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ZITHOLELE CONSULTING (PTY) LTD

Hydrogeological Impact Assessment for Medupi Flue Gas Desulphurisation Retrofit Project

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REPORT

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Golder Associates

Executive Summary

Introduction

Golder Associates Africa (Golder) has been appointed by Zitholele Consulting (Pty) Ltd to provide a hydrogeological specialist impact assessment for the Medupi Flue Gas Desulphurisation (FGD) Retrofit Project. This investigation is part of Eskom's Environmental Impact Assessment (EIA), Waste Management Licence (WML) application and Water Use Licence Application (WULA) for the proposed Flue Gas Desulphurisation retrofit to Medupi Power Station.

This document reports on the Impact Assessment for groundwater at the Medupi FGD Retrofit Project as per Scope of Work.

Objectives

The main objectives of the groundwater specialist study are to:

- Characterise the prevailing groundwater situation;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution and flow directions;
- Determine baseline groundwater quality;
- Conduct a *qualitative* assessment of the impact of the proposed Medupi FGD Retrofit Project on the groundwater system; and
- Provide a conceptual model of groundwater impacts.

Scope of Work

The Confirmed scope of work assessed in this DEIR includes assessment of the following activities and infrastructure:

- Construction and operation of a rail yard/siding to transport Limestone from a source defined point via the existing rail network to the Medupi Power Station and proposed rail yard / siding. The rail yard infrastructure will include storage of fuel (diesel) in above ground tanks and 15m deep excavation for tippler building infrastructure;
- Construction and operation of limestone storage area, preparation area, handling and transport via truck and conveyor to the FGD system located near the generation units of the Medupi Power Station;
- The construction and operation of the wet FGD system that will reduce the SO_2 content in the flue gas emitted;
- Construction and operation of associated infrastructure required for operation of the FGD system and required services to ensure optimal functioning of the wet FGD system. The associated FGD infrastructure include a facility for storage of fuel (diesel), installation of stormwater infrastructure and conservancy tanks for sewage;
- The handling, treatment and conveyance of gypsum and effluent from the gypsum dewatering plant. Disposal of gypsum on the existing ADF is not included in the current EIA application and will be addressed in the ADF WML amendment application.
- Pipeline for the transportation of waste water from the gypsum dewatering plant and its treatment at the WWTP that will be located close to the FGD infrastructure within the Medupi Power Station;
- Construction and operation of the WWTP;

- Management, handling, transport and storage of salts and sludge generated through the waste water treatment process at a temporary waste storage facility. In terms of the EIA process impacts related to the management of salts and sludge will be considered in the EIR. However, licencing of the storage activity and requirements relating to the waste storage facility will be assessed in the WML registration application process.
- The transportation of salts and sludge via trucks from the temporary waste storage facility to a final Waste Disposal Facility to be contracted by Eskom for the first 5 years of operation of the FGD system. Long term disposal of salts and sludge will be addressed though a separate independent EIA process to be commissioned by Eskom in future.
- Disposal of gypsum together with ash on the existing licenced ash disposal facility (ADF), with resulting increase in height of the ADF from 60m to 72m.

The following groundwater scope of work was followed for the Medupi FGD Retrofit Project to adhere to the objectives mentioned above:

- Desk Study;
- Site visit and hydrocensus;
- Groundwater sampling x 10 samples;
- Conceptual Hydrogeological model of Medupi FGD Retrofit Project;
- Provide a qualitative assessment of the potential impacts that may be associated with the construction of the proposed rail yard and FGD infrastructure;
- Provide mitigation measures for prevention and/or mitigation of any potential groundwater impacts; and
- Groundwater specialist report.

Groundwater Baseline

Locality

Medupi Power Station is located approximately 17km west of Lephalale and 6km SW of Matimba Power Station on the farm Naauwontkomen 509LQ, Limpopo Province. The Medupi FGD Retrofit Project fall within the A42J quaternary catchment area.

Climate and Rainfall

Climate

The climate of Medupi Power Station and surrounding regions is characterised by hot, moist summers and mild, dry winters. The area experiences high temperatures in the summer months, with daily maximum temperatures exceeding 40 degrees on a regular basis.

The occurrence of frost is rare during winter, but occurs occasionally in most years, but usually not severely (IGS 2008).

Rainfall

The long-term annual average rainfall for the study area is 429.1mm as measured since 1977 to 2007, of which 90% falls between October and March (SA Weather Service, 2008).

Geology

Local Geology

The local geology of the area can be subdivided into a northern and southern type. The Matimba Power station and all its facilities, except for the ash dump, as well as Grootegeluk Mine, lies on Karoo sediments. The existing licensed disposal facility, Medupi Power Station and the Matimba ash dump lie on Waterberg sandstone, just south of the Eenzaamheid fault.

The existing licensed disposal facility and Medupi Power Station are underlain by the sediments of the Waterberg Group (siliclastic red bed successions). This is part of the up-thrown sediments comprising the fining upward conglomerate-quartzites facies assemblages of the Mogalakwena Formation. The Waterberg sediments are somewhat recrystallised and fully oxidised; hence the hardness and red colour of the rock. A thin but permeable layer of sandy topsoil overlies it (IGS 2008).

Regional Hydrogeology

Regional Hydrogeology

Two distinct and superimposed groundwater systems are present in the geological formations of the coal fields in South Africa, as described by Hodgson and Grobbelaar (1999). They are the upper weathered aquifer and the system in the fractured rock below (IGS 2008).

Weathered Aquifer System

The top 5-15 m normally consists of soil and weathered rock. The upper aquifer is associated with the weathered horizon. In boreholes, water may often be found at this horizon. The aquifer is recharged by rainfall.

Fractured Aquifer System

The grains in the fresh rock below the weathered zone are well cemented, and do not allow significant water flow. All groundwater movement therefore occurs along secondary structures such as fractures, cracks and joints in the rock. These structures are best developed in sandstone and quartzite; hence the better water-yielding properties of the latter rock type. Dolerite sills and dykes are generally impermeable to water movement, except in the weathered state.

Hydrocensus

A total of 17 boreholes were surveyed during a hydrocensus conducted in September 2015 at Medupi FGD Retrofit Project and surrounding area. The 16 water levels were measured ranging between 4.41 to 69.98mbgl (metres below ground level), whereas the average water level is 30.4mbgl.

All coordinates were measured with a hand-held GPS using the WGS 84 reference datum.

Groundwater samples were collected at 10 of these boreholes, as per Golder’s standard sampling procedures and submitted to Waterlab Laboratories in Pretoria an accredited laboratory.

Hydrocensus Groundwater Quality

The following constituents of the hydrocensus groundwater samples exceed the SANS 241 (2011) maximum allowable standard:

- EC, boreholes BU02 and BU03;
- TDS, boreholes BU02 and BU03;
- Na, boreholes BU02 and GE03;
- Cl, boreholes BU01, BU02 and BU03;
- N, boreholes BU02 and BU03. These two boreholes have elevated Nitrate values (Class III; 16mg/l and IV; 66mg/l respectively). This water quality poses chronic health risks is and represents poor and unacceptable water quality. The elevate nitrate concentrations is probably related to point source pollution caused by animal farming and stockades;
- Al, boreholes KR01,KR03 and KR05;
- F, boreholes BU01, BU02,BU03 and KR03;
- Fe, boreholes KR01,KR05, BU02, VER05 and GE01; and
- Mn, borehole BU02.

Baseline Groundwater Quality

The baseline groundwater quality of the Medupi FGD Retrofit Project area is based on macro chemistry analyses of the sampled hydrocensus boreholes. The concentrations are compared to the SANS 241:2011 water quality standard and the baseline quality are represented by the Median of the concentrations. The baseline water quality of the combined sampled boreholes is summarised in table below.

Baseline Groundwater Quality

Item	Physical Parameters			Macro Determinants (Major Ions and Trace Metals)								Minor Determinant		
	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	MALK Mg/l	F mg/l	Fe mg/l	Mn mg/l
No. of Records	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10% Percentile	5.67	15.35	112.8	6.165	1.9525	11.804	2.5892	16.2	5	0.2	8	0.2	0.0408	0.0421
Median Baseline water Quality	**7.3**	**75.8**	**450**	**27.66**	**21.385**	**80.285**	**6.7065**	**101.5**	**38**	**0.25**	**242**	**1.1**	**1.5715**	**0.106**
Average	7	103.19	642.2	57.1504	30.3111	105.095	10.1201	207	34.3	8.58	201.2	1.3	2.5966	0.1782
90% Percentile	7.53	212.4	1377.6	140.5	67.629	203.87	18.855	532.6	62.9	21	357.2	2.34	6.6366	0.3691
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5

Aquifer Recharge

The Chloride Ratio Method was used to estimate the aquifer recharge for the Medupi FGD Retrofit Project area. Recharge =1.8 % of the MAP 429.1mm =7.7mm per annum. This recharge value (7.7mm) is slightly lower but more site specific than the values indicated on the published hydrogeological maps as 10 to 15mm per annum.

Groundwater Conceptual Model

The conceptual model is based on two distinct types of aquifers which are present in the geological formations of the coal fields in South Africa:

- Upper weathered aquifer system; and
- Fractured weathered aquifer system.

Existing Groundwater Monitoring Boreholes

Groundwater quality and water levels are currently monitored by Eskom at Medupi Power station at 30 existing boreholes. Some of these boreholes are positioned around the Medupi FGD Retrofit Project area and could act as monitoring boreholes for the facility. However, three of these boreholes (MBH08. MBHO9 and MBH07) are dry or water levels are too low to sample.

The water quality of the existing boreholes is largely poor quality, with classes ranging from Class 0 to Class IV, water quality.

Groundwater Levels and Flow Directions

From available data and previous groundwater studies, the groundwater flow from the Medupi FGD Retrofit Project is primarily away from the site, towards the east/south-east and northeast towards the non-perennial Sandloop River.

Groundwater Risk Rating

The Medupi FGD Retrofit Project area scores a risk rating of 16 and poses a moderate risk of impacting on the surrounding groundwater regime. Possible impacts on the groundwater need to be investigated further.

These ratings are consistent with the National vulnerability map of South Africa prepared by the WRC (Water Research Commission), using the DRASTIC methodology.

Impact Assessment Medupi FGD Project Area

In order to address the amended scope of work for Medupi FGD (2017) the following SOW are included based on the Impact assessment methodology provided by Zitholele:

- Construction and operation of the FGD system within the Medupi Power Station Footprint;
- Construction and operation of the railway yard/siding and diesel storage facilities, and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF;
- A qualitative opinion on impact on groundwater, if any, if ash and gypsum is disposed together on the existing ADF considering the ADF will have an appropriate liner since both ash and gypsum is classified as type 3 wastes; and
- Provide a qualitative opinion whether groundwater could potentially be impacted with the construction of the FGD within the Medupi PS footprint. From the aerial view it is evident that the entire Medupi GD footprint area is disturbed during the construction activities at the power station.

The potential groundwater impacts that the **FGD system** and the **operation of the railway yard/siding, diesel storage facilities** and **limestone and gypsum handling facilities between the Medupi Power Station and existing ADF**, poses to the groundwater regime are discussed as follows for the different phases:

- Existing impacts – these are current activities that potentially have an impact on the groundwater regime. These activities include Matimba Power Station and ADF, Medupi Power station and the existing licensed disposal facility, however Grootegeluk mine are excluded due to the Eenzaamheid fault serving as a barrier to interactions.
- Cumulative impacts - **include the existing activities plus the FGD system** and **the operation of the railway yard/siding, diesel storage facilities and limestone** and **gypsum handling facilities between the Medupi Power Station and existing ADF**; and
- Residual impacts- are the post-mitigation activities. This rating considers the cumulative impacts when proposed mitigation measures are effectively implemented.

The existing activities and the FGD system pose the following potential impacts on the groundwater:

- A change in the groundwater quality;
- A change in the volume of groundwater in storage or entering groundwater storage (recharge); or
- A change in the groundwater flow regime.

Potential Impacts from the FGD System

Groundwater Quality

The predicted impacts from the FGD system on the ambient groundwater quality is:

- Of Moderate significance during pre-construction, construction and operational phases; and
- Low significance during the decommissioning phase.

Groundwater Volume and Flow Regime

The construction and operation of the FGD system, is expected to have a minor change in the volume of water entering groundwater storage (reduced recharge in comparison to status quo conditions) and with negligible changes expected in the groundwater flow regime.

The predicted impact of the FGD system on the groundwater volume and flow is:

- Of Low significance during pre-construction phase and Low to moderate during the construction and operational phases. The significance during the decommissioning phase is Low.

Potential Impacts from the Railway Yard/siding, diesel storage facilities and Limestone and gypsum handling facilities between the Medupi Power Station and existing ADF

Groundwater Quality

The predicted impacts from the railway yard/siding, diesel storage facilities and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the ambient groundwater quality is:

- Of Low significance during pre-construction and of moderate significance during the construction and operational phases; and
- Low of significance during the decommissioning phase.

Groundwater Volume and Flow Regime

The predicted impact that the railway yard/siding, diesel storage facilities and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the groundwater volume and flow may have include:

- Of Low significance during pre-construction phase and of low to moderate significance during the construction phase. The significance during the operational and decommissioning phases is of Low significance.

Professional Opinion on trucking of Type 1 waste to Hazardous Disposal Facility

For the first five (5) years of the operational phase, sludge and salts will be stored at a temporary waste storage facility, after which it will be trucked to a licensed hazardous waste disposal site. During transportation of hazardous waste, the trucking contractor should adhere to all regulations and standards of both environmental and mining acts. Safe working procedures (SWP) for transportation of hazardous waste must be in place, to minimize the risk of contamination to the environment and groundwater should a spillage occur.

A hazardous spillage could contaminate the groundwater, and samples of any nearby boreholes should be analysed and monitored after a spillage incident. Storage of the Type 1 waste (hazardous waste) on site may result in risks to contamination the groundwater regime. This risk can be managed by ensuring that construction is done to good quality, after the facility is registered, and prepared in line with NEMWA Norms and Standards for Storage of Waste. Trucking of Type 1 waste to a licensed hazardous waste disposal site is effectively would effect a positive impact on site.

Possible impacts on the groundwater regime associated with trucking process of Type 1 waste, to a licensed hazardous waste disposal site are based on a simplified groundwater risk assessment and are presented in the table below. The risk rating is based on a possible risk/impact that activities from the trucking process of type 1 waste poses to the groundwater regime. Assessment is based on positive and negative outcome of impact/risk to the groundwater regime.

Activity	Positive Impacts	Negative Impacts
Removal of hazardous waste from temporary waste storage facility	Removal of contamination source	None
Transportation of hazardous waste to a licensed hazardous waste disposal site	Removal and transportation of hazardous waste	None
Spillage during transportation of hazardous waste	None	Contamination of groundwater and impacting on existing users in vicinity of spillage
Disposal of hazardous waste	Disposal of hazardous waste	None

Qualitative Opinion on Impact on Groundwater, if Ash and Gypsum is Disposed together on the Existing ADF

The existing licensed disposal facility is designed for a 50 year life period and will have a liner that is designed according to the appropriate waste classification of the ash. The liner for the facility will be installed at appropriate frequencies, e.g. every two years. This is to reduce risk of damage to the liner due to exposure for long periods of time.

Considering that the ADF is proposed to have a Class C liner, in line with waste classification as per the NEMWA GNXX, since both ash and gypsum classified as Type 3 wastes will be disposed, the disposal of ash and gypsum together will probably not have a significant impact on the groundwater regime. This rehabilitation of WDF approach serves as a mitigation measure against groundwater contamination and poses a minimal risk of contamination on the groundwater.

Qualitative Opinion whether Groundwater could potentially be impacted with the Construction of the FGD within the Medupi Power Station Footprint

During any construction phase involving disturbing of top soil by earth moving equipment and trucks, possible spillage could occur which could contaminate the groundwater. This contamination, however, will be point source only and within the site boundaries.

Safe working procedures (SWP) for construction work must be in place, to minimize the risk of contamination to the environment and groundwater should a spillage occur. Any accidental spillage should be cleaned up immediately to limit contamination and if intensity is high, the impact must be reversed with the applicable mitigation and management actions.

The potential impact whether groundwater could potentially be impacted with the Construction of the FGD within the Medupi Power Station Footprint is considered as a low to moderate significance.

Conclusions

The following groundwater conclusions are made from the investigation and available data for the Medupi FGD Project:

- The existing licensed disposal facility is mainly underlain by Waterberg sediments comprising of sandstone, subordinate conglomerate, siltstone and shale;
- The initial regional groundwater conceptual model identifies two aquifer zones namely weathered, and fractured aquifer zones, but needs to be confirmed and updated, supported by future test pumping and borehole logs;
- The average groundwater level measured during the hydrocensus for the area of investigation is 30.4mbgl;

- Based on the hydrocensus water quality analyses , the background groundwater quality of the existing licensed disposal facility is Marginal (Class II) to Poor (Class III - IV) water Quality;
- Only boreholes GE06 and VER02 groundwater quality are representative of calcium magnesium bicarbonate type of water (Ca, Mg–(HCO_3). This water type represents unpolluted groundwater (mainly from direct rainwater recharge) and are probably representative of the pristine background water quality;
- The following inorganic constituents as identified during the hydrocensus exceed the SANS 241 (2011) drinking water compliance standards EC, TDS, Na, Cl, N, Al, F, Fe and Mn;
- The groundwater vulnerability of the existing licensed disposal facility proposed is shown on the national groundwater vulnerability map as low to medium;
- According to simplified groundwater risk rating assessment, the existing licenced disposal facility have a risk rating of 16, and poses a moderate risk of impacting on the surrounding groundwater regime. Possible impacts on the groundwater need to be investigated further;
- Following a decision by ESKOM to utilize the existing licenced disposal facility, a qualitative impact assessment was conducted on this site. Gypsum and ash are to be disposed on the existing licenced disposal facility;
- Based on the qualitative impact assessment, the existing activities and the licensed disposal facility poses the following potential impacts on the groundwater system:
  - A change in the groundwater quality;
  - A change in the volume of groundwater in storage or entering groundwater storage (recharge); or
  - A change in the groundwater flow regime.
- The predicted impacts from the FGD system (2017 SOW) on the ambient groundwater quality is:
  - Of Moderate significance during pre-construction, construction and operational phases; and
  - Low significance during the decommissioning phase.
- The predicted impact of the FGD system on the groundwater volume and flow is:
  - Of Low significance during pre-construction phase and Low to moderate during the construction and operational phases. The significance during the decommissioning phases are Low.
- The predicted impacts from the railway yard and limestone and gypsum handling facilities (2017 SOW) between the Medupi Power Station and existing ADF activities on the ambient groundwater quality is:
  - Of Low significance during pre-construction and of Moderate significance during the construction and operational phases; and
  - Low of significance during the decommissioning phase.
- The predicted impact the railway yard and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the groundwater volume and flow is:
  - Of Low significance during pre-construction phase and of Low to Moderate significance during the construction phase. The significance during the operational and decommissioning phases are of Low significance.

Recommendations

Following the groundwater baseline and IA investigation the following is recommended:

- Monthly monitoring of exiting Eskom monitoring boreholes groundwater levels and quality. Monitoring should be conducted to be consistent with the existing WUL (Licence no.: 01 /A1042/ABCEFGI/5213);

- Monitoring boreholes MBH08, MBHO9 and MBH07 which are dry or water level are too low to sample and need to be replaced to ensure monitoring coverage in these areas;
- Aquifer testing of new monitoring boreholes to determine hydraulic parameters and update initial groundwater conceptual model. The groundwater conceptual model with aquifer parameters provide the basic input into a groundwater numerical model;
- Groundwater sampling of newly drilled monitoring boreholes;
- The newly-drilled monitoring boreholes should be incorporated into the existing monitoring programme. The following monitoring tasks should be conducted to be consistent with the existing WUL Licence no.: 01 /A1042/ABCEFGI/5213;
- Bi-annually groundwater monitoring of existing groundwater user's boreholes in the area surrounding the existing licensed disposal facility (In radius of ~ 3.0 km).
- Development of a numerical groundwater flow & transport model (or update of existing models) and Impact Assessment. This model to include Medupi Power station (MPS) and the Medupi FGD Project;
- Use model predictions to predict the pollution plume from the Medupi FGD Project area and Medupi Power station;
- Update mitigation and management measures for the Medupi FGD Project on numerical model outcome and predictions.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Golder Associates Africa (Golder) has been appointed by Zitholele Consulting (Pty) Ltd to provide a hydrogeological specialist impact assessment for the Medupi Flue Gas Desulphurisation (FGD) Retrofit Project. This investigation is part of Eskom's Environmental Impact Assessment (EIA), Waste Management Licence (WML) application and Water Use Licence Application (WULA) for the proposed Flue Gas Desulphurisation retrofit to Medupi Power Station.

This document reports on the Impact Assessment for groundwater at the Medupi FGD Retrofit Project as per Scope of Work.

2.0 STUDY AREA

The Medupi FGD Retrofit Project is located within a radius of 10 km from the existing Medupi Power Station, Lephalale.

3.0 OBJECTIVES

The main objectives of the groundwater specialist study are to:

- Characterise the prevailing groundwater situation;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution and flow directions;
- Determine baseline groundwater quality;
- Conduct a *qualitative* assessment of the impact of on the groundwater system; and
- Provide a conceptual model of groundwater impacts.

4.0 SCOPE OF WORK

The Confirmed scope of work assessed in this DEIR includes assessment of the following activities and infrastructure:

- Construction and operation of a rail yard/siding to transport Limestone from a source defined point via the existing rail network to the Medupi Power Station and proposed rail yard / siding. The rail yard infrastructure will include storage of fuel (diesel) in above ground tanks and 15m deep excavation for tippler building infrastructure;
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the management of salts and sludge will be considered in the EIR. However, licencing of the storage activity and requirements relating to the waste storage facility will be assessed in the WML registration application process.

- The transportation of salts and sludge via trucks from the temporary waste storage facility to a final Waste Disposal Facility to be contracted by Eskom for the first 5 years of operation of the FGD system. Long term disposal of salts and sludge will be addressed though a separate independent EIA process to be commissioned by Eskom in future.
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The following groundwater scope of work was followed for the Medupi FGD Retrofit Project to adhere to the objectives mentioned above:

- Desk Study;
- Site visit and hydrocensus;
- Groundwater sampling x 10 samples;
- Conceptual Hydrogeological model of Medupi FGD Retrofit Project;
- Provide a qualitative assessment of the potential impacts that may be associated with the construction of the proposed rail yard and FGD infrastructure;
- Provide mitigation measures for prevention and/or mitigation of any potential groundwater impacts; and
- Groundwater specialist report.

5.0 GROUNDWATER BASELINE

5.1 Locality

Medupi Power Station is located approximately 17km west of Lephalale and 6km SW of Matimba Power Station on the farm Naauwontkomen 509LQ, Limpopo Province (Figure 1). The Medupi FGD Retrofit Project area fall on the A42J quaternary catchment area.

5.2 Topographical Setting

5.2.1 Existing Licensed Disposal Facility

The topography of the Medupi FGD Retrofit Project area slopes gently to the east and the site falls within the A42J quaternary catchment area (Figure 1). The maximum elevation on existing licensed disposal facility is to the west of the site and is indicated as 913 mamsl. The site slopes gently at ~ 0.3% towards the east. The fall from west to east along the site is ~ 10m. The lowest point on site is ~903 mamsl.

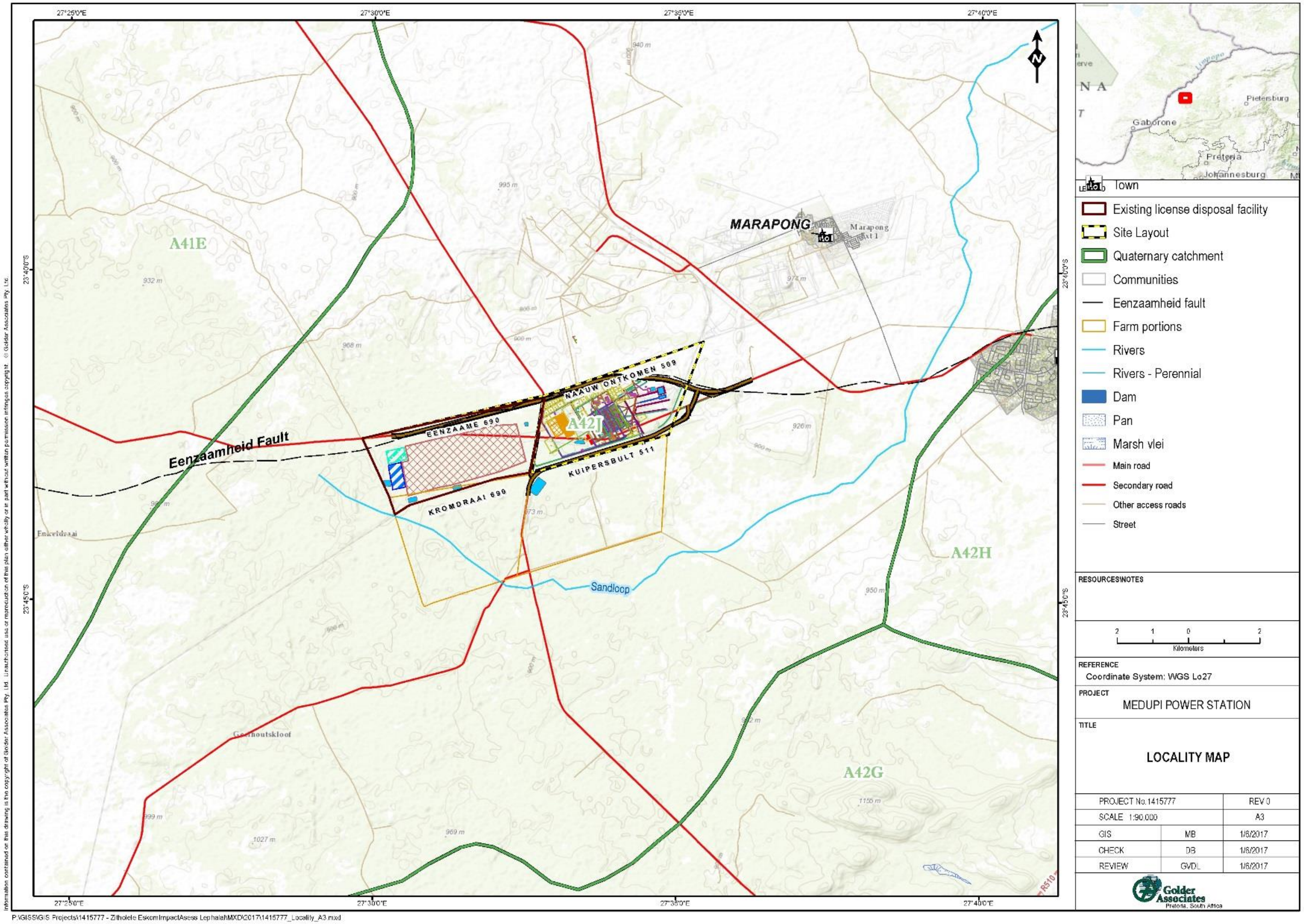

Figure 1: Locality Map

5.3 Climate and Rainfall

5.3.1 Climate

The climate of Medupi Power Station and surrounding regions is characterised by hot, moist summers and mild, dry winters. The area experiences high temperatures in the summer months, with daily maximum temperatures exceeding 40 degrees on a regular basis.

The occurring of frost is rare during winter, but occurs occasionally in most years, but usually not severely (IGS 2008).

5.3.2 Rainfall

The long-term annual average rainfall for the study area is 429.1mm (Figure 2) measured since 1977 to 2007, of which 90% falls between October and March (SA Weather Service, 2008).

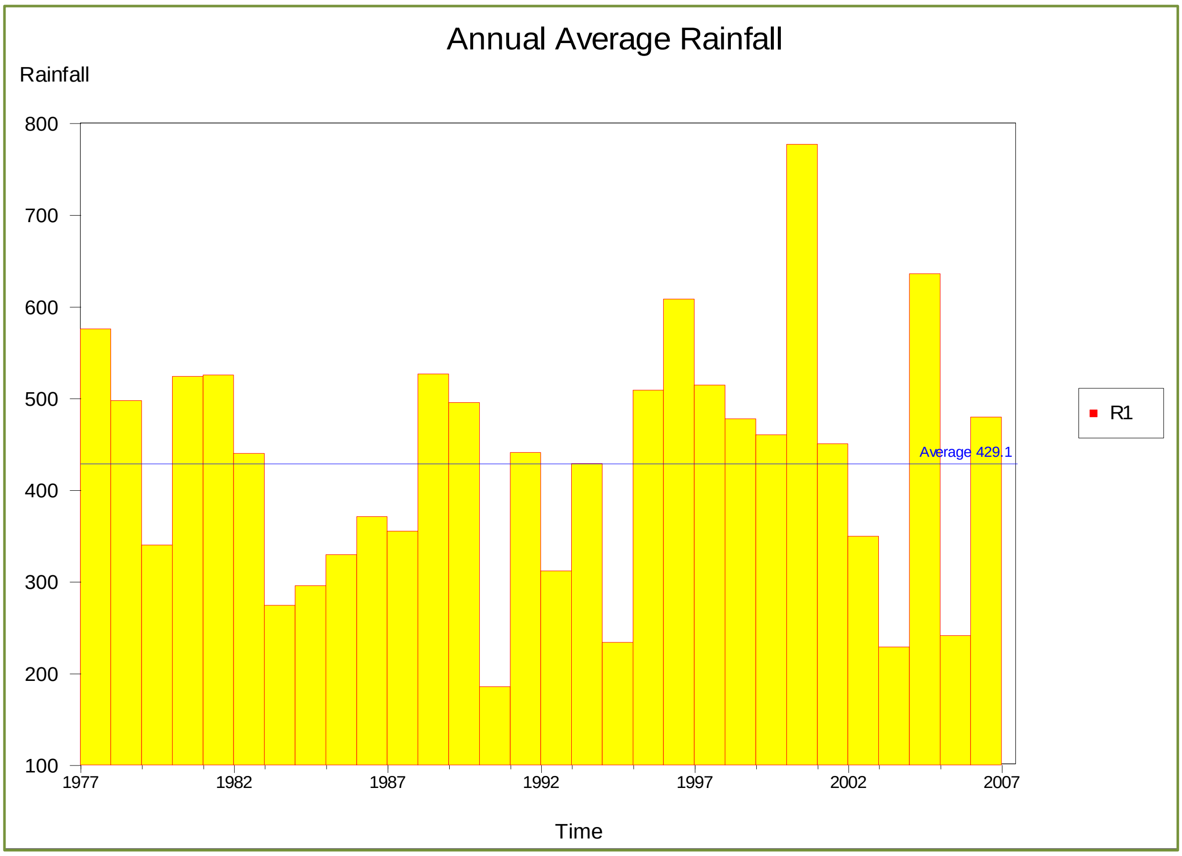

Figure 2: Annual Rainfall for the Medupi Area, Weather Bureau (IGS 2008)

5.4 Geology

5.4.1 Regional Geology

Based on 1:250 000 geological map series 2326, Ellisras (Council for Geoscience), the regional geology in the area is characterised by sedimentary rocks of the Karoo Supergroup (Figure 3). The Waterberg Coalfield is composed of sediments of the Karoo Supergroup and forms a graben structure, bound in the north by the Zoetfontein fault and in the south by the Eenzaamheid fault (Figure 3). The Daarby fault subdivides the coalfield into the shallow open-cast able western part of the coalfield and the deeper north-eastern part of the coalfield (IGS 2008).

The Zoetfontein fault resulted from pre-/during Karoo depositional tectonism, whilst the Eenzaamheid and Daarby faults resulted from post-Karoo depositional tectonism. All the units of the Karoo Supergroup are present in this coalfield, and the subdivision of the Karoo Sequence is mainly based on lithological boundaries, consisting, from top to bottom, of the Stormberg Group (Letaba), followed by the Beaufort

Group, the Ecca Group and the Dwyka Group. The Waterberg Group represents the basin depositional floor, which is mainly composed of the Paleoproterozoic (mokolian) quartzites, arkoses and conglomerates. Regionally, the Waterberg sediments rest on the rocks of the Transvaal Sequence (IGS 2008).

5.4.2 Structural Geology

The Daarby fault is a major north-east, then north-west trending fault, assumed to be part of one set of events, as both legs exhibit the same throw and throw direction. Thus both faults are combined into one name. The Daarby fault has a down throw of 360m to the north, and the fault dips at an angle of between 50^{o} and 60^{o} to the north. It serves to bring the up-thrown Beaufort and Ecca Groups to the south into contact with the down-thrown Letaba, Clarens, Elliott and Molteno formations to the north (IGS 2008).

The Eenzaamheid fault (Figure 3), situated south of the Daarby fault, and has a throw of 250m to the north, bringing the up-thrown Waterberg sediments on the southern side of the fault into contact with the down-thrown Beaufort and Ecca groups on the northern side of the fault. The angle of the Eenzaamheid fault is near vertical (IGS 2008).

5.4.3 Local Geology

The local geology of the area can be subdivided into a northern and southern type. The Matimba Power station and all its facilities, except for the ash dump, as well as Grootegeluk Mine, lies on Karoo sediments. The existing licensed disposal facility, Medupi Power Station and the Matimba ash dump lie on Waterberg sandstone, just south of the Eenzaamheid fault (Figure 4).

The existing licensed disposal facility and Medupi Power Station is underlain by the sediments of the Waterberg Group (siliclastic red bed successions). This is part of the up-thrown sediments comprising the fining upward conglomerate-quartzites facies assemblages of the Mogalakwena Formation. The Waterberg sediments are somewhat recrystallised and fully oxidised; hence the hardness and red colour of the rock. A thin but permeable layer of sandy topsoil overlies it (IGS 2008).

5.4.3.1 Medupi FGD Retrofit Project Geology

The Medupi FGD Retrofit Project area is intersected by the EW trending Eenzaamheid Fault near the northern boundary (Figure 4). This regional fault separates the Waterberg rocks from the Karoo strata to the north.

South of the fault the site is generally overlain by sandy soil at surface. On the southern side of the Eenzaamheid fault, below the sandy soil the site is underlain by Waterberg sediments (Figure 4) comprising of sandstone, subordinate conglomerate siltstone and shale.

The portion of the existing licensed disposal facility site north of the Eenzaamheid fault zone is underlain by Karoo sediments of the Beaufort and Ecca groups, comprising of mudstones, sandstone, grit, siltstone, carbonaceous shale and coal.

This Eenzaamheid fault zone could act as a preferred groundwater flow path.

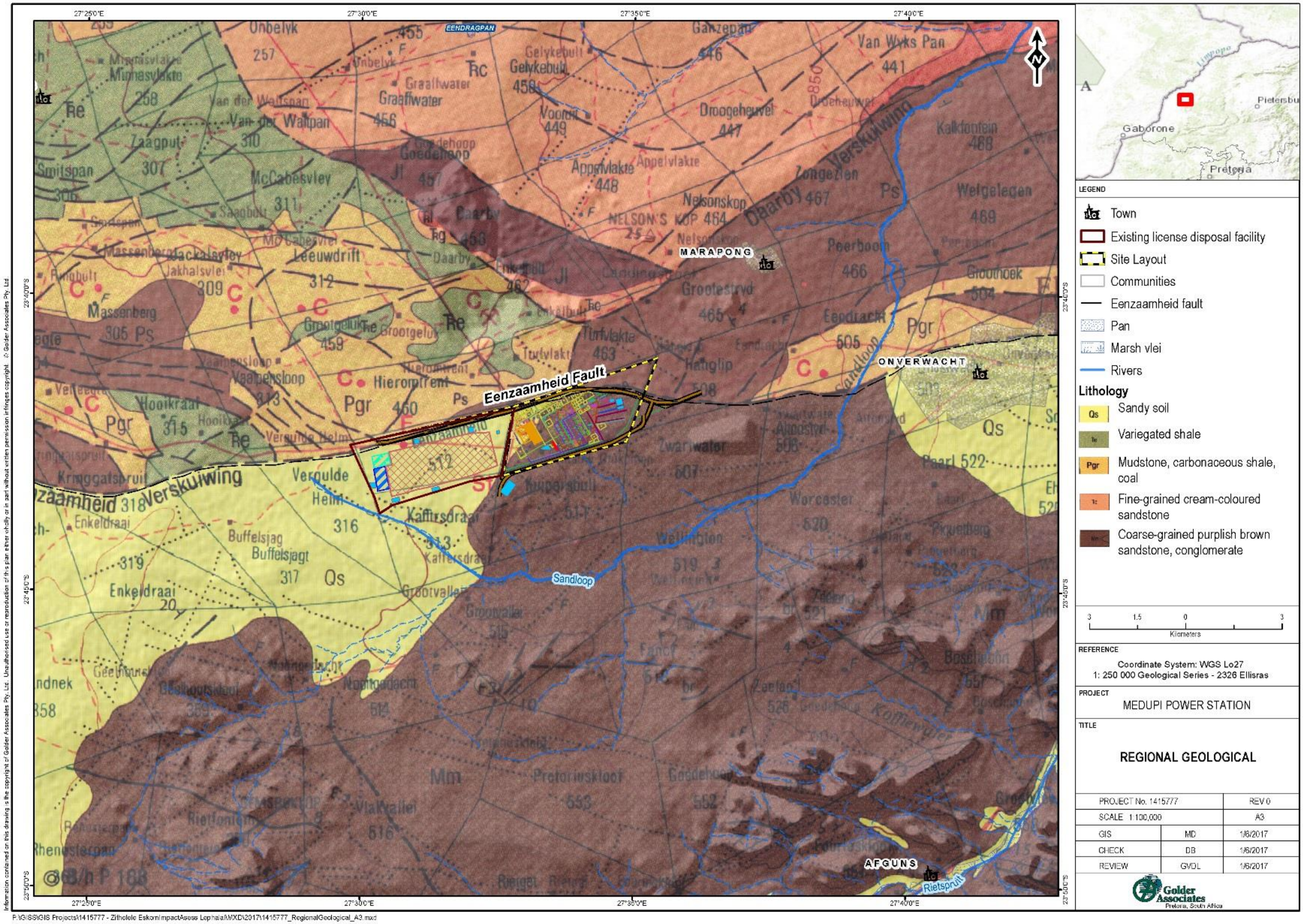

Figure 3: Regional Geology

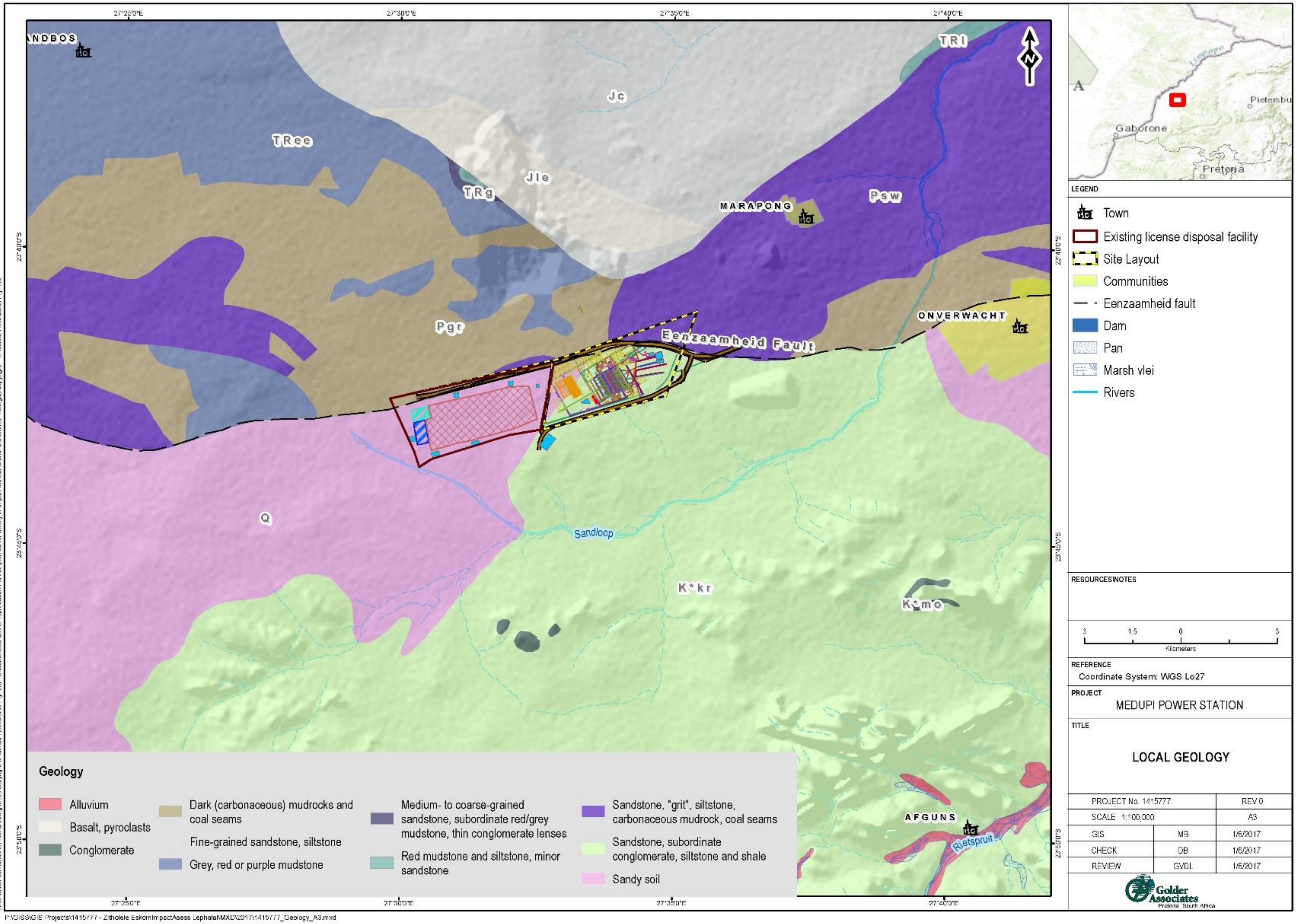

Figure 4: Local Geology

5.5 Regional Hydrogeology

5.5.1 Aquifer Systems

Two distinct and superimposed groundwater systems are present in the geological formations of the coal fields in South Africa, as described by Hodgson and Grobbelaar (1999). They are the upper weathered aquifer and the system in the fractured rock below (IGS2008).

5.5.1.1 Weathered Aquifer System

The upper 5-15 m of the weathered aquifer system normally consists of soil and weathered rock. The upper aquifer is associated with the weathered horizon. In boreholes, water may often be found at this horizon. The aquifer is recharged by rainfall.

Rainfall that infiltrates into the weathered rock reaches impermeable layers of solid rock underneath the weathered zone. Movement of groundwater on top of the solid rock is lateral and in the direction of the surface slope. This water reappears on surface at fountains, where the flow paths are obstructed by barriers such as dolerite dykes, paleo-topographic highs in the bedrock, or where the surface topography cuts into the groundwater level at streams; the Waterberg coalfields area is drier than most other coal areas, and the effect will be less significant. It is suggested that less than 60% of the water recharged to the weathered zone eventually emanates in streams (Hodgson and Krantz, 1998). The rest of the water is evapotranspirated or drained by other means (IGS2008).

The weathered zone is generally low-yielding, because of its insignificant thickness. Few farmers therefore tap this water by boreholes. The quality of the water is normally excellent and can be attributed to many years of dynamic groundwater flow through the weathered sediments. Leachable salts in this zone have been washed from the system long ago (IGS2008).

5.5.1.2 Fractured Aquifer System

The fractured aquifer system (~ 15 to 40m) present in the fresh rock below the weathered zone are well cemented, and do not allow significant water flow. All groundwater movement therefore occurs along secondary structures such as fractures, cracks and joints in the rock. These structures are best developed in sandstone and quartzite; hence the better water-yielding properties of the latter rock type. Dolerite sills and dykes are generally impermeable to water movement, except in the weathered state.

In terms of water quality, the fractured aquifer always contains higher salt loads than the upper weathered aquifer. The higher salt concentrations are attributed to a longer contact time between the water and rock (IGS2008).

5.6 Hydrocensus

A hydrocensus as was conducted during September 2015 at the Medupi FGD Retrofit Project and surrounding area is indicated on Figure 5. A total of 17 boreholes were surveyed and are summarised in Table 1.

The objective of the hydrocensus was to:

- Locate private owned boreholes and springs;
- Determine the status of existing boreholes;
- Borehole use and equipment;
- Record GPS coordinates of boreholes;
- Measure static water levels; and
- Collect representative groundwater samples to determine current baseline groundwater quality.

The hydrocensus was conducted on accessible farms and surrounding areas. Three boreholes KR01, KR02 (blocked), KR03 were located on the farm Kromdraai to the south of the Medupi FGD Retrofit Project area. KR01 is used for domestic all-purpose whereas KR03 is used for stock watering.

The 14 remaining hydrocensus boreholes are located to the west and south west of the Medupi FGD Retrofit Project area (Figure 5), on the farms surrounding the existing licensed disposal facility. Groundwater in the investigation area is mainly used for domestic and stock watering purposes, with no irrigation use reported.

From the available groundwater flow data, the inferred groundwater flow is primarily westwards and towards the Sandloop River from the Medupi FGD Retrofit Project area. Any contamination plume originating from the Medupi FGD Retrofit Project area will disperse towards groundwater users in these directions, impacting the groundwater quality negatively. Should it be proven that the existing licensed disposal facility have negatively impacted the groundwater quality, existing groundwater users will have to be provided with an alternative water supply.

Towards the north of Medupi FGD Retrofit Project area, the Eenzaamheid fault will probably prevent contamination spreading north and dewatering from Grootegeluk mine to affect the investigation area and existing groundwater users.

The 17 water levels that were measured during the hydrocensus area, range between 4.41 to 69.98mbgl (metres below ground level), whereas the average water level is 30.4mbgl.

All coordinates were measured with a hand-held GPS using the WGS 84 reference datum.

Groundwater samples were collected at 10 of these boreholes as indicated on Figure 7. These samples were collected as per Golder's standard sampling procedures and submitted to Waterlab Laboratories in Pretoria an accredited laboratory.

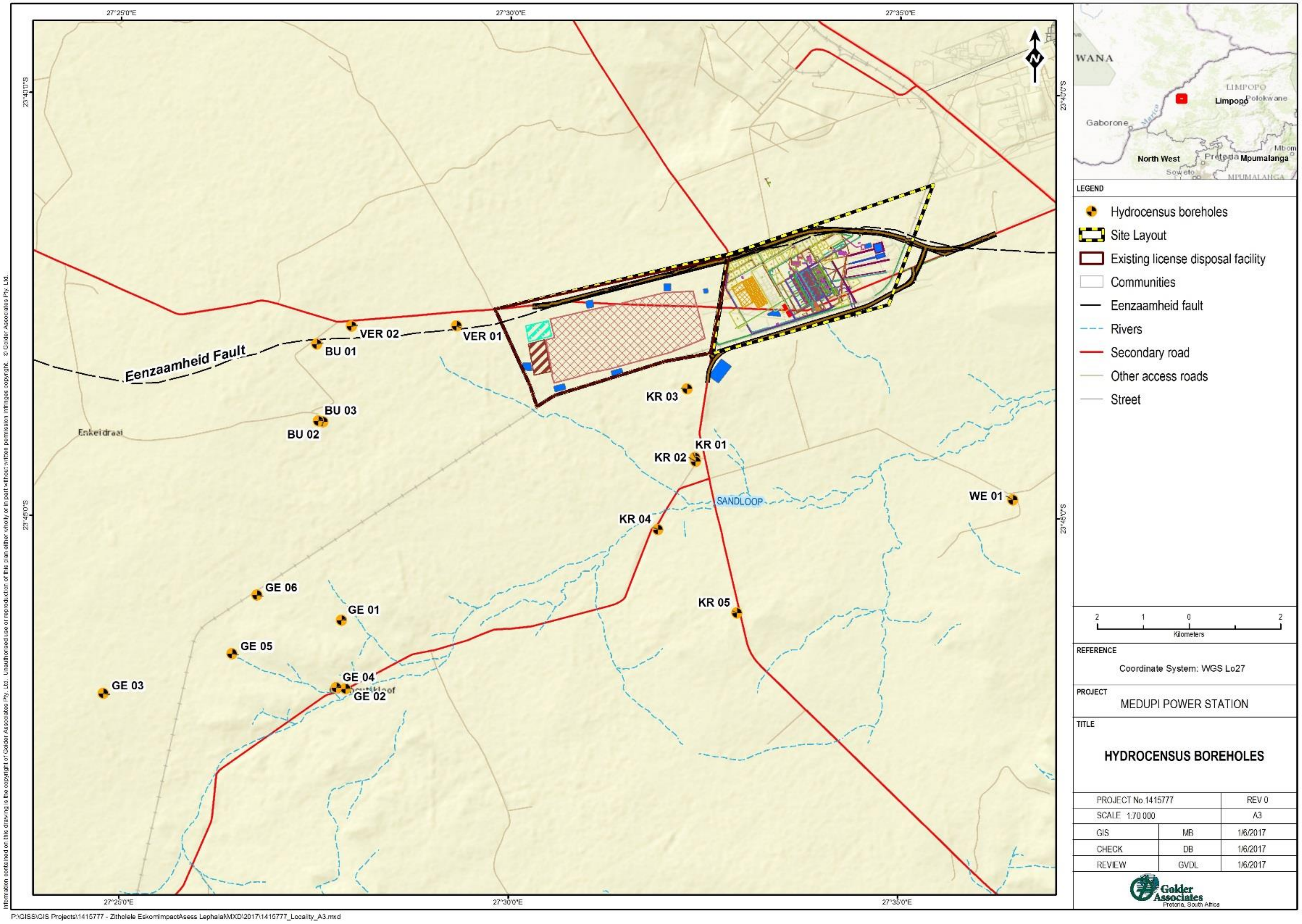

Figure 5: Hydrocensus Borehole Positions

Table 1: Hydrocensus Boreholes

Borehole No. on Map	Latitude	Longitude	Site Name	Owner	Equipment	Diameter (mm)	SWL (mbgl)	Use	Condition of Facility
BU 01	-23.71608	27.45864	BUFFELSJAGT	-	Submersible	165	59.18	Domestic/All purpose	Working
VER 01	-23.71242	27.48856	VERGULDE HELM	Hendri Hills	None	165	42.32	Unused	Open
VER 02	-23.71256	27.46608	VERGULDE HELM	Hendri Hills	Submersible	-	69.99	Domestic/All purpose	Working
BU 02	-23.73142	27.46008	BUFFELSJAGT	-	Submersible	165	64.63	Domestic/All purpose	Working
BU 03	-23.73122	27.45906	BUFFELSJAGT	-	Submersible	165	66.98	Domestic/All purpose	Working
GE 01	-23.77053	27.46417	GEELHOUTSKLOOF	-	None	165	13.88	Unused	Open
GE 02	-23.78397	27.46506	GEELHOUTSKLOOF	-	Submersible	165	9.47	Domestic/All purpose	Working
GE 03	-23.78503	27.41322	GEELHOUTSKLOOF	-	Submersible	165	55.56	Domestic/All purpose	Working
GE 04	-23.78378	27.46308	GEELHOUTSKLOOF	-	Windmill	165	9.17	Unused	Broken
GE 05	-23.77717	27.44075	GEELHOUTSKLOOF	-	Submersible	165	9.78	Domestic/All purpose	Not Working
GE 06	-23.76558	27.44603	GEELHOUTKLOOF	-	Submersible	165	24.21	Stock Watering	Working
KR 01	-23.73822	27.53972	KROMDRAAI	Eskom (Lessee Mr Etienne Rossouw)	Submersible	165	4.41	Domestic/All purpose	Working
KR 02	-23.73897	27.53986	KROMDRAAI	Eskom (Lessee Mr Etienne Rossouw)	None	165	Blocked	Unused	Open
KR 03	-23.72469	27.53794	KROMDRAAI	Eskom (Lessee Mr Etienne Rossouw)	Submersible	165	15.28	Stock Watering	Working
KR 04	-23.75239	27.53183	KROMDRAAI	Eskom (Lessee Mr Etienne Rossouw)	None	165	5.72	Unused	Open
KR 05	-23.76881	27.54878	KROMDRAAI	Eskom (Lessee Mr Etienne Rossouw)	Submersible	165	26.62	Domestic/All purpose	Working
WE 01	-23.74628	27.60775	WELLINGTON	Chris Booysen	Windmill	165	8.82	Unused	Not Working
Minimum							4.41		
Maximum							69.99		
Average							30.4		

5.7 Groundwater Quality

The published hydrogeological maps (DWAF 1996) indicate the average Electrical conductivity (EC) at the existing licensed disposal facility in the range of 70-300mS/m, this value is higher than the SANS 241:2011 drinking water compliance limit of 170mS/m (Figure 6).

5.7.1 Baseline Groundwater Quality, 2015

A total of 10 groundwater samples were collected in the investigation area during the hydrocensus (Figure 7). The hydrocensus was conducted on accessible farms and surrounding area of the existing licensed disposal facility.

These samples were collected as per Golder's standard sampling procedures submitted to Waterlab Laboratories in Pretoria an accredited laboratory.

The objective of the groundwater sampling was to determine the baseline groundwater quality of the investigation area and water quality (class) of existing groundwater users.

The Analytical Result Certificates of the samples taken during hydrocensus are attached in Appendix A.

5.7.2 Groundwater Chemical Parameters

The groundwater samples were analysed for the following constituents:

- pH, EC, TDS, Total Alkalinity;
- Standard cations Ca, Mg, Na, K;
- Standard anions Cl, SO4, NO_3; and
- ICP-MS Scan for soluble metals.

5.7.3 Water quality Standards

The analytical results of the groundwater samples were compared to the following standards;

- Department of Water Affairs and Forestry, domestic water quality guidelines, volume 1,1996 and Water Research Commission, water quality guidelines, 1998;
- South African National Standards, drinking water standards, 2011 (SANS 241:2011); and
- South African Water Quality Guidelines (SAWQG), Volume 5: Agricultural Use – Livestock Watering (DWAF, 1996).

The SANS 241:2011 drinking water standard is used as reference in Table 3, whereas the DWAF 1998 guidelines were used to classify water quality classes (Table 2).

Table 2: DWAF Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

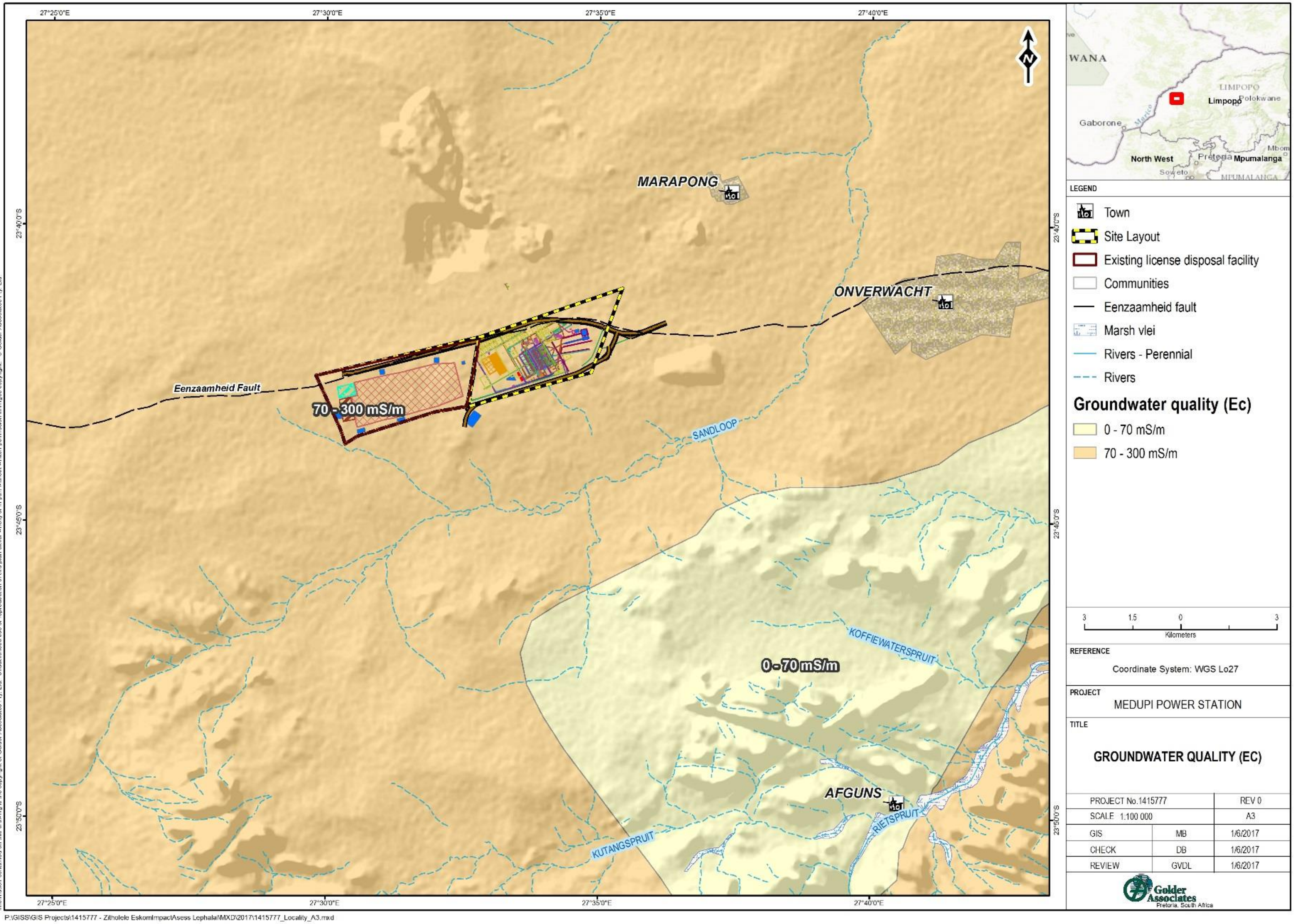

Figure 6: Hydrogeological Map Series Average Groundwater Electrical conductivity (EC) Values

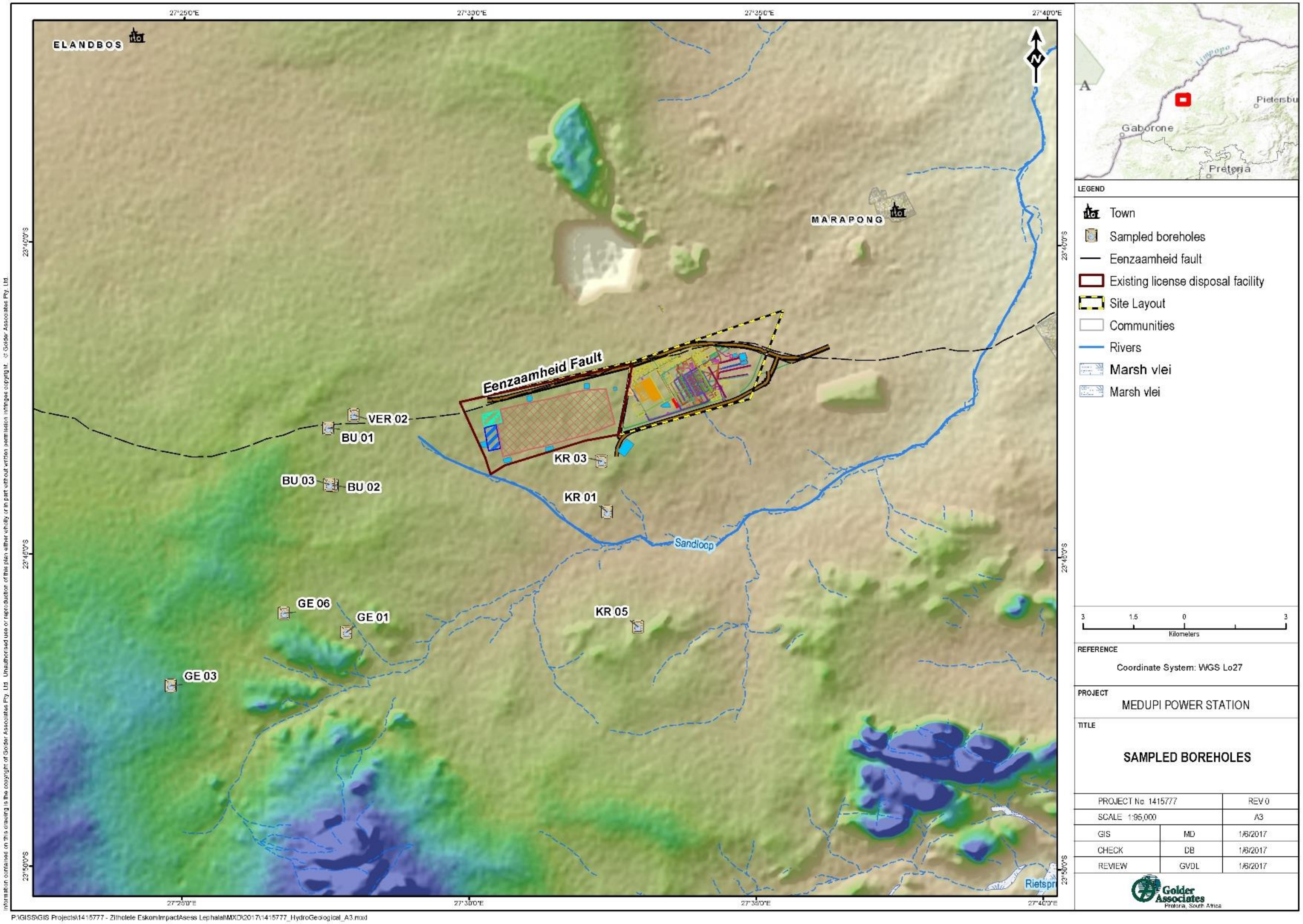

Figure 7: Sampled Boreholes

5.7.4 Groundwater Analytical Results

The analytical results (major cations and anions) of sampled boreholes are listed in Table 3. A highlighted value in red exceeds the SANS 241:2011 maximum allowable limit, whereas the water quality classes are classified using the DWAF (1998) drinking water standards (black highlighted values exceeding class I).

The following constituents of the groundwater samples exceed the SANS 241 (2011) maximum allowable standard:

- EC, boreholes BU02 and BU03;
- TDS, boreholes BU02 and BU03;
- Na, boreholes BU02 and GE03;
- Cl, boreholes BU01, BU02 and BU03;
- N, boreholes BU02 and BU03. These two boreholes have elevated Nitrate values (Class III; 16mg/l and IV; 66mg/l respectively). This water quality poses chronic health risks is and represents poor and unacceptable water quality. The elevate nitrate concentrations is probably related to point source pollution caused by animal farming and stockades;
- Al, boreholes KR01,KR03 and KR05;
- F, boreholes BU01, BU02,BU03 and KR03;
- Fe, boreholes KR01,KR05, BU02, VER05 and GE01; and
- Mn, borehole BU02.

The constituents of borehole GE06 are all below the SANS 241 (2011) maximum allowable standard, and are representing a Class 0 water quality.

The boreholes with elevated EC, TDS, Na, Cl, Al, F, Fe and Mn concentrations are probably related to the geology of the surrounding area.

None of the sampled boreholes have elevated SO_4 concentrations above background groundwater quality levels.

Table 3: Hydrocensus Analytical Results

Borehole Number	Physical Determinants			Chemical Determinants												Water Quality Class
	pH	EC (mS/m)	TDS (mg/l)	MALK (mg/l)	Ca (mg/l)	K (mg/l)	Mg (mg/l)	Na (mg/l)	Cl (mg/l)	NO_3 as N (mg/l)	SO_4 (mg/l)	Al (mg/l)	F (mg/l)	Fe (mg/l)	Mn (mg/l)	
KR05	7.3	31	180	160	14.57	2.601	<2	52.47	9	<0.2	8	**0.715**	0.3	**2.143**	0.044	III
BU03	7.3	**288**	**1896**	292	**186.4**	22.59	**95.25**	**237.8**	**664**	**66**	62	0.1	**2.2**	0.108	<0.025	IV
KR01	5.7	15.7	116	8	6.462	6.399	3.619	11.21	25	<0.2	24	**0.576**	**0.9**	**7.056**	0.068	I
KR03	5.4	27.4	198	8	11.26	6.992	5.197	23.29	36	2	51	**2.207**	**2.7**	0.566	**0.138**	III
BU02	7.5	**204**	**1320**	288	**135.4**	16.99	64.56	**194.8**	**518**	**16**	36	0.255	**2.2**	**6.59**	**0.775**	III
VER02	7.4	**112**	**652**	356	77.3	15.34	34.14	**108.1**	**167**	0.5	40	<0.100	1.3	**3.614**	**0.324**	III
BU01	7.5	**178**	**1058**	368	81.3	18.44	54.05	**194.4**	**336**	<0.2	71	0.103	**2.3**	**1**	0.09	II
GE03	7.8	**124**	**670**	276	23.38	6.421	16.57	**200.1**	**280**	<0.2	41	<0.100	0.7	0.042	**0.122**	II
GE01	7.1	12.2	84	48	3.492	2.483	1.525	16.91	18	<0.2	<5	0.13	<0.2	**4.817**	**0.131**	III
GE06	7	39.6	248	208	31.94	2.945	26.2	11.87	17	0.3	<5	<0.100	<0.2	0.03	0.065	0
SANS241: 2011 Max. Allowable Limit	9.7	<170	1200	-	-	-	-	200	300	11	500	0.3	1.5	0.3	0.5	
Class 0 Max. Allowable Limit	9.5	<70	<450	-	<80	<25	<70	<100	<100	<6	<200	-	<0.7	<0.01	<0.1	0
Class 1 Max. Allowable Limit	10	150	1000	-	150	50	100	200	200	10	400	-	0.7-1.0	0.01-0.2	0.1-0.4	I
Class 2 Max. Allowable Limit	10.5	370	2400	-	300	100	200	400	600	20	600	-	1.0-1.5	0.2-2.0	1.0-4.0	II
Class 3 Max. Allowable Limit	11	520	3400	-	>300	500	400	1000	1200	40	1000	-	1.5-3.5	2.0-10.0	4.0-10.0	III
Class 4 Max. Allowable Limit	>11	>520	>3400	-		>500	>400	>1000	>1200	>40	>1000	-	>3.5	>10.0	>10.0	IV
South African Water Quality Guidelines (SAWQG), Volume 5 – Agricultural Use – Livestock Watering Target Range	-	154	1000	-	1000	-	500	2000	1500	1000	100	5.0	2.0	10	10	
Minimum	5.4	12.2	84	8	3.492	2.483	<2	11.2	9	<0.2	<5	<0.100	<0.2	0.030	<0.025	
Maximum	7.8	288	1896	368	186.4	22.59	95.250	237.8	664	66.0	71	2.207	2.7	7.056	0.775	
Average	7	103.19	642.2	201.2	57.1504	10.1201	30.311	105.1	207	8.6	34	0.439	1.3	2.597	0.178	

5.7.5 Baseline Groundwater Quality

The baseline groundwater quality of the Medupi FGD Retrofit Project area is based on macro chemistry analyses of the hydrocensus sampled boreholes. The concentrations are compared to the SANS 241:2011 water quality standard and the baseline quality are represented by the Median of the concentrations. The baseline water quality of the combined sampled boreholes are summarised in Table 4 below.

Table 4: Baseline Groundwater Quality

Item	Physical Parameters			Macro Determinants (Major Ions and Trace Metals)								Minor Determinant		
	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3 mg/l	MALK Mg/l	F mg/l	Fe mg/l	Mn mg/l
No. of Records	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10% Percentile	5.67	15.35	112.8	6.165	1.9525	11.804	2.5892	16.2	5	0.2	8	0.2	0.0408	0.0421
Median Baseline water Quality	**7.3**	**75.8**	**450**	**27.66**	**21.385**	**80.285**	**6.7065**	**101.5**	**38**	**0.25**	**242**	**1.1**	**1.5715**	**0.106**
Average	7	103.19	642.2	57.1504	30.3111	105.095	10.1201	207	34.3	8.58	201.2	1.3	2.5966	0.1782
90% Percentile	7.53	212.4	1377.6	140.5	67.629	203.87	18.855	532.6	62.9	21	357.2	2.34	6.6366	0.3691
Max. Allowable Limit (SANS 241:2011)	<5 >9	<170	<1200	<300	<100	<200	<100	<300	<500	<11	-	<1.5	<0.3	<0.5

5.7.6 Groundwater Classification

The groundwater quality results of sampled boreholes are visually represented on Piper and expanded Durov diagrams to distinguish between the different water quality classes/types.

Piper Diagrams

Piper diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the left triangle and the anion percentages in the right triangle. A projection of these cation and anion presentations onto the central diamond presents the chemical signature of the major ion composition of the water.

The sampled boreholes GE06 and VER02 groundwater quality on the Piper diagram (Figure 8) show a signature of calcium magnesium bicarbonate type of water (Ca, Mg)$(HCO_3)_2$. This type of water is associated with recent rainfall recharge and unpolluted groundwater (blue sector).

Sampled boreholes GE01 and KR05 groundwater quality on the Piper diagram (Figure 8) show a signature of sodium bicarbonate/chloride type of water (green sector), whereas BU01, BU02, BU03, KR01 show a signature of calcium/sodium sulphate water and GE03 (black sector) show a signature of sodium chloride type of water respectively.

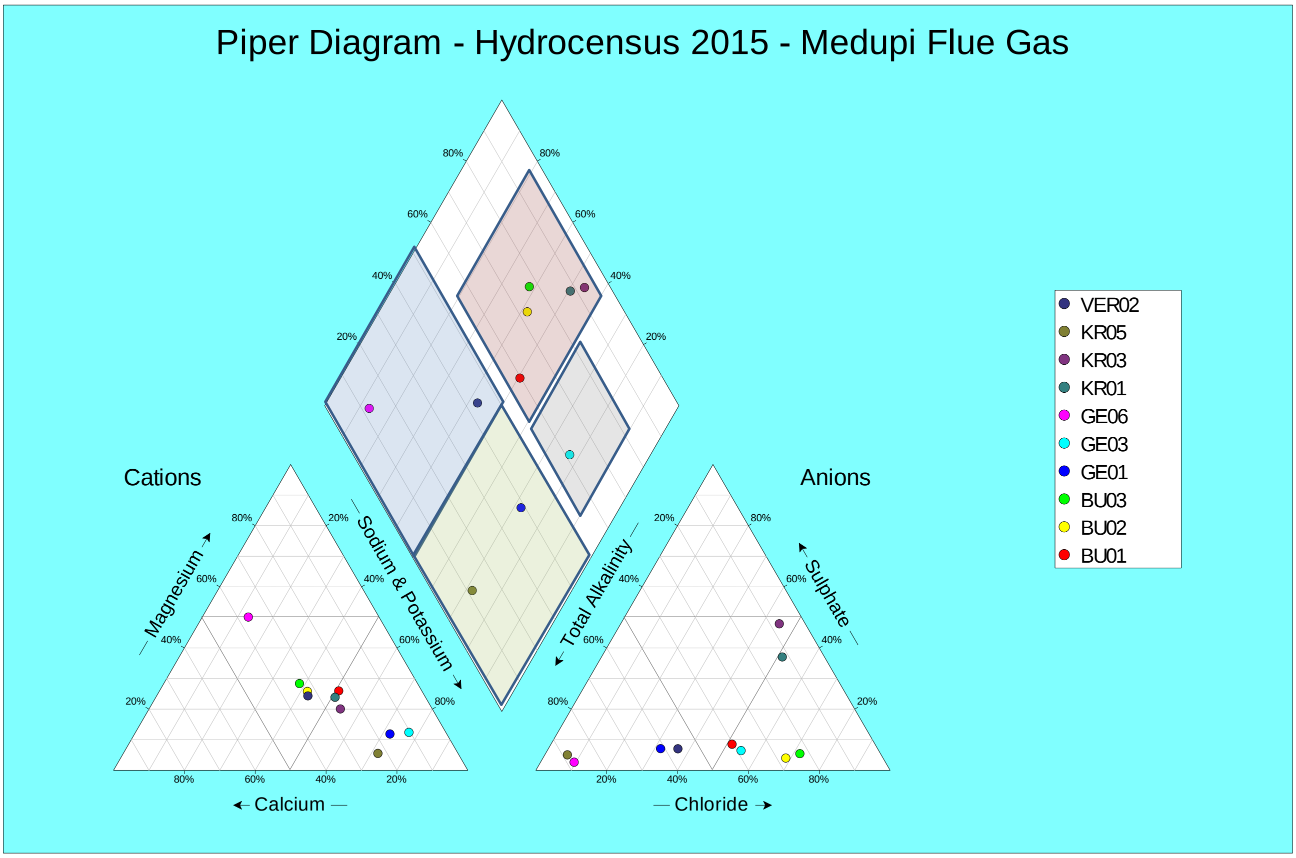

Figure 8: Piper Diagram Hydrocensus Boreholes

Expanded Durov Diagrams

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the top part of the diagram and the anion percentages in the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydrochemical environments and conditions.

The expanded Durov diagram Figure 8 differentiates between five types of water:

- On the Expanded Durov Diagram boreholes GE06 and VER02 plot on the blue sector of the diagram and represent [recharged] unpolluted groundwater.
- The results of sample GE01 and KR05 plot on the red sector representative of sodium potassium bicarbonate type of water (Na, K)$(HCO_3)_2$. The plot position on the diagram indicates towards minor sodium potassium enrichment.
- Sampled borehole KR03 plot on the green sector and are representative of sodium potassium sulphate type of water (Na, K)SO_4. The plot position on the diagram indicates water with minor sodium, potassium and sulphate enrichment.
- Sampled boreholes BU02 and BU03 plot on the yellow sector and are representative of magnesium chloride type of water (Mg) Cl. The plot position on the diagram indicates water with minor magnesium and chloride enrichment.
- Samples BU01, GE03, and KR01 plot on the purple sector representative of sodium, potassium chloride type of water (Na, K)Cl. The plot position on the diagram indicates water with minor sodium, potassium and chloride enrichment, associated with natural saline water and deep mine water.

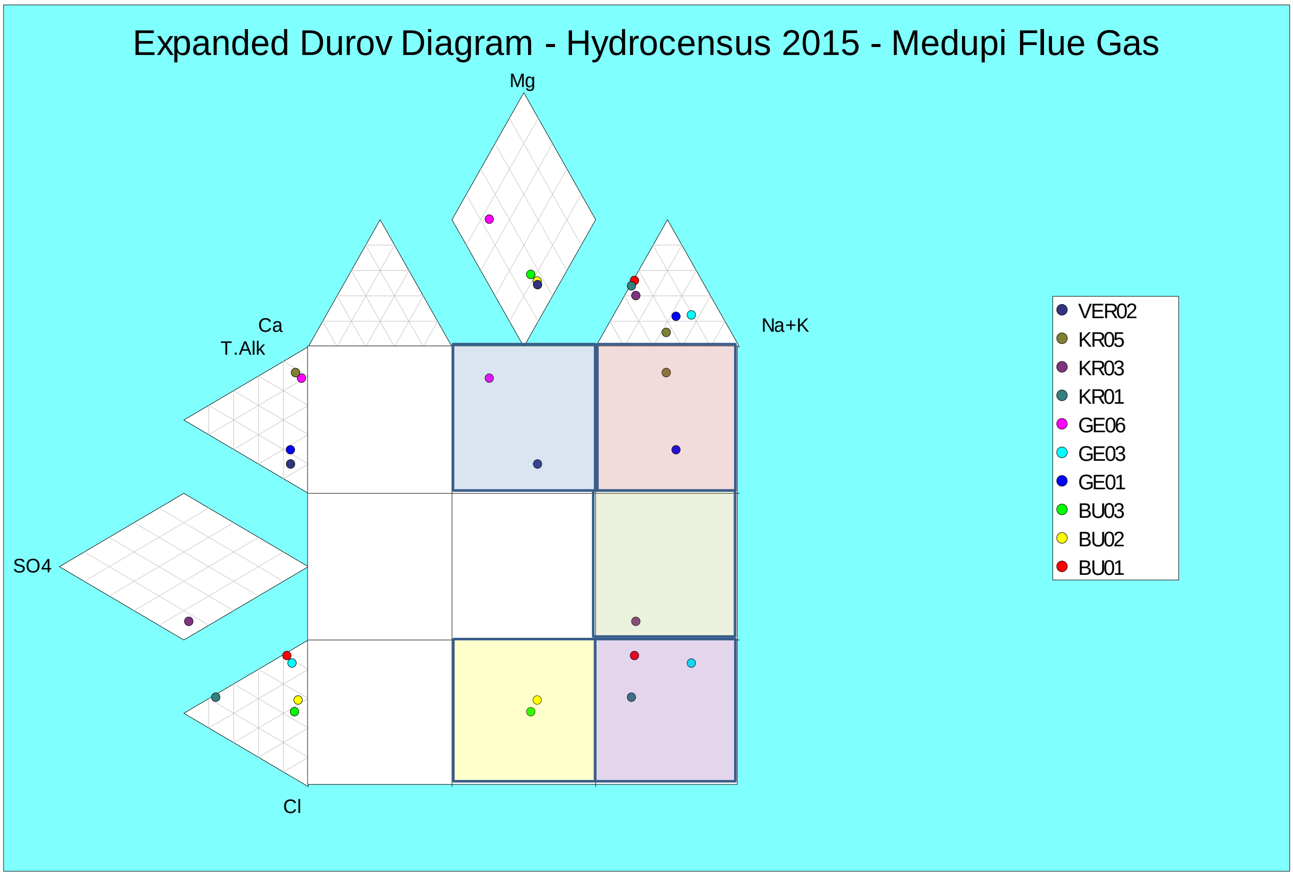

Figure 9: Expanded Durov Diagram Hydrocensus Boreholes

5.8 Aquifer Recharge

5.8.1 Regional Aquifer Recharge

From the published hydrogeological maps (DWAF 1996) the average recharge for Medupi FGD Retrofit Project area is shown as between 10 to 15mm per annum (Figure 10).

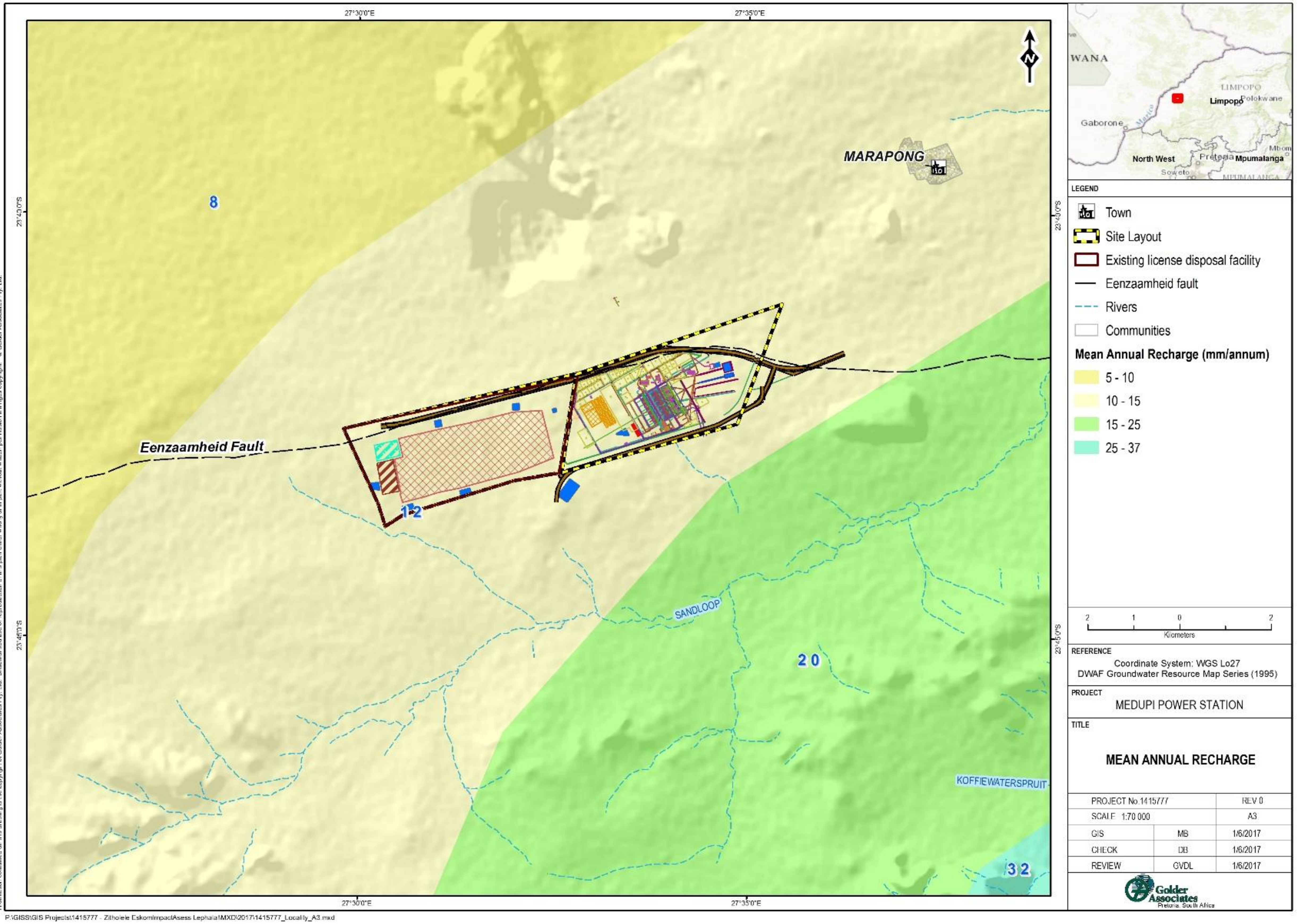

Figure 10: Groundwater Mean Annual Recharge (Vegter 1996)

5.8.2 Chloride Ratio Method

The Chloride Ratio Method was used to estimate the aquifer recharge for the Medupi FGD Retrofit Project area. The Chloride method calculates the recharge using the ratio between the average chloride in rainfall and the average chloride in the groundwater.

The chloride concentration should only result from the natural, hydrological, and evaporative processes as expressed below:

$$\mathbf{RE}\ \% = \frac{\mathbf{Clr}}{Clgw} X100$$

Where: Cl_r is the concentration of chloride in rainfall (mg/l)

Cl_{gw} is the concentration of chloride in the groundwater (mg/l)

= 0.6 mg/l / 32.34 mg/l (Harmonic Mean groundwater samples)

=1.8%

The Harmonic mean of chloride was calculated from the hydrocensus groundwater samples analysed in 2015. The current accepted concentration of chloride concentration in rainfall for the area is 0.6 mg/l.

Recharge =1.8 % of the MAP 429.1mm =7.7mm per annum. This recharge value (7.7mm) is slightly lower but more site specific than the values indicated on the published hydrogeological maps as 10 to 15mm per annum (Figure 10).

5.9 Groundwater Vulnerability

Groundwater vulnerability gives an indication of how susceptible an aquifer is to contamination. Aquifer vulnerability is used to represent the intrinsic characteristics that determine the sensitivity of various parts of an aquifer to being adversely affected by an imposed contaminant load.

A national scale groundwater vulnerability map of South Africa was prepared by the WRC (Water Research Commission), using the DRASTIC methodology that includes the following components:

- **D**epth to groundwater;
- **R**echarge due to rainfall;
- **A**quifer media;
- **S**oil media;
- **T**opography;
- **I**mpact of the vadose zone; and
- Hydraulic **C**onductivity.
- Groundwater vulnerability was classified into six classes ranging from very low to very high.

Groundwater vulnerability for the Medupi FGD Retrofit Project area is shown on the national groundwater vulnerability map (Figure 11) is indicated as low to medium.

The probability that the Medupi FGD Retrofit Project area site will have a major impact on the groundwater is limited but needs to be monitored.

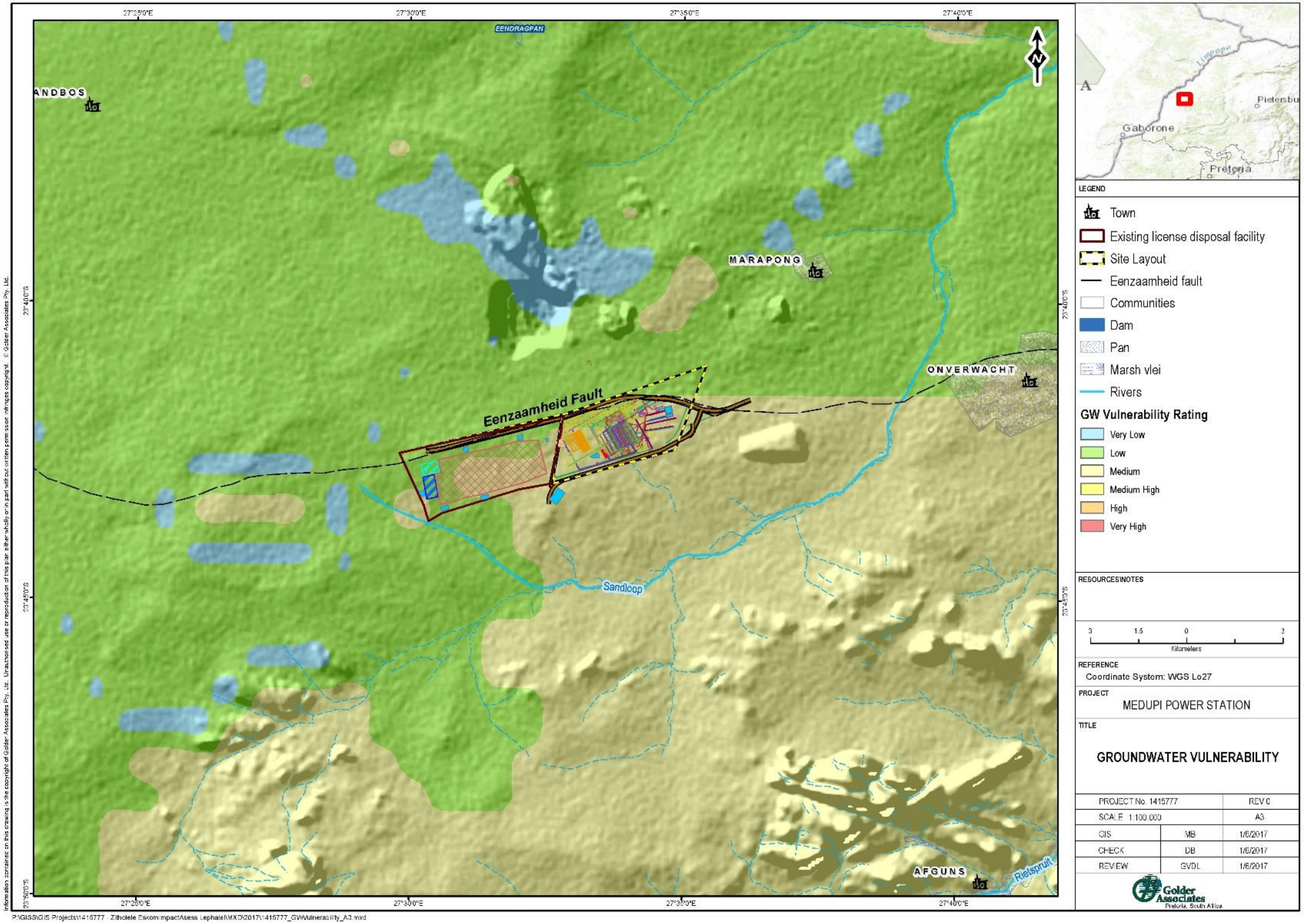

Figure 11: Groundwater Vulnerability Map

5.10 Groundwater Conceptual Model

A conceptual groundwater model is an interpretation of the characteristics and dynamics of an aquifer system which is based on an examination of all available hydrogeological data for a modelled area. This includes the external configuration of the system, location and rates of recharge and discharge, location and hydraulic characteristics of natural boundaries, and the directions of groundwater flow throughout the aquifer system.

The conceptual model forms the basis for the understanding of the groundwater occurrence and flow mechanisms in the area of investigation, and will be used as a basis for future numerical groundwater modelling of the Medupi FGD Retrofit Project.

Based on the available data an initial groundwater conceptual model was compiled for the Medupi FGD Retrofit Project area (Figure 12).

The Golder 2009 site investigation summarized the hydraulic parameters for the Medupi Power station as follows:

- The average k value for dry boreholes subjected to falling head tests is 0.025 m/d;
- Slug test K values varied from 0.035 m/d (GA036) to 3.01 m/day (GA009) with an average value of 0.89 m/d;
- Transmissivity values obtained for the 5 main boreholes tested inside the current pit average $22m^2/d$;
- Transmissivity for tested boreholes outside of the excavated area is < $8m^2/d$; and
- The storage coefficient for the shallow aquifer is estimated to be between 4.4×10^{-5} and 2.2×10^{-4}.

The conceptual model is based on two distinct types of aquifers which are present in the geological formations of the coal fields in South Africa:

- Upper weathered aquifer system; and
- Fractured aquifer system.

5.10.1 Weathered Aquifer System

The upper weather aquifer zone is ~ 5-15m and comprises of soil and weathered rock. The aquifer is recharged by rainfall.

5.10.2 Fractured Aquifer System

The fractured aquifer zone is ~ 15-40m and comprises of fractured rock.

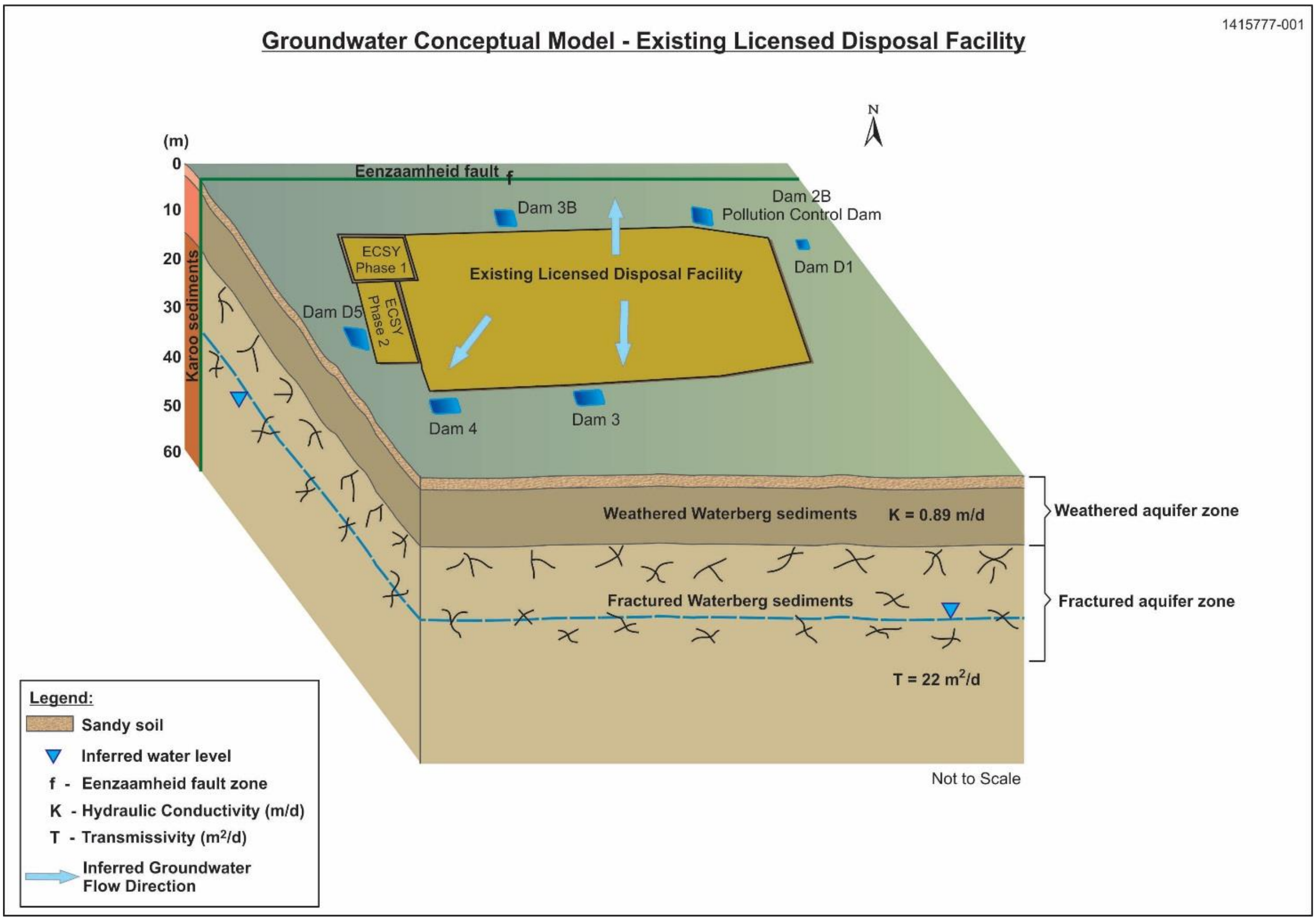

Figure 12: Initial Groundwater Conceptual Model for Medupi FGD Retrofit Project area and existing disposal facility

5.11 Aquifer Classification and Borehole Yield

The hydrocensus did not yield any specific borehole yielding information. The published hydrogeological maps series by DWAF (1996) was used to define the regional aquifer classification (Figure 13). The aquifer is classified as a minor aquifer system with fractured aquifer zones (Figure 14).

The published hydrogeological maps (DWAF 1996) indicate that the average borehole yield in the area is between 0.5l/s and 2.0l/s (Figure 14).

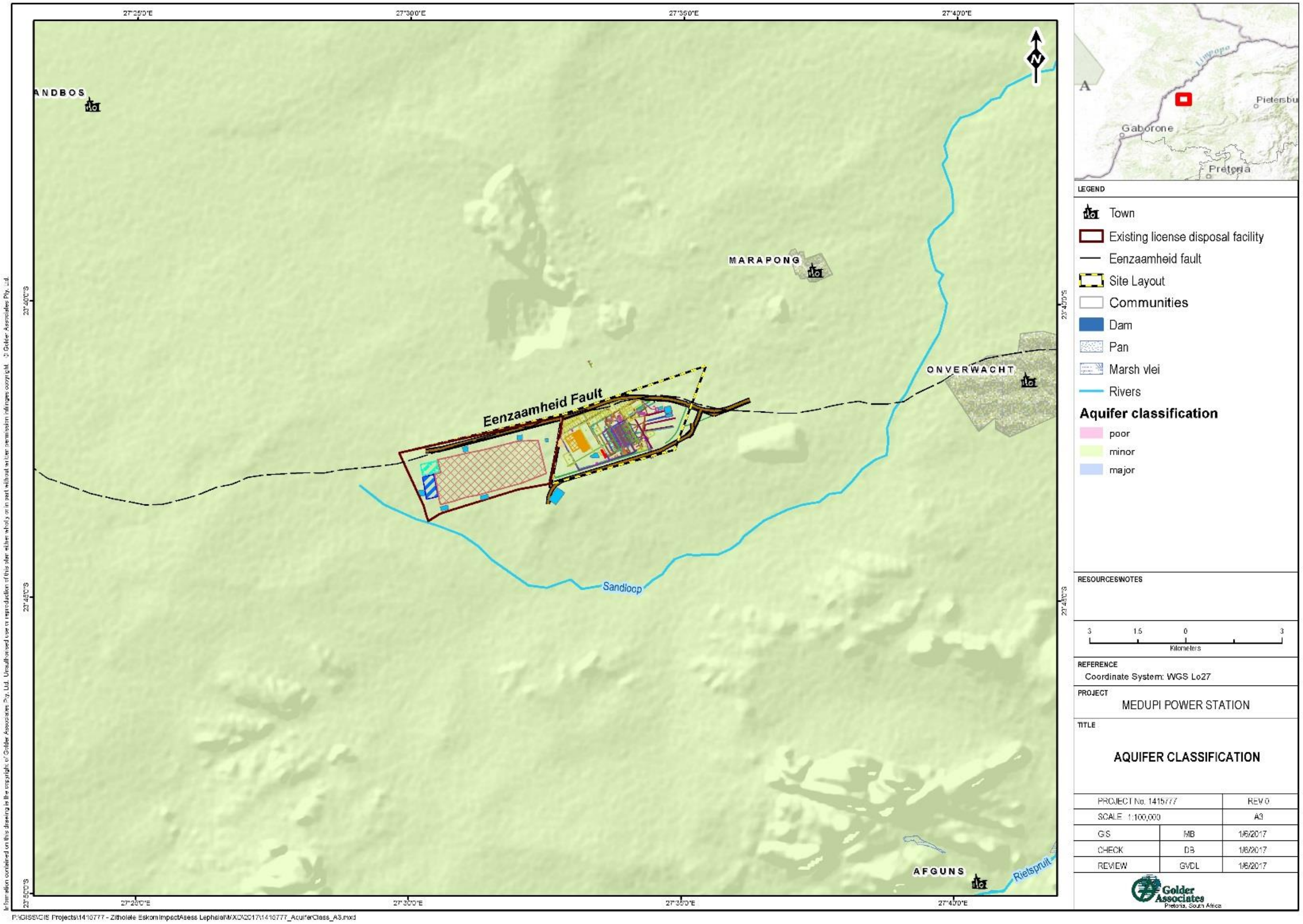

Figure 13: Aquifer Classification

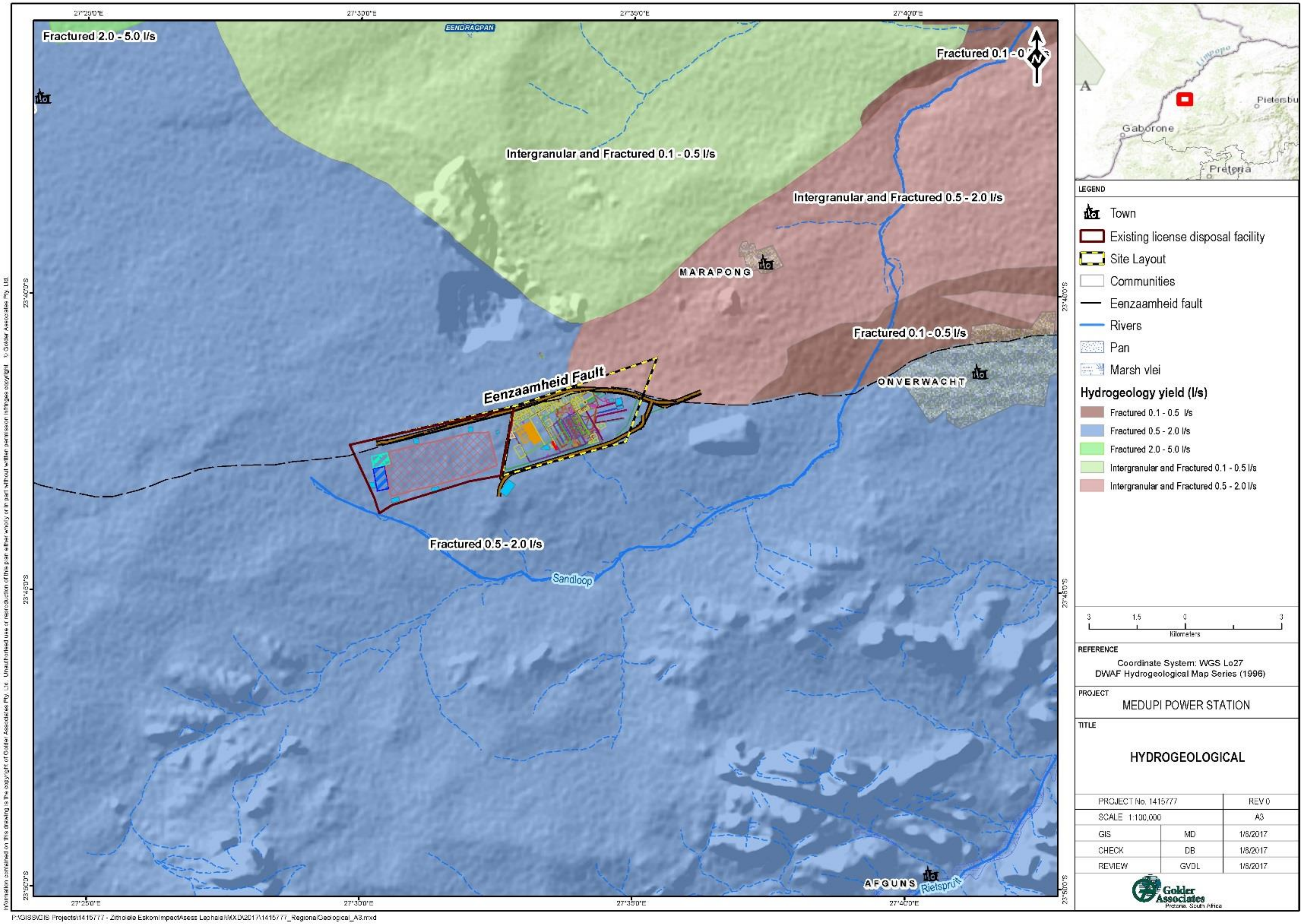

Figure 14: Hydrogeology Map

5.12 Existing Groundwater Monitoring

Groundwater quality and water levels are currently monitor by Eskom at Medupi Power station at 30 existing boreholes as indicated on Figure 15. Some of these boreholes are positioned around the Medupi FGD Retrofit Project area and could act as monitoring boreholes for the FGD project. However, three of these boreholes (MBH08. MBHO9 and MBH07) are dry or water level are too low to sample and need to be replaced to ensure monitoring coverage in these areas.

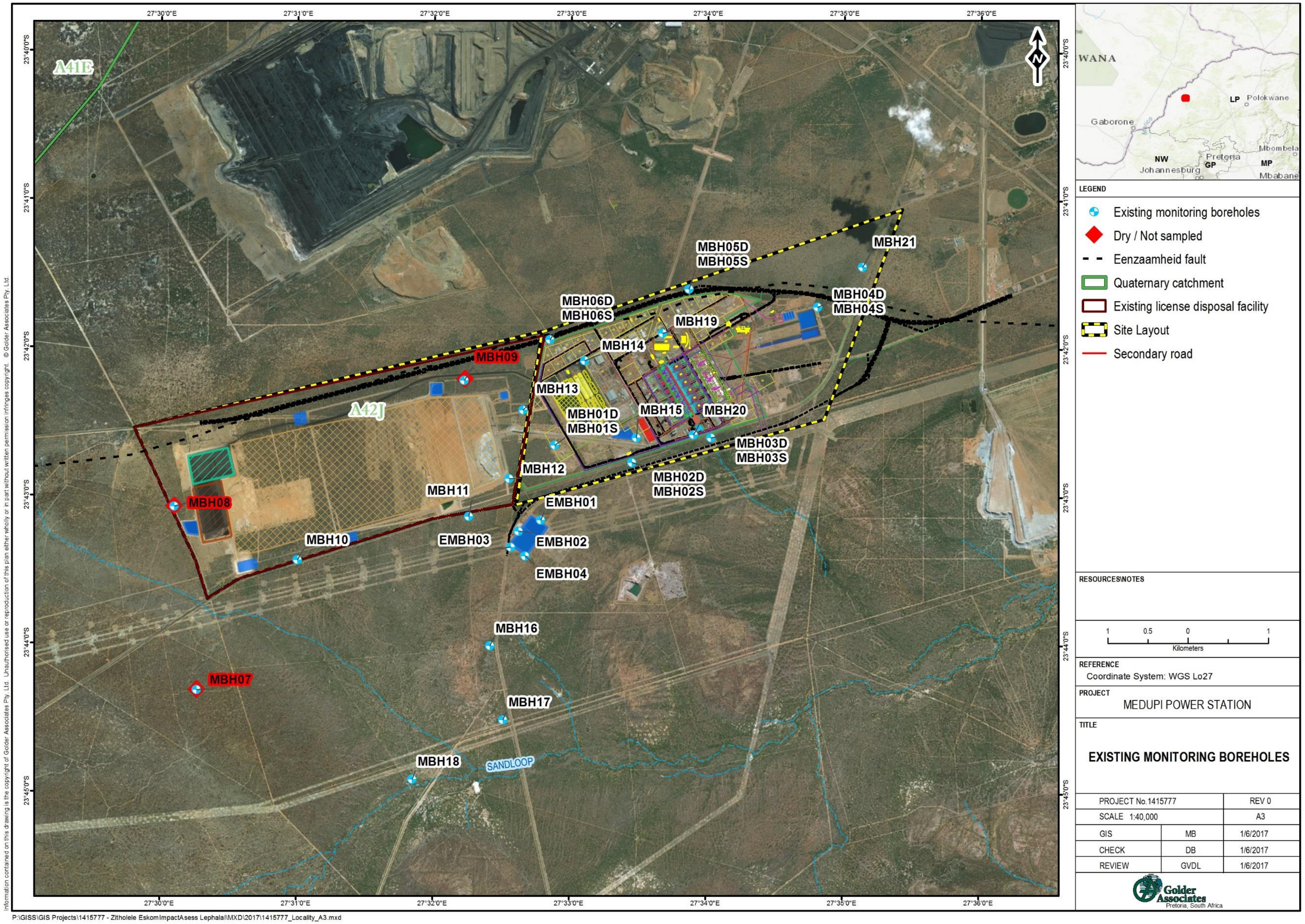

Figure 15: Exiting Groundwater Monitoring Boreholes

5.12.1 Existing Borehole Groundwater Quality

The latest 2016 analytical results (client database) of the existing groundwater monitoring boreholes were compared to the following standards;

- Department of Water Affairs and Forestry, domestic water quality guidelines, volume 1,1996 and Water Research Commission, water quality guidelines, 1998;
- South African National Standards, drinking water standards, 2011 (SANS 241:2011); and
- South African Water Quality Guidelines (SAWQG), Volume 5: Agricultural Use – Livestock Watering (DWAF, 1996).

The SANS 241:2011 drinking water standard is used as reference in Table 6, whereas the DWAF 1998 guidelines were used to classify water quality classes (Table 5).

Table 5: DWAF Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

5.12.2 Groundwater Analytical Results

The analytical results (major cations and anions) of the existing monitoring boreholes are listed in Table 6. A highlighted value in red exceeds the SANS 241:2011 maximum allowable limit, whereas the water quality classes are classified using the DWAF (1998) drinking water standards (black highlighted values exceeding class I).

The following constituents of the existing groundwater samples exceed the SANS 241 (2011) maximum allowable standard; EC, TDS, Na, Cl, N, SO_4, Al, F, Fe; and Mn,

The water quality of the existing boreholes is largely poor quality, with classes ranging from Class 0 to Class IV, water quality.

Table 6: Summarised Chemistry of Existing Boreholes (Nov 2016)

Borehole	Physical Determinants			Chemical Determinants												Water Quality Class
Number	pH	EC (mS/m)	TDS (mg/l)	MALK (mg/l)	Ca (mg/l)	K (mg/l)	Mg (mg/l)	Na (mg/l)	Cl (mg/l)	NO_3 as N (mg/l)	SO_4 (mg/l)	Al (mg/l)	F (mg/l)	Fe (mg/l)	Mn (mg/l)	
MBH2	5.22	10.4	76	9.48	1.51	6.15	2.96	7.97	13	0.423	14.1	<0.005	0.263	<0.004	<0.001	0
MBH3	5.77	13.2	84	26.9	4.97	6.49	5.42	7.85	17.2	0.293	10.8	0.211	0.917	<0.004	<0.001	I
MBH3D	6.57	23.6	144	61.2	13.7	8.93	7.51	15.3	18.7	0.212	33.7	<0.004	0.441	<0.001	<0.003	0
MBH4	6.29	16.5	86	86	8.03	7.81	8.19	7.74	8.41	0.258	11	<0.002	1.84	<0.001	<0.003	I
MBH4S	4	1754	10208	<1.99	115	110	281	2885	6815	0.194	<0.141	<0.002	<0.263	<0.001	<0.003	IV
MBH4D	8.17	356	1798	718	37.6	35.2	81.2	695	788	0.538	38.2	<0.002	4.13	<0.002	<0.001	II
MBH5D	6.65	433	3468	167	272	44.7	142	472	1187	0.196	291	<0.002	1.26	<0.001	<0.003	III
MBH6D	6.09	77.4	518	115	28.6	15.8	16.4	119	99.1	11.7	70.9	<0.002	5.02	<0.001	<0.003	II
MBH10D	5.67	32.6	226	51.4	8.99	10.4	9.4	35.3	77.7	0.476	4.25	<0.002	0.263	<0.002	0.001	0
MBH11	6.97	711	4386	678	191	173	264	1063	2002	0.718	350	<0.005	2.79	<0.005	<0.005	IV
MBH12	6.51	450	2746	169	198	37.9	184	525	1152	0.42	453	<0.001	1.06	<0.005	<0.001	III
MBH13	6.96	519	3074	657	141	66.5	156	864	1357	6.12	111	<0.002	4.98	<0.003	<0.001	III
MBH14	6.82	203	1632	179	140	20.5	104	252	101	45.1	714	<0.007	4.08	<0.011	<0.001	IV
MBH15	7.53	683	5088	911	172	70	361	1108	757	368	836	<0.007	4.92	<0.009	<0.001	IV
MBH17	6.88	55.2	342	200	25.2	7.13	19.1	71.5	74.4	0.52	9.37	<0.005	2.1	<0.009	<0.001	0
MBH18	7.84	278	1538	607	11.3	16.6	12.5	632	533	0.372	173	<0.005	8.96	<0.009	<0.007	II
MBH19	6.75	681	4780	247	592	25.6	326	420	2174	0.914	96.9	<0.005	1.01	<0.009	0.37	IV
MBH20	4.75	19.1	144	5.03	6.46	5.82	4.92	15.3	29.8	3.57	17.6	0.713	0.88	<0.009	<0.001	I
MBH21	7.3	175	1086	504	129	37.4	41.1	206	232	5.28	117	<0.005	2.29	<0.009	<0.001	II
SANS241: 2011 Max. Allowable Limit	9.7	<170	1200	-	-	-	-	200	300	11	500	0.3	1.5	0.3	0.5	
Class 0 Max. Allowable Limit	9.5	<70	<450	-	<80	<25	<70	<100	<100	<6	<200	-	<0.7	<0.01	<0.1	0
Class 1 Max. Allowable Limit	10	150	1000	-	150	50	100	200	200	10	400	-	0.7-1.0	0.01-0.2	0.1-0.4	I
Class 2 Max. Allowable Limit	10.5	370	2400	-	300	100	200	400	600	20	600	-	1.0-1.5	0.2-2.0	1.0-4.0	II
Class 3 Max. Allowable Limit	11	520	3400	-	>300	500	400	1000	1200	40	1000	-	1.5-3.5	2.0-10.0	4.0-10.0	III
Class 4 Max. Allowable Limit	>11	>520	>3400	-		>500	>400	>1000	>1200	>40	>1000	-	>3.5	>10.0	>10.0	IV
South African Water Quality Guidelines (SAWQG), Volume 5 – Agricultural Use – Livestock Watering **Target Range**	-	154	1000	-	1000	-	500	2000	1500	1000	100	5	2	10	10	
Minimum	4.00	10.4	76	5.0	1.51	5.8	2.96	7.74	8.41	0.194	4.25	0.211	0.263	<0.001	0.001	
Maximum	8.17	1754.0	10208	911.0	592.0	173.0	361.0	2885.0	6815.0	368.0	836.0	0.713	8.96	<0.011	0.37	
Average	6.46	341.6	2180	299.6	110.3	37.2	106.7	494.84	917.7	23.437	186.21	0.462	2.62		0.1855	

5.12.3 Possible Impacted Boreholes

The latest Sulphate and EC concentrations, of both the hydrocensus and existing boreholes were classed based on the DWAF water quality classification and are indicated figures Figure 16 and Figure 17. The groundwater quality status of these boreholes were used to illustrate potential deteriorating of groundwater quality in boreholes, associated with possible impacts from existing pollution sources.

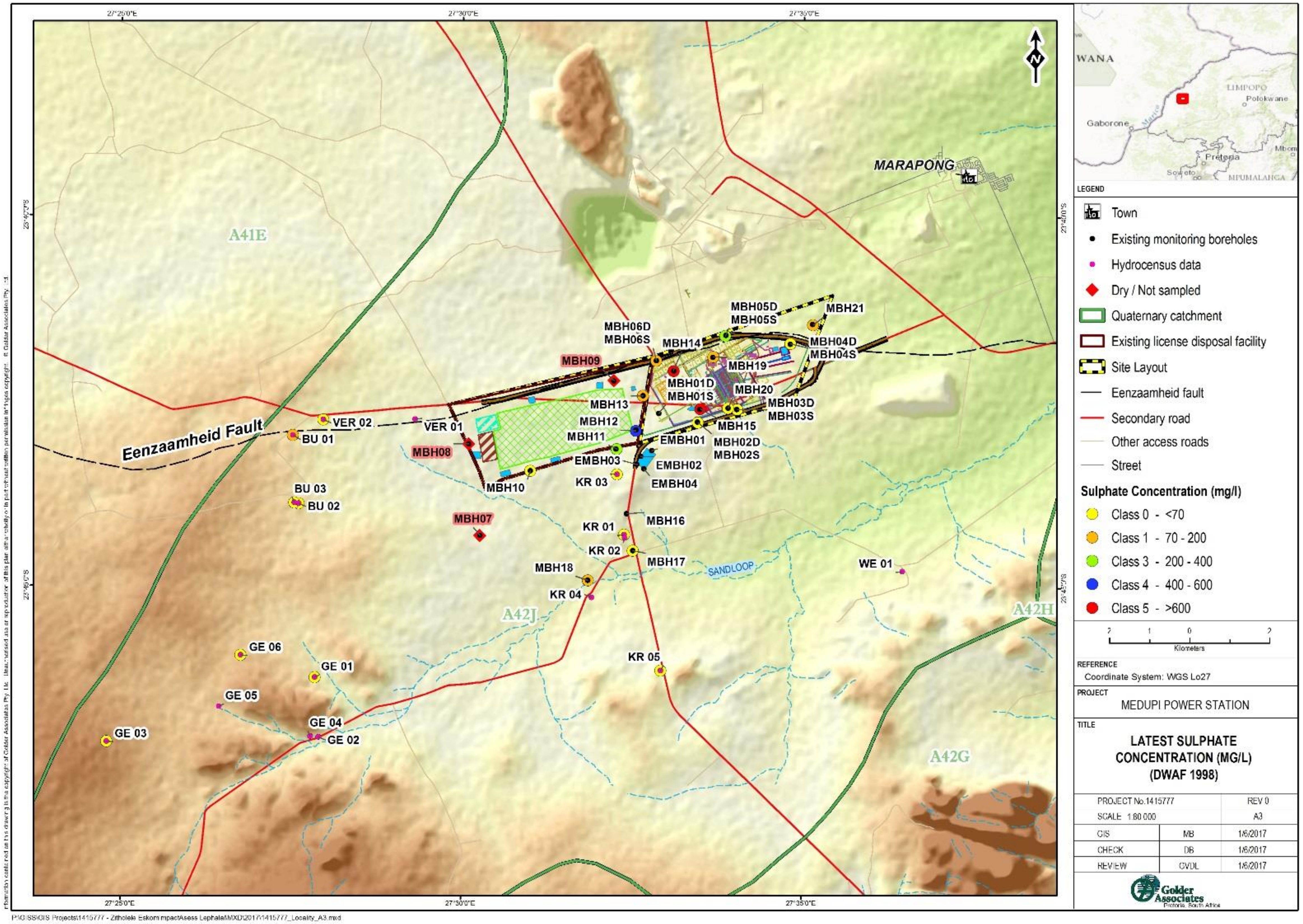

Figure 16: Latest Sulphate Concentrations (mg/l)

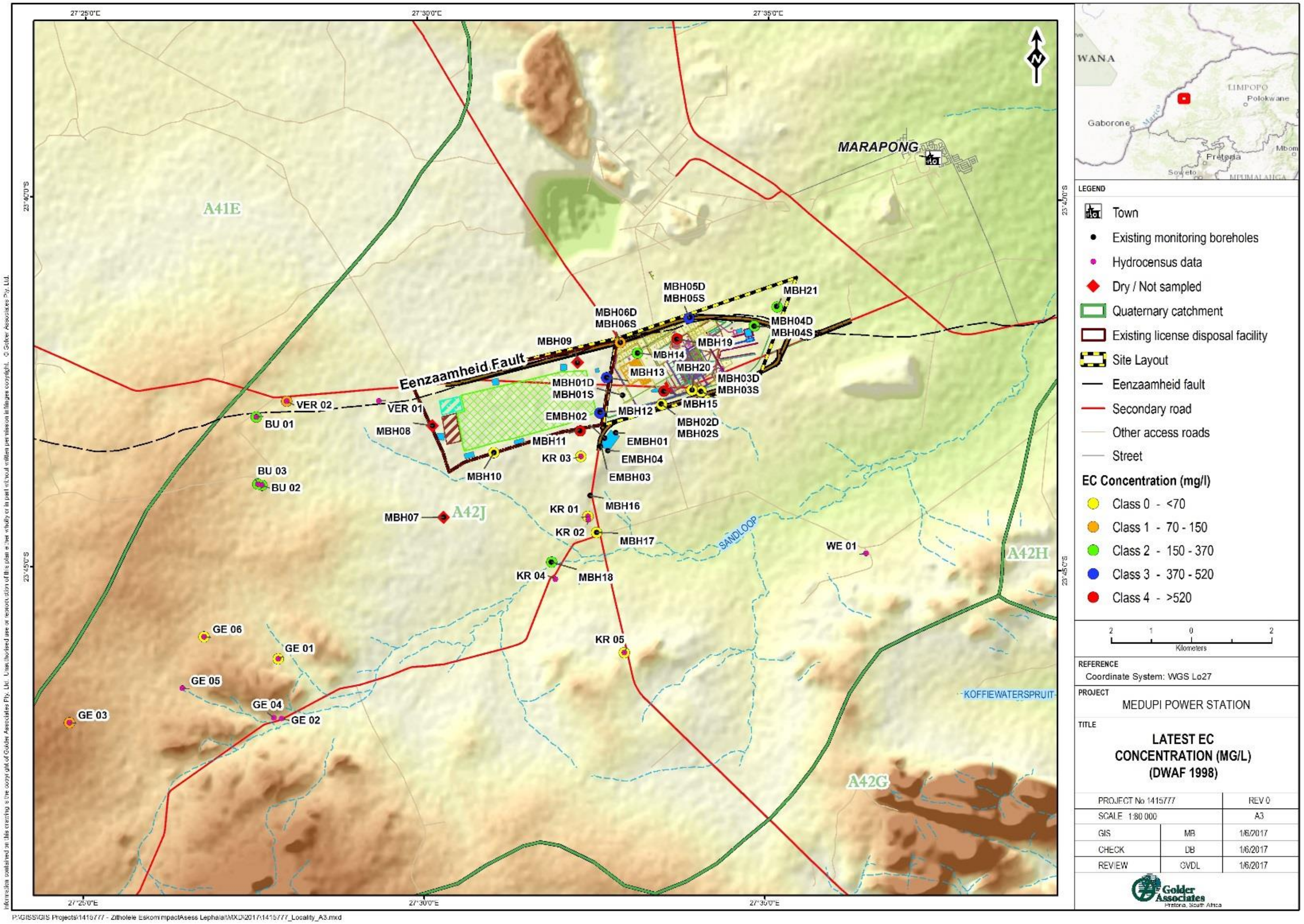

Figure 17: Latest EC Concentrations (mg/l)

5.13 Groundwater Levels and Flow Direction

The published hydrogeological maps (DWAF 1996) indicate the water level to be between 20 to 40mbgl (Figure 18).

The water levels measured during the hydrocensus ranges between 4.41 to 69.98mbgl, with the average water level as 30.4mbgl.

Sixteen water levels were measured during the 2015 hydrocensus and are listed in Table 7. It must be noted that the some of these water levels may be influenced by pumping and may not be static levels.

Table 7: Water Levels 2015

Borehole Number	Altitude (mamsl)	SWL(mbgl)	SWL (mamsl)
BU 01	933	59.18	874
VER 01	921	42.32	878
VER 02	927	69.99	857
BU 02	936	64.63	871
BU 03	934	66.98	867
GE 01	931	13.88	917
GE 02	926	9.47	916
GE 03	968	55.56	912
GE 04	927	9.17	918
GE 05	939	9.78	929
GE 06	949	24.21	925
KR 01	899	4.41	895
KR 03	914	15.28	899
KR 04	893	5.72	888
KR 05	919	26.62	893
WE 01	889	8.82	880
Minimum	889	4.41	857
Maximum	968	69.99	929
Average	925	30.4	895

From the available data and previous groundwater studies, the groundwater flow from the Medupi FGD Retrofit Project area is primarily away from the site, towards the east/south-east and northeast towards the non-perennial Sandloop River (Figure 19). The initial groundwater level and flow directions at the Medupi FGD Retrofit Project area and Medupi Power station are indicated in Figure 20 (IGS 2008)

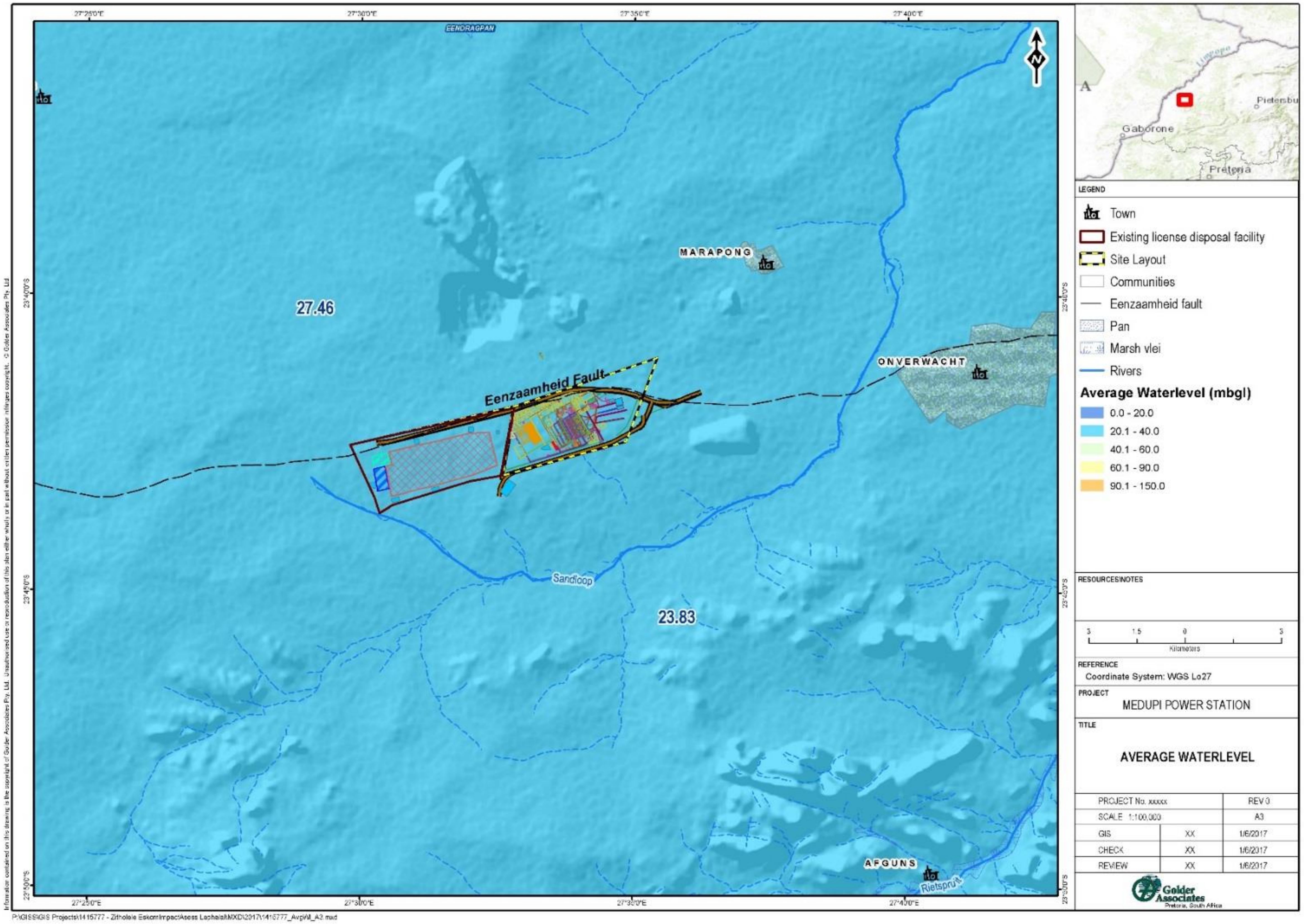

Figure 18: Average Ground Water Level (DWAF 1996)

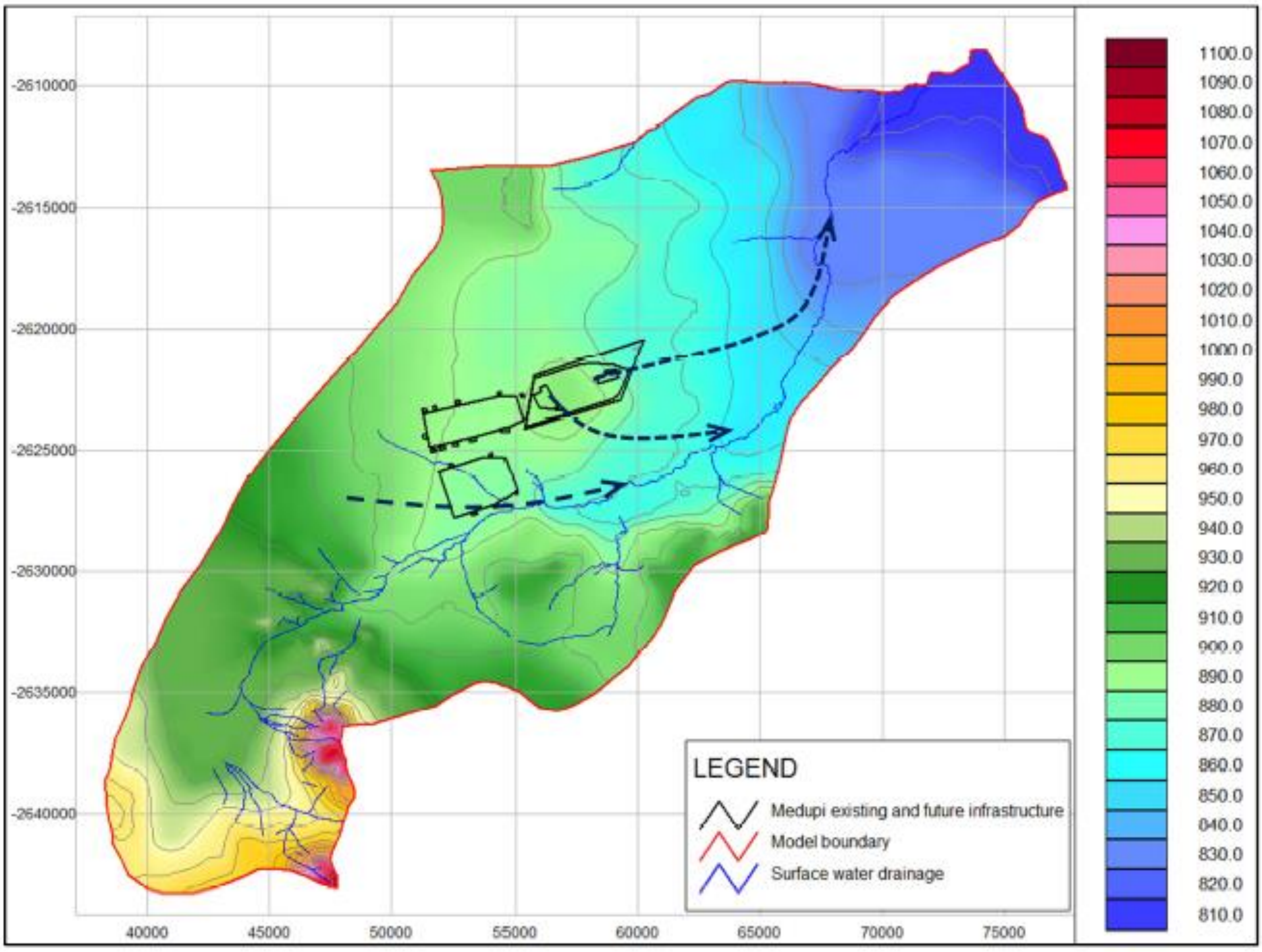

Figure 19: Groundwater Elevation Contour map (Adapted from Groundwater Complete - 2017).

5.13.1 Possible Plume Prediction

Institute for Groundwater Studies (IGS) constructed a groundwater numerical model in 2008, where the mass transport model was run for a simulation period of 50 years. The contamination sites included in the study, were the existing licenced disposal facility, coal stockyard and dirty terrace dam.

The simulation of a possible plume prediction over 50 years is indicated in Figure 21 . This simulation correspond with the inferred groundwater flow directions for the existing licenced disposal facility.

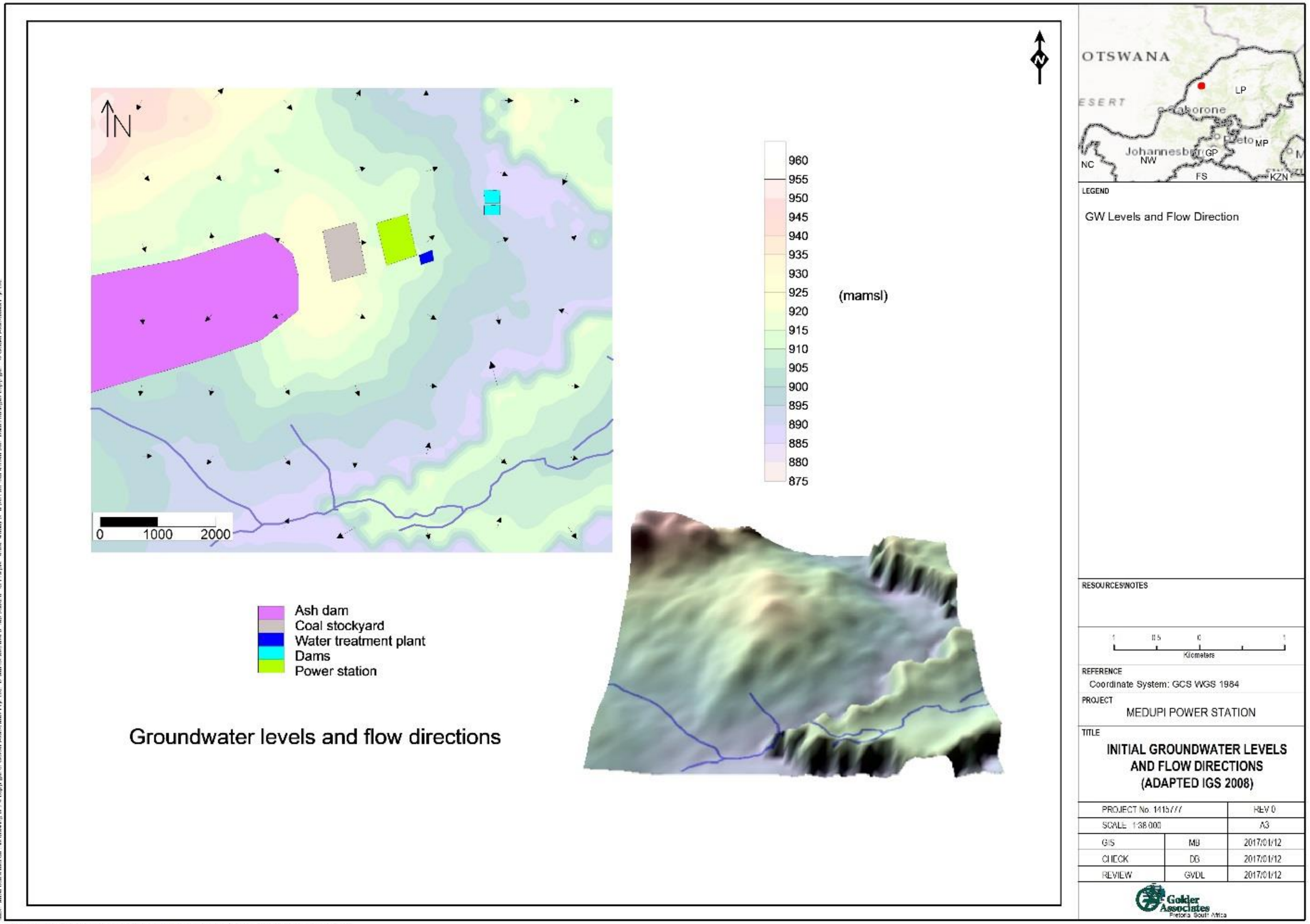

Figure 20: Initial Groundwater Levels and Flow Directions (Adapted IGS 2008)

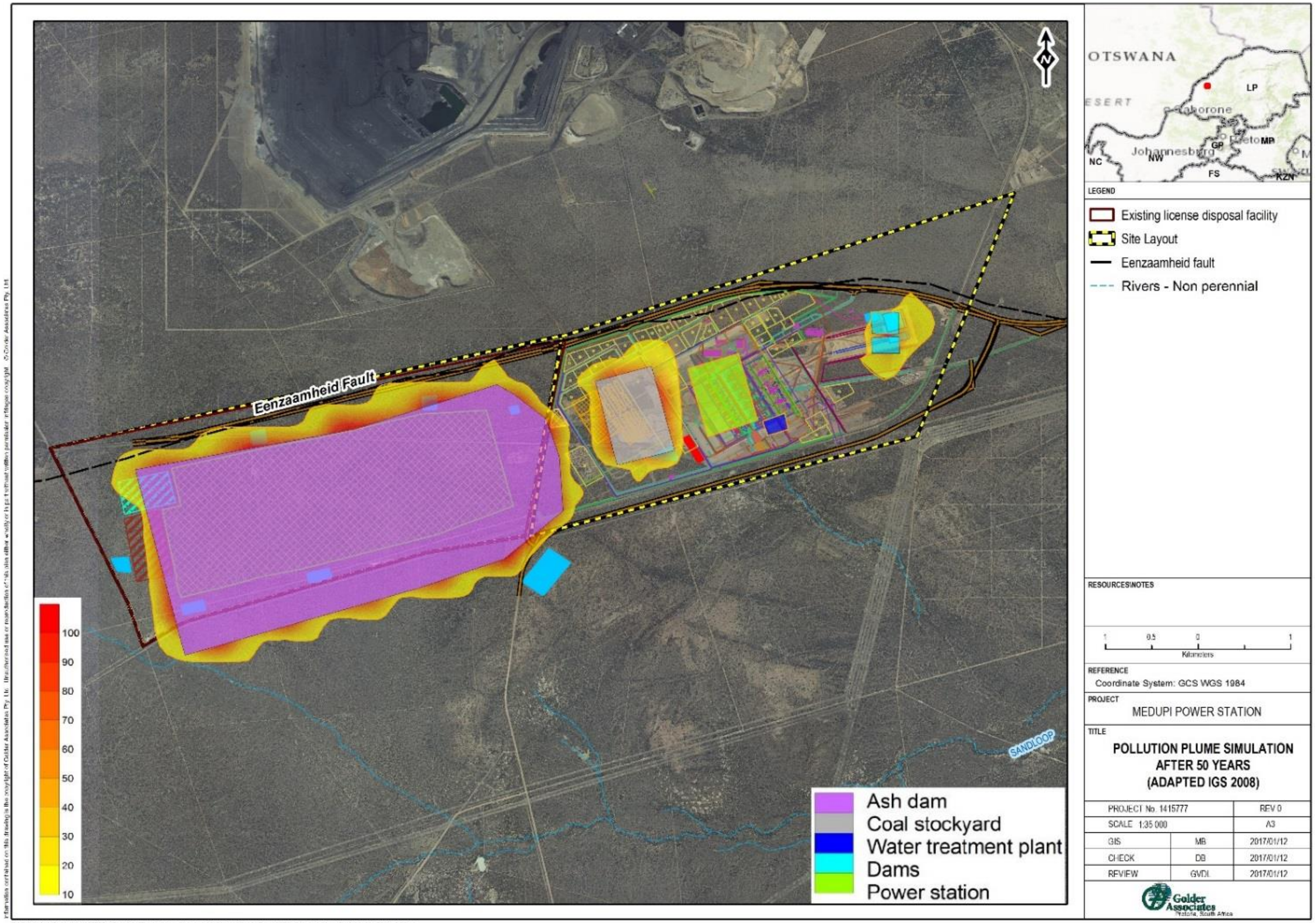

Figure 21: Pollution Plume Simulation after 50 years (Adapted IGS 2008)

6.0 GROUNDWATER RISK RATING

Possible impacts on the groundwater regime from the Medupi FGD Retrofit Project area were based on a simplified groundwater risk rating assessment and are presented in Table 8. Risk rating is based on a possible risk/impact that the Medupi FGD Retrofit Project area poses to the groundwater regime. Rating is on a scale of 1 to 5 pending on number of classes assigned, with 1 the lowest rating and 5 the highest possible risk.

The following hydrogeological criteria were applied to the risk rating of the Medupi FGD Retrofit Project area:

6.1 Aquifer Classification

The aquifer classification is based on the National groundwater aquifer classification map of South Africa:

- Major – rating of 3;
- Minor – rating of 2; and
- Poor - rating of 1;

6.2 Aquifer Systems

Aquifer systems in South Africa are grouped in four basic Categories based on the character of the water bearing features of the formation material:

- Karst – rating of 4;
- Intergranular – rating of 3;
- Intergranular and fractured – rating of 2; and
- Fractured – rating 1.

6.3 Borehole Yield Classes

Based on national groundwater borehole yield classes, yield is classed into 4 classes:

- Yields from 0.1- 0.5l/s rating of 1;
- Yields from 0.5 – 2.0l/s rating of 2;
- Yields from 2.0- 5.0/s rating of 3;
- Yields from >0.5l/s rating of 4;

6.4 Local Geology Structures

Local geology structure was grouped into 3 classes based on higher groundwater occurrences and Transmissivity values associated with these structures:

- Fault zones, rating of 4;
- Dolerite dyke contact zones, rating of 3;
- Lineaments and quartz veins ranting of 2; and
- No know structures, rating of 1.

6.5 Groundwater Quality

The groundwater quality classes are based on the National groundwater quality (electrical conductivity (EC/mS/m) map information. The risk rating for groundwater quality is based on that all water resources should be protected against water quality deterioration from a specific standard. A risk rating of 4 is therefore allocated to Class 0:

Class 0, (EC<70mS/m) – rating of 4;

Class 1, (EC 70mS/m to 300mS/m) – rating of 3;

Class 2, (EC 300mS/m to 1000mS/m) – rating of 2; and

Class 3 and 4, (EC>1000mS/m) – rating of 1.

6.6 Vulnerability

The groundwater vulnerability classes are based on the national groundwater vulnerability map information:

- Very Low, rating of 1;
- Low, rating of 2;
- Low to medium, rating of 3;
- Medium, rating of 4; and
- High, rating of 5;

6.7 Number of Existing Groundwater users within a 1km Radius of Medupi FGD Retrofit Project area

Number of reported existing groundwater users within a 1km radius of the site was grouped into 3 classes:

- > 10 rating of 3;
- 5 to 10, rating of 2; and
- < 5, rating of 1.

6.7.1 Medupi FGD Retrofit Project area - Risk Rating

The existing licensed disposal facility scores a risk rating of 16 and poses a moderate risk of impacting on the surrounding groundwater regime. Possible impacts on the groundwater need to be investigated further.

These ratings are consistent with the National vulnerability map of South Africa prepared by the WRC (Water Research Commission), using the DRASTIC methodology.

Table 8: Site Selection Ranking and Rating

SITE SELECTION RANKING	SITE 13
Aquifer Classification	Minor
	2
Aquifer System	Fractured
	1
Borehole Yield	0.5 - 2.0l/s
	2
Local Geology Structures	Fault zone
	4
Groundwater Quality EC (mS/m)	Class 0 and 1
	3
Aquifer Vulnerability	Low to Medium
	3
Number of reported existing groundwater users within a 1km radius	<5
	1
SCORE	16

7.0 IMPACT ASSESSMENT MEDUPI FGD PROJECT AREA

In order to address the amended scope of work for Medupi FGD (2017) the following SOW are included based on the Impact assessment methodology provided by Zitholele:

- Construction and operation of the FGD system within the Medupi Power Station Footprint;
- Construction and operation of the railway yard/siding and diesel storage facilities, and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF;
- A qualitative opinion on impact on groundwater, if any, if ash and gypsum is disposed together on the existing ADF considering the ADF will have an appropriate liner since both ash and gypsum is classified as type 3 wastes; and
- Provide a qualitative opinion whether groundwater could potentially be impacted with the construction of the FGD within the Medupi PS footprint. From the aerial view it is evident that the entire Medupi GD footprint area is disturbed during the construction activities at the power station.

The potential groundwater impacts that the **FGD system (**Figure 22**)** and the **operation of the railway yard/siding, diesel storage facilities** and **limestone and gypsum handling facilities between the Medupi Power Station and existing ADF**, poses to the groundwater regime are discussed as follows for the different phases:

- Existing impacts – these are current activities that potentially have an impact on the groundwater regime. These activities include Matimba Power Station and ADF, Medupi Power station and the existing licensed disposal facility, however Grootegeluk mine are excluded due to the Eenzaamheid fault serving as a barrier to interactions.
- Cumulative impacts - **include the existing activities plus the FGD system** and **the operation of the railway yard/siding, diesel storage facilities and limestone** and **gypsum handling facilities between the Medupi Power Station and existing ADF**; and
- Residual impacts- are the post-mitigation activities. This rating considers the cumulative impacts when proposed mitigation measures are effectively implemented.

The existing activities and the FGD system pose the following potential impacts on the groundwater:

- A change in the groundwater quality;
- A change in the volume of groundwater in storage or entering groundwater storage (recharge); or
- A change in the groundwater flow regime.

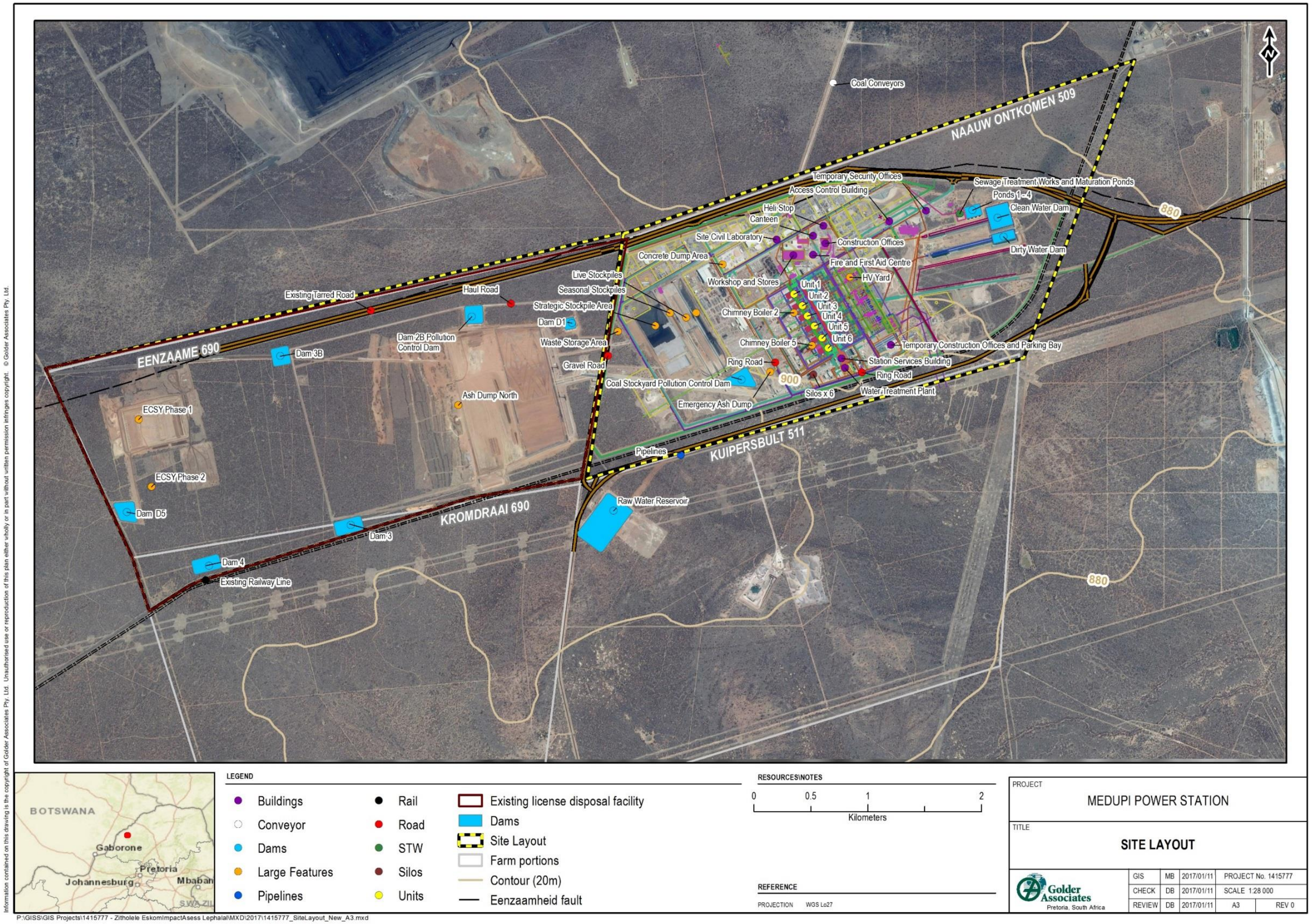

Figure 22: Medupi Site Outlay

7.1 Impact Assessment Methodology

The impacts will be ranked according to the based on the Impact Assessment Methodology provided by Zitholele as described below. Where possible, mitigation measures will be provided to manage impacts. In order to ensure uniformity, a standard impact assessment methodology will be utilised so that a wide range of impacts can be compared with each other. The impact assessment methodology makes provision for the assessment of impacts against the following criteria, as discussed below.

7.1.1 Nature of the impact

Each impact should be described in terms of the features and qualities of the impact. A detailed description of the impact will allow for contextualisation of the assessment.

7.1.2 Extent of the impact

Extent intends to assess the footprint of the impact. The larger the footprint, the higher the impact rating will be. Table 9 below provides the descriptors and criteria for assessment.

Table 9: Criteria for the assessment of the extent of the impact

Extent Descriptor	Definition	Rating
Site	Impact footprint remains within the boundary of the site.	1
Local	Impact footprint extends beyond the boundary of the site to the adjacent surrounding areas.	2
Regional	Impact footprint includes the greater surrounds and may include an entire municipal or provincial jurisdiction.	3
National	The scale of the impact is applicable to the Republic of South Africa.	4
Global	The impact has global implications	5

7.1.3 Duration of the impact

The duration of the impact is the period of time that the impact will manifest on the receiving environment. Importantly, the concept of reversibility is reflected in the duration rating. The longer the impact endures, the less likely it is to be reversible. See Table 10 for the criteria for rating duration of impacts.

Table 10: Criteria for the rating of the duration of an impact

Duration Descriptor	Definition	Rating
Construction / Decommissioning phase only	The impact endures for only as long as the construction or the decommissioning period of the project activity. This implies that the impact is fully reversible.	1
Short term	The impact continues to manifest for a period of between 3 and 5 years beyond construction or decommissioning. The impact is still reversible.	2
Medium term	The impact continues between 6 and 15 years beyond the construction or decommissioning phase. The impact is still reversible with relevant and applicable mitigation and management actions.	3
Long term	The impact continues for a period in excess of 15 years beyond construction or decommissioning. The impact is only reversible with considerable effort in implementation of rigorous mitigation actions.	4
Permanent	The impact will continue indefinitely and is not reversible.	5

7.1.4 Potential intensity of the impact

The concept of the potential intensity of an impact is the acknowledgement at the outset of the project of the potential significance of the impact on the receiving environment. For example, SO_2 emissions have the potential to result in significant adverse human health effects, and this potential intensity must be accommodated within the significance rating. The importance of the potential intensity must be emphasised within the rating methodology to indicate that, for an adverse impact to human health, even a limited extent and duration will still yield a significant impact.

Within potential intensity, the concept of irreplaceable loss is taken into account. Irreplaceable loss may relate to losses of entire faunal or floral species at an extent greater than regional, or the permanent loss of significant environmental resources. Potential intensity provides a measure for comparing significance across different specialist assessments. This is possible by aligning specialist ratings with the potential intensity rating provided here. This allows for better integration of specialist studies into the environmental impact assessment. See Table 11 and Table 12 below.

Table 11: Criteria for impact rating of potential intensity of a negative impact

Potential Intensity Descriptor	Definition of negative impact	Rating
High	Significant impact to human health linked to mortality/loss of a species/endemic habitat.	16
Moderate-High	Significant impact to faunal or floral populations/loss of livelihoods/individual economic loss.	8
Moderate	Reduction in environmental quality/loss of habitat/loss of heritage/loss of welfare amenity	4
Moderate-Low	Nuisance impact	2
Low	Negative change with no associated consequences.	1

Table 12: Criteria for the impact rating of potential intensity of a positive impact

Potential Intensity Descriptor	Definition of positive impact	Rating
Moderate-High	Net improvement in human welfare	8
Moderate	Improved environmental quality/improved individual livelihoods.	4
Moderate-Low	Economic development	2
Low	Positive change with no other consequences.	1

It must be noted that there is no HIGH rating for positive impacts under potential intensity, as it must be understood that no positive spinoff of an activity can possibly raise a similar significance rating to a negative impact that affects human health or causes the irreplaceable loss of a species.

7.1.5 Likelihood of the impact

This is the likelihood of the impact potential intensity manifesting. This is not the likelihood of the activity occurring. If an impact is unlikely to manifest then the likelihood rating will reduce the overall significance. Table 13 provides the rating methodology for likelihood.

The rating for likelihood is provided in fractions in order to provide an indication of percentage probability, although it is noted that mathematical connotation cannot be implied to numbers utilised for ratings.

Table 13: Criteria for the rating of the likelihood of the impact occurring

Likelihood Descriptor	Definition	Rating
Improbable	The possibility of the impact occurring is negligible and only under exceptional circumstances.	0.1
Unlikely	The possibility of the impact occurring is low with a less than 10% chance of occurring. The impact has not occurred before.	0.2
Probable	The impact has a 10% to 40% chance of occurring. Only likely to happen once in every 3 years or more.	0.5
Highly Probable	It is most likely that the impact will occur and there is a 41% to 75% chance of occurrence.	0.75
Definite	More than a 75% chance of occurrence. The impact will occur regularly.	1

7.1.6 Cumulative Impacts

Cumulative impact are reflected in the potential intensity of the rating system. In order to assess any impact on the environment, cumulative impacts must be considered in order to determine an accurate significance. Impacts cannot be assessed in isolation. An integrated approach requires that cumulative impacts be included in the assessment of individual impacts.

The nature of the impact should be described in such a way as to detail the potential cumulative impact of the activity.

7.1.7 Significance Assessment

The significance assessment assigns numbers to rate impacts in order to provide a more quantitative description of impacts for purposes of decision making. Significance is an expression of the risk of damage to the environment, should the proposed activity be authorised.

To allow for impacts to be described in a quantitative manner in addition to the qualitative description given above, a rating scale of between 1 and 5 was used for each of the assessment criteria. Thus the total value of the impact is described as the function of significance, which takes cognisance of extent, duration, potential intensity and likelihood.

Impact Significance = (extent + duration + potential intensity) x likelihood

Table 14 provides the resulting significance rating of the impact as defined by the equation as above.

Table 14: Significance rating formulas

Score	Rating	Implications for Decision-making
< 3	Low	Project can be authorised with low risk of environmental degradation
3 - 9	Moderate	Project can be authorised but with conditions and routine inspections. Mitigation measures must be implemented.
10 - 20	High	Project can be authorised but with strict conditions and high levels of compliance and enforcement. Monitoring and mitigation are essential.
21 - 26	Fatally Flawed	Project cannot be authorised

7.2 Potential Impacts from the FGD System

7.2.1 Groundwater Quality

The predicted impacts from the FGD system on the ambient groundwater quality is:

- Of Moderate significance during pre-construction, construction and operational phases; and
- Low significance during the decommissioning phase.

The Impact from the FGD system on the ambient groundwater quality of the underlying weathered aquifer for the different phase are listed inTable 15 to Table 18.

Table 15: FGD System Pre-Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	*1*	2	4	**0.2**	1 - LOW
	Cumulative (current and FGD)	*1*	2	4	**0.5**	4 - MOD
	Post Mitigation	*1*	1	2	**0.1**	0 - LOW

Table 16: FGD System Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	*1*	2	4	**0.5**	4 - MOD
	Cumulative (current and FGD)	*1*	2	4	**0.5**	4 - MOD
	Post Mitigation	*1*	1	2	**0.1**	0 - LOW

Table 17: FGD System Operational

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	*2*	3	4	**0.75**	7 - MOD
	Cumulative (current and FGD)	*2*	3	4	**0.75**	7 - MOD
	Post Mitigation	*1*	3	2	**0.2**	1 - LOW

Table 18: FGD System Decommissioning

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	*1*	2	2	**0.2**	1 - LOW
	Cumulative (current and FGD)	*1*	3	2	**0.2**	1 - LOW
	Post Mitigation	*1*	2	1	**0.1**	0 - LOW

7.2.2 Groundwater Volume and Flow Regime

The construction and operation of the FGD system, is expected to have a minor change in the volume of water entering groundwater storage (reduced recharge in comparison to status quo conditions) and with negligible changes expected in the groundwater flow regime.

The predicted impact of the FGD system on the groundwater volume and flow is:

- Of Low significance during pre-construction phase and Low to moderate during the construction and operational phases, if the operator limits any “on-site” pollution to an absolute minimum (within the dilution potential of annual recharge. The significance during the decommissioning phases are Low.

The Impact from the FGD system on the groundwater quantity/recharge and flow regime for the different phases are listed in Table 19 to Table 22.

Table 19: FGD System Pre-Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	1	2	2	0.2	1 - LOW
	Cumulative (current and FGD)	1	2	4	0.2	1 - LOW
	Residual/Post Mitigation	1	1	2	0.1	0 - LOW
Groundwater Flow	Existing	1	2	2	0.2	1 - LOW
	Cumulative	2	2	2	0.2	1 - LOW
	Post Mitigation	1	1	2	0.1	0 - LOW

Table 20: FGD System Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	1	2	2	0.5	3 - MOD
	Cumulative (current and FGD)	2	2	4	0.5	4 - MOD
	Post Mitigation	1	1	2	0.1	0 - LOW
Groundwater Flow	Existing	1	2	2	0.75	4 - MOD
	Cumulative	2	2	2	0.2	1 - LOW
	Post Mitigation	1	1	2	0.1	0 - LOW

Table 21: FGD System Operational

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	2	3	2	0.2	1 - LOW
	Cumulative (current and FGD)	1	2	4	0.5	4 - MOD
	Post Mitigation	2	2	2	0.1	1 - LOW
Groundwater Flow	Existing	2	3	2	0.2	1 - LOW
	Cumulative (current and FGD)	1	2	4	0.2	1 - LOW
	Post Mitigation	2	2	2	0.1	1 - LOW

Table 22: FGD System Decommissioning

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume	Existing	1	2	2	0.2	1 - LOW
	Cumulative (current and FGD)	1	2	2	0.2	1 - LOW
	Post Mitigation	1	2	1	0.1	0 - LOW
Groundwater Flow/recharge	Existing	1	2	2	0.2	1 - LOW
	Cumulative (current and FGD)	1	2	2	0.2	1 - LOW
	Post Mitigation	1	2	1	0.1	0 - LOW

7.3 Potential Impacts from the Railway Yard and Limestone and gypsum handling facilities between the Medupi Power Station and existing ADF

7.3.1 Groundwater Quality

The predicted impacts from the railway yard and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the ambient groundwater quality is:

- Of Low significance during pre-construction and of moderate significance during the construction and operational phases; and
- Low of significance during the decommissioning phase.

The Impact from the railway yard and limestone and gypsum handling facilities on the ambient groundwater quality of the underlying weathered aquifer for the different phases are listed in Table 23 to Table 26.

Table 23: Railway Yard and Handling Facilities Pre-Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	1	2	2	0.2	1 - LOW
	Cumulative (current and railway yard and facilities)	1	2	4	0.2	1 - LOW
	Post Mitigation	1	1	2	0.1	0 - LOW

Table 24: Railway Yard and Handling Facilities Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	1	2	2	0.5	3 - MOD
	Cumulative (current and railway yard and facilities)	1	2	4	0.5	4 - MOD
	Post Mitigation	1	1	2	0.1	0 - LOW

Table 25: Railway Yard and Handling Facilities Operational

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	2	3	4	0.75	7 - MOD
	Cumulative (current and railway yard and facilities)	2	2	8	0.5	6 - MOD
	Post Mitigation	1	3	2	0.2	1 - LOW

Table 26: Railway Yard and Handling Facilities Decommissioning

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater quality	Existing	1	2	2	0.2	1 - LOW
	Cumulative (current and railway yard and facilities)	1	3	2	0.2	1 - LOW
	Post Mitigation	1	2	1	0.1	0 - LOW

7.3.2 Groundwater Volume and Flow Regime

The predicted impact the railway yard and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the groundwater volume and flow is:

- Of Low significance during pre-construction phase and of low to moderate significance during the construction phase. The significance during the operational and decommissioning phases are of Low significance.

The Impact from the railway yard and limestone and gypsum handling facilities on the groundwater quantity/recharge and flow regime for the different phases are listed in Table 27 to Table 30.

Table 27: Railway Yard and Handling Facilities Pre-Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	1	2	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	2	4	**0.2**	1 - LOW
	Residual/Post Mitigation	1	1	2	**0.1**	0 - LOW
Groundwater Flow	Existing	1	2	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	2	4	**0.2**	1 - LOW
	Post Mitigation	1	1	2	**0.1**	0 - LOW

Table 28: Railway Yard and Handling Facilities Construction

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	1	2	2	**0.5**	3 - MOD
	Cumulative (current and railway yard and facilities)	1	2	2	**0.5**	3 - MOD
	Post Mitigation	1	1	2	**0.1**	0 - LOW
Groundwater Flow	Existing	1	2	2	**0.75**	4 - MOD
	Cumulative (current and railway yard and facilities)	1	2	2	**0.2**	1 - LOW
	Post Mitigation	1	1	2	**0.1**	0 - LOW

Table 29: Railway Yard and Handling Facilities Operational

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume/recharge	Existing	2	3	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	1	4	**0.2**	1 - LOW
	Post Mitigation	2	2	2	**0.1**	1 - LOW
Groundwater Flow	Existing	2	3	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	1	4	**0.2**	1 - LOW
	Post Mitigation	2	2	2	**0.1**	1 - LOW

Table 30: Railway Yard and Handling Facilities Decommissioning

Description of Impact	Impact type	Extent	Duration	Potential Intensity	Likelihood	Rating
Groundwater Volume	Existing	1	2	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	2	2	**0.2**	1 - LOW
	Post Mitigation	1	2	1	**0.1**	0 - LOW
Groundwater Flow/recharge	Existing	1	2	2	**0.2**	1 - LOW
	Cumulative (current and railway yard and facilities)	1	2	2	**0.2**	1 - LOW
	Post Mitigation	1	2	1	**0.1**	0 - LOW

7.4 Professional opinion on Trucking of Type 1 Waste to a Hazardous Disposal Facility

For the first five (5) years of the operational phase, sludge and salts will be stored at a temporary waste storage facility, after which it will be trucked to a licensed hazardous waste disposal site. During transportation of hazardous waste, the trucking contractor should adhere to all regulations and standards of both environmental and mining acts. Safe working procedures (SWP) for transportation of hazardous waste must be in place, to minimize the risk of contamination to the environment and groundwater should a spillage occur.

A hazardous spillage could contaminate the groundwater, and samples of any nearby boreholes should be analysed and monitored after a spillage incident. Storage of the Type 1 waste (hazardous waste) on site may result in risks to contamination the groundwater regime. This risk can be managed by ensuring that construction is done to good quality, after the facility is registered, and prepared in line with NEMWA Norms and Standards for Storage of Waste. Trucking of Type 1 waste to a licensed hazardous waste disposal site is effectively would effect a positive impact on site.

Possible impacts on the groundwater regime associated with trucking process of type 1 waste, to a licensed hazardous waste disposal site are based on a simplified groundwater risk assessment and are presented in Table 31. The risk rating is based on a possible risk/impact that activities from the trucking process of type 1 waste poses to the groundwater regime. Assessment is based on positive and negative outcome of impact/risk to the groundwater regime.

Table 31: Groundwater Risk Assessment

Activity	Positive Impacts	Negative Impacts
Removal of hazardous waste from existing licensed waste disposal facility	Removal of contamination source	None
Transportation of hazardous waste to a licensed hazardous waste disposal site	Removal and transportation of hazardous waste	None
Spillage during transportation of hazardous waste	None	Contamination of groundwater and impacting on existing users in vicinity of spillage
Disposal of hazardous waste	Disposal of hazardous waste	None

7.5 Qualitative Opinion on Impact on Groundwater, if Ash and Gypsum is Disposed together on the Existing ADF

The existing licensed disposal facility is designed for a 50 year life period and will have a liner that is designed according to the appropriate waste classification of the ash. The liner for the facility will be installed at appropriate frequencies, e.g. every two years. This is to reduce risk of damage to the liner due to exposure for long periods of time.

Considering that the ADF is proposed to have a Class C liner, in line with waste classification as per the NEMWA GNXX, since both ash and gypsum classified as Type 3 wastes will be disposed, the disposal of ash and gypsum together will probably not have a significant impact on the groundwater regime. This rehabilitation of WDF approach serves as a mitigation measure against groundwater contamination and poses a minimal risk of contamination on the groundwater.

A numerical groundwater model was constructed by Groundwater Complete (January 2017) to simulate possible pollution migration in the aquifer system underlying Medupi.

Two model scenarios were simulated, namely:

- A worst case scenario where the North dump and the entire surface area of the plant were assigned contaminated recharge (Figure 23), and
- A most probable scenario where the North dump and only the coal stockyard and sewage treatment plant (together with its recovery dams) were simulated as source areas (Figure 24).

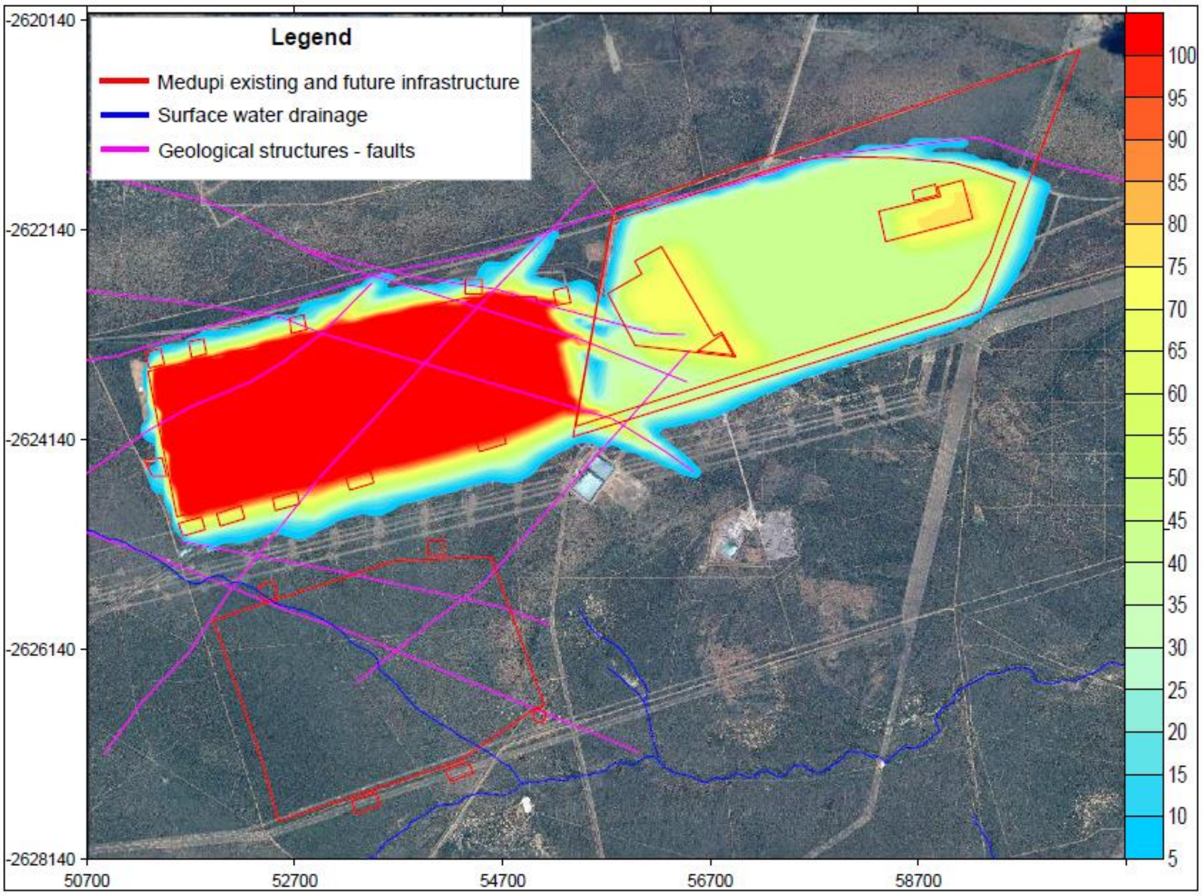

Figure 23: Model simulated pollution plumes for Scenario 1 at 50 years post closure (%) (Adapted from Groundwater Complete – 2017)

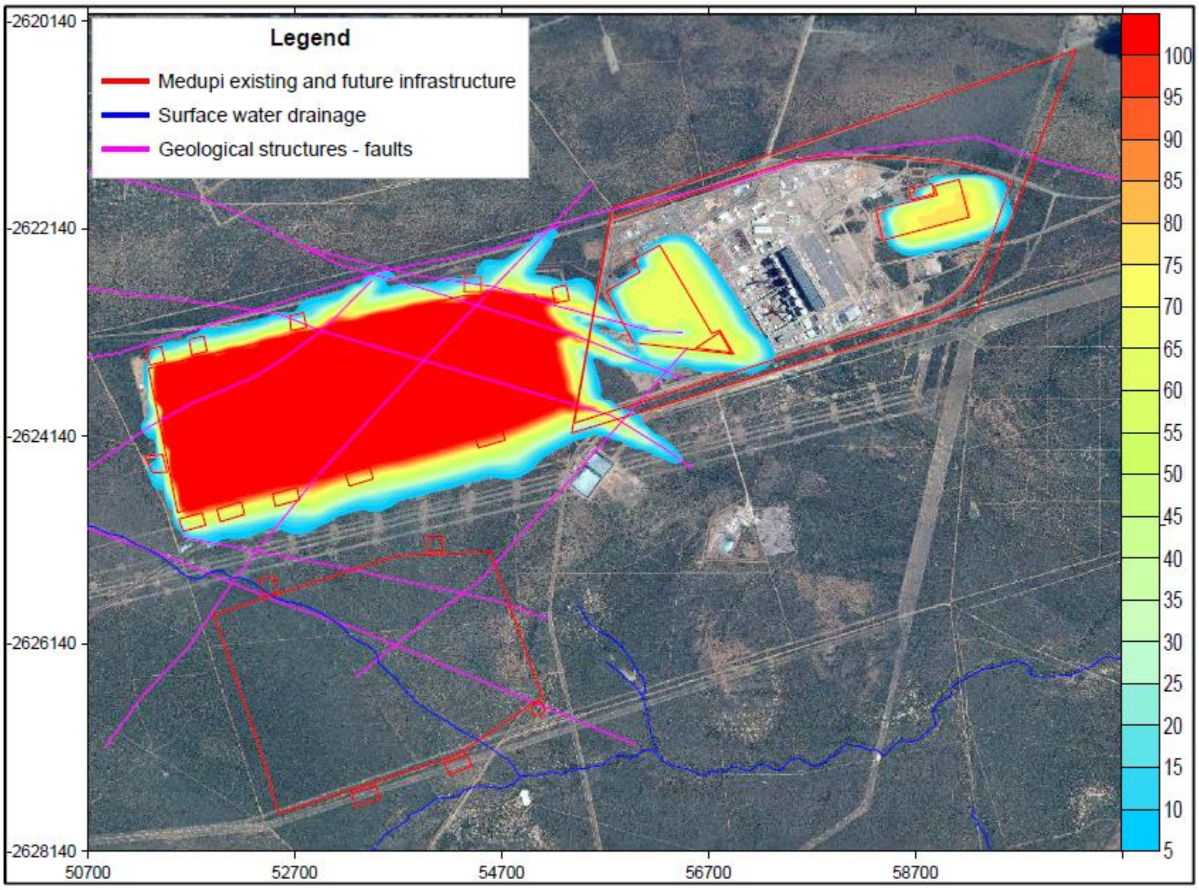

Figure 24: Model simulated pollution plumes for Scenario 2 at 50 years post closure (%) (Adapted from Groundwater Complete – 2017)

7.6 Qualitative Opinion whether Groundwater could potentially be impacted with the Construction of the FGD within the Medupi Power Station Footprint

During any construction phase involving disturbing of top soil by earth moving equipment and trucks, possible spillage could occur which could contaminate the groundwater. This contamination, however, will be point source only and within the site boundaries.

Safe working procedures (SWP) for construction work must be in place, to minimize the risk of contamination to the environment and groundwater should a spillage occur. Any accidental spillage should be cleaned up immediately to limit contamination and if intensity is high, the impact must be reversed with the applicable mitigation and management actions.

The potential impact whether groundwater could potentially be impacted with the Construction of the FGD within the Medupi Power Station Footprint is considered as a low to moderate significance.

8.0 MITIGATION MEASURES

The proposed mitigation measures that can be implemented at the Medupi FGD Project, should a leakage or contamination plume occur, are summarised below:

- The existing licenced disposal facility needs to be lined during the construction phase;
- The type 3 waste in a Class C barrier system and the Type 1 wastes in a Class A liner system;
- The existing licenced disposal facility needs to be rehabilitated at closure;

- Monthly groundwater monitoring of Eskom monitoring boreholes is recommended to form part of the mitigation and management of the Medupi FGD Project. This monitoring must be included in the monitoring network and will function as an early warning system for contaminant migration (if any);
- Frequent inspection and maintenance of liners; and
- Scavenger borehole system, to contain pollution on site must only be implemented if any contamination is detected at monitoring boreholes.

9.0 CONCLUSIONS

The following groundwater conclusions are made from the investigation and available data for the Medupi FGD Project:

- The existing licensed disposal facility is mainly underlain by Waterberg sediments comprising of sandstone, subordinate conglomerate, siltstone and shale;
- The initial regional groundwater conceptual model identifies two aquifer zones namely weathered, and fractured aquifer zones, but needs to be confirmed and updated, supported by future test pumping and borehole logs;
- The average groundwater level measured during the hydrocensus for the area of investigation is 30.4mbgl;
- Based on the hydrocensus water quality analyses , the background groundwater quality of the existing licensed disposal facility is Marginal (Class II) to Poor (Class III - IV) water Quality;
- Only boreholes GE06 and VER02 groundwater quality are representative of calcium magnesium bicarbonate type of water (Ca, Mg–(HCO_3). This water type represents unpolluted groundwater (mainly from direct rainwater recharge) and are probably representative of the pristine background water quality;
- The following inorganic constituents as identified during the hydrocensus exceed the SANS 241 (2011) drinking water compliance standards EC, TDS, Na, Cl, N, Al, F, Fe and Mn;
- The groundwater vulnerability of the existing licensed disposal facility proposed is shown on the national groundwater vulnerability map as low to medium;
- According to simplified groundwater risk rating assessment, the existing licenced disposal facility have a risk rating of 16, and poses a moderate risk of impacting on the surrounding groundwater regime. Possible impacts on the groundwater need to be investigated further;
- Following a decision by ESKOM to utilize the existing licenced disposal facility, a qualitative impact assessment was conducted on this site. Gypsum and ash are to be disposed on the existing licenced disposal facility;
- Based on the qualitative impact assessment, the existing activities and the licensed disposal facility poses the following potential impacts on the groundwater system:
  - A change in the groundwater quality;
  - A change in the volume of groundwater in storage or entering groundwater storage (recharge); or
  - A change in the groundwater flow regime.
- The predicted impacts from the FGD system (2017 SOW) on the ambient groundwater quality is:
  - Of Moderate significance during pre-construction, construction and operational phases; and
  - Low significance during the decommissioning phase.
- The predicted impact of the FGD system on the groundwater volume and flow is:

- Of Low significance during pre-construction phase and Low to moderate during the construction and operational phases. The significance during the decommissioning phases are Low.

- The predicted impacts from the railway yard and limestone and gypsum handling facilities (2017 SOW) between the Medupi Power Station and existing ADF activities on the ambient groundwater quality is:
  - Of Low significance during pre-construction and of Moderate significance during the construction and operational phases; and
  - Low of significance during the decommissioning phase.
- The predicted impact the railway yard and limestone and gypsum handling facilities between the Medupi Power Station and existing ADF activities on the groundwater volume and flow is:
  - Of Low significance during pre-construction phase and of Low to Moderate significance during the construction phase. The significance during the operational and decommissioning phases are of Low significance.

10.0 RECOMMENDATIONS

Following the groundwater baseline and IA investigation the following is recommended:

- Monthly monitoring of exiting Eskom monitoring boreholes groundwater levels and quality. Monitoring should be conducted to be consistent with the existing WUL (Licence no.: 01 /A1042/ABCEFGI/5213);
- Monitoring boreholes MBH08, MBHO9 and MBH07 which are dry or water level are too low to sample and need to be replaced to ensure monitoring coverage in these areas;
- Aquifer testing of new monitoring boreholes to determine hydraulic parameters and update initial groundwater conceptual model. The groundwater conceptual model with aquifer parameters provide the basic input into a groundwater numerical model;
- Groundwater sampling of newly drilled monitoring boreholes;
- The newly-drilled monitoring boreholes should be incorporated into the existing monitoring programme. The following monitoring tasks should be conducted to be consistent with the existing WUL Licence no.: 01 /A1042/ABCEFGI/5213;
- Bi-annually groundwater monitoring of existing groundwater user's boreholes in the area surrounding the existing licensed disposal facility (In radius of ~ 3.0 km).
- Development of a numerical groundwater flow & transport model (or update of existing models) and Impact Assessment. This model to include Medupi Power station (MPS) and the Medupi FGD Project;
- Use model predictions to predict the pollution plume from the Medupi FGD Project area and Medupi Power station;
- Update mitigation and management measures for the Medupi FGD Project on numerical model outcome and predictions.

11.0 REFERENCES

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Golder 2011. Medupi Power Station: Shallow Dewatering – Numerical modelling update: Report No: 10613234-10802-1.

IGS 2008. Geohydrological Interpretation, Modelling and Impact Risk Assessment for Medupi Power Station. Report No: 2008/28/PDV.

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1: 500 000, Hydrogeological Map Series of RSA (1996).

Groundwater Complete 2017. Eskom Medupi Power Station. Report on Numerical Groundwater Modelling Results.

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APPENDIX A

Analytical Result Certificates of Hydrocensus Samples

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SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2015 - 09 - 28 **Date completed:** 2015 - 10 – 09

Project number: 159 **Report number: 54819** **Order number: 93428**

Client name: Golder Associates **Contact person: Mr. D. Brink**

Address: P.O. Box 6001 Halfway House 1685 **e-mail: dbrink@golder.co.za**

Telephone: 011 313 1058 **Facsimile: -** **Mobile: 083 379 2666**

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification				
		KR05	BU03	KR01	KR03	BU02
Sample Number		16952	16953	16954	16955	16956
pH – Value at 25°C *	WLAB001	7.3	7.3	5.7	5.4	7.5
Electrical Conductivity in mS/m at 25°C *	WLAB002	31.0	288	15.7	27.4	204
Total Dissolved Solids at 180°C *	WLAB003	180	1 896	116	198	1 320
Total Alkalinity as $CaCO_3$ *	WLAB007	160	292	8	8	288
Chloride as Cl	WLAB046	9	664	25	36	518
Sulphate as SO_4	WLAB046	8	62	24	51	36
Fluoride as F *	WLAB014	0.3	2.2	0.9	2.7	2.2
Nitrate as N	WLAB046	<0.2	66	<0.2	2.0	16
ICP-MS Scan *	WLAB050	See Attached Report:54819 -A				
% Balancing*	---	95.0	95.7	96.4	94.7	97.1

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification				
		VER02	BU01	GE03	GE01	GE06
Sample Number		16957	16958	16959	16960	16961
pH – Value at 25°C *	WLAB001	7.4	7.5	7.8	7.1	7.0
Electrical Conductivity in mS/m at 25°C *	WLAB002	112	178	124	12.2	39.6
Total Dissolved Solids at 180°C *	WLAB003	652	1 058	670	84	248
Total Alkalinity as $CaCO_3$ *	WLAB007	356	368	276	48	208
Chloride as Cl	WLAB046	167	336	280	18	17
Sulphate as SO_4	WLAB046	40	71	41	<5	<5
Fluoride as F *	WLAB014	1.3	2.3	0.7	<0.2	<0.2
Nitrate as N	WLAB046	0.5	<0.2	<0.2	<0.2	0.3
ICP-MS Scan *	WLAB050	See Attached Report:54819 –A				
% Balancing*	---	96.0	97.4	89.5	98.1	96.4

*** = Not SANAS Accredited**

Tests marked “Not SANAS Accredited” in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

A. van de Wetering

Technical Signatory

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSIS

WATERLAB

Project Number : **159**
Client : **Golder Assosiates**
Report Number : **54819-A**

Sample Origin	Sample ID	Ag (mg/L)	Al (mg/L)	As (mg/L)	Au (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Bi (mg/L)	Ca (mg/L)	Cd (mg/L)	Ce (mg/L)	Co (mg/L)
KR05	16952	<0.010	0.715	<0.010	<0.010	0.071	0.085	<0.010	<0.010	15	<0.010	<0.010	<0.010
BU03	16953	<0.010	0.100	<0.010	<0.010	0.166	0.326	<0.010	<0.010	186	<0.010	<0.010	<0.010
KR01	16954	<0.010	0.576	<0.010	<0.010	0.023	0.163	<0.010	<0.010	6	<0.010	<0.010	<0.010
KR03	16955	<0.010	2.21	<0.010	<0.010	0.024	0.297	<0.010	<0.010	11	<0.010	<0.010	0.010
BU02	16956	<0.010	0.255	0.067	<0.010	0.143	0.206	<0.010	<0.010	135	<0.010	<0.010	<0.010
VER02	16957	<0.010	<0.100	0.016	<0.010	0.141	0.210	<0.010	<0.010	77	<0.010	<0.010	<0.010
BU01	16958	<0.010	0.103	0.019	<0.010	0.169	0.075	<0.010	<0.010	81	<0.010	<0.010	<0.010
GE03	16959	<0.010	<0.100	<0.010	<0.010	0.157	0.114	<0.010	<0.010	23	<0.010	<0.010	<0.010
GE01	16960	<0.010	0.130	<0.010	<0.010	0.022	0.081	<0.010	<0.010	3	<0.010	<0.010	<0.010
GE06	16961	<0.010	<0.100	<0.010	<0.010	0.019	0.515	<0.010	<0.010	32	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Cr (mg/L)	Cs (mg/L)	Cu (mg/L)	Dy (mg/L)	Er (mg/L)	Eu (mg/L)	Fe (mg/L)	Ga (mg/L)	Gd (mg/L)	Ge (mg/L)	Hf (mg/L)	Hg (mg/L)
KR05	16952	<0.010	<0.010	0.020	<0.010	<0.010	<0.010	2.14	0.014	<0.010	<0.010	<0.010	<0.010
BU03	16953	<0.010	<0.010	0.022	<0.010	<0.010	<0.010	0.108	0.034	<0.010	<0.010	<0.010	<0.010
KR01	16954	<0.010	<0.010	0.031	<0.010	<0.010	<0.010	7.06	0.029	<0.010	<0.010	<0.010	<0.010
KR03	16955	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.566	0.050	<0.010	<0.010	<0.010	<0.010
BU02	16956	<0.010	<0.010	0.147	<0.010	<0.010	<0.010	6.59	0.024	<0.010	<0.010	0.025	<0.010
VER02	16957	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	3.61	0.029	<0.010	<0.010	<0.010	<0.010
BU01	16958	<0.010	<0.010	0.125	<0.010	<0.010	<0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010
GE03	16959	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.042	0.016	<0.010	<0.010	<0.010	<0.010
GE01	16960	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	4.82	0.015	<0.010	<0.010	<0.010	<0.010
GE06	16961	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.030	0.082	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Ho (mg/L)	In (mg/L)	Ir (mg/L)	K (mg/L)	La (mg/L)	Li (mg/L)	Lu (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Nb (mg/L)
KR05	16952	<0.010	<0.010	<0.010	2.6	<0.010	0.024	<0.010	<2	0.044	<0.010	52	<0.010
BU03	16953	<0.010	<0.010	<0.010	23	<0.010	0.045	<0.010	95	<0.025	<0.010	238	<0.010
KR01	16954	<0.010	<0.010	<0.010	6.4	<0.010	<0.010	<0.010	4	0.068	<0.010	11	<0.010
KR03	16955	<0.010	<0.010	<0.010	7.0	<0.010	<0.010	<0.010	5	0.138	<0.010	23	<0.010
BU02	16956	<0.010	<0.010	<0.010	17.0	<0.010	0.053	<0.010	65	0.775	<0.010	195	<0.010
VER02	16957	<0.010	<0.010	<0.010	15.3	<0.010	0.050	<0.010	34	0.324	<0.010	108	<0.010
BU01	16958	<0.010	<0.010	<0.010	18.4	<0.010	0.087	<0.010	54	0.090	<0.010	194	<0.010
GE03	16959	<0.010	<0.010	<0.010	6.4	<0.010	0.169	<0.010	17	0.122	<0.010	200	<0.010
GE01	16960	<0.010	<0.010	<0.010	2.5	<0.010	0.024	<0.010	2	0.131	<0.010	17	<0.010
GE06	16961	<0.010	<0.010	<0.010	2.9	<0.010	0.017	<0.010	26	0.065	<0.010	12	<0.010

Sample Origin	Sample ID	Nd (mg/L)	Ni (mg/L)	Os (mg/L)	P (mg/L)	Pb (mg/L)	Pd (mg/L)	Pt (mg/L)	Rb (mg/L)	Rh (mg/L)	Ru (mg/L)	Sb (mg/L)	Sc (mg/L)
KR05	16952	<0.010	0.021	<0.010	0.584	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BU03	16953	<0.010	0.050	<0.010	<0.010	<0.010	<0.010	<0.010	0.025	<0.010	<0.010	<0.010	<0.010
KR01	16954	<0.010	0.074	<0.010	0.111	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
KR03	16955	<0.010	0.026	<0.010	0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010
BU02	16956	<0.010	0.085	<0.010	0.042	0.501	<0.010	<0.010	0.028	<0.010	<0.010	<0.010	<0.010
VER02	16957	<0.010	0.047	<0.010	0.039	<0.010	<0.010	<0.010	0.015	<0.010	<0.010	<0.010	<0.010
BU01	16958	<0.010	0.035	<0.010	0.050	0.026	<0.010	<0.010	0.022	<0.010	<0.010	<0.010	<0.010
GE03	16959	<0.010	<0.010	<0.010	0.049	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
GE01	16960	<0.010	0.048	<0.010	0.033	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
GE06	16961	<0.010	0.010	<0.010	0.061	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Se (mg/L)	Si (mg/L)	Sm (mg/L)	Sn (mg/L)	Sr (mg/L)	Ta (mg/L)	Tb (mg/L)	Te (mg/L)	Th (mg/L)	Ti (mg/L)	Tl (mg/L)	Tm (mg/L)
KR05	16952	<0.010	10.1	<0.010	<0.010	0.288	<0.010	<0.010	<0.010	<0.010	0.026	<0.010	<0.010
BU03	16953	0.016	28	<0.010	<0.010	1.51	<0.010	<0.010	<0.010	<0.010	0.301	<0.010	<0.010
KR01	16954	<0.010	13.7	<0.010	<0.010	0.054	<0.010	<0.010	<0.010	<0.010	0.010	<0.010	<0.010
KR03	16955	<0.010	19.7	<0.010	<0.010	0.059	<0.010	<0.010	<0.010	<0.010	0.025	<0.010	<0.010
BU02	16956	0.011	23	<0.010	<0.010	1.08	<0.010	<0.010	<0.010	<0.010	0.199	<0.010	<0.010
VER02	16957	<0.010	5.8	<0.010	<0.010	0.540	<0.010	<0.010	<0.010	<0.010	0.110	<0.010	<0.010
BU01	16958	<0.010	11.8	<0.010	<0.010	0.700	<0.010	<0.010	<0.010	<0.010	0.121	<0.010	<0.010
GE03	16959	<0.010	8.8	<0.010	<0.010	0.279	<0.010	<0.010	<0.010	<0.010	0.036	<0.010	<0.010
GE01	16960	<0.010	11.4	<0.010	<0.010	0.060	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
GE06	16961	<0.010	29	<0.010	<0.010	0.169	<0.010	<0.010	<0.010	<0.010	0.048	<0.010	<0.010

Sample Origin	Sample ID	U (mg/L)	V (mg/L)	W (mg/L)	Y (mg/L)	Yb (mg/L)	Zn (mg/L)	Zr (mg/L)
KR05	16952	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BU03	16953	<0.010	<0.010	<0.010	<0.010	<0.010	0.093	<0.010
KR01	16954	<0.010	<0.010	<0.010	<0.010	<0.010	0.527	<0.010
KR03	16955	<0.010	<0.010	<0.010	<0.010	<0.010	0.029	<0.010
BU02	16956	0.012	<0.010	<0.010	<0.010	<0.010	0.113	<0.010
VER02	16957	0.000	<0.010	<0.010	<0.010	<0.010	0.007	<0.010
BU01	16958	0.007	<0.010	<0.010	<0.010	<0.010	1.354	<0.010
GE03	16959	0.002	<0.010	<0.010	<0.010	<0.010	0.026	<0.010
GE01	16960	0.000	<0.010	<0.010	<0.010	<0.010	0.469	<0.010
GE06	16961	0.001	<0.010	<0.010	<0.010	<0.010	0.014	<0.010

APPENDIX B

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