by GHT Consulting: P01, P03, P02, P31, P29, P23 and P20. Boreholes GHT 01 and GHT 02 are newly drilled boreholes by GHT Consulting. MA 01 and MA 02 are newly drilled boreholes by GCS. Borehole HP 01 is a privately owned production borehole used for garden irrigation & stock watering. All these boreholes should be included in the proposed monitoring plan for site Alternative 1. Boreholes MA1 and HP01 can be monitored bi-annually whereas the remainder of boreholes should be monitored quarterly.

Site Alternative 2

A detailed hydrocensus was conducted as part of the hydrogeological investigation whereby properties within a 2km radius of Alternative 2 were visited. During the visit, details including water use type, volumes, water levels and coordinates were obtained.

In total, 16 boreholes were identified surrounding Alternative 2 including the boreholes drilled for this project. The water levels ranged from 17mbgl to 23.94mbgl. The water use is mostly for domestic purposes as well as stock watering.

The geophysical investigation did not confirm the presence of younger intrusive formation or fault zones within the footprint of the proposed ash disposal facility.

The drilling at site Alternative 2 included the installation of one downgradient borehole on the farm Droogeheuwel, namely MA5 which was drilled to a depth of 40 metres. No further boreholes were drilled surrounding this option based on the presence of existing boreholes which were used as monitoring boreholes, namely GPN05 and APV02.

The groundwater flow direction for site Alternative 2 is in an easterly direction. The flow direction contours were based on water levels collected from eight boreholes surrounding the site.

The short duration constant discharge test was performed to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters. Aquifer testing was conducted on GPN05, APV02 and MA5, which indicated transmissivities which ranged from 0.1 to 6.67 m^2/day.

A comparison in the groundwater chemistry was made between the boreholes surrounding site Alternative 1 and site Alternative 2; there is a clear distinction between the results. Although several boreholes associated with site Alternative 2 indicated elevated concentrations of parameters mentioned earlier which appear to be problematic, it is clear that the concentrations in general are much lower than those associated with boreholes surrounding site Alternative 1.

Boreholes APV02, GPN05 and MA05 which were included in this investigation should be monitored on a quarterly basis. Additionally, boreholes NGA090, GPN07 and DHL08 located at a further distance from the proposed site should also be monitored on a quarterly basis.

Conveyer belt route

During the sensitivity mapping process, the following components were identified as sensitive areas; faults or lineaments and production boreholes. The conveyer belt does not traverse/intersect any production boreholes but does traverse the Daarby fault.

The conveyer belt route will traverse two faults, namely the Daarby fault and another north of the Daarby fault. However, the only adverse environmental impacts of conveyor belts for coal transport are coal dust losses during loading, unloading, or transport. Therefore the risk is associated with this is considered minimal.

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LIST OF ACRONYMS

COC - Contaminant of Concern

DWA - Department of Water Affairs

EC - Electrical Conductivity

EIA - Environmental Impact Assessment

ICP MS - Inductively coupled plasma mass spectrometry

GRIP - Groundwater Resource Information Project

GRDM - Groundwater Resource Directed Measures

LCT - Leachable Concentration Thresholds

MAMSL – Metres above mean sea level

MBCH - Meters below collar height

MBGL - meters below ground level

NEMA - National Environmental Management Act

NEMWA - National Environmental Management Waste Act

NGA - National Groundwater Archive

SANAS - South African National Accreditation System

SANS - South African National Standard

SAWQG - South African Water Quality Guidelines for Domestic Water Use

SWL - Static Water Level

TDS - Total Dissolved Solids

WML - Waste Management Licensing

1 INTRODUCTION

GCS was appointed by Royal HaskoningDHV as a groundwater specialist to undertake the hydrogeological investigation associated with the proposed Matimba Power Station continuous ash disposal facility and conveyor belt which forms part of the EIA (Environmental Impact Assessment) and Waste Management Licensing (WML) application process.

Matimba Power Station, located in the Limpopo Province close to Lephalale (Ellisras), is a 3990MW installed capacity base load coal fired power station, consisting of 6 units. Matimba is a direct dry cooling power station, an innovation necessitated by the severe shortage of water in the area where it is situated. The station obtains its coal from the Exxaro Grootegeluk Colliery for the generation of electricity.

Ash is generated as a by-product from combustion of coal from the power station and Matimba produces approximately 6 million tons of ash annually. This ash is currently being disposed by means of 'dry ashing' approximately three kilometres south of the Matimba power station on the Eskom owned Farm Zwartwater 507 LQ.

Matimba Power Station envisages the continuation of ash disposal (dry ashing) and therefore, Eskom requires the licensing of its proposed continuous ash disposal facility in terms of the National Environmental Management Waste Act (NEM:WA), Act 59 of 2008 and the EIA Regulations (2010) promulgated under the National Environmental Management Act (NEMA) Act 107 of 1998 (as amended) as well as the National Water Act, 1998 (NWA) (Act No 36 of 1998).

The development of a continuous development is an ash disposal facility site with the following specifications:

- Capacity of airspace of 297 million m^3 (remaining); and
- Ground footprint of 651 Ha (Remaining fenced Area including pollution control dams).
- This ash disposal facility will be able to accommodate the ashing requirements of the power station for the next 44 years.

However, the EIA process requires the investigation of alternatives and as such an 8km technically feasible radius was delineated from the Matimba Power Station (source of the ash) to identify any potential alternative sites. It is within this 8km radius that a technically feasible and environmentally least sensitive site/s has to be identified. Two Site Alternatives were considered, namely Alternative 1 and Alternative 2 (refer to Figure 4.1).

2 SCOPE OF WORK

The scope of work for the EIA phase of the hydrogeological investigation is detailed as follows:

- Desktop study, including a review of previous GCS reports for similar studies conducted in the area. Review of consultant reports made available by the client;
- Review of hydrocensus data obtained from previous studies conducted by GCS;
- Gap analysis - all sensitive receptors and data limitations were highlighted in the report.
- Intrusive field investigation conducted for both site alternatives including:
    - Hydrocensus within a 2km radius of the alternative site;
    - Geophysical investigations;
    - Drilling on additional monitoring boreholes;
    - Aquifer testing of newly drilled monitoring boreholes;
    - Groundwater sampling of newly drilled boreholes and Hydrocensus boreholes;
    - Analysis of chemistry;
    - Risk rating and impact assessment of the alternative sites and proposed conveyor belt;
    - Proposed groundwater monitoring plan.

○

3 METHODOLOGY

3.1 Desktop Study

GCS assessed all available geological and hydrogeological data. All existing groundwater data was reviewed and assessed during the desktop study.

A study of the 1: 50 000 topographical, 1: 250 000 geological and 1:500 000 hydrogeological maps and satellite images were conducted during the desktop study. All relevant information was sourced from the client as well as from the relevant government departments where available. Any existing groundwater data captured in the National Groundwater Archive (NGA), GRIP (Groundwater Resource Information Project) obtained from the Department of Water Affairs was utilised.

The following data sources were used during the study:

- Topographic map (1:50 000): 2327 DA and DC;
- Geological map (1:250 000): 2326 Ellisras;
- The groundwater resources of the Republic of South Africa, sheets 1 and 2 (Vegter 2045);
- GRDM, Groundwater Resource Directed Measures. (GRDM) Training Manual; and
- The National Groundwater Archive (NGA), Department of Water Affairs;
- GHT Consulting Scientists, 2012. Matimba Power Station, Routine Monitoring Phase 61, First Quarter 2012, Final Report. Report number: RVN630.1/1321.
- Waste Classification of Ash Disposed at the Existing Ash Disposal Facilities conducted by Jeffares & Green;
- Groundwater monitoring data as part of the first quarter monitoring conducted In 2012 by GHT Consulting Services;
- Audit and site assessment data obtained by GHT Consulting Services in May 2011;

4 SITE DESCRIPTION – ASH DISPOSAL FACILITY

4.1 Project Details

The Matimba Power Station is located in the Limpopo Province close to Ellisras. Ash is generated as a by-product due to the combustion of coal from the power station. This ash is currently being disposed by means of 'dry ashing' at an ash disposal facility located on Eskom owned land, approximately 3km south of the Matimba Power Station.

The EIA process requires the investigation of alternatives and as such an 8km technically feasible radius was delineated from the Matimba Power Station (source of the ash) to identify any potential alternative sites. It is within this 8km radius that a technically feasible and environmentally least sensitive site has to be identified for the establishment of the ash disposal facility. Two Alternatives were considered, namely:

- Alternative 1 - located adjacent to the existing ash disposal facility, south of the Power Station.
- Alternative 2: located north of the Matimba Power Station located on portions of the farms Vooruit 449 LQ, Droogeheuvel 447LQ, Ganzepan 446 LQ and Appelvlakte 448 LQ.

4.2 Topography and Hydrology

The topography of the area slopes in an easterly direction (Figure 4.1) towards the Sandloop River, which is a non-perennial river flowing in a north easterly direction towards the Mokolo River. The Mokolo River is a large perennial river, which is a tributary of the Limpopo River. The Sandloop River is a sensitive receptor occurring within the eastern portion of the 8km buffer.

4.3 Surrounding Land Use - Alternative 1

The land use surrounding the current ash disposal facility and the study area is as follows:

North: Natural veld

East: Marapong informal settlement, Onverwacht suburb and Sandloop River

South: Natural veld, Sandloop River and existing Ash Disposal Facility

West: Medupi Power Station and Grootegeluk Mine

4.4 Surrounding Land Use - Alternative 2

The land use surrounding Alternative site 2 is as follows:

North: Natural veld

East: Natural veld

South: Natural veld

West: Natural veld, Grootegeluk Mine

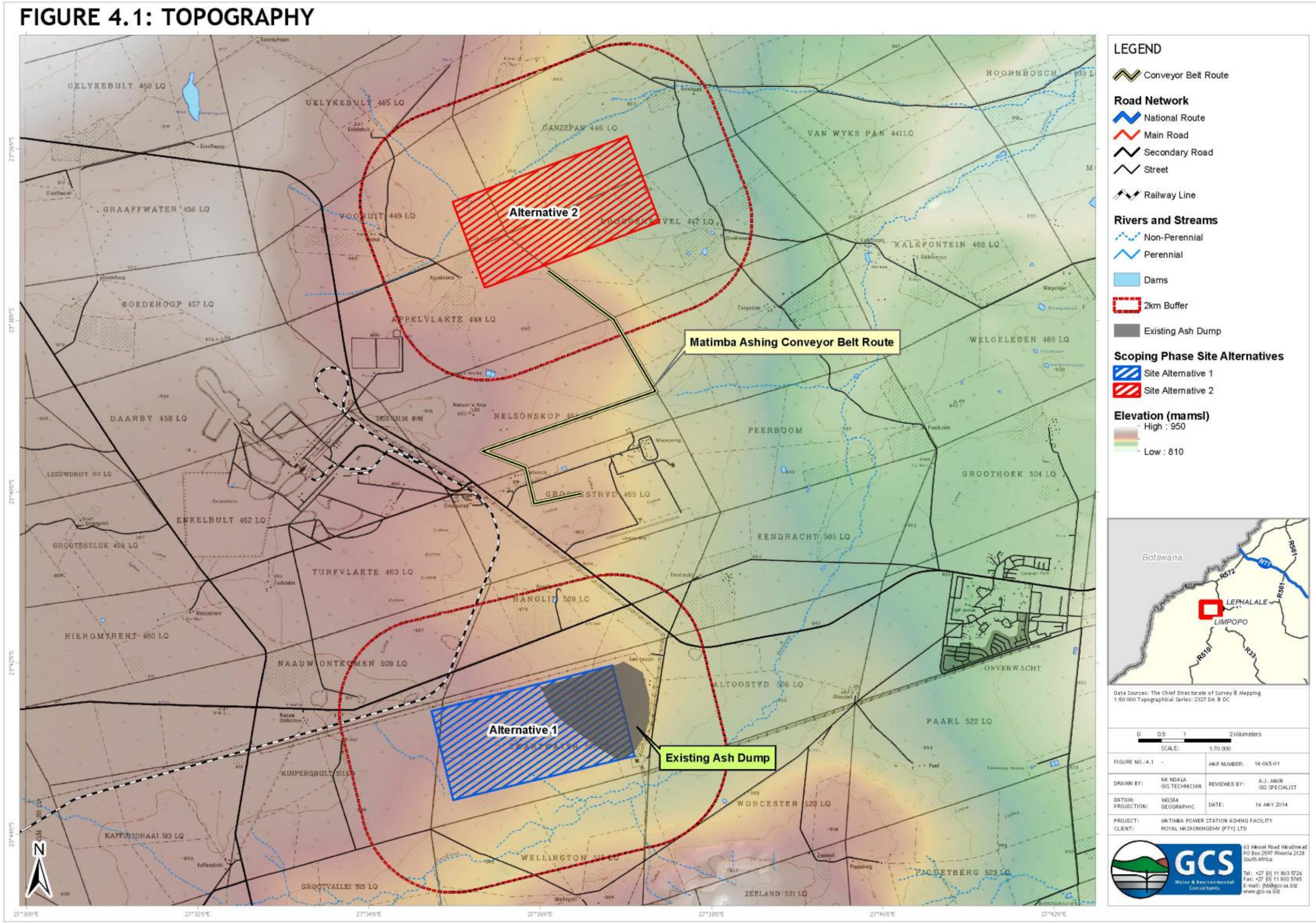


Figure 4.1: Study Area Topography Map

5 GEOLOGICAL DESKTOP STUDY

Sediments and volcanics of the Waterberg Group and Karoo Supergroup underlie the study area within the 8km radius. Table 5.1 presents the lithostratigraphy of the area.

Table 5.1: Lithostratigraphy

Age	Supergroup / Group		Formation	Alternative Name	Lithology
Jurassic	Karoo	Stormberg	Letaba	Letaba Formation	Basalt
Triassic			Clarens	Clarens Formation	Fine-grained cream-coloured sandstone
Triassic			Lisbon*	Elliot Formation	Red mudstone and siltstone
Triassic			Greenwich*	Molteno Formation	Red sandstone and conglomerate
Triassic		Beaufort	Eendragtpan*	Beaufort Group	Variegated shale
Permian		Ecca	Grootegeluk*	Upper Ecca Group	Mudstone, carbonaceous shale, coal
Permian			Goedgedacht *	Middle Ecca Group	Gritty mudstone, mudstone, sandstone, coal
Permian			Swartrant*	Lower Ecca Group	Sandstone, gritstone, mudstone, coal
Permian / Carboniferous		Dwyka	Wellington*	Dwyka Group	Mudstone, siltstone, minor grit
Carboniferous			Waterkloof*	Dwyka Group	Diamictite, mudstone
Mokolian	**Waterberg**		Mogalakwena	Mogalakwena Fm	Coarse-grained purplish brown sandstone

*Not yet approved by the South African Committee on Stratigraphy (SACS)

5.1 Site Geology

Figure 5.1, a portion of the 1:250 000 geological map 2326 Ellisras, shows the geological setting of the study area. The Matimba Ash disposal facility and southern portions of the 8km buffer is underlain by the Mogalakwena Formation of the Waterberg Group. The Formation is comprised of coarse grained purplish brown sandstone.

The Eenzaamheid Fault separates the Waterberg Group in the south from the Karoo Supergroup sediments underlying the remainder of the 8km buffer area to the north. The Swartrant and Grootegeluk Formations of the Karoo Supergroup are located in the central, western and eastern portions. The Swartrant Formation consists of sandstone, gritstone, mudstone and coal and the Grootegeluk Formation consists of mudstone, carbonaceous shale and coal.

The Daarby Fault separates the Swartrant Formation from the Clarens Formation to the north of the buffer area. The Clarens Formation consists of fine grained cream coloured sandstone. No faults are located within the Waterberg Group sediments within the southern portions of the 8km buffer. Several smaller faults are associated with the Swartrant Formation, Grootegeluk Formation and Clarens Formation of the Karoo Supergroup.

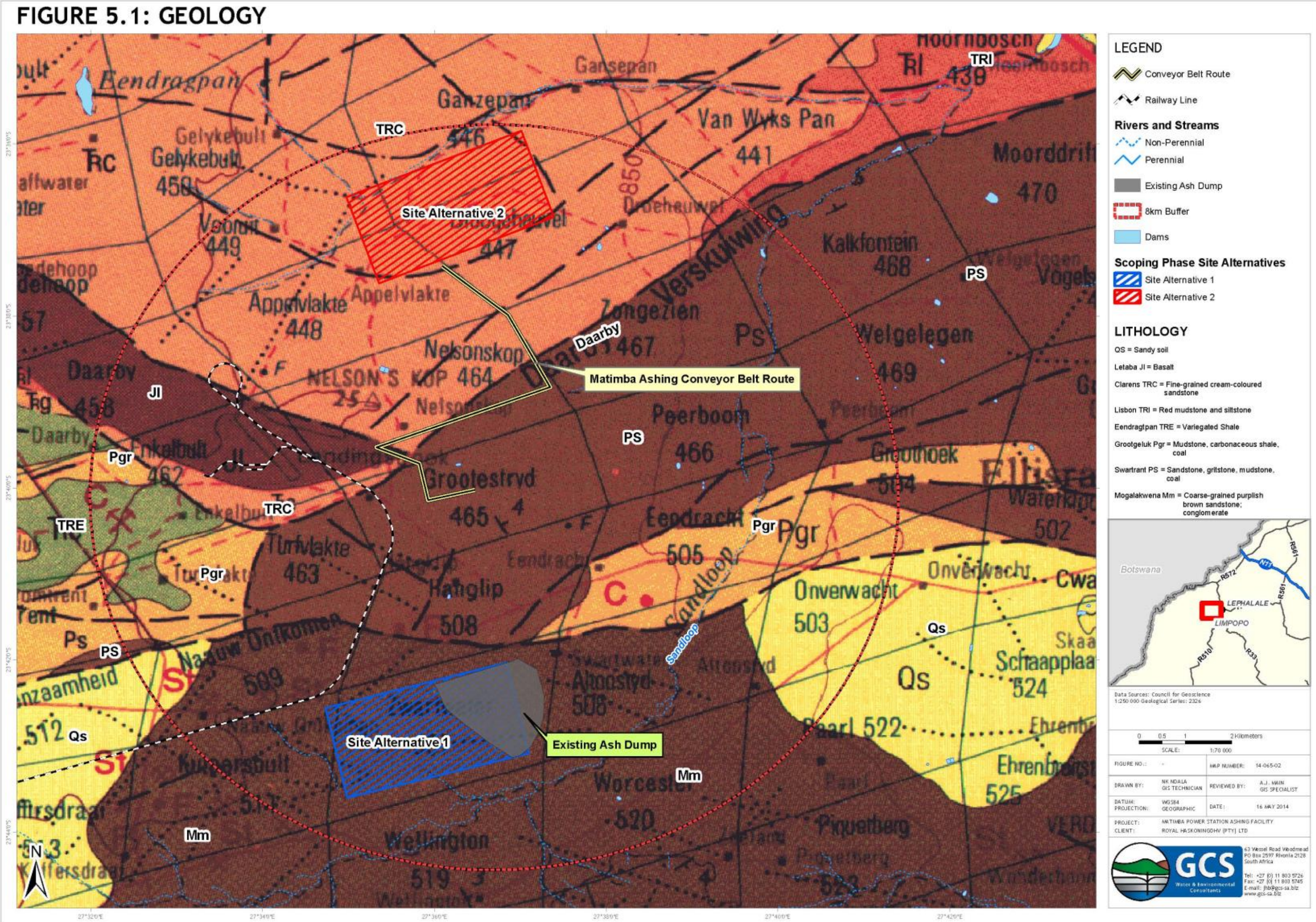


Figure 5.1: Geological Map of the Study Area

5.2 Structural Geology

The study areas are located within the Waterberg Coalfield, which comprises a graben structure with the Eenzaamheid fault forming the southern boundary and the northern boundary is delineated by the Zoetfontein fault. Archaean granite rocks outcrop to the north of the Zoetfontein fault and sediments of the Waterberg Group outcrop to the south of the Eenzaamheid fault.

The geological structures can enhance the groundwater potential in the area by increasing the permeability and transmissivity of the host rock. Secondary processes, such as faulting and fracturing, can create secondary fractured rock aquifers.

5.2.1 The Daarby Fault

The Daarby Fault is a major northeast then northwest trending fault, assumed to be a combination of two faults.

The down throw (amount of vertical displacement of rocks due to faulting) of 360m to the north serves to bring the Grootegeluk Formation rocks to the south in contact with the younger Clarens Formation sandstone and Letaba Formation basalts in the north. Thus the fault divides the coalfield into a shallow (opencast) coal area to the south of the Daarby Fault, and a deep north coal area. The Daarby fault is impermeable (GCS, 2009)

5.2.2 The Eenzaamheid Fault

The Eenzaamheid fault has a throw of 250m to the north and the fault is near vertical Figure 5.1. The fault brings the up thrown Waterberg Group sediments on the south side of the fault in contact with shallow coal on the northern side of the fault.

The permeability of the Eenzaamheid fault is not clear, initial groundwater contours indicated that the fault was impermeable and that dewatering at the mine did not impact on the Waterberg Group sediments to the south of the fault. Subsequent groundwater modelling (GCS, 2009) indicates that plume migration will occur along the fault, indicating an increased transmissivity along the fault between the two geological units.

The Eenzaamheid fault has enhanced groundwater potential and could be targeted for groundwater resource development. The fault can also act as a preferential flow path for groundwater and potential contamination. Any possible contaminant sources should not be constructed on the fault as the fault would facilitate the migration of contaminants off site, which could possibly impact on surrounding groundwater users.

5.2.3 Minor faulting

Associated step faults are identified within the area, especially where the Eenzaamheid and Daarby faults are in the closest proximity (approximately 2 km). The associated faults have varying strikes (orientation of a geologic feature), throws, and throw direction. These faults have increased the in situ permeability of these rocks and influence the groundwater flow patterns.

Indications from exploration drilling are that the Daarby and Eenzaamheid faults are linked. This area also acts as a groundwater flow barrier as dewatering occurs within the Grootegeluk and Eendragtpan Formations, but not in the Swartrant Formation, as recognised from the groundwater modelling.

5.3 The Grootegeluk Coal Deposits

The Grootegeluk coal mine produces coking coal from the Grootegeluk and Goedgedacht Formations (Upper and Middle Ecca Group).

The Grootegeluk Formation comprises intercalated shale and bright coal, with an average depth of 60 m. Coking and middlings grade coal are obtained from this formation.

Opencast mining occurs within the shallow coal, south of the Daarby Fault. Dewatering occurs which has led to the decline of the groundwater levels around the workings.

Coal deposits occur on farms:
- Eenzaamheid (north of the Eenzaamheid fault)
- Naauwontkomen (north of the Eenzaamheid fault)
- Appelvlakte (at depth)
- Nelsonskop (at depth)
- Droogeheuvel (at depth)
- Zongezien (at depth)

6 HYDROGEOLOGICAL DESKTOP STUDY

6.1 Regional Hydrogeology

The groundwater potential of the formations located in the study area is limited in their pristine state due to low permeability, storage, and transmissivity. Secondary processes, such as weathering, fracturing, etc., are required to enhance the groundwater potential.

Based on regional data, as compiled on the 1:500 000 hydrogeological map 2326 Polokwane, the following hydrogeological information is available for the formations on site:

Table 6.1 Geology and Hydrogeological conditions at site (from Royal HaskoningDHV, 2013)

Geology	Hydrogeology
Letaba Formation	Basic extrusive rocks (basalt)
	Intergranular and fractured aquifers
	Borehole yields 0.1 to 0.5 l/s
Clarens Formation	Argillaceous and arenaceous rocks
	Intergranular and fractured aquifers
	Borehole yields 0.1 to 0.5 l/s
Ecca group	Upper and middle Ecca (Grootegeluk)
	Fractured aquifers
	Borehole yields 0.5 to 2.0 l/s
Ecca Group (Swartrant)	Lower Ecca
	Intergranular and fractured aquifers
	Borehole yields 0.5 to 2.0 l/s
Dwyka Group	Predominately arenaceous rocks
	Fractured aquifers
	Borehole yields 0.5 to 2.0 l/s
Waterberg Group	Predominantly arenaceous rocks
	Fractured aquifers
	Borehole yields 0.5 to 2.0 l/s

6.2 Regional Groundwater Occurrence and Aquifers

Based on the geology within the study area, the structural geology, and the geomorphology, the following conditions can arise to enhance aquifer development within the study area:

- The fractured transition zone between weathered and fresh bedrock
- Fractures along contact zones between the host rocks due to heating and cooling of rocks involved with the intrusions
- Contact zones between sedimentary rocks of different types
- Interbed or bedding plane fracturing
- Openings on discontinuities formed by fracturing
- Faulting due to tectonic forces
- Stratigraphic unconformities
- Zones of deeper weathering
- Fractures related to tensional and decompressional stresses due to off-loading of overlying material
- Groundwater occurs within the joints, bedding planes and along dolerite contacts within the Waterberg Group sediments. Groundwater potential is generally low in these rocks, with 87% of borehole yields < 3 l/s.

6.3 Quaternary Catchment

Data from relevant hydrogeological databases including, the National Groundwater Archive (NGA) was obtained from the Department of Water Affairs. The 8km radius study area fall within two quaternary catchments, namely A42J and A42H as indicated in Table 6.2. Both Site Alternatives fall within quaternary catchment A42J.

Table 6.2: Summarized Quaternary Catchment Information (GRDM, 2010)

Quaternary Catchment	Total Area (km^2)	Recharge mm/a	Current use Mm^3/a	Exploitation Potential Mm^3/a	Rainfall mm/a
A42J	1810.8	7.25	0.19	7	428
A42H	1056.6	14.77	0.06	5	518

6.4 Site Specific Hydrogeology

According to the 1:500 000 Hydrogeological Map of Polokwane 2326 (2003), the southern portion of study area, south of the Eenzaamheid fault as well as the Grootegeluk Formation is mostly associated with fractured aquifers based on the geology. The average groundwater yields associated with these aquifers, range from 0.5-2 l/s.

Numerous faults transect the study area. Lithology north of the Eenzaamheid fault consists of intergranular and fractured aquifers associated with the Swartrant and Clarens Formations with yields ranging from of 0.5-2.0 l/s for the Swartrant Formation and 0.1-0.5l/s for the Clarens Formation.

Borehole information derived from the Department of Water Affairs (DWA), National Groundwater Archive (NGA) and the monitoring data from the power station and Grootegeluk coal mine allowed for an assessment of the hydrogeology, aquifers and water levels in the area.

6.5 Groundwater Levels

Data was collected from the National Groundwater Archive (NGA) boreholes, from the Department of Water Affairs, the GRIP (Groundwater Resource Information Project) database, as well as data supplied from the monitoring boreholes present at Matimba Power Station and the Grootegeluk Mine compiled for previous GCS studies. The localities of these boreholes have been plotted on Figure 6.1 below.

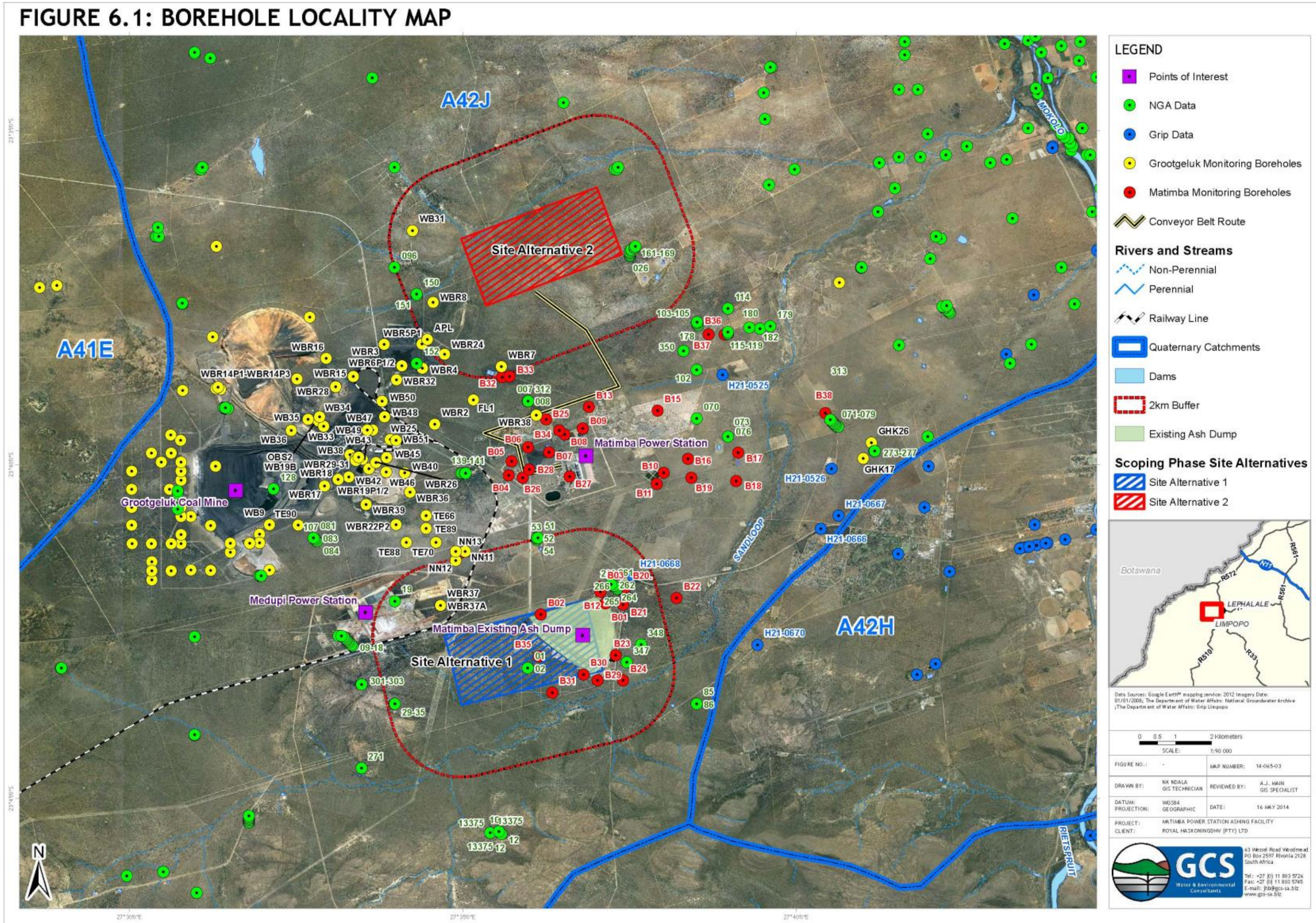


Figure 6.1: Borehole Locality Map

The data for the NGA and GRIP boreholes was compiled for quaternary catchments A42J and A42H. Table 6.3 lists the details of the NGA boreholes plotted on Figure 6.1 located within the 8km buffer. Water level data and water use were not available for all boreholes in the database. The water levels ranged from 1.83 to 60.96 metres below ground level (mbgl), which were measured between 1953 and 1972.

Table 6.3: NGA Borehole Data within the 8km Buffer

Geosite Info Identifier	Latitude	Longitude	Water Level Measurement Date	Water Level (mbgl)	Water Use
1	-23.7174	27.5997	-	-	-
2	-23.7174	27.5997	-	-	-
7	-23.6507	27.5997	-	-	-
8	-23.6508	27.5997	1958/04/23	27.43	-
9	-23.7116	27.55553	-	-	-
10	-23.7119	27.55581	-	-	-
11	-23.7094	27.55303	1958/02/11	30.48	-
13	-23.7096	27.55359	1958/01/04	9.14	-
14	-23.7099	27.55387	1958/08/04	10.36	-
15	-23.7102	27.55414	1958/07/18	21.34	-
16	-23.7105	27.55442	1958/06/04	45.72	-
17	-23.7107	27.5547	1958/01/25	60.96	-
18	-23.711	27.55498	-	-	-
19	-23.7007	27.56642	1958/04/30	13.72	
26	-23.6144	27.62526	1960/08/25	21.34	-
29	-23.7263	27.56637	1960/02/10	22.86	-
30	-23.7263	27.56637	1959/12/14	22.86	-
31	-23.7263	27.56638	1961/06/09	48.77	-
33	-23.7263	27.56639	1960/10/31	18.29	-
35	-23.7263	27.5664	1959/11/24	22.86	-
51	-23.6849	27.6022	-	-	-
52	-23.6849	27.60192	-	-	-
53	-23.6852	27.60192	1953/06/05	60.96	-
54	-23.6855	27.60192	1953/06/30	24.38	-
70	-23.6552	27.64192	-	-	-
71	-23.6555	27.67526	1957/01/12	33.53	-
72	-23.6557	27.67553	1957/01/04	27.43	-
73	-23.6596	27.64972	-	-	-
74	-23.656	27.67581	1951/10/30	30.48	-
75	-23.6563	27.67609	1957/12/14	33.53	-

76	-23.6597	27.6497	-	-	-
77	-23.6566	27.67637	-	-	-
78	-23.6569	27.67664	-	-	-
79	-23.6571	27.67692	1957/12/14	39.62	-
83	-23.6855	27.54664	-	-	-
85	-23.7263	27.64192	1956/09/15	9.14	-
86	-23.7263	27.64192	1956/10/10	6.4	-
96	-23.6174	27.56637	-	-	-
102	-23.643	27.64192	1965/08/11	24.08	-
103	-23.631	27.64193	-	-	-
104	-23.6313	27.64192	1953/10/07	33.53	-
105	-23.6316	27.64194	1958/04/09	30.48	-
107	-23.593	27.66637	-	-	-
114	-23.6277	27.6497	1957/02/02	33.53	-
115	-23.6338	27.6497	-	-	-
116	-23.6341	27.64971	1955/08/18	42.67	-
117	-23.6335	27.6497	-	-	-
118	-23.6341	27.64972	1955/09/17	51.82	-
119	-23.6338	27.6497	1955/10/07	35.05	-
128	-23.6727	27.53609	-	-	-
150	-23.6241	27.57192	-	-	-
152	-23.6244	27.57192	1958/02/19	21.34	-
161	-23.6146	27.62527	1960/08/05	24.38	-
162	-23.6141	27.62526	-	-	-
163	-23.6138	27.62528	1960/08/16	27.43	-
164	-23.6135	27.62526	1954/03/02	23.77	-
165	-23.6124	27.62637	1990/06/14	23	-
166	-23.6121	27.62664	-	-	-
167	-23.6127	27.62637	-	-	-
168	-23.613	27.62553	-	-	-
169	-23.6132	27.62553	-	-	-
178	-23.6319	27.6422	1991/07/25	24	-
179	-23.6321	27.66026	-	-	-
180	-23.6324	27.65498	-	-	-
182	-23.6632	27.74414	-	-	-
261	-23.6966	27.62053	1955/10/10	3.05	Stock Watering

262	-23.6969	27.62081	1964/10/01	20.42	-
263	-23.6969	27.62109	-	-	-
264	-23.6971	27.62137	1965/05/11	18.29	Stock Watering
265	-23.6974	27.62164	1952/04/28	60.96	-
266	-23.6977	27.62192	1952/06/05	27.43	Domestic
271	-23.7424	27.55803	1972/07/27	23.16	Stock Watering
273	-23.6632	27.68636	1953/12/18	35.66	Irrigation
274	-23.6632	27.6863	1980/05/28	15	-
275	-23.6632	27.68637	1980/06/03	50	-
276	-23.6632	27.68636	-	-	-
277	-23.6632	27.68638	1980/06/23	50	-
301	-23.7216	27.55803	1953/12/05	3.35	Agriculture
302	-23.7216	27.55804	1953/11/16	1.83	-
303	-23.7216	27.55804	1953/11/16	1.83	-
312	-23.6507	27.59971	1954/03/11	19.81	-
347	-23.716	27.62442	1995/10/03	64	-
348	-23.7116	27.62803	-	-	-
10	-23.7582	27.59248	1957/09/17	7.32	-
12	-23.7588	27.59303	1963/11/30	18.29	-

The GRIP data presented in Table 6.4 has also been plotted on Figure 6.1 indicating five boreholes within the 8km buffer area.

Table 6.4: GRIP Borehole Data within the 8km Buffer

Borehole ID	Latitude	Longitude	Current status	Water Level (mbgl)	Borehole Depth (m)
H21-0668	-23.69438	27.62591	Destroyed	32.54 m	-
H21-0525	-23.64426	27.64834	-	-	-
H21-0526	-23.66763	27.67558	-	-	-
H21-0667	-23.67939	27.67733	-	32.54	300
H21-0666	-23.68264	27.67292	-	33.31	216
H21-0670	-23.71166	27.65713	-	3.96	213

Monitoring borehole data was obtained for both the Matimba Power Station (Table 6.5) and the Grootegeluk Mine (Table 6.6).

Only data for boreholes located within the 8km buffer and was included in this study. Additional borehole data is presented in Appendix A for reference purposes. The data for the Matimba Power Station was obtained from GHT Consulting Scientists, who conducted the surface and groundwater monitoring from 2005 to 2012.

The groundwater level monitoring for the Matimba Power Station monitoring boreholes located within the 8km radius of the power station are presented in Table 6.5. In total there are 40 boreholes located within this radius, monitoring areas in close proximity to the ash disposal facility as well as the power station, although several boreholes are not functional. The water levels in these boreholes ranged from 2.75mbgl to 29.95mbgl.

Of the boreholes monitoring the existing ash disposal facility, two boreholes have been destroyed, B30 was covered with ash and not sealed correctly, creating a pathway for contaminant transport. B35 has been destroyed due to maintenance work. Borehole B12 is currently blocked (GHT Consulting Scientists, 2012).

Table 6.5: Matimba Power Station Monitoring Borehole Data (GHT Consulting Scientists, 2012)

BH ID	Latitude	Longitude	Borehole locality	Depth (m)	Water level (m)
B01	-23.701283	27.61905	Monitoring borehole, North-eastern corner of ash stack	10	7.68
B02	-23.704067	27.602933	Monitoring borehole, northern perimeter of ash stack	30	20.18
B03	-23.6972	27.617717	Monitoring borehole, northern-eastern corner northern ash water collecting dam P05	13	14.41
B04	-23.66935	27.594967	Monitoring borehole western perimeter of old rehabilitated waste site.	15	11.85
B05	-23.6658	27.59565	Monitoring borehole northern perimeter of old rehabilitated waste site	15	7.42
B06	-23.662383	27.599733	Monitoring borehole north-eastern corner of CSP, North of transfer house.	13	9
B07	-23.663607	27.604917	Monitoring borehole northern perimeter of CSP, North of conveyer	13	5.38
B08	-23.6591	27.608867	Monitoring borehole north western corner of CSP, dirty water runoff dams	13	6
B09	-23.65755	27.613367	Monitoring borehole north -eastern corner of CSP dirty water run-off dams P02	7&25	3.78
B10	-23.6687	27.633667	Monitoring borehole southern corner of station drain dams POD	6	3.75
B11	-23.671433	27.631983	Monitoring borehole eastern corner of station drain dams POD	6	4.5
B12	-23.698383	27.617867	Monitoring borehole, south-eastern corner of northern ash water collecting dam P05	5.5	Dry/block ed
B13	-23.65225	27.61495	Monitoring borehole North -Western corner of Marapong.downstream of CSY.B08,B09,B25,&B34	13	7.45
B14	-23.50885	27.654583	Monitoring borehole west of Marapong sport grounds. Downstream of CSY,B08,B09,B25,&B13	13	6.89
B15	-23.65315	27.632083	Monitoring borehole in Marapong village, house 2883.downstream of CSY,B08,B09,B25,B34,B13&B34	14	2.75
B16	-23.665217	27.639667	Monitoring borehole North -East of station drain dams POD on private farm Peerboom 466.downstream from P03,B10 &B11	13	9.45
B17	-23.663667	27.652267	Monitoring borehole North -East of station drain dams P03, on the private farm Peerboom 466.downstream from	30	No access

			P03,B11,&B16		
B18	-23.670735	27.651698	Monitoring borehole east of the station drain dams P03 on private farm Eendracht 505.downstream from P03,B10 & B19	~	11.31
B19	-23.669868	27.640573	Monitoring borehole east of station drains dams P03,on the private farm Eendracht 505.downstream from P03,B10,B11 & B19	~	6.43
B20	-23.697317	27.624133	Monitoring borehole, east of water return dams P05 next to fence. Downstream of P05, B03, B12	17	14.47
B21	-23.701533	27.62355	Monitoring borehole, North-east of ash stack next to fence. Downstream of ash stack, P05, B01, B03 & B12	15	6.45
B22	-23.699983	27.636833	Monitoring borehole, north-east of ashing area of private farm Altopostyd 506. Downstream of ash stack, P05, B01, B03, B12, B20 & B21.	25	17.41
B23	-23.714267	27.621667	Monitoring borehole, eastern perimeter of ash stack & north-eastern corner of eastern ash water collecting dam P06	12	7.96
B24	-23.72055	27.623517	Monitoring borehole, north-east of ashing area of private farm Worcester 520. Downstream of ash stack P06, B23 & B29	11	2.88
B25	-23.6553	27.604267	Monitoring bore north of CSY inside security area at new development. Downstream of CSP,B06,B07,&B34	19	Damaged
B26	-23.6699	27.598367	Monitoring borehole eastern perimeter of old rehabilitated of old rehabilitated waste site	13	Dry
B27	-23.669633	27.610067	Monitoring borehole east of fuel tanks and filling stations in power station area	9	4.46
B28	-23.6679	27.600017	Monitoring borehole south -western corner of CSP north of ash transfer house	12	5.8
B29	-23.720467	27.617117	Monitoring borehole south-eastern corner of ash stack	13	5.9
B30	-23.719017	27.61355	Monitoring borehole southern perimeter of ash stack	11	Destroyed
B31	-23.723533	27.605833	Monitoring borehole south of ash stack. Downstream of ash stack, B30 & B35	19	13.96
B32	-23.64485	27.5932	Monitoring borehole west of sewage plant between plant and old natural ponds.	24	20.28
B33	-23.644667	27.595167	Monitoring borehole east of sewage plant next to dirt road.	25	20.48
B34	-23.658083	27.60755	Monitoring borehole north of CSY at access gate to irrigation dam P08	9	5.88
B35	-23.7145	27.602383	Monitoring borehole south and downstream of ash stack.	7	Destroyed
B36	-23.634117	27.648783	Monitoring borehole north-east of power station area on private farm Zongezien 467. Borehole at farm house	~	No access
B37	-23.634117	27.6449	Monitoring borehole north -east of power station area on private farm Zongezien 467.Borehole at farm house	33	29.98
B37i	~	~	Monitoring borehole north - east of power station area on private farm Zongezien 467	~	Location unknown

B38	-23.6538	27.674017	Monitoring borehole east of power station area on private farm peerboom 466.Borehole at farm house .Downstream from B17 & B18	NA	Collapsed
B40	~	~	Monitoring borehole east of power station area on private farm peerboom 466. Downstream from B17&B18	~	Location unknown

The monitoring boreholes surrounding the Grootegeluk Mine are presented in Table 6.6. An extensive groundwater monitoring network surrounds the Mine with a large proportion located within the 8km buffer area. The water levels in these boreholes ranged from 3mbgl to 60.95mbgl. The variation in water levels is possibly due to the de-watering activities of the Grootegeluk open cast mining to the west of the 8km buffer.

Table 6.6: Grootegeluk Mine Monitoring Borehole Data

Borehole ID	Latitude	Longitude	Elevation (mamsl)	Water Level Elevation (mamsl)	Water Level (mbgl)
GHK17	-23.66506	27.68348	845.67	816.65	29.02
GHK26	-23.6612	27.68553	843.7	818.2	25.5
NN11	-23.68831	27.58406	877.76	854.04	23.72
NN12	-23.69057	27.58162	880.36	830.4	49.96
NN13	-23.68834	27.58165	879.99	856.18	23.81
OBS2	-23.65586	27.54733	902.41	892.85	9.56
TE66	-23.67933	27.57422	883.51	862.03	21.48
TE70	-23.68608	27.5767	881.76	862.46	19.3
TE88	-23.68609	27.5693	885.6	875.54	10.06
TE89	-23.68256	27.57424	882.78	865.13	17.65
TE90	-23.68176	27.5423	894.67	841.32	53.35
WB19B	-23.65576	27.5473	902.38	873.28	29.1
WB25	-23.66033	27.56523	895.3	890.57	4.73
WB33	-23.65708	27.54863	901.35	888.4	12.95
WB34	-23.65471	27.54765	904.19	881.24	22.95
WB35	-23.65532	27.54468	902.44	871.46	30.98
WB36	-23.65809	27.54053	901.7	883.36	18.34
WB40	-23.66874	27.56888	895.24	888.52	6.72
WB42	-23.66978	27.55489	893.58	883.53	10.05
WB43	-23.66533	27.55837	894	884.68	9.32
WB45	-23.6649	27.56437	895.01	889.64	5.37
WB46	-23.66846	27.5643	894.11	890.37	3.74
WB47	-23.65798	27.56088	896.72	891.91	4.81
WB48	-23.65475	27.56388	896.02	891.77	4.25
WB49	-23.65794	27.55955	896.78	889.73	7.05
WB50	-23.65078	27.56328	896.61	880.61	16
WB51	-23.6606	27.56676	895.39	885.07	10.32
WB9	-23.68162	27.53508	897.7	839.35	58.35
WBR14P1	-23.6452	27.54194	911.51	882.64	28.87
WBR14P2	-23.6452	27.54194	911.51	882.75	28.76
WBR14P3	-23.6452	27.54194	911.51	897.26	14.25
WBR15	-23.64467	27.55609	902.24	890.77	11.47
WBR16	-23.64011	27.54922	908.68	886.36	22.32
WBR17	-23.67195	27.54886	894.38	874.59	19.79

WBR18	-23.67015	27.55221	892.98	888.46	4.52
WBR2	-23.65657	27.57637	897	888.6	8.4
WBR22P2	-23.68158	27.5668	886.65	854.55	32.1
WBR24	-23.63901	27.57888	887.27	875.92	11.35
WBR26	-23.66612	27.5617	894.67	889.5	5.17
WBR28	-23.64722	27.5516	905.54	888.83	16.71
WBR29	-23.66501	27.55661	894.9	889	5.9
WBR3	-23.63658	27.56375	893.17	890.17	3
WBR30	-23.66564	27.55663	894.73	888.93	5.8
WBR31	-23.66472	27.55734	894.88	888.97	5.91
WBR32	-23.64543	27.56684	893.6	888.2	5.4
WBR36	-23.67355	27.57018	892.82	887.06	5.76
WBR37	-23.70176	27.57775	895.23	881.03	14.2
WBR37A	-23.70176	27.57786	895.27	881.9	13.37
WBR38	-23.65431	27.6018	873.6	860.25	13.35
WBR39	-23.67662	27.55924	891.02	886.26	4.76
WBR4	-23.64251	27.57335	890.44	887.56	2.88
WBR5P1	-23.63652	27.57322	886.57	884.23	2.34
WBR6P1	-23.64195	27.56813	896.33	896.78	-
WBR6P2	-23.64195	27.56813	896.33	889.59	6.74
WBR7	-23.6422	27.5931	886.94	863.95	22.99
WBR8	-23.62611	27.57597	879.55	867.67	11.88
APL	-23.63539	27.57458	-	-	-
FL1	-23.65051	27.58611	-	-	-
WBR39	-23.67662	27.55924	891.02	-	-
WB31	-23.60821	27.57079	882.02	-	-

6.5.1 Groundwater Flow Directions

The water level data obtained from the Matimba monitoring programme and selected data from the Grootegeluk monitoring was used to contour the groundwater levels and determine the groundwater flow direction.

Figure 6.2 presents the general groundwater flow direction across and around the 8km site area. The groundwater flow direction is an easterly direction across the study area, towards the Sandloop River.

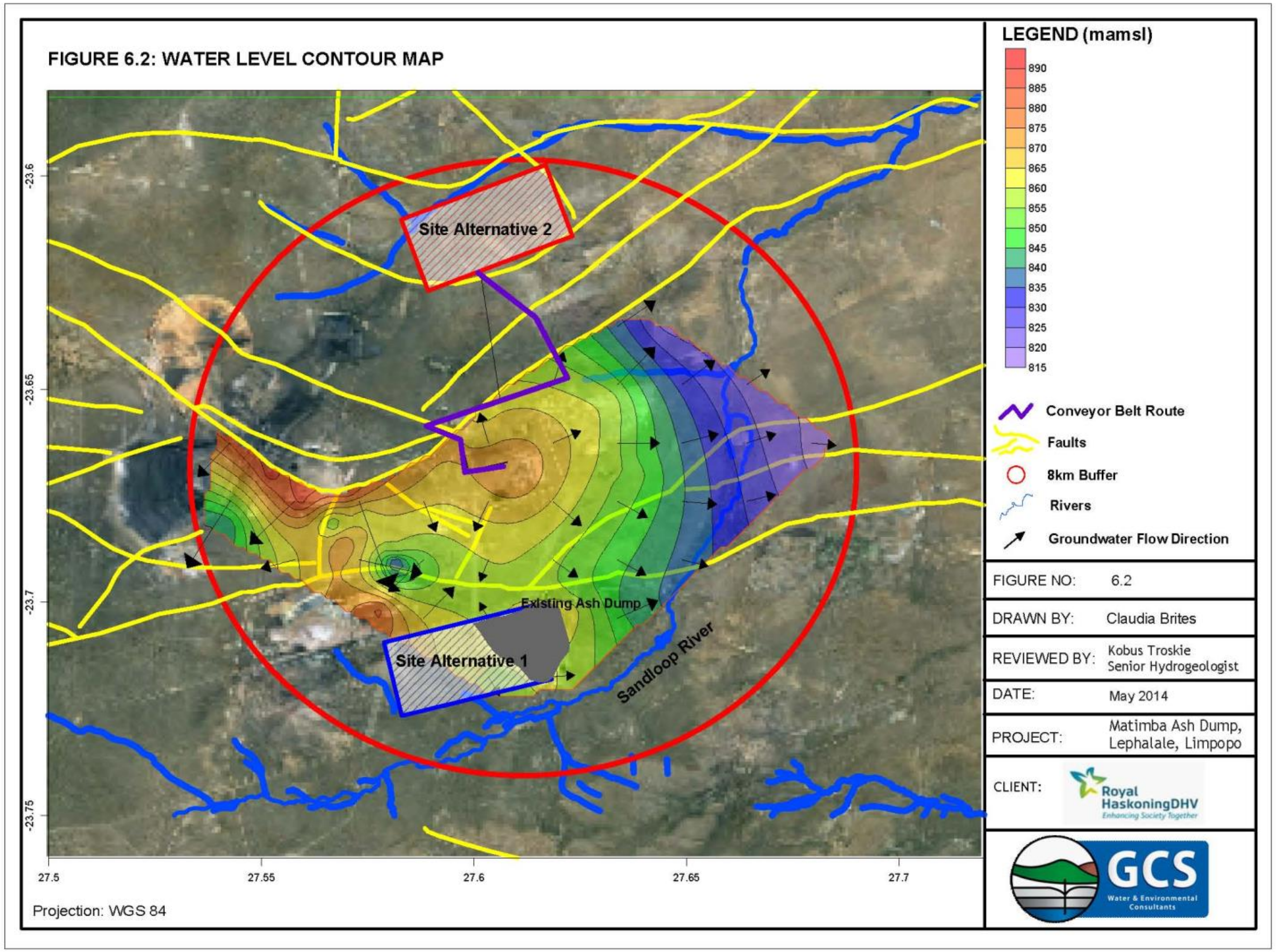


Figure 6.2: Groundwater Flow Direction

6.5.2 Bayesian Estimate

The elevations of the boreholes were plotted against the water level elevations in mamsl (metres above mean sea level), in order to determine if there is a correlation between the two variables which would indicate that the groundwater levels follow the topographical slope of the area. Figure 6.3 below, plots both the Grootegeluk Mine and Matimba Power Station monitoring borehole data set. This indicates a 55% correlation, which suggests a poor relationship between the groundwater levels and the topography. The poor correlation is due to the existing dewatering impacts at the Grootegeluk mine and elevated water levels due to seepage.

Figure 6.4 plots the Matimba borehole data set which indicates a 76% correlation. This suggests a better correlation of the elevation with the groundwater level and indicates that the cone of depression from the dewatering has not been extended to intersect the aquifer(s) in the immediate vicinity of the Matimba Power Station.

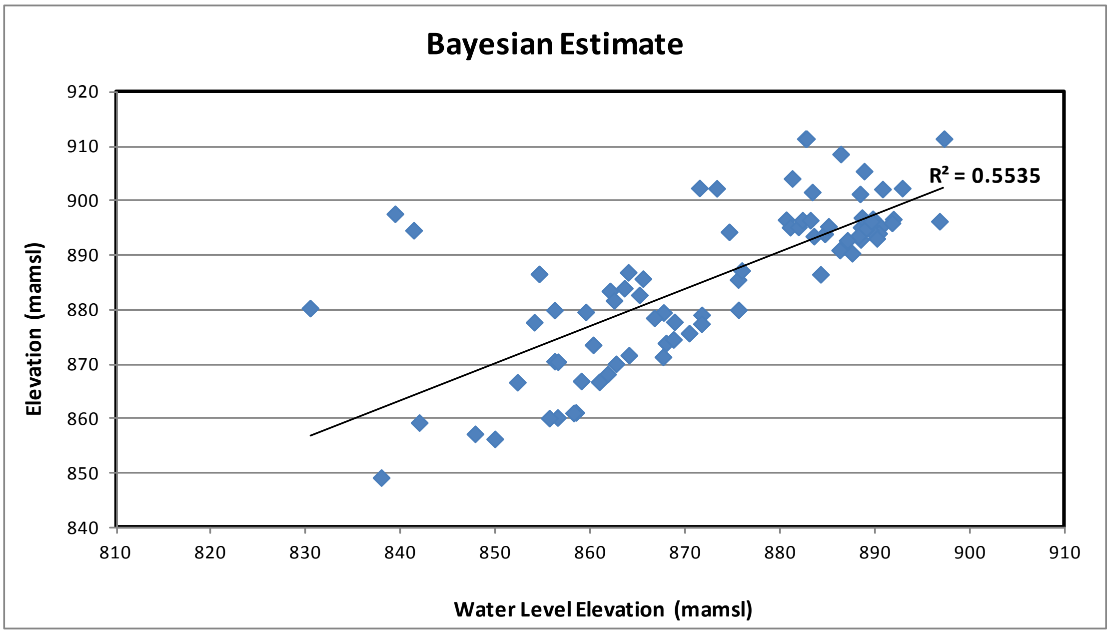


Figure 6.3: Linear relationship between topography and groundwater elevation - Grootegeluk Mine & Matimba boreholes

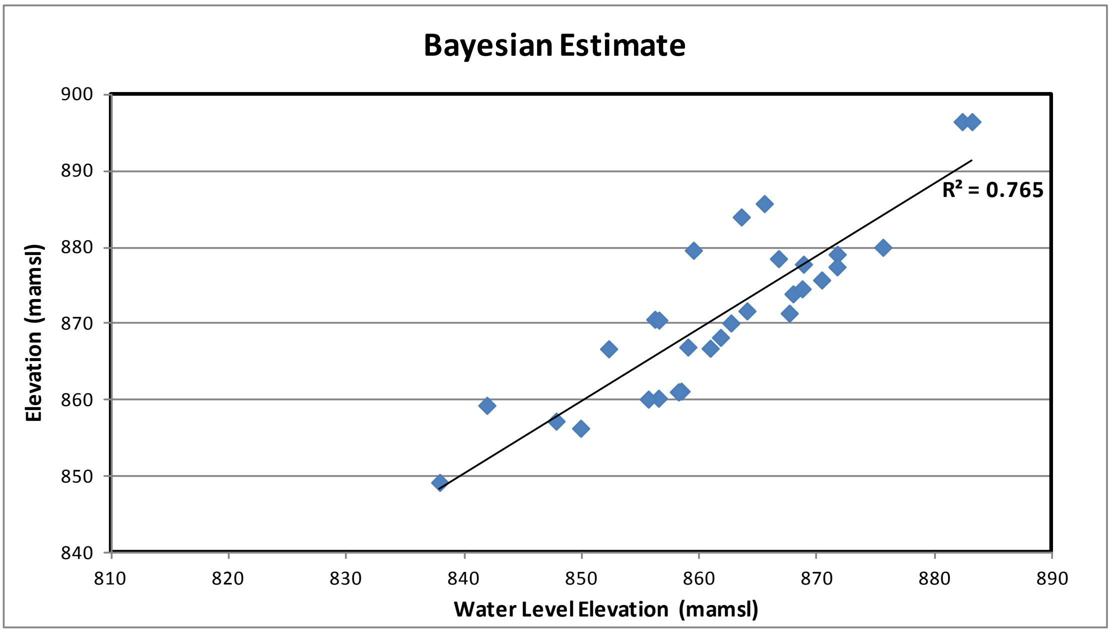


Figure 6.4: Linear relationship between topography and groundwater elevation - Matimba boreholes

6.6 Groundwater Chemistry

All functional boreholes in close proximity to the ash disposal facility were sampled as part of the monitoring conducted by GHT Consulting Scientists in May 2012.

6.7 Existing ash disposal facility

6.7.1 Groundwater Quality

Boreholes B12, B30 and B35 were destroyed/dry and therefore not sampled. Majority of the boreholes were classified as above the recommended limit when compared to the SABS South African National Standard: Drinking Water, SANS 241-1: 2011 limit.

The chemistry indicated several parameters which exceeded the limit in certain boreholes including electrical conductivity, sodium, chloride, sulphate, manganese and iron. The non-compliance of the water quality within the boreholes is potentially from the ash disposal facility (GHT Consulting Scientists, 2012).

Boreholes B29 and B31 are located downgradient of the ash disposal facility, with B29 located adjacent to the ash disposal facility and B31 further from the ash disposal facility. The chemistry indicated excessive concentrations of certain parameters. The EC values exceeded the SANS 241-1:2011 of 170mS/m, with values of 1374 and 1082mS/m in B29 and B31 respectively. The sodium concentration exceeded the SANS limit of 200mg/l with concentrations of 2081 and 2147mg/l in B29 and B31 respectively. The chloride concentrations exceeded the SANS limit of 300mg/l with concentrations of 4256 and 3657mg/l in B29 and B31 respectively. From the results it is evident that certain parameters are present in excessive concentrations directly downgradient of the ash disposal facility. Borehole B24, located further downgradient from B29, indicated high sulphate concentrations, however, more parameters were compliant in comparison to B29, located closer to the ash disposal facility.

Borehole B23 is located downgradient and adjacent to the ash disposal facility. The chemistry indicated high concentrations of indicator parameters (electrical conductivity, sodium, chloride and sulphate) (GHT Consulting Scientists, 2012). Boreholes B3 and B22 indicated compliance with the SANS standard for parameters analysed. B22 is located at quite a distance from the ash disposal facility and B3 is upgradient.

6.7.1.1 Electrical Conductivity

The Electrical Conductivity (EC) measurements as reported in the GHT Consulting Scientists for the first quarter of 2012 indicated elevated EC measurements. The contours indicate elevated EC measurements surrounding the existing ash disposal facility located within the southern portion of the 8km buffer, with boreholes B29 and B31, located downgradient of the ash disposal facility indicated elevated EC concentrations. Similarly, borehole B18, which is located east of the Power Station drain dams, monitoring the Power Station area, indicated elevated EC concentrations within this borehole.

6.7.1.2 Coal Stockyard

Majority of the boreholes in this area indicated elevated parameters, except for boreholes B13 and B15 which indicated suitable water quality which implies that the coal stockyard has not impacted on the water quality (GHT Consulting Scientists, 2012). Several parameters exceeded the limits in some of these boreholes, namely, sulphate, fluoride, sodium, magnesium and chloride.

The boreholes located within the rehabilitated waste site, indicated elevated sodium, chloride, iron and nitrate concentrations.

6.7.2 Power Station

The water quality within these boreholes were for the most part satisfactory. One borehole, B18 indicated elevated electrical conductivity, sodium, calcium, magnesium, chloride, sulphate and nitrate. Borehole B27, indicated elevated nitrate.

6.7.3 Groundwater Use

Groundwater abstraction occurs within the study area for the following purposes:

- Primarily stock or game watering;
- Domestic use;
- Agricultural use;

Reticulated (piped) water is supplied to the area, either via the municipality, Eskom, or Grootegeluk Coal Mine.

7 DETAILED FIELD INVESTIGATION

GCS conducted a detailed hydrogeological investigation for both site alternatives, namely Alternative 1 located adjacent to the existing ash disposal facility and Alternative 2 located on portions of farm Vooruit 449 LQ, Droogeheuvel 447LQ, Ganzepan 446 LQ and Appelvlakte 448 LQ.

7.1 Hydrocensus

A hydrocensus was conducted as part of the hydrogeological investigation whereby properties within a ± 2km radius of both Alternative 1 and Alternative 2 were visited. During the visit, details including water use type, volumes, water levels and coordinates were obtained. The results of the hydrocensus for Alternative 1 are presented in Table 7.1 and Table 7.2 for Alternative 2.

The positions of the hydrocensus boreholes surrounding the two sites alternative are presented in Figure 7.1 and

Figure 7.2.

7.1.1 Site Alternative 1

Groundwater levels were measured in all boreholes which were accessible. In total 16 boreholes were identified surrounding site alternative 1 within a 2km radius according to requirements by the DWA. This includes the four boreholes drilled as part of this study. The boreholes are mostly used for domestic purposes as well as stock watering and the irrigation of gardens.

Many of the boreholes identified during the hydrocensus were Matimba monitoring boreholes. According to the reports reviewed as part of the Scoping phase, the boreholes were referred to with the prefix B, whereas during the actual field investigation, the boreholes were labelled as P. The boreholes referred to in Table 6.5 and Table 7.1 therefore refer to the same boreholes, but are however labelled differently.

In total 11 water levels were recorded in these boreholes. The water levels ranged from 5.63mbgl to 21.47mbgl.

The water levels of the Matimba monitoring boreholes recorded during the hydrocensus are very similar to the water levels recorded in Table 6.5 as recorded during the first quarter in 2012 by GHT Consulting Scientists.

Table 7.1: Hydrocensus Data for Alternative 1

BH name	Co-ordinates, WGS 84 Geographic		Depth (m)	Water level (mbgl)	Pump type	Daily volumes (l/day)	Reservoir (l)	Known Yield (l/s)	Use
	S	E							
MA 01	-23.71	27.58282	40	17.63	GCS Pump installed	-	None	0,71l/s	Monitoring
MA 02	-23.7305	27.58542	40	15.45	GCS Pump installed	-	None	0,71l/s	Monitoring
MA 03	-23.7213	27.61943	40	Dry	Dry	-	-	-	Monitoring
MA 04	-23.7213	27.61943	40	Dry	Dry	-	-	-	Monitoring
GHT 01	-23.7256	27.60345	35	Dry	None - Monitoring BH	-	-	-	Monitoring
GHT 02	-23.7269	27.59853	35	17.1	None - Monitoring BH	-	-	-	Monitoring
P 12	-23.6984	27.61783	15	Dry/collapsed	None - Monitoring BH	-	-	-	Monitoring
P01	-23.7012	27.6190	30	6.21	None - Monitoring BH	-	-	-	Monitoring
P 03	-23.6972	27.61782	40	14.26	None - Monitoring BH	-	-	-	Monitoring
P 02	-23.7041	27.60293	40	21.47	None - Monitoring BH	-	-	-	Monitoring
P 31	-23.7236	27.60577	30	14.06	None - Monitoring BH	-	-	-	Monitoring
P29	-23.7204	27.61705	30	5.63	None - Monitoring BH	-	-	-	Monitoring
P 23	-23.7143	27.6216	40	8.16	None - Monitoring BH	-	-	-	Monitoring
P20	-23.6973	27.62408	40	7.09	None - Monitoring BH	-	-	-	Monitoring
P21	-23.7015	27.6235	40	5.72	None - Monitoring BH	-	-	-	
HP 01	-23.6854	27.60393	Unknown	Approx 7m	Submersible	1000l/day	Cement dam	1,5l/s	Garden irrigation & stock watering

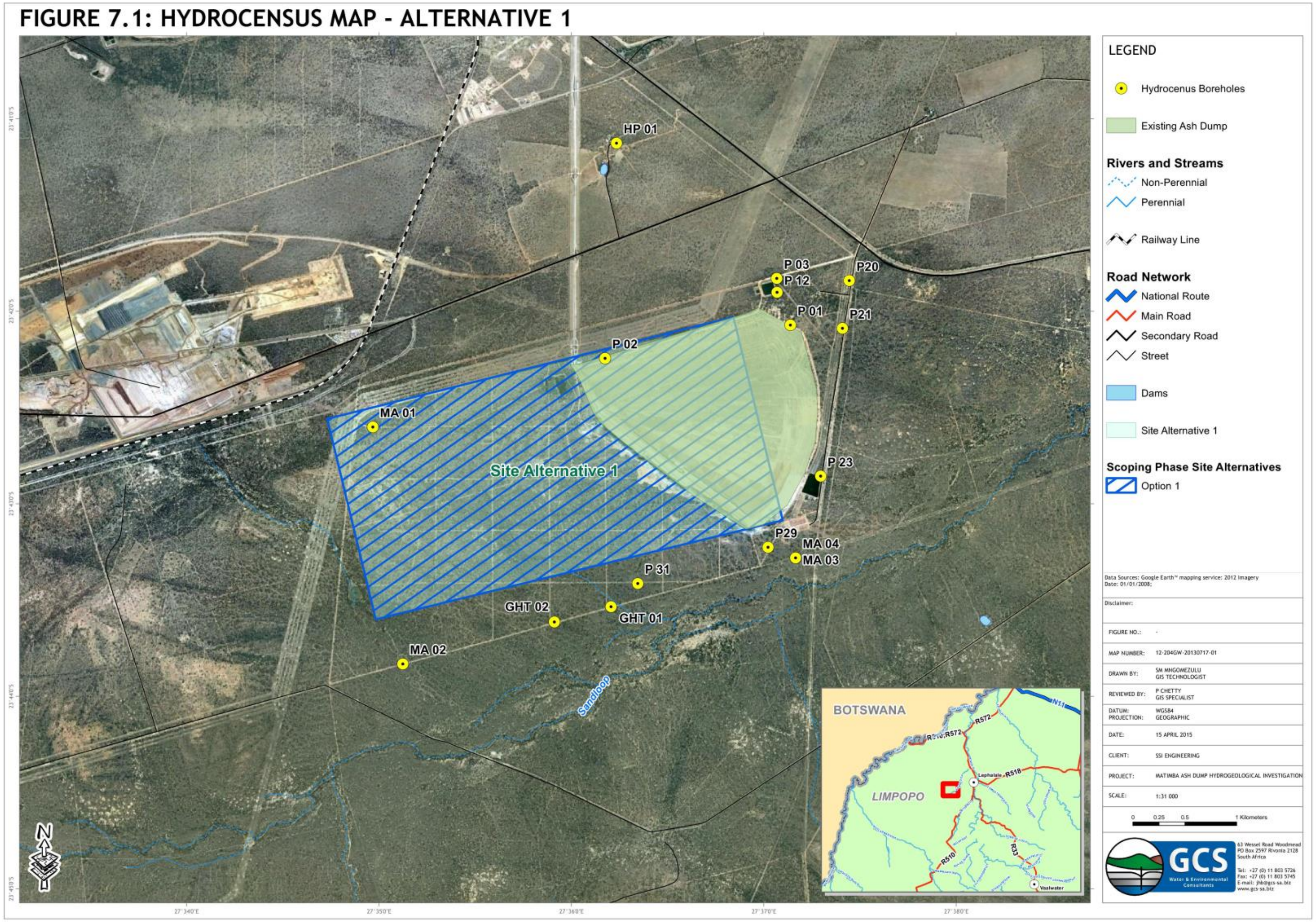


Figure 7.1: Localities of Hydrocensus Boreholes – Alternative 1

7.1.2 Site Alternative 2

Groundwater levels were measured in all boreholes which were accessible. In total 16 boreholes were identified surrounding site alternative 2 including the one borehole drilled for this Site Alternative.

The water levels ranged from 17mbgl to 23.94mbgl. The water use is mostly for domestic purposes as well as stock watering.

Table 7.2: Hydrocensus Data for Alternative 2

BH name	Co-ordinates, WGS 84 Geographic		Depth (m)	Water level (mbgl)	Pump type	Daily volumes (l/day)	Reservoir (l)	Known Yield (l/s)	Use
	S	E							
APV 02	-23.6257	27.58165	100	17.75	Submersible	once daily	2 x 5000 jojo	1.3	Stock watering
APV 01	-23.6291	27.58563	65	17.74	Submersible	filled 3xweek	5000l jojo	Approx 0.3l/s	Domestic, irrigation of garden
NGA 096	-23.6166	27.56757	65	-	Mono	Not in use	None	Approx 1-2l/s	
WB 31	-23.6082	27.57072	Approx 80	23.94	Submersible	1000l/day	2200l jojo	Approx 1.5l/s	Domestic & stock watering
MA 05	-23.6157	27.63042	40	22.87	GCS Pump installed	-	None	0.71l/s	-
DHL 123	-23.616	27.6355	Unknown	-	Submersible	4000l/day	4 x 2200l jojo	0.2l/s each	Domestic
DHL 05	-23.6154	27.6336	Approx 80m	-	Submersible	1000l/day	Waterhole	0.1l/s	Game - Watering hole
DHL 07	-23.6157	27.62408	Approx 80m	-	Submersible	1000l/day	Waterhole	0.1l/s	Game - Watering hole
DHL 08	-23.6265	27.61908	Approx 80m	-	Submersible	1000l/day	Cement dam	0.1l/s	Domestic
GPN 07	-23.5851	27.60082	Approx 65m	19.11	Windpump - Broken	-	Cement dam	-	Stock watering
GPN 06	-23.596	27.59937	Approx 100m	-	Mono	1000l/day	Cement dam	0.1l/s	Stock watering
GPN 01	-23.5895	27.62602	Unknown	-	Mono	1000l/day	2x2200l jojo	0.1l/s	Stock watering
GPN 05	-23.597	27.63763	80	23.11	GCS Pump installed	-	None	0.71l/s	-
GPN 04	-23.5884	27.62388	Approx 40m	17	Not equipped	-	-	-	-
GPN 03	-23.5881	27.62575	Unknown	-	Mono	1xweek	2x2200l jojo	0.1l/s	Domestic
GPN 02	-23.5901	27.62632	100m	22.71	Submersible	1000l/day	Cattle crib	0.1l/s	Stock watering

Figure 7.2: Localities of Hydrocensus Boreholes – Alternative 2

7.2 Geophysical Investigation

GCS conducted a geophysical investigation in order to determine the underlying geological structures and to investigate the presence of zones of preferential groundwater flow in the area. The geophysical investigation was also conducted in order to identify the most suitable location for the drilling of the monitoring boreholes. The magnetic method was used in order to determine the location of any structures or contacts between different lithologies.

The geophysical surveys were conducted on and off site. The magnetic geophysical surveys were conducted on site from the 11th to the 14th of June 2013 whereby a total of three magnetic geophysical traverses were completed in order to delineate the most favourable drilling targets. The results from the geophysical surveys were analysed in order to detect any anomalies that may be present. The data plotted is presented in Appendix B.

7.2.1 Alternative 1

Geophysical profiling of the site was limited due to the existence of the overhead power lines located to the north and east of the site. A total of three geophysical lines were conducted on Alternative 1:

- Line 1 was conducted in a west to east direction on the proposed site area.
- Line 2 was conducted in a south west to north east direction.
- Line 3 was conducted in a south to north direction.

The location of the traverses are shown on Figure 7.3. No targets were identified based on the data obtained from Line 1 & 3. A target was identified on Line 2 at a distance of 2.5km from the starting point in the south western corner. Initially the position of a downgradient borehole was planned for this location, however, during the site investigation, another groundwater consultant was conducting borehole drilling and also earmarked this position for drilling. Therefore GCS made the decision to move the borehole position to a different location. The four boreholes drilled on site included one 40 metre upgradient borehole (MA1), two 40 metre downgradient boreholes (MA2 & MA3) and one 15 metre downgradient borehole (MA4).

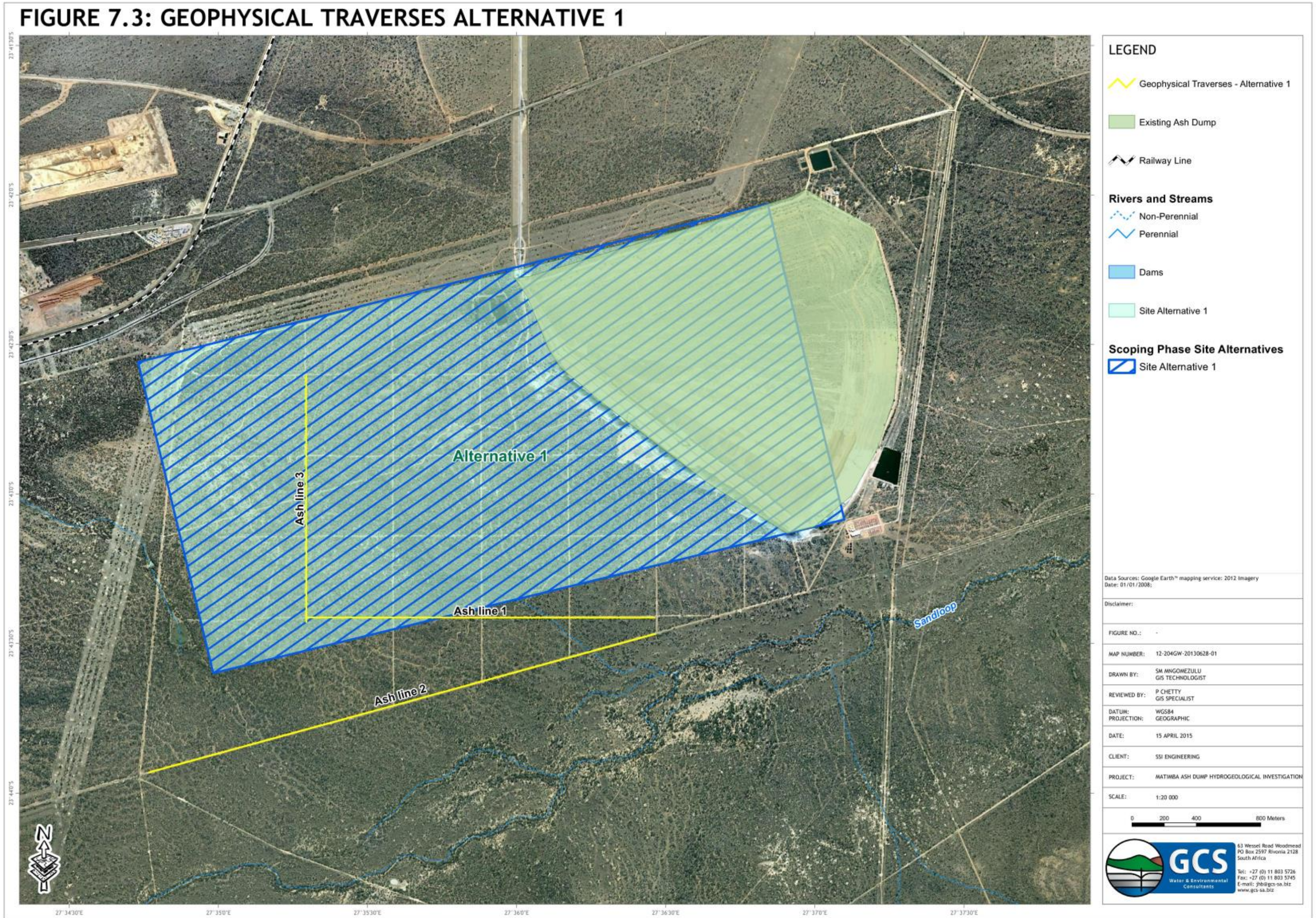


Figure 7.3: Geophysical Traverses Alternative 1

7.2.2 *Alternative 2*

A total of five geophysical lines were conducted on site Alternative 2.

- Ganzepan Line 1 & 3 and Droogeheuwel Line 1 were conducted in a west to east direction.
- Ganzepan Line 2 and Droogeheuwel Line 2 were conducted in a north west to south west direction.

The locations of the traverses have been plotted on Figure 7.4. No targets were identified based on the geophysical results.

Only one borehole was drilled for this site, which was located downgradient of the site. The borehole was drilled to a depth of 40 metres and was located on the farm Droogeheuwel. The remaining proposed upgradient and downgradient boreholes were not drilled for this site alternative as two boreholes were identified during the hydrocensus which were suitable to be utilized as monitoring boreholes. This included one borehole on the farm Ganzepan and the other borehole was located on farm Appelvlakte.

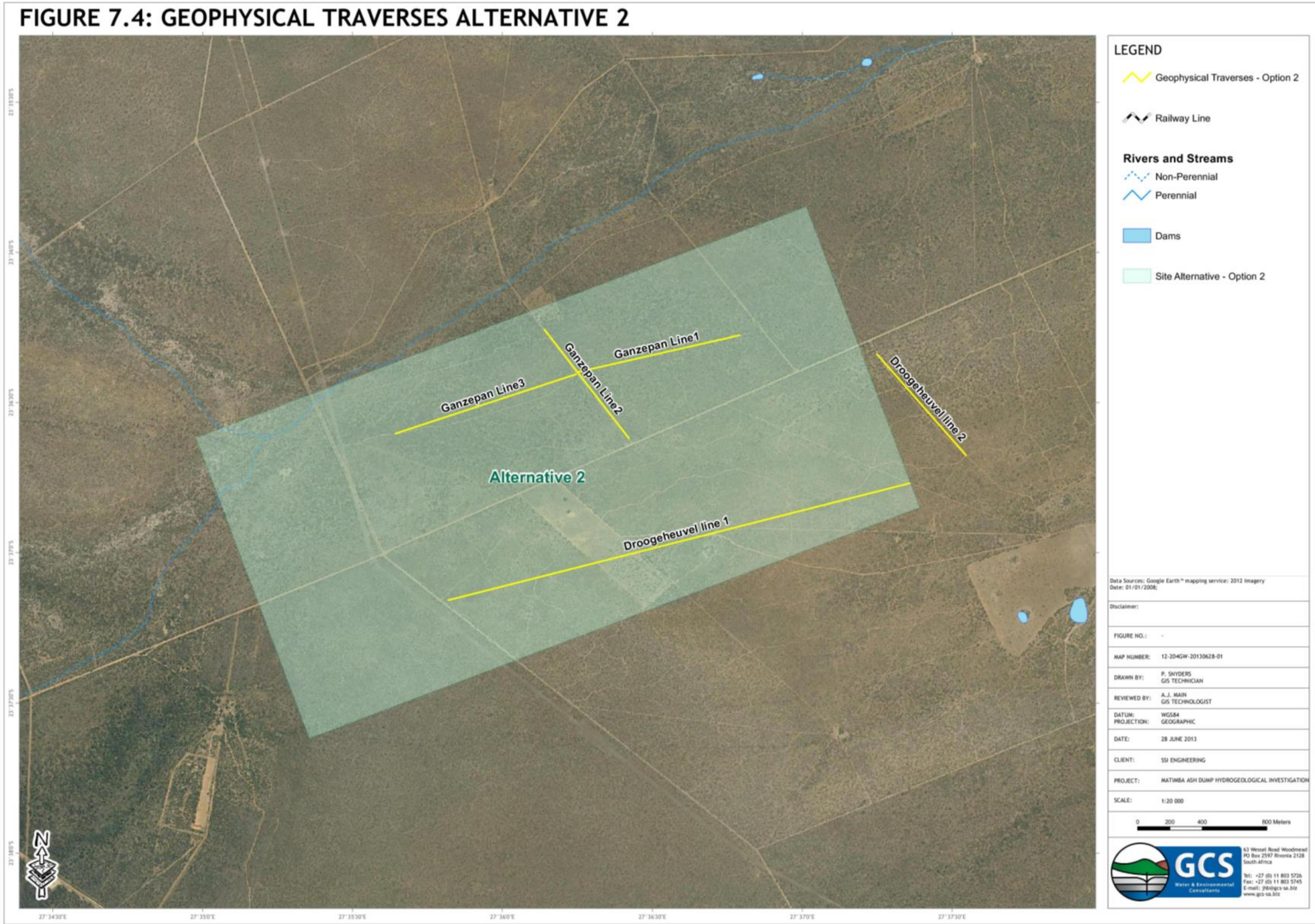


Figure 7.4: Geophysical Traverses Alternative 2

7.3 Borehole Installation

Ferreira Drilling was contracted to supply the drilling services for the selected boreholes. The drilling comprised air-rotary-percussion drilling to construct the boreholes. The final depths of the boreholes ranged from 15 to 40 metres. The borehole logs are presented in Appendix C.

Drilling was conducted from the 4th until the 7th of July 2013. The drill chips returned were logged at 1 metre intervals by the geologist on site. Water strikes, construction details, and blow yields (the volume of water per unit of time blown from the borehole during drilling) were recorded during the drilling programme. All boreholes were logged in terms of lithology and aquifer intersection. The distribution of the various casing types (i.e. slotted or solid) were determined on site by a GCS Hydrogeologist. The general construction specifications for standard monitoring boreholes are the following:

- 125mm OD PVC slotted casing;
- 125mm OD PVC solid casing;
- A PVC end cap;
- 2 to 5mm diameter silica gravel pack;
- A seal of concrete slurry to a depth of 1m below ground level;
- A concrete plinth; and
- A steel stand-pipe with a lockable steel cap.

The details of the boreholes for site Alternative 1 are recorded in Table 7.3 and Table 7.4 for site Alternative 2.

7.3.1 Site Alternative 1

In total, four boreholes were drilled surrounding Alternative 1. These include:

- One up-gradient borehole north west of the ash disposal facility, namely MA1. The borehole was drilled to a depth of 40 metres. MA1 was drilled on the proposed footprint of Alternative 1 as there was no alternative position other than drilling on the Medupi Power Station property. If Alternative 1 is the preferred site, borehole MA1 will be functional until the late depositional phases of the project as it is located on the western portion and deposition would initiate on the eastern boundary.

- Borehole MA2 was drilled as a downgradient borehole of the ash disposal facility. Water levels were recorded in MA1 and MA2 and ranged between 17.63 and 15.45mbgl.

- Boreholes MA3 and MA4 were also drilled down-gradient of the site. These two boreholes serve as a shallow and deep borehole monitoring pair as MA3 was drilled to 40 metres and MA4 was drilled to 15 metres. Both boreholes were drilled dry and no water level was recorded.

No major water strikes were encountered during drilling, only minor seepage was evident.

Table 7.3: Boreholes Parameters of newly drilled boreholes - Alternative 1

Borehole ID	Coordinates (WGS 84, Geographic)		Elevation (mamsl)	Depth of borehole (mbgl)	Collar Height (m)	SWL (mbch)	SWL (mbgl)
	S	E					
MA1	-23.710000°	27.582817°	893.40	40	0.4	18.03	17.63
MA2	-23.730517°	27.585417°	876.14	40	0.4	15.85	15.45
MA3	-23.721333°	27.619433°	864.15	40	0.4	Dry	Dry
MA4	-23.721317°	27.619450°	864.15	15	0.4	Dry	Dry

(SWL) static water level
(mbgl) metres below ground level
(mbch) metres below collar height
(mamsl) metres above mean sea level

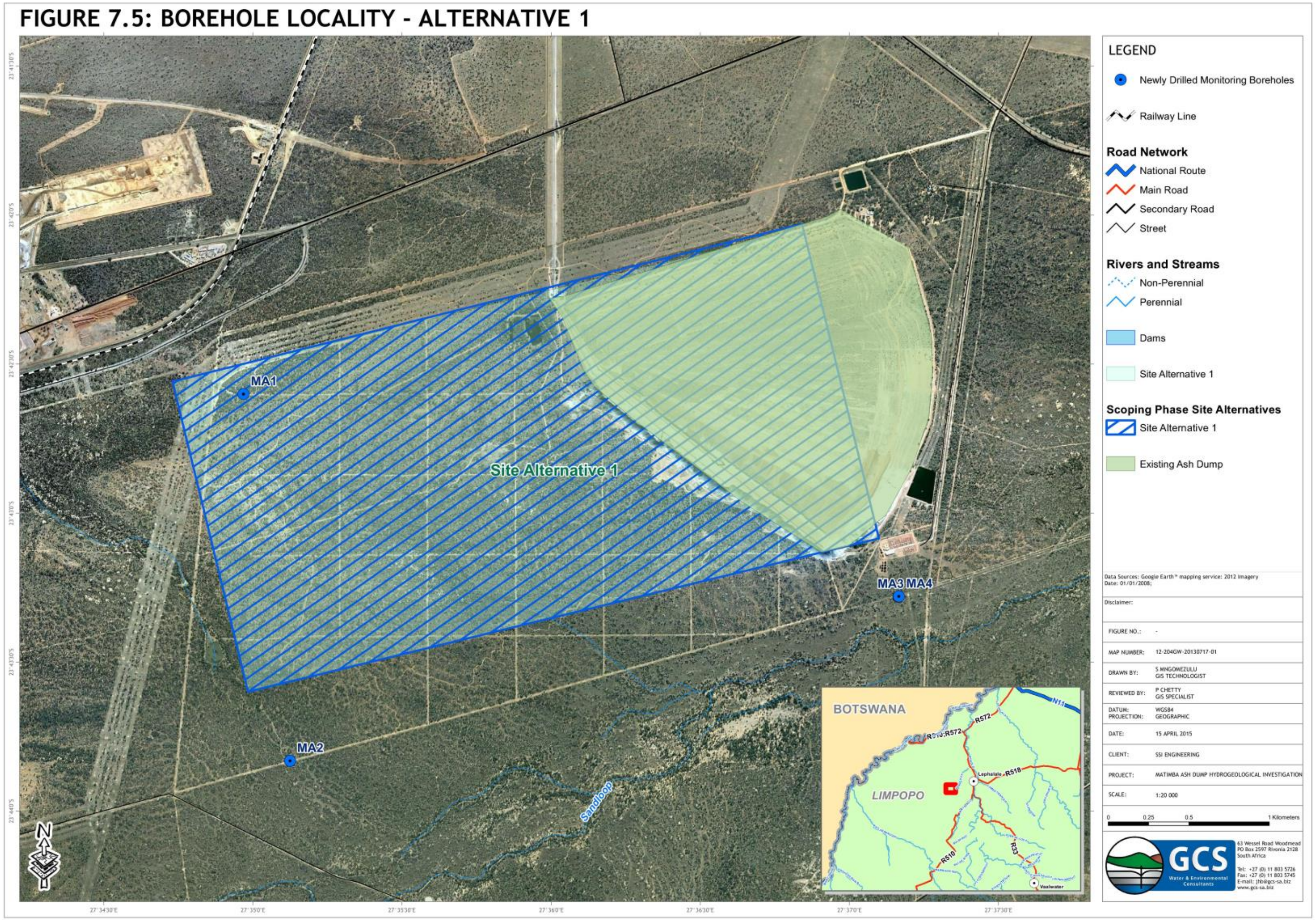


Figure 7.5: Borehole Locality Map – Alternative 1

7.3.2 Site Alternative 2

The drilling at site Alternative 2 included the installation of one borehole on the farm Droogeheuwel, namely MA5 which was drilled to a depth of 40 metres. This serves as a downgradient borehole should the ash disposal facility be developed on this site option. No further boreholes were drilled surrounding this option, based on the presence of existing boreholes which were included into the groundwater monitoring program.

Borehole APV02 is an existing borehole on the farm property Appelvlakte 448 LQ. A water level of 17.75mbgl was recorded and this borehole serves as a downgradient monitoring borehole.

Borehole GPN05 located upgradient of the site is located on the farm portion Ganzepan 446 LQ. A water level of 23.11mbgl was recorded in this borehole.

Table 7.4: Boreholes Parameters - Alternative 2

Borehole ID	Coordinates (WGS 84, Geographic)		Elevation (mamsl)	Depth of borehole (mbgl)	Collar Height (m)	SWL (mbch)	SWL (mbgl)
	S	E					
MA5	-23.615683°	27.630417°	855.52	40	0.3	23.17	22.87
APV02	-23.625683°	27.581650°	879.65	100	0.5	18.15	17.75
GPN05	-23.597000°	27.637633°	850.21	80	0.4	23.51	23.11

(mbgl) metres below ground level
(mbch) metres below collar height
(mamsl) metres above mean sea level

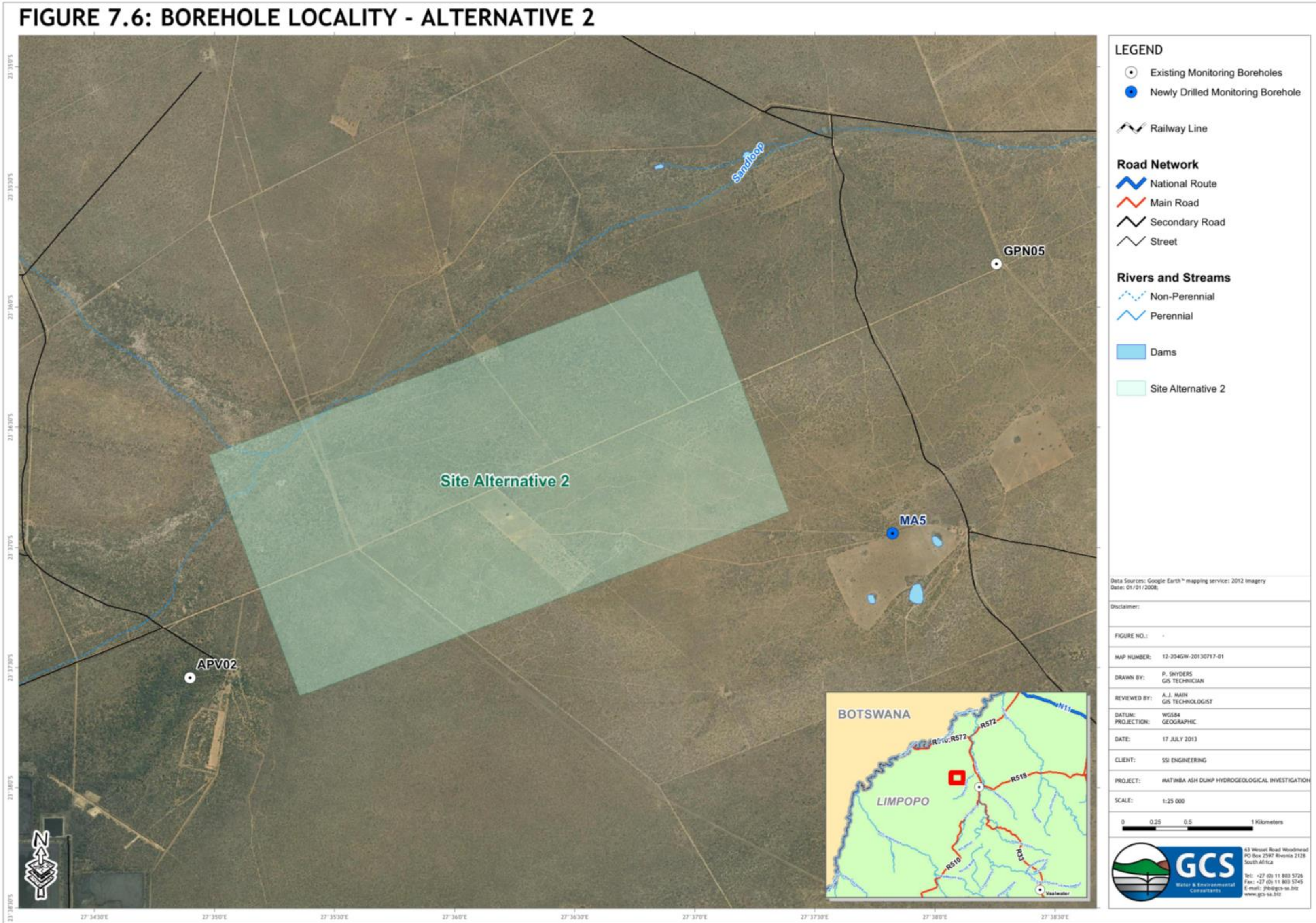


Figure 7.6: Borehole Locality Map – Alternative 2

7.4 Groundwater Levels & Flow Direction

The water levels collected during the hydrocensus and the borehole drilling on both sites were used to determine the groundwater levels for the site areas.

7.4.1 Alternative 1

The groundwater flow direction for site Alternative 1 is generally in an easterly direction (refer to Figure 7.7) towards the Sandloop River. The flow direction contours were based on water levels collected from 11 different boreholes surrounding the site area. The flow direction associated with the eastern portion of the current ash disposal area is somewhat different to the general easterly direction. This is most likely due to potential seepage occurring from the ash disposal facility resulting in shallower water levels immediately downgradient of the existing ash disposal facility.

7.4.2 Alternative 2

The groundwater flow direction for site Alternative 2 is in an easterly direction (Figure 7.8). The flow direction contours were based on water levels collected from eight different boreholes surrounding the site area.

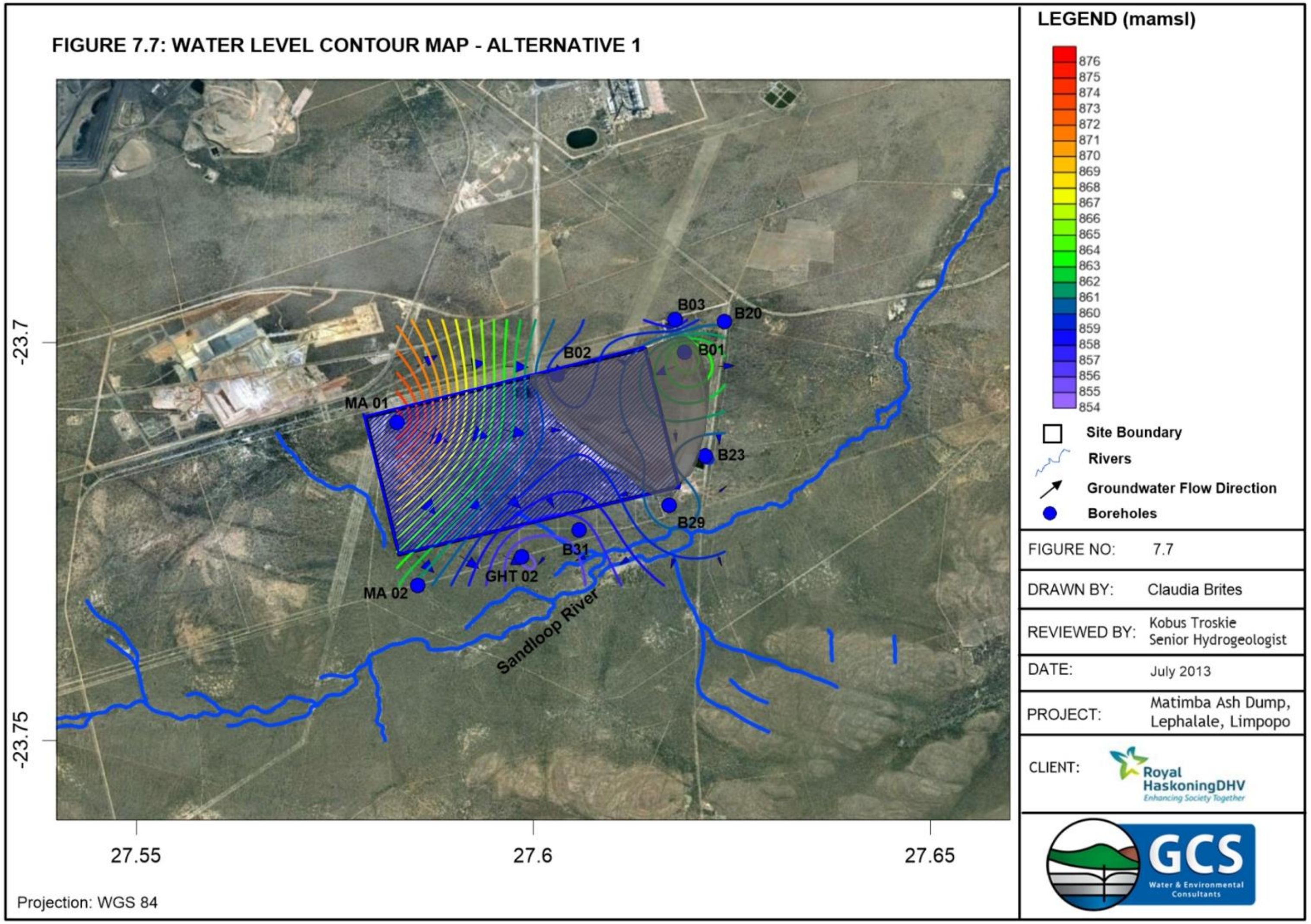


Figure 7.7: Water Level Flow Direction Map – Alternative 1

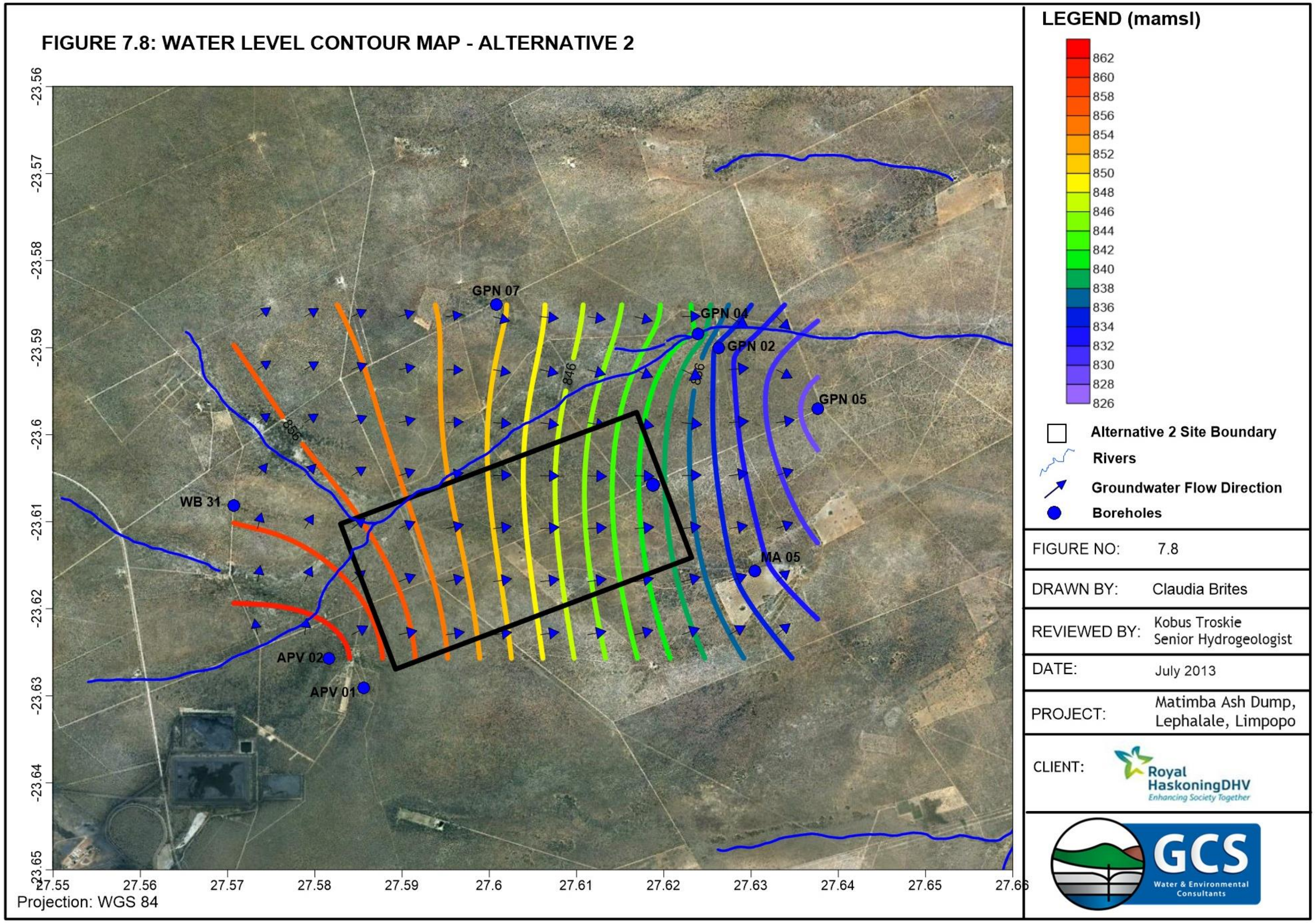


Figure 7.8: Water Level Flow Direction Map - Alternative 2

7.5 Aquifer Testing

Aquifer testing was carried out from the 6th to the 10th of July 2013. The aquifer testing comprised of short duration constant rate testing that was carried out on two newly drilled boreholes (MA1 & MA2) on site Alternative 1.

Aquifer testing was also carried out on the one newly drilled borehole (MA5) located at site Alternative 2 and the two existing monitoring boreholes on site Alternative 2 (APV02 & GPN05).

The short duration constant discharge test is used to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters i.e. transmissivity and storativity. Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Storativity is a measure of the volume of water stored and released in an aquifer. The testing also allows for the identification of impermeable or recharge boundaries. The test involved monitoring the drawdown of the water level in the borehole while the discharge is kept constant.

The recovery test provided an indication of the ability of a borehole and aquifer to recover from the stress of abstraction. This ability can again be analysed to provide information with regards to the hydraulic properties of the groundwater system. The duration of the tests varied, based on how fast the borehole was pumped dry after which recovery was measured up until 90%.

The results of the aquifer testing were interpreted in order to provide a better understanding of the aquifer hydraulic characteristics of the geological formations and the calculation of travel times of pollutants and the risk of contamination.

7.5.1 Site Alternative 1

The results of the aquifer testing for the boreholes associated with site Alternative 1 are presented in Table 7.5.

Table 7.5: Aquifer Test Results - Site Alternative 1

Borehole ID	Borehole SWL (mach)	Borehole Depth (m)	Pump Installation (mach)	Test (min)	Recovery Test (min)	Test Rate (l/s)	% Recovery	Transmissivity Theis residual drawdown/recovery method (m^2/day)
MA1	17.42	40	38	2.5	360	0.7	74%	0.04
MA2	17.31	40	38	4	180	0.9	72%	0.06

Results of the aquifer testing were interpreted by using the software Aqtesolv.

The aquifer test results are representative of a low yielding aquifer with transmissivity values ranging from 0.04 to 0.06 m^2/day.

The analysis of the aquifer test data is presented in Appendix D and Appendix E.

7.5.2 Site Alternative 2

The results of the aquifer testing for the boreholes associated with site Alternative 2 are presented in Table 7.6.

Table 7.6: Aquifer Test Results - Site Alternative 2

Borehole ID	Borehole SWL (mach)	Borehole Depth (m)	Pump Installation (mach)	Test (min)	Recovery Test (min)	Test Rate (l/s)	% Recovery	Transmissivity Theis residual drawdown/recovery method (m^2/day)
MA5	23.17	40	37	4	240	0.9	97%	0.15
APV02	18.15	100	75	240	180	1.4	94%	6.67
GPN05	23.28	40	38	10	400	0.9	99%	0.1

The results indicate that boreholes MA5 and GPN05 were low yielding with short pumping periods and longer recovery periods. Borehole APV02 underwent a drawdown test of 240 minutes with a pumping rate of 1.4l/s.

The transmissivity of the aquifer unit was determined using Aqtesolv and is tabulated above. The transmissivity in the three boreholes ranged from 0.1 to 6.67 m^2/day. The analysis of the aquifer test data is presented in Appendix D and Appendix E.

7.6 Groundwater Sampling

Samples collected were submitted to M&L laboratory services a SANAS accredited laboratory based in Johannesburg, South Africa. Field observations for each sampling point, consisting of the following information, were recorded on field data sheets:

- Date of sampling;
- Coordinates of each borehole;
- Depth of water level;
- General characteristics of the water samples such as colour, turbidity and smell as well as visual observations of the sample site.

The field parameters measured in the site and hydrocensus boreholes of site Alternative 1 are presented below in Table 7.7 and include pH, temperature, EC and TDS.

Two newly drilled monitoring boreholes and 10 hydrocensus boreholes surrounding site Alternative 1 were sampled during the hydrocensus investigation.

Table 7.7: Field Parameters of Site & Hydrocensus Boreholes - Alternative 1

Borehole	pH	Temperature (°C)	EC (mS/cm)	TDS (ppm)
MA 01	6.98	25.1	25.4	231
MA 02	6.51	22.1	1870	4310
MA 03	Dry			
MA 04	Dry			
P02	6.79	23.5	395	2680
P29	6.21	21.8	1291	9110
P01	6.02	22	114.1	829
P21	6.59	19.1	825	390
P23	7.02	22.3	5440	3820

P03	6.62	20.7	45.9	314
P31	6.65	24.5	123.8	8650
P20	6.53	21.8	79.9	371
GHT 02	6.5	24.3	380	2840
HP 01	7.51	22.4	244	1250

The field parameters measured in the site and hydrocensus boreholes of site Alternative 2 are presented below in Table 7.8 and include pH, temperature, EC and TDS.

One newly drilled monitoring borehole and six hydrocensus boreholes surrounding site Alternative 2 were sampled during the hydrocensus investigation.

Table 7.8: Field Parameters of Site & Hydrocensus Boreholes - Alternative 2

Borehole	pH	Temperature (°C)	EC (mS/cm)	TDS (ppm)
MA 05	6.5	21.4	65.0	245
APV 02	6.14	18.6	834	2710
GPN05	6.41	21.7	71.5	524
NGA 096	Inaccessible			
DHL 123	6.46	25.6	57.3	276
GPN 07	6.97	23.3	95.3	655
APV 01	7.05	17	479	3330

All water samples collected underwent the analysis as stipulated in Table 7.9 below.

Table 7.9: Constituents required for analysis

pH Value	Nitrate as N
Conductivity	Fluoride,F
Total Dissolved Solids	Nitrite as N
Calcium,Ca	Aluminium, Al
Magnesium, Mg	Manganese, Mn
Sodium,Na	Iron, Fe
Potassium,K	Zinc, Zn
Free and Saline Ammonia as NH4	Lead, Pb
Total Alkalinity as $CaCO_3$	Copper, Cu
P Alk as $CaCO_3$	Total Chromium, Cr
Bicarbonate,HCO_3	Phosphate, PO_4
Carbonate, CO_3	Cadmium, Cd
Chloride,Cl	Nickel, Ni
Sulfate,SO_4	Vanadium, V
Nitrate,NO_3	Arsenic

The water qualities measured within all boreholes sampled were compared to the SANS (South African National Standard) 241-1:2011 water quality standards for drinking water as well as the target values of the South African Water Quality Guidelines for Domestic Water Use (SAWQG) as published by the Department of Water Affairs (DWA) which is used as a guideline. The chemistry results for site Alternative 1 are presented in Table 7.10 and Table 7.11 for site Alternative 2. The laboratory certificates are presented in Appendix F.

Site Alternative 1 Monitoring Boreholes

MA1: This is a newly drilled borehole which was sited upgradient of the current and proposed ash disposal facility. The chemistry indicated that TDS (Total Dissolved Solids), chloride and iron exceeded the DWA drinking guidelines. Manganese exceeded the SANS standard. Overall the water quality is generally good in comparison with the existing downgradient monitoring boreholes.

MA2: This is a newly drilled borehole drilled south west of the current and proposed ash disposal facility. The chemistry results indicated several elevated constituents. This includes conductivity, TDS, chloride, fluoride, sulphate, calcium, potassium, sodium, manganese, magnesium and lead all which exceeded the SANS standards. The iron concentration exceeded the DWA guideline.

Site Alternative 1 Hydrocensus Boreholes

HP01: This is a hydrocensus borehole identified during the investigation used for domestic and stock watering purposes. The borehole is located north of the current ash disposal facility. The chemistry results indicated several elevated constituents: conductivity, TDS, chloride, fluoride, calcium, sodium and magnesium all exceeded the SANS standards. The sulphate and manganese concentrations exceeded the DWA guideline.

P02: This is a hydrocensus borehole identified during the investigation. P02 is a Matimba monitoring borehole located on the northern perimeter of the ash disposal facility. The chemistry results indicate several elevated constituents: conductivity, TDS, chloride, sulphate, calcium, sodium, manganese, magnesium and iron all exceeded the SANS standards. The ammonia and fluoride concentrations exceeded the DWA guideline.

P03: This is a hydrocensus borehole identified during the investigation. P03 is a Matimba monitoring borehole located on the north-eastern corner of the current ash disposal facility monitoring an ash water collecting dam. The quality of the water is good with only manganese exceeding the DWA guideline.

P01: This is a hydrocensus borehole identified during the investigation. P01 is a Matimba monitoring borehole located on the north-eastern corner of the ash disposal facility. The chemistry results indicated several elevated constituents: conductivity, TDS, sulphate, aluminium, calcium, manganese, magnesium and arsenic which all exceeded the SANS standards. The sodium concentration exceeded the DWA guideline. The pH is also very low with a value of 3.5 which does not comply with the SANS standard.

P20: This is a hydrocensus borehole identified during the investigation. P20 is a Matimba monitoring borehole located east of water return dams (P05) next to the fence and downstream of monitoring boreholes P05, P03, P12 (refer to Figure 6.1 for locality). The quality of the water is good with only fluoride exceeding the SANS limits and conductivity, chloride, sodium, manganese and iron exceeding the DWA guideline.

P21: This is a hydrocensus borehole identified during the investigation. P21 is a Matimba monitoring borehole located north-east of the ash stack next to the fence, downstream of ash stack, P05, P01, P03 & P12. The chemistry results indicated several elevated constituents. This includes elevated TDS, sulphate, calcium, manganese, magnesium and iron which all exceeded the SANS standards. The conductivity and sodium concentrations exceeded the DWA guideline.

P23: This is a hydrocensus borehole identified during the investigation. P23 is a Matimba monitoring borehole located on the eastern perimeter of ash disposal facility & north-eastern corner of the eastern ash water collecting dam (P06). The chemistry results indicated several elevated constituents: conductivity, TDS, chloride, sulphate, calcium, sodium, manganese and magnesium which all exceeded the SANS standards.

P29: This is a hydrocensus borehole identified during the investigation. P29 is a Matimba monitoring borehole located on the south-eastern corner, downgradient of the ash disposal facility. The chemistry results indicated several elevated constituents: elevated conductivity, TDS, chloride, calcium, potassium, sodium, manganese, magnesium and iron which all exceeded the SANS standards. The ammonia and fluoride concentrations exceeded the DWA guideline.

P31: This is a hydrocensus borehole identified during the investigation. P31 is a Matimba monitoring borehole located south and downgradient of the ash disposal facility and boreholes P30 & P35 (refer to Figure 6.1 for locality). The chemistry results indicated several elevated constituents. This includes elevated TDS, chloride, fluoride, calcium, potassium, sodium, manganese, magnesium and iron which all exceeded the SANS standards. The conductivity concentration exceeded the DWA guideline.

GHT02: This is a hydrocensus borehole identified during the investigation. This is a new monitoring borehole drilled by GHT consultants at the same time this investigation was conducted. The chemistry indicated elevated conductivity, TDS, chloride, fluoride, calcium, sodium, manganese and magnesium which all exceeded the SANS standards. The sulphate concentration exceeded the DWA guideline.

A pollution index determination is useful for selecting parameters which are reliable pollution indicators. A sampling point is selected which indicates the lowest elemental concentrations. In this case, borehole MA1 was chosen as this borehole as it is located upgradient of the existing ash disposal facility. The concentrations for all other boreholes are then divided by the concentrations of borehole MA1. The parameters which indicate consistent high ratios are considered to be reliable indicators of pollution.

Overall, the general trend of the boreholes indicated similar parameters which generally exceeded the drinking water limits. Most of these parameters indicated very high concentrations. These problematic parameters as identified through the pollution index include: conductivity, TDS; chloride; sulphate; calcium; sodium; manganese and magnesium. Most of the boreholes indicated poor water quality with these parameters in high concentrations. This was with the exception of boreholes MA1 (newly drilled upgradient), P03 and P20. The chemistry results of the remaining boreholes indicated the effect of the current ash disposal facility on the groundwater environment.

Table 7.10: Chemistry Analysis of the Boreholes Sampled - Site Alternative 1

			Site Boreholes		Hydrocensus Boreholes									
Parameter	DWA Drinking Water	SANS 241-1: 2011	MA 01	MA 02	HP 01	P02	P03	P01	P20	P21	P23	P29	P31	GHT 02
Conductivity mS/m @ 25°C	<70	<170	43.7	1768	225.4	369	41.1	221.3	72.1	156.4	492	1951	116.3	349
pH at 25°C	6-9	5-9.7	7.2	6.3	7.9	7.1	7.2	3.5	6.9	6.5	7.6	6.7	7.2	8.2
Total Dissolved Solids	<450	<1200	262	12392	1460	2732	246	2088	400	1280	4060	13176	7440	1936
Ammonia as NH4	1	NS	<0.10	<0.10	<0.10	6.3	<0.10	0.3	0.1	0.5	<0.10	2.6	0.9	<0.10
Bicarbonate, HCO_3	NS	NS	134	141	237	502	105	0	258	91	844	284	421	417
Carbonate, CO_3	NS	NS	0	0	0	0	0	0	0	0	0	0	0	0
Chloride, Cl	<100	<300	61	6710	460	552	28	23	113	30	720	7718	3809	822
Fluoride, F	1	1.5	0.7	1.7	4.7	1.3	0.7	<0.100	4	<0.100	1.8	1.5	1.7	5.3
Hydroxide alkalinity as OH-	NS	NS	0	0	0	0	0	0	0	0	0	0	0	0
Nitrate as N	<6	<11	<0.1	0.6	<0.1	<0.1	0.4	4.7	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Nitrate, NO_3	NS	NS	<0.1	2.5	<0.1	<0.1	1.7	21	<0.1	<0.1	<0.1	<0.1	<0.1	0.5
Nitrite as N	NS	0.9	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Phosphate as PO4	NS	NS	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	0.49	<0.12	<0.12	<0.12
Sulfate, SO_4	<200	<500	13.7	809	326	813	71	1377	4.5	803	1248	118	314	212
Total Alkalinity as $CaCO_3$	NS	NS	110	116	194	412	86	<1.000	212	75	692	233	345	342
Aluminium as Al	0.15	0.3	1.4	<0.003	0.02	<0.003	0.004	31	0.09	0.004	<0.003	<0.003	<0.003	0.04
Calcium hardness	NS	NS	18.2	1439	205	410	47	529	43	357	867	1389	510	110
Calcium, Ca	<32	NS	7.3	576	82	164	18.7	212	17.4	143	347	556	204	44
Potassium, K	<50	NS	8.6	118	17.1	40	7.3	49	10.1	28	33	104	63	24
Sodium, Na	<100	<200	76	2931	379	542	57	160	117	100	671	3298	2098	697
Manganese, Mn	<0.05	0.5	0.28	8.9	0.24	1.3	0.32	2.1	0.49	2.8	0.7	2.8	2.6	0.32
Magnesium hardness	NS	NS	35	2260	152	568	32	317	82	333	782	2202	942	173
Magnesium, Mg (mg/l)	<30	NS	8.6	549	37	138	7.8	77	19.9	81	190	535	229	42
Iron, Fe	<0.1	2	0.78	0.24	0.02	4.4	0.03	0.09	0.36	51	0.08	8.7	0.27	0.03
Zinc as Zn	3	5	0.008	0.03	0.04	0.006	0.006	0.04	0.005	0.01	0.02	0.03	0.01	0.006
Lead, Pb	<0.01	0.01	0.009	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper as Cu	1	2	0.02	0.08	0.03	0.06	0.01	0.07	0.02	0.04	0.07	0.07	0.07	0.03
Arsenic as As	0.01	0.01	<0.001	<0.001	0.009	<0.001	<0.001	0.04	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium as V	0.1	0.2	0.01	0.1	0.04	0.08	0.01	0.06	0.02	0.07	0.09	0.1	0.09	0.04
Chromium as Cr	NS	0.05	0.005	0.007	0.004	0.007	0.003	0.05	0.004	0.005	0.007	0.006	0.007	0.004
Cadmium as Cd	NS	0.003	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Sum of Anions meq/l	NS	NS	4.24	208.513	23.883	40.793	4.05	29.682	7.727	19.068	60.208	224.839	120.934	34.714
Sum of Cations meq/l	NS	NS	4.594	204.452	24.068	44.166	4.226	25.157	7.848	18.883	63.031	217.909	121.931	36.574
% Error	NS	NS	4.007	-0.983	0.386	3.97	2.127	1.665	0.777	-0.487	2.291	-1.565	0.411	2.609
Chemical Balance	NS	NS	In	In	In	In	In	In	In	In	In	In	In	In
Values in red indicate concentration exceeding the more stringent standard														
Values in green indicate concentration exceeding the less stringent stndard														

Site Alternative 2 Monitoring Boreholes

GPN 05: This is an existing production borehole which was used as a monitoring borehole, which is located downgradient of the proposed ash disposal facility at site Alternative 2. The quality of the water is good with the TDS, chloride and iron concentrations exceeding the DWA guideline. Manganese exceeded the SANS limits.

APV02: This is an existing production borehole which was used as a monitoring borehole, which is located upgradient of the proposed ash disposal facility at site alternative 2. The water quality indicated concentrations exceeding of conductivity, TDS, chloride, sulphate, calcium, sodium, magnesium and iron all exceeded the SANS standards.

MA5: This is a newly drilled borehole located downgradient of the proposed ash disposal facility. The chemical analysis indicated conductivity, TDS, chloride, sodium and manganese, concentrations exceeded the DWA limits. Aluminium and iron exceeded the SANS limits.

Site Alternative 2 Hydrocensus Boreholes

APV01: This is a hydrocensus borehole identified during the investigation. The chemical analysis indicated conductivity, TDS, nitrate as N, sulphate, calcium, sodium and magnesium concentrations exceeded the SANS limits. Fluoride exceeded the DWA limits.

NGA090: This is a hydrocensus borehole identified during the investigation. The quality of the water is good with only iron exceeding the DWA limits.

GPN07: This is a hydrocensus borehole identified during the investigation. The chemical analysis indicated conductivity, TDS, ammonia, chloride, sodium and manganese concentrations exceeded the DWA limits.

DHL123: This is a hydrocensus borehole identified during the investigation. The quality of the water is good with only fluoride and sodium exceeding the DWA limits.

A comparison in the groundwater chemistry is also made between the boreholes surrounding site Alternative 1 and site Alternative 2. There is a clear distinction between the results. Although several boreholes associated with site Alternative 2 indicated elevated concentrations of parameters mentioned earlier which appear to be problematic, it is clear that the concentrations in general are much lower than those associated with boreholes surrounding site Alternative 1.

Table 7.11: Chemistry Analysis of the Boreholes Sampled - Site Alternative 2

Parameter	DWA Drinking Water	SANS 241-1: 2011	Site Monitoring Boreholes			Hydrocensus Boreholes			
			GPN 05	APV 02	MA5	APV 01	NGA 090	GPN 07	DHL 123
Conductivity mS/m @ 25°C	<70	<170	65.4	484	79.5	453	40.2	92.5	53.3
pH at 25°C	6-9	5-9.7	6.3	7.3	7.4	7.6	7.3	7.1	8.1
Total Dissolved Solids	<450	<1200	482	3762	598	3244	246	618	316
Ammonia as NH4	1	NS	<0.10	<0.10	<0.10	<0.10	<0.10	1.2	<0.10
Bicarbonate, HCO_3	NS	NS	21	311	89	313	65	113	230
Carbonate, CO_3	NS	NS	0	0	0	0	0	0	0
Chloride, Cl	<100	<300	169	997	179	1019	78	207	40
Fluoride, F	1	1.5	0.4	0.8	0.1	1	0.1	0.1	0.2
Hydroxide alkalinity as OH-	NS	NS	0	0	0	0	0	0	0
Nitrate as N	<6	<11	1.1	3.2	4.4	15.4	1.9	<0.1	4.7
Nitrate, NO_3	NS	NS	4.8	14.3	19.5	68	8.6	0.2	21
Nitrite as N	NS	0.9	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Phosphate as PO4	NS	NS	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	0.37
Sulfate, SO_4	<200	<500	0.4	932	3.2	879	36	<0.2	7.6
Total Alkalinity as $CaCO_3$	NS	NS	17	255	73	257	53	93	189
Aluminium as Al	0.15	0.3	<0.003	<0.003	10.9	<0.003	0.06	<0.003	0.01
Calcium hardness	NS	NS	24	944	28	839	57	46	10
Calcium, Ca	<32	NS	9.5	378	11.1	336	23	18.5	4
Potassium, K	<50	NS	5.2	28	6.3	28	5.7	9.4	6.3
Sodium, Na	<100	<200	100	502	142	500	45	136	118
Manganese, Mn	<0.05	0.5	0.13	0.005	0.07	0.004	0.002	0.2	0.001
Magnesium hardness	NS	NS	21	379	32	667	40	18.9	11.5
Magnesium, Mg (mg/l)	<30	NS	5.2	92	7.8	162	9.6	4.6	2.8
Iron, Fe	<0.1	2	0.36	0.003	5.5	0.04	0.22	0.006	0.02
Zinc as Zn	3	5	<0.005	0.04	0.01	0.04	0.02	0.008	0.005
Lead, Pb	<0.01	0.01	0.004	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Copper as Cu	1	2	0.006	0.05	0.01	0.07	0.01	0.007	0.004
Arsenic as As	0.01	0.01	0.004	<0.001	<0.001	0.001	0.007	0.003	<0.001
Vanadium as V	0.1	0.2	0.008	0.06	0.03	0.09	0.01	0.007	0.01
Chromium as Cr	NS	0.05	0.003	0.005	0.02	0.006	0.004	0.003	0.004
Cadmium as Cd	NS	0.003	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001
Sum of Anions meq/l	NS	NS	5.212	52.887	6.893	53.321	4.152	7.692	5.412
Sum of Cations meq/l	NS	NS	5.376	48.988	7.528	52.599	4.04	7.437	5.739
% Error	NS	NS	1.549	-3.827	4.403	-0.682	-1.367	-1.686	2.932
Chemical Balance	NS	NS	In	In	In	In	In	In	In
Values in red indicate concentration exceeding the more stringent standard									
Values in green indicate concentration exceeding the less stringent standard									

8 ASH STORAGE FACILITY LEACHATE

Drawing on research that has been done in South Africa on the impacts of ash from coal-fired power stations on specifically groundwater the following conclusions can be made. Numerous mitigation measures, as discussed in Section 11, and best environmental practises are available for implementation:

- The concentration of metals in the coal type determines the concentration of metals in the ash and therefore the leachate.
- Studies on South African sites show contamination of soils and groundwater directly under the ash disposal facility, with limited plume development and movement at well selected sites.
- Shallower water tables will develop as a mound under the disposal site, driving the groundwater flow in the direction of streams or other discharge points.
- Over the long term life of the ash disposal facility, the pH tends to decrease to around 7 and the mobilization of metals becomes problematic with low pH levels.
- Acid leaching will take place from the coal stockpiles (if not mitigated), increasing the overall potential for groundwater contamination.

Table 8.1: Major elements found in groundwater due to leaching from different ash disposal sites in South Africa (Adapted from M. Kolosa (2012)

Power Station	Wet/ Dry	Elements of concern from site monitoring	Geology	Status
Tutuka	Dry	Na, Cl, Ca and SO_4	The site falls within the Carboniferous to early Jurassic aged Karoo Basin. Sediments here fall within the Permo-Triassic aged Northern facies of the Ecca Series	In use
Duvha	Wet	Salinity, SO_4, Na, Mg, Al, B, As, Cr, Fe, Ni, Se and Zn	Karoo environment consisting of sandstone, siltstone, mudstone and shale.	In use
Hendrina	Wet	SO_4	Karoo Supergroup, comprising of the Ecca Group and Dwyka Formation.	In use
Kragbron (Taaibos and Highveld)	Wet	SO_4	Underlain by the Karoo Super sedimentary rocks of the Ecca and Beaufort groups	20 years old not in use
Matimba	Dry	Na, Ca, Mg, K, Cl, SO_4, Fe, Mn and B.	Coal occurs in both Vryheid and Grootegeluk formation of the Karoo Supergroup	In use
Majuba	Wet	Na, SO_4, F and B	Built on Ecca and Beaufort sedimentary formation of the Karoo Supergroup	In use

8.1 Matimba Ash Disposal Facility Leachate Results

Laboratory test results carried out on representative samples of the Ash by Jeffares & Green (Pty) Ltd. The samples were collected in February 2013 and underwent the following analysis:

Acid rain leach (ARL) procedure (ARLP) extraction followed by:

- Semi-quantitative 33 element ICP MS (Inductively coupled plasma mass spectrometry) scan
- Cations and anions including Cr(VI), Ca, Na, K, Mg, SO4, Cl, F, NH_4, NO3 and pH

- The only Contaminant of Concern (CoC) that exceeded the Acceptable Risk Level was hexavalent chromium (CrVI) but all other potential CoCs had a concentration lower than the respective ARL.

Aqua regia digestion followed by:

- Semi-quantitative 33 element ICP scan
- These results show elevated total concentrations of Ba in all the samples of ash, exceeding the TCT0 threshold level (total concentration thresholds for particular contaminants in a waste), while the total concentrations of all other potential CoCs were within acceptable levels.

Deionised water (1:20) extraction followed by:

- Semi-quantitative 33 element ICP scan
- Analysed for cations and anions including Cr(VI), Ca, Na, K, Mg, SO_4, Cl, F, NH_4, NO_3 and pH
- The soluble Chromium (Cr) and Boron (B) concentrations in all three ash samples exceeded the LCT0 threshold
- The CrVI concentration in two of the ash samples exceeded the LCT0 threshold
- Leachable Molybdenum (Mo) concentration in the ash sampled from the new stockpile 1 exceeded the LCT0 threshold.

Based on the leachable concentrations, mitigation in the form of lining the ash disposal facility is required in order to prevent or minimize groundwater contamination.

9 POTENTIAL IMPACT OF CONVEYER BELT

9.1 Background

Conveyor belts are normally used in mine-mouth power plants to bring coal from the mining area to the storage or usage area. Conveyor belts can be used for coal transport in hilly terrain where roads are relatively inaccessible. Conveyors have the advantage of being relatively maintenance free but have the disadvantage of location inflexibility, making a truck haul still necessary. The only adverse environmental impacts of conveyor belts for coal transport are coal dust losses during loading, unloading, or transport.

An EIA/EMP report was compiled in 2010 (Savannah Environmental) to address the impact of infrastructure development (including a conveyer belt) between the Matimba power station and the Medupi power station. During this study the following conclusions were made:

- There are no unique ecosystems, habitats for plant and animal life, wetlands, or conservation and eco-tourism activities that will be impacted by the mine developments.
- Due to the location of the coal silo (at Medupi) and the coal supply conveyer within existing mining areas, it is not expected that construction or operation will have a significant impact on aesthetics, groundwater, geohydrology, air quality or noise within the current mining areas.

The Matimba power station area displays a very similar environment to the Medupi station, therefore very little impact is expected from the construction and operation of the Matimba conveyer belt.

9.2 Matimba Coal Mine conveyer belt

The proposed Matimba Coal mine conveyer belt will transport coal from the mine area to an ash disposal location. The conveyer belt route alternative one will follow the farm boundary between Nelsonskop and Zongezien.

No monitoring boreholes from Grootegeluk Mine or boreholes from the NGA and GRIP databases are in immediate vicinity of the proposed route (Figure 7.2).

10 RISK RATING OF PROPOSED SITES AND CONVEYER BELT

A preliminary risk rating was applied and the sites were ranked to determine which site was the most suitable in terms of having the least impact on the groundwater environment. This is tabulated in Table 10.1, Table 10.2, and Table 10.4. Additionally, the risk associated with the conveyor belt has been tabulated in Table 10.3.

The risk rating takes into consideration the following:

- Geological structures (lineaments, intrusions and faults);
- Groundwater levels;
- Non-perennial and perennial drainage lines;

- The proximity of production boreholes relative to each of the sites; and
- Existing water quality.

Table 10.1: Risks Associated with the Alternative 1

Alternative 1: The site is located adjacent to the existing ash disposal facility, south of the Matimba Power Station
Geology: Alternative 1 is underlain by the Mogalakwena Formation of the Waterberg Group. The Formation is comprised of coarse grained purplish brown sandstone.
Hydrology and Hydrogeology: Non-perennial drainage lines are located within the 1km buffer. Sixteen boreholes are located within a 2km radius of this option. These boreholes were identified during the hydrocensus and are used mostly for monitoring purposes and one borehole is used for stock watering and irrigation.
Impacts: The production borehole used for stock watering and irrigation purposes is considered a sensitive receptor and must therefore be protected from any contamination. The non-perennial Sandloop river is also considered a sensitive receptor. The impacts of the existing ash disposal facility are already evident.
Rating: Medium

Table 10.2: Risks Associated with the Alternative 2

Alternative 2: The site is located north of the Matimba Power Station on portions of the farms Vooruit 449 LQ, Droogeheuvel 447LQ, Ganzepan 446 LQ and Appelvlakte 448 LQ.
Geology: Karoo Supergroup - Clarens Formation consists of fine grained cream coloured sandstone.
Hydrology and Hydrogeology: Non-perennial drainage lines are located within the 1km buffer. Sixteen boreholes are located within a 2km radius of this option. These boreholes were identified during the hydrocensus and are used mostly for domestic purposes as well as stock watering and irrigation.
Impacts: The production boreholes used for domestic purposes are considered sensitive receptors. An un-named non-perennial river is located north of the site.
Rating: High

Table 10.3: Risks Associated with the Conveyer Belt Route

Conveyor Belt: The conveyer belt route will follow the farm boundary between Nelsonskop and Zongezien in a northerly direction towards ash disposal facility alternative two.
Geology: The belt starts at the facility on a coarse grained purplish brown sandstone and as it traverses to the north it crosses the Clarens Formation, consisting of fine grained cream coloured sandstone. The conveyer belt route will traverse two faults (one the Daarby fault and another just north of the Daarby fault).
Hydrology and Hydrogeology: Non-perennial drainage lines are located within the 1km buffer. No production boreholes are located in immediate vicinity of conveyer belt route.
Impacts: The faults on the property have been identified as sensitive areas, but due to the minimal expected environmental impacts typically associated with conveyor belts, the impact is low.
Rating: Low

10.1 Risk Rating Summary

The hydrological, hydrogeological and geological risks were taken into consideration for each site. The different aspects identified per site were given a rating from being a fatal flaw to very good (ideal) as presented in Table 10.4 below. The groundwater levels and use of boreholes retrieved from the hydrocensus were plotted and interpolated by geographical information system (GIS) and incorporated into the risk assessment. This risk rating is specifically based on the hydrogeological, geological and site specific components of each site.

Table 10.4: Risk Rating Summary

Site selection elements	Site Suitability Rating		Weighting Factor
	Site Alternative 1	Site Alternative 2	
Groundwater levels - Hydrocensus data	4	3	0.5
Presence of intrusive lithologies, linear Structures	3	2	1
Topography gradient	3	3	0.5
Downgradient from Dams/Rivers	3	4	1
Non-perennial drainage lines	3	4	0.5
Perennial drainage lines	N/A	N/A	1
Proximity of production boreholes	4	2	1
Cumulative impacts	4	2	1
Subtotal	**19**	**15**	
Ranking	**1**	**2**	
	LEGEND		
	fatal flaw	**1**	
	poor	**2**	
	average	**3**	
	good	**4**	
	very good (ideal)	**5**	

Based on the risk rating above, Alternative 1 is ranked as the more suitable option according the following criteria:

- Further distance from geological structures in comparison to Alternative 2;
- Less production boreholes and groundwater users within a 2km radius of the site;
- The effect of the current ash disposal facility is already evident in the groundwater quality.

11 SIGNIFICANCE RATING SCALES

The potential environmental impacts associated with the project are evaluated according to its nature, extent, duration, intensity, probability and significance of the impacts, whereby:

- ***Nature***: A brief written statement of the environmental aspect being impacted upon by a particular action or activity.
- ***Extent***: The area over which the impact will be expressed. Typically, the severity and significance of an impact have different scales and as such bracketing ranges are often required. This is often useful during the detailed assessment phase of a project in terms of further defining the determined significance or intensity of an impact. For example, high at a local scale, but low at a regional scale;
- ***Duration***: Indicates what the lifetime of the impact will be;
- ***Intensity***: Describes whether an impact is destructive or benign;
- ***Probability***: Describes the likelihood of an impact actually occurring; and
- ***Cumulative***: In relation to an activity, means the impact of an activity that in itself may not be significant but may become significant when added to the existing and potential impacts eventuating from similar or diverse activities or undertakings in the area.

Table 11.1 provides the criteria upon which the rating of the impacts are determined.

Table 11.1: Criteria to be used for the Rating of Impacts

CRITERIA	DESCRIPTION			
EXTENT	**National (4)** The whole of South Africa	**Regional (3)** Provincial and parts of neighbouring provinces	**Local (2)** Within a radius of 2 km of the construction site	**Site (1)** Within the construction site
DURATION	**Permanent (4)** Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient	**Long-term (3)** The impact will continue or last for the entire operational life of the development, but will be mitigated by direct human action or by natural processes thereafter. The only class of impact which will be non-transitory	**Medium-term (2)** The impact will last for the period of the construction phase, where after it will be entirely negated	**Short-term (1)** The impact will either disappear with mitigation or will be mitigated through natural process in a span shorter than the construction phase
INTENSITY	**Very High (4)** Natural, cultural and social functions and processes are altered to extent that they permanently cease	**High (3)** Natural, cultural and social functions and processes are altered to extent that they temporarily cease	**Moderate (2)** Affected environment is altered, but natural, cultural and social functions and processes continue albeit in a modified way	**Low (1)** Impact affects the environment in such a way that natural, cultural and social functions and processes are not affected
PROBABILTY OF OCCURANCE	**Definite (4)** Impact will certainly occur	**Highly Probable (3)** Most likely that the impact will occur	**Possible (2)** The impact may occur	**Improbable (1)** Likelihood of the impact materialising is very low

Table 11.2 details the significance rating scale which is used to total the total number of points scored for each impact and indicates the level of significance of the impact.

Table 11.2: The Significance Rating Scale

Low impact (4 - 6 points)	A low impact has no permanent impact of significance. Mitigation measures are feasible and are readily instituted as part of a standing design, construction or operating procedure.
Medium impact (7 - 9 points)	Mitigation is possible with additional design and construction inputs.
High impact (10 - 12 points)	The design of the site may be affected. Mitigation and possible remediation are needed during the construction and/or operational phases. The effects of the impact may affect the broader environment.
Very high impact (13 - 16 points)	Permanent and important impacts. The design of the site may be affected. Intensive remediation is needed during construction and/or operational phases. Any activity which results in a "very high impact" is likely to be a fatal flaw.
Status	Denotes the perceived effect of the impact on the affected area.
Positive (+)	Beneficial impact.
Negative (-)	Deleterious or adverse impact.
Neutral (/)	Impact is neither beneficial nor adverse.

11.1 Impact Assessment

The ash disposal facility may have the following impacts on the groundwater environment as discussed in detail below.

11.1.1 Construction Phase - Hydrocarbon contamination

During the construction phase, hydrocarbon contamination is possible due to the presence of heavy machinery on site. Spillages may occur which may impact both the soil and groundwater environment. The impacts are costly and difficult to clean up, however, only small amounts envisaged.

Table 11.3 tabulates the impact of hydrocarbon contamination on site and the impacts on the soil and groundwater environment. The associated ratings and scores of the impact after mitigation measures are in place are detailed below. The score of 9 points results in a medium impact.

Table 11.3: Groundwater Impact Table Description during Construction Phases - No Mitigation Measures

	Unmitigated			
Impact description	**Extent**	**Duration**	**Intensity**	**Probability**
Hydrocarbon contamination associated with heavy machinery on site	Local	Long Term	Moderate	Possible

Score	2	3	2	2

Table 11.4 tabulates the impact of hydrocarbon contamination on site and the impacts on the soil and groundwater environment with mitigation measures in place. The mitigation measures would include secondary containment for all fuel stored on site and implementing the proposed groundwater monitoring programme as detailed in Section 12. This would allow for the early detection of water quality deterioration associated with the site. Accurate oil records must be kept (purchased, disposal, and recycled). Ensure clean up protocols are in place and followed. The score of 9 points results in a medium impact.

Table 11.4: Groundwater Impact Table Description during Construction Phases - With Mitigation Measures

	Mitigated			
Impact description	Extent	Duration	Intensity	Probability
Hydrocarbon contamination associated with heavy machinery on site	Local	Long Term	Moderate	Possible
Score	2	3	2	2

11.1.2 Operational and Closure Phases - Poor quality artificial recharge from the ash disposal facility

The major potential impacts of ash disposal on groundwater resources are generally associated with changes in the pH of the water, the increase in salt content and the concentration of the potentially toxic trace elements. The most important factor in determining the resulting pollution impact of the ash is the way in which it is disposed.

During dry disposal, the ash still has a moisture content of up to 15% as this water is added to suppress dust during transport and deposition.

Fly ash mainly consists of small, glassy hollow particles and contains all the natural elements, and in comparison with the parent material is enriched in trace elements. Studies show that trace elements are usually concentrated in the smaller ash particles. The ash is usually enriched in arsenic, boron, calcium, molybdenum, sulphur, selenium and strontium.

By understanding the chemistry of the ash, a better insight into its reactions with various other elements can be reached. The pH of the ash is normally elevated due to the abundance of calcium oxide. Calcium oxide usually constitutes about 8 % of the ash and is of great importance in the forming of the pozzolanic layer. As stated above, another factor that plays an important role is the presence of water in the ash. If there is enough water to isolate the ash from the atmosphere (as is the case with wet disposal) the ash will not be able to react with the oxygen in the air and the pozzolanic layer will not be able to form.

Should the ash be wetted and dried cyclically, the ash will have time to react with the atmosphere. This will cause a reaction between calcium oxide and the carbon dioxide that will then lead to the crystallisation of calcium carbonate (limestone). Another reaction that occurs is that between calcium and sulphate that results in the crystallisation of gypsum.

These two minerals (calcium carbonate and gypsum) form the so-called pozzolanic layer, which is a layer of very low permeability. The layer can be expected to occur in the upper

0.5 m of the ash disposal infrastructure. It is thus evident that the formation of the pozzolanic layer is mostly confined where wetting and drying of ash occurs, during deposition in the wet process and near the surface on a dry ash pile.

Leaching from these ash disposal sites may occur. Leaching experiments show that the element composition of the leachate does not necessarily reflect that of the whole ash sample proportionally. This suggests that for some elements a correlation of leachate quality to whole ash properties cannot be made. This is because the rate at which these elements will leach from the ash is dependent on:

- The form in which the element is present within the ash;
- The location of the element within the ash matrix; and
- Whether the element has been absorbed on to the ash particle surface.

Parts of the ash spheres are chemically stable in the environment and are resistant to weathering due to the alumino silicate matrix. Any element present in this matrix will be less readily available for leaching. However, elements absorbed onto the surface of the ash spheres will be more readily leached. Un-combusted mineral material may account for the presence of high concentrations of certain elements in the whole ash analysis. Leachate generated from these ashes may however, not reflect the high concentrations because the extraneous material associated with the ash are not in a form that is susceptible to leaching.

Water contained in the ash material during deposition can leach constituents from the ash disposal facility and transport it to the surrounding environment. Additional water that is recharged from rainfall will supplement the interstitial water and contribute to the leaching of elements. The water that migrates through the facility can either seep out along the edge of the ash storage facility and enter the surrounding environment as surface water, or migrate vertically to the bottom of the disposal facility and enter the underlying soil from where it can recharge and contaminate the aquifers.

The quality of the water seeping from the ash disposal facility is determined by performing leach and element enrichment testing. This includes a distilled water leachate test and acid-base accounting tests to determine the acid-neutralising and acid-generating capacity of the ash from which the net neutralising potential is calculated. The volume of water that will seep from the ash storage facility in the long term will be affected by the recharge from rainfall.

Table 11.5 tabulates the impact of poor quality artificial recharge from the ash disposal facility and the associated ratings and scores of the impact before mitigation measures are in place. The same impact applies to operational and closure phases.

Table 11.5: Groundwater Impact Table Description during Operation and Closure Phases - No Mitigation Measures

	Unmitigated			
Impact description	**Extent**	**Duration**	**Intensity**	**Probability**
Poor quality artificial recharge from the ash disposal facility	Local	Long Term	High	Highly Probable
Score	2	3	3	3

The score of 11 points results in a high impact.

Table 11.6 tabulates the impact of poor quality artificial recharge from the ash disposal facility and the associated ratings and scores of the impact after mitigation measures are in place.

Table 11.6: Groundwater Impact Table Description during Operation and Closure Phases - With Mitigation Measures

	Mitigated			
Impact description	**Extent**	**Duration**	**Intensity**	**Probability**
Poor quality artificial recharge from the ash disposal facility	Local	Long Term	Moderate	Possible
Score	2	2	2	2

The mitigation measures would include lining the ash disposal facility. This would reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 12. This would allow for the early detection of water quality deterioration associated with the site. The score of 8 points results in a medium impact.

11.1.3 Operation Phase - Conveyor Belt Risks

During the operational phase, the loss of ash on the conveyor belt during the transportation from the power station to the ash disposal facility may have a detrimental effect on the soil and groundwater environment. In the event that this occurs, poor quality leachate may occur as a result of ash being deposited along the conveyor route.

Table 11.7 tabulates the impact of loss of ash during transportation on the conveyor belt and the impacts on the soil and groundwater environment. The associated ratings and scores of the impact after mitigation measures are in place are detailed below. The score of 8 points results in a medium impact.

Table 11.7: Groundwater Impact Table Description during Operational Phase - No Mitigation Measures

	Unmitigated			
Impact description	**Extent**	**Duration**	**Intensity**	**Probability**
Loss of ash during transportation on the conveyor belt	Site	Long Term	Moderate	Possible
Score	1	3	2	2

Table 11.8 tabulates the impact of the loss of ash during transportation on the conveyor belt and the associated ratings and scores of the impact after mitigation measures are in place.

Table 11.8: Groundwater Impact Table Description during Operational Phase - With Mitigation Measures

	Mitigated			
Impact description	**Extent**	**Duration**	**Intensity**	**Probability**
Loss of ash during transportation on the conveyor belt	Site	Long Term	Moderate	Possible
Score	1	3	2	2

The mitigation measures would include regular inspections along the conveyor belt route along sensitive areas mapped (fault areas) in order to visibly identify any areas where ash has been deposited on the soil. The ash must then be removed and transported to the ash disposal facility.

11.2 Risk areas related to conveyer belt

In the 2013 GCS report (Hydrogeological Desktop Study: Continuous Ash Disposal Facility for the Matimba Power Station) sensitive areas were identified for the placement of the ash disposal facility. The map derived from the investigation is shown in Figure 8.1.

The following components were then identified as sensitive areas for the placement of the ash disposal facility:

- Faults or lineaments;
- Production boreholes as indicated by the NGA and GRIP borehole database;
- A buffer area of 100 metres from the rivers within the 8km buffer.

The conveyer belt route will traverse 2 faults (one the Daarby fault and another just north of the Daarby fault). However, the only adverse environmental impacts of conveyor belts for coal transport are coal dust losses during loading, unloading, or transport. Therefore the risk is classified as low.

12 PROPOSED GROUNDWATER MANAGEMENT PLAN

A Groundwater Management Plan is required to ensure that the ash disposal facility does not impact negatively on groundwater levels and quality to unacceptable levels. To ensure that the groundwater environment is protected, monitoring of water quality and levels is required on an on-going basis. The recommended monitoring includes groundwater level and groundwater quality monitoring as well as the visual inspection of the boreholes, as outlined below.

Both sites, namely, Alternative 1 and Alternative 2 have sufficient amounts of monitoring boreholes surrounding the site, located both upgradient and downgradient. It is imperative that these boreholes are monitored on a regular basis.

For site Alternative 1, there are monitoring boreholes which are located on the footprint of the site. It is important that if Alternative 1 is selected as the site for the ash disposal facility that any borehole located on the site footprint is backfilled using a cement – bentonite slurry so as to prevent direct migration of potentially poor quality water into the aquifers.

The following boreholes are currently being monitored by GHT Consulting: P01, P03, P02, P31, P29, P23 and P20. Boreholes GHT 01 and GHT 02 are newly drilled boreholes by GHT Consulting. MA 01 and MA 02 are newly drilled boreholes by GCS. Borehole HP 01 is a production borehole used for garden irrigation & stock watering. All these boreholes should be included in the proposed monitoring plan for site Alternative 1. Boreholes MA1 and HP01 can be monitored bi-annually whereas the remainder of boreholes should be monitored quarterly as indicated in Table 12.1.

Boreholes APV 02, APV 01, WB 31, MA 05, DHL 123, DHL 05, DHL 07, DHL 08, GPN 07, GPN 06, GPN 01, GPN 05, GPN 04, GPN 03, GPN 02 are all boreholes located around the Alternative 2 site. Boreholes APV02, GPN05 and MA05 which were included in this investigation should be monitored on a quarterly basis. Additionally, boreholes NGA090, GPN07 and DHL08 located at a further distance from the proposed site should be monitored on a quarterly basis as indicated in
Table 12.2.

A large data set is currently in place for Alternative 1 as groundwater monitoring is already in place. Therefore all new data collected from the existing boreholes must be compared to the existing data to identify any trends in the groundwater levels and chemistry over time. Long-term groundwater monitoring at similar ash disposal facilities have indicated varying degrees of groundwater quality deterioration.

It is recommended that the following parameters must be recorded: pH, EC, Na, K, Ca, Mg, K, NH4-N, Cl, SO4, F, NO3-N, N, PO4, TDS, Total Alkalinity, bicarbonate, carbonate, Al, Mn, Fe, Zn, Pb, Cu, Cr, Cr (VI), B, Mo, Cd and Ni;

Typically groundwater monitored within boreholes adjacent to ash disposal facilities indicates a rise in the salt content of the groundwater due to seepage from surface sources and also because of the dissolution of salt from the previously unsaturated zones. The increase in salinity is, therefore, a combination of artificial recharge from poor quality (saline) surface water sources and the mobilisation of salts in the exposed zones in the boreholes.

The rate of salts leaching into the subsurface depends on the ash disposal facility (wet versus dry), liners, soil /geology and depth to water level. Typically very slow migration of salts and metals are expected if the site is well selected and managed.

Water levels are in general are expected to rise due to the availability of water on the site and increase in recharge from both the clean water and dirty water systems. This will cause a flow gradient away from the site, even in slight upgradient direction of groundwater flow.

If the monitoring data indicates the need for corrective action, the magnitude of the impact must be assessed by an appropriately qualified and experienced specialist and the necessary measures put forward based on the magnitude of the impact.

Table 12.1: Monitoring Schedule for Alternative 1

Borehole ID	Co-ordinates, WGS 84 Geographic		Frequency of Monitoring	Current Borehole Use	Analysis
	S	E			
MA1	-23.71	27.58282	Bi-annual	GCS Monitoring borehole	As per Table 8.9
MA2	-23.7305	27.58542	Quarterly	GCS Monitoring borehole	As per Table 8.9
HP 01	-23.6854	27.60393	Bi-annual	Production borehole	As per Table 8.9
P01	-23.7012	27.6190	Quarterly	GHT Monitoring	As per Table 8.9
P03	-23.6972	27.61782	Quarterly	GHT Monitoring	As per Table 8.9
P31	-23.7236	27.60577	Quarterly	GHT Monitoring borehole	As per Table 8.9
P29	-23.7204	27.61705	Quarterly	GHT Monitoring borehole	As per Table 8.9

P23	-23.7143	27.6216	Quarterly	GHT Monitoring borehole	As per Table 8.9
P20	-23.6973	27.62408	Quarterly	GHT Monitoring borehole	As per Table 8.9

Table 12.2: Monitoring Schedule for Alternative 2

Borehole ID	Co-ordinates, WGS 84 Geographic		Frequency of Monitoring	Current Borehole Use	Analysis
	S	E			
APV02	-23.6257	27.58165	Bi-annual	Production borehole	As per Table 8.9
GPN05	-23.597	27.63763	Quarterly	Production borehole	As per Table 8.9
MA05	-23.6157	27.63042	Bi-annual	Production borehole	As per Table 8.9
NGA090	-23.6166	27.56757	Quarterly	Production borehole	As per Table 8.9
GPN07	-23.5851	27.60082	Quarterly	Production borehole	As per Table 8.9
DHL08	-23.6265	27.61908	Quarterly	Production borehole	As per Table 8.9

13 CONCLUSIONS

GCS undertook a hydrogeological desktop study for the proposed continuous ash disposal facility for the Matimba Power Station, which will form part of the EIA (Environmental Impact Assessment) and Waste Management Licensing (WML) process.

The study aims to identify the best suitable locality for the ash disposal facility.

GCS assessed all available geological and hydrogeological data as part of the hydrogeological investigation within an 8km radius of the Matimba Power Station. All existing groundwater data obtained from previous GCS projects, data provided by the client as well as government data was reviewed and included in the assessment.

Two sites alternatives were considered during the EIA Phase, namely Alternative 1 located south of the Matimba Power Station on farm Zwartwater 507LQ and Alternative 2 located north of the Matimba Power Station located on portions of farms Vooruit 449 LQ, Droogeheuvel 447LQ, Ganzepan 446 LQ and Appelvlakte 448 LQ.

13.1 Alternative 1

A detailed hydrocensus was conducted as part of the hydrogeological investigation whereby properties within a 2km radius of Alternative 1 were visited. During the visit, details including water use type, volumes, water levels and coordinates were obtained.

Majority of the boreholes identified surrounding Alternative 1 during the hydrocensus were Matimba monitoring boreholes. In total 11 water levels were recorded in these boreholes. The water levels ranged from 5.63mbgl to 21.47mbgl. The water use is mostly for domestic purposes as well as stock watering.

The geophysical investigation did not yield results and therefore monitoring boreholes were installed according to the positions required, which were upgradient and downgradient of the proposed sites.

In total, four boreholes were drilled surrounding Alternative 1. MA1 was drilled upgradient and MA2, MA3 and MA4 were drilled downgradient with depths which ranged from 15m to 40m.

The groundwater flow direction for site Alternative 1 is generally in an easterly direction towards the Sandloop River. The flow direction contours were based on water levels collected from 10 boreholes. The flow direction associated with the eastern portion of the current ash disposal area is somewhat different to the general easterly direction as described earlier. This is most likely due to potential seepage occurring from the ash disposal facility resulting in shallower water levels immediately downgradient of the ash disposal facility.

The short duration constant discharge test was performed to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters. Aquifer testing was conducted on MA1 & MA2, which indicated relatively low transmissivities which ranged from 0.04 to 0.06 m^2/day.

A review of the chemistry of the Matimba Power Station monitoring boreholes sampled, indicated a general trend with similar parameters which generally exceeded the drinking water limits. Most of these parameters indicated very high concentrations. These problematic parameters as identified through the pollution index include the following: Conductivity, TDS; chloride; sulphate; calcium; sodium; manganese and magnesium.

Majority of the boreholes indicated poor water quality with these parameters in high concentrations. This was with the exception of the newly drilled upgradient borehole MA1, P03 and P20. The chemistry results of the remaining boreholes indicated the effect of the existing ash disposal facility on the groundwater environment.

Based on the risk rating of the site, Alternative 1 is favoured over Alternative 2 according to the following criteria:

- Groundwater levels – Slightly deeper than Alternative 2;
- Presence of intrusive lithologies – Further distance to intrusive lithologies in comparison to Alternative 2;
- Proximity of production boreholes – Only 1 production borehole was identified in the 2km radius of the site compared to the 13 hydrocensus boreholes in use surrounding Alternative 2.
- Existing water quality – The risk rating of Alternative 1 is reduced by placing the ash disposal facility adjacent to the existing ash disposal facility as the water quality has already been compromised due to the presence of the ash disposal facility.

The following boreholes are currently being monitored by GHT Consulting: P01, P03, P02, P31, P29, P23 and P20. Boreholes GHT 01 and GHT 02 are newly drilled boreholes by GHT Consulting. MA 01 and MA 02 are newly drilled boreholes by GCS. Borehole HP 01 is a production borehole used for garden irrigation & stock watering. All these boreholes should be included in the proposed monitoring plan for site Alternative 1.

13.2 Alternative 2

A detailed hydrocensus was conducted as part of the hydrogeological investigation whereby properties within a 2km radius of Alternative 2 were visited. During the visit, details including water use type, volumes, water levels and coordinates were obtained.

In total 16 boreholes were identified surrounding Alternative 2 including the boreholes installed for this project. The water levels ranged from 17mbgl to 23.94mbgl. The water use is mostly for domestic purposes as well as stock watering.

The geophysical investigation did not yield results and therefore monitoring boreholes were installed according to the positions required, which were upgradient and downgradient of the proposed sites.

The drilling at site Alternative 2 included the installation of one downgradient borehole on the farm Droogeheuwel, namely MA5 which was drilled to a depth of 40 metres. No further boreholes were drilled surrounding this option, based on the presence of existing boreholes which were used as monitoring boreholes, namely GPN05 and APV02.

The groundwater flow direction for site Alternative 2 is in an easterly direction. The flow direction contours were based on water levels collected from eight different boreholes surrounding the site area.

The short duration constant discharge test was performed to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters. Aquifer testing was conducted on GPN05, APV02 and MA5, which indicated transmissivities which ranged from 0.1 to 6.67 m^2/day.

A comparison in the groundwater chemistry was made between the boreholes surrounding site Alternative 1 and site Alternative 2. There is a clear distinction between the results. Although several boreholes associated with site Alternative 2 indicated elevated concentrations of parameters mentioned earlier which appear to be problematic, it is clear that the concentrations in general are much lower than those associated with boreholes surrounding site Alternative 1.

Boreholes APV02, GPN05 and MA05 which were included in this investigation should be monitored on a quarterly basis. Additionally, boreholes NGA090, GPN07 and DHL08 located at a further distance from the proposed site should be monitored on a quarterly basis.

13.3 Conveyer belt

During the sensitivity mapping process, the following components were identified as sensitive areas; faults or lineaments and production boreholes. The conveyer belt does not traverse/intersect any production boreholes but does traverse the Daarby fault.

The conveyer belt route will traverse two faults (one the Daarby fault and another just north of the Daarby fault). However, the only adverse environmental impacts of conveyor belts for coal transport are coal dust losses during loading, unloading, or transport. Therefore the risk is associated with this is considered minimal.

14 REFERENCES

GRDM, Groundwater Resource Directed Measures, GRDM Training Manual, 2010.

GHT Consulting Scientists, 2012. Matimba Power Station, Routine Monitoring Phase 61, First Quarter 2012, Final Report. Report number: RVN630.1/1321.

GCS (2008): Proposed 200/400/800 Mw Coal-Fired Power Station and Additional Black Start Generation Facility at Walvis Bay, Namibia - Site Selection Geology, Hydrogeology, Soil & Hydrology (08-198).

Kolosa, M. (2012) Investigation of salt leach potential of Tutuka dry ash dump. MSc in progress. University of the Western Cape. Bellville

Jeffares & Green (2013). Waste Classification of Ash Disposed at the Existing Ash Disposal Facilities, at the Matimba Power Station Ash Disposal Facility, Lephalale, Limpopo Province.

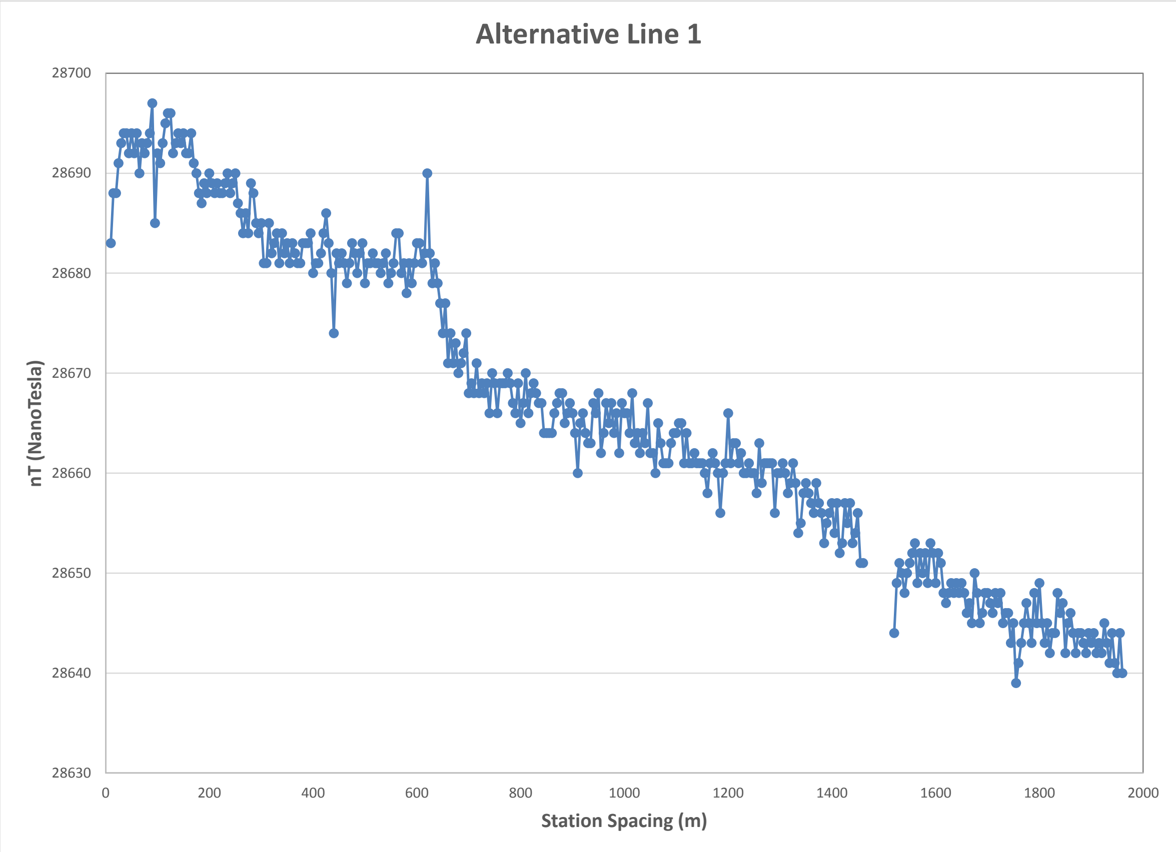
APPENDIX A
GROOTEGELUK MONITORING BOREHOLE DATA

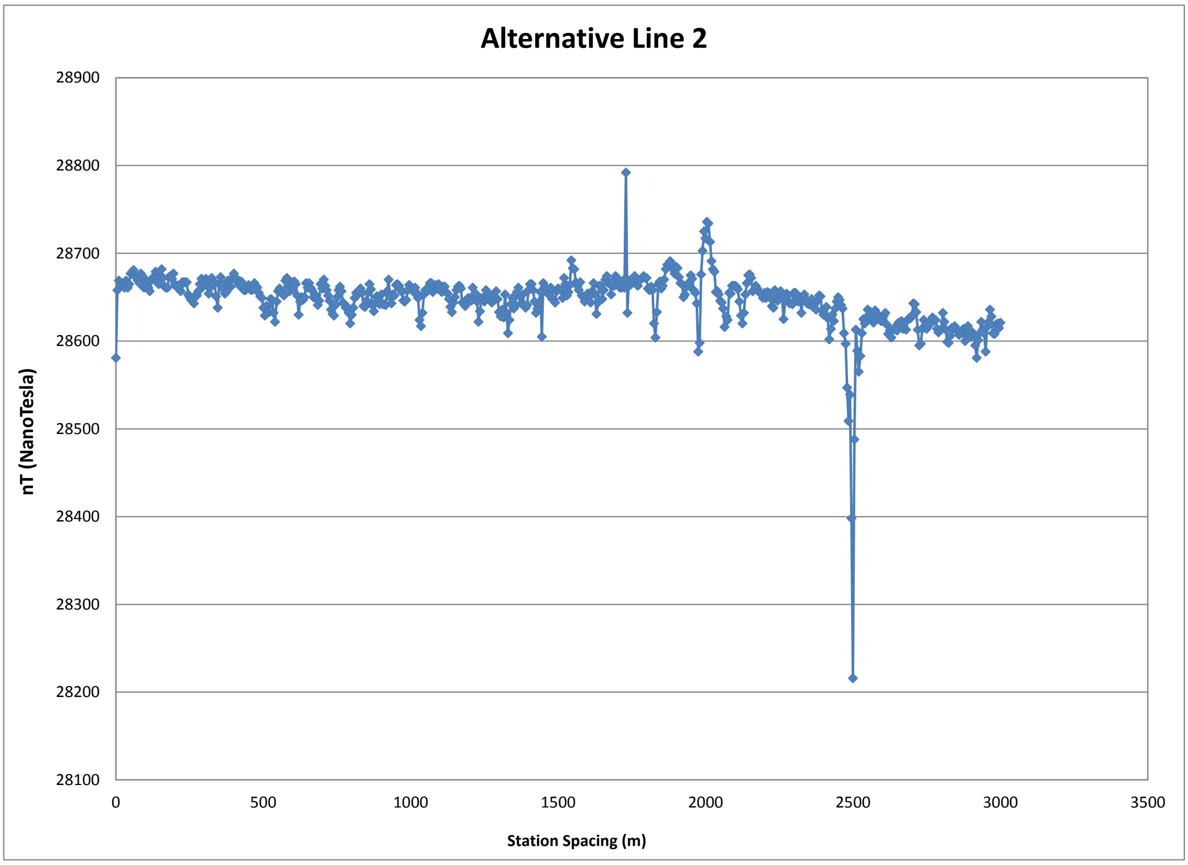
Borehole ID	Latitude	Longitude	Water Level (mbgl)
WB38	-23.66411	27.55528	8.96
ETSPE60	-23.66701	27.52157	18.36
GHK17	-23.66506	27.68348	29.02
GHK26	-23.6612	27.68553	25.5
GK37	-23.67963	27.51541	54.59
GK61	-23.68398	27.53257	40.55
GK71	-23.68642	27.51302	77.3
GK72	-23.68407	27.513	76.45
GK74	-23.67954	27.51298	63.88
GK75	-23.67724	27.51296	69.53
GK78	-23.67052	27.51295	60.84
GK79	-23.66831	27.51299	80.25
GK85	-23.68634	27.50564	62.64
GK87	-23.68633	27.50074	57.3
GK89	-23.6818	27.52034	63.05
GK91	-23.68177	27.5007	42.5
GK92	-23.6773	27.50068	34.5
GK93	-23.67277	27.5007	53.25
GK94	-23.68634	27.51054	81.1
GK95	-23.67276	27.51009	58.98
HT26	-23.68623	27.53256	41.69
HT27	-23.68625	27.53014	57.68
HT32	-23.68853	27.52529	72.58
HT33	-23.68627	27.52526	55.52
HT40	-23.69086	27.50566	63.3
HT41	-23.69536	27.50568	58.88
HT44	-23.69299	27.51545	61.62
HT46	-23.69309	27.51058	81.53
HT47	-23.6931	27.50568	74.62
LT11	-23.66058	27.51292	55.23
LT13	-23.66375	27.51046	58.62
LT14	-23.65923	27.51044	55.43
LT15	-23.66376	27.50556	55.07
LT16	-23.66831	27.50069	57.98
LT17	-23.66601	27.50802	60.95
LT9	-23.66597	27.51293	61.96
NN11	-23.68831	27.58406	23.72
NN12	-23.69057	27.58162	49.96
NN13	-23.68834	27.58165	23.81
OBS10	-23.64781	27.52289	9.22
OBS2	-23.65586	27.54733	9.56
OBS3	-23.6476	27.52172	11.1
TE66	-23.67933	27.57422	21.48
TE70	-23.68608	27.5767	19.3
TE88	-23.68609	27.5693	10.06

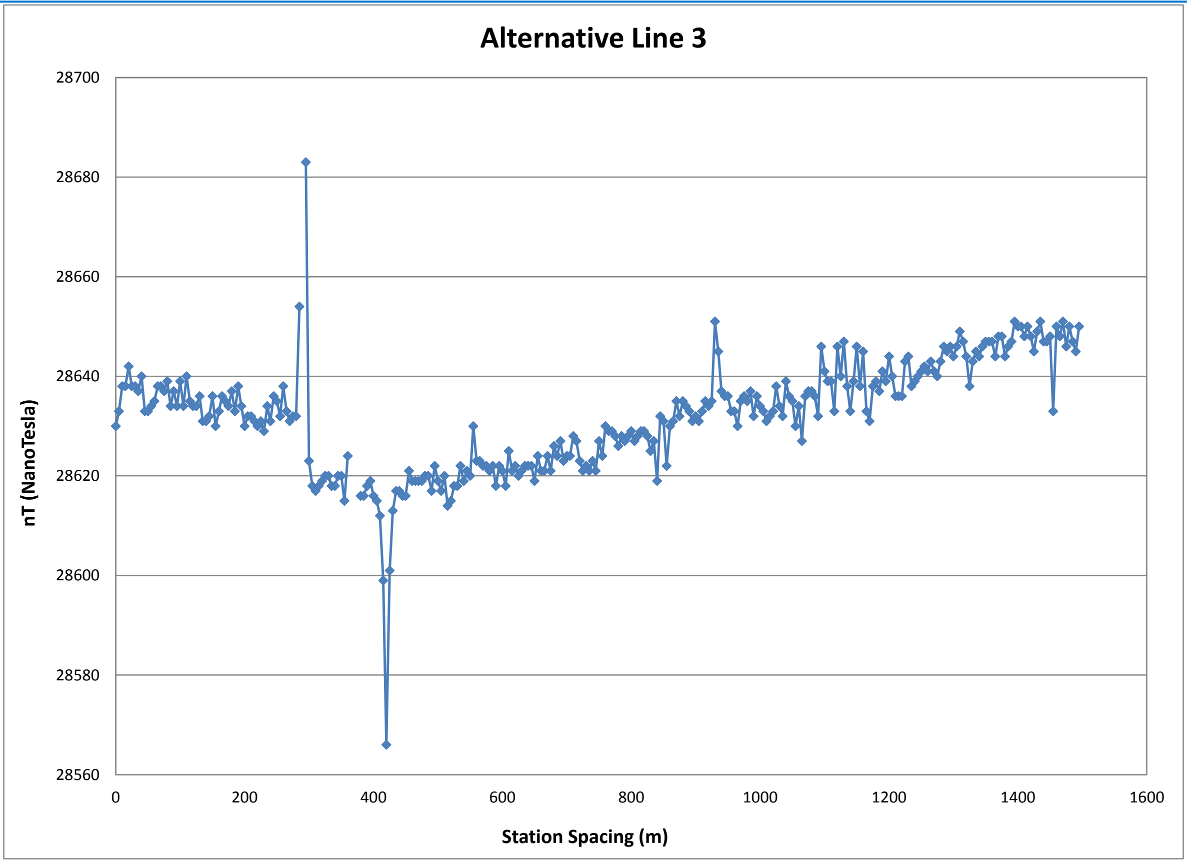
TE89	-23.68256	27.57424	17.65
TE90	-23.68176	27.5423	53.35
WB19B	-23.65576	27.5473	29.1
WB25	-23.66033	27.56523	4.73
WB33	-23.65708	27.54863	12.95
WB34	-23.65471	27.54765	22.95
WB35	-23.65532	27.54468	30.98
WB36	-23.65809	27.54053	18.34
WB40	-23.66874	27.56888	6.72
WB41	-23.66767	27.55999	11.51
WB42	-23.66978	27.55489	10.05
WB43	-23.66533	27.55837	9.32
WB45	-23.6649	27.56437	5.37
WB46	-23.66846	27.5643	3.74
WB47	-23.65798	27.56088	4.81
WB48	-23.65475	27.56388	4.25
WB49	-23.65794	27.55955	7.05
WB50	-23.65078	27.56328	16
WB51	-23.6606	27.56676	10.32
WB9	-23.68162	27.53508	58.35
WBR10	-23.63479	27.52091	33.44
WBR13	-23.64816	27.51341	33.8
WBR14P1	-23.6452	27.54194	28.87
WBR14P2	-23.6452	27.54194	28.76
WBR14P3	-23.6452	27.54194	14.25
WBR15	-23.64467	27.55609	11.47
WBR16	-23.64011	27.54922	22.32
WBR17	-23.67195	27.54886	19.79
WBR18	-23.67015	27.55221	4.52
WBR19P1	-23.67035	27.55221	9.4
WBR19P2	-23.67035	27.55221	4.24
WBR2	-23.65657	27.57637	8.4
WBR22P2	-23.68158	27.5668	32.1
WBR24	-23.63901	27.57888	11.35
WBR25	-23.64727	27.52225	10.37
WBR26	-23.66612	27.5617	5.17
WBR28	-23.64722	27.5516	16.71
WBR29	-23.66501	27.55661	5.9
WBR3	-23.63658	27.56375	3
WBR30	-23.66564	27.55663	5.8
WBR31	-23.66472	27.55734	5.91
WBR32	-23.64543	27.56684	5.4
WBR34	-23.69304	27.5204	65.97
WBR35	-23.69299	27.53509	63.09
WBR36	-23.67355	27.57018	5.76
WBR37	-23.70176	27.57775	14.2
WBR37A	-23.70176	27.57786	13.37
WBR38	-23.65431	27.6018	13.35
WBR39	-23.67662	27.55924	4.76
WBR4	-23.64251	27.57335	2.88
WBR5P1	-23.63652	27.57322	2.34

WBR6P1	-23.64195	27.56813	-0.45
WBR6P2	-23.64195	27.56813	6.74
WBR7	-23.6422	27.5931	22.99
WBR8	-23.62611	27.57597	11.88
WBR9	-23.62977	27.54518	42.98

APPENDIX B
GEOPHYSICAL DATA



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28660
28640
28620
28600
28580
28560
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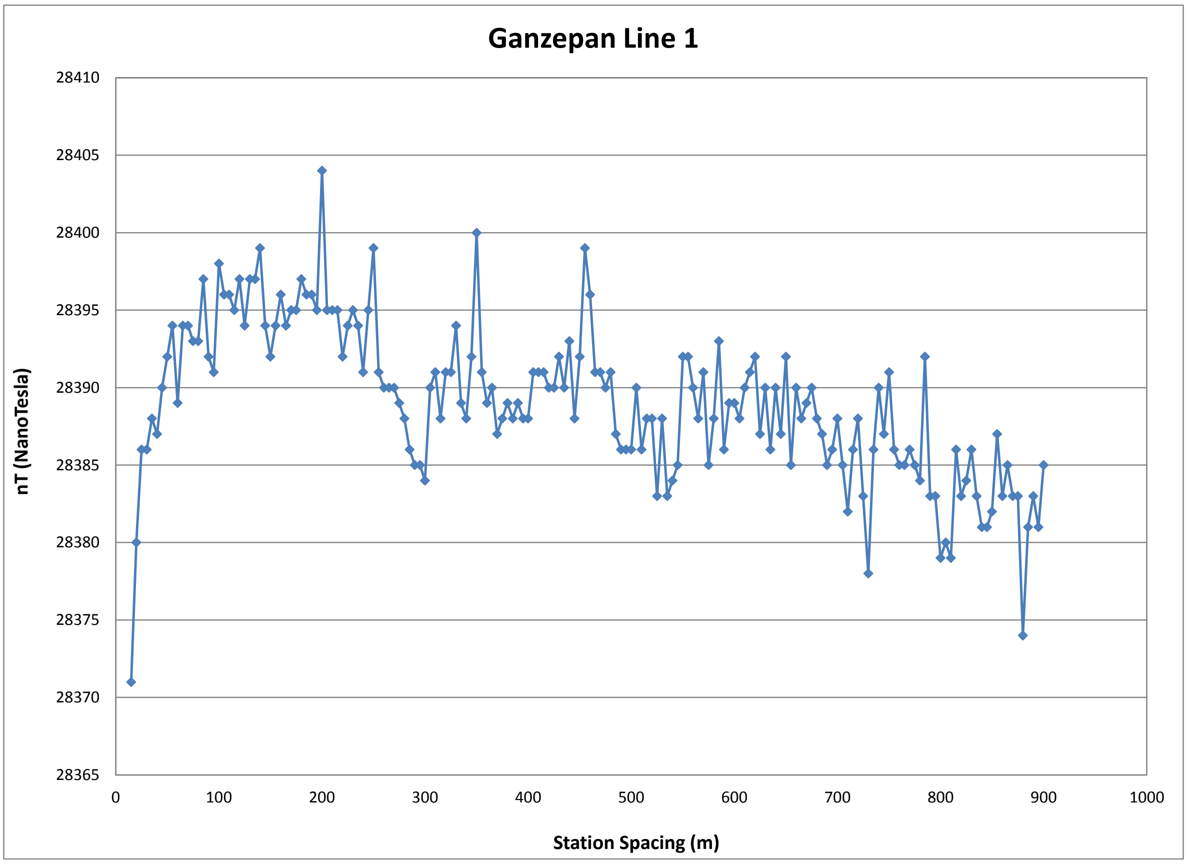
400
600
800
1000
1200
1400
1600
Station Spacing (m)


Ganzepan Line 1
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28400
28395
28390
28385
28380
28375
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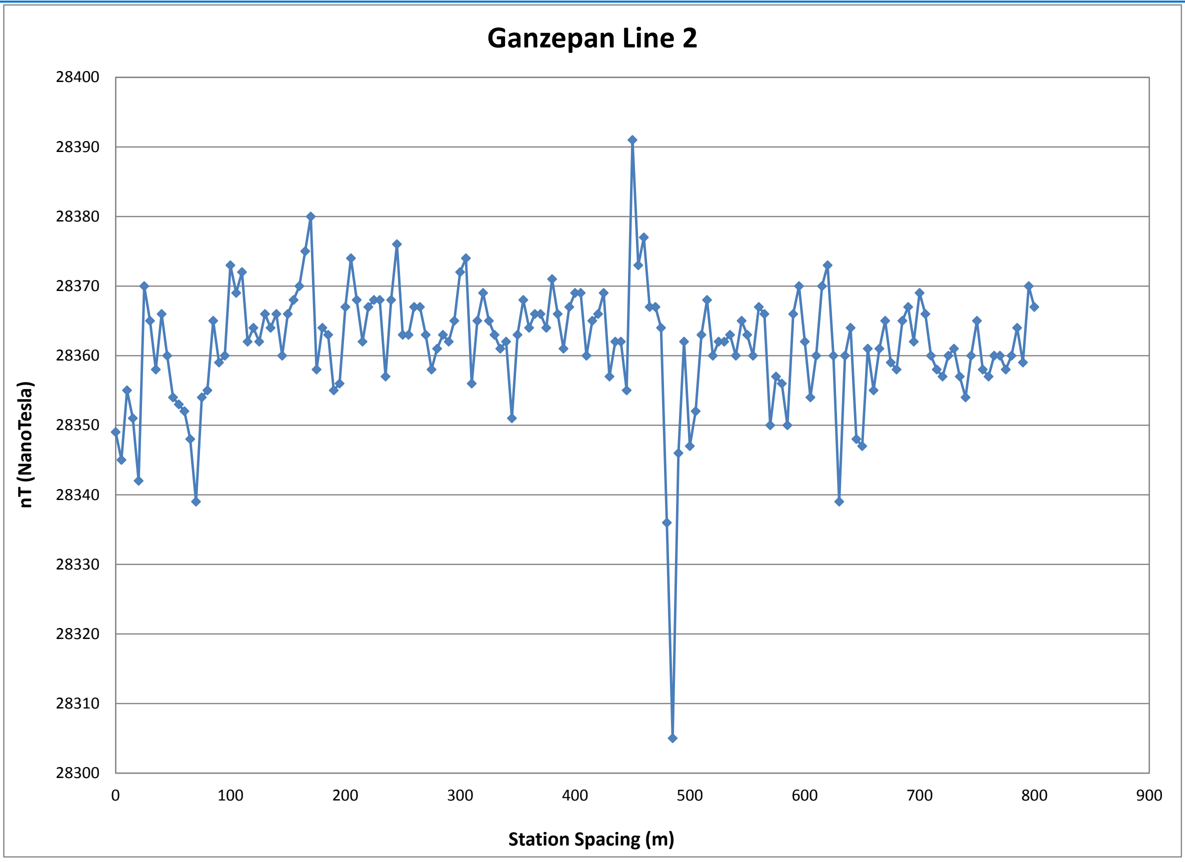
200
300
400
500
600
700
800
900
1000
Station Spacing (m)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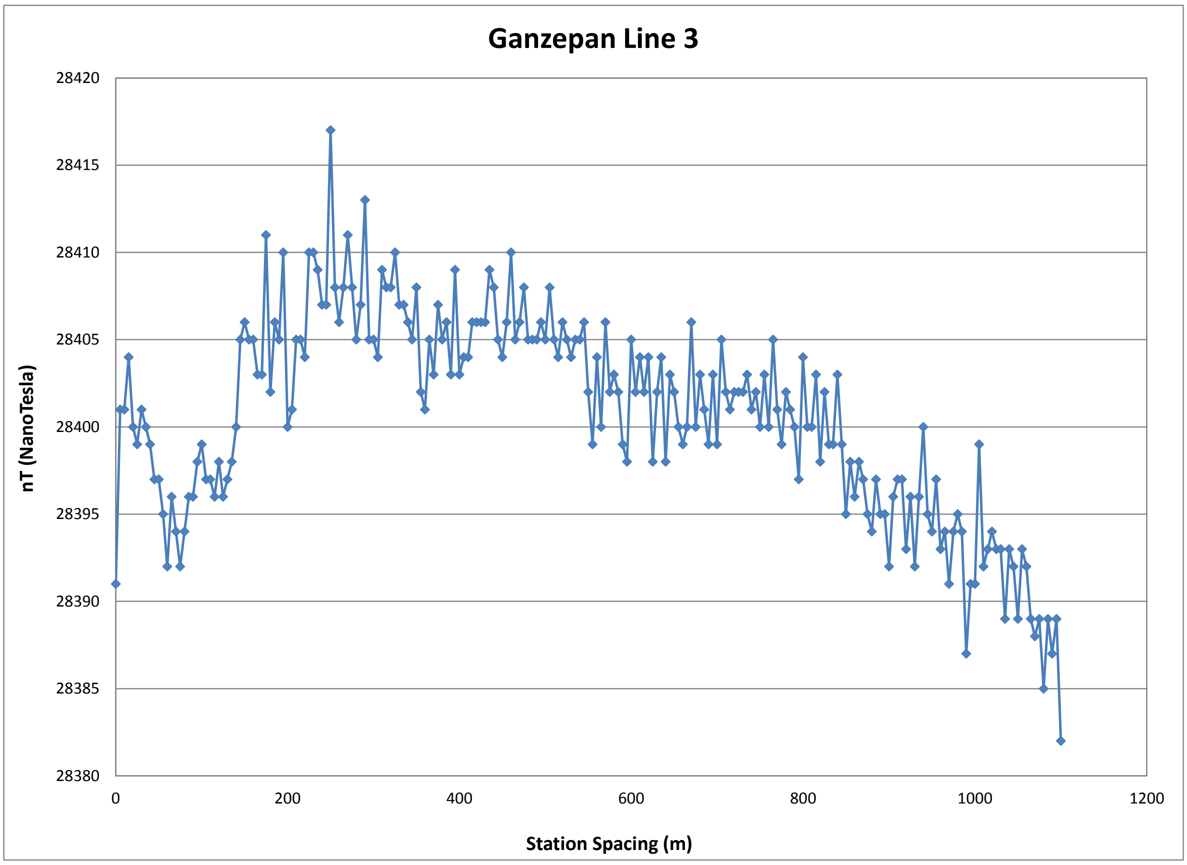
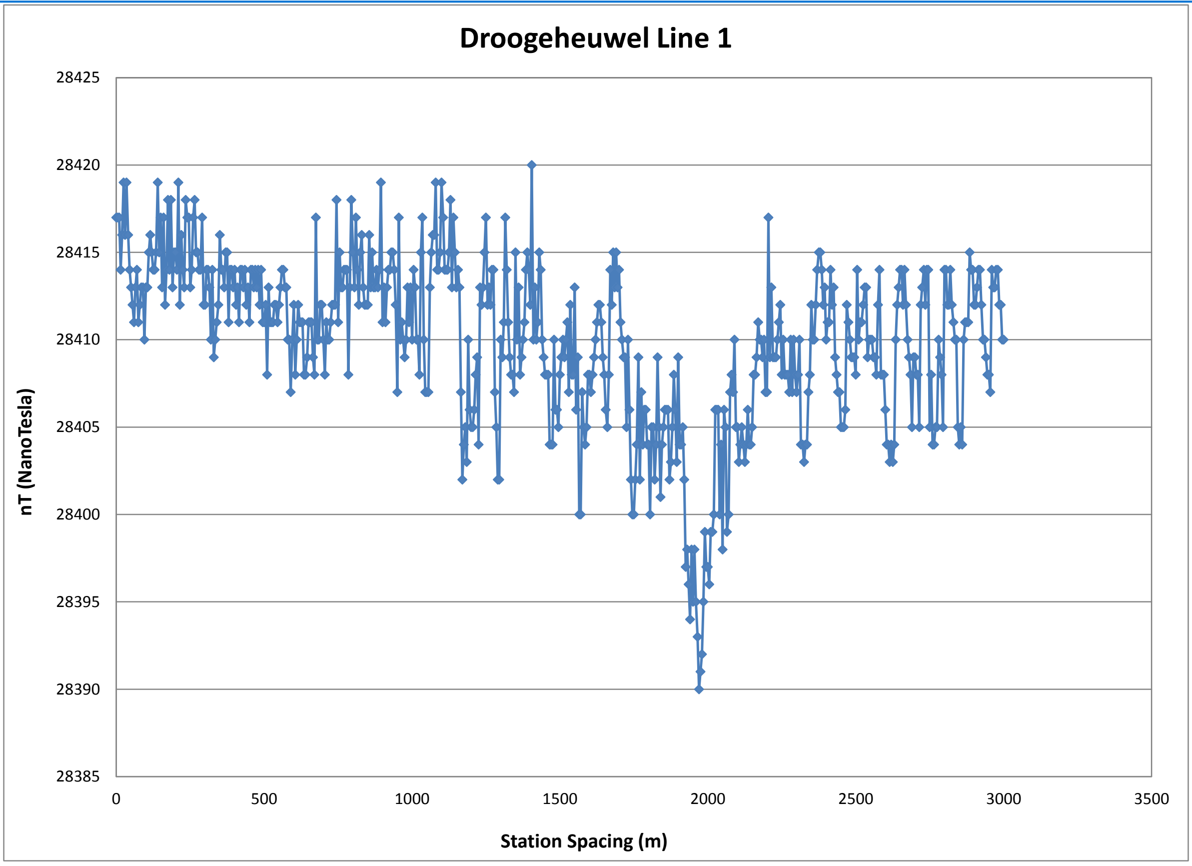
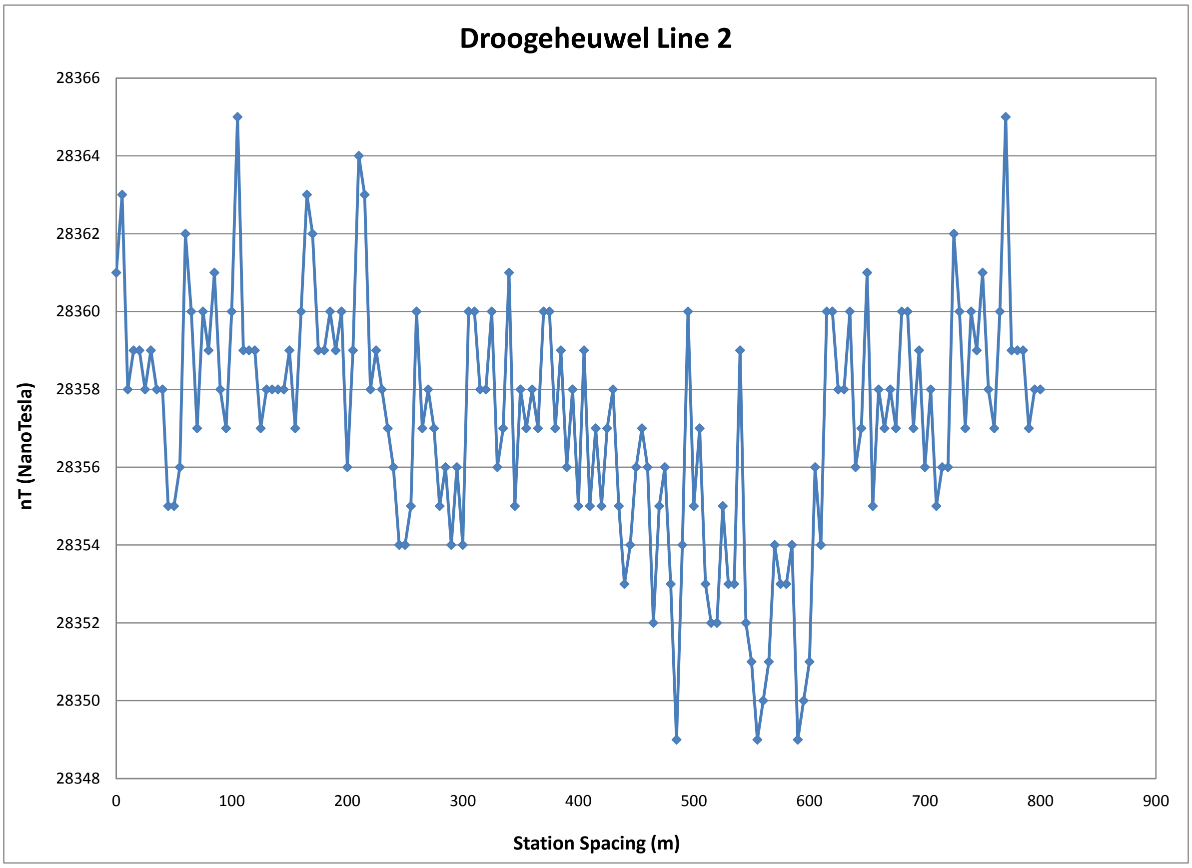
0
100
200
300
400
500
600
700
800
900
Station Spacing (m)

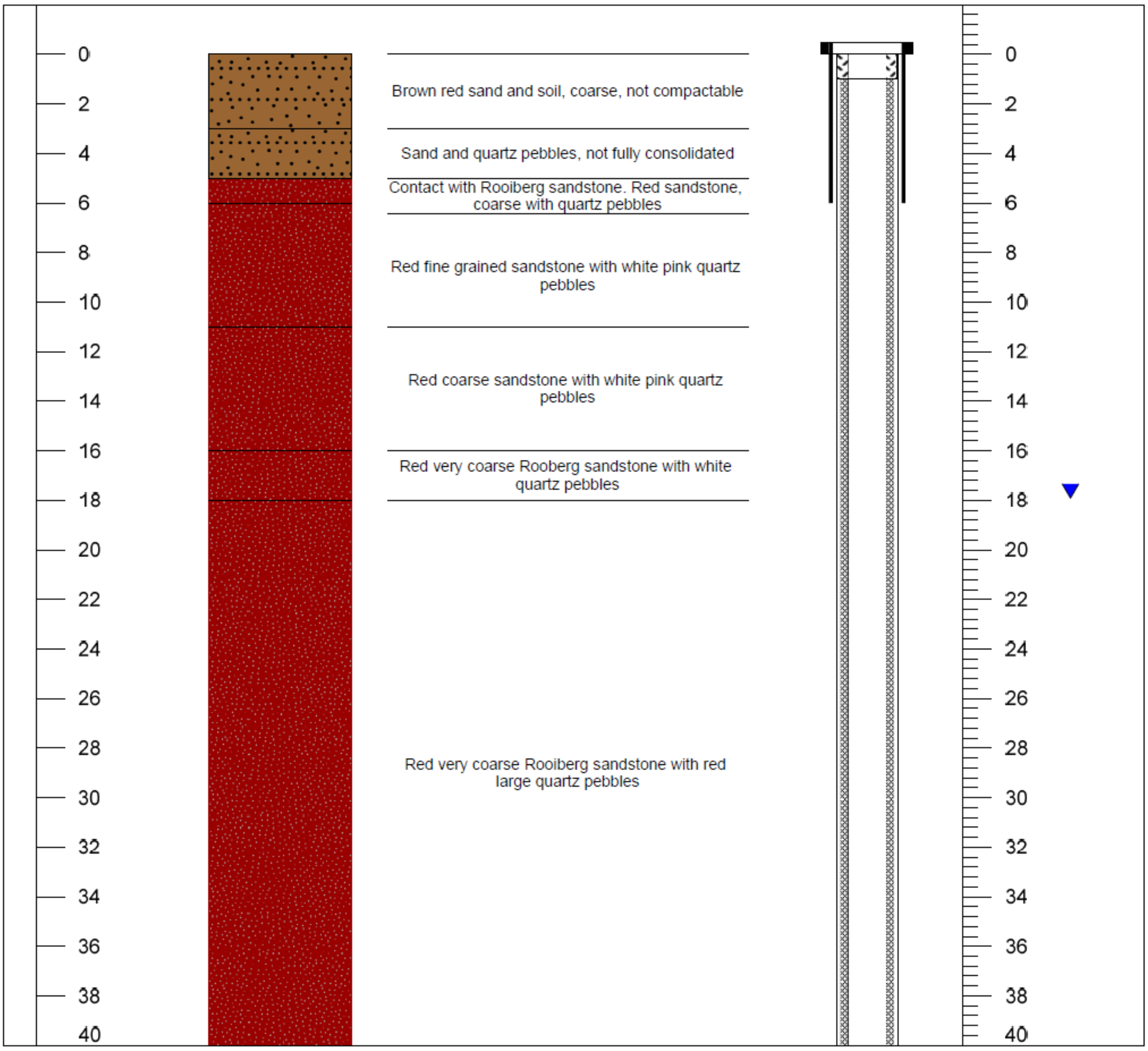

Ganzepan Line 3
nT (NanoTesla)
28420
28415
28410
28405
28400
28395
28390
28385
28380
0
200
400
600
800
1000
1200
Station Spacing (m)


Droogeheuwel Line 1
28425
28420
28415
28410
28405
28400
28395
28390
28385
nT (NanoTesla)
0
500
1000
1500
2000
2500
3000
3500
Station Spacing (m)


Droogeheuwel Line 2
28366
28364
28362
28360
28358
28356
28354
28352
28350
28348
nT (NanoTesla)
0
100
200
300
400
500
600
700
800
900
Station Spacing (m)

APPENDIX C
BOREHOLE LOGS

GCS	PROJECT: Matimba Hydrogeological Investigation	BOREHOLE ID: MA1
	LOCATION: Lephalale	LATITUDE: 23°42'36.00"S
	DRILLING CONTRACTOR: Ferreiras Drilling	LONGITUDE: 27°34'58.14"E
	DRILLING METHOD: Percussion drilling	WATER LEVEL DEPTH: 17.63
	DATE COMPLETED: 5/7/2013	DEPTH: 40
Depth (m)	Graphic log / Description	Well Construction

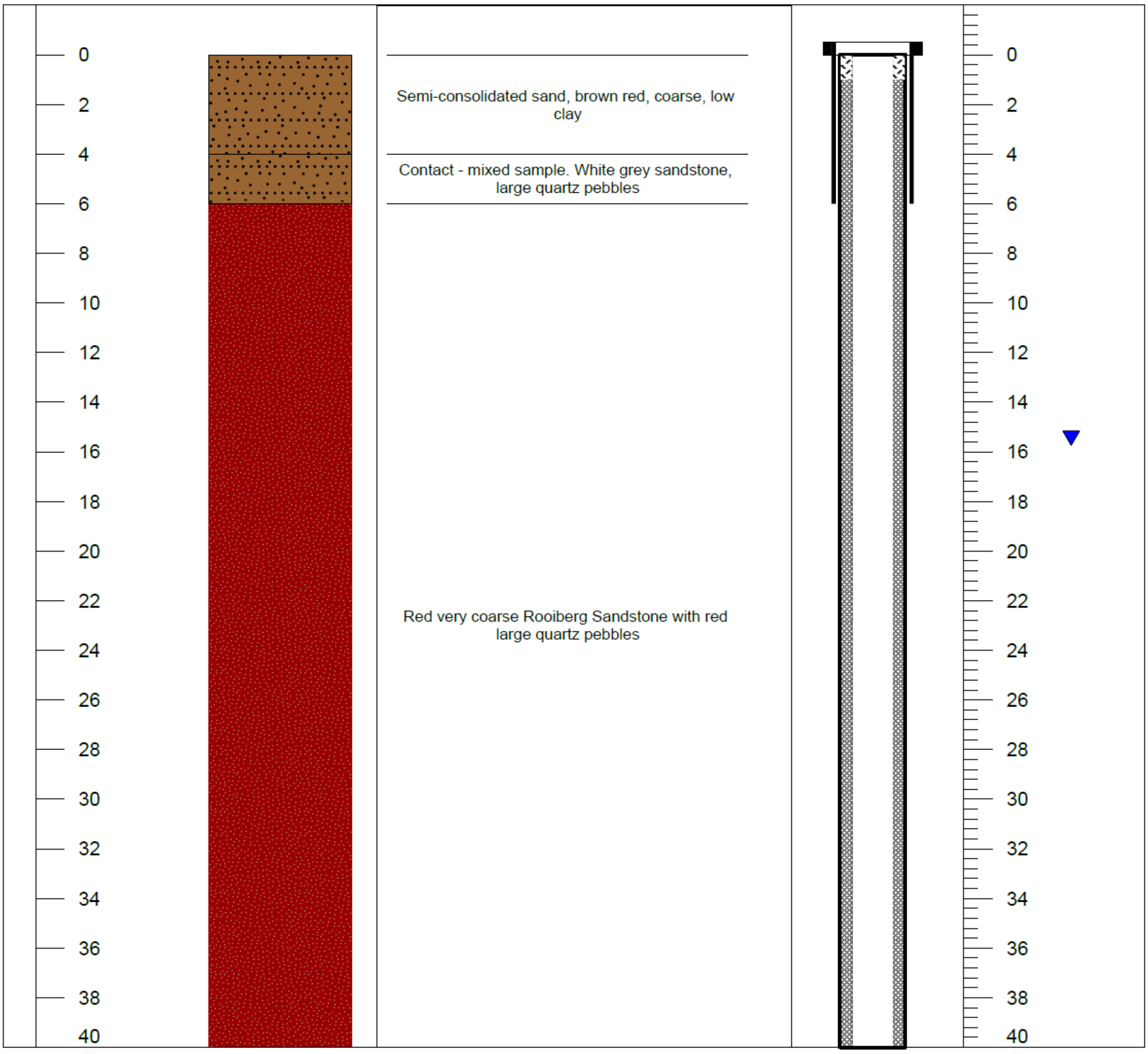


Royal HaskoningDHV
Enhancing Society Together

Well Construction Legend
- Casing
- BH diameter
- Fill
- Steel
- Cement
- Cap

GCS Water & Environmental Consultants	PROJECT: Matimba Hydrogeological Investigation	BOREHOLE ID: MA02
	LOCATION: Lephalale	LATITUDE: 23°43'49.86"S
	DRILLING CONTRACTOR: Ferreiras Drilling	LONGITUDE: 27°35'7.50"E
	DRILLING METHOD: Percussion drilling	WATER LEVEL DEPTH: 15.45
	DATE COMPLETED: 6/7/2013	DEPTH: 40

Depth (m)	Graphic log	Description	Well Construction

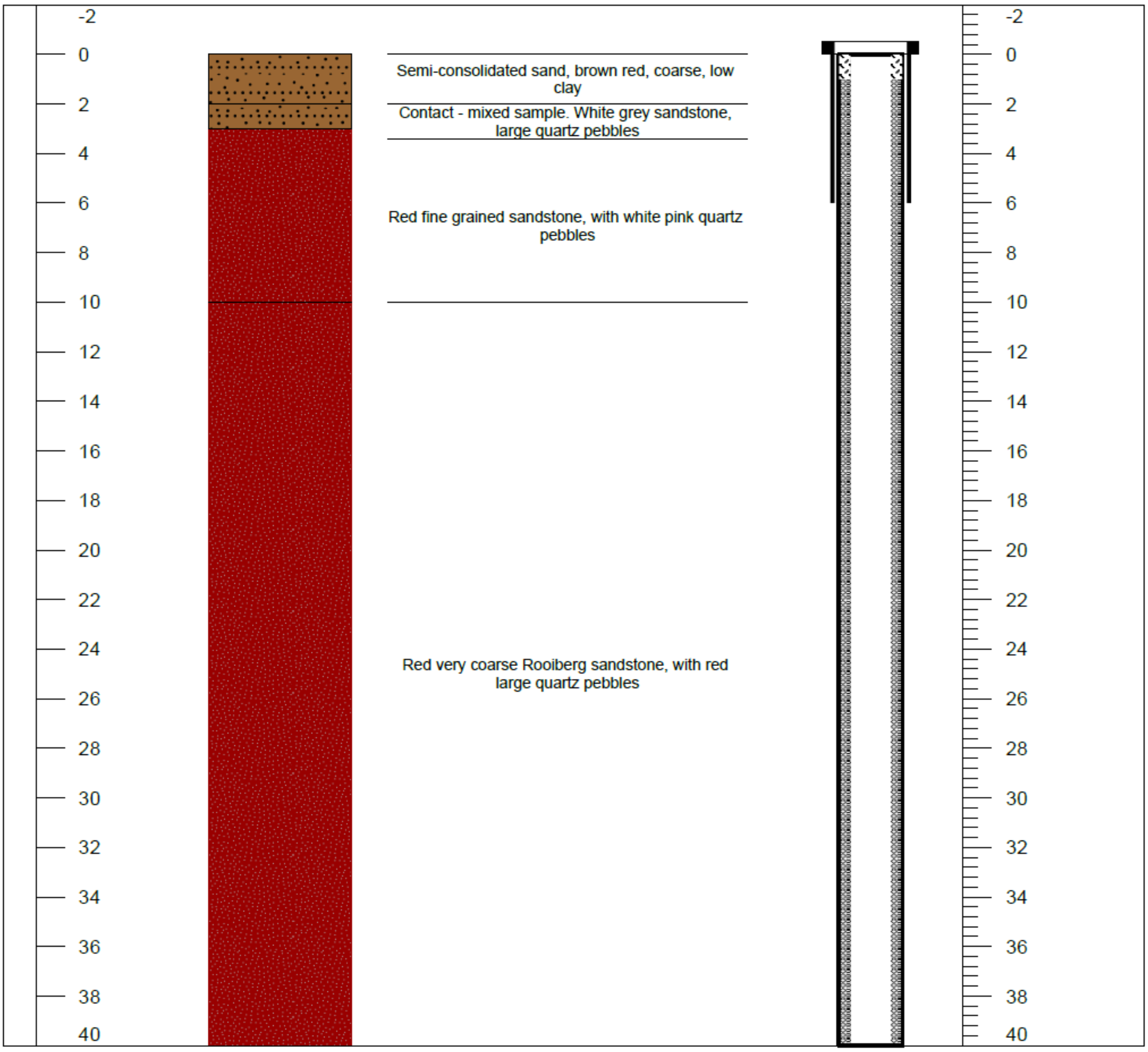


Royal HaskoningDHV Enhancing Society Together

- Casing
- Cement
- BH diameter
- Fill
- Screen
- Steel
- Cap

	PROJECT: Matimba Hydrogeological Investigation	BOREHOLE ID: MA03
	LOCATION: Lephalale	LATITUDE: 23°43'16.80"S
	DRILLING CONTRACTOR: Ferreiras Drilling	LONGITUDE: 27°37'9.96"E
	DRILLING METHOD: Percussion drilling	WATER LEVEL DEPTH: Dry
	DATE COMPLETED: 6/7/2013	DEPTH: 40

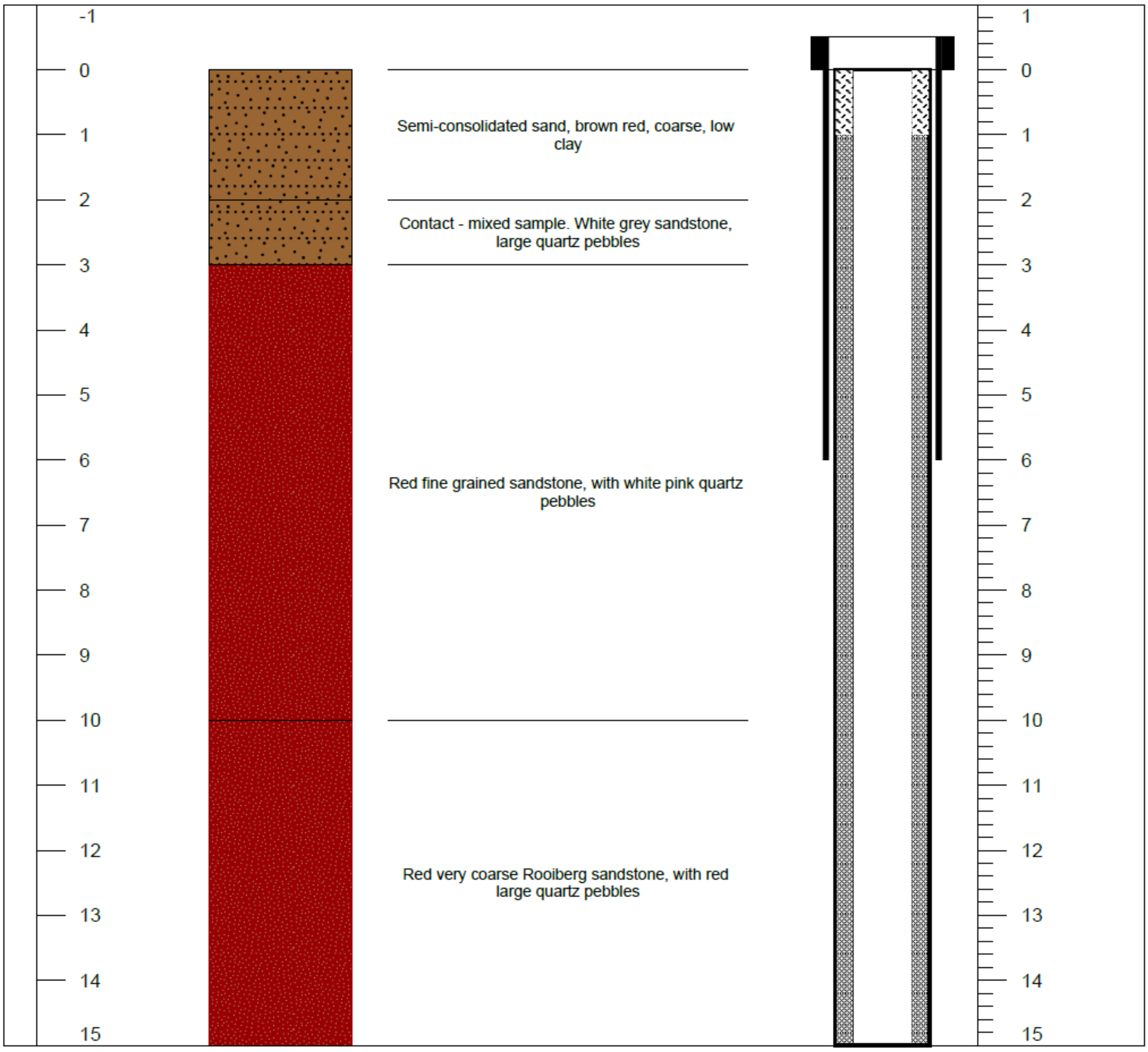
Depth (m)	Graphic log	Description	Well Construction



Well Construction Legend
- Casing
- BH diameter
- Fill
- Steel
- Cap
- Cement

GCS Water & Environmental Consultants	PROJECT: Matimba Hydrogeological Investigation	BOREHOLE ID: MA04
	LOCATION: Lephalale	LATITUDE: 23°43'16.74"S
	DRILLING CONTRACTOR: Ferreiras Drilling	LONGITUDE: 27°37'10.02"E
	DRILLING METHOD: Percussion drilling	WATER LEVEL DEPTH: Dry
	DATE COMPLETED: 7/7/2013	DEPTH: 15

Depth (m)	Graphic log	Description	Well Construction

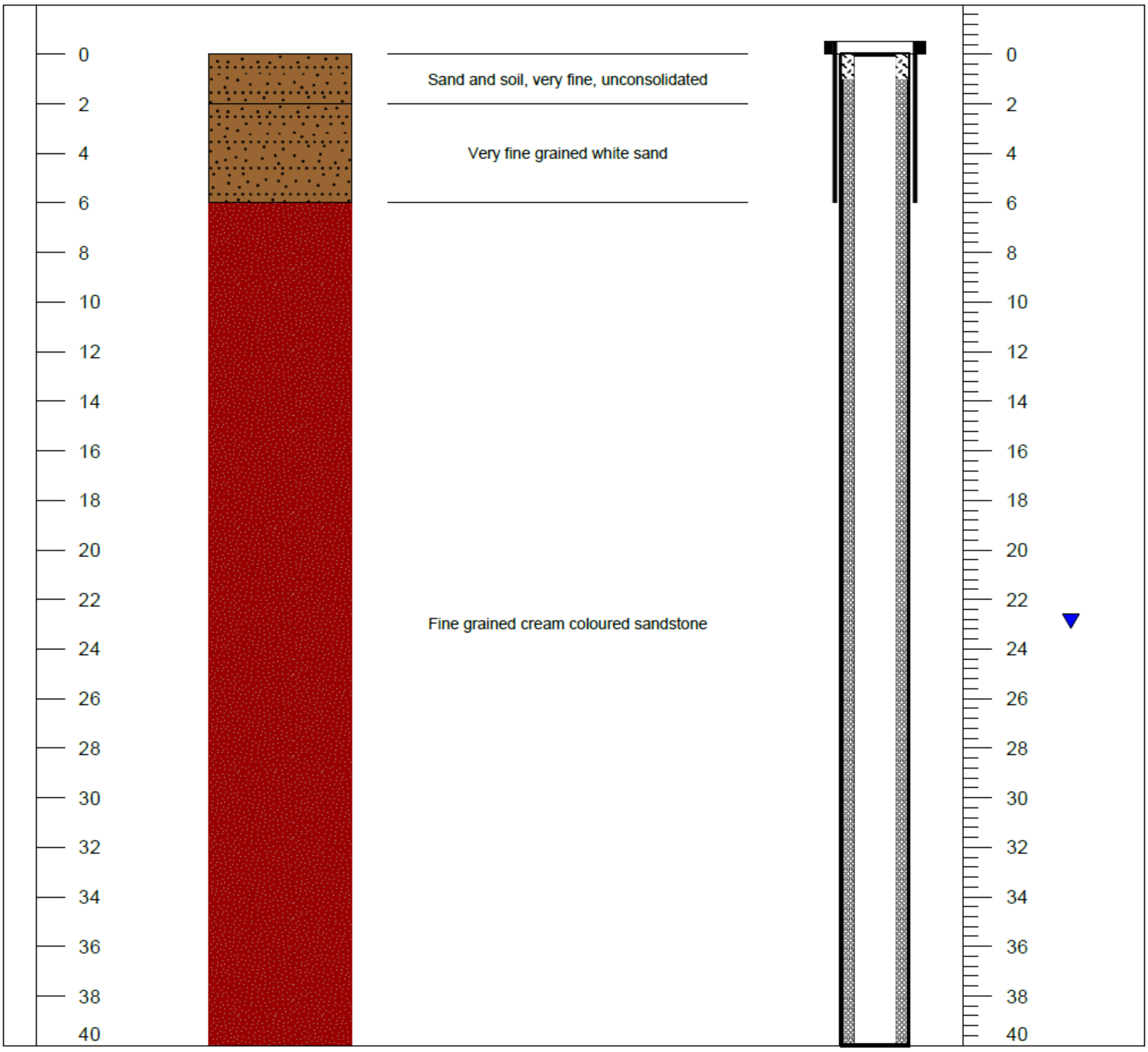


Royal HaskoningDHV
Enhancing Society Together

Well Construction Legend
- Casing
- BH diameter
- Fill
- Steel
- Cement
- Cap

GCS Water & Environmental Consultants	PROJECT: Matimba Hydrogeological Investigation	BOREHOLE ID: MA05
	LOCATION: Lephalale	LATITUDE: 23°36'56.46"S
	DRILLING CONTRACTOR: Ferreiras Drilling	LONGITUDE: 27°37'49.50"E
	DRILLING METHOD: Percussion drilling	WATER LEVEL DEPTH: 22.87
	DATE COMPLETED: 7/7/2013	DEPTH: 40

Depth (m)	Graphic log	Description	Well Construction

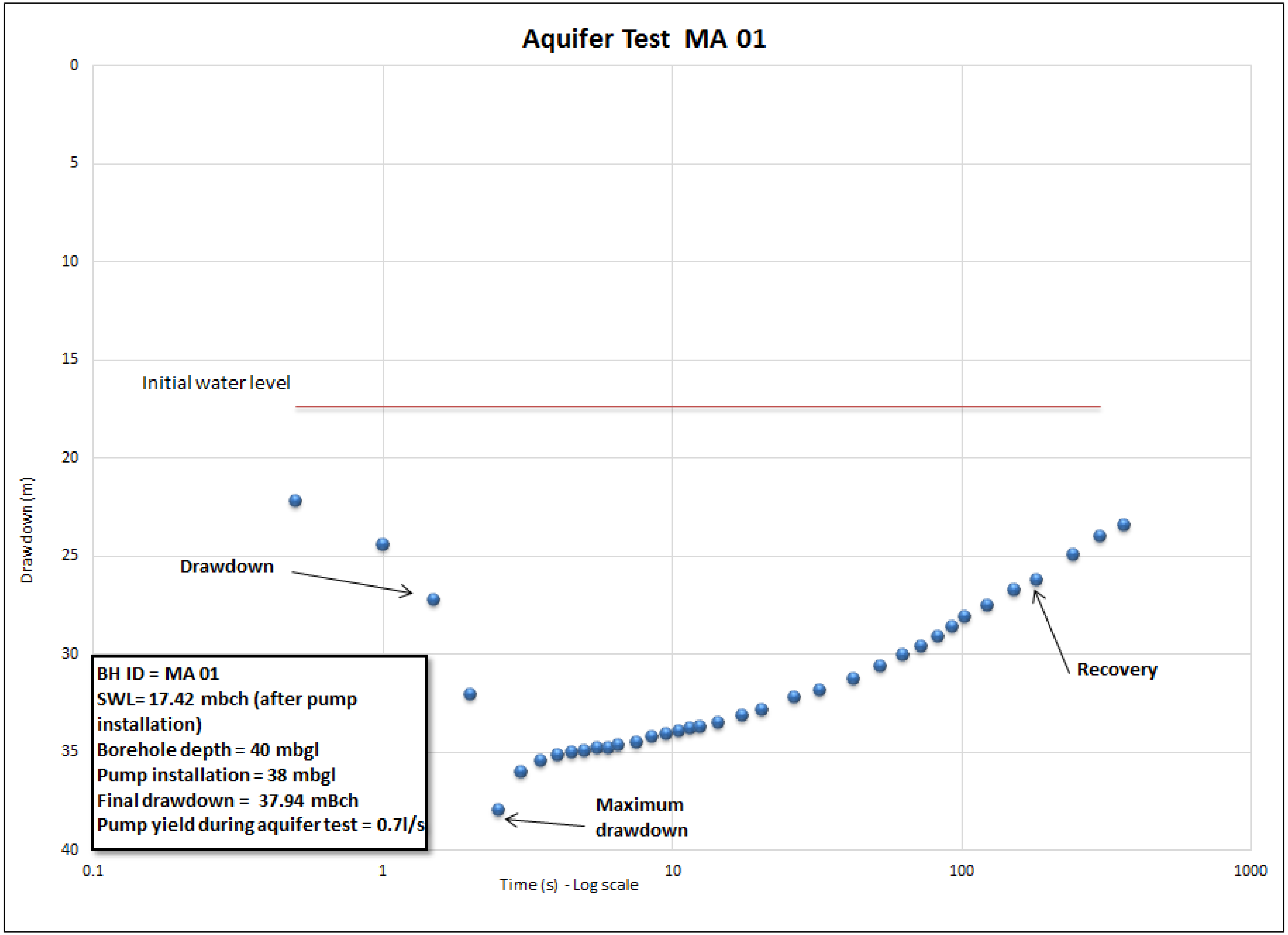


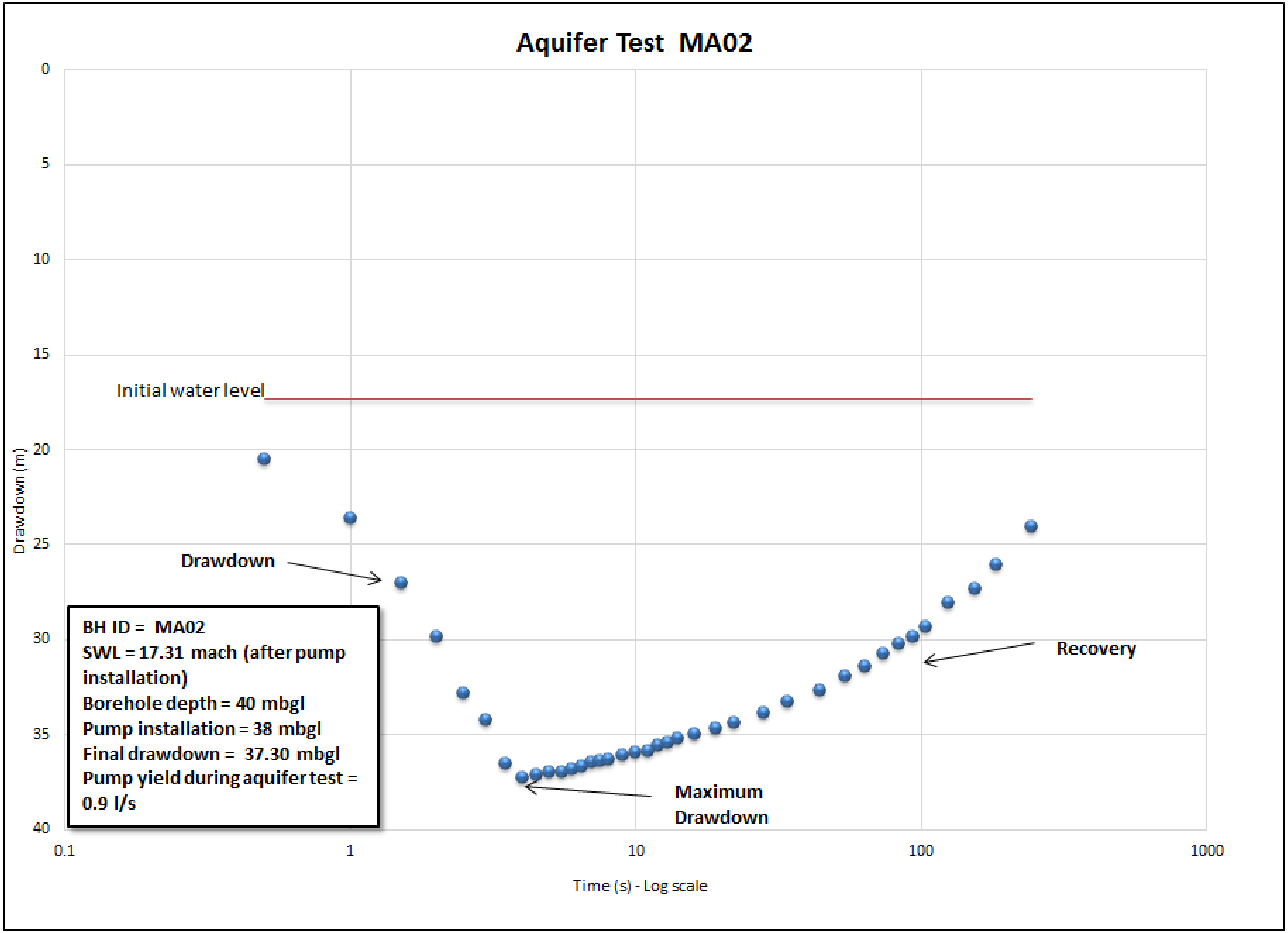
Royal HaskoningDHV Enhancing Society Together

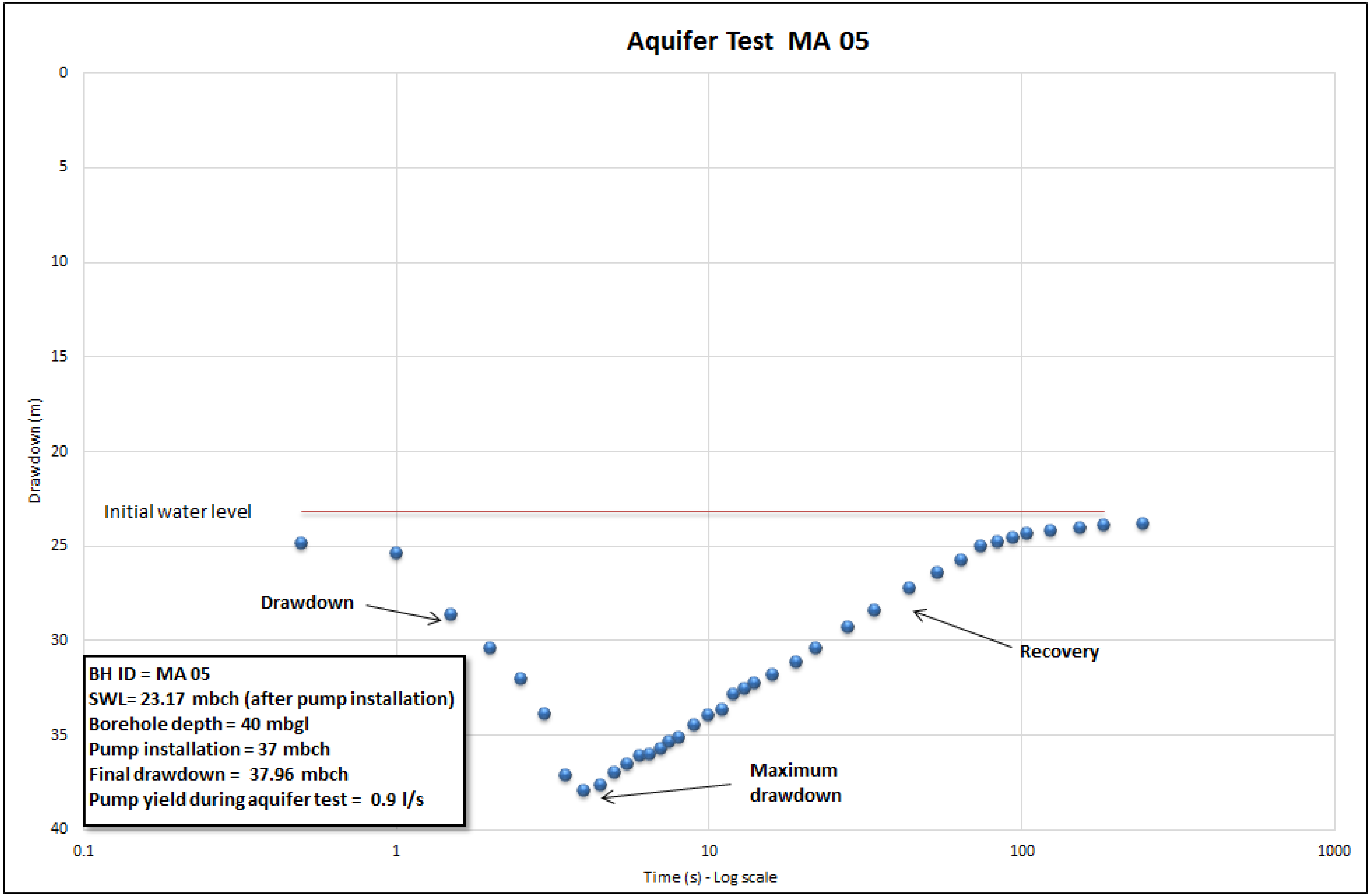
Well Construction Legend

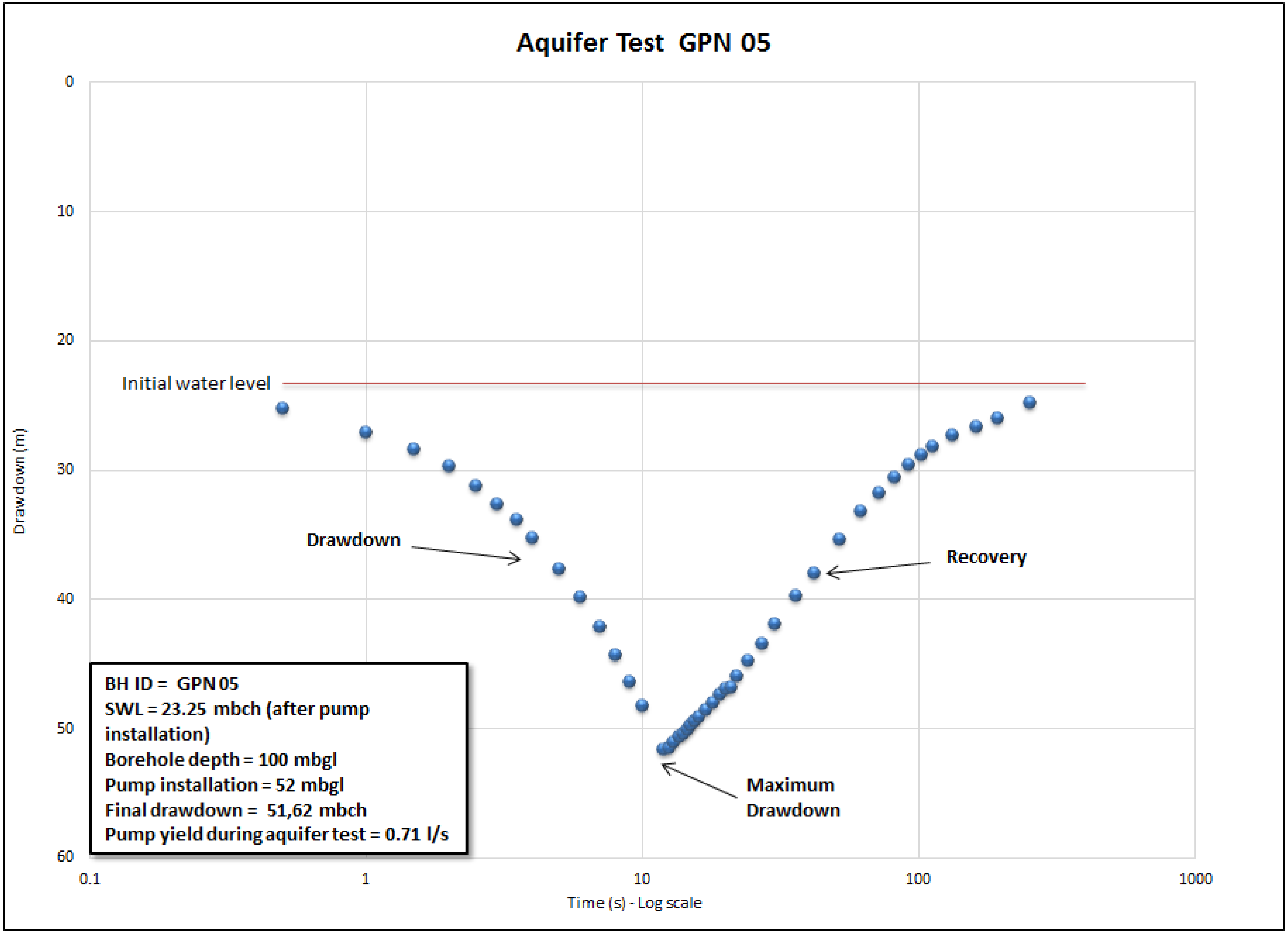
- Casing
- BH diameter
- Fill
- Steel
- Cement
- Cap

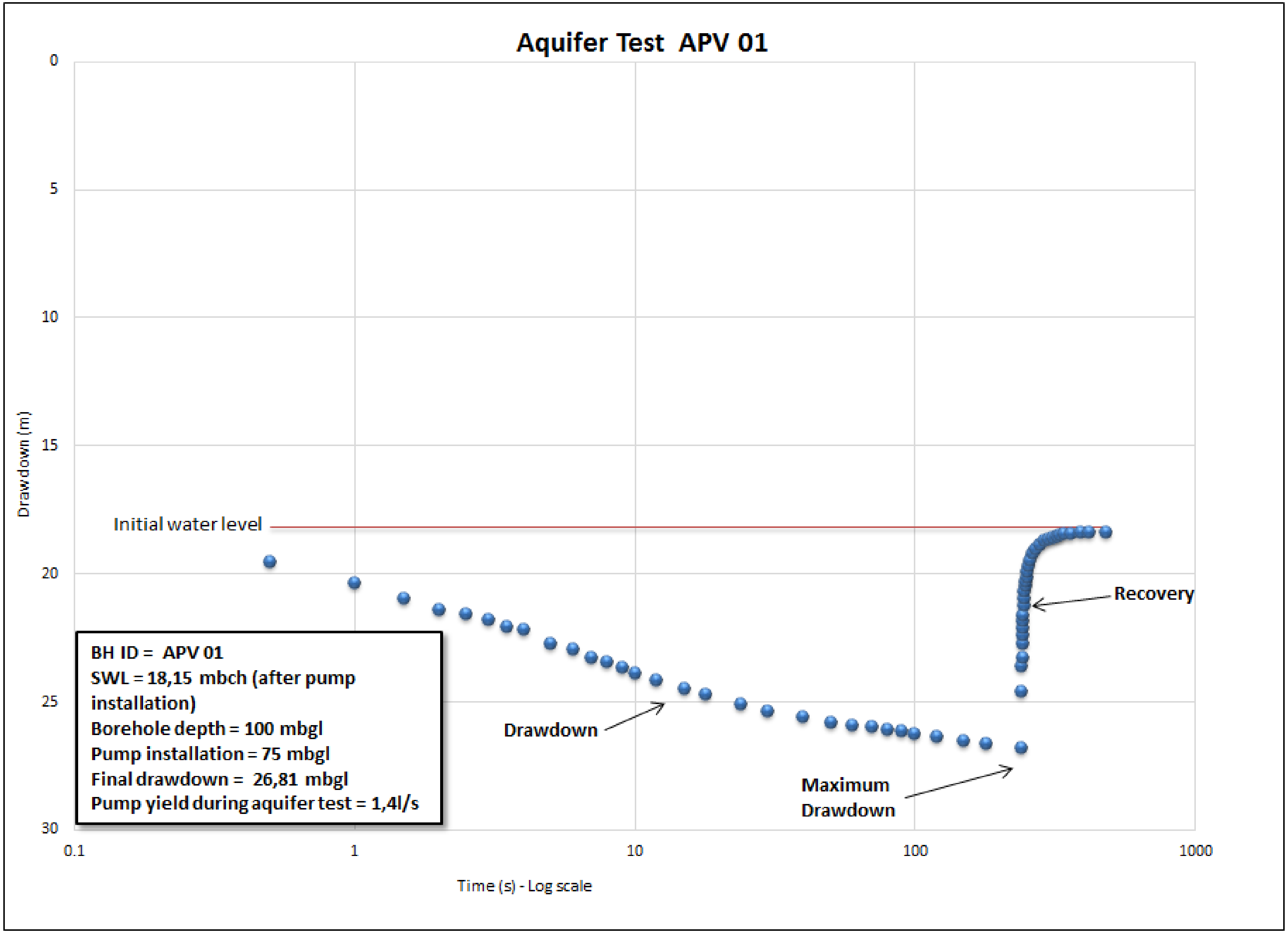
APPENDIX D
AQUIFER TEST DATA



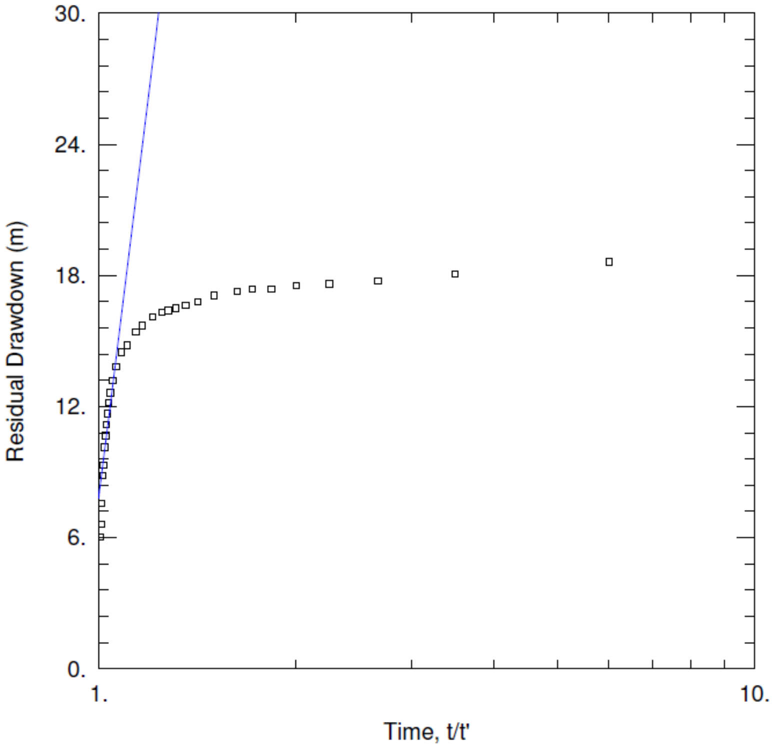

Aquifer Test MA02
Initial water level
Drawdown
Maximum Drawdown
Recovery
BH ID = MA02
SWL = 17.31 mach (after pump installation)
Borehole depth = 40 mbgl
Pump installation = 38 mbgl
Final drawdown = 37.30 mbgl
Pump yield during aquifer test = 0.9 l/s
Drawdown (m)
0
5
10
15
20
25
30
35
40
0.1
1
10
100
1000
Time (s) - Log scale


Aquifer Test MA 05
Drawdown (m)
0
5
10
15
20
25
30
35
40
Initial water level
Drawdown
Recovery
Maximum drawdown
BH ID = MA 05
SWL= 23.17 mbch (after pump installation)
Borehole depth = 40 mbgl
Pump installation = 37 mbch
Final drawdown = 37.96 mbch
Pump yield during aquifer test = 0.9 l/s
0.1
1
10
100
1000
Time (s) - Log scale


Aquifer Test GPN 05
Drawdown (m)
0
10
20
30
40
50
60
0.1
1
10
100
1000
Time (s) - Log scale
Initial water level
Drawdown
Recovery
Maximum Drawdown
BH ID = GPN 05
SWL = 23.25 mbch (after pump installation)
Borehole depth = 100 mbgl
Pump installation = 52 mbgl
Final drawdown = 51,62 mbch
Pump yield during aquifer test = 0.71 l/s


Aquifer Test APV 01
Drawdown (m)
0
5
10
15
20
25
30
0.1
1
10
100
1000
Time (s) - Log scale
Initial water level
Recovery
Drawdown
Maximum Drawdown
BH ID = APV 01
SWL = 18,15 mbch (after pump installation)
Borehole depth = 100 mbgl
Pump installation = 75 mbgl
Final drawdown = 26,81 mbgl
Pump yield during aquifer test = 1,4l/s

APPENDIX E
AQUIFER TEST ANALYSIS



WELL TEST ANALYSIS

Data Set: S:\...\MA1.aqt
Date: 07/25/13 Time: 11:07:27

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: MA1
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MA1	0	0

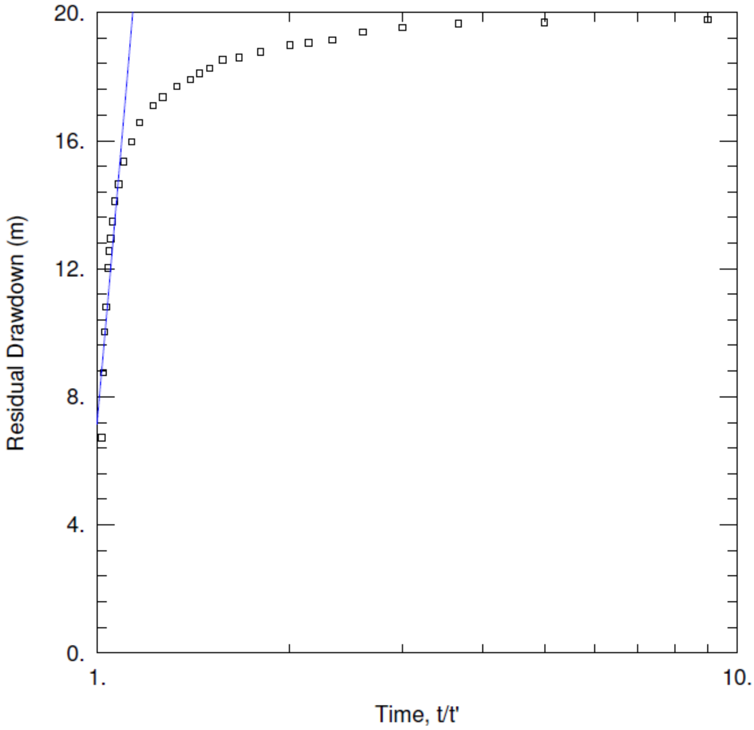
Observation Wells

Well Name	X (m)	Y (m)
▫ MA1	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.04566 m^2/day S/S' = 0.9286



WELL TEST ANALYSIS

Data Set: S:\...\MA2.aqt
Date: 07/25/13 Time: 11:15:34

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: MA2
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MA2	0	0

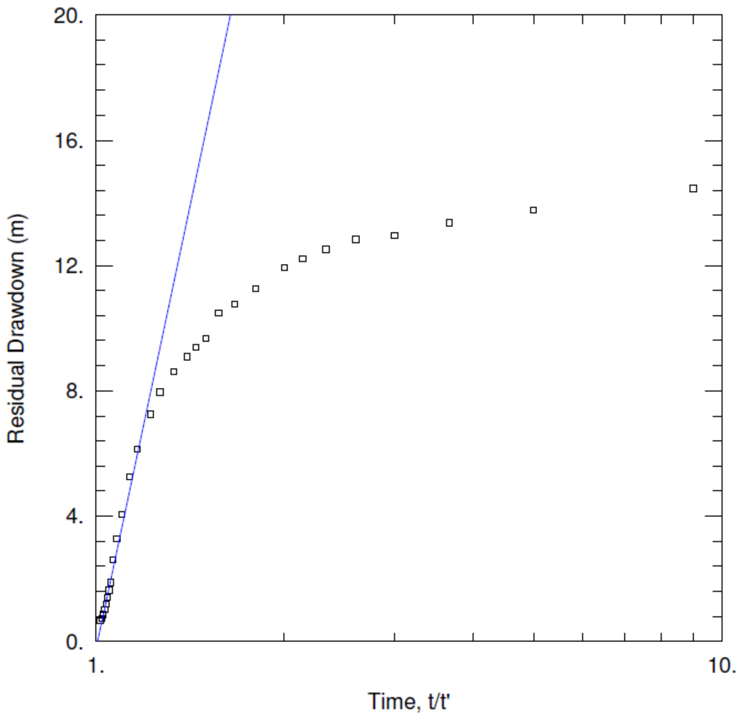
Observation Wells

Well Name	X (m)	Y (m)
▫ MA2	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.06178 m^2/day S/S' = 0.9311



WELL TEST ANALYSIS

Data Set: S:\...\MA5.aqt
Date: 07/25/13 Time: 11:21:47

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: MA5
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MA2	0	0

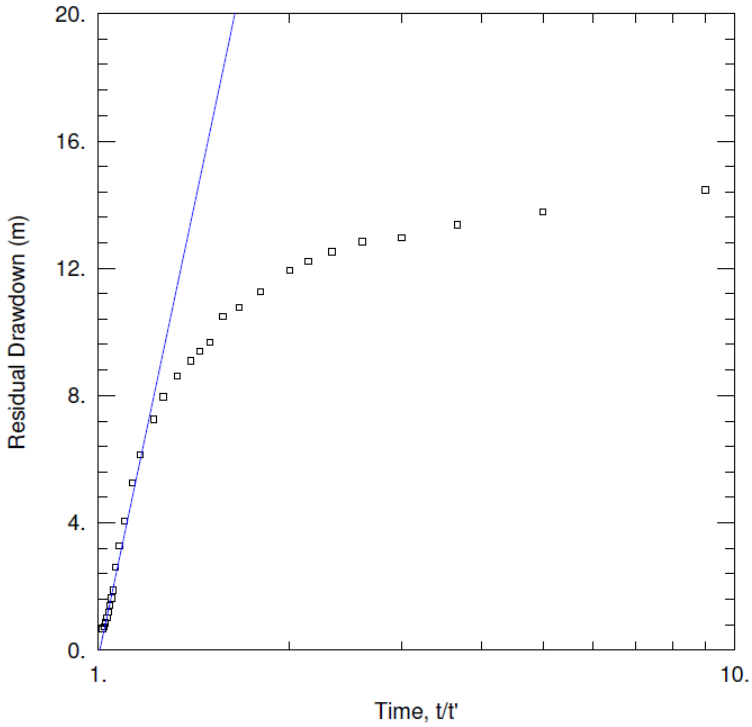
Observation Wells

Well Name	X (m)	Y (m)
▫ MA2	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1511 m^2/day S/S' = 1.007



WELL TEST ANALYSIS

Data Set: S:\...\MA5.aqt
Date: 07/26/13 Time: 08:25:46

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: MA5
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MA5	0	0

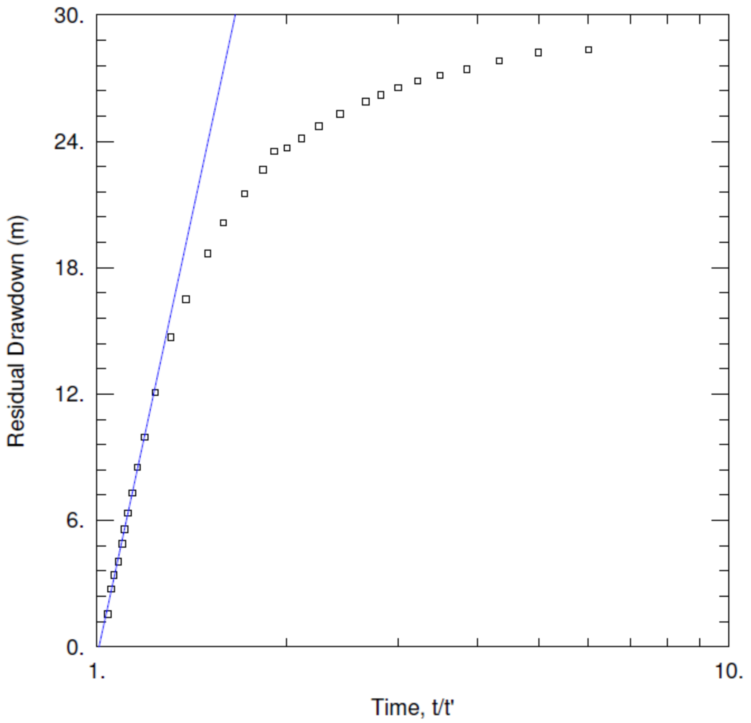
Observation Wells

Well Name	X (m)	Y (m)
▫ MA5	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1511 m^2/day S/S' = 1.007



WELL TEST ANALYSIS

Data Set: S:\...\GPN05.aqt
Date: 07/25/13 Time: 11:26:24

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: GPN05
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
GPN05	0	0

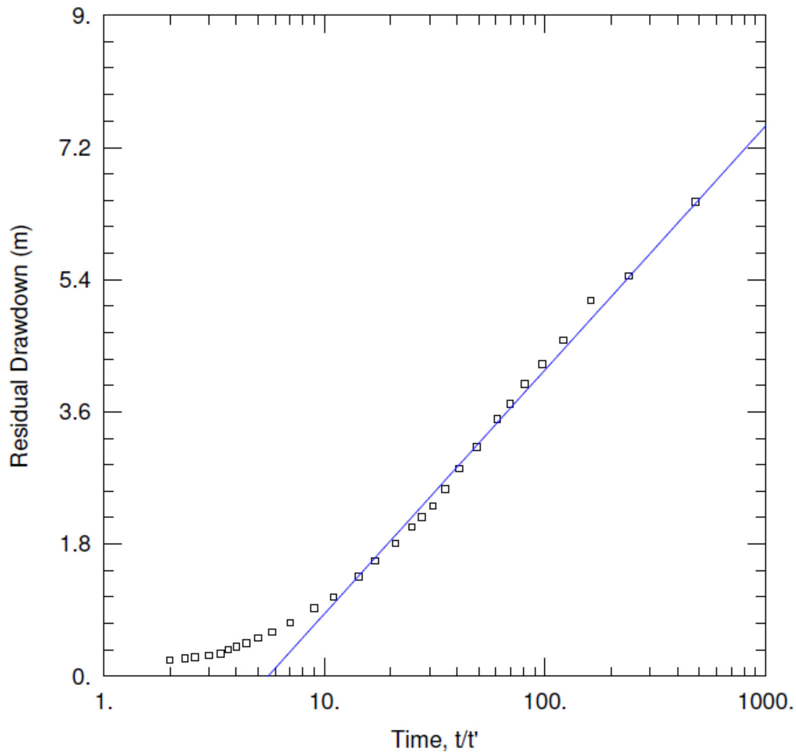
Observation Wells

Well Name	X (m)	Y (m)
▫ GPN05	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1023 m^2/day S/S' = 1.009



WELL TEST ANALYSIS

Data Set: S:\...\APV02.aqt
Date: 07/25/13 Time: 11:22:48

PROJECT INFORMATION

Company: GCS
Client: RHDHV
Project: 12-204
Location: Lephalale
Test Well: APV02
Test Date: July 2013

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
APV02	0	0

Observation Wells

Well Name	X (m)	Y (m)
▫ APV02	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 6.672 m^2/day S/S' = 5.56

APPENDIX F
LABORATORY CHEMISTRY