DIGBY WELLS ENVIRONMENTAL

Environmental Impact Assessment for Sasol Mining: Syferfontein Block 4 Underground Coal Mine

Surface Water Specialist Report

Project Number:

SAS1744

Prepared for:

Sasol Mining (Pty) Ltd

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This document has been prepared by Digby Wells Environmental.

Report Type:	**Surface Water Specialist Report**
Project Name:	**Environmental Impact Assessment for Sasol Mining: Syferfontein Block 4 Underground Coal Mine**
Project Code:	**SAS1744**

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed the independent environmental consultants by Sasol Mining (Pty) Ltd (hereafter Sasol Mining) to undertake a Baseline Assessment for the Block 4 Syferfontein (Syferfontein) underground coal mining located in the Govan Mbeki Local Municipality and reserves north of Syferfontein in the Emalahleni Local Municipality within the Mpumalanga province.

This surface water report details the methodology and findings of the baseline water quality quantity. The study indicates that the water quality is fit for drinking water, domestic use and agricultural use (irrigation and livestock) as determined from the Department of Water Affairs and Forestry (DWAF) water quality guidelines. However, severe aesthetic effects (discolouration) occur in the presence of iron, aluminium and manganese. ‘

The mining will be underground based with no surface infrastructure; therefore not many impacts are anticipated of the surface water quality and quantity. However the identified impact that could pose alteration to the surface hydrology was the potential subsidence associated with giving in of overburden if inadequate pillars are left with bord and pillar mining. Mitigation could include ensuring that

The most significant impact realisable from underground mining in Block 4 would potentially be subsidence that would results in altered subcatchment hydrology. The only mitigation measure that can be taken to prevent or limit the occurrence of subsidence is to ensure the underground mine design is within the safety factors recommended. However, this can be coupled with subsidence prediction studies which should therefore lead any backfilling should suitable backfilling material be identified

It is recommended that monitoring of surface water resources should be implemented if groundwater studies detect areas where surface and groundwater interact given there will be underground mining with no surface infrastructure on site; and any new and existing mining activities in should implement water management measures for reuse and recycle as mining is a biggest water user.

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LIST OF ABBREVIATIONS AND ACRONYMS

ARM	Alternative Rational Method
AWS	Automatic Weather Station
BPG	Best Practice Guidelines
DRE	Design Rainfall Estimation
DWA	Department of Water Affairs
GN 704	Government Notice of Regulation 704
LoM	Life of Mine
MAP	Mean Annual Precipitation
MAE	Mean Annual Evaporation
MAR	Mean Annual Runoff
MPRDA	Mineral And Petroleum Resources Development Act 28 of 2002
mamsl	metres above mean sea level

NEMWA	National Environmental Management Waste Act (Act 59 of 2008),
NEMA	National Environmental Management Act (Act 107 of 1998)
NWA	National Water Act (Act 36 of 1998)
SANS 241	South African National Standard 241
SANAS	South African National Accreditation Standards
SWMP	Surface Water Management Plan
SAWS	South African Weather Service
SABS	South African Bureau of Standards
UPD	Utilities Programmes for Drainage
WRC	Water Research Commission
WMA	Water Management Area
WARMS	Water Users Registration Management Systems
WQO	Water Quality Objectives

1 Introduction

Digby Wells Environmental (Digby Wells) has been appointed the independent environmental consultants by Sasol Mining (Pty) Ltd (Sasol Mining) to undertake a baseline assessment for the Block 4 Syferfontein (Syferfontein) underground coal mining and reserves north of Syferfontein. The Block 4 mine is located in the Govan Mbeki Local Municipality (GMLM) whilst the reserves north of Syferfontein in the Emalahleni Local Municipality within the Mpumalanga Province (see Plan 1 for an illustration of the Regional Setting of the respective Project). The proposed Project is envisaged to be mainly underground mining method. This report details findings of the surface water quality and quantity baseline assessment

1.1 Project Description

1.2 Study Area

1.2.1 Project Location

The proposed Project is located in the Govan Mbeki Local Municipality (GMLM) near the settlement of Kinross close to the N17 National route (see Plan 2 for the local setting). The proposed Syferfontein mine is located in close proximity to several towns and settlements namely Secunda (14 km SE), Evander (8 km S), Trichardt (13.5 km SE) and Kinross (3.7 km S) (see Plan 2 for the local setting). The proposed Project area is 52.2 km^2 in size and spans over several farm areas depicted in Plan 3 namely:

- Vaalbank 96 IS;
- Zondagsfontein 124 IS;
- Dieplaagte 123 IS;
- Langsloot 99 IS;
- Zondagskraal 125 IS; and
- Wildebeestfontein 122 IS.

The reserves north of Syferfontein in the Emalahleni Local Municipality cover a site area of 27.1 km^2 over the following farms;

- Riversdale 119 IS;
- Rietfontein 101 IS; and
- Rietfontein 100 IS.

1.2.2 Site Characterisation

The topographical model indicates that the elevation of the Project area ranges from approximately 1680 to 1580 metres above mean sea level (mamsl) from the southern to a northerly direction. The Project area is situated on a relatively high-lying area surrounded by mildly undulating topography.

The northern part of the Project area is characterised by a slope rise of 0 to 3%; while the southern boundary is dominated by a slope rise of 3 to 6%. There are also isolated portions of isolated slightly steeper slopes of between 6 to 9% that occur on the south east and south west of the Project area.

The reserves in the north of Syferfontein are situated in a low lying area on a floodplain of the Dwars-in-de-wegspruit and Trichardspruit, elevation ranging from 1560 mamsl in the west to around 1592 mamsl towards the east.

1.2.3 Catchment Description

The proposed Project area is located in the Olifants Water Management Area (WMA 04) in the upper catchment areas of quaternary catchment B11D (Plan 4). The reserves north of Syferfontein are located within two quaternary catchments with a greater portion in B11D and a smaller section in B11C. The proposed project area occupies 9.5 % of the B11D quaternary catchment whilst the extension area reserves north of Project area occupy 0.8 % and 4% of B11C and B11D catchments respectively as depicted in Table 3-1.

Table 1-1: Summary of the surface water attributes of the two quaternary catchments

Site	Quaternary Catchment	Quaternary Catchment area (km^2)	Project area (km^2)	Portion covered by project %
Block 4	B11D	551	52.2	9.5
Northern reserves	B11D	551	24.1	4.4
Northern reserves	B11C	371	3.03	0.8

1.2.4 Water Resources

1.2.4.1 Local Catchment

There are several streams draining the proposed Project site as indicated in Plan 5. Most of the streams are non-perennial and drain into small dams and pans. The streams of concern are the:

- Vaalbankspruit and its tributaries;
- The Trichardspruit drains through the Rietfontein dam;

- The Dwars-in-die-wegspruit; and
- The Steenkoolspruit.

The Project area is drained by the Vaalbankspruit which flows along the northern boundary and is fed by a number of tributaries which are non-perennial draining the site. The Vaalbankspruit further drains into the Dwars-in-diewegspruit towards the north east. On the east boundary of the Project site, the Trichardspruit drains from south to north through the Rietfontein Dam then through the northern reserves site. The Trichardspruit and Dwars-in-diewegspruit reach a confluence then flow into the Steenkoolpruit which then after confluence with the Wilge River flows towards the Olifants River. In this light, the Vaalbankspruit subcatchment in which the Project site is located, in quaternary catchment B11D makes up the headwaters of the of the Olifants river water management area.

1.2.4.2 Regional Catchment

The Olifants River flows north-east, through the provinces of Mpumalanga and Limpopo, into Mozambique. Major tributaries of the Olifants River are the Wilge, Moses, Elands and Ga-Selati on the left bank and the Klein Olifants, Steelport and Blyde on the right bank. Outside of the Olifants river catchment, the Letaba River is a major tributary (catchment area 3,264 km2) that originates in South Africa and joins the Olifants River in the Kruger National Park, just before the river flows into Mozambique.

The Olifants Catchment covers about 54 570 km^2 and is subdivided into 7 secondary catchment (excluding the Letaba River catchment), 13 tertiary and 114 quaternary catchments (IWMI, 2008). The Olifants River and some of its tributaries, namely the Klein Olifants River, Elands River, Wilge River and Bronkhorstspruit, rise in the Highveld grasslands. There are several large dams in the Olifants River Catchment which include the Witbank Dam, Renosterkop Dam, Rust de Winter Dam, Blyderivierspoort Dam, Loskop Dam, Middelburg Dam, Ohrigstad Dam, Arabie Dam and the Phalaborwa Barrage. In addition, there are many smaller and minor dams in this catchment, which have a considerable combined capacity.

The upper reaches of the Olifants River Catchment are characterised mainly by mining, agricultural and conservation activities

The Olifants River system has been recorded as one of the most polluted river systems in southern Africa, this is largely attributed to the high number of anthropogenic stressors that are present, particularly in the upper catchment, and the changes to water quality that have resulted from these activities (Oberholster, et al., 2011). According to Oberholster et al. (2011) these stressors consist of intensive coal mining activity, coal-fired power generation, industrial activities and agriculture, combined with a general decline in the operation and management of waste water treatment infrastructure, especially sewage treatment.

1.2.5 Climate

South African Weather Service (SAWS) does not have an Automatic Weather Station (AWS) within the reasonable distance from the proposed Syferfontein coal mine site that would give representative and accurate climate data. Site specific (meso-scale model) MM5 modelled meteorological data set for a full three years (2009 to 2011) was obtained from Lakes Environmental Consultants in Canada to determine local prevailing weather conditions(Lakes Environmental, 2012).

1.2.5.1 Temperature

Three-year average monthly maximum, mean and minimum temperatures for Syferfontein are given in Table 3-2. The average monthly maximum temperatures range from 21.3°C in January to 7.5°C in July, with monthly minima ranging from 19.9°C in December to 6.6°C in July. Annual mean temperature for Syferfontein is given as 14.5°C.

Table 1-2: Average monthly minimum, maximum and mean temperature values derived from the Syferfontein modelled data (2009 - 2011)

Temperature (deg °C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	21.3	20.2	19.3	15.5	12.2	8.8	7.5	11.0	15.5	17.4	19.5	21.1	15.8
Monthly Min.	19.5	18.6	18.0	13.6	11.1	7.4	6.6	9.7	13.9	17.1	18.6	19.9	14.5
Monthly Mean	20.5	19.5	11.5	14.7	11.5	8.0	6.9	10.2	14.8	17.2	19.1	20.3	14.5

1.2.5.2 Precipitation

The Syferfontein Project area lies in the rainfall zone B1A according to the Water Research Commission (WRC) Reports K5/1491 (WRC, 2005). The mean monthly precipitation for the climatic period from 1920 to 2004 periods determined for the rainfall region is depicted in Figure 3-1.

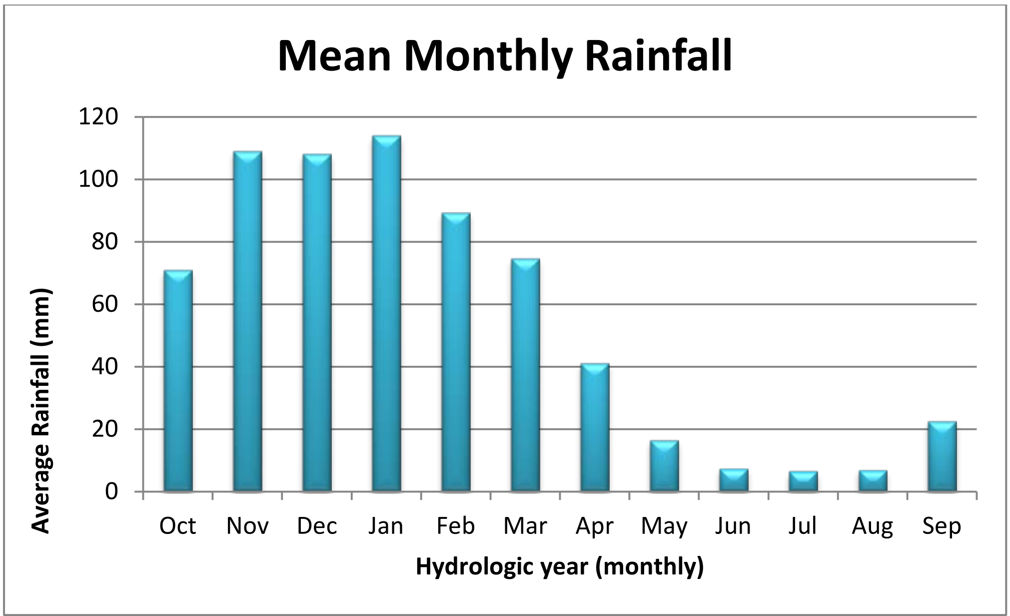

Figure 3-1: WRC, 2005 mean monthly rainfall for rainfall region B1A (1920 to 2004)

Recent records obtained from 2009 to 2011 as shown in Table 3-3, the three year annual maximum, minimum and mean monthly precipitation rates for the Syferfontein site are 82 mm, 43 mm and 57 mm, respectively. The highest monthly maximum precipitation (210 mm) occurs for January. The rate decreases down to 8 mm in July. The monthly minimum precipitation ranges between 129 mm in December and no precipitation in June and July.

Table 1-3: Average monthly precipitation derived from the Syferfontein modelled data (2009-2011)

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	210	92	110	67	16	9	8	28	31	93	116	208	82
Monthly Min.	119	50	49	8	9	0	0	1	19	24	103	129	43
Monthly Mean	158	77	13	42	13	3	3	10	23	64	110	167	57

1.2.5.3 Evaporation

As shown in Table 3-4, the annual maximum, minimum and mean monthly evaporation rates for the Standerton area for the period 1960 - 1987 are 186 mm, 89 mm and 140 mm, respectively. The highest monthly maximum evaporation (264 mm) occurs for December. The rate decreases significantly down to 106 mm in June. The monthly minimum evaporation ranges between 153 mm in January and 7 mm in April. SAWS stopped monitoring evaporation in 1987.

Table 1-4: Maximum, minimum and mean monthly evaporation rates for the Standerton area evaporation station for 1960 - 1987 period (South African Weather Service)

Evaporation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	228	188	196	140	123	106	122	178	231	259	200	264	186
Monthly Min.	153	110	100	7	60	61	68	89	118	147	140	17	89
Monthly Mean	180	149	147	107	95	80	89	131	164	184	168	186	140

1.3 Terms of Reference

The surface water quality and quantity aspects that require detailed assessment in the EIA phase are as follows:

- To undertake a desktop assessment of the surface water environment including the catchment characterisation, hydrological calculations of base flow, flood peaks (1:20, 1:50 and 1:100 over 24 hours) and hydrological baseline of the catchment;
- To undertake a desktop selection of strategic water quality monitoring sites up and downstream of the proposed project site;
- To conduct a field survey and surface water quality sampling up and downstream of the site as well as on-site. The samples will be submitted a South African National Accreditation Standards (SANAS) accredited laboratory for chemical analysis;
- To conduct data capturing, interpretation and benchmarking against South African National Standard (SANS) 241: 2011 and any other in-stream Water Quality Objectives (WQO) to determine the baseline water quality;
- To undertake surface water quantity and quality impact assessment of the listed activities using a Digby Wells developed methodology;
- The identified impacts will be weighted and the mitigation measures required to decrease their significance will be developed and significance post-mitigation will be determine;
- To develop surface water management plan (SWMP) indicating actions for implementation throughout the LoM and the responsible persons;

- To develop a surface water quality monitoring plan indicating monitoring sites, frequency of monitoring, the variables to be analysed and database management;
- Compile a salt and water balance report; and
- A floodline assessment will be undertaken in a separate study to indicate the 1:50 and 1:100 floodlines as well as the buffer zones (on which no activities may take place unless if exempted by the DWA from some of the GN 704 regulations).

1.4 Aims and Objectives

This report will detail the findings of the specialist study form the results of the baseline assessments to the results of the impacts assessments identification and proposed mitigation and monitoring methods

2 Methodology

The baseline surface water assessment was carried out in three phases namely:

- A desktop study to characterise the site, identify sampling points and to conduct hydrological characterisation;
- A site visit to assess the site characteristics, collect water quality samples; and
- A report compilation.

The surface water quality and quantity methodologies used in the Project are detailed below.

2.1 Surface Water Hydrology

Desktop methodologies were used to determine the hydrology of the site including flood peak calculations.

The catchment attributes namely Mean Annual Runoff (MAR), Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAR) were obtained from the Water Research Commission (WRC) Reports K5/1491 (WRC, 2005). The MAR represents the average annual volume of water that finds its way to the surface water resources after the rainfall (MAP) events and when evaporation (MAE) and infiltration volumes have been deducted from the MAP. Information on the rainfall and rainfall zones was also obtained from the WRC report.

2.1.1 24-hr Design Rainfall Event

Extreme event rainfall depths were determined from the South African Weather Services (SAWS) rainfall information database for six sites closest to the study area were identified (Plan 6). A 24 hour design rainfall depths model was run on a Design Rainfall Estimation (DRE) in South Africa software (Smithers and Schulze, 2003) for the 1: 50 and 1: 100 year return periods. The closest rainfall stations are summarised in Table 6-1

Table 2-1: Summary of the closest SAWS rainfall stations used for the DRE

Station Name	Station Number	Distance	Record	Latitude	Longitude	MAP
LANGSLOOT	0478292_W	5.1	80	26°22 '	29°10 '	698
TWEEDRAAI	0478386_W	7.4	57	26°25 '	29°12 '	667
DRIEFONTEIN	0478360_W	10.5	64	26°29 '	29°11 '	678
KRIEL (POL)	0478406_W	18	88	26°16 '	29°14 '	626
RIETVLEI	0441215_W	19.9	43	26°35 '	29°7 '	611
TIKVOH	0478567_W	21.1	36	26°28 '	29°19 '	667

2.1.2 Streamflow Analysis

There are no DWA stream flow gauges within 20km downstream or upstream of the Project's site. Although DWA database indicates stations within the B11D catchment there are no records associated with them. Therefore no nearby stations were observed to be useful for hydrograph analysis of streamflow from the Project site or upstream of it.

2.1.3 Flood peak flows

2.1.3.1 Subcatchment Delineation

Subcatchments were delineated to cover the streams within the Project boundary catchments and were utilised to determine the 24 hr flood volumes for the 1: 50 and 1: 100 yr extreme events. The same subcatchments will be utilised for floodlines determinations in a separate report. The delineated subcatchments are highlighted in Plan 7.

The subcatchments were characterised for the peak flows calculations as detailed in the Drainage Manual (SANRAL, 2007). The values of each of these model parameter classes were then determined by professional subjective judgement/ discretion, and visual inspection on the terrain and fraction of the catchment. The most important parameters are:

- Area distribution – which is estimated based on the catchment area and respective areas covered by the rural, urban and reservoirs;
- Rural area surface slope – which was characterised based on the respective slope (%) classifications to define flat areas from hilly areas and steep area;
- Rural area permeability – which is estimated from the a qualitative guide of soil texture for the classification of the soil permeability as in the Drainage Manual (SANRAL, 2007) and soil maps (1:250 000 interactive map from Agricultural Research Council) and estimation of percentage area by visual inspection;
- Vegetation – which was estimated from site inspections observations and satellite imagery visual classification;
- Urban area parameters – which were based on site observations and inspections;
- The number of days on which thunder was heard – obtained from the WRC Report and the SAWS;

- Dolomitic areas – the percentage dolomitic area was determined based on the geology map and using visual inspection and estimation; and
- Overland or defined water course flow – where the average slope of a catchment greater than 5% and catchment larger than 5 km^2 assumes that defined water courses exist.

2.1.3.2 Calculation of Flood Peak Flows

The flood peaks for a 1:50 and 1:100 year flood peak flows were calculated taking into account the parameters determined from the delineated sub-catchments. The peak flows were determined utilising the several rainfall runoff models within the Utilities Programmes for Drainage (UPD) software (Version 1.0.2) (SANRAL, 2007)

The selected methods were the Rational Method and the Alternative Rational Method (ARM) based on the sub-catchment size.

Rational Method

The most widely used method for determining peak flows from small catchments, i.e <15 km^2. The basis of the relationship is the law of conservation of mass and the hypothesis is that the runoff rate is directly proportional to the size of the contributing area and the rainfall intensity, the latter a function of the return period. The Rational Method is a simplistic method of peak flow estimation, which includes a composite estimation of the runoff coefficient, allows for the influence of slope, soil, permeability, vegetation and land cover to be considered. A runoff coefficient of 0.35 was used for the respective catchments. A time of concentration is calculated, enabling a more realistic estimation of the Depth Duration Frequency design rainfall event.

The peak flow is obtained from the following relationship:

$Q = 0.36CIA$

Where: Q = peak flow (m^3/s)

C = runoff coefficient (dimensionless)

I = average rainfall intensity over the catchment (mm/hr)

A = effective area of the catchment (km^2)

3.6 = conversion factor

Alternative Rational Method

This method is based on the rational method with the point precipitation being adjusted to take into account local South African conditions. This method can work for large catchments without any limitation.

2.2 Surface Water Quality

Surface water quality assessment entailed the identification of sampling points located up- and downstream of the site as well as strategic points on site (in relation to the opencast and underground mining location) at a desktop level. A site visit was then conducted to collect samples and to confirm the site characteristics required for the hydrological assessment.

2.2.1 Surface Water Quality Sampling

An initial 16 sites were determined for baseline studies (Plan 8) given the numerous water resources draining the area. As it was concluded that there will be no infrastructure on site, the anticipated impacts form the mining would therefore be small to none, therefore nine sites were finalised for sampling, with the remainder assigned to further assessments for as additional monitoring points should infrastructure be set up on the site, the additional sites should be monitored.

On the site visit 2013 - 04 - 24), eight of nine identified samples were collected and the remainder was stagnant. The samples were collected in line with the South African Bureau of Standards (SABS, 2001) methodology and DWA BPG: 3 Water Monitoring Systems. The sample collection locations are summarised in Table 6-2 below

Table 2-2: Summary of the sampled sites on Block 4

Site Name	Farm Name
SW_004	On farm Zondagsfontein 124 IS portion 3 upstream of a dam within the Project site
SW_006	In farm Dieplaagte 123 IS portion 7 just close to Project eastern boundary
SW_007	On farm Spandow 121 IS portion 1, just upstream of confluence of tributaries to the Trichardspruit on the south eastern boundary of the Block 4
SW_009	Located in farm Zwakfontein 120 IS portion 24, dowstream of the project boundary before confluece with Dwars-in-die-wegspruit
SW_010	Located in the farm RIETFONTEIN 100 IS portion 9 on the Dwars-in-die-wegspruit before confluence with Trichardspruit
SW_011	On the farm LANGSLOOT 99 IS portion 3 dowstream of the Project boundary on a tributary to the with Dwars-in-die-wegspruit
SW_012	Within the farm ONVERWACHT 97 portion 5 is immediately downstream of confluence
SW_014	Within the farm ONVERWACHT 97 IS portion 2 at a bridge on Vaalbankspruit and a confluence with tributary draining through several dams in and out of the Project site.
SW_015	On the farm ONVERWACHT 97 IS portion 16 on a small tributary draining the Project site toward the Vaalbankspruit/Dwars-in-die-wegspruit

Additional sites were sampled on the 2013-09-04 for the Syferfontein northern reserves as detailed in

Table 2-3: summary of sites sampled from

Sample Point	Farm Name
SW17	Located on the farm TWEEDRAAI 139 IS
SW18	Located on the farm Riversdale 119IS on a diversion of the tributary to the Trichardspruit
SW19	Is located in the farm RIETFONTEIN 100IS, downstream of the Rietfontein Dam on the Trichardspruit
SW20	Is located on th Dwars in de wagspruit in the farm RIETFONTEIN 100IS. It is located upstream of the confluence with the Trichardspruit
SW21	A site located further downstream of SW20 after confluence with the Trichardspruit and another tributary. It is within the farm RIETFONTEIN 100IS
SW22	Located on the Zwakfontein 120IS upstream of the Rietfonetin dam on the stream diversion
SW23	Located on the farm RIETFONTEIN 100IS, the most downstream location of the project boundary

2.2.2 Baseline Water Quality

The collected samples were submitted to Waterlab, a SANAS accredited laboratory for analysis. The variables analysed in the laboratory are listed in Table 2-4.

Table 2-4: Summary of the parameters/ variables analysed

Total Dissolved Solids (TDS);	Potassium as K;
Sulphate as SO_4;	Chlorides as Cl;
Sodium as Na;	Iron as Fe;
Magnesium as Mg;	Manganese as Mn;
Nitrate NO_3 as N;	Electrical Conductivity (EC);
Fluoride as F;	Total Alkalinity as $CaCO_3$;
Calcium as Ca;	pH-Value at 25° C;
Free and Saline Ammonia as N;	Aluminium as Al;

The units of measurement are mg/l except pH and EC measured in pH units and mS/m respectively.

The data obtained from the laboratory (Appendix C) was benchmarked against the South African National Standards (SANS) 241: 2011 Drinking Water (SABS, 2011) and used to determine the baseline water quality. The SANS 2011 standards limits for chronic health were utilised as the upper class for the maximum allowable limits and the stricter aesthetic value limits were used as the stricter limits.

The water quality was benchmarked against the South African National Standards (SANS) 241: 2011 for drinking water (SABS, 2011). This stream is not necessarily used for drinking water but comparison with drinking water guidelines was to ensure its levels compared to stringent water quality guidelines.

2.3 Water Use and Availability

Based on the understanding of the site and the previous studies conducted by Digby Wells on various projects, the water use and availability in the area was determined.

2.4 Impact Assessment

The impact assessment methodology is described in the Section 4.

3 Results and Discussion

3.1 Hydrology Assessment

3.1.1 Catchment Description

The surface water attributes of the affected catchments namely MAR, MAP and MAR are summarised in Table 3-1 (WRC, 2005) indicating that the ratio of precipitation: evaporation of 42% whilst the rainfall that ends up as runoff is 7%.

Table 3-1: Summary of the surface water attributes of the two quaternary catchments

Quaternary Catchment	Total Area (km^2)	Rainfall Zone	MAP (mm)	MAR (mm)	MAR m^3* 10^6	Evaporation Zone	MAE (mm)
B11D	551	B1A	671	44.6	24.6	4A	1599
B11C	371	B1A	673	53.3	19.8	4A	1552

3.1.2 24-hr Design Rainfall Event

The 24 hour design rainfall depths for the 50 and 100 year return periods for the six rainfall station gauges (Plan 6) as determined using the DRE in South Africa software (Smithers and Schulze, 2003) are summarised in Table 3-2

Table 3-2: Calculated 24 hour design rainfall depth

Return period	1: 2	1: 5	1: 10	1: 20	1: 50	1: 100	1: 200
24 Hour Rainfall Depth (mm)	63.6	85.4	100.9	116.8	138.7	156.3	174.9

3.1.3 Flood peaks

3.1.3.1 Subcatchment Delineation

Delineated subcatchments were delineated for four streams draining the Project site as depicted in Plan 7. The delineated subcatchments were utilised for determining are flood peaks and the obtained characteristics are depicted in Table 3-3.

Table 3-3: Summary of delineated subcatchments with subcatchment characteristics and details

Subcatchment	Area (km^2)	Longest stream length (km)	Elevation difference 85% - 10% of stream length (m)	Proportion of catchment in % within slope classes	
				<3%	3 - 10 %
A	13.0	6.95	30.9	10.10	89.9
B	15.0	5.57	35	7.65	92.4
C	5.35	2.93	18.2	0.43	99.6
D	13.3	6.37	44.6	11.8	88.2

3.1.3.2 Peak flows

The estimated design flood peaks flows were determined for the delineated subcatchments for the 1: 50 year and 1:100 year recurrence period flood events according. The summary of the calculated flows are presented in Table 3-4.

Table 3-4: Estimated design flood peak flows

Subcatchment	Area (km^2)	Rational		Alternative Rational	
		1:50	1:100	1:50	1:100
A	13.0	44.8	57.7	49.6	60.0
B	15.0	64.0	82.2	71.3	86.5
C	5.35	29.6	38.3	32.4	36.3
D	13.3	58.6	75.4	64.9	78.8

The results indicate that the flood peak flow range between 29 and 71 m^3/s for the 1: 50 and between 38.2 and 287 m3/s for the 1: 100 return periods. In line with Schedule 6 of GN R 704 of the NWA, the design, operation and maintenance of water conveyances and containment facilities must be able to contain the 1: 50 year 24 hour flood peak.

3.2 Surface Water Quality

3.2.1 Sampling

A summary of the sites sampled, their location and a brief description is presented in Table 3-5 and shown in Plan 8: Surface Water Quality Monitoring Sites

Table 3-5: A summary of the sampling site visit performed location and the site observation

Site Name	X – coordinate	Y - coordinate	Comment
SW_004	29.12056528	-26.40030345	Sample was collected from low water levels with slow flow and fish was observed on site
SW_006	29.17398516	-26.41010035	Sample was collected from low water level with flowing water, cattle nearby the site
SW_007	29.18234209	-26.41284423	Sample was collected and the river had low flows
SW_009	29.20002559	-26.36589169	Sample collected, stream with high flows
SW_010	29.19140824	-26.34600891	Low water levels with flow with construction of road and bridge taking place, and a sample was collected
SW_011	29.1672094	-26.36139975	Low water levels with flow and a sample was collected
SW_012	29.15015979	-26.36247799	Low water levels with flow and a sample was collected
SW_014	29.13024139	-26.35816804	Sample collected from the low water levels with flow and maize fields were observed near the site
SW_015	29.15501224	-26.38577845	Stagnant and very low water level therefore was not sampled
SW_017	29.20226292	-26.42099103	Not sampled and not accessed
SW_022	29.20863739	-26.36636563	Sampled and flowing
SW_018	29.23525555	-26.36649089	Not sampled and not accessed
SW_019	29.21747792	-26.34920156	Sampled and flowing

Site Name	X – coordinate	Y - coordinate	Comment
SW_020	29.21321671	-26.34354649	Sampled and flowing
SW_021	29.22059616	-26.33670824	Sampled and flowing
SW_023	29.22629773	-26.32271215	Sampled and flowing

3.2.2 Baseline Water Quality

The surface water quality data indicated in Table 3-6, summarises the water quality data from the various sampling sites Plan 8. When benchmarked against the SANS 241 Drinking water standards, the data indicated that the metals concentration for elements Aluminium (Al), Iron (Fe) and Manganese (Mn) exceeded aesthetic water quality levels.

Al levels exceeded the acceptable drinking water quality of 0.5 mg/l for SW_004 and SW_014 with levels at 1.12 and 0.53 mg/l respectively. However for SW_007, Al levels were within acceptable drinking water levels.

The concentration of dissolved aluminium in unpolluted water at neutral pH is 0.005 mg/l or less (DWAF, 1996), this implies that the elevated Al levels could emanate from anthropogenic sources. These sources could be attributed to the pollution (including waste disposal) activities taking place at the town of Kinross and the upstream smaller dams.

Elevated Fe and Mg were however within the acceptable drinking water quality for a maximum exposure period of 70 years for the sites SW_004, SW_007, SW_011, SW_012 and SW_14. These can be characteristic of the area.

The consequence of human consumption of water with elevated Al that exceeds 0.5 mg/l if water intake is 5 % of the total daily intake is that no acute health effects are expected. However, severe aesthetic effects (discolouration) occur in the presence of iron or manganese. The predominant land use in the area is agriculture however, levels of Al in the range 0.1 to 0.5 mg/l in soil solution could result in plant toxicity. However, the interaction of Al and soils (through adsorption) could reduce the potential for plant toxicity. The levels of Al for the water have no adverse effects on any livestock ingesting the water.

The Fe levels (1 to 10 mg/l) have slight health effects expected in young children, and sensitive individuals if consumed over seven years. The levels determined below 0.3 mg/l have slight aesthetic effect whilst those from 0.3 mg/l upwards have increasing adverse effects. The most likely effect from the Fe levels determined is aesthetic (taste and colour). For other domestic uses (washing and bathing) there are no expected effects. For agricultural use (irrigation) there are no effects to plant below 5 mg/l. The toxicity to plants can be expected at 20 mg/l and even then, the interaction of the water and soils tend to reduce toxicity. For livestock watering, Fe is an essential constituent of animal diet and has a low order of toxicity in low concentration of less than 10 mg/l.

The Mn levels in the range of 0.15 to 1.0 have increasingly severe staining and taste problems but present no health effects when used for domestic uses. When utilised for irrigation, elevated Mn levels within the range 0.1 to 1.5 results in moderate problems encountered with clogging of drip irrigation systems whilst effects on plants are highly dependent on the tolerance to Mn by the particular plants. It is also dependant on the particular soil type. Elevated Mn if the water is used for livestock watering is not anticipated to have toxicity effects in the ranges up to 10 mg/l.

The baseline quality indicated that the water is of aesthetic quality in most parameters of water quality with the exception of Al, Mn and Fe (Class II). However in terms of Al, for two of the sample sites water exceeds the acceptable drinking water quality limits.

The water quality is fit for drinking but in small amounts domestic use and agricultural use (irrigation and livestock) as determined from the DWAF water quality guidelines (DWAF, 2006).

Table 3-6: Surface water quality data benchmarked against the SANS 241: 2011

Sample ID		Total Dissolved Solids	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
Class I	**(Aesthetic Recommended)**	<1200	<10	<300	N/S	<250	<150	<70	<200	<50	<0.3	<0.1	<170	5-9.5	<0.3	<1.5	<1
Class II	**(Drinking water Max. Allowable)**	2400	11	600	N/S	500	300	100	400	100	2	0.5	370	4-5 or 9.5-10	0.5	2	1.5
	Duration (years)	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs	70yrs
SW_004		292	-1.00	24.0	220	42.0	28.0	34.0	35.0	5.30	1.34	0.27	51.1	7.90	1.12	0.50	0.80
SW_006		220	-1.00	21.0	140	28.0	18.0	21.0	25.0	1.70	0.05	-1.00	35.6	9.10	-1.00	-1.00	0.30
SW_007		324	-1.00	27.0	200	46.0	27.0	27.0	38.0	4.60	0.43	0.10	52.8	8.40	0.40	-1.00	0.70
SW_009		306	-1.00	18.0	232	36.0	34.0	29.0	26.0	4.10	0.16	0.06	51.3	8.10	0.17	0.20	0.60
SW_010		244	-1.00	23.0	144	44.0	26.0	17.0	27.0	4.60	0.19	0.03	41.7	8.20	0.22	-1.00	0.50
SW_011		542	0.60	50.0	244	155.0	59.0	52.0	37.0	4.50	0.10	0.25	84.6	8.20	0.11	-1.00	0.50
SW_012		258	-1.00	24.0	148	41.0	26.0	17.0	28.0	4.50	0.31	0.07	41.3	8.10	0.24	-1.00	0.50
SW_014		230	-1.00	23.0	136	31.0	21.0	14.0	30.0	4.90	0.96	0.18	38.1	7.90	0.53	-1.00	0.50
SW_020		395	0.18	33.0	254	67.0	48.0	40.2	50.6	3.16	0.00	0.00	66.1	8.44	0.00	0.30	0.36
SW_022		121	0.57	5.3	82	21.5	19.4	11.2	9.9	3.10	0.00	0.00	23.0	8.15	0.00	0.14	0.29
SW_023		138	0.21	6.9	96	22.4	22.0	12.9	12.3	3.14	0.00	0.00	25.8	8.29	0.00	0.20	0.29
SW_021		210	0.15	11.6	149	32.9	31.5	20.0	20.7	3.09	0.00	0.00	38.3	8.46	0.00	0.17	0.28
SW_019		133	0.75	7.3	90	22.1	21.1	12.4	11.9	3.45	0.00	0.00	24.2	8.23	0.00	0.31	0.26

N/S - Not specified: Meaning no standards have been specified

3.3 Water Use and Availability

3.3.1 Land Use

The Project area is dominated by several land uses in the area include

- Agriculture activities;
  - Irrigation farming;
  - Livestock rearing;
- Mining; and
- Urban and rural settlements

Some of the land is covered in water resources and wetlands.

3.3.2 Water Users

The DWA has a Water Users Registration Management Systems (WARMS) database for each of the WMAs and quaternary catchments. The water user database is based on authorised water uses captured by DWA and may not be representative of all water users on the ground. The surface water users identified from the WARMS database provided in 2013 are:

- Agriculture (for irrigation);
- Agriculture (for livestock watering); and
- Mining.

The majority of water users in the B11D catchment area are agricultural particularly for irrigation as depicted in Plan 9. However, the water users information detailed indicates that mining is allocated more water as highlighted below which could mean in this area mining required more water and would require water management strategies therefore;

Water Users	Allocated Water use
Agriculture (for Irrigation)	41 000 to 290 800 m^3/yr
Agriculture (for Livestock watering)	100 to 8235 m^3/yr
Mining	1825 to 602250 m^3/yr

The water sources are dams and streams / rivers, and boreholes. A significant quantity of the water used in this catchment is from dams and streams/ rivers also making water an important resource to the water users.

4 Impact Assessment

The impacts of the construction and operation of the proposed pipeline and ash backfilling project on the receiving surface water resources were assessed at different stages of the development of the pipeline according to the methodology indicated in Table 4-1

A clearly defined rating scale is used to assess each impact in terms of severity, spatial extent and duration (which determines the consequence) and in terms of the frequency of the activity and the frequency of the related impact (which determines the likelihood of occurrence). The overall impact significance, is then determined via a significance rating matrix Table 4-2 utilising the scores obtained for consequence and likelihood of occurrence, in order to assign a final impact rating.

Table 4-1: Impact Assessment methodology

Rating	Severity	Spatial scale	Duration	Probability
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage.	International The effect will occur across international borders	Permanent: No Mitigation No mitigation measures of natural process will reduce the impact after implementation.	Certain/ Definite. The impact will occur regardless of the implementation of any preventative or corrective actions.
6	Significant impact on highly valued species, habitat or ecosystem.	National Will affect the entire country	Permanent: Mitigation Mitigation measures of natural process will reduce the impact.	Almost certain/Highly probable It is most likely that the impact will occur.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate	Province/ Region Will affect the entire province or region	Project Life The impact will cease after the operational life span of the project.	Likely The impact may occur.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year	Municipal Area Will affect the whole municipal area	Long term 6-15 years	Probable Has occurred here or elsewhere and could therefore occur.

Rating	Severity	Spatial scale	Duration	Probability
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month.	Local Local extending only as far as the development site area	Medium term 1-5 years	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.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants.	Limited Limited to the site and its immediate surroundings	Short term Less than 1 year	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the project but has happened elsewhere. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Very limited Limited to specific isolated parts of the site.	Immediate Less than 1 month	Highly unlikely/None Expected never to happen.

Table 4-2 : Significance categories

Significance Consequence (severity + scale + duration)										
		1	3	5	7	9	11	15	18	21
Probability / Likelihood	1	1	3	5	7	9	11	15	18	21
	2	2	6	10	14	18	22	30	36	42
	3	3	9	15	21	27	33	45	54	63
	4	4	12	20	28	36	44	60	72	84
	5	5	15	25	35	45	55	75	90	105

	6	6	18	30	42	54	66	90	108	126
	7	7	21	35	49	63	77	105	126	147

Significance		
High	108- 147	
Medium-High	73 - 107	
Medium-Low	36 - 72	
Low	0 - 35	

The assessment of surface water quality and quantity impacts on the proposed Project site from the proposed mining activities listed Table 4-3 were carried out.

Table 4-3: Activities list

Activity No.	Activity	Timeframe
Construction Phase		
1	Construction of underground structures - incline	201? – Jan 20??
2	Transportation of materials & workers on site	201? – Jan 20??
3	Temporary storage of lubricants and fuels.	201? – Jan 20??
Operational Phase		
4	Underground bord and pillar mining method.	Life of the mine (approximately 30 years with the potential to extent this period)
7	Storage, handling and treatment of hazardous products (fuel, explosives, and oil) and management of waste.	Life of the mine (approximately 30 years with the potential to extent this period)
Decommissioning phase		
8	Decommissioning of underground mine.	After the life of mine
Post-closure Phase		
11	Post-closure and water and subsidence monitoring	After the life of mine

Activities in the construction phase will be carried out on existing infrastructure and no surface infrastructure on the Block 4 Project site will be developed. The existing access routes will be used. It is therefore not anticipated to have impacts on both surface water quality and quantity within the Project Site form the construction phase or the decommissioning phase.

During the operational phase no direct surface water impacts are anticipated in terms of quality or quantity. However subsidence could occur during operation and post closure resulting in surface water quantity impacts.

In underground mining operations, where there has been undermining of streams, potential leakage of surface water to the subsurface through fractures streambed could become an issue (Jankowski J and Knights P, 2010). This mine induced fracturing could result in increased rainfall infiltration, reduced runoff and reduced baseflow discharge thus resulting in streamflow reduction and loss particularly during the low flow conditions affecting the catchments water balance. Coupled with this is subsidence which can also cause open fractures which allows for surface water to flow into lower strata or open mine workings.

It is important to note that in many cases, subsidence is mostly inevitable when underground mining is undertaken with it being aggravated by mine dewatering. It has also been established that greater depths of overburden do not generally prevent subsidence, but may delay timeline. However, some mitigation strategies can be put in place should it occur with almost none that can eliminate subsidence. (Blodgett and Kuipers, 2002 and Bauer. 2008 in the University of Laberta lesson notes.

The identified potential impact from this Project is subsidence and consequent fracturing of the lower strata that could have implications of the surface water flow and streamflows.

4.1 Operational Phase

After the area (including streams) has been undermined there is a possibility that subsidence could occur. These could result in depressions and fractures those impacts on the natural drainage patterns and affecting the water balance.

These subsidence could occur on a limited area but depending on scale, impacts could spread to local extent as the site is located upstream of the Waterval River catchment area. This impact could be a permanent impact on the landscape if not avoided or minimised and has a serious impact on the environment as it changes the entire geomorphology of the landscape. The impact is likely if the correct design factors are not used to undermine the area and as a result the significance of the impact is rated as Medium-High as shown in the table below

4.1.1 Impact: Potential subsidence on the undermined surface

Criteria	Details / Discussion
Description of impact	Subsidence potential could occur when mining takes place which can also cause open fractures which allows for surface water to flow into lower strata or open mine

Criteria	Details / Discussion				
	workings. This could occur as a result of pillars being mined out completely or partially not adequate to support overburden material. As a result mine induced fracturing could result in increased rainfall infiltration, reduced runoff and reduced baseflow discharge thus resulting in streamflow reduction and loss particularly during the low flow conditions affecting the catchments water balance.				
Mitigation required	▪ The correct safety factors to be used to insure reduced collapse of undermined areas ▪ The subsidence prediction calculations should be carried out based on the various factors such as geology, extraction patterns and ore thickness amongst others; ▪ Annual subsidence monitoring (Aerial surveys/ Land surveys) can assist in determining where the impact is taking place and planning control of damages; and ▪ Where it is feasible backfilling could be considered				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	Beyond project life (6)	Local (3)	Very serious, long-term High - negative (-5)	Probable (4)	56
Post-Mitigation	Beyond project life (6)	Limited (2)	Moderately high - negative (4)	Improbable (2)	24

4.2 Post-Closure

4.2.1 Impact: Subsidence

The subsidence impact described in the operational phase applies in the Post-Closure phase as well.

5 Cumulative Impacts

The project area is dominated by several streams and water resources including farm dams. Therefore, subsidence would result in an alteration of the hydrology of the area which could impact on the general catchment water balance. The water balance is important for other land uses determines such as agriculture and other mining activities within the area.

6 Summary of Significant Impacts

The most significant impact realisable from underground mining in Block 4 would potentially be subsidence that would results in altered subcatchment hydrology.

7 Mitigation Measures and Management Plan

The only mitigation measure that can be taken to prevent or limit the occurrence of subsidence is to ensure the underground mine design is within the safety factors recommended. This can be coupled with subsidence prediction studies which should therefore lead any backfilling should suitable backfilling material be identified.

8 Monitoring Programme

It is recommended that the area is mapped annually by aerial surveys to check for any subsidence taking place and then if subsidence has occurred corrective actions need to be implemented to minimise/reduce any further impacts from occurring.

9 Recommendations and Knowledge Gaps

The following is recommended to maintain the quality of the surface water at proposed mining site:

- Monitoring of surface water resources should be implemented if groundwater studies detect areas where surface and groundwater interact given there will be underground mining with no surface infrastructure on site; and
- Any new and existing mining activities in the area should implement water management measures for reuse and recycle as mining is a biggest water user in the catchment.

10 Conclusion

The following conclusions were drawn from the baseline:

- The water quality is fit for drinking (if the Al can be treated at two locations), domestic use and agricultural use (irrigation and livestock) as determined from the DWAF water quality guidelines (DWAF, 2006). However it could pose several aesthetic issues at most sites;
- There are several water resources in the area, mining being the water user although there are many registered agricultural uses in the area;
- Four subcatchments were delineated within the Project site boundary; and
- The results indicate that the flood peak flow range between 29 and 71 m^3/s for the 1: 50 and between 38.2 and 287 m^3/s for the 1: 100 return periods.

Potential impacts could arise during and after the area (including streams) has been undermined there is a possibility that subsidence could occur. These could result in depressions and fractures those impacts on the natural drainage patterns and affecting the water balance.

11 References

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Appendix A: Plans

Plan 1: Regional Setting

Plan 2: Local Setting

Plan 3: Land Tenure

Plan 4: Quaternary Catchment

Plan 5: Water Resources

Plan 6: Rainfall Stations

Plan 7: Subcatchments

Plan 8: Surface Water Quality Monitoring Sites

Plan 9: WARMS Water Users

Appendix B: Declaration of Independence

Appendix C: Laboratory Data

Appendix D: Appendix Title