Groundwater Assessment for the Proposed Active Water Treatment Plant at South32 Klipspruit Colliery, Mpumalanga Province

Groundwater Report

Project Number:

SOU5014

Prepared for:

South32 SA Coal Holdings (Pty) Ltd

July 2018

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Project Name:	**Groundwater Assessment for the Proposed Active Water Treatment Plant at South32 Klipspruit Colliery, Mpumalanga Province**
Project Code:	**SOU5014**

Name	**Responsibility**	**Signature**	**Date**
Simamkele Baqa	Report Writer		July 2018
Andre van Coller	Reviewer		July 2018

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Details of the Specialist

This Specialist Report has been compiled by the following specialists:

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Highest Qualification	MSc Hydrogeology
Years of experience in specialist field	0-1

Declaration of the Specialist

I, **Simamkele Baqa**, as the appointed specialists hereby declare/affirm the correctness of the information provided or to be provided as part of the application, and that I:

- in terms of the general requirement to be independent, other than fair remuneration for work performed/to be performed in terms of this application, have no business, financial, personal or other interest in the activity or application and that there are no circumstances that may compromise my objectivity;
- in terms of the remainder of the general requirements for a specialist, am fully aware of and meet all of the requirements and that failure to comply with any the requirements may result in disqualification;
- have disclosed/will disclose, to the applicant, the Department and interested and affected parties, all material information that have or may have the potential to influence the decision of the Department or the objectivity of any report, plan or document prepared or to be prepared as part of the application; and
- am aware that a false declaration is an offence in terms of regulation 48 of the 2014 NEMA EIA Regulations.

Signature of the specialist

Simamkele Baqa

Full Name and Surname of the specialist

Digby Wells Environmental

Name of company

July 2018

Date

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by South32 SA Coal Holdings (Pty) Ltd (hereafter South32) to undertake an Environmental Impact Assessment (EIA) in relation to proposed active Water Treatment Plant (WTP) capable of treating 10 Mega litres of mine affected water from the balancing dam at Klipspruit Colliery approximately 3km west of the town of Ogies in Mpumalanga Province.

It is understood that the project area is made up of two types of aquifers; upper weathered aquifer, fractured rock aquifer and the Pre-Karoo fractured rock aquifer. These aquifers can be classified as minor systems with relatively good water quality (TDS <300 mg/L), moderate vulnerability and medium susceptibility to contamination. The groundwater flow direction mimics surface topography and is predominantly in a south to north direction varying slightly at the various sites.

Groundwater quality monitoring data (received from the client) was analysed to determine the current quality in the groundwater and whether pollution has affected the boreholes. The following observations were made at the respective boreholes as labelled:

- The pH values for the sampled boreholes varied between 6.4 at KGMB9 and 7.4 at BSW3 and KGMB16 with an average of 7.1. All boreholes are below the recommended KPS WUL limits of 8.8. Though all borehole had pH below the recommended WUL these show pH of an acidic rain to neutral pH considered a good groundwater quality.
- Although all boreholes fall below the recommended KPS WUL limits, these are still considered to be within an acceptable range (pH of 6 to 8) as per DWS general guidelines for drinking water. Generally, it is not ideal to have one pH value (such as KPS WUL pH of 8.79) as a compliance measure as the pH values generally vary from one place to another within the same site. It is recommended that the WUL compliance measures be reviewed and an appeal be made to DWS to reconsider some of the WQO.
- All samples fall within the recommended KPS WUL limits for Electrical Conductivity (EC),Calcium (Ca), Magnesium (Mg), Sodium (Na), potassium (K) and Chloride (Cl) concentration;
- The sulphate (SO_4) concentration for all samples falls within the recommended WUL limits of 10.36 mg/L except BSW3, KGMB4 and KGMB16; and
- All boreholes exceeded the Nitrates (NO_3) and Fluoride (F) WUL limits of 0.11 mg/L and 0.14 mg/L respectively. The results show that NO_3 and F concentration has been consistently high as observed during the baseline studies.

In summary, BWS3, KGMB4 and KGMB16 are the most contaminated boreholes compared to other boreholes with KGMB16 the worst water quality. Further, during the baseline studies, Borehole BWS4 was the most contaminated borehole (based on the pH and sulphates) compared to other boreholes. The high sulphate can be directly traced back to

the oxidation of the sulphur mineralogy associated with the coal in the area which causes Acid Mine Drainage (low pH and higher SO_4).

Background water quality for un-impacted groundwater within the site is typically characterised by pH of 5.8 to 8.2, with EC values around 66mS/m. Average SO_4 in un-impacted groundwater varies from 4.3 to 17.4mg/L and average NO_3 concentration in groundwater ranges from 10.6 mg/L to 26.8 mg/L. Average Aluminium (Al) concentration varies from 0.01mg/L to 0.2mg/L and average Manganese (Mn) concentration varies from 0.01mg/L to 0.7mg/L. Average Iron (Fe) concentration varies from 0.2mg/L to 0.5mg/L. Other elements, such as Ca, Mg, Na, K, Cl, F, Ammonia ($N\text{-}NH_4$), Phosphate (PO_4) and Silica (Si), are also in low concentration. These concentrations are considered representative of un-impacted groundwater that resides within the site.

The water quality of the aquifers indicates that groundwater has already been impacted and this is mainly due to mining activities. Therefore, it is deemed that the proposed KPS WTP will have a negligible impact (if any) on the environment if managed well as the treatment plant will be a proper engineering structure and the discharged water will comply with the Department of Water and Sanitation (DWS quality) standards for discharged water.

Based on the above conclusion it is deemed that the current groundwater environment is not susceptible to the proposed activities if managed correctly.

The following recommendations are made:

- Site clearing should be restricted to areas of absolute necessity and the activity should be conducted over a short duration (i.e. during pre-construction and construction only), if possible;
- Site clearance and construction activities should take place above the water table (approximately 2.98 mbgl at KGMB6), at the unsaturated zone, (if possible), no impact on the groundwater will then be expected;
- The sludge or brine should be deposited in a certified waste facility based on waste classifications and geochemical assessments done on the material; and
- It is recommended that the KPS WUL compliance measures be relooked and an appeal be made to DWS to reconsider some of the water quality objectives (WQO) such as the pH.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AMD	Acid Mine Drainage
BH	Borehole
DMR	Department of Mineral Resources
CBE	Charge Balance Error
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GN R 704	NWA amendment of Regulation 704 of 1999

HDPE	High Density Polyethylene
KPS	Klipspruit Colliery
km	Kilometre
L	Litre
L/s	Litre per second
L/h	Litre per hour
Ml	Mega Litres
magl	metres above ground level
mamsl	metres above mean sea level
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
mbgl	metres below ground level
mg/ℓ	milligrams per litre
mm	millimetre
mm/a	millimetre per annum
ms	mili-seconds
mS/m	milli Siemens per metre
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
NWA	National Water Act (Act 36 of 1998)
RQO	Resource Quality Objectives
SANAS	South African National Accreditation System
TDS	Total Dissolved Solids
WISH	Windows interpretation system for hydrogeologist
WTP	Water Treatment Plant
WUL	Water Use License

1 Introduction

South32 SA Coal Holdings (Pty) Limited (hereafter South32) owns the Klipspruit Colliery (KPS), near Ogies in the Mpumalanga Province. Contaminated water that is being generated at KPS by mining activities exceeds the re-use capacity within the operations, whilst the storage capacity in mined out areas has reached its limits. The result of this is the risk of spillages or discharges to the natural environment. Effective management of this risk is essential to continued operations at KPS ensuring access to coal resources as well as securing and maintaining the requisite environmental licences and authorisations to operate and expand. Water treatment is thus required and South32 proposes to construct a modular Water Treatment Plant (WTP) and ancillary infrastructure to treat mine-affected water (the Project). South32 has appointed Digby Wells Environmental (Digby Wells) as the independent Environmental Assessment Practitioner to undertake the environmental-legal application processes and Specialist studies relevant to this proposed project.

To attain the required approval for the KPS WTP project, South32 is undertaking a detailed groundwater impact assessment study. The specialist groundwater impact assessment is conducted to provide the baseline groundwater conditions as well as to identify and to assess potential groundwater impacts that may arise from the proposed development and its associated activities according to the hydrogeological characteristics, monitoring data and process description of the mine water treatment plant.

Thus, a groundwater impact assessment study is undertaken in line with the Department of Water and Sanitation (DWS) Best Practice Guideline for Impact Prediction and is guided by following legislative requirements:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA);
- Regulation 636 under the National Environmental Management: Waste Act;
- National Water Act (Act 36 of 1998) (NWA);
- NWA amendment of Regulation 704 (GN R 704) of 1999; and
- The National Environmental management Act (Act 107 of 1998): 2017 amendments to the Environmental Impact Assessment (EIA) Regulations.

1.1 Motivation and Description of the Proposed Water Treatment Plant

KPS requires an active WTP capable of treating 10Ml/day of mine affected water from the balancing dam (Figure 1-1). The WTP is to be established within the operational area of the mine in the south-eastern corner of the Mining Right boundary, adjacent to KPS project offices. The proposed WTP will be modular in design and constructed in three phases, starting at a capacity of 2Ml/day, upgradeable to 3.3Ml/day and then increments of 3.3Ml/day to 10Ml/day. Contaminated water will be abstracted from the Balancing Dam at KPS and pumped to the WTP. After treatment, clean water that complies with the Resource Water Quality Objectives (RWQO) for the Wilge River catchment is proposed to be discharged into the Saalklapspruit at the northern boundary of the KPS operation adjacent to the N12 national highway.

The treatment process will be based on the use of membrane desalination with brine softening and will consist of the following steps:

- Pre-treatment of the feed water using pH adjustment and disinfection to remove organics from the system that can cause fouling and scaling of the membranes;
- Removal of the dissolved metals by chemical oxidation followed by the removal of precipitates and suspended solids using flocculation and coagulation unit processes;
- Ultrafiltration (UF) will be used to remove fine particles from the feed water to the Reverse Osmosis (RO) unit processes. This is necessary to prevent fouling and scaling of the RO membranes; and
- Product water conditioning is required to ensure the pH meets the discharge requirements.

This process will produce gypsum sludge and brine. The gypsum sludge will be dewatered at the WTP and then loaded onto trucks for off-site disposal at a licenced waste management facility designed for this type of material. The brine will be recycled back into the treatment process until the salinity requires that a portion be depleted from the system. This small volume of brine will be stored in tanks within the proposed WTP footprint from where it will be pumped into road tankers and transported to a third-party waste management site licenced to receive this waste.

The infrastructure layout of the project is depicted in Figure 1-1 and the key infrastructure components of the project scope are as follows:

- A Feed Water Line comprising of a pump station and 1.5km High Density Poly Ethylene (HDPE) pipeline from the Balancing Dam to the WTP site capable of pumping 10Ml/day;
- A return water system from the WTP to the Balancing Dam along the same route as the Feed Water Line for the management of treated water that does not comply with the requirements for release to the catchment;
- A WTP Area with a footprint of approximately 1.5ha for the establishment and operation of a modular WTP with a maximum throughput of 10Ml/day. This includes the development and use of facilities for the storage and handling of hazardous chemicals used in the treatment process;
- A Discharge Line comprising of a 4km HDPE pipeline along the eastern boundary of KPS to transfer the treated water for discharge to the Saalklapspruit. Two pipeline routes are required to accommodate advancing mining and rehabilitation activities along the proposed pipeline servitude, and will be implemented at different stages of the project; and

- A dissipation structure at the proposed discharge point, alongside the N12 National Highway.

Supporting services such as the new powerline and change houses and ablution facilities (connected to existing sewage line) are also included in the project.

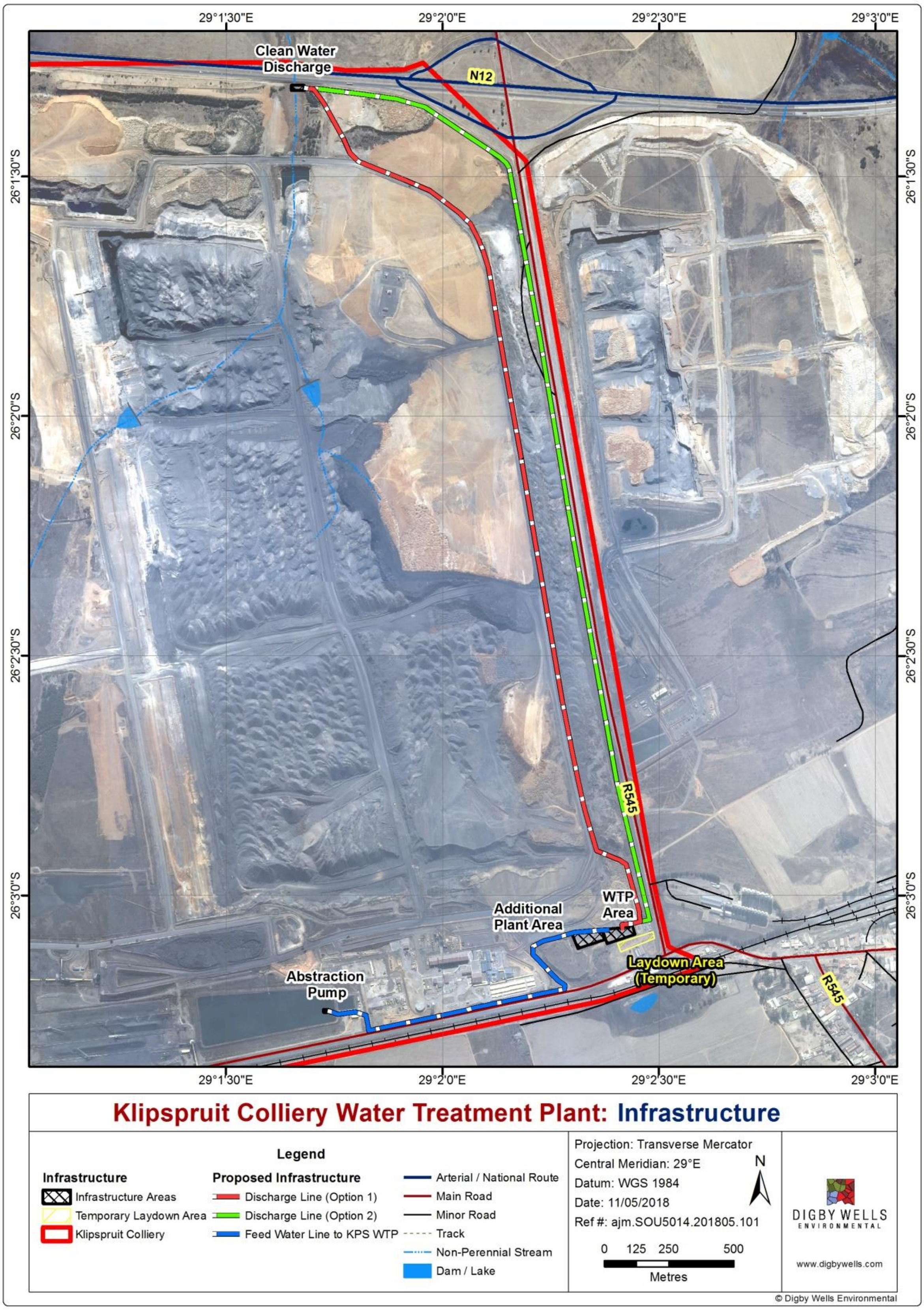

Figure 1-1: KPS WTP Infrastructure

1.2 Study Aims and Objectives

The objective of the hydrogeological study includes the assessment of the potential impacts and mitigation plans for the proposed WTP on the groundwater resource.

The specific objectives of the hydrogeological study include:

- Detailing the baseline groundwater conditions;
- Understanding the potential contamination sources and receptors; and
- Identifying potential impacts that can arise as part of the proposed activity and recommend on the potential mitigation measures to be implemented.

2 Site Description

The proposed site/WTP will be established in the south-eastern corner of the KPS mine boundary, close to the KPS project office, within the operational area of KPS (Figure 1-1).

2.1 Topography and Drainage

The project area occurs within the B20G quaternary catchment topographically characterised by gently undulating hills and valleys (Figure 2-1). The topographical model indicates that the elevation of the project area decreases from 1.612 metres above mean sea level (mamsl) in the south to 1.482 mamsl in the north. The majority of the project area has gentle slopes of less than 4°. Isolated slopes of between 4° and 11.3° occur along the sides of the ridges and river valleys. There is a ridge running in an east-west direction in the southern part of the project area (Digby Wells, 2017).

The main streams draining the catchment B20G are as follows:

- Saalklapspruit – first order perennial stream flowing towards the north; and
- Grootspruit – first order perennial stream flowing towards the north.

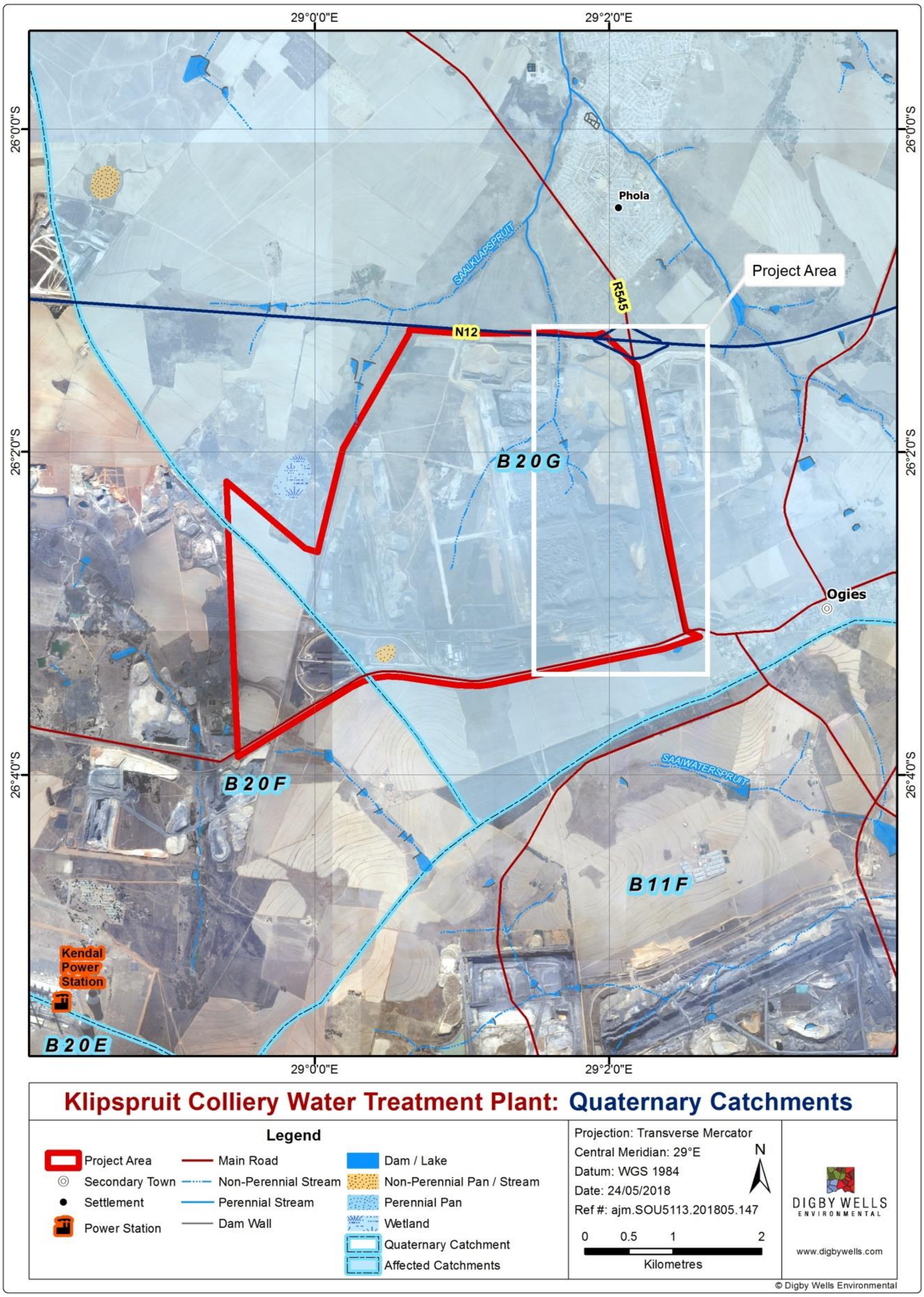

Figure 2-1: Local Setting

2.2 Climate

KPS is located within temperate climate region, experiencing warm summers and dry cold winters. The mean daily temperature varies from 13.2 ºC and 25.8 ºC in mid-summer months (January) and 0.2 ºC and 17.1 ºC during mid-winter months (July). The section below provides the climatic conditions (temperature, rainfall and evaporation) of the project area.

2.2.1.1 Rainfall

Table 2-1 present the average monthly rainfall for the quaternary catchment B20G. This is based on the averages of monthly rainfall data from a period of 1920 to 2009. Figure 2-2 below present the summary of the average monthly climatic data for B20G quaternary catchment.

Table 2-1: Summary of rainfall data extracted from the WRC, 2012

Month	Mean Monthly Precipitation (MMP) (mm)
January	122
February	91
March	84
April	41
May	16
June	8
July	6
August	6
September	20
October	68
November	112
December	113
MAP	**686**

From the rainfall data above, higher rainfall values (112 mm, 113 mm and 122 mm) were recorded for the months of November, December and January respectively whilst the lowest rainfall was recorded in July and August (MMP of 6 mm for both months).

2.2.1.2 Evaporation

Monthly evaporation data was obtained from the WRC, 2012. The project area lies within quaternary catchments B20G, which has a Mean Annual Evaporation (MAE) of 2750mm. The evaporation obtained is based on Symons Pan evaporation measurements and needs to be converted to lake evaporation. This is due to the Symons Pan being located below the ground surface and painted black which results in the temperature in the water being higher than that of a natural open water body. The Symons Pan figure is then multiplied by a lake evaporation factor to obtain the adopted lake evaporation figure which presents the monthly evaporation rates of a natural open water body, this was calculated to be a total average of 2315 mm/a. Table 2-2 is a summary of the evaporation for the B20G quaternary.

In this area, higher evaporation rates are experienced during the months of January, March and April whilst the low evaporation occurs in August, September and October. The potential average annual evaporation rate of 1410 mm is higher than the average annual precipitation rate of 686 mm. This area is thus a semi-arid area.

Table 2-2: Summary of evaporation data

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	180.8	0.81	146.4
February	170.6	0.82	139.9
March	187.8	0.83	155.9
April	184.5	0.84	155.0
May	153.8	0.88	135.3
June	151.8	0.88	133.6
July	116.7	0.88	102.7
August	98.3	0.87	85.5
September	79.8	0.85	67.9
October	87.4	0.83	72.5
November	115.7	0.81	93.7
December	149.9	0.81	121.4
Total	**1677**	**N/A**	**1410**

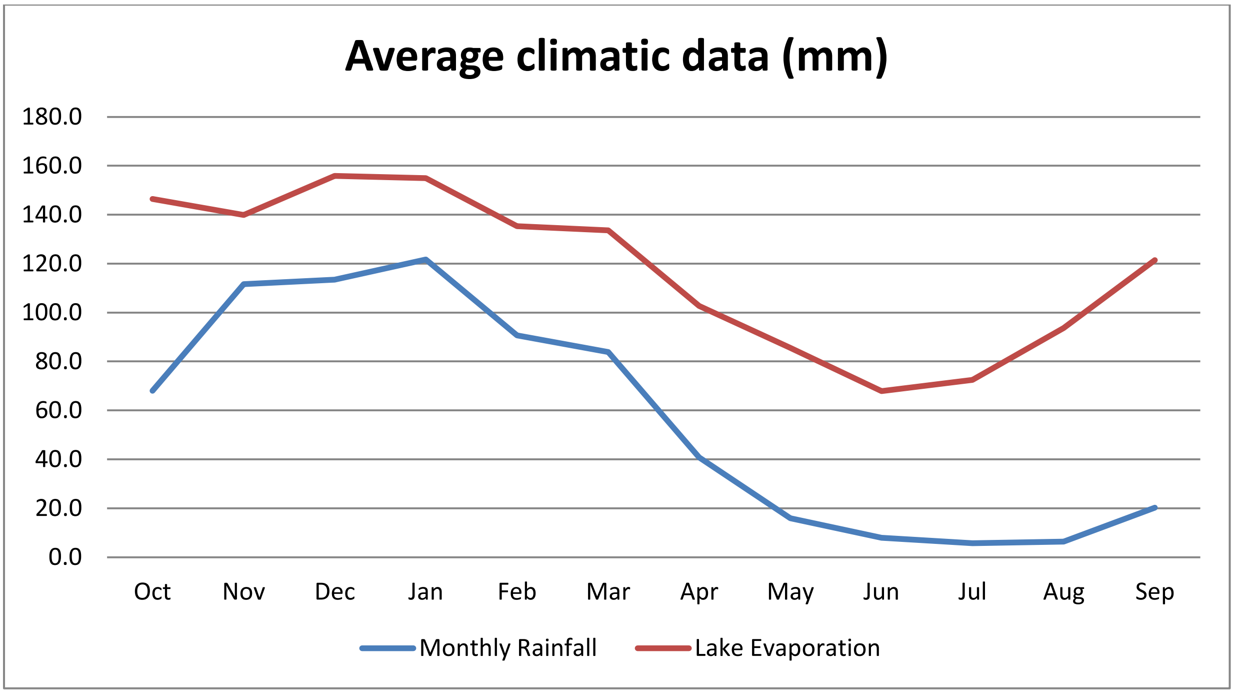

Figure 2-2: Summary of the average monthly climatic data for B20G quaternary catchment

2.3 Geology

KPS falls within the Witbank Coalfield, and comprises of sedimentary sequences and formations of the Karoo Supergroup. The Karoo Supergroup in the project area comprises of the Ecca Group and the underlying Dwyka Group. The regional geology is presented in Figure 2-3.

The sediments, typically found, in the Ecca Group are coarse to fine grained sandstone, siltstone, shale and coal, which often occur as interbedded units. The underlying Dwyka Group comprises predominantly of tillite, siltstone and occasionally shale. Underlying the Dwyka Group, are a number of lithologies associated with the Bushveld Complex (in the north), Witwatersrand Supergroup (in the south), Waterberg Supergroup (in the northwest) and Transvaal Supergroup (in the west).

Structurally, the Karoo Supergroup is relatively undisturbed. Presences of faults are uncommon; however fractures occur frequently in the competent sandstone and coal units. Dolerite intrusions are common throughout the entire Karoo Supergroup and occur predominantly as dykes and sills. The Ogies dyke runs east-west along the southeast of the project area.

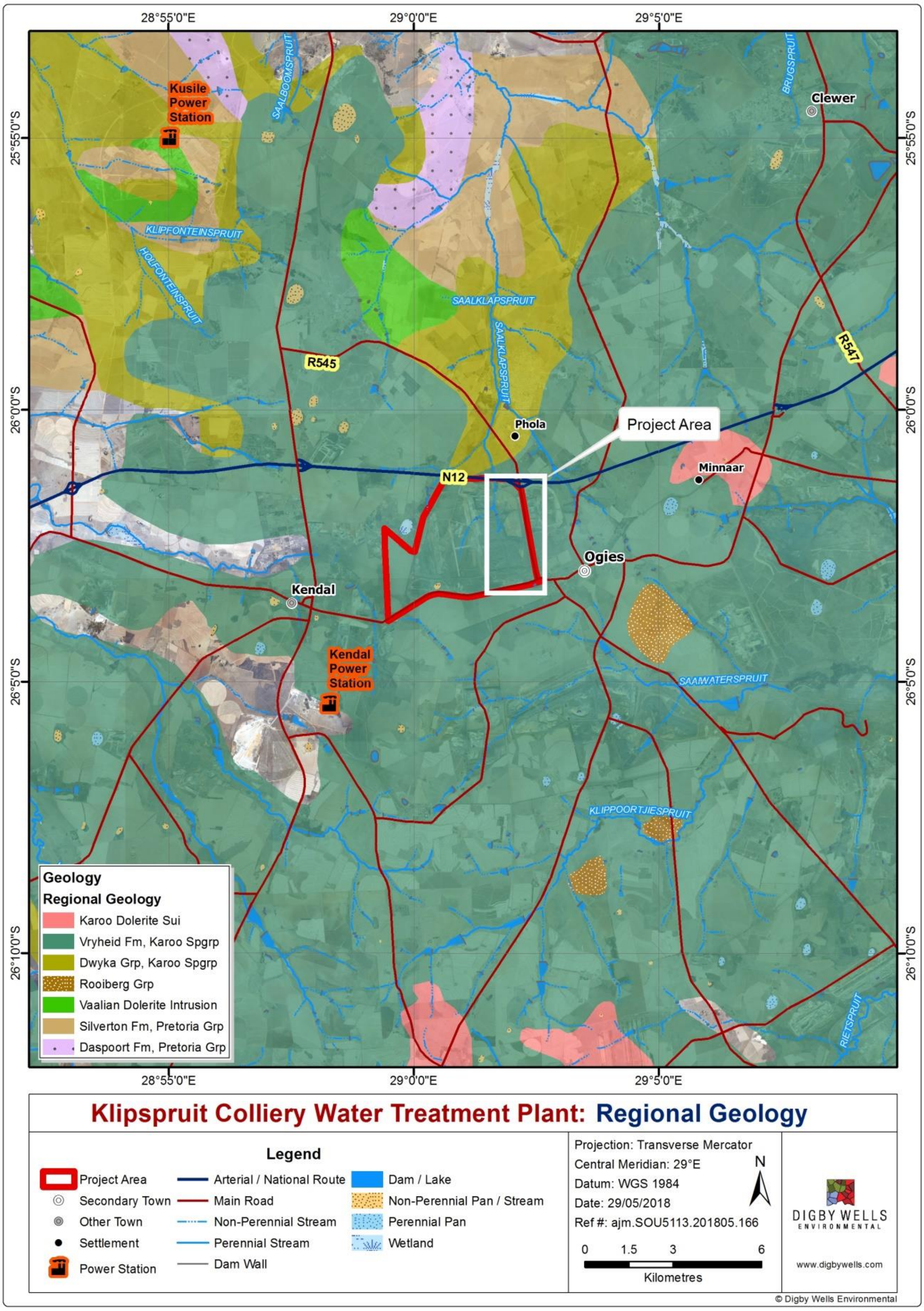

Figure 2-3: Regional Geology

2.4 Boreholes

Existing boreholes in the project area were identified during the desktop assessment and the site visit conducted by Digby Wells in May 2018. Table 2-3 and Figure 2-4 show the distribution of boreholes, with their various uses i.e. private boreholes used predominantly for domestic use and other boreholes are used for monitoring purposes. The remaining boreholes are either blocked, are not in use or their use is unknown.

Table 2-3: Local Boreholes

Site ID	X m (WGS29)	Y m (WGS29)	Groundwater Use
KGMB10	3503.594	-2883061	Monitoring
KGMB13	-899.654	-2882131	Monitoring
KGMB4	3741.852	-2880535	Monitoring
KGMB7	1687.491	-2882710	Monitoring
KGMB8	-862.613	-2882935	Monitoring
KGMB9	732.8722	-2883719	Monitoring
BSW3	3672.977	-2879636	Monitoring
BWS4	4367.32	-2881941	Monitoring
KGBH16	2319.232255	-2882768	Monitoring
KGBH11B	-8.90731	-2882310	Monitoring
KGBH17	1081.146475	-2882054	Monitoring
KGMB6	3687.146	-2882583	Monitoring
WELBH01	-2879676.0000	5585.5562	Private Borehole
WELBH02	-2877436.0000	6758.9382	Private Borehole
WELBH03	-2877154.0000	6918.9683	Private Borehole
WELBH05	-2877240.0000	7293.5522	Private Borehole
WELBH06	-2877175.0000	7428.9443	Private Borehole
WELBH11	-2872625.0000	2423.2271	Private Borehole
WELBH12	-2872791.0000	2346.8832	Private Borehole
WELBH50	7139.385497	-2882169.433	Unknown
WELBH51	4869.145568	-2884569.518	Unknown

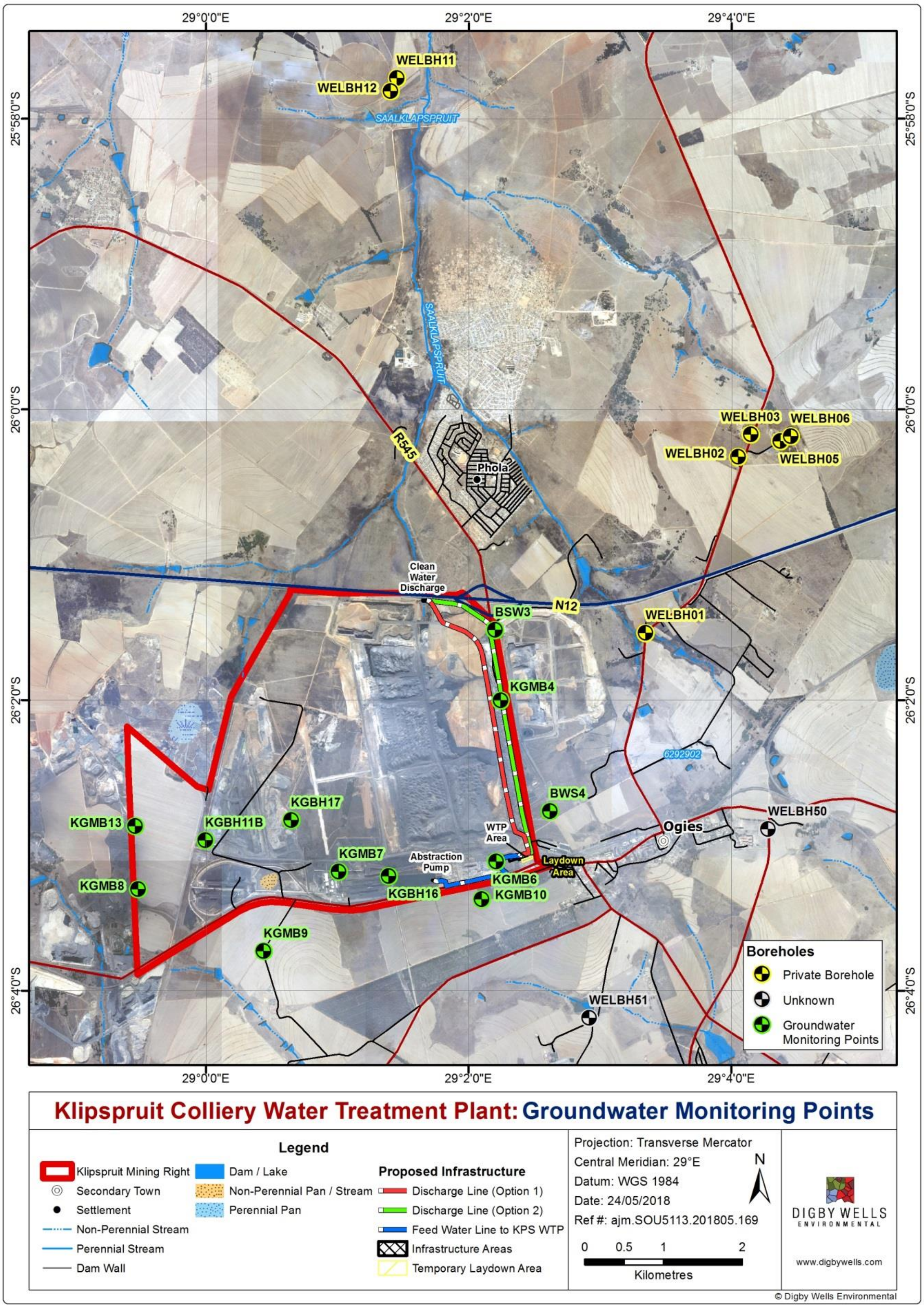

Figure 2-4: KPS Groundwater monitoring points

3 Methodology

This section of the report describes the methodology adopted in determining the status quo of the KPS hydrogeological system.

3.1 Data used in this report

Qualitative research approaches were utilized in the acquisition of all relevant hydrogeological background information and data. This included both site visit and secondary data as follows:

3.1.1 Site Visit

A site visit was conducted in May 2018 to familiarise the project personnel with the groundwater settings of the proposed KPS treatment plant area in relation to the nearby mining activities and receiving environment.

3.1.2 Secondary data

A review of the literature conducted within the KPS mining area was made to provide an understanding of the baseline hydrogeological background. The reviewed literature included geological and hydrogeological maps, reports and other databases.

3.2 Desktop Study

This phase involved a review of available hydrogeological and geological data. Available data was selected and stored into a WISH database. This was later used to develop and have clear understanding of the hydrogeology of the project area.

The reports, plans and database files reviewed as part of this phase included:

- Digby Wells, 2016; Application for Amendment of the Klipspruit Extension: Weltevreden Environmental Authorisation for the Inclusion of Pit H; Numerical Model Report.
- Digby Wells, 2016, KPS EMP Consolidation
- JMA Consulting (Pty) Ltd, 2008, Compilation of Geology and groundwater inputs for the Klipspruit.
- Golder Associates, 2016, Klipspruit Preliminary Groundwater Model
- Golder Associates, 2017, Water and Salt Balance Report 2016 for the KPS.
- JMA CC, 2005, Klipspruit mine: Clean coal and middlings stockpiles groundwater pollution assessment geohydrological modelling.
- WRC, 2012. *Water Resources of South Africa, 2012 Study (WR2012)*", Water Research Commission, Pretoria.

3.3 Impact Assessment

Impacts and risks were identified based on a description of the activities to be undertaken. Once impacts were identified, a numerical environmental significance rating process was undertaken which utilises the probability of an event occurring and the severity of the impact as factors to determine the significance of a particular environmental impact.

The severity of an impact was determined by taking the spatial extent, the duration and the severity of the impacts into consideration. The probability of an impact was then determined by the frequency at which the activity takes place or is likely to take place and by how often the type of impact in question has taken place in similar circumstances.

Following the identification and significance ratings of potential impacts, mitigation and management measures were incorporated into the Environmental Management Plan (EMPr).

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = CONSEQUENCE X PROBABILITY X NATURE

Where

Consequence = intensity + extent + duration

And

Probability = likelihood of an impact occurring

And

Nature = positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix (Table 3-2) calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 3-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 3-3).

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, (i.e., there may already be some mitigation included in the engineering design). If the specialist determines the potential impact is still too high, additional mitigation measures are proposed.

Table 3-1: Impact assessment parameter ratings

Rating	Intensity/ Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or **highly** sensitive environments. Irreplaceable damage to **highly sensitive** cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or **moderate to highly** sensitive environments. Irreplaceable damage to cultural/social resources of **moderate to highly** sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur.>65 but <80% probability.

Rating	Intensity/ Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or **highly** sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or **moderately** sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/ Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
3	Moderate loss and/or damage to biological or physical resources of **low to moderately** sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local including the site and its immediate surrounding area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	**Minor loss and/or effects** to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited extending only as far as the development site area.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/ Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
1	**Minimal to no loss** and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 3-2: Probability/consequence matrix

Significance																																					
-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Consequence

Table 3-3: Significance rating description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

3.4 Reporting

All information, data, maps and interpretations were compiled into a detailed technical report that is the deliverable of the hydrogeological specialist investigation of the project EIA, with conclusions and recommendations on risks, mitigation and monitoring requirements as stipulated by the authorities.

The site-specific Groundwater Impact Assessment methodology and risk rating that were used are the same as described in the EIA guidelines and is in accordance with the corresponding regulations.

A groundwater monitoring plan was compiled based on the conditions and activities on site and include the location of the monitoring boreholes, frequency of monitoring, list of chemical parameters to be monitored, sampling methodology, description of data capturing and reporting requirements. This will be provided on the EMP (Section 9).

4 Baseline Environment

4.1 Aquifers Description

According to Hodgson and Krantz (1998), three distinct groundwater systems occur in the study area, namely and are summarised in further detail below:

- Upper weathered aquifer;
- Fractured aquifer; and
- Pre-Karoo fractured aquifer.

The weathering profile of the Ecca Group sediments on average varies between 5m to 12m in thickness. The upper weathered aquifer occurs within this zone, usually as perched aquifer overlying impermeable shale or clay layers. This aquifer is generally low yielding, but of good quality as a result of dynamic groundwater flow and recharge washing away leachable salts.

The fractured aquifer occurs beneath the weathered aquifer, within fresh sedimentary formations. These sediments are typically well cemented, limiting significant permeation of water through, with the presence of secondary structures (fractures) providing the main pathway for groundwater movement. However, not all secondary structures are water-bearing. The yields for this aquifer system are typically low with the coal seams frequently having the highest hydraulic conductivities. The water quality associated with this aquifer system contains higher salt loads as a result of longer residence times in the aquifer.

Pre-Karoo aquifers have only been intersected on a few occasions, as a result of great depths required to reach the aquifer. Boreholes which have intersected this aquifer are generally low yielding with inferior water quality and low recharge capabilities due to the overlying impermeable Dwyka tillite. Where dolomites of the Transvaal Supergroup underlay the Karoo Supergroup, boreholes may obtain high yields with good water quality.

4.2 Aquifer Classification

The aquifers of South Africa are defined according to their water supply potential, water quality and local importance for strategic purposes within an aquifer classification scheme and map. The aquifer classification map (Parsons, 1993) identifies the Karoo aquifers in the project area as minor systems with relatively good water quality (TDS <300 mg/L), moderate vulnerability and medium susceptibility to contamination, where:

- Vulnerability is defined as the tendency or likelihood for contamination to reach a specified position in the aquifer; and
- Susceptibility is defined as a qualitative measure of the relative ease with which contamination can reach a groundwater aquifer.

4.3 Groundwater Levels and Flow Direction

Groundwater level data was acquired from the Klipspruit Colliery monitoring database. Groundwater levels vary between 1.1 and 23.3 mbgl, with an average of 8.6 mbgl. Groundwater level time series (Figure 4-1) indicates that groundwater level fluctuations have been relatively shallow varying from 1 mbgl to 15 mbgl except at borehole BSW3 which signifies possible groundwater abstraction or dewatering nearby. Generally, the groundwater elevation varies from 1591 mamsl and 1501 mamsl. The groundwater elevation varies from 1591 metres above mean sea level (mamsl) and 1501mamsl. The groundwater flow direction is predominantly in a south to north direction varying slightly at the various sites as shown in Figure 4-2.

The long straight lines within the time series graphs indicate the absence of monitoring results along those periods. This could likely be periods of dryness and as such no measurements were recorded during those periods.

Table 4-1: KPS Groundwater Level

Site ID	X m (WGS29)	Y m (WGS29)	Groundwater Level (mbgl)		
			30/04/2018	25/05/2018	27/06/2018
KGMB10	3503.594	-2883061	1.11	1.11	1.11
KGMB9	732.8722	-2883719	4.16	4.60	5.28
KGMB13	-899.654	-2882131	8.22	8.38	8.3
KGMB4	3741.852	-2880535	6.82	8.87	8.15
KGMB7	1687.491	-2882710	8.80	8.78	9.5
KGMB8	-862.613	-2882935	3.45	3.79	3.86
BSW3	3672.977	-2879636	18.83	21.51	23.33
BWS4	4367.32	-2881941	14.07	15.02	Blocked
KGMB11B	-8.90731	-2882310	19.99	19.99	-
KGMB6	3687.146	-2882583	3.28	2.98	-
KGMB16	2319.232255	-2882768	2.91	3.43	3.64
KGBH17	1081.146475	-2882054	14.63	14.67	14.78

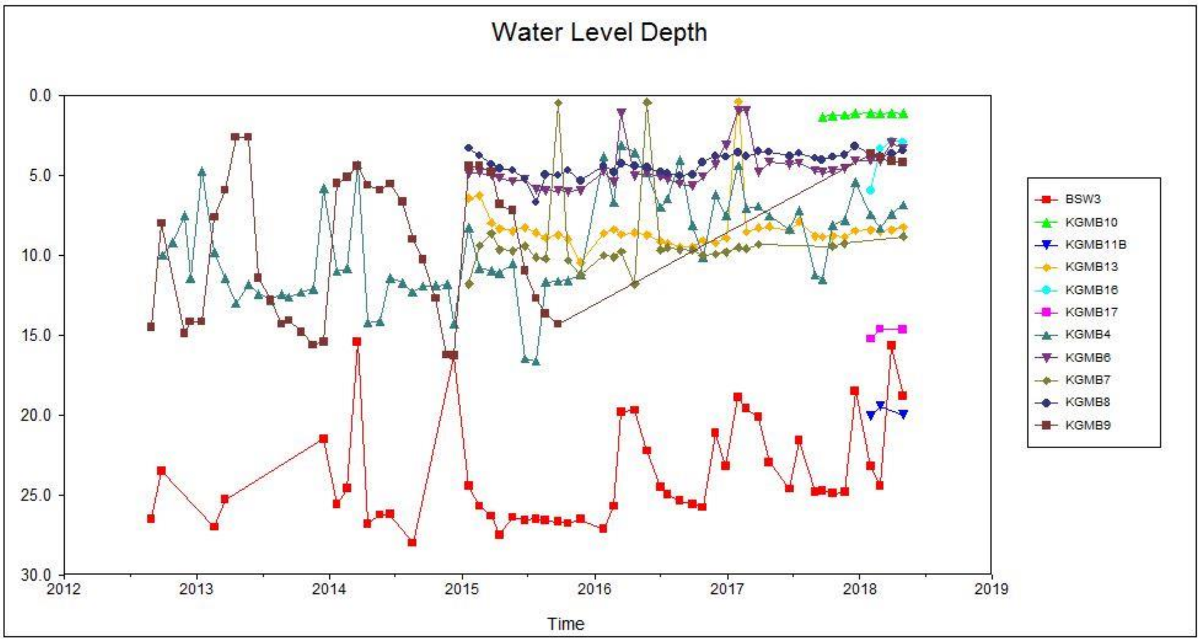

Figure 4-1: Groundwater Level Trend

4.4 Groundwater Quality

Groundwater quality (Table 4-2 to Table 4-5) was received from the KPS monitoring database and is compared to the KPS Water Use License (WUL). The purpose of the interpretation is to determine the baseline groundwater quality in and around the proposed KPS WTP area.

4.4.1 Groundwater Quality in June 2018: Compliance with WUL

- The pH values for the sampled boreholes varied between 6.4 at KGMB9 and 7.4 at BSW3 and KGMB16 with an average of 7.1. All boreholes are below the recommended WUL limits of 8.8. Though all borehole had pH below the recommended WUL these show pH of an acidic rain to neutral pH considered a good groundwater quality. Borehole BWS4 which had an acidic pH of 3.4 during the baseline studies was not analysed (had bees) and therefore we cannot tell whether the borehole is still contaminated or not (further details regarding the borehole water quality is presented in Section 4.4.2).
- Although all boreholes fall below the recommended WUL limits, these are still considered to be within an acceptable range (pH of 6 to 8) as per DWS general guidelines for drinking water. Generally, it is not ideal to have one pH value (such as WUL pH of 8.79) as a compliance measure as the pH values generally vary from one place to another within the same site. It is recommended that the WUL compliance measures be reviewed and an appeal be made to DWS to reconsider some of the WQO.

- All samples fall within the recommended WUL limits for EC, Ca, Mg, Na, K and Cl concentration;
- The sulphate concentration for all samples falls within the recommended WUL limits of 10.36 mg/L except BSW3, KGMB4 and KGMB16; and
- All boreholes exceeded the NO_3 and F WUL limits of 0.11 mg/L and 0.14 mg/L respectively. The results show that NO_3 and F concentration has been consistently high as observed during the baseline studies.

In summary, BSW3, KGMB4 and KGMB16 seems to be the most contaminated boreholes compared to other boreholes with KGMB16 the worst water quality.

4.4.2 Baseline Groundwater Quality in March 2018: Compliance with WUL

pH values varied between 3.4 at BWS4 and 7.6 at KGMB4 with an average of 6.6. All boreholes are below the recommended WUL limits of 8.8. The acidic pH at BWS4 is indicative of possible contamination from beams and the stockpiles area, and/ or contamination from Anglo Zibulo operations as the borehole locates between the two collieries (KPS and Anglo Zibulo).

All samples fall within the recommended WUL limits for EC, Na, K and Cl concentration, and within the WUL limits of 32.6 mg/L for Ca concentration except BWS4, KGMB6 and KGMB16. While, borehole BWS4 exceeds the WUL limit of 32.7 for Mg concentration.

Borehole BSW3, BWS4, KGMB4, KGMB6 and KGMB16 all exceed the recommended WUL SO_4 concentration of 10.4mg/l except borehole KGMB9 and KGMB11B. All samples exceed the WUL limits of 0.11mg/l for nitrates concentration except for KGMB6. While all samples exceed the recommended WUL limits of 0.14 mg/L for fluoride concentration.

In summary, BWS4 seems to be the most contaminated borehole (based on the pH and sulphates) compared to other boreholes.

4.4.3 Background Groundwater Quality Conditions

Un-impacted groundwater within the site under consideration is typically characterised by pH of 5.8 to 8.2, with EC values around 66mS/m (Table 4-3 and Table 4-4). Average SO_4 in un-impacted groundwater varies from 4.3 to 17.4mg/l and average NO_3 concentration in groundwater ranges from 10.6mg/l to 26.8mg/l. Average Al concentration varies from 0.01mg/l to 0.2mg/l and average Mn concentration varies from 0.01mg/l to 0.7mg/l. Average Fe concentration varies from 0.2mg/l to 0.5mg/l. Other elements, such as Ca, Mg, Na, K, Cl, F, $N\text{-}NH_4$, PO_4 and Si, are also in low concentration. These concentrations are considered representative of un-impacted groundwater present within the site.

4.4.4 Typical Groundwater Quality conditions for impacted borehole

Typical groundwater quality for an impacted (contaminated) borehole is shown in Table 4-5.

Borehole BWS4 is characterised by an acidic pH with relatively high TDS and SO_4 (Figure 4-3 to Figure 4-5). Elevated TDS resembles the sulphates concentration and thus the high sulphates concentration is the major contributor to the elevated TDS. The high sulphate can be directly traced back to the oxidation of the sulphur mineralogy associated with the coal in the area which causes Acid Mine Drainage (AMD) (low pH and higher SO_4). As previously indicated in Section 4.4.1, the acidic pH coupled by high SO_4 and TDS at BWS4 is indicative of possible contamination from berms and the stockpiles area.

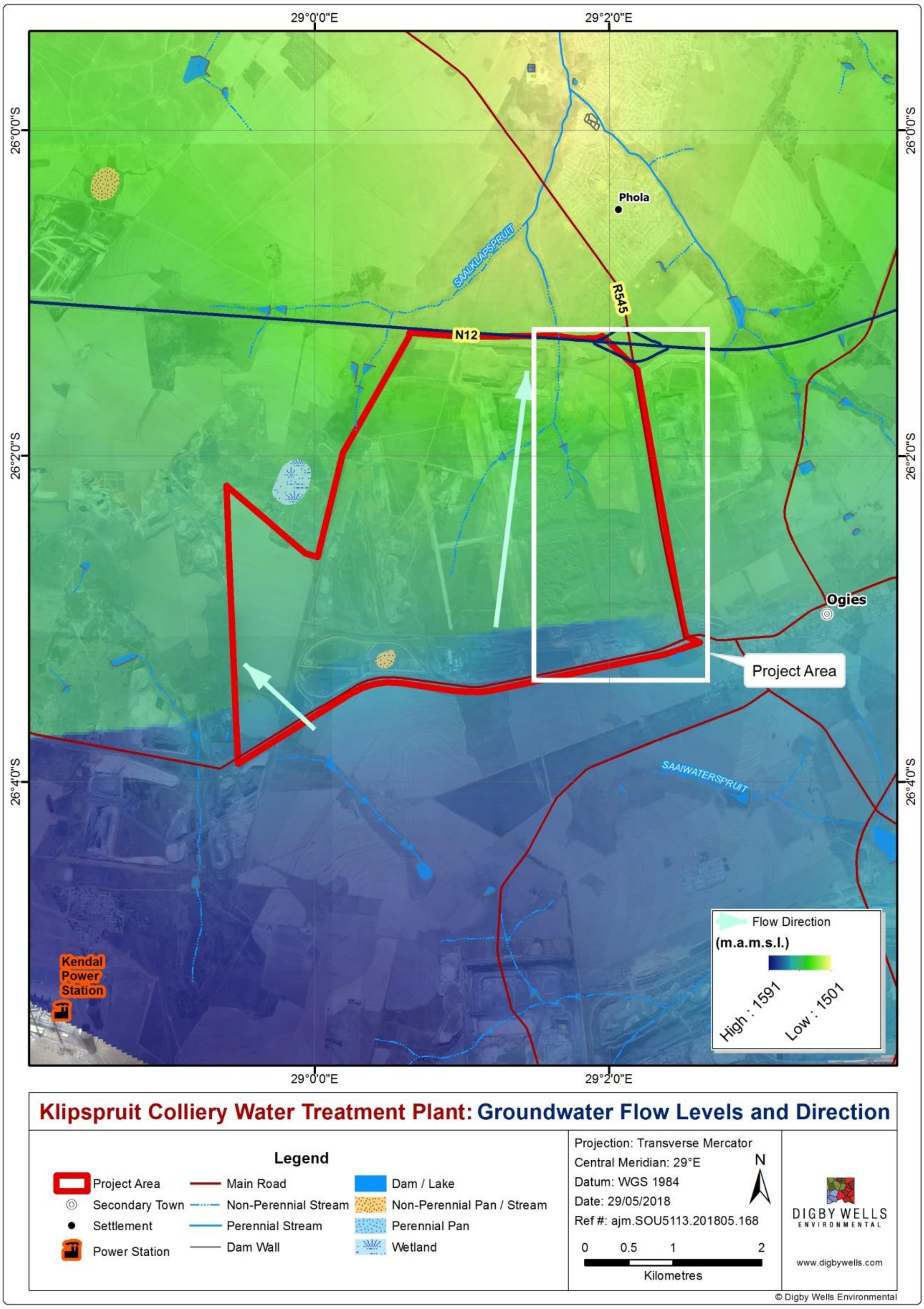

Figure 4-2: Groundwater Level Flow Direction

Table 4-2: Groundwater Quality in June 2018

Sample ID	Date	pH	EC	TDS	TSS	Alkalinity	Turbidity	Ca	Mg	Na	K	Cl	SO_4	NO_3-N	F	Al	Fe	Mn	N-NH_4	PO4	Si
WUL		8.79	75.52	NS	NS	NS	NS	32.56	32.71	44	NS	36.34	10.36	0.11	0.14	NS	NS	NS	NS	NS	NS
KGMB4	2018/06/27	6.9	36.8	230	34.8	103	55.4	14.8	11.15	34.1	3.56	6.79	82.2	<0.1	<0.2	0.01	0.04	0.26	4.9	<0.1	4.51
BSW3	2018/06/27	7.4	27.2	170	30	98	9.79	16.7	8.18	19.3	5.63	11.5	15.9	4.6	<0.2	0.02	0.01	<0.01	<0.2	<0.1	3.26
KGMB9	2018/06/27	6.4	14.3	168	314	23	43	3.65	3.61	9.2	2.07	3.38	2.83	25.8	<0.2	0.01	0.03	0.02	0.42	<0.1	8.74
KGMB13	2018/06/27	6.5	9.68	86	13.6	18	3.67	1.36	0.92	6.2	3.28	3.81	3.54	11.3	<0.2	0.04	0.02	0.01	0.3	<0.1	8.2
KGMB8	2018/06/27	6.6	6.55	30	36	14	41.1	0.84	0.62	5.14	1.09	1.62	2.58	1.55	<0.2	0.04	0.08	<0.01	<0.2	<0.1	5.16
KGMB16	2018/06/27	7.4	46.3	304	10.8	62	3.9	34	17.3	25.1	4.59	3.49	160	0.89	0.31	0.02	0.01	0.01	<0.2	<0.1	7.12
KGMB11B	2018/06/27	6.8	10.7	60	248	29	111	1.5	1.2	8.8	3.41	2.32	7.28	2.3	<0.2	0.63	0.39	<0.01	<0.2	<0.1	21.2
KGMB17	2018/06/27	7.1	17.1	160	217	61	401	8.63	3.4	11.7	2.54	2.42	2.6	16.6	<0.2	0.02	0.4	0.02	<0.2	<0.1	20

Table 4-3: Baseline Groundwater quality in March 2018

Sample ID	Date	pH	EC	TDS	TSS	Alkalinity	Turbidity	Ca	Mg	Na	K	Cl	SO_4	NO_3-N	F	Al	Fe	Mn	N-NH_4	PO4	Si
WUL		8.79	75.52	NS	NS	NS	NS	32.56	32.71	44	NS	36.34	10.36	0.11	0.14	NS	NS	NS	NS	NS	NS
KGMB4	2018/03/29	7.6	19	100	90	30	25	5	3	9	1	5	15	8	<0.2	0.01	<0.01	<0.01	0.2	<0.1	3
KGMB9	2018/03/29	6.6	12	276	238	7	121	4	4	9	1	5	1	50	<0.2	0.01	0.01	0.02	<0.2	<0.1	6
BSW3	2018/03/29	7.06	25	264	20	70	12	14	8	21	6	17	15	29	<0.2	0.01	0.01	<0.01	<0.2	<0.1	3
BWS4	2018/03/29	3.38	88	702	131	-	196	73	38	41	3	11	436	14	0.23	0.12	0.47	0.49	0.26	<0.1	4
KGMB11B	2018/03/29	6.21	13	82	416	58	270	8	3	11	4	4	6	1	<0.2	0.54	0.12	0.08	<0.2	<0.1	27
KGMB6	2018/03/29	7.05	45	328	38	98	99	39	21	24	7	32	118	<0.1	0.21	0.02	0.01	0.08	<0.2	<0.1	8
KGMB16	2018/03/29	6.5	40	324	20	58	22	35	19	24	5	5	173	2	0.35	0.01	0.02	0.45	<0.2	<0.1	4

Notes:

NS – No standard

NG – No guideline

SAR – Sodium Absorption Ratio

Values highlighted blue indicate that the measured value exceed the SAWQG for domestic use, brown indicate that the measured value exceeds the SAWQG for livestock watering and green indicate that the measure value exceeds the SAWQG for irrigation use. Red indicates that the measured value exceeds more than one of the above water quality guidelines.

Table 4-4: Background (typical) groundwater quality data for selected boreholes at Klipspruit Colliery

BH ID	BH Statistics	pH	EC mS/m	TDS mg/l	TSS mg/l	Total Alkalinity	Turbidity	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	NO_3-N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	N-NH4 mg/l	PO4 mg/l	Si mg/l
BSW3	No. of Samples	15																			
	Minimum	7.0	24.9	170.0	16.4	70.0	4.1	14.0	8.0	19.3	5.6	11.5	3.9	0.6	0.3	0.0	0.0	0.0	0.2	<0.1	2.1
	Average	7.6	39.2	275.6	57.1	160.1	33.4	30.3	14.2	27.1	8.4	15.3	17.4	10.6	0.3	0.1	0.5	0.7	3.3	-	3.3
	Maximum	8.2	66.3	382.0	200.0	318.0	96.7	56.7	27.0	41.0	12.9	22.2	57.1	35.7	0.5	0.6	5.2	1.7	12.3	<0.1	4.8
KGMB9	No. of Samples	9																			
	Minimum	5.8	6.2	9.0	9.0	5.0	9.0	0.4	1.3	8.9	1.0	3.3	1.0	3.5	<0.2	0.0	0.0	0.0	0.3	<0.1	5.8
	Average	6.5	10.1	136.7	243.4	16.9	101.8	3.6	3.2	9.4	2.5	4.3	4.3	26.8	-	0.0	0.2	0.1	0.9	-	8.7
	Maximum	7.0	14.3	276.0	411.0	34.0	206.0	4.7	4.8	10.6	5.1	8.3	11.7	50.0	<0.2	0.1	0.8	0.9	2.4	<0.2	11.4
KGMB13	No. of Samples	12																			
	Minimum	6.3	6.7	50.0	0.8	5.0	3.7	1.4	0.9	4.5	3.1	2.2	2.2	4.8	<0.2	0.0	0.0	0.0	0.2	0.0	6.8
	Average	6.5	8.2	65.3	19.9	8.8	13.5	2.8	2.0	7.0	4.0	4.6	4.6	21.7	-	0.2	0.2	0.0	0.3	0.0	8.0
	Maximum	7.0	10.1	86.0	77.6	18.0	32.4	4.1	3.5	9.1	5.3	6.6	9.0	32.0	<0.2	0.9	0.8	0.0	0.3	0.0	8.7

Table 4-5: Typical groundwater quality for (BWS4) an impacted boreholes

BH ID	BH Statistics	pH	EC mS/m	TDS mg/l	TSS mg/l	Total Alkalinity	Turbidity	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3-N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	N-NH4 mg/l	PO4	Si
BWS4	Number of Samples	10																			
	Minimum	3.0	11.6	78.0	48.0	11.0	7.9	7.8	3.5	7.5	2.1	3.9	19.6	0.4	0.2	0.0	0.0	0.0	0.2	<0.1	3.6
	Average	5.6	92.5	757.0	188.1	16.8	142.4	86.6	45.3	56.4	4.0	11.1	461.7	21.0	0.2	0.1	0.4	0.3	0.3	-	6.4
	Maximum	7.1	230.0	2102.0	410.0	34.0	312.0	267.0	137.0	142.0	5.9	23.0	1330.0	43.2	0.2	0.2	2.0	0.5	0.4	<0.1	8.4

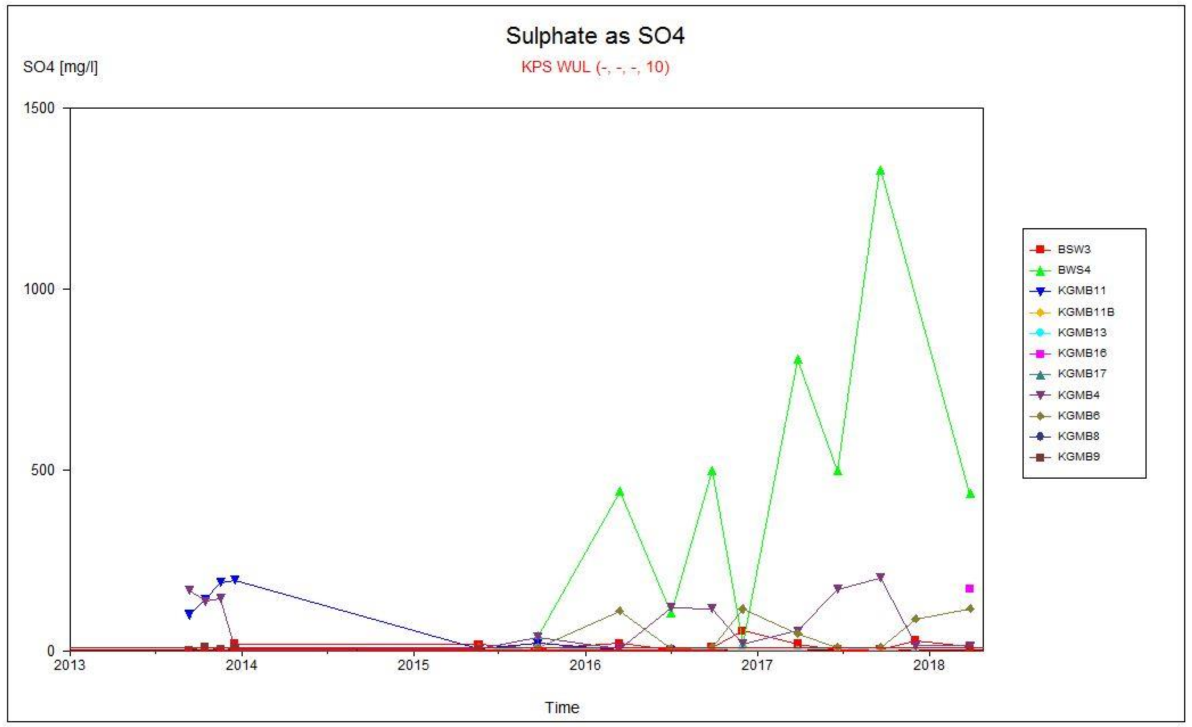

Figure 4-3: Sulphate trend in groundwater at KPS Colliery

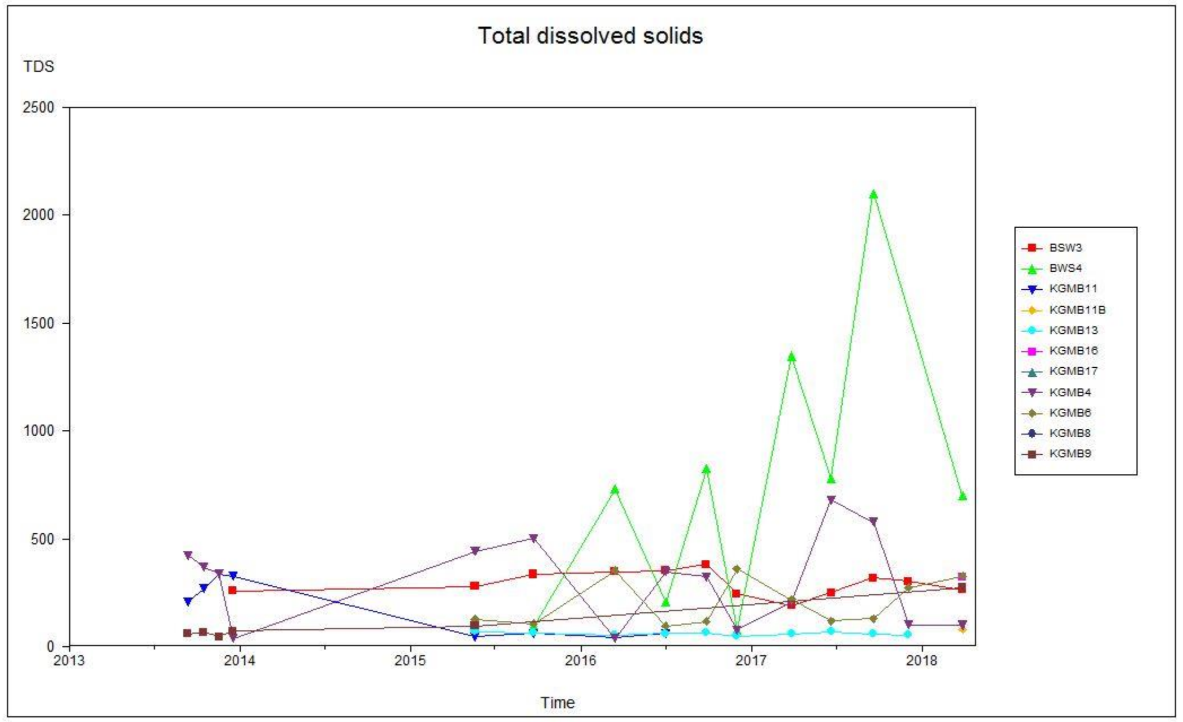

Figure 4-4: Total dissolved solids in groundwater at KPS Colliery

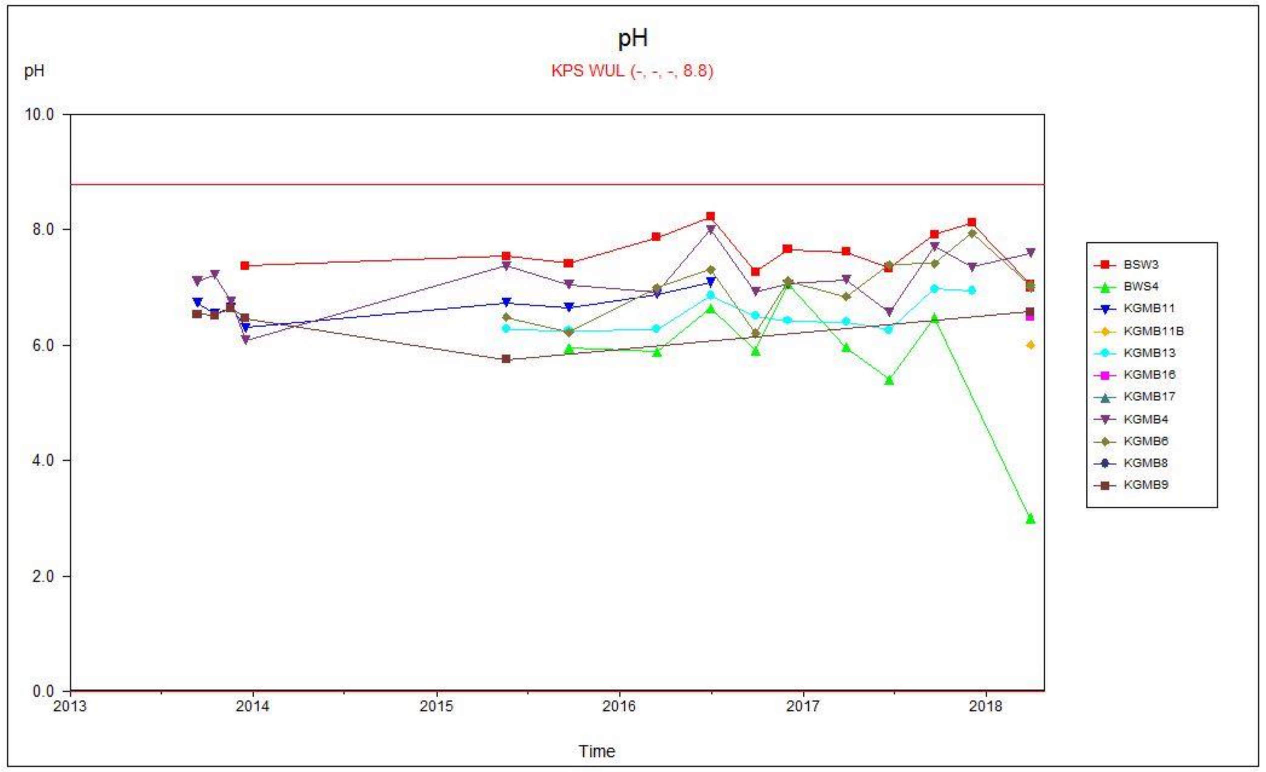

Figure 4-5: pH trend analysis in groundwater at KPS Colliery

4.5 Diagnostic Plots

The water chemistry was also displayed using a Piper diagram as shown in Figure 4-6. A Piper diagram is used to classify the water type by plotting the ratios of the major cations (Ca, Mg, Na and K) and anions (Cl, SO_4 and HCO_3+CO_3) as two points in tri-linear fields. These two points are then extended into the main diamond-shaped field of the Piper diagram to plot as one point. The diagram shows that the water can be classified into three main groups:

- Group 1: The calcium-magnesium-bicarbonate type water (left quarter of the Piper diagram), enriched with alkalinity as a dominant anion. This water type is not impacted by mine and its signature is indicative of recently recharged to dynamic flow (within the aquifer) with some cation mixing.
- Group 2: The sodium-bicarbonate dominant water (bottom quarter) is typical of dynamic groundwater flow within an aquifer, with the sodium replacing calcium and magnesium in solution. This water type is not impacted by mine.
- Group 3: The sulphate dominant type water (top quarter) characterised by their increased SO_4 signature, with no dominant cation. KGMB6 and KGMB16 fall in this group. The lack of alkalinity means that the water does not have buffering capacity to neutralise acid. This chemical signature indicates that these boreholes are mine-impacted with increased sulphate being the main constituent of concern as a result of AMD.

Boreholes plotting with centred zone (including right quarter) are indicative of mixing within the aquifer possibly due dynamic groundwater flow.

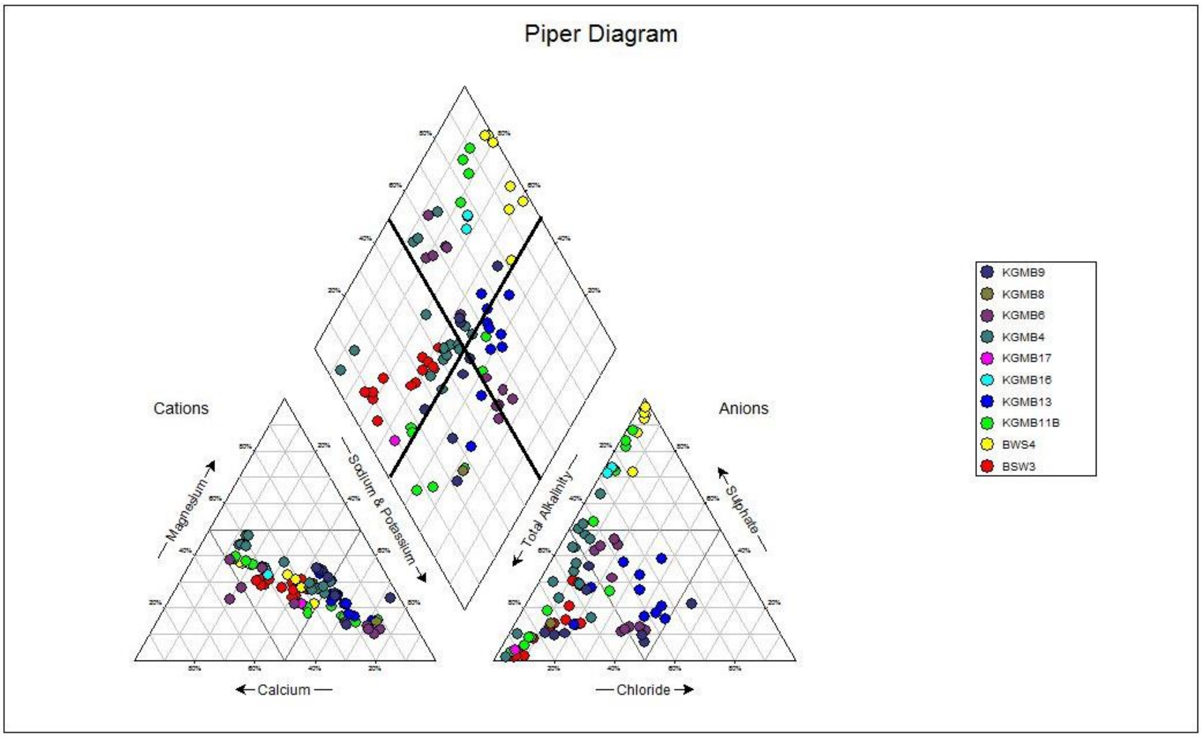

Figure 4-6: Time series Piper diagram

5 Study Limitations and Assumptions

The following gaps were identified during the study;

- Process description for the KPS WTP was provided by South32 for the EIA report. The geochemical and waste classification of the slurry and brine was not undertaken as the plant has not been constructed and no pilot plant samples have been generated (no slurry or brine available). However, it is assumed that the geochemical waste, such as the slurry or brine, will be assessed and be deposited in a certified waste facility off site. No geochemical waste is assumed to exist on site; and
- It is assumed that discharged treated waste water will comply with DWS water quality standards.

6 Impact Assessment and Mitigation Planning

The potential groundwater impacts were assessed considering the project lifetime: pre-construction, construction, operation and potentially its decommissioning phase. Table 6-1 summarises the identified potential impacts.

6.1 Project Activities

The lists of project activities that are relevant to the groundwater impact assessment are presented in Table 6-1.

Table 6-1: Description of Activities to be assessed

Project Phase	Project Activity
Pre-Construction and Construction	Site Clearance, removal of the top soil and vegetation and excavation.
	Temporary storage and handling of hazardous products, including fuel as well as waste
	Water Abstraction and Use
	Waste Generation, Storage and Disposal
Operations	Waste Generation, temporary Storage and off-site Disposal
Decommissioning and Closure	Construction and decommissioning (including removal of all infrastructure and rehabilitation) of the WTP, discharged wastewater.

6.2 Potential Groundwater Impacts

Potential impacts are assessed in this section considering the pre-construction and construction, operational and closure phases. The list of project activities can be found in Table 6-1. **Only project activities that are likely to result in a groundwater impact are assessed below.** The potential groundwater impacts are listed below for the pre-construction and construction phase of the project. These are considered to be the only potential activities that would have significant environmental impact:

6.2.1 Pre-Construction and Construction Phase

6.2.1.1 Project Activities Assessed

WTP activities during the construction phase that could result in groundwater impacts include:

- Site clearance and topsoil removal across the project area;

Table 6-2: Interactions and impacts during the construction phase

Interaction	Impact
Site clearance, removal of top soil and vegetation and excavation.	▪ No impact on the groundwater is expected, as the site clearance is expected to take place above the water table. Further, based on the available water level data within the proposed project area, groundwater level varies from 2.98 to 3.3 mbgl at KGMB6 and from 2.9 to 3.6 mbgl at KGBH16. Therefore, no impact on the groundwater resource is expected as the planned excavations (≤2

Interaction	Impact
	mbgl) are expected to be located above the water table. ▪ Lowering of the water table, if the site clearing will take place below the water table

6.2.1.1.1 Impact Description

The water table within the proposed WTP area is shallow, ranging between 1.1m and 3.28m below ground surface. Any site clearing or construction activities that would involve excavation below the water table depth will have a potential impact on the groundwater quantity and quality.

6.2.1.1.2 Management Objectives

The following are management objectives defined for the construction phase:

- Site clearance, removal of top soil and vegetation and excavation has to cover a minimal area and it has to be managed efficiently and be carried in dry season where there is less chances of or no recharge into the aquifer; and
- Site clearance and construction activities should take place above the water table, if applicable. No impact on the groundwater is expected if the activities take place above the water table.

6.2.1.1.3 Management Actions and Targets

The following actions and targets are required:

- Restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity;
- Avoid constructing below the water table as far as possible; and
- Continue with the current monitoring programme. The positions of the monitoring boreholes are provided in Section 9.2.

6.2.1.1.4 Pre-Construction and Construction Phase Impact Ratings

The significance rating of the potential impacts before and after mitigation is provided in Table 6-3.

Table 6-3: Potential Impacts during the Construction Phase

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and vegetation, and excavation			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Site clearing			
Prior to mitigation/ management			
Duration	Short term (2)	Pre-construction and construction activities are expected to be short-lived.	Negligible (negative) – 8
Extent	Limited (2)	Site clearing will only occur within and immediately around the Project site	
Intensity x type of impact	Minor - negative (-1)	Any site clearing, removal of the top soil and vegetation and dewatering (if any) will have minor environmental significance.	
Probability	Unlikely (2)	▪ No impact on the groundwater is expected, as the site clearance is expected to take place above the water table. ▪ Dewatering during the construction phase (if any) is unlikely to cause environmental impact considering limited rock permeability, the duration and excavation depth.	
Mitigation/ Management actions			
▪ Site clearance and removal of top soil and vegetation has to cover minimal area and it has to be managed efficiently and be carried in dry season where there less chances of or no recharge into the aquifer. ▪ Continue with current groundwater monitoring programme.			
Post- mitigation			
Duration	Short term (2)	Any lowering of the water table during the construction phase is expected to be shallow and recover relatively quickly	Negligible (negative) – 4
Extent	Limited (2)	Only the area in the site clearing area will be affected	

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and vegetation, and excavation			
Dimension	**Rating**	**Motivation**	**Significance**
Intensity x type of impact	Minimal - negative (-1)	Considering that the construction phase will be for a short period, the intensity will be minimal	
Probability	Unlikely (2)	It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plan	

7 Cumulative Impacts

Observing the project area and its surroundings (within 5km radius of the project area) the area consists of mixed land uses ranging from undeveloped to semi-developed residential areas, a developed area (Ogies town), mining activities in south-west as well as agricultural activities (Figure 7-1). The potential cumulative impacts include:

- Possible depletion of natural water resources, or contamination of groundwater and surface water (deterioration of water quality at the Saalklapspruit river and in downstream areas) should the development not be managed properly (such as if wastewater treatment plant plan and monitoring programme is not implemented);
- Existing water quality and quantity impacts from the mining activities;
- Increased waste generation (including wastewater generation, slurry and brine) which could result on groundwater and surface water contamination; and
- A positive cumulative impact is the predicted future decant will be managed through the WTP.

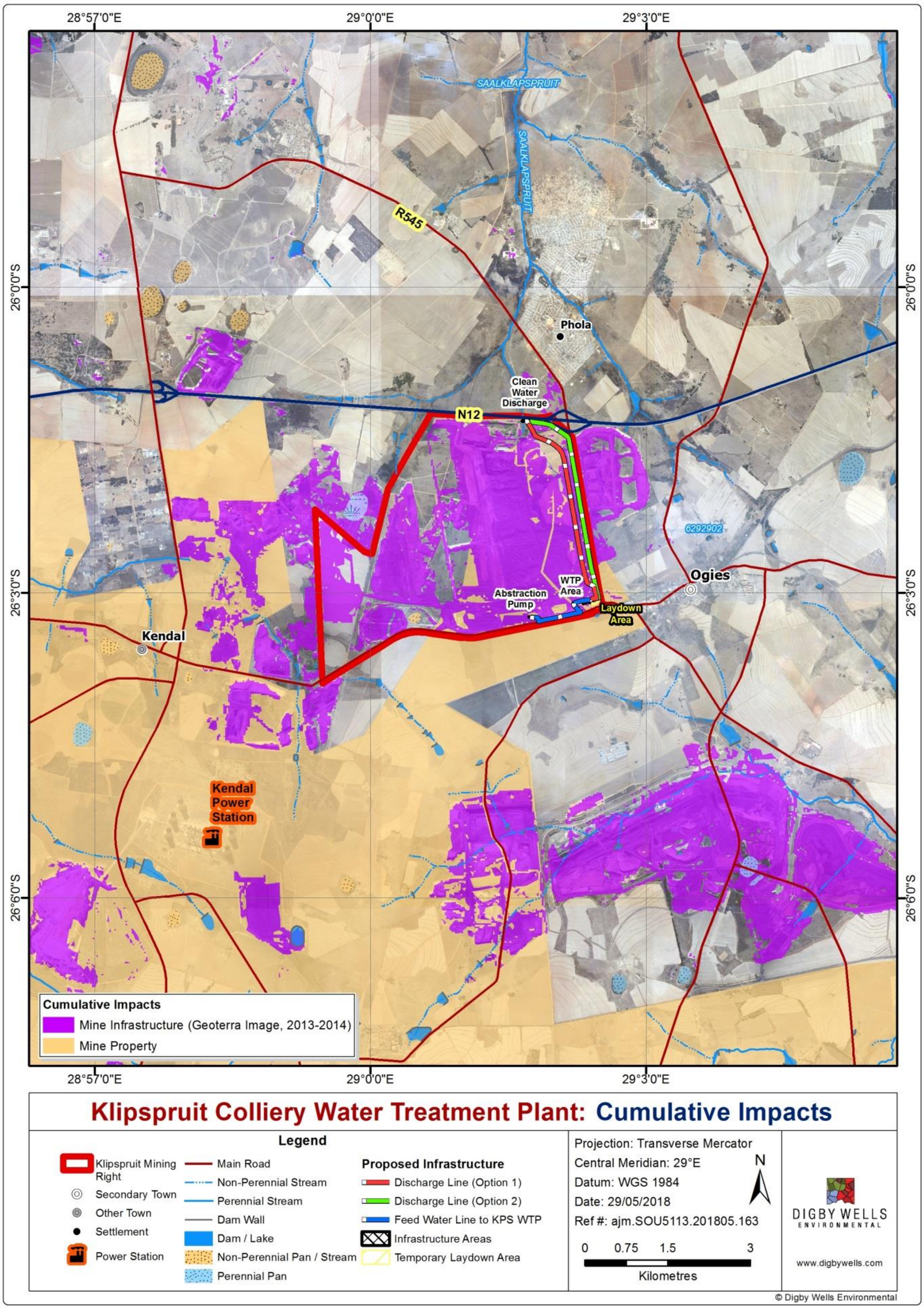

Figure 7-1: Cumulative Impact Map

8 Unplanned Events and Low Risks

The unplanned events that may happen at the project site and the proposed mitigation plan are listed in Table 8-1.

Table 8-1: Unplanned Events, Low Risks and their Management Measures

Unplanned event	Potential impact	Mitigation / Management / Monitoring
Hydrocarbon spills from bulk storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities.	▪ Infiltration of the spilled substances may reach the groundwater table, thus polluting the shallow aquifer. ▪ Infiltration of dirty water into the groundwater and contaminating the aquifers	▪ Hydrocarbons and hazardous materials must be stored in bunded areas and refuelling should take place in contained areas; ▪ Ensure that oil and silt traps are well maintained; ▪ Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills; ▪ Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place; ▪ Monitoring boreholes, particularly those located within the construction area (KGMB6 and KGMB10), have to be monitored for both water level and quality to detect any changes in quality; and ▪ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality.
Spills / leaks on the pipeline transferring polluted water from the Balancing dam to the WTP.	▪ Contamination of groundwater	▪ Regular inspections of the pipeline for any leaks. Seeping pipeline should be sealed; and ▪ Ensure that storm water management structures are put in place to capture all spills and to convey to the pollution control dam nearby.

9 Environmental Groundwater Management Plan

The objective of an Environmental Management Plan (EMP) is to present mitigation measures that (a) manage undue or reasonably avoidable adverse impacts associated with the development and (b) to enhance potential positives.

9.1 Project Activities with Potentially Significant Impacts

Potentially significant impacts that require mitigation or management are listed in Table 9-1.

Table 9-1: Potentially Significant Impact

Activity	Aspects	Potential Significant Impacts
Site clearing	Water table	▪ Lowering of the water table if excavation during the site clearing process is going to take place below the water table.

9.2 Groundwater Monitoring Plan

South32 has a groundwater monitoring plan and/ or program which covers the proposed project area. Therefore, the current groundwater monitoring has to continue during all phases of the plant operation to identify impacts over time, and that effective measures can be undertaken at the early stage before negative impacts to the environment takes place.

9.2.1 Monitoring Boreholes

The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the proposed project area; and
- Monitor the lowering of the water table (if any) and the radius of influence.

Due to a good monitoring data set existing for the mine, it is recommended that the current monitoring network should continue during all phases of the plant operation to identify impacts over time.

9.2.2 Groundwater Level

The current groundwater level monitoring must continue to detect any changes or trends in groundwater elevation and flow direction.

9.2.3 Data Storage

During any project, effective hydrogeological decisions require comprehensive information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. To minimise groundwater contamination, it is necessary to utilise all relevant groundwater monitoring data.

The generation and collection of this data is very expensive as it requires intensive investigations and therefore the data has to be managed in a centralised database to optimise on cost efficiency. Digby Wells has compiled a WISH-based database during the course of this investigation and it is highly recommended that the applicant utilise this database and continuously update and manage it as new data becomes available.

10 Sensitivity of the Site

The water quality of the aquifers indicates that groundwater contamination has already taken place and this is mainly due to mining activities. Therefore it is deemed that the proposed KPS WTP will have a negligible impact (if any) on the environment if managed well as the treatment plant will be lined and the discharged water will comply with DWS standards for discharged water.

Based on the above conclusion it is deemed that the current groundwater environment is not sensitive to the proposed activities if managed well.

11 Conclusions and Recommendations

11.1 Conclusions

11.1.1 Baseline Hydrogeological Findings

From the reviewed literature it is understood that the project area is made up of two types of aquifers; upper weathered aquifer, fractured rock aquifer and the Pre-Karoo fractured rock aquifer. Further, these aquifers can be classified as minor systems with relatively good water quality (TDS <300 mg/l), moderate vulnerability and medium susceptibility to contamination. The groundwater flow direction mimics surface topography and is predominantly in a south to north direction varying slightly at the various sites.

Groundwater quality monitoring data (received from the client) was analysed to determine the current groundwater quality in the groundwater and whether pollution has affected the boreholes. The following observations were made:

11.1.2 Groundwater Quality in June 2018: Compliance with WUL

- The pH values for the sampled boreholes varied between 6.4 at KGMB9 and 7.4 at BSW3 and KGMB16 with an average of 7.1. All boreholes are below the recommended WUL limits of 8.8. Though all borehole had pH below the recommended WUL these show pH of an acidic rain to neutral pH considered a good groundwater quality.
- Although all boreholes fall below the recommended WUL limits, these are still considered to be within an acceptable range (pH of 6 to 8) as per DWS general guidelines for drinking water. Generally, it is not ideal to have one pH value (such as WUL pH of 8.79) as a compliance measure as the pH values generally vary from one place to another within the same site. It is recommended that the WUL compliance measures be reviewed and an appeal be made to DWS to reconsider some of the WQO.
- All samples fall within the recommended WUL limits for EC, Ca, Mg, Na, K and Cl concentration;

- The sulphate concentration for all samples falls within the recommended WUL limits of 10.36 mg/L except BSW3, KGMB4 and KGMB16; and
- All boreholes exceeded the NO_3 and F WUL limits of 0.11 mg/L and 0.14 mg/L respectively. The results show that NO_3 and F concentration has been consistently high as observed during the baseline studies.

In summary, BSW3, KGMB4 and KGMB16 are the most contaminated boreholes compared to other boreholes with KGMB16 the worst water quality. During the baseline studies BWS4 was the most contaminated borehole (based on the pH and sulphates) compared to other boreholes.

Background water quality for un-impacted boreholes within the site under consideration is typically characterised by pH of 5.8 to 8.2, with EC values around 66mS/m. Average SO_4 in un-impacted groundwater varies from 4.3 to 17.4mg/l and average NO_3 concentration in groundwater ranges from 10.6mg/l to 26.8mg/l. Average Al concentration varies from 0.01mg/l to 0.2mg/l and average Mn concentration varies from 0.01mg/l to 0.7mg/l. Average Fe concentration varies from 0.2mg/l to 0.5mg/l. Other elements, such as Ca, Mg, Na, K, Cl, F, $N\text{-}NH_4$, PO_4 and Si, are also in low concentration. These concentrations are considered representative of un-impacted groundwater that resides within the site.

11.1.3 Recommendations

The following recommendations were made:

- Site clearing should be restricted to areas of absolute necessity and the activity should be conducted over a short duration, if possible;
- Site clearance and construction activities should take place above the water table, at the unsaturated zone, (if possible), no impact on the groundwater will then be expected;
- The sludge or brine should be deposited in a certified waste facility based on waste classifications and geochemical assessments done on the material; and
- It is recommended that the WUL compliance measures be reviewed and an appeal be made to DWS to reconsider some of the water quality objectives (WQO).

12 References

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Appendix A: Resource Water Quality Objectives

Parameter	WQO	Unit
SO_4	200	mg/L
F	2.5	mg/L
Al	0.105	mg/L
As	0.095	mg/L
Cd	0.003	mg/L
Cr (VI)	0.121	mg/L
Cu	0.006	mg/L
Hg	0.00097	mg/L
Mn	0.99	mg/L
Pb	0.0095	mg/L
Se	0.022	mg/L
Zn	0.0252	mg/L
Chlorine	3 µg/L dissolved.1 µg/L free Cl	
Endosulfan	0.00013	mg/L
Atrazine	0.0785	mg/L