REPORT

Hydrology/Hydrogeology Report for the Proposed Discard Facility at Zibulo Opencast Operation

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Executive Summary

Anglo American Inyosi Coal (Pty) Ltd (AAIC) proposes to develop a discard facility at its opencast operations at Zibulo Colliery, situated near Ogies in the Mpumalanga Province. Zibulo Colliery comprises both underground and opencast mining operations. The mine produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections and the remaining one million tonnes from its opencast pit. The underground operations incorporate bord and pillar continuous mining methods while the contractor-run box cut development (Zibulo Opencast) utilises a small dragline and truck and shovel fleet. The opencast area commenced in 2009 and supplies coal to local and international markets.

Zibulo Opencast consists of a single pit operation with a pit length of approximately 1 km and is classified as a mini pit, with two active mining cuts, North and East. Coal from the opencast operations is transported via truck to the Phola Coal Processing Plant (PCPP) for beneficiation, where it is washed together with the underground coal which is transported to the PCPP via a 16 km conveyor.

The PCPP is a 50:50 venture between AAIC and South32 SA Coal Holdings (Pty) Ltd (South32), receiving ROM coal predominantly from AAIC's Zibulo operation and South32's Klipspruit operation. The coarse and fine discard produced from the PCPP is currently deposited onto a surface discard facility on South32's Klipspruit Colliery. The facility is reaching capacity and by 2021 an alternative discard facility is required to service the discard requirement of Zibulo Colliery.

Zibulo Opencast falls in the upper Olifants sub-catchment of the Olifants Water Management Area. The open-cast workings fall within quaternary catchment B20G. The area drains to the Saalklapspruit/ Saalboomspruit via an unnamed tributary. This in turn drains into the Wilge River which drains to the Loskop Dam, after which the Olifants River flows through Mpumalanga and the central part of the Kruger National Park to Mozambique.

The main water users in the area relate to the Town of Phola located directly north of Zibulo Opencast, where both formal and informal residential areas are located. While the majority of the areas receive water from the eMalahleni Local Municipality, it is likely that there are informal dwellers who do use water directly from the river and small farm dams downstream of the mine. Further downstream water is used for irrigation.

In respect of legislation of water resource protection, classification of the water resources has been undertaken and Resource Quality Objectives (RQO) have been set for the Olifants WMA (Government Notice No 466, 22 April 2016, Government Gazette No 39943).

There are several unnamed tributaries in and around the project site:

- Two tributaries flowing north from the Ogies railway siding to i) the western boundary of Zibulo colliery where it is then diverted around the pit, and ii) along the eastern side of Zibulo Opencast and then through the township of Phola, and another downstream of the township of Phola to confluence with the Saalboomspruit just upstream of the Phola Wastewater Treatment Works.
- An unnamed tributary flowing north from Klipspruit Colliery to join the Saalboomspruit upstream of the R545 Road that passes the township of Phola.

All of these show elevated total dissolved solids and sulphate, as well as metals such as aluminium, iron and manganese at levels that can impact ecological and human health.

Groundwater quality measured in the Zibulo area indicate elevated total dissolved solids, however the latest indicates that the water quality falls within domestic use guidelines, for those parameters measured.

Groundwater quality within the backfilled opencast areas, including the overlying discard dump, is expected to deteriorate due to acid mine drainage and other chemical interactions between the geological and the groundwater regime. The resulting groundwater pollution plume will migrate along the new local and regional hydraulic gradients as the water table rebounds. Based on the topographic setting of the mine and the post-closure topography including the discard dump, the rebounding water table will lead to surface decant of mine water of approximately 620 m^3/d (0.62 ML/d). Based on the current mine plan, the expected critical level to prevent surface decant is estimated at 1 527 mamsl, while the Environmental Critical Level (ECL) to prevent diffuse decant will be at a lower level and depends on the actual weathering depth around the pit perimeter (assumed to be 15 m for the model simulations).

While a limited spreading of leachate from the backfilled pit (with or without the discard dump) into the weathered aquifer is expected for its western, southern, and eastern edges, the migration of the plume towards the north is significant and may trigger potential off-site migration. Post closure water levels within the backfilled pit (with or without discard dump) and surrounding aquifer should be monitored, and pit water levels managed below environmentally critical levels (i.e. weathered aquifer elevation within the downstream area of the backfilled pit) to prevent potential decant of mine water to surface or into the weathered aquifer. Potentially abstracted groundwater should be treated, re-used, or discharged into the environment.

The geochemistry results indicated that the discard materials are likely to produce near-neutral, saline drainage with low concentration of metals upon exposure to rainfall. The SPLP leachate results show that the following analytes are likely to be elevated in drainage from the discard dump:

- Electrical conductivity, total dissolved solids, manganese, sulphate, calcium, magnesium, and fluoride.

The NAG results indicated that when exposed to oxidation conditions for a long period of time, the discard materials will produce acidic (ARD) drainage with elevated levels of metals. The following elements are likely to be elevated:

- pH (acidic), electrical conductivity, total dissolved solids, sulphate, sodium, nitrate, phosphate, magnesium, aluminium, cobalt, iron, molybdenum, manganese, calcium, vanadium, and sodium absorption ratio (SAR).

The key potential surface and groundwater impacts are:

1) Erosion and riparian vegetation disturbance during the construction of the conveyor,
2) Surface water contamination during the operational phase,
3) Groundwater contamination during the operational phase, and
4) Decant of contaminated water to the surface water resources post closure.

In all cases the initial impact significance rating was rated as moderate or high, however, with mitigation this could be reduced to low in most cases.

Acronyms/Abbreviations

AAIC	Anglo American Inyosi Coal
ARD	Acid Rock Drainage
DWS	Department of Water and Sanitation
EWR	Ecological Water Requirements
EWRP	eMalahleni Water Reclamation Plant
IWUL	Integrated Water Use Licence
LOM	Life of Mine
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
Mamsl	metres above mean sea level
MAP	Mean Annual Precipitation
NAG	Net acid generation
NIWIS	National Integrated Water Information System
OC	Opencast
PCPP	Phola Coal Processing Plant
PCD	Pollution Control Dam
REC	Recommended Ecological Category
ROM	Run of Mine
RQO	Resource Quality Objectives
SPLP	Synthetic precipitation leaching procedure
UG	Underground
WQPL	Water Quality Planning Limits

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1.0 INTRODUCTION

Anglo American Inyosi Coal (Pty) Ltd (AAIC) proposes to develop a discard facility at its opencast operations at Zibulo Colliery, situated near Ogies in the Mpumalanga Province.

1.1 Background

Zibulo Colliery comprises both underground and opencast mining operations. The mine produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections and the remaining one million tonnes from its opencast pit. The underground operations incorporate bord and pillar continuous mining methods while the contractor-run box cut development (Zibulo Opencast) utilises a small dragline and truck and shovel fleet. The opencast area commenced in 2009 and supplies coal to local and international markets.

Zibulo Opencast consists of a single pit operation with a pit length of approximately 1 km and is classified as a mini pit, with two active mining cuts, North and East. Coal from the opencast operations is transported via truck to the Phola Coal Processing Plant (PCPP) for beneficiation, where it is washed together with the underground coal which is transported to the PCPP via a 16 km conveyor. The PCPP is a 50:50 venture between AAIC and South32 SA Coal Holdings (Pty) Ltd (South32), receiving ROM coal predominantly from AAIC's Zibulo operation and South32's Klipspruit operation. The coarse and fine discard produced from the PCPP is currently deposited onto a surface discard facility on South32's Klipspruit Colliery. The facility is reaching capacity and by 2021 an alternative discard facility is required to service the discard requirement of Zibulo Colliery.

1.2 Project Locality

Zibulo Opencast is situated in the eMalahleni Local Municipality in the Mpumalanga Province (Figure 1), located immediately north west of the Town of Ogies.

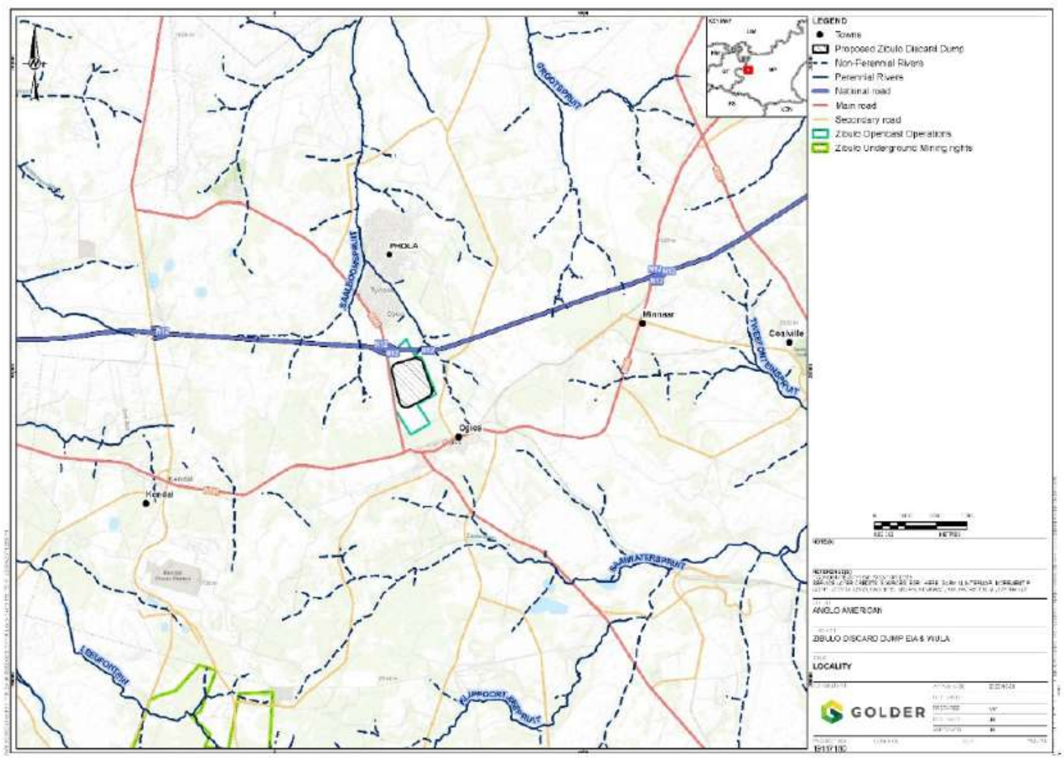


Figure 1: Project Locality

1.3 Project Description

The proposed project is a new discard facility to be developed over the mined-out opencast pit at Zibulo Opencast. The discard facility will have a life of approximately fifteen (15) years, a total discard disposal capacity of 26 000 000 m^3 (Figure 2) and extend over an area of approximately 150 hectares.

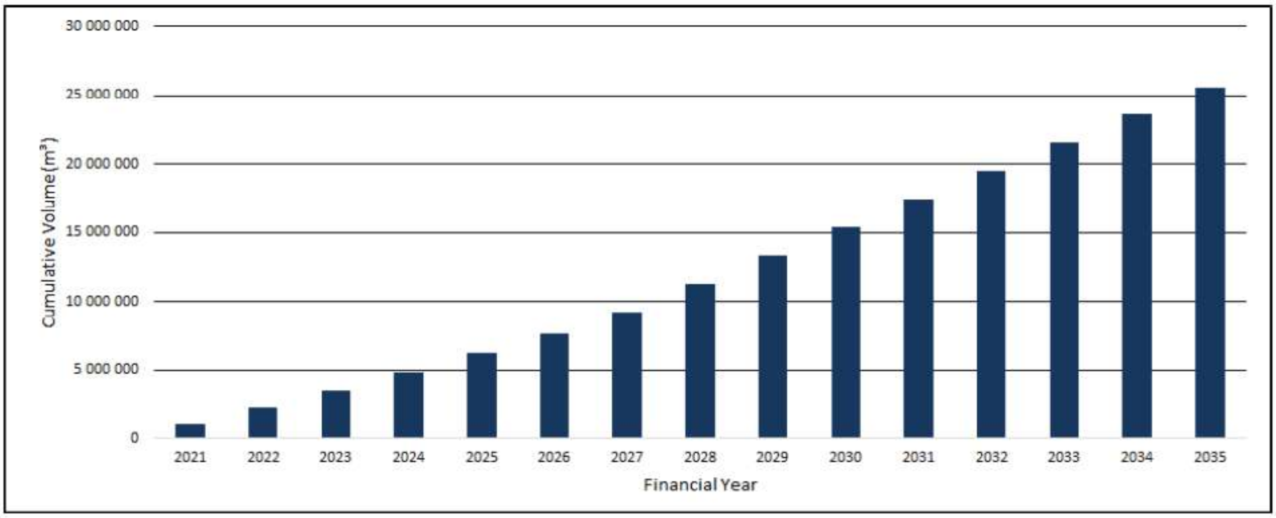


Figure 2: Discard production over the LOM

The discard facility will be designed such that it will be placed over the backfilled pit as illustrated in Figure 3. The facility is anticipated to have a maximum height of 27.5 m above the pit's rehabilitated landform.

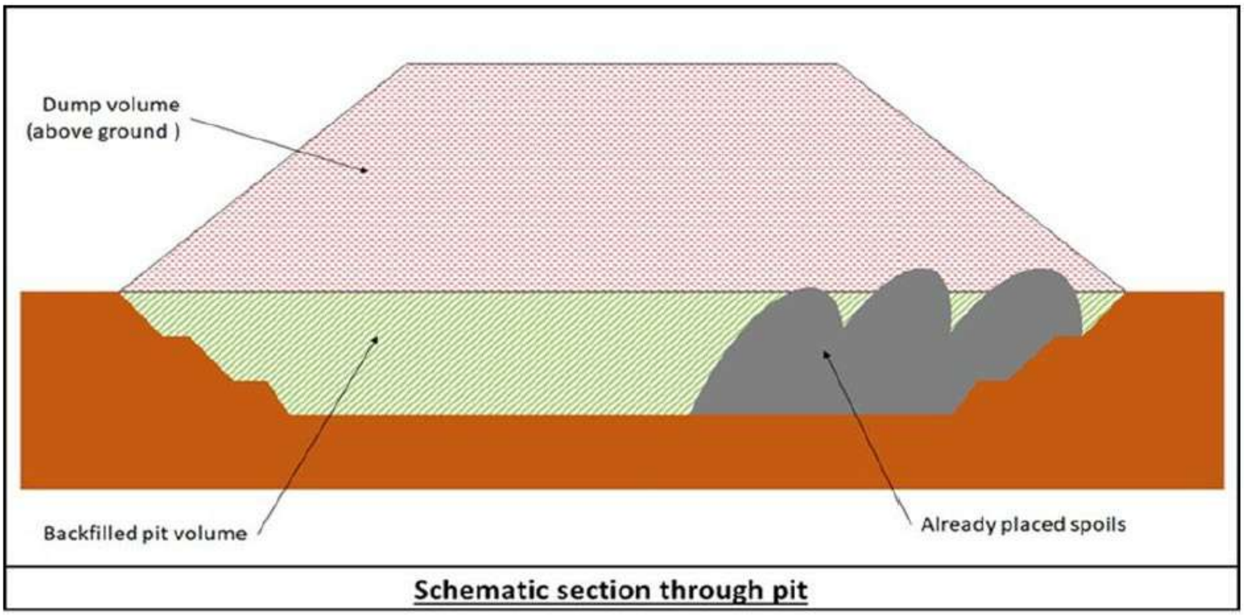


Figure 3: Proposed design of the Zibulo discard facility

The material deposited on the Zibulo discard dump will be deposited as a single stream consisting of coarse discards and filtered fines with the moisture content of the filter cake being around 20 – 23%. The facility will therefore be a dry placed discard waste facility and not a hydraulically placed tailings storage facility.

Seepage from the discard will be managed by the existing pit water management system in place. Excess mine water make intercepted at the pit is currently sent to the eMalahleni Water Reclamation Plant (EWRP) (via Klipspruit Colliery's balancing dam) for treatment.

Rehabilitation of the discard facility will require the construction of a cover that will be installed during ongoing rehabilitation.

The cover will allow for:

- A growth medium suitable for the establishment of vegetation to limit erosion; and
- Limit seepage into the discard facility.

Soil for the cover will be sourced from on site.

Discard (generated at PCPP) will be transported to the site via a new conveyor (Figure 4). It is proposed that the new conveyor follow the alignment of the existing conveyor linking the South32 Klipspruit extension project to the PCPP. The proposed new conveyor will lie immediately north of the existing conveyor and cross the R545 road on a dedicated bridge crossing. Soon after the crossing of the R545, the conveyor will turn north to the opencast pit for final discard disposal. The entire extent of the conveyor route is confined to mine property belonging to either South32 or AAIC.

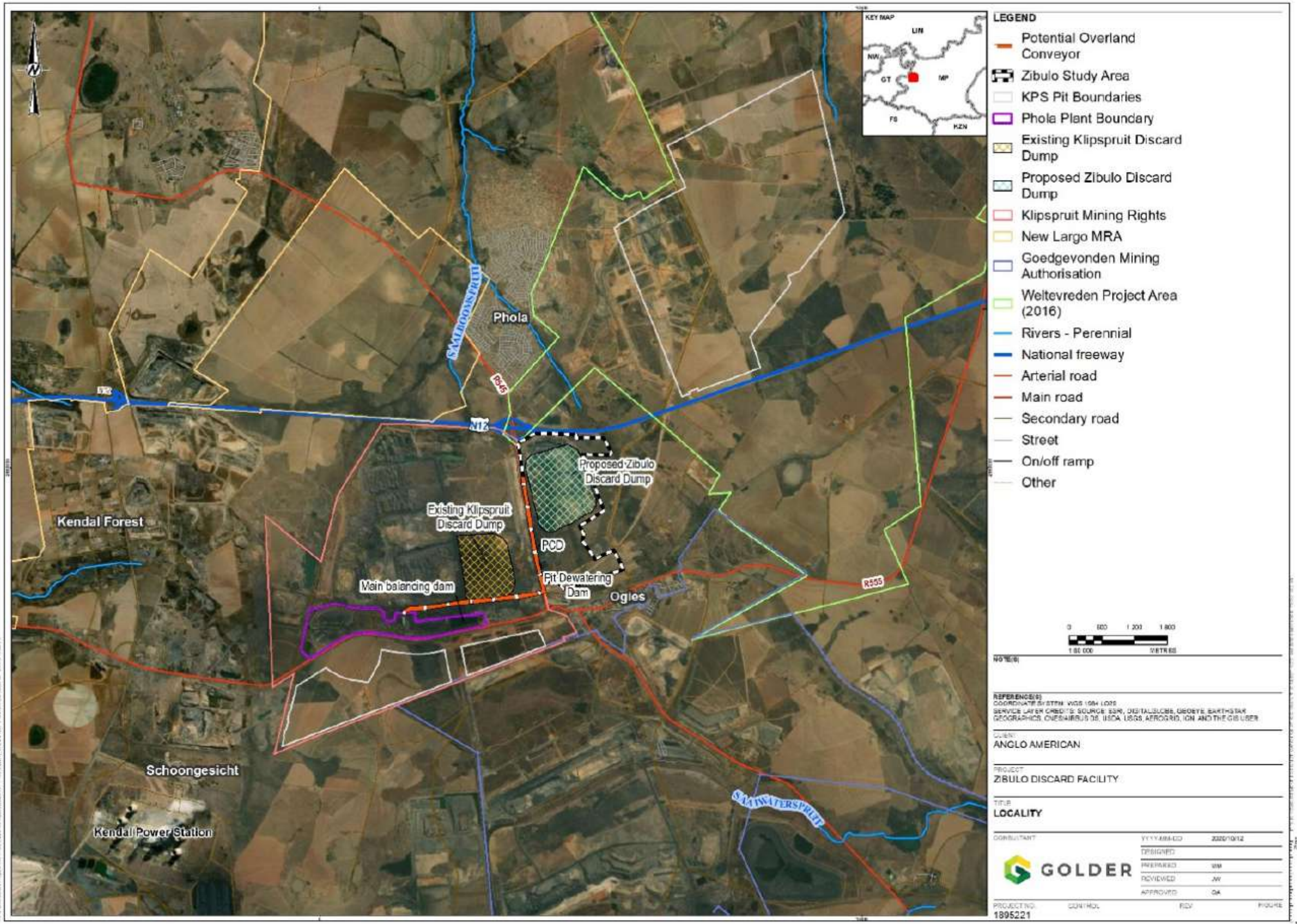


Figure 4: Project Components

2.0 BASELINE STUDY

2.1 Objectives of baseline investigations

The baseline describes the catchment and project area in respect of surface water resources and hydrological data for the current situation. It informs the impact assessment to support the various legislative requirements.

2.2 Climate

Zibulo Opencast is located in the Highveld Coalfields, an area that experiences warm, temperate climate with maximum temperatures exceeding 27°C in the summer months and temperatures below 2°C during the winter months. The Highveld is a summer rainfall region with November, December and January experiencing the highest rainfall months, and little to no rain in the winter months.

2.2.1 Climate change

The main drivers of climate change are population and economic growth, with an increasing demand for goods and services and for the energy to provide these. Due to their high energy demand supplied from non-renewable sources, transportation, industry, commerce, and the residential sector are the greatest contributors to Green House Gas (GHG) emissions. The energy sector in South Africa is responsible for about 89% of the national emissions of CO_2, mainly from energy industries (57%), transportation (9%) and manufacturing and construction (9%) (DEA, 2014). Other sources of emissions are industrial processes and agriculture. The bigger area in which the proposed site is located has extensive mining, large residential areas (Phola and Ogies), some industries in the Town of Ogies, and agriculture.

The sections to follow include some data provided by the DWS National Integrated Information System (NIWIS).

The image and graph downloaded from the DWS NIWIS, indicates three areas within quaternary catchment B20G in which Zibulo Opencast is located: B20G1, 2 and 3. Zibulo Opencast is located in B20G1. An average streamflow reduction of 34.8% is estimated for the area, the highest for B20G, from 59.34 m^3/s to 38.67 m^3/s, where the present data used was from 1975 – 2006 and the future was modelled for 2016 – 2045.

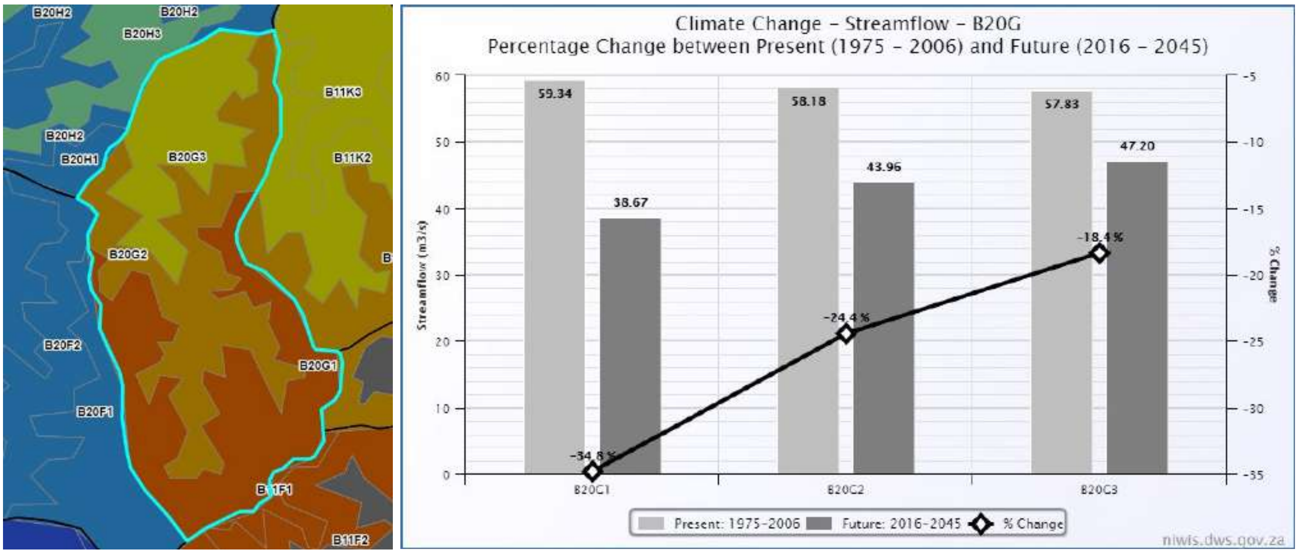


Figure 5: Streamflow changes for B20G (NIWIS, 2020[1])

[1] http://www.dwa.gov.za/niwis2/ClimateChange

The temperature changes expected in B20G are estimated to be an increase of 17.6% by 2045.

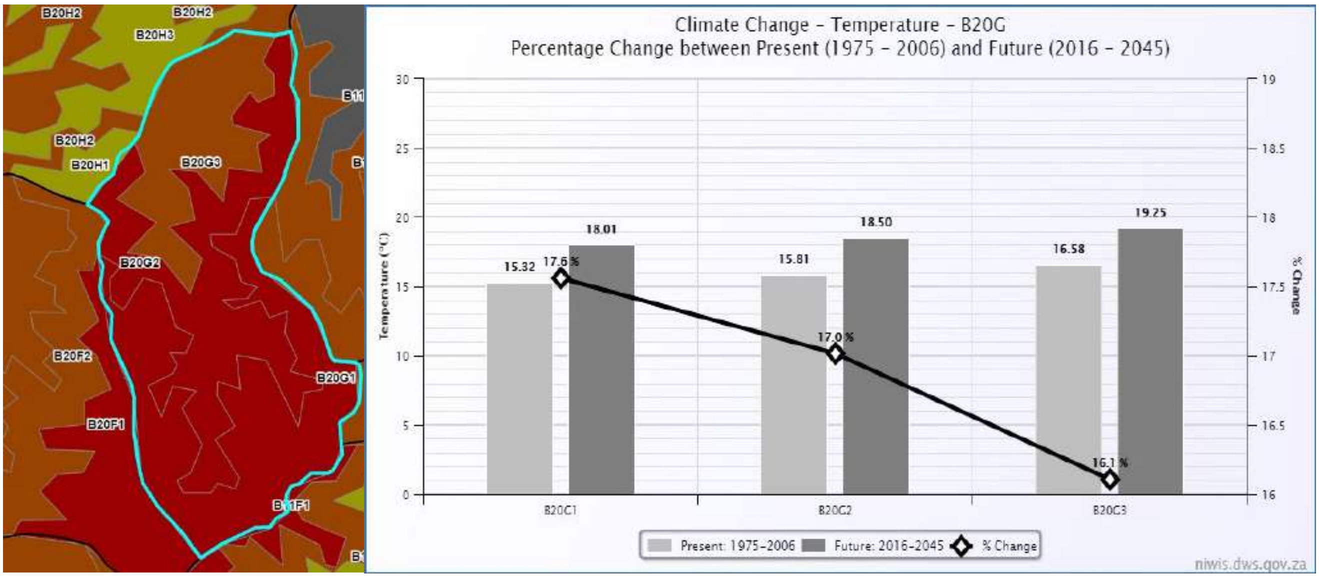


Figure 6: Temperature changes expected

2.2.2 Rainfall

Two sources of rainfall data were used for the water balance model and stormwater manager plan.

- For historic sequences and calibration purposes the precipitation depths measured at the on-site weather station were used. Hourly rainfall data received from the client covers the period from Jan 2016 to Dec 2020.
- For future scenarios (as well as historic periods with missing site data) synthetic rainfall records using a stochastic rainfall simulator were generated. The simulator was calibrated to ensure the rainfall sequences generated are statistically equivalent to the long-term historic record selected. This data was sourced through the Daily Rainfall Data Extraction Utility (Kunz, 2004).

The metadata for two rainfall stations that were analysed are presented in Table 1. The selection of the two stations was based on the stations being the closest to the site with reasonably long and reliable records.

Table 1: Metadata for the rain gauges

Station Name	Station No	Distance (km)	Latitude (deg)	Longitude (deg)	Record (years)	Reliable (%)	MAP (mm)	Altitude (mamsl)
Strehla	0477762 W	9.11	26°14’	29°03’	74	69.4	681	1 573
Cologne	0478009 W	7.39	26°08’	29°01’	74	65.6	673	1 622

The unpatched and patched daily rainfall data for the stations are plotted in Figure 2 and Figure 3. Strehla station has only 8% patched data and Cologne station has 13% patched data. The average monthly rainfall depths are presented in Figure 4.

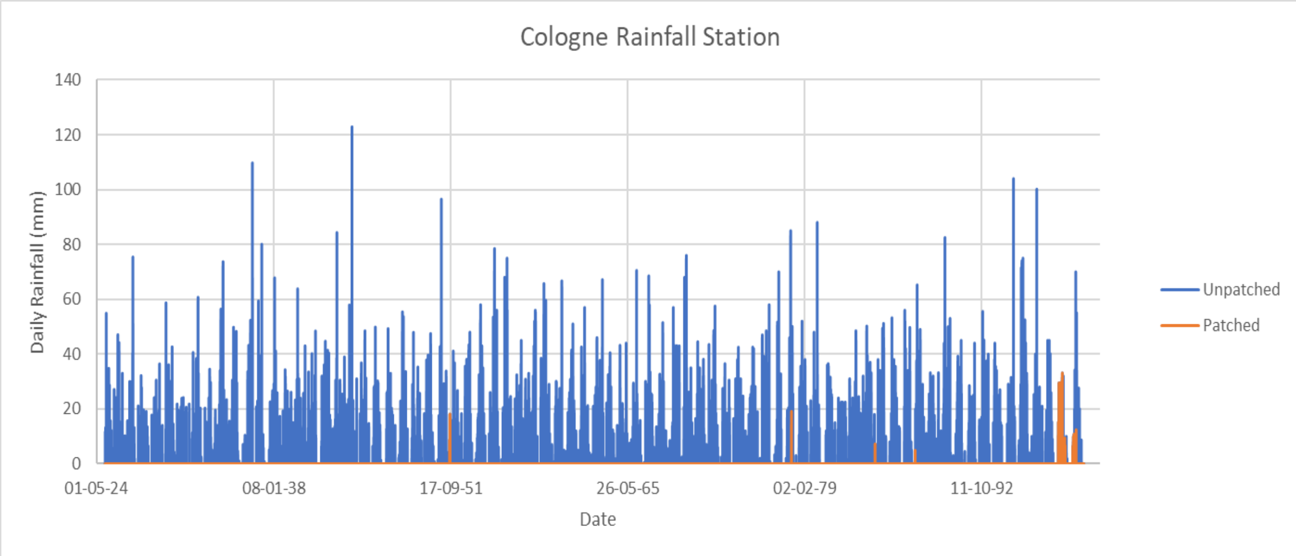
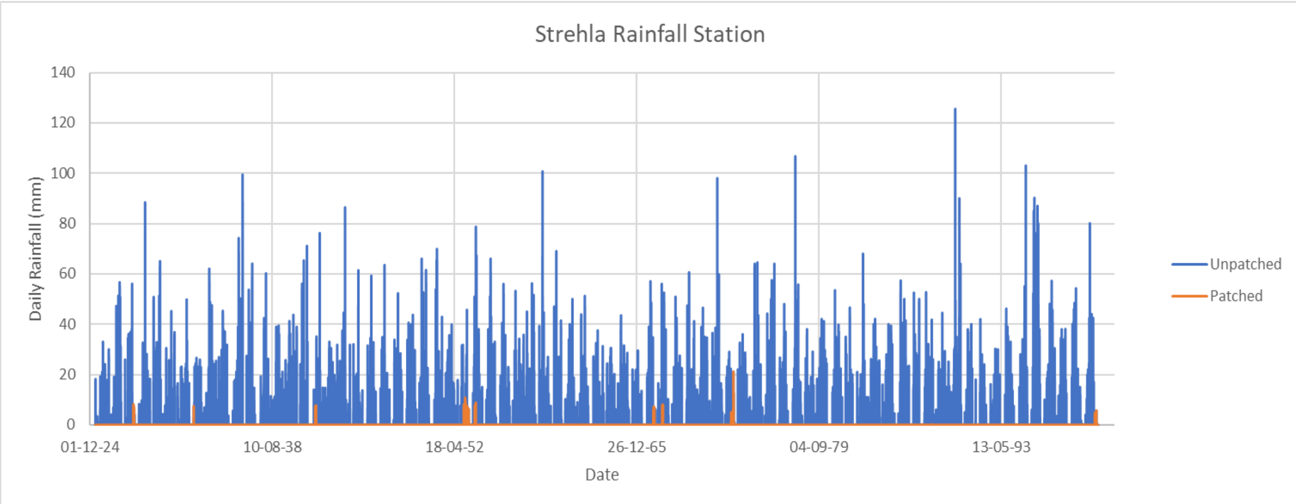
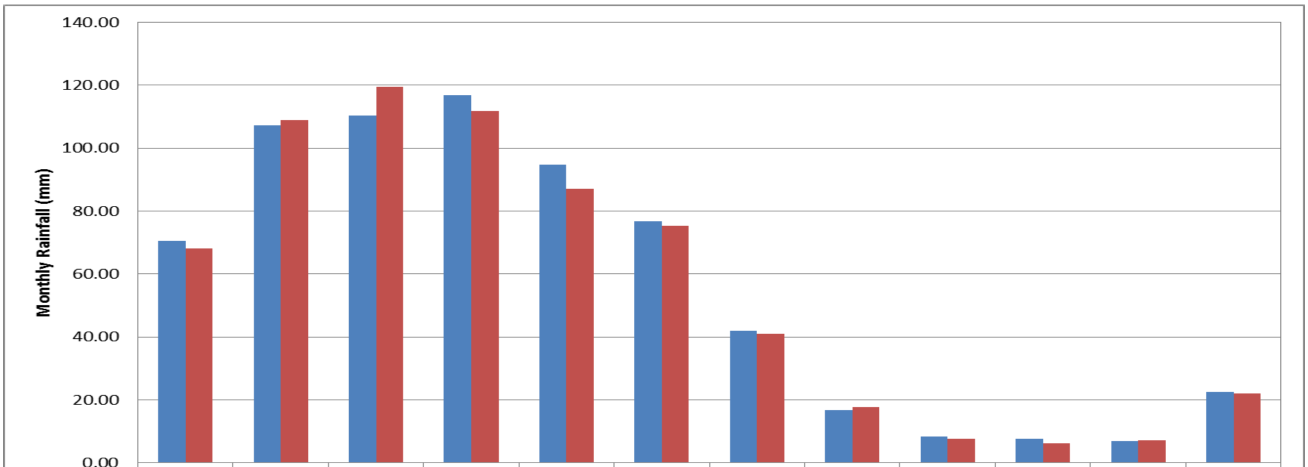


Figure 7: Cologne station daily rainfall





	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Strehla	70.61	107.31	110.45	116.87	94.77	76.76	41.87	16.83	8.37	7.68	6.95	22.56
Cologne	68.23	108.93	119.51	111.89	87.03	75.39	41.10	17.71	7.58	6.28	7.19	21.99

Figure 9: Average monthly rainfall for the stations analysed

Figure 5 shows a plot of the cumulative rainfall over time indicating a slight difference between the two stations for the period between 1985 and 1994. While Strehla station is slightly further from Zibulo Opencast, the percentage patched data is lower and was thus selected for use in the study.

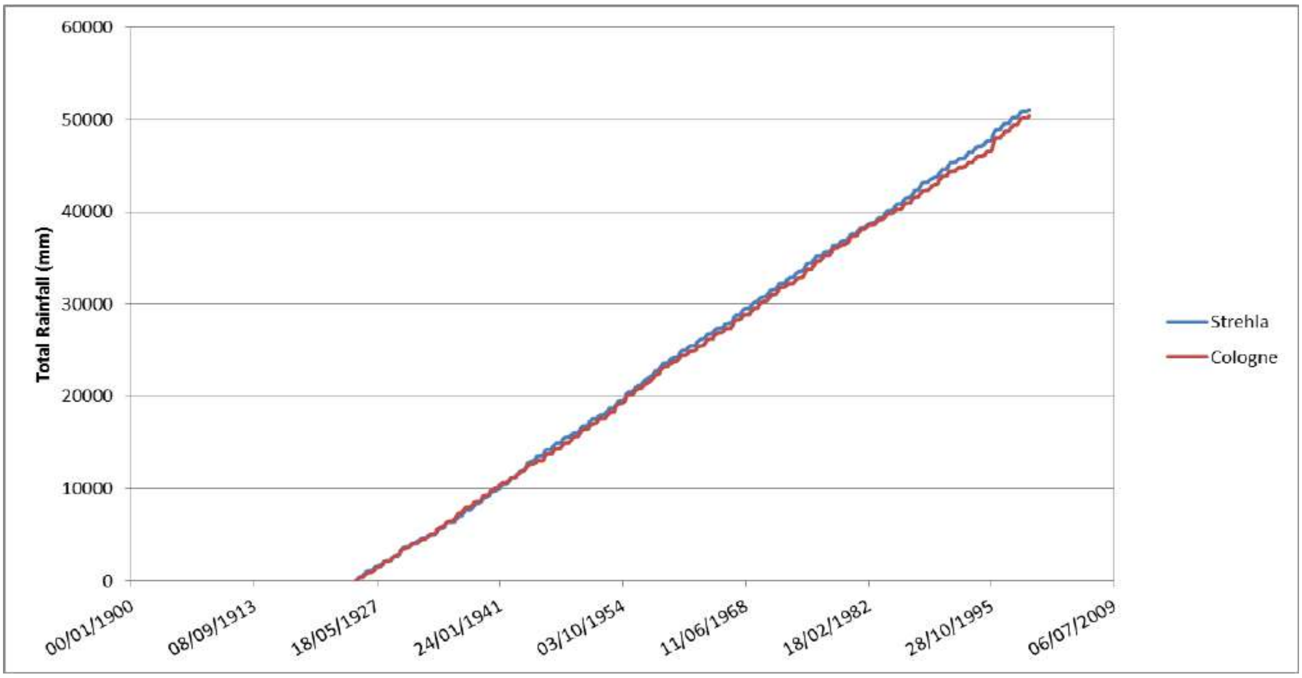


Figure 10: Cumulative Rainfall for the stations

The regional rainfall statistics are therefore based on the Strehla station data. The cumulative distribution function of annual rainfall is presented in Figure 6. The analysis shows that:

- The Mean Annual Precipitation (MAP) is 681 mm/annum (mm/a) with 50% of the years receiving from 487 mm/a to 782 mm/a; and
- The amount of rainfall varies considerably from year to year. The annual rainfall varies from 372 mm/a to 1 050 mm/a. A dry year (defined as the 5th percentile) will receive 450 mm/a and a wet year (defined as the 95th percentile) can receive 950 mm/a.

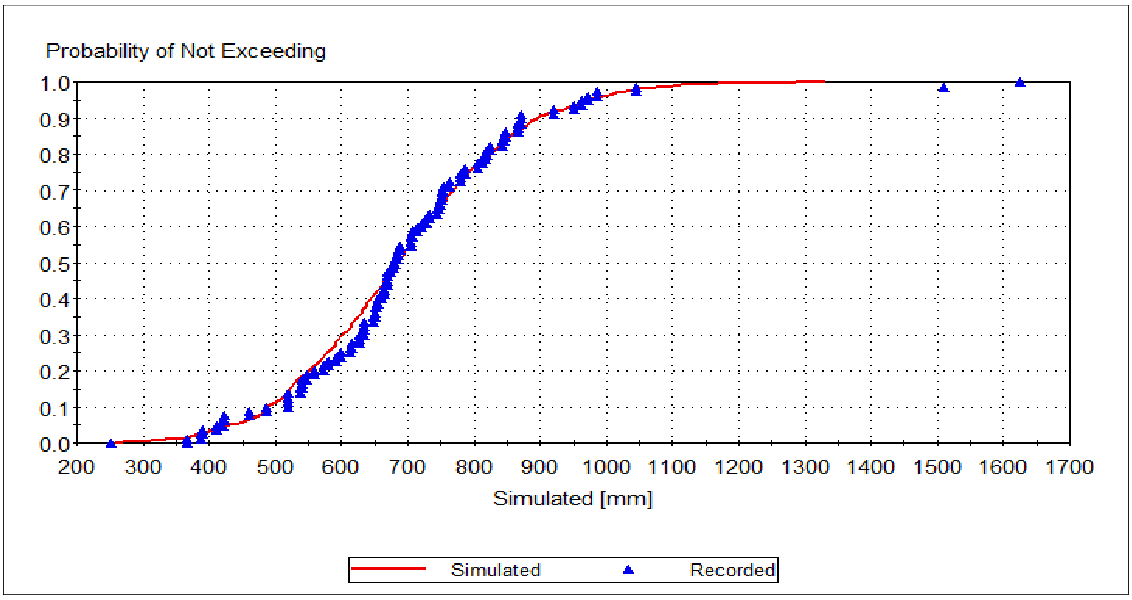


Figure 11: Cumulative distribution function of annual rainfall at the Strehla rain gauge

The boxplot of monthly rainfalls is presented in Figure 7. It provides a visual summary of:

- The centre of the data (the median - the centre line of the box);
- The variation (interquartile range - the box height);
- The skewness (the relative size of box halves); and
- The presence or absence of outliers ("far outside" values represented by the 1st and 99th Percentile).

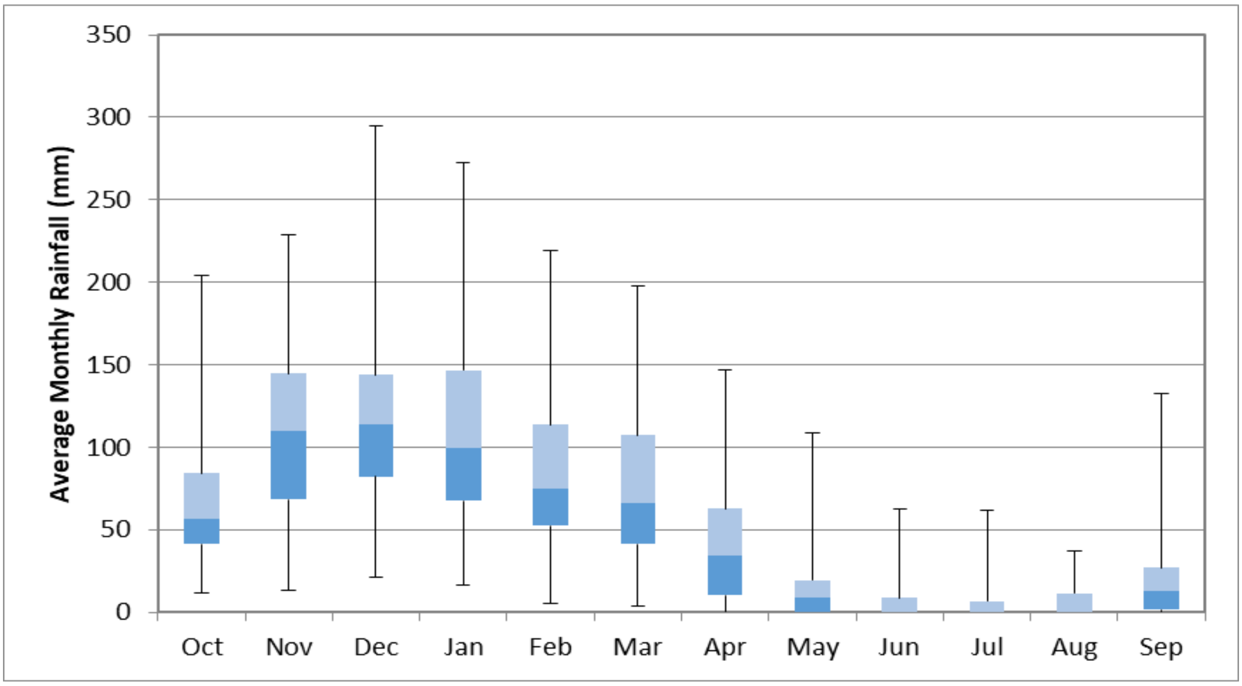


Figure 12: Box plot of monthly rainfall from Strehla Station record (0477762 W) from 1925 to 1999

The analysis of monthly rainfall shows that:

- The dry season occurs between May and September and receives less than 9% of the annual rainfall;
- The wet season occurs between October and April and receives more than 91% of the annual rainfall. On average, 74% of the annual rain falls within a period of 5 months (November to March); and
- The wettest month is January with a median around 113 mm/month. The maximum monthly rainfall recorded is 265 mm/month.

Several probability distributions were fitted to the recorded 24-hour maximum annual storm events. The Log Pearson III distribution (LP3) fitted the data best. Storm depths for the various specified recurrence intervals, based on this fitted distribution, are presented in Table 2.

Table 2: 24-hour storm rainfall for various annual recurrence intervals

Return Period in years	2	5	10	20	50	100	200
LP3 Distribution (mm/d)	54	72	83	95	110	121	133

In respect of climate change, the DWS NIWIS indicates a marginal rainfall change of a 3.2% decrease in B20G1 (Figure 13).

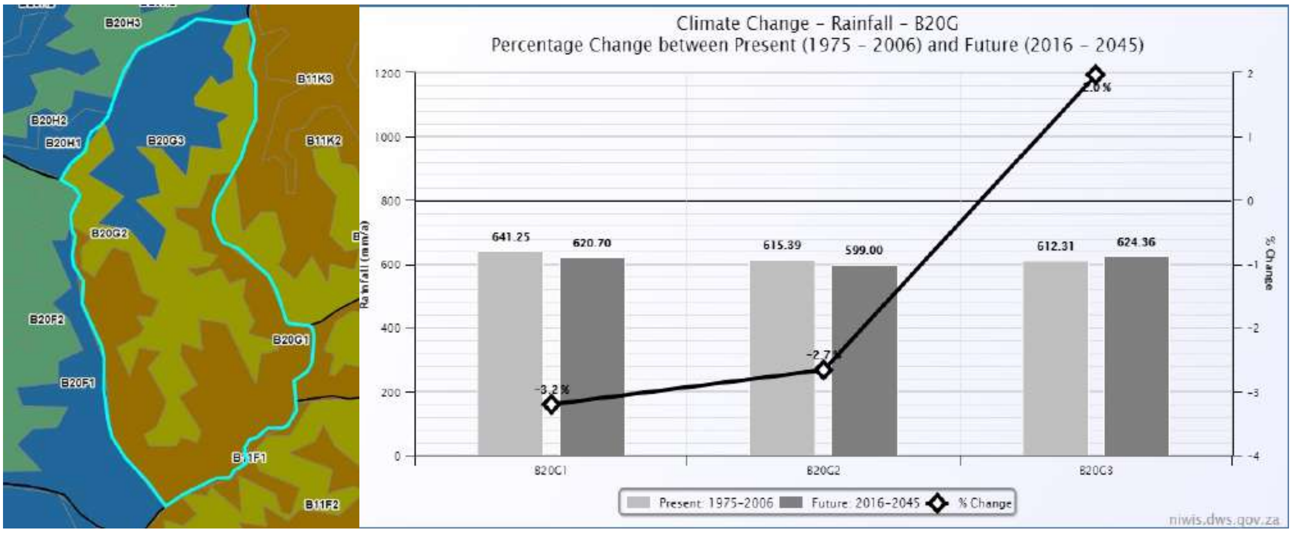


Figure 13: Rainfall changes expected (NIWIS[1])

The DWS NIWIS has indicated that the expected wet spells will increase by 14.5% in the B20G1 area.

2.2.3 Evaporation

The nearest Symons(S)-Pan Evaporation station to Zibulo Opencast is B1E001, approximately 30 km away from the opencast mining operations and has a Mean Annual Evaporation of 1 470 mm/year. The average monthly S-Pan evaporation rates for the station are presented in Table 3 and plotted in Figure 14 together with the average monthly rainfall depths calculated from the daily rainfall data measured at the Strehla rainfall station. Take note that the mean annual evaporation is more than twice the mean annual precipitation. The S- pan potential evaporation data was used to estimate evaporation rates in the water balance model.

Table 3: Average monthly S-pan evaporation

mm/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Evaporation	165	138	130	97	80	65	73	99	137	164	159	164	1 471

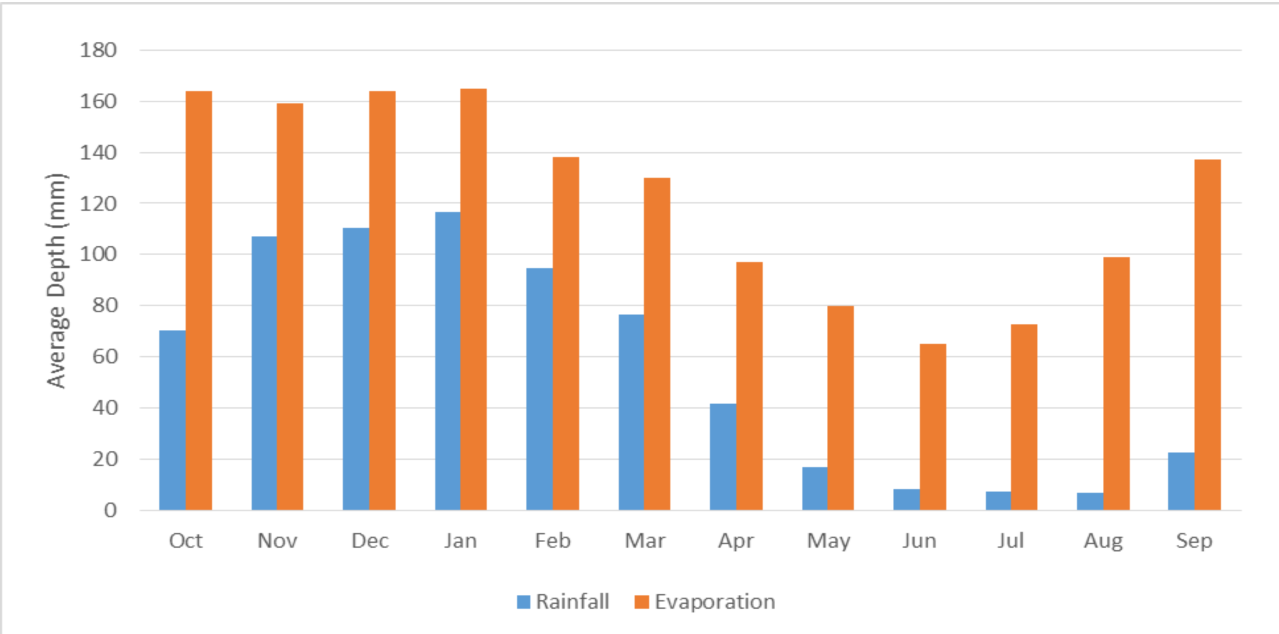


Figure 14: Average monthly evaporation and precipitation

The DWS NIWIS[1] indicate an estimated 12% increase in evaporation (Figure 15).

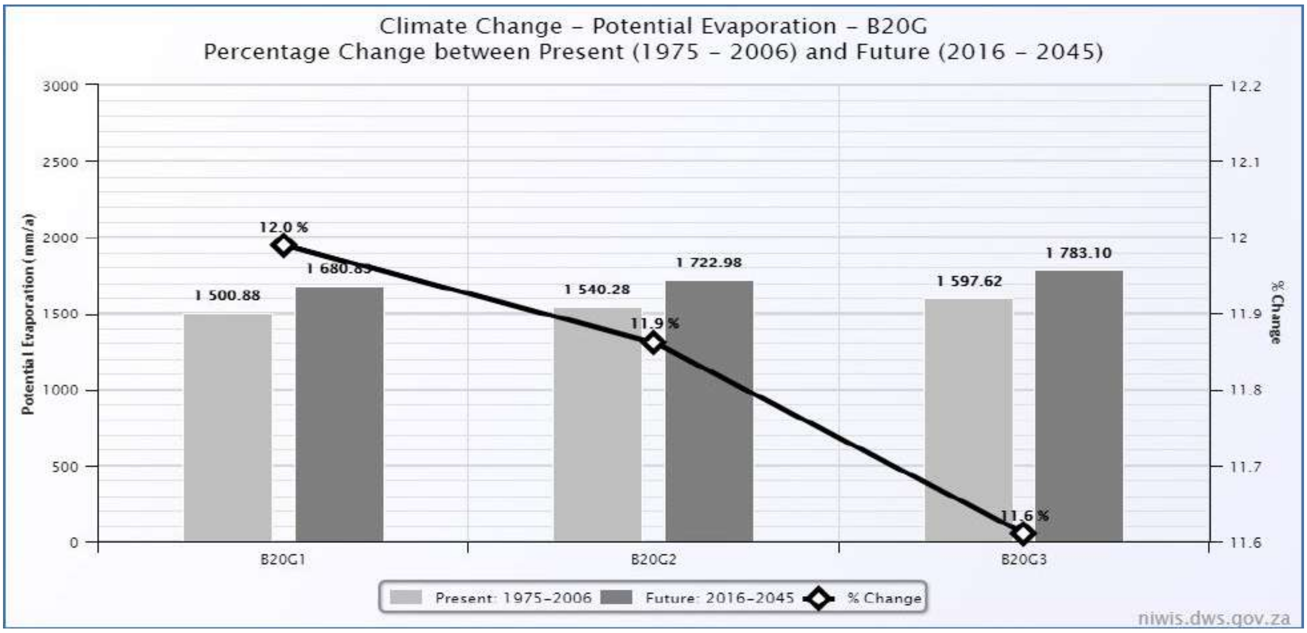


Figure 15: Estimated evaporation rate changes (NIWIS[1])

2.3 Water Users

The Town of Phola is located directly north of Zibulo Opencast, where both formal and informal residential areas are located. While the majority of the areas receive water from the eMalahleni Local Municipality, it is likely that there are informal dwellers who do use water directly from the river and small farm dams downstream of the mine. Further downstream water is used for irrigation.

2.4 Hydrological description

Zibulo Opencast falls in the upper Olifants sub-catchment of the Olifants Water Management Area. The open cast workings fall within quaternary catchment B20G (Figure 16). The area drains to the Saalklapspruit/ Saalboomspruit via an unnamed tributary. This in turn drains into the Wilge River which drains to the Loskop Dam, after which the Olifants River flows through Mpumalanga and the central part of the Kruger National Park to Mozambique.

2.4.1 Catchment Description

The Saalboomspruit (sometimes also referred to as the Saalklapspruit) flows north from the N12, to confluence with the Wilge River approximately 40 km downstream, just outside the Ezemvelo Nature Reserve. The river starts just below the South 32 Klipspruit MRA, north west of Zibulo Opencast (Figure 16).

There are several unnamed tributaries in and around the project site (Figure 7):

- Two tributaries flowing north from the Ogies railway siding to i) the western boundary of Zibulo colliery where it is then diverted around the pit, and ii) along the eastern side of Zibulo Opencast and then through the township of Phola, and another downstream of the township of Phola to confluence with the Saalboomspruit just upstream of the Phola Wastewater Treatment Works.
- An unnamed tributary flowing north from Klipspruit Colliery to join the Saalboomspruit upstream of the R545 Road that passes the township of Phola.

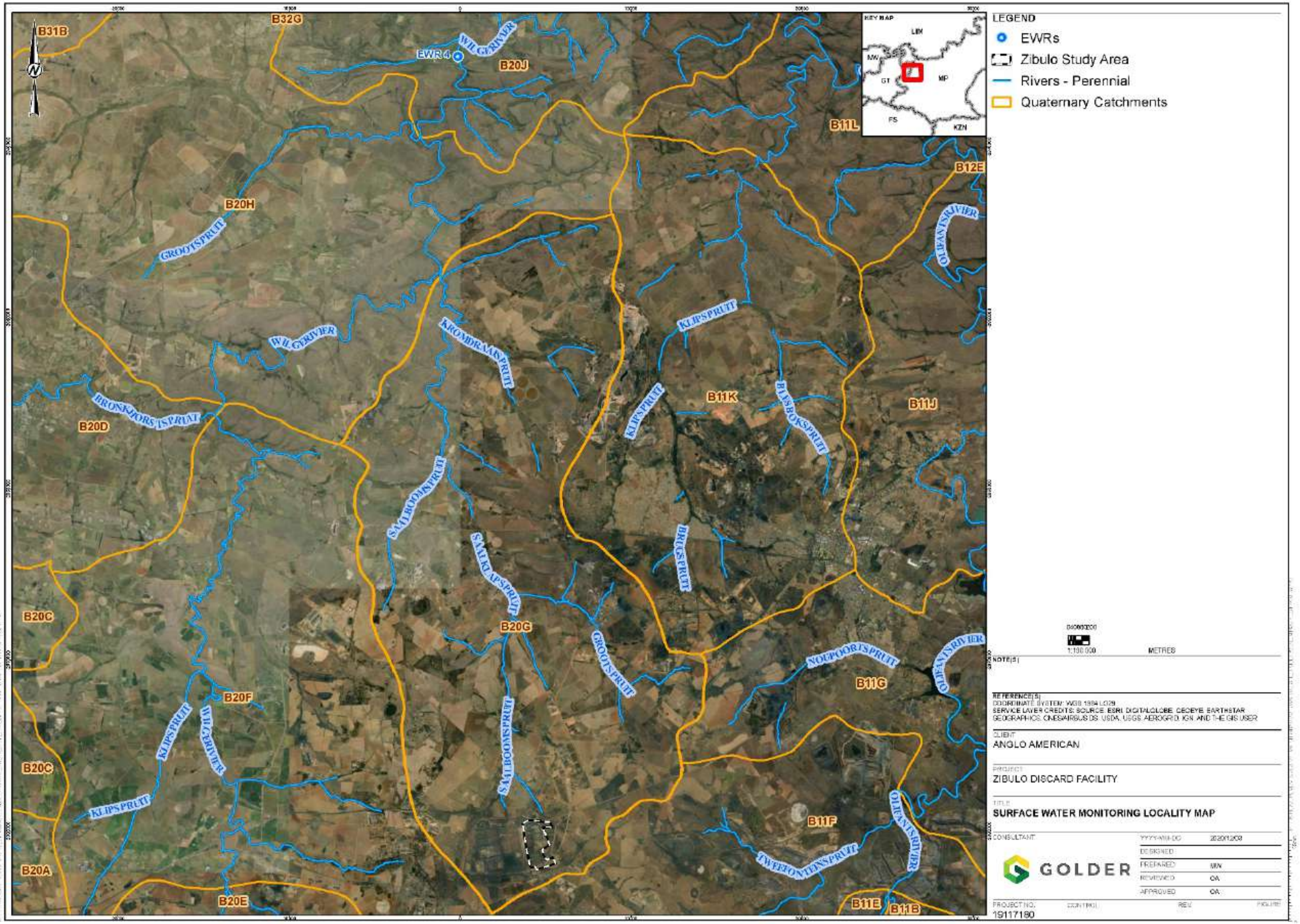


Figure 16: Zibulo Opencast area in relation to the quaternary catchments and Saalboomspruit

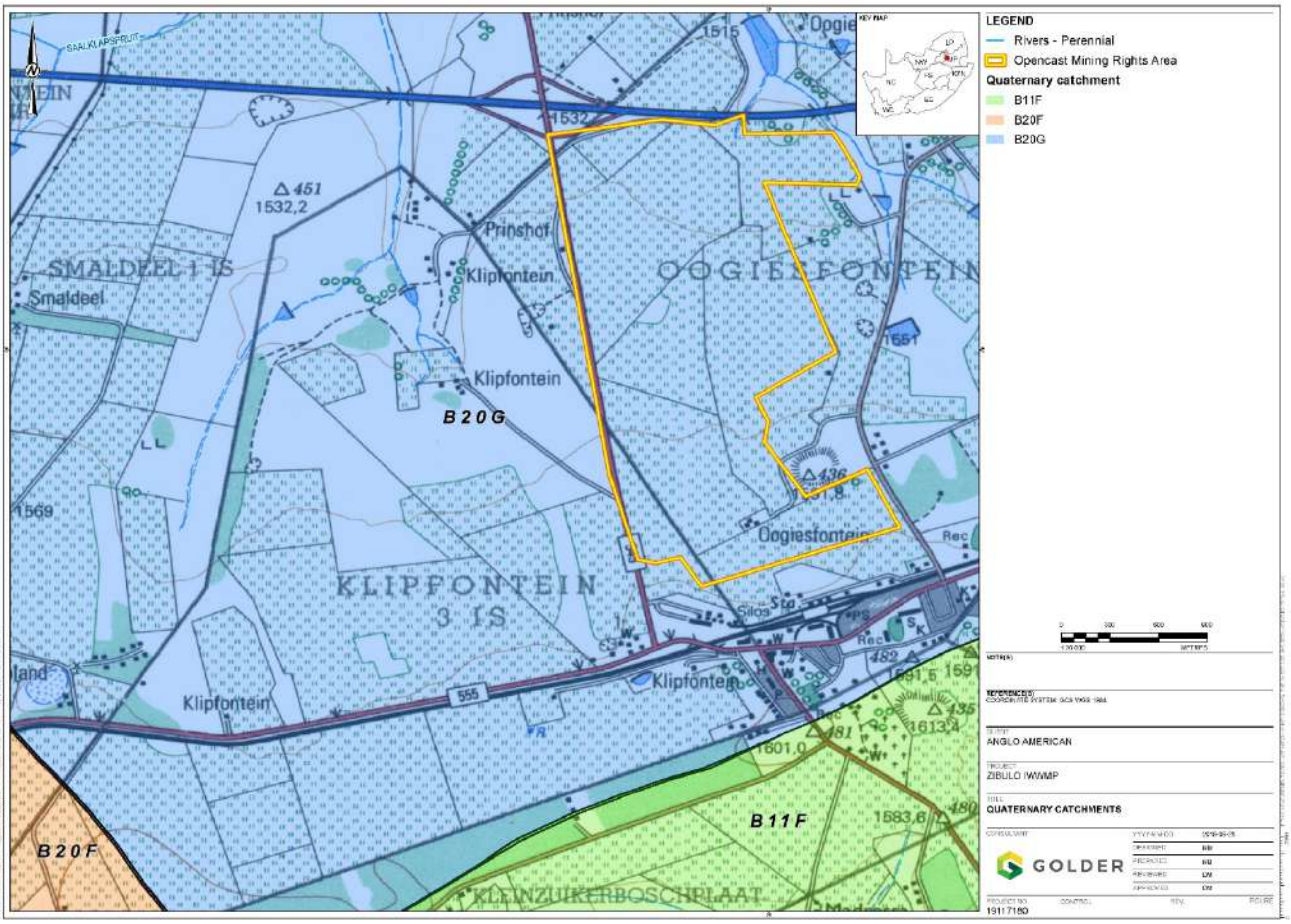


Figure 17: Quaternary Drainage Regions around Zibulo

2.4.2 Water Resource Protection

Classification of the water resources has been undertaken and Resource Quality Objectives (RQO) have been set for the Olifants WMA (Government Notice No 466, 22 April 2016, Government Gazette No 39943).

Water resources classification took place with the following principles at the forefront of implementation:

1) Maximising economic returns from the use of water resources.

2) Allocating and distributing the costs and benefits of utilising the water resource fairly; and

3) Promoting the sustainable use of water resources to meet social and economic goals without detrimentally impacting on the ecological integrity of the water resource.

The Saalboomspruit falls into the Wilge River Area which has been classified as a Class II. This means that the rivers in the area are moderately used and are rivers in which the water resources condition have been moderately modified from its pre-development condition. While the Saalboomspruit at the confluence of the Wilge River has been categorised as a C ecological category, and it is unlikely that the river in the upper reaches of the quaternary catchment is in the same state, it is important that improvements to the river system and sustainable protection is implemented to maintain the C category, contribute to the category B Recommended Ecological Category (REC) at the Ecological Water Requirements site (EWR 4) in the Wilge River, about 17km downstream of the Wilge/ Saalboomspruit confluence.

The site at which Resource Quality Objectives (RQO) have been set is on the Wilge River (EWR4) (illustrated in Figure 16). The RQOs relevant to B20G, are:

- Quantity: Low flows should be improved in order to maintain the river habitat for the ecosystem and ecotourism.
- Quality: The RQO water quality numerical limits set at EWR 4 are set out in Table 4.

Table 4: RQO Numerical Limits for Site EWR 4

Variable	Numerical Limit
Sulphate	≤ 200 mg/L
Fluoride	≤ 2.5 mg/L
Aluminium	≤ 0.105 mg/L
Arsenic	≤ 0.095 mg/L
Cadmium (hard)	≤ 0.003 mg/L
Hexavalent chromium	≤ 0.121 mg/L
Copper (hard)	≤ 0.006 mg/L
Mercury	≤ 0.00097 mg/L
Manganese	≤ 0.99 mg/L
Lead (hard)	≤ 0.0095 mg/L
Selenium	≤ 0.022 mg/L
Zinc	≤ 0.0252 mg/L
Chlorine (free chlorine)	≤ 0.0031 mg/L
Endosulfan	≤ 0.00013 mg/L
Atrazine	≤ 0.0785 mg/L

- Instream habitat and biota:
  - Instream habitat must be in a moderately modified or better condition to sustain instream biota.
  - Instream biota must be in a moderately modified or better condition and at sustainable levels.
  - Low and high flows must be suitable to maintain the river habitat and ecosystem condition.
  - Water quality:
    - Overall salt and sulphate concentrations must be at a level where it does not threaten the ecosystem or agricultural users, and
    - Toxics must not negatively impact on the ecosystem or agricultural users.
- River Riparian Zone habitat:
  - The riparian zone must be in a largely natural or better condition.
  - Riparian vegetation must be in a moderately modified condition
  - Low flows must be in a moderately modified or better condition. High flows must be suitable to sustain the riparian zone habitat.

2.4.3 Water Quality Planning Limits

The Olifants Water Management Area has been divided into Management Units that can comprise a quaternary catchment or several quaternary catchments, or even a portion of a quaternary catchment. This was done in order to manage the sub-catchments more easily and support the implementation of the Resource Directed Measures described above. Water Quality Planning Limits (WQPL) have been set for each management unit within the Upper Olifants sub-catchment (DWS, 2016). Zibulo Colliery falls within Management Unit 20 and the WQPLs are described in Table 5.

2.4.4 Integrated Water Use Licence

Zibulo Opencast has an Integrated Water Use Licence No: 04/B20G/AGJ/809. The IWUL includes water resource limits for rivers and groundwater. These are included in Table 5.

Table 5: Water Quality Planning Limits for the Saalboomspruit in MU20 and IWUL Limits

Variable	Units	IWUL limits	WQPL for Saalboomspruit
pH		6.5 to 8.4	6.5 to 8.4
Electrical Conductivity	mS/m	-	75
Total Dissolved Solids	mg/L	280	500
Calcium	mg/L	25	80
Magnesium	mg/L	20	50
Sodium	mg/L	20	70
Potassium	mg/L	-	25
Alkalinity	mg/L	-	120
Chloride	mg/L	20	45
Sulphate	mg/L	60	400
Nitrate	mg/L	6	0.5
Nitrite	mg/L	-	-
Fluoride	mg/L	-	0.75
Aluminium	mg/L	-	0.02
Iron	mg/L	-	0.1
Manganese	mg/L	-	0.02
Ammonium	mg/L	-	0.05
Acidity	mg/L	-	-
Total Hardness	mg/L	-	-
Orthophosphate as P	mg/L	-	0.025

2.5 Surface Water Quality

2.5.1 Surface water monitoring sites

The Zibulo Opencast surface water monitoring sites are described in Table 6 and illustrated in Figure 21. These sites are located to assess the water chemistry in all the streams around Zibulo Opencast, up and downstream of the sites.

Table 6: Surface water monitoring sites around Zibulo Opencast

Site ID	Latitude	Longitude	Description
ZC1	-25.96756	29.02706	Most downstream point in Saalboomspruit downstream of Phola
ZC2	-26.005407	29.02587	Saalboomspruit on the R545 crossing near Phola
ZC3	-26.02106	29.02753	Small tributary downstream of Klipspruit Opencast on N12
ZC4	-26.04488	29.04836	Canal from Ogies to Zibulo Opencast (Upstream Locality)
ZC5	-26.0276717	29.05469167	Tributary east of Zibulo Opencast
ZC6	-26.0258767	29.05585	Tributary east of Zibulo Opencast at road crossing
ZC7	-26.02272	29.051617	Combined ZC5 and ZC6 tributaries downstream of Zibulo Opencast
ZC8	-26.022928	29.046566	Tributary draining north, downstream of Zibulo Opencast, to the unnamed tributary that flows through Phila to the Saalboomspruit

2.5.2 Surface water quality assessment

Statistics for the period July 2010 to August 2019 (large gaps for the years 2012 to 2016) are included in Table 7 and Table 8. Figure 18 illustrates the 95 percentile data at the points in and around Zibulo Opencast comparing against the IWUL limits set, as well as against the WQPLs.

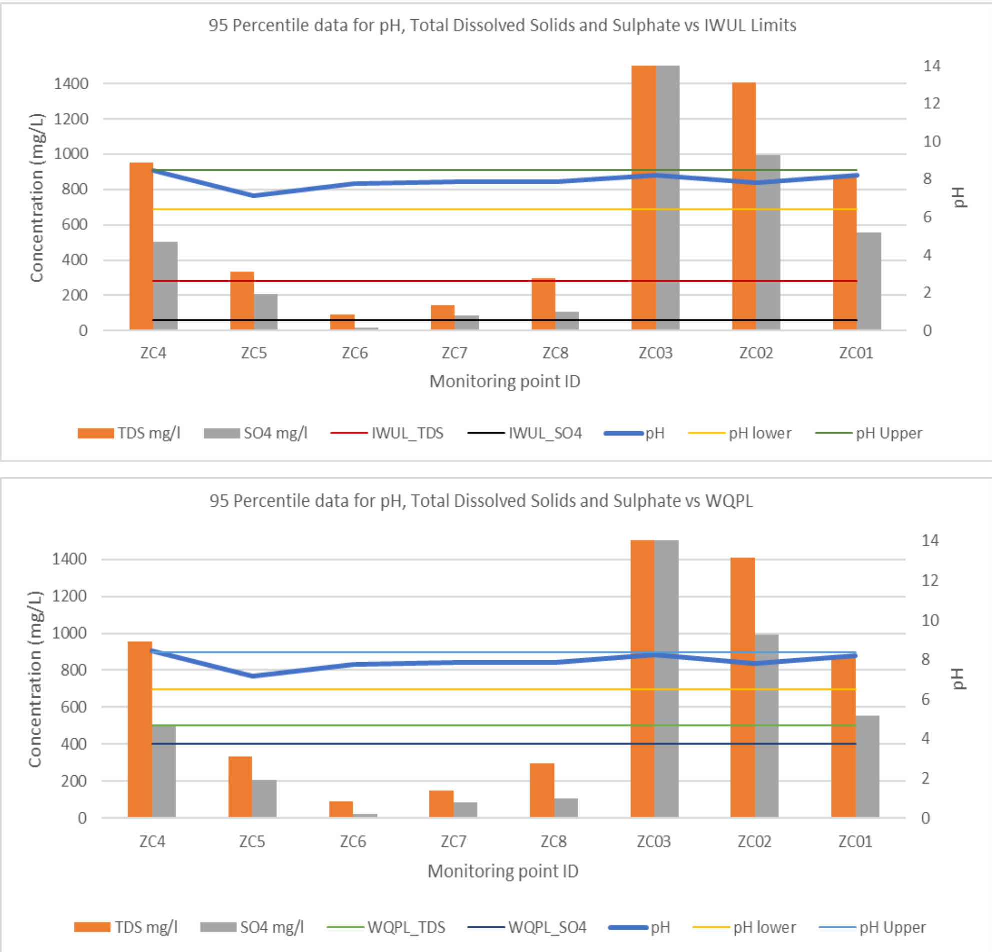


Figure 18: 95 Percentile data for TDS, pH and sulphate concentrations

The following are noted:

- The unnamed tributaries east of Zibulo Opencast are the least contaminated.
- pH ranged from 5.72 to 6.33 for the lower limit (5 percentile data), and 7.15 to 8.44 for the upper limit (95 percentile data), so in most cases within or close to the IWUL limit and WQPL of 6.5 to 8.4.
- The canal from Ogies to Zibulo Opencast, the upstream site, shows average TDS of 774 mg/L (ranging from 249 to 1 288 mg/L) (Figure 19) and an average sulphate concentration of 345 mg/L (ranging from 42.3 to 673 mg/L). The trends illustrate the impact that the small stream draining from Klipspruit has on the downstream point ZC02 at Phola, and that the river improves by the time it reaches the point downstream of Phola, ZC01.

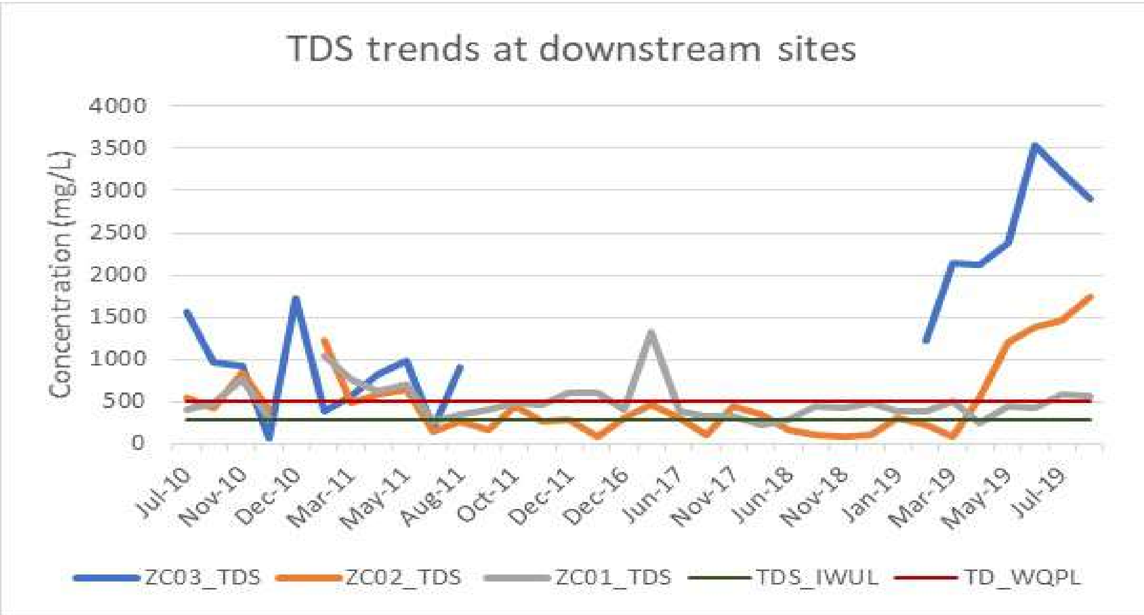


Figure 19: Trends for TDS at the downstream sites ZC03, ZC02 and ZC01

- Monitoring point ZC3 located on the unnamed tributary draining from Klipspruit Opencast near the N12, shows the highest level of contamination with an average TDS concentration of 1 092 mg/L (ranging from 60 to 3 532 mg/L) and an average sulphate concentration of 627 mg/L (ranging from 19.1 to 2 440 mg/L).
- Downstream monitoring points ZC2, on the Saalboomspruit on the R545 crossing near Phola, and most downstream point ZC1, on the Saalboomspruit downstream of Phola show slight improvements with average TDS concentrations of 331 mg/L (ranging from 75 to 1742 mg/L) and 433 mg/L (ranging from 224 to 1328 mg/L) respectively; and average sulphate concentrations of 143 mg/L (ranging from 9.14 to 1 224 mg/L) and 126 mg/L (ranging from 68 to 934 mg/L) respectively.
- The highest concentrations of metals were aluminium, 2.15 mg/L, iron, 2.03 mg/L and manganese, 5.37 mg/L at the downstream sites. Figure 20 illustrates the trends for manganese at the three downstream sites showing that site ZC03 draining from Klipspruit is highly impacted and impacts the lower site ZC02. The recovery of the river by ZC01 is important.
- 95 percentile data for calcium, chloride, sodium and potassium are exceeded at all monitoring points.

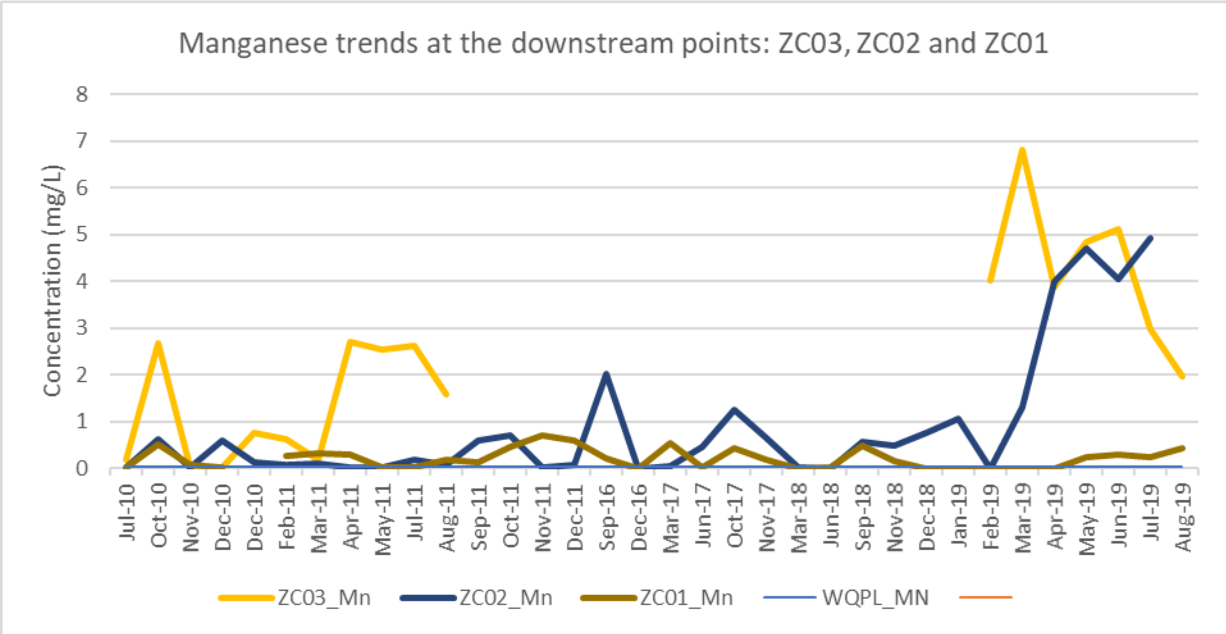


Figure 20: Manganese trends at the downstream points ZC03, ZC03 and ZC01

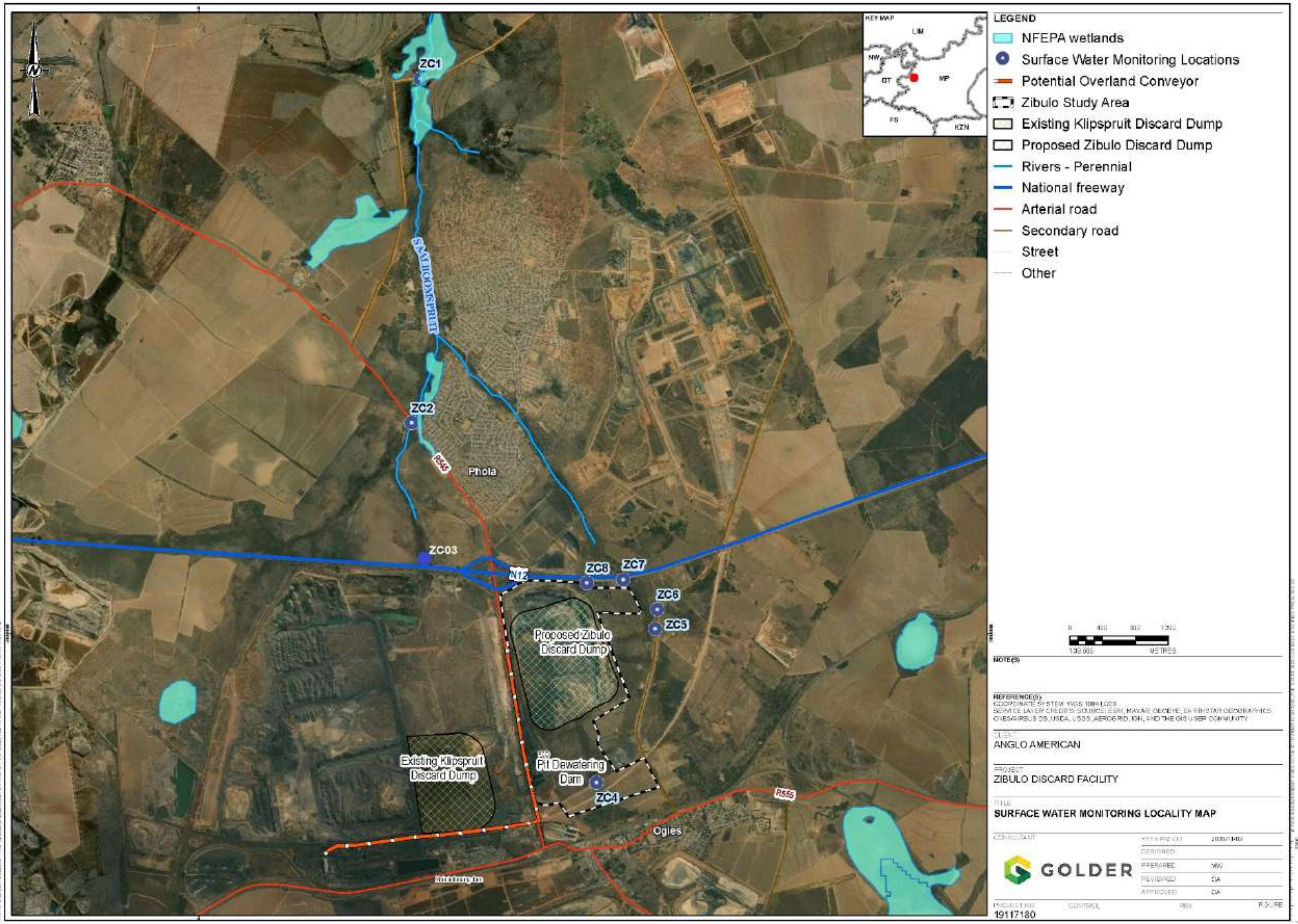


Figure 21: Surface water monitoring sites

Table 7: Water Quality Statistics for ZC4, ZC5, ZC6 and ZC7

Variable	Unit	IWUL Limit	WQPL	ZC4			ZC5			ZC6			ZC7		
				95%	50%	5%	95%	50%	5%	95%	50%	5%	95%	50%	5%
pH		6.5 - 8.4	6.5 - 8.4	8.44	7.07	6.33	7.15	6.24	5.96	7.76	7.26	5.99			
Electrical Conductivity	mS/m	-	75	127.75	103.50	68.80	54.91	17.15	10.95	12.80	7.38	5.94	7.86	6.84	5.99
Total Dissolved Solids	mg/L	280	500	953.75	776.00	512.50	333.15	130.50	60.85	89.60	48.00	17.10	23.19	9.91	7.59
Calcium	mg/L	25	80	86.80	70.70	45.53	37.41	8.08	4.91	7.19	3.66	2.06	145.40	59.00	32.30
Magnesium	mg/L	20	50	75.78	61.05	24.20	23.02	4.41	2.43	3.56	2.25	1.54	17.57	4.95	3.57
Sodium	mg/L	20	70	90.93	63.15	25.08	35.32	19.15	8.55	11.12	6.77	1.97	8.03	2.93	2.22
Potassium	mg/L	-	25	18.60	5.78	4.21	4.54	1.46	0.72	4.40	1.58	0.60	14.98	8.67	3.51
Alkalinity	mg/L	-	120	373.50	118.50	58.53	64.53	15.10	1.14	33.79	12.90	3.41	2.93	1.29	0.63
Chloride	mg/L	20	45	80.68	58.35	26.05	33.09	14.25	8.10	12.70	6.42	1.56	42.38	21.90	5.53
Sulphate	mg/L	60	400	502.50	344.50	85.20	207.05	39.30	6.25	19.06	5.90	0.45	13.32	8.28	2.82
Nitrate	mg/L	6	0.5	7.11	1.07	0.33	0.87	0.38	0.24	2.28	1.25	0.54	4.80	2.49	0.75
Nitrite	mg/L	-		7.64	0.13	0.01	2.78	0.12	0.01	10.76	0.16	0.03	48.80	13.00	10.00
Fluoride	mg/L	-	0.75	0.60	0.47	0.22	0.46	0.36	0.20	0.47	0.47	0.15	1.49	0.60	0.32
Aluminium	mg/L	-	0.02	0.08	0.01	0.01	2.15	0.01	0.00	0.33	0.03	0.01	0.67	0.47	0.18
Iron	mg/L	-	0.1	0.91	0.01	0.01	2.03	0.46	0.04	0.57	0.16	0.01	0.26	0.01	0.01
Manganese	mg/L	-	0.02	0.77	0.09	0.01	3.42	0.32	0.01	0.09	0.01	0.00	0.93	0.14	0.01
Ammonium	mg/L	-	0.05	23.23	0.39	0.01	0.68	0.10	0.01	0.42	0.06	0.01	0.83	0.11	0.00
Acidity	mg/L	-		92.98	39.20	6.00	70.90	25.90	4.27	24.23	14.00	4.12	0.48	0.09	0.01
Total Hardness	mg/L	-		512.40	307.00	183.20	203.30	179.00	40.40	31.95	19.50	11.35	34.10	15.70	5.60
Calcium Hardness	mg/L	-		211.30	141.50	95.25	14.00	14.00	14.00	18.10	11.00	7.60	86.45	26.50	20.00

Variable	Unit	IWUL Limit	WQPL	ZC4			ZC5			ZC6			ZC7		
				95%	50%	5%	95%	50%	5%	95%	50%	5%	95%	50%	5%
Magnesium Hardness	mg/L	-		311.60	160.50	89.65	11.00	11.00	11.00	15.00	11.00	6.30	64.10	13.00	10.70
Orthophosphate as P	mg/L	-	0.025	2.89	0.25	0.02	0.55	0.29	0.02	0.47	0.03	0.01	7.98	0.17	0.03

red highlights values >IWUL limits/ WQPLs where IWUL limit not available.

Table 8: Water Quality Statistics for ZC8, ZC03, ZC02 and ZC01

Variable	Unit	IWUL Limit	WQPL	ZC8			ZC03			ZC02			ZC01		
				95%	50%	5%	95%	50%	5%	95%	50%	5%	95%	50%	5%
pH		6.5 - 8.4	6.5 - 8.4	7.87	6.31	5.81	8.24	7.09	5.72	7.81	7.03	6.21	8.21	7.40	6.59
Electrical Conductivity	mS/m	-	75	33.77	12.10	10.58	335.35	130.00	37.63	181.20	51.10	15.10	103.12	66.70	38.12
Total Dissolved Solids	mg/L	280	500	295.20	96.00	64.10	3273.60	1092.00	168.45	1408.20	331.00	83.60	866.60	433.00	256.60
Calcium	mg/L	25	80	28.67	4.96	3.32	456.50	152.50	41.72	184.80	37.90	10.88	119.80	37.20	22.80
Magnesium	mg/L	20	50	15.65	3.37	2.57	311.85	100.90	16.34	128.00	22.40	5.85	65.44	22.90	12.06
Sodium	mg/L	20	70	25.02	12.00	9.09	59.75	30.65	7.05	50.24	22.10	6.81	85.86	46.60	24.62
Potassium	mg/L	-	25	6.04	1.63	1.06	17.64	6.51	1.90	11.30	5.92	3.17	13.38	8.86	5.17
Alkalinity	mg/L	-	120	62.83	15.95	3.16	338.20	75.95	26.04	220.60	44.70	13.02	251.00	129.00	55.92
Chloride	mg/L	20	45	38.33	17.35	7.50	31.86	7.60	2.13	31.94	15.30	4.93	53.66	35.80	14.02
Sulphate	mg/L	60	400	106.75	16.10	9.21	2323.55	627.00	138.02	994.00	143.00	15.14	555.20	126.00	71.84
Nitrate	mg/L	6	0.5	0.89	0.60	0.34	1.79	0.53	0.46	1.16	0.67	0.46	4.47	0.65	0.46
Nitrite	mg/L	-		4.94	1.23	0.11	5.86	0.14	0.01	14.38	0.11	0.03	9.88	0.34	0.01
Fluoride	mg/L	-	0.75	0.72	0.47	0.18	0.54	0.47	0.47	0.48	0.47	0.47	0.47	0.47	0.47
Aluminium	mg/L	-	0.02	0.61	0.08	0.01	0.12	0.01	0.01	0.19	0.01	0.01	0.10	0.01	0.01
Iron	mg/L	-	0.1	0.62	0.19	0.01	0.63	0.06	0.01	0.86	0.01	0.01	0.80	0.01	0.01

Variable	Unit	IWUL Limit	WQPL	ZC8			ZC03			ZC02			ZC01		
				95%	50%	5%	95%	50%	5%	95%	50%	5%	95%	50%	5%
Manganese	mg/L	-	0.02	1.38	0.16	0.01	5.37	2.57	0.02	4.32	0.46	0.00	0.57	0.17	0.00
Ammonium	mg/L	-	0.05	0.58	0.12	0.01	1.30	0.42	0.01	14.86	0.35	0.04	18.21	6.60	0.08
Acidity	mg/L	-		30.07	13.15	5.07	80.20	37.50	6.41	79.33	24.80	8.28	61.23	21.50	9.14
Total Hardness	mg/L	-		88.80	40.00	17.20	2560.10	1777.00	1044.40	1114.40	184.00	48.90	369.60	181.00	114.30
Calcium Hardness	mg/L	-		18.70	16.00	13.30	1235.10	802.00	495.30	510.40	95.00	25.10	189.40	89.00	63.30
Magnesium Hardness	mg/L			24.40	19.00	13.60	1327.90	975.00	548.40	604.00	92.00	22.90	192.80	94.00	51.90
Orthophosphate as P	mg/L		0.025	0.64	0.24	0.01	0.62	0.25	0.01	1.05	0.04	0.01	2.72	0.96	0.18

red highlights values >IWUL limits/ WQPLs where IWUL limit not available.

2.6 Regional Geology

The Witbank Coalfield comprises six coal seams (numbered 1 through to 6 from the base upwards) contained in a 70 m thick succession comprised predominantly of sandstone with subordinate siltstone, mudstone, and shale (Vryheid Formation).

The distribution of the No. 1 and No. 2 Seams is largely determined by the pre-Karoo topography and the subcrops of all seams are controlled by the present-day erosion surface. Generally, the No. 1, 2, 4 and 5 Seams are considered economic based on seam thickness and quality. Intrusive dolerite dykes and sills are ubiquitous and devolatilization of the coal seams can be significant. The basement and Dwyka Group are unconformably overlain by coal bearing Vryheid Formation of the Ecca Group comprising the six recognised coal seams separated by sedimentary packages consisting mainly of sandstone and thinly laminated siltstone with subordinate mudstone and shale.

2.6.1 Geology in the area of Zibulo Opencast

The Zibulo Colliery is located close to the north western margin of the Witbank Coalfield basin. The coal seams are contained within the Vryheid Formation of the Karoo Sequence. Due to the presence of palaeo-highs as well as present day erosion, not all the coal seams are always developed across the resource area.

The stratigraphy of the Zibulo resource area is typical of the Witbank Coalfield. Five main coal seams are present: which are numbered in ascending, stratigraphical order (No. 1 Seam to No. 5 Seam). The Zibulo resources are contained in the No. 2, No. 4 and No. 5 Seams. Sediments of shale, siltstone and sandstone overlie and separate the various coal seams. Underlying the lowermost coal seam is a the coarse grained diamictite of Pre-Karoo rocks. The overburden thickness and development of the coal seams is dependent on the present day surface topography and the pre-Karoo basement floor.

The average depth of weathering is approximately 8.7m in the Zibulo resource area. Shallow weathering can often be attributed to the outcropping of the dolerite sills.

Within the Zibulo Colliery opencast area the S4T is mostly weathered away, except in the southern portion of the resource area where its thickness increases from 2m to 4m. S4S seam is between 0.5m to 3m thick and weathered away to the north and north-east of the resource area. The S2T only occurs in the south-eastern portion of the opencast area. There is no distinct parting that separates the S2T and S2S sub-seams. The S2 is therefore mined as a package comprising the S2T and S2S.

2.7 Hydrogeological description

Three different aquifer types occur in the resource area shallow perched aquifers, shallow weathered zone Karoo aquifers, and deep fractured Karoo aquifers.

The shallow perched aquifers are essentially restricted to the soil horizon (soft overburden). The host rock types for the other two aquifer types are clastic sedimentary rock and the coal seams. A large range in grain size is evident for the argillaceous to arenaceous sediments, which will ultimately influence the hydraulic characteristics of the host rock. The coal seams are considered to be uniform in their hydraulic characteristics with the exception of their contact zones. The perched aquifer usually displays unconfined conditions; the shallow weathered zone aquifer displays unconfined to semi-unconfined conditions, while the deep aquifer predominantly displays confined conditions. Ground water flow in all three aquifer types is essentially horizontal. However, interconnection between the aquifer types can introduce vertical flow components.

Small dolerite intrusions and large sills are widely developed and may cause localised compartmentalisation. The presence of the dykes and sills may also influence the yielding capacity in some areas. The presence of the graben structure in the northern part of the reserve will allow enhanced water flow due to the discrete faults associated with the structure.

2.7.1 Groundwater levels

The latest borehole levels monitoring undertaken indicates that groundwater levels range from 3.5 mbgl (metres below ground level) to 24.2 mbgl based on the data collated from Zibulo monitoring data (Table 9). DeltaH (2020) also reports water levels collated from the Strategic Fuel Fund (SFF) responsible for water level monitoring for the Ogies ‘old’ underground workings (Table 10). Groundwater levels range from 2.8 mbgl to 8.39 mbgl within the shallow aquifer. Deeper groundwater levels of up to 68.9 mbgl are measured in the deeper piezometers representing the deeper fractured rock aquifer and the influence of the ‘old’ underground mine workings. As part of the Zibulo Southern Box-cut project additional monitoring and aquifer characteristics boreholes were drilled (Table 11). Three boreholes were drilled to assess the potential for upfront dewatering of the proposed southern box-cut. A further three boreholes were drilled along the perimeter of the Zibulo pit and the Ogies SFF underground bunker/ mine workings. Zibulo borehole locations are illustrated in Figure 22.

Table 9: Groundwater levels (JMA, 2005 and Delta, 2020)

Borehole ID	Level	JMA, 2005			Delta, 2020	
		Date Measured	Water Level (m)	Water Level (Mamsl)	Last measured date	Median WL (mbgl)
BSW01	S	Jun-04	5.91	1525.09	Mar-17	5.8
BSW02	S	Jun-04	6.88	1535.12	Nov-18	7.4
BSW03	S	Jun-04	25.52	1510.98	Mar-19	24.2
BSW04	S	Jun-04	6.57	1572.43	Jun-18	14.7
BSW05	S	Jun-04	8.46	1566.54	Mar-19	6.7
BSW06	S	Jun-04	4.84	1518.16	Mar-19	5.6
BSW07	S	Jun-04	3.74	1546.26	Mar-19	3.5
BSW08	S	Jun-04	5.55	1536.45	-	-
BSW09	S	Jun-04	5.56	1564.44	Dec-16	7.4
WSW14	S	-	-	-	Sep-16	8.6

Table 10: Summary of water levels for the old Ogies underground workings

Borehole ID	Median WL (Deep) (mbgl)	Median WL (Shallow) (mbgl)	Last measurement	Count
CSIR-1	-		Vandalised	-
CSIR-2	2.90	2.80	Jun-19	16
O11-RRA	7.47	-	blocked	5
O11A	7.94	-	Dry	1
O11C	-		6.15	18
O12	5.60		Jun-19	16
O18	52.97	7.67	Vandalised	9
O20	42.97	6.30	Jun-19	18
O22	68.92	6.45	Jun-19	15
O27	18.21	8.39	Jun-19	15

Table 11: Newly drilled Zibulo Opencast boreholes (Delta, 2020)

Borehole ID	Longitude	Latitude	BH Depth (mbgl)	Water Strike	Water Level (mbgl)
BSW10	29.04714	-26.03952	50	none	-
BSW11	29.05106	-26.03579	50	none	8.43
BSW12	29.05214	-26.03479	55	none	28.94
BSW13p	29.04694	-26.04282	55	none	collapsed
BSW14p	29.04555	-26.04349	55	none	11.41
BSW15p	29.04558	-26.04001	40	1 m	14.47

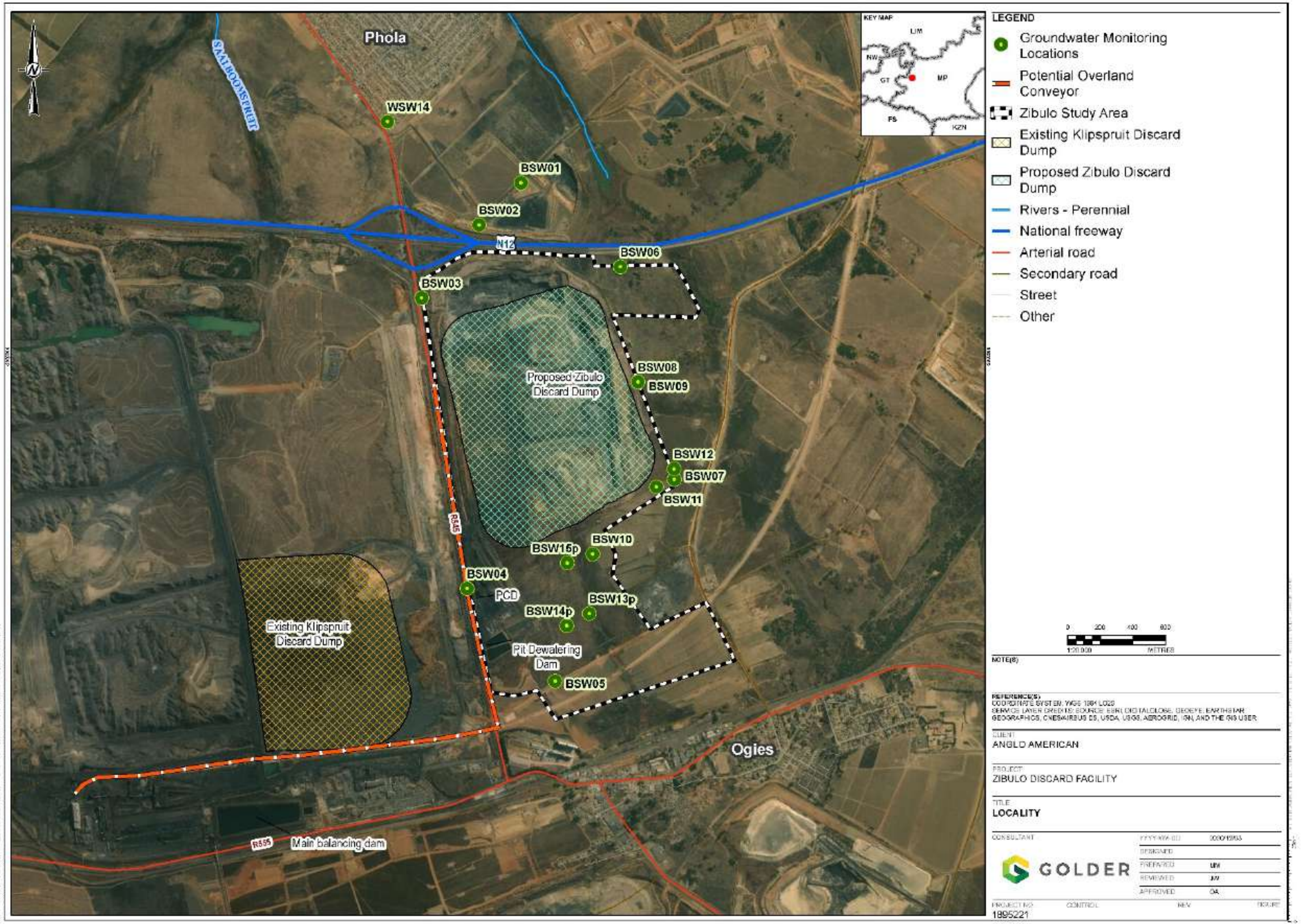


Figure 22: Borehole locations

2.7.2 Recharge/ seepage

A higher proportion of rainfall infiltration and recharge may occur in areas where the natural vegetation is reduced and the natural permeability is increased such in stripped or backfilled areas, areas of inward draining or areas of increased fracturing (and potentially subsidence) associated with mining. Considering the substantial uncertainty associated with recharge/ seepage estimates in general and for mining influenced areas in specific, Delta H moderated the different values and used the estimates set out in Table 12. The percentage values are generally used in AAIC groundwater model applications.

Table 12: Estimated recharge for Zibulo Opencast (Delta H, 2020)

Unit	Life of Mine		Post-closure	
	% of MAP	mm/a	% of MAP	mm/a
Weathered Karoo and Alluvium	3%	22	3%	22
Open cuts	20%	143	n/a	n/a
Unrehabilitated spoils	15%	105	n/a	n/a
Rehabilitated spoils	8%	57	8%	57

n/a: not applicable

2.7.3 Groundwater quality

The borehole water quality is set out in Table 13. On the whole the water quality in all the boreholes complies to the specifications for drinking water (SANS 241: 2015) and the Zibulo Opencast integrated water use licence limits. BSW04, located adjacent to the Pollution Control Dam (PCD), shows non-compliance against the IWUL limits for pH and sulphate. Zibulo Colliery is in the process of implementing measures at the PCD to address further contamination emanating from this facility.

Table 13: Borehole water quality

Parameter	SANS 241-1 (2015)	Zibulo OC IWUL	BSW01	BSW02	BSW03	BSW04	BSW05	BSW06	BSW07	BSW09	WSW14
No. of samples			15	24	22	22	20	40	17	17	14
Latest Sample date			Mar-17	Nov-18	Sep-19	Sep-19	Mar-19	Jun-19	Jun-19	Dec-16	Mar-16
pH	5 - 9.7	6.2 - 8	8.0	6.7	7.5	5.8	7.2	6.5	7.7	7.0	7.3
EC mS/m	170	54	13.2	5.2	36.9	31.8	18.1	0.8	26.6	13.9	8.3
TDS mg/L	1200	344	68.5	25.5	227.5	185.5	104.0	24.0	156.0	80.5	37.0
Total Hardness mg/L			51.0	10.0	134.0	116.0	62.5	9.0	111.5	27.0	29.0
Ca mg/L	150	71	11.6	1.9	31.0	23.4	16.5	1.7	28.0	5.8	6.7
Mg mg/L	70	16	5.6	1.3	14.3	14.0	5.4	1.1	10.2	3.1	3.0
Na mg/ L	200	40	3.7	2.2	21.4	12.8	12.3	3.6	11.4	17.9	2.2
K mg/L		8	5.9	3.9	7.4	3.3	4.1	1.1	6.5	3.0	2.9
TALK $CaCO_3$/L		272	61.1	17.3	144.5	11.0	96.2	13.9	143.0	73.2	34.1
Cl mg/L	300	29	2.3	2.3	11.1	6.6	1.9	3.3	5.2	1.3	2.0

Parameter	SANS 241-1 (2015)	Zibulo OC IWUL	BSW01	BSW02	BSW03	BSW04	BSW05	BSW06	BSW07	BSW09	WSW14
SO_4 mg/L	250/ 500	20	1.1	2.0	12.5	99.9	1.4	0.6	1.0	0.4	0.8
F mg/L	1.5	6.6	0.35	0.43	0.27	0.18	0.36	0.33	0.63	0.24	0.16
NO3-N mg/L	11		0.28	0.34	0.74	4.77	0.34	0.61	0.31	0.28	0.24
NH4-N mg/L	1.5		1.49	0.21	0.09	0.06	0.08	0.29	1.00	0.14	0.08
PO4 mg/L			0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Al mg/L	0.3	0.66	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.003
Fe mg/L	0.3 / 2	47	0.006	0.009	0.006	0.005	2.810	0.009	0.006	3.430	0.003
Mn mg/L	0.5	0.59	0.002	0.027	0.012	0.004	0.003	0.042	0.058	0.251	0.013
Zn mg/ L	5		0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002

The Pollution Control Dams (PCDs) of both the Zibulo underground (UG) and opencast (OC) sections are identified as potential sources of groundwater pollution and are therefore good indicators of the dewatered mine water qualities. The sample number and median concentrations of selected constituents of groundwater samples from Zibulo Opencast water monitoring data are given in Table 14. The main constituents of concern (acidity and sulphate concentrations) are indicative of acid mine drainage from sulphur enriched waste rocks (OC) or exposed host rocks (UG). The water quality samples of the opencast PCD show an increasing trend in sulphate concentrations. It is noted that this increasing trend may be as a result of the Klipspruit contribution of water to Zibulo's PCDs as part of the exchange program which started in 2017, and maty be skewing the picture.

Table 14: Median water quality results of the PCDs located at the open cast sections (Jan-2015 to Sep-2019) (Delta H, 2020)

	Zibulo OC IWUL limits	ZC PC1	ZC PC2
No. of samples		32	33
pH	6.2 to 8.0	8.1	8.3
EC mS/m	54	170.5	204.0
TDS mg/L	344	1 433.0	1 662.0
Total Hardness mg/L	-	948.0	1 025.5
Ca mg/L	71	179.0	215.0
Mg mg/L	16	86.1	87.5
Na mg/L	40	71.1	137.0
K mg/L	8	12.0	11.5
TALK $CaCO_3$/L	272	156.0	269.0
Cl mg/L	29	11.7	14.0
SO_4 mg/L	20	843.0	882.0

	Zibulo OC IWUL limits	ZC PC1	ZC PC2
F mg/L	6.6	2.13	3.95
NO_3-N mg/L	-	0.88	0.77
NH_4-N mg/L	-	0.15	0.14
PO_4 mg/L	-	0.02	0.06
Al mg/L	0.66	0.003	0.003
Fe mg/L	47	0.003	0.003
Mn mg/L	0.59	0.076	0.060
Zn mg/L	-	0.002	0.002

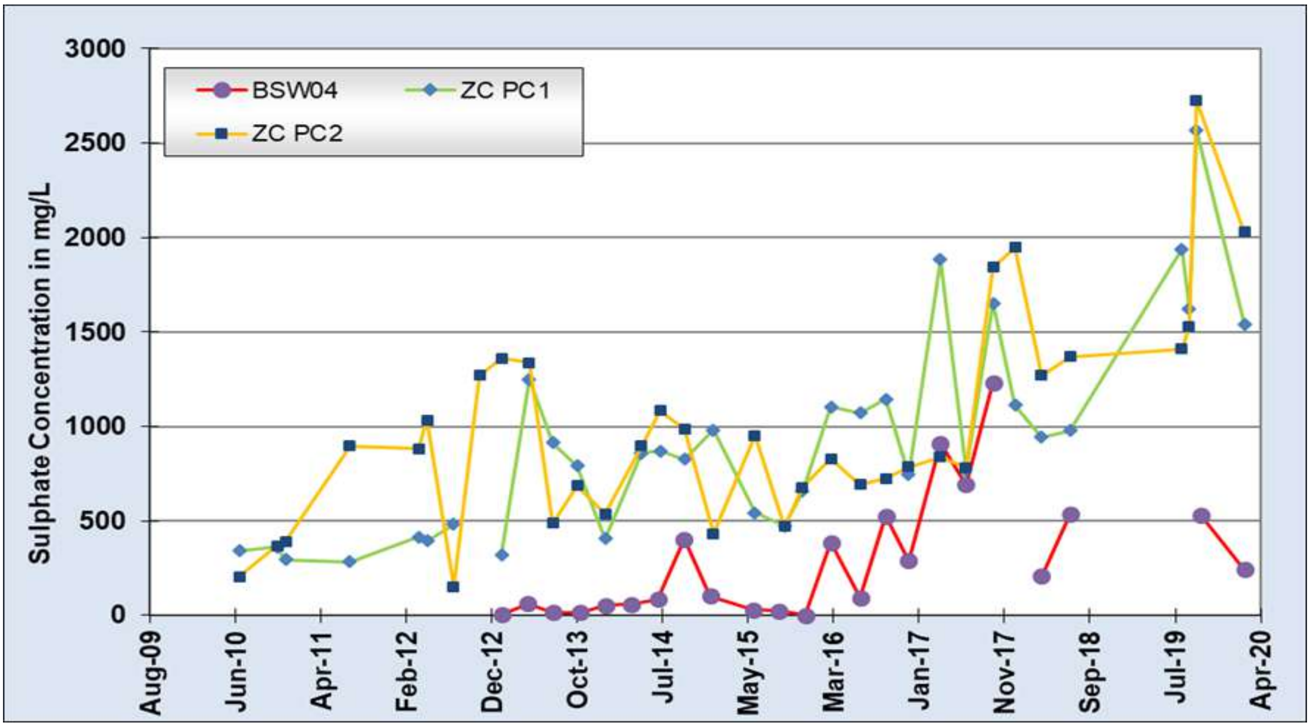


Figure 23: Sulphate trends for the Zibulo Opencast PCDs and borehole BSW04 (June-2010 to Apr-2020) (Delta H, 2020)

3.0 OPENCAST AND DISCARD IMPACT MODELLING

Delta H ran a model to assess the discard impact modelling, the details of which are included in the memo attached as Appendix B to the report.

3.1 Post closure simulation for Zibulo Opencast

The simulations were run for the case without the discard dump (base case) and with the discard dump. The outcomes are described in the sections to follow.

3.1.1 Base case (no discard)

To reduce the overall water-make at the end of life of mine, AAIC envisages reshaping the surface topography of the backfilled areas to maximise free draining areas. For the backfilling of the Zibulo opencast area, a drainage system will be re-created in the place of the existing relict wetland system that will transport all clean surface water runoff to the wetland in the north. The backfilled areas will also be top soiled and seeded to stimulate growth of vegetation, thereby minimising the infiltration of rainwater recharging the spoils material.

Figure 25 illustrates the base case pollution plume with no discard (with a cut-off value of 250 mg/l sulphate, which is the aesthetic health (SANS 241-1:2015) limit) 50- and 100-years post-closure. The 500 mg/l sulphate contour is also shown, which represent the acute health (poses an immediate unacceptable health risk) (SANS 241-1:2015) limit. Note that for comparison purposes of the model scenarios, all plumes are shown with an equal scale. The pollution plume from the Zibulo opencast spoils extends 50 years post-closure approximately 400 m north north-east towards the surface water drainage line. Smaller plume extents are predicted towards the north northwest. After 100 years the plume has migrated approximately 650 m north north-east. Only a limited spreading of leachate from the backfilled pit into the weathered aquifer is expected for its western, southern, and eastern edges.

Surface decant is expected to occur at the most north north-eastern edge of the pit. The timing of decant is subject to rehabilitation timelines, as well as rebounding rate of in-pit water levels. The simulated head rebound to surface decant elevation and the long-term decant rate is shown in Figure 24. Long-term (base case) decant rates is estimated at around 540 m^3/d (or ~0.54 ML/d). Based on the current mine plan, the preliminary critical level to prevent surface decant is 1 527 mamsl, while the Environmental Critical Level (ECL) to prevent diffuse decant into the shallow weathered aquifer will be at a lower level (depending on the actual weathering depth from the pit walls).

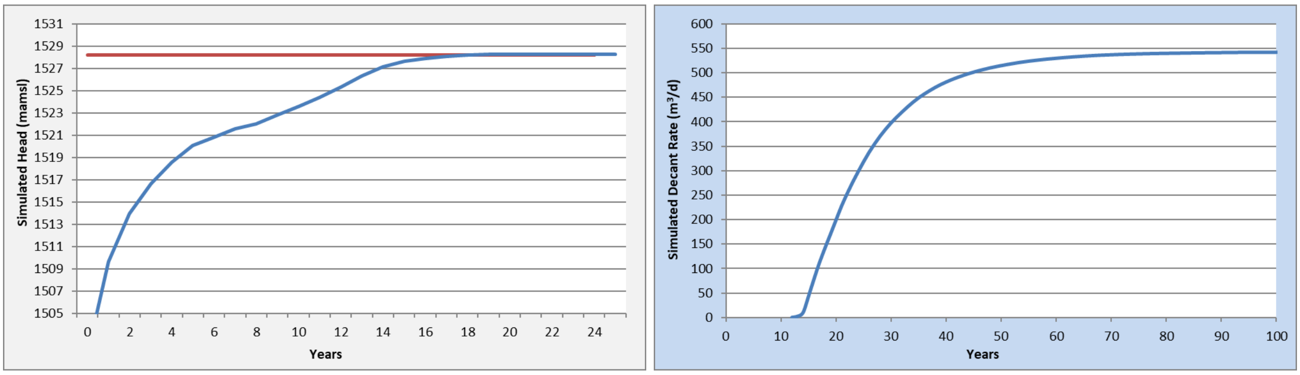


Figure 24: Simulated head rebound in the north north-eastern edge of the Zibulo open cast and post-closure decant (base-case)

3.1.2 Zibulo Discard Facility

As described in Section 1.3, a coal discard facility is required at Zibulo Colliery to service the discard requirement for a Life of Mine (LoM) of 14 years, and the proposed site for the new discard facility is the current opencast pit at Zibulo. The discard dump will be designed such that it will be placed within and over the backfilled pit (Figure 3). Two post-closure transport model scenarios were considered: an 'uncapped' and 'capped' (~600 mm)'. The sulphate concentrations and seepage rates developed by Golder for the Klipspruit discard dump, which serves as a proxy for the proposed Zibulo discard dump, were used in the model. The source term, i.e., the leachate concentrations and seepage rates for the two model scenarios, uncapped and capped (600 mm), were provided by Golder Associates (Golder, 2020) and applied in the model scenarios without scrutiny.

Table 15: Modelled long-term sulphate concentrations for the Klipspruit discard dump (Golder, 2020)

Cover	Recharge Rate %	Modelled Sulphate (mg/L)
Uncapped*	25	4376

Cover	Recharge Rate %	Modelled Sulphate (mg/L)
Capped DD (600 mm cover) (Contaminant transport model scenarios)	14	4522
Capped DD (700 mm cover)	13.33	4527
Capped DD (800 mm cover)	12.73	4531
Capped DD (900 mm cover)	12	4537

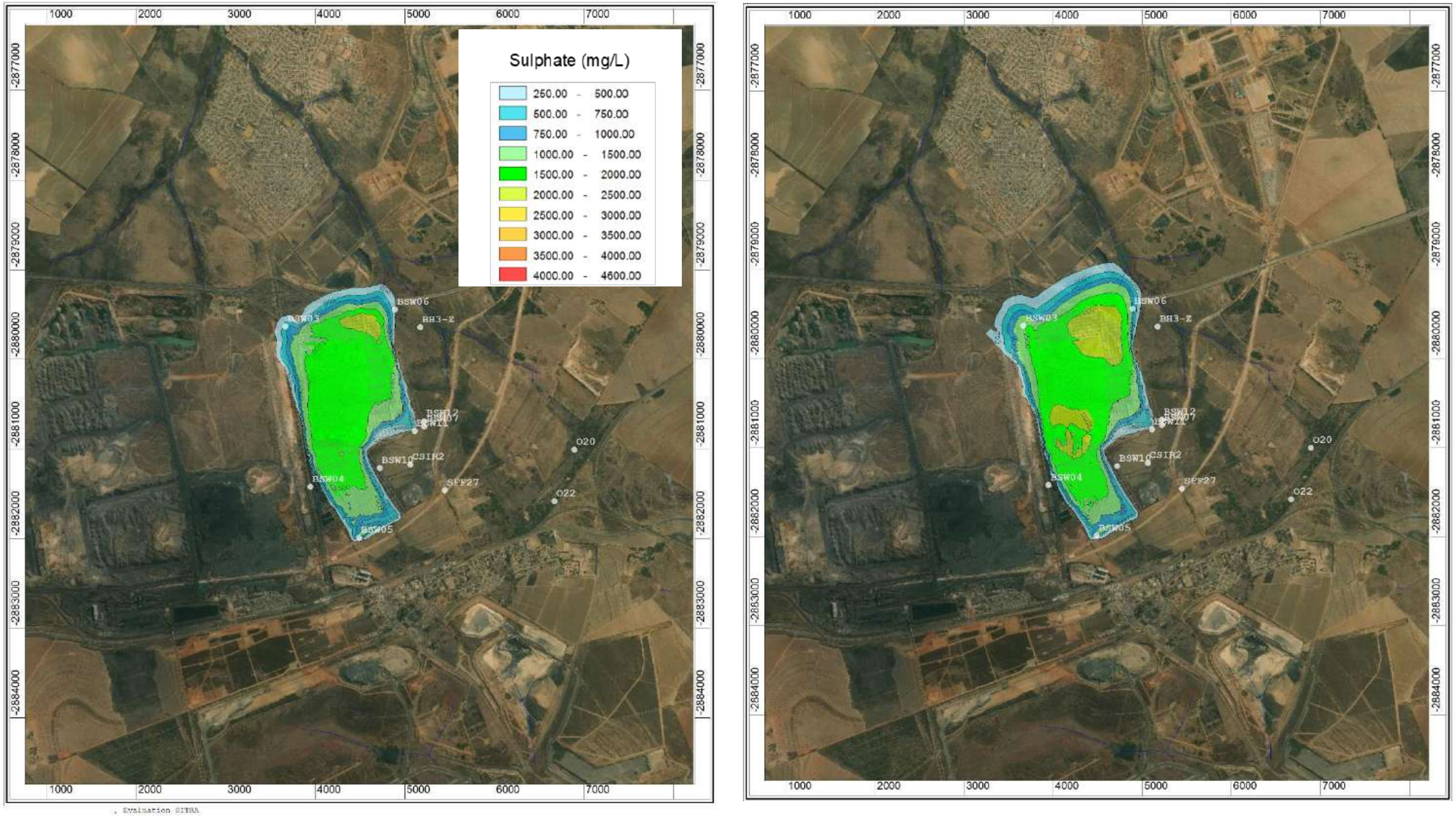


Figure 25: Simulated sulphate concentrations for the base case (no discard) scenario after 50- and 100-years post-closure (Delta H, 2020)

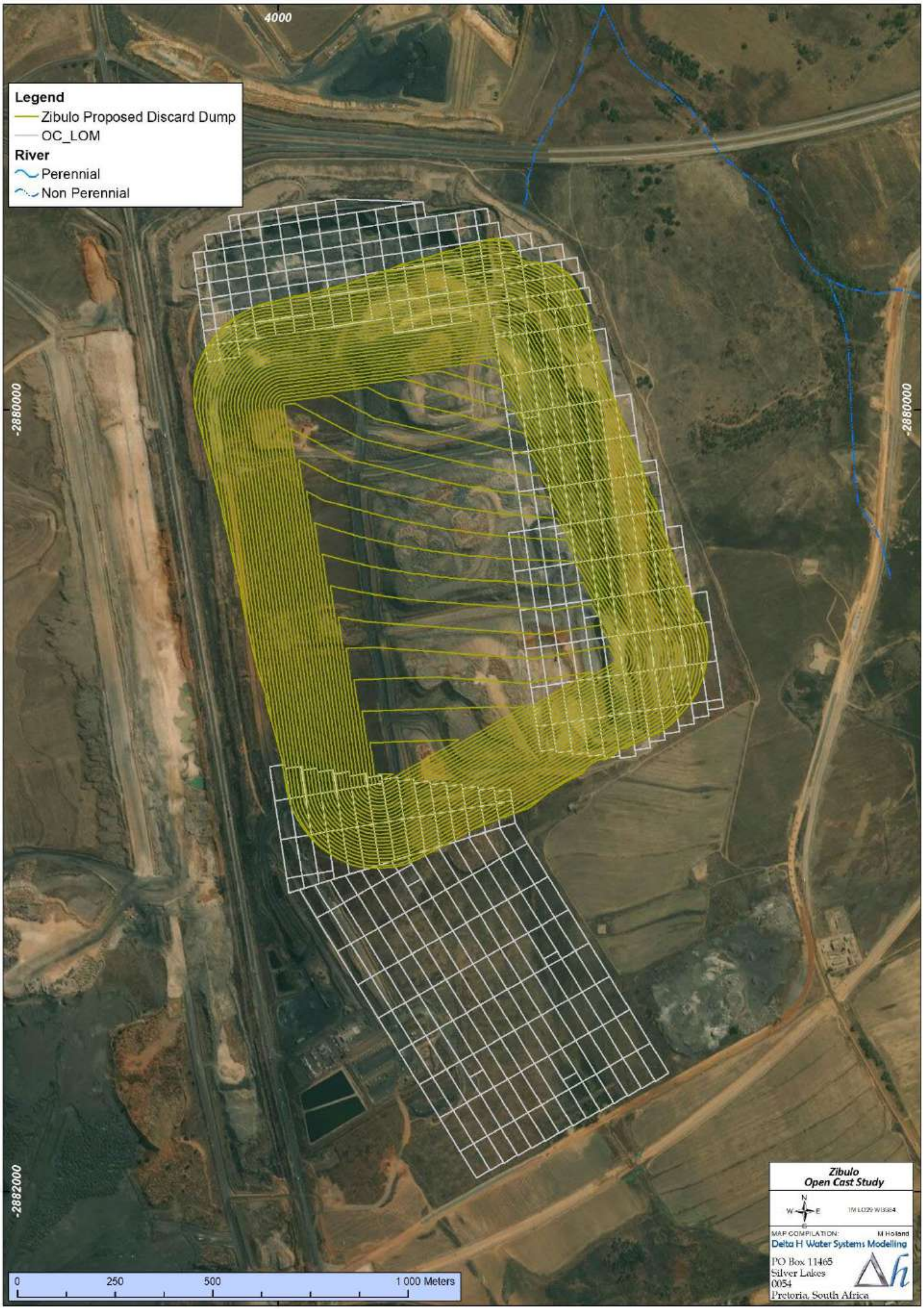


Figure 26: Proposed Zibulo discard dump (Delta H, 2020)

Figure 28 and Figure 29 illustrate the pollution plumes for the uncapped and capped predictive scenarios. The pollution plume from the Zibulo discard dump extends 50 years and 100 years post closure approximately 570 m and 800 m north, respectively. The pollution plume for the capped scenario, with an assumed lower seepage rate (but similar sulphate concentration) is expectedly smaller and extends 50 years and 100 years post closure approximately 480 m and 700 m.

As the expected critical level to prevent surface decant or Environmental Critical Level (ECL) to prevent diffuse decant into the weathered aquifer are dependent on the pit layout and weathering depth around the perimeter of the pit only, they remain unchanged from the base scenario. However, since the estimated recharge rate of the discard dump (Table 15) is higher than the rate estimated for rehabilitated spoils (Table 12), the long-term decant rates are higher than for the base case scenario and estimated at approximately:

- 818 m^3/d (or ~0.82 ML/d) for the uncapped scenario, and
- 620 m^3/d (or ~0.62 ML/d) for the capped scenario.

A mitigated model scenario considered four abstraction boreholes to manage the backfill water levels below an ECL of 1 512 mamsl (for an assumed average weathering depth of 15 m) to prevent surface and diffuse decant. The boreholes were implemented in the model as constant head boundary conditions with heads iteratively adjusted until plume containment was achieved. The required number and drawdown of such abstraction boreholes will obviously have to be based on actual field drilling and hydraulic test results for the backfill material.

Once the water levels are managed below ECL, hydraulic gradients are mostly reversed inwards and plume migration (Figure 30) contained. Since the cone of dewatering 'pulls' additional water from the surrounding aquifer into the backfilled pit area, required dewatering rates will exceed predicted decant rates. A combined long-term abstraction rate of approximately 851 m^3/d (or ~0.85 ML/d) (Figure 27) from the four abstraction boreholes (up-gradient of the decant area) is predicted for the capped scenario (in comparison to a predicted decant rate of 620 m^3/d).

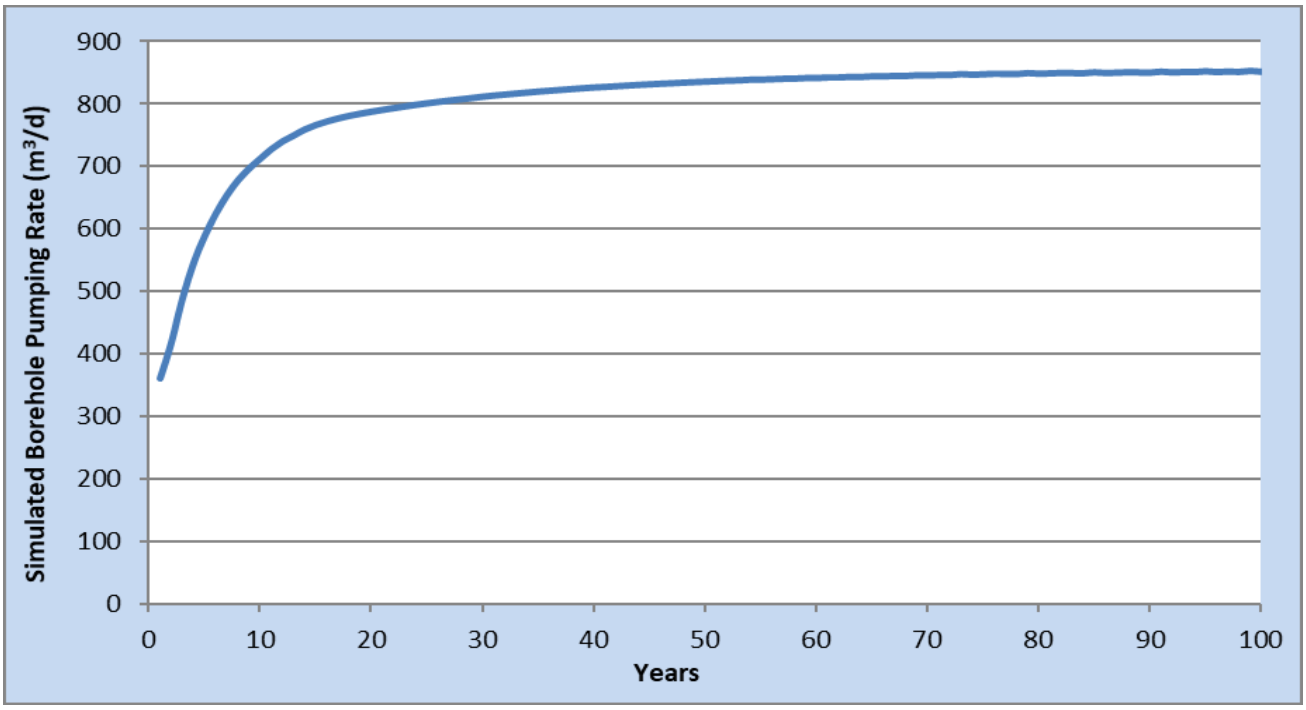


Figure 27: Simulated borehole pumping rate post-closure to prevent surface decant and limit diffuse decant (Delta H, 2020)

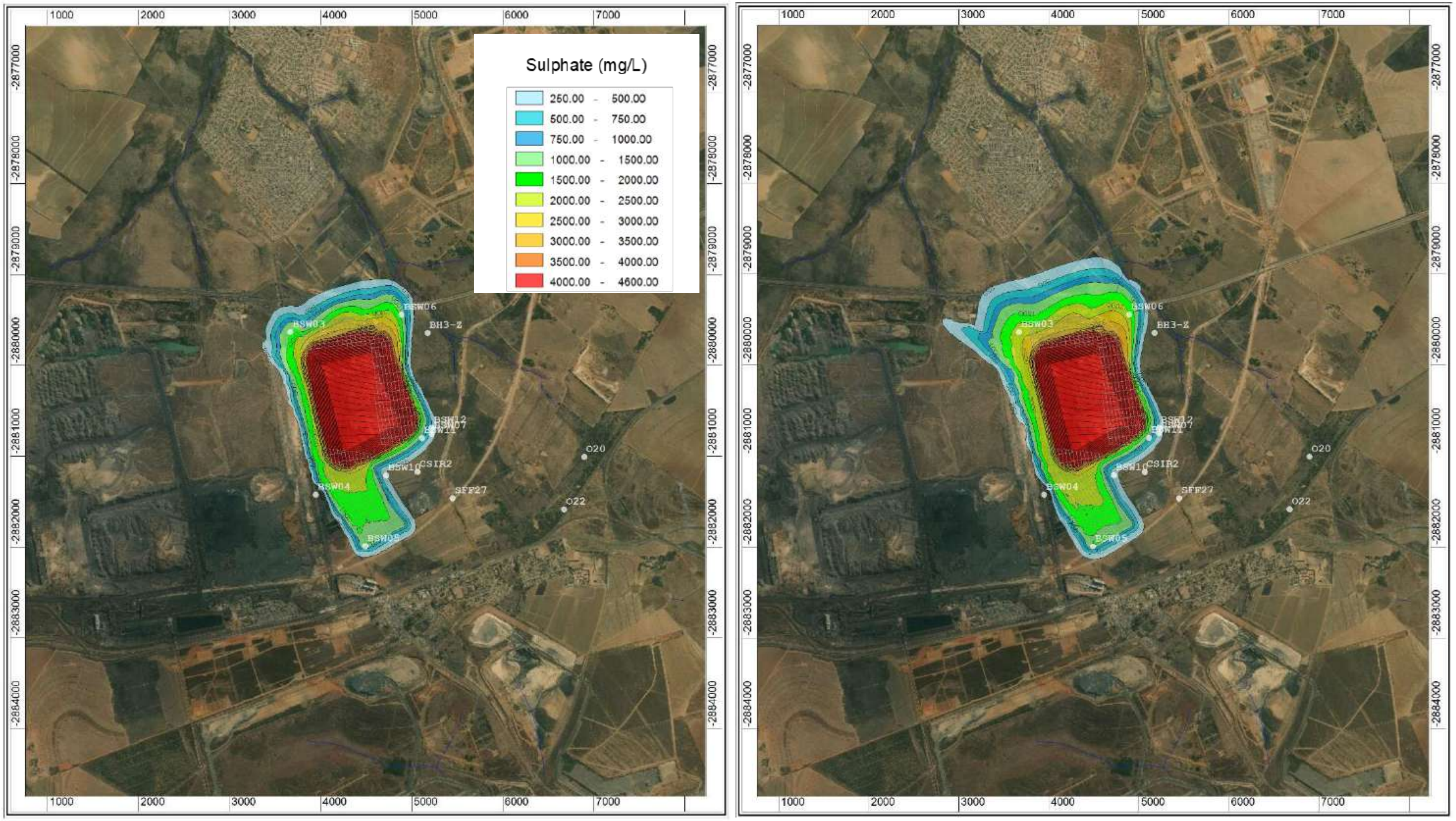


Figure 28: Simulated sulphate concentrations for the *uncapped* scenario after 50- and 100-years post-closure (Delta, 2020)

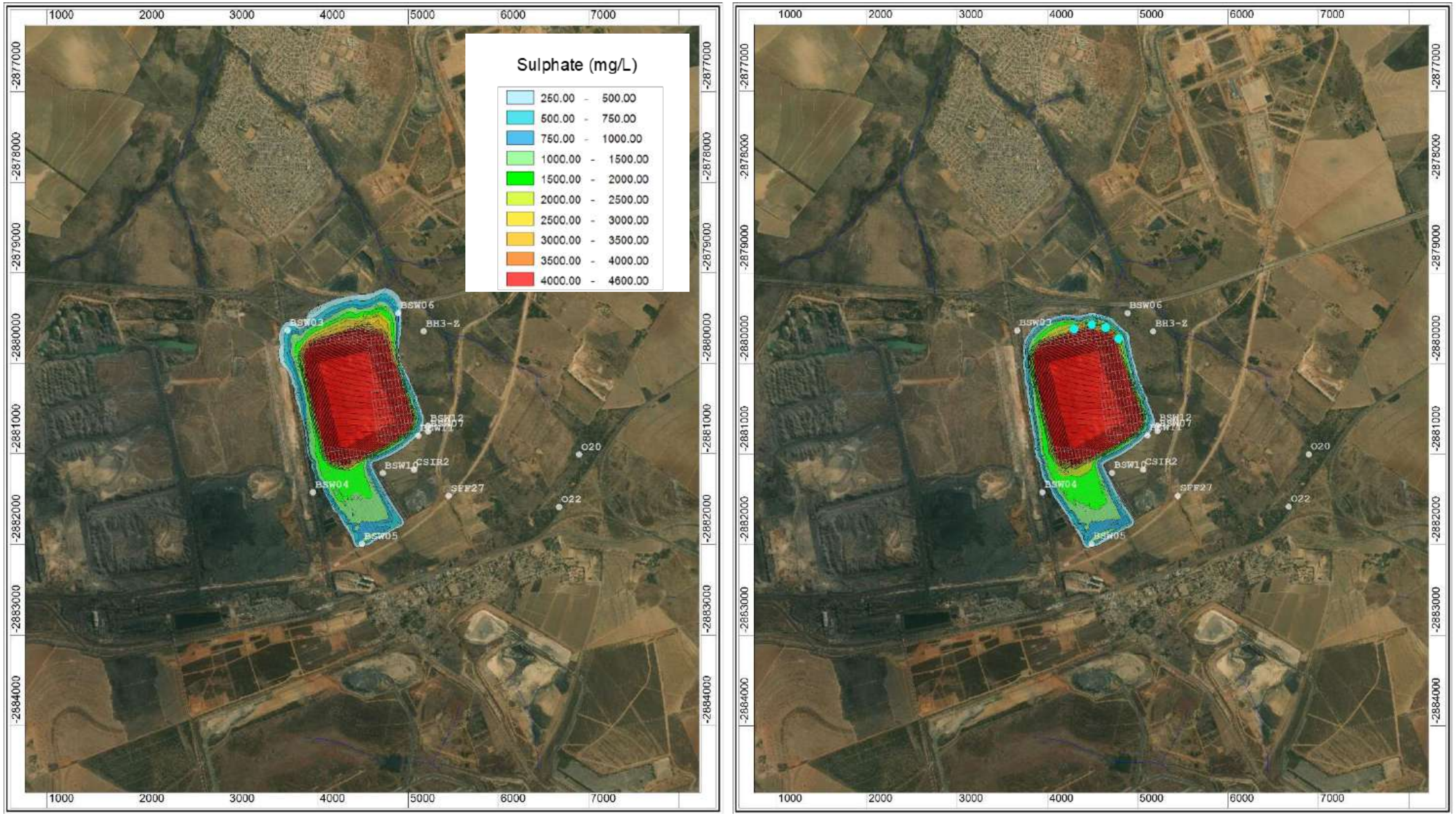


Figure 29: Simulated sulphate concentrations for the *capped* scenario after 50- and 100-years post-closure (Delta, 2020)

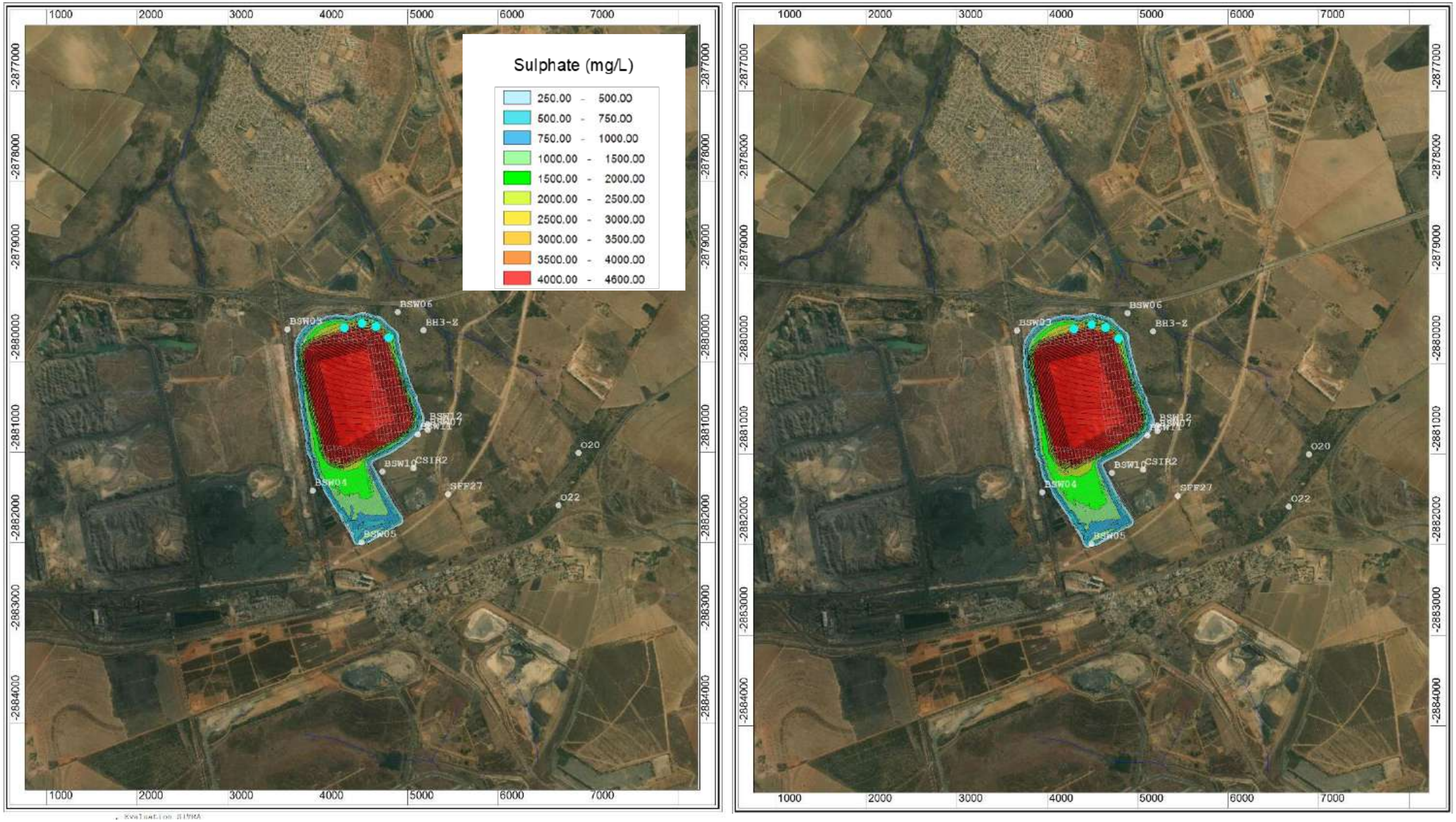


Figure 30: Simulated sulphate concentrations for the capped (and pumping) scenario after 50- and 100-years post-closure (light blue dots showing abstraction borehole positions) (Delta, 2020)

3.1.3 Conclusions from the discard impact modelling

Groundwater quality within the backfilled opencast areas, including the overlying discard dump, is expected to deteriorate due to acid mine drainage and other chemical interactions between the geological and the groundwater regime. The resulting groundwater pollution plume will migrate along the new local and regional hydraulic gradients as the water table rebounds. Based on the topographic setting of the mine and the post-closure topography including the discard dump, the rebounding water table will lead to surface decant of mine water of approximately 620 m^3/d (0.62 ML/d). Based on the current mine plan, the expected critical level to prevent surface decant is estimated at 1 527 mamsl, while the Environmental Critical Level (ECL) to prevent diffuse decant will be at a lower level and depends on the actual weathering depth around the pit perimeter (assumed to be 15 m for the model simulations).

While a limited spreading of leachate from the backfilled pit (with or without the discard dump) into the weathered aquifer is expected for its western, southern, and eastern edges, the migration of the plume towards the north is significant and may trigger potential off-site migration. Post closure water levels within the backfilled pit (with or without discard dump) and surrounding aquifer should be monitored and pit water levels managed below environmentally critical levels (i.e. weathered aquifer elevation within the downstream area of the backfilled pit) to prevent potential decant of mine water to surface or into the weathered aquifer. Potentially abstracted groundwater should be treated, re-used, or discharged into the environment.

Three discard dump monitoring boreholes to augment the existing Zibulo opencast monitoring network were identified as part of the Zibulo Southern Box-Cut project (Table 16).

Table 16: Proposed discard dump monitoring boreholes

Borehole ID	Longitude	Latitude	Target Area
BSW16	29.04898	-26.02725	East
BSW17	29.04493	-26.02294	North
BSW18	29.03772	-26.031474	West

* *has been drilled and is located between the Klipspruit and the Zibulo opencast areas*

4.0 WATER BALANCE

4.1 Introduction

The water reticulation schematic is shown in Figure 31. The water at the Zibulo Underground section is currently managed separately from the water at the opencast section. The water at the underground mining section is pumped to the 20ML (PCD2) and 7.5ML (PCD1) dams on surface where it is re-used underground in the continuous miners and sent to the Phola Coal Plant to wash coal. The operational water management currently practised at the Zibulo North and South opencast pits is to pump water collected in the pit sumps to the 40ML Dam. Water stored in the dam can be released to the 9ML and 1ML dams for dust suppression water. The runoff from the crushing plant at the opencast section is collected in the 9ML Dam and can be released to 1ML Dam for use as dust suppression water. Excess water at the opencast is pumped from the 40ML Dam to the EMalahleni Water Reclamation Plant (EWRP) for treatment. South32's Klipspruit Colliery can send up to 2 ML/d to the 40ML Dam for transfer to the EWRP for treatment. The potable water for the Zibulo Colliery is supplied from the EWRP via the Phola Coal Plant.

The discard is planned to be deposited on the North pit spoils. The mining of the North pit will be completed by 2022 (See Figure 32). The pit post mining topography was to be free draining with the clean runoff being returned to the environment. The pit was to fill with water and once the water level reaches the Environmental Critical Level pumped using boreholes to the 40ML Dam for treatment at the EWRP. The discard dump will change the planned free draining pit topography with the stormwater runoff from the discard dump over the 15-year operational life of the dump being directed into a void/sump that will be left in the pit until the deposition on the dump is completed. The water collecting in the pit will be pumped to the 40ML Dam where water will be used for dust suppression and any excess water pumped to EWRP for treatment. The change to the operational water balance due to the dump is the stormwater runoff directed to the pit before the dump is rehabilitated and the runoff is returned to the environment. The runoff will provide additional water that will have to be managed in the polluted water management system. The recharge volumes through the dump into the pit spoils will be similar to the volumes that would have reported to the pit through the levelled spoils without the dump in place.

The objective of the application of the operational water balance model is to assess the ability of the water management system to manage the additional dump runoff water. The closure aspects of water management are addressed using the groundwater model.

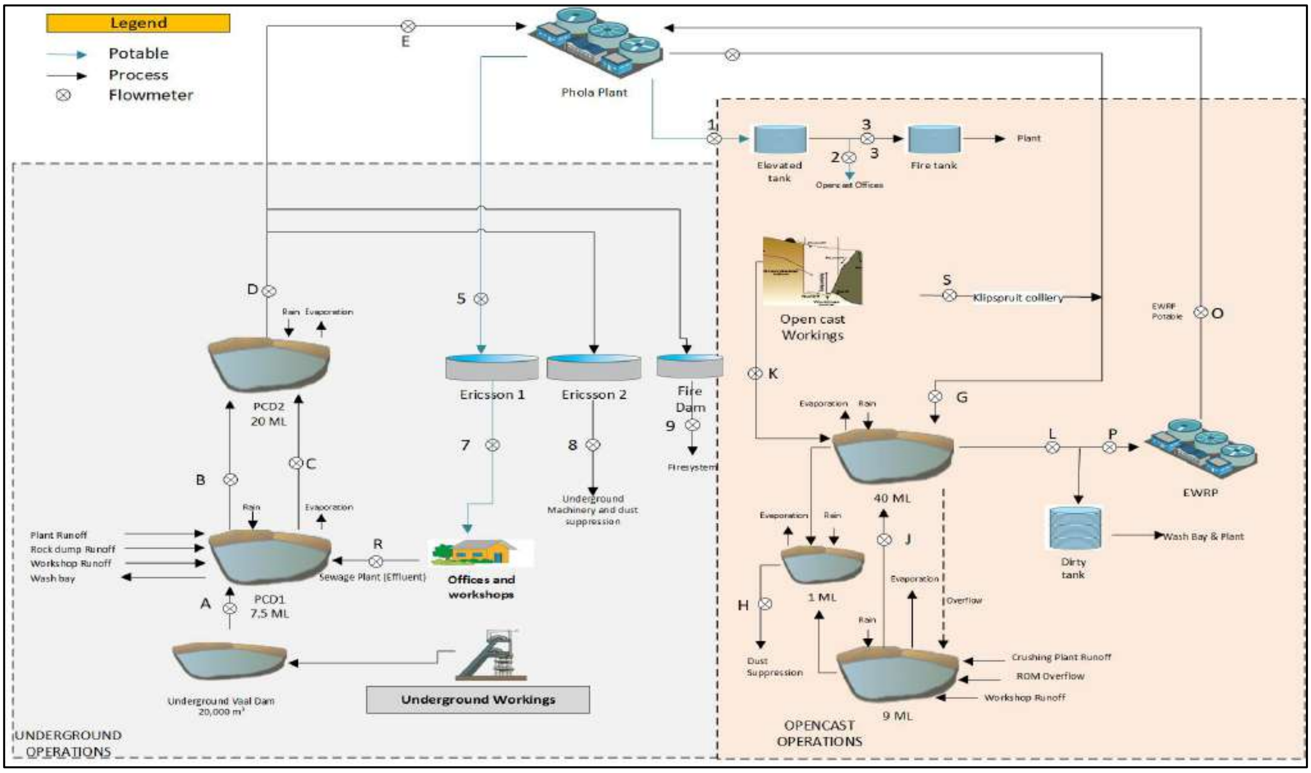


Figure 31: Water reticulation schematic for Zibulo Colliery

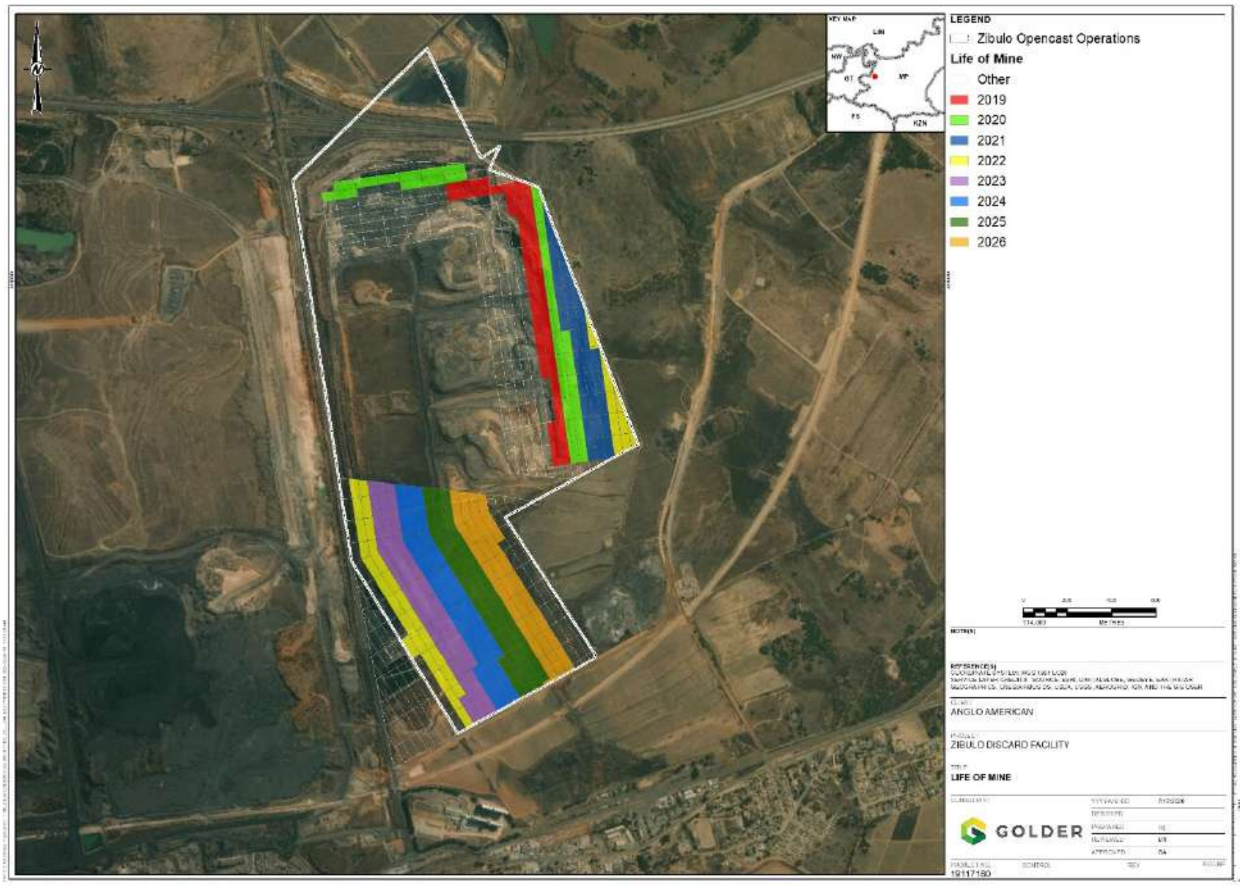


Figure 32: Mine plans for Zibulo North and South opencast pits

4.2 Model Inputs and assumptions

The model inputs and assumptions are summarised below:

- The mine plan as shown in Figure 32 was used in the modelling;
- The construction of the discard dump is assumed to start in 2022 when the mining of the North Pit is completed;
- The dump will be operational for 15 years ending in 2036;
- The stormwater will be directed to a sump/void in the pit. The runoff and recharge to the North Pit will be pumped from the pit to the 40ML Dam once the pit water level reaches the ECL;
- The ECL level was taken as 1512 masl in the North Pit. The volume stored in the pit at ECL is 2.84 million m^3 based on a porosity of 0.25;
- The North Pit has no water in storage at the start of the simulations;
- The discard dump is not concurrently rehabilitated;
- Klipspruit Colliery sends up to 2 ML/d to the 40ML Dam if the volume of water stored in the dam is less than 50%;
- Up to 3 ML/d can be sent to EWRP from the 40ML Dam;

- The cover placed on the rehabilitated areas of the North pit will be removed before the discard is placed;
- The average recharge through the uncapped dump and levelled spoils will be 25% of the annual rainfall depth; and
- Any excess water at Zibulo Underground section will be managed at the underground and will not be sent to the 40ML Dam at the opencast section.

4.3 Model Results

The model was run for the simulation period 1 Jan 2022 to 1 Jan 2037 when the deposition of material on the discard dump is complete. A 100 realisations were run for the simulation period and the probability of spill at the 40ML Dam was assessed based on the assumptions and inputs listed above. A plot of the volume stored in the 40ML Dam is shown plotted in Figure 33. Once mining of the North and South pits is complete, the pits will fill and water will be pumped from the pits once the ECL is reached. Plots of the simulated increase in the water volume stored in the pits after mining is complete is shown in Figure 34 and Figure 35 for the North and South pits respectively.

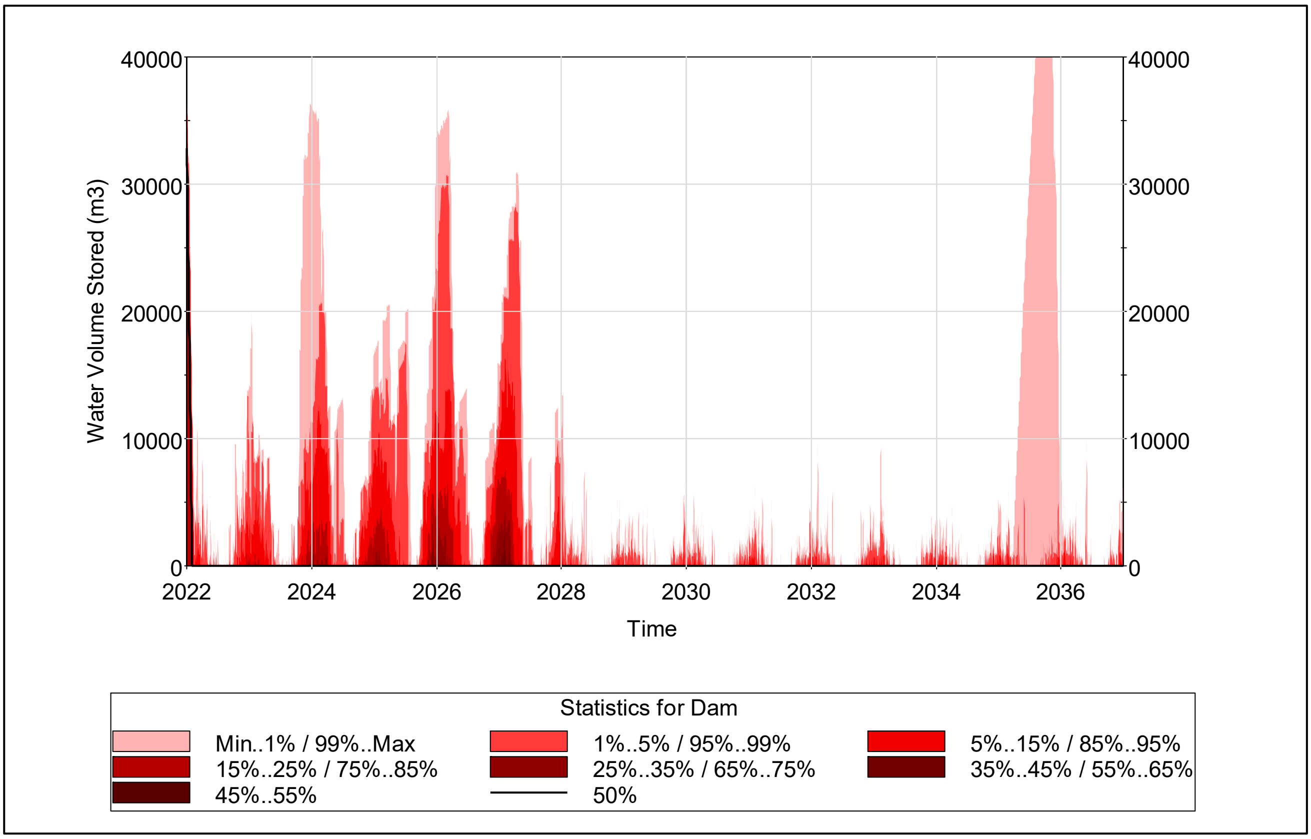


Figure 33: Plot of simulated water volumes stored in 40ML Dam

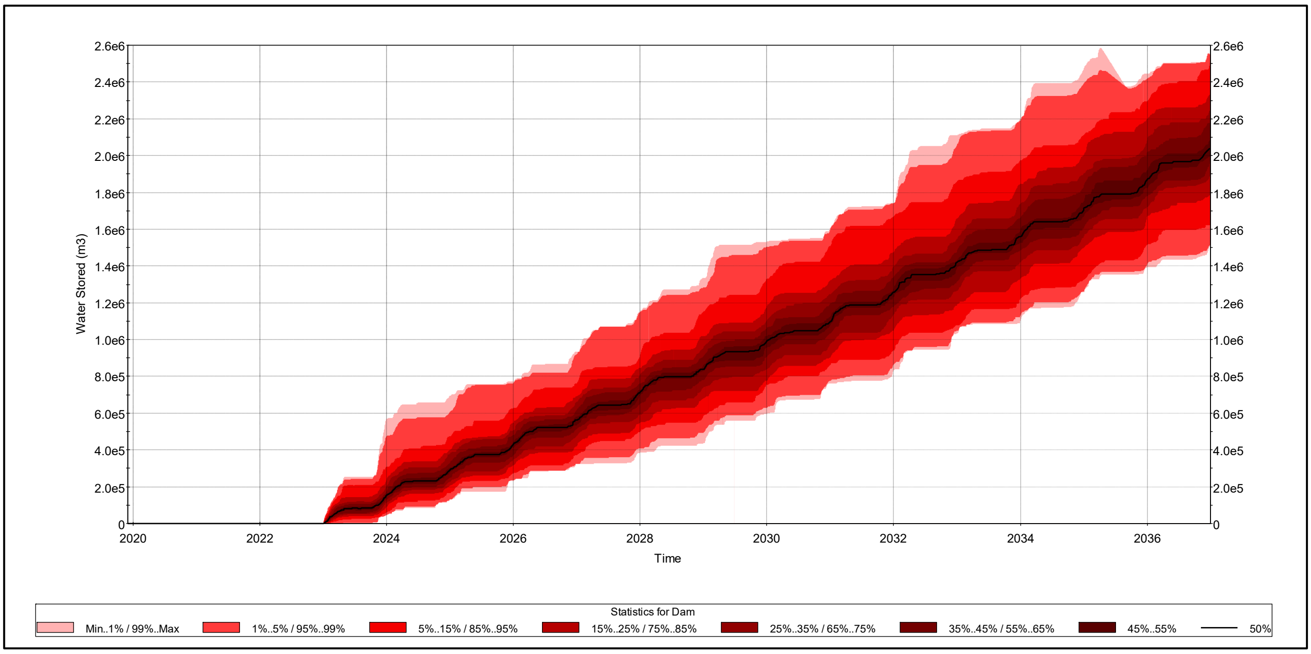


Figure 34: Plot of simulated water volumes stored in the North pit

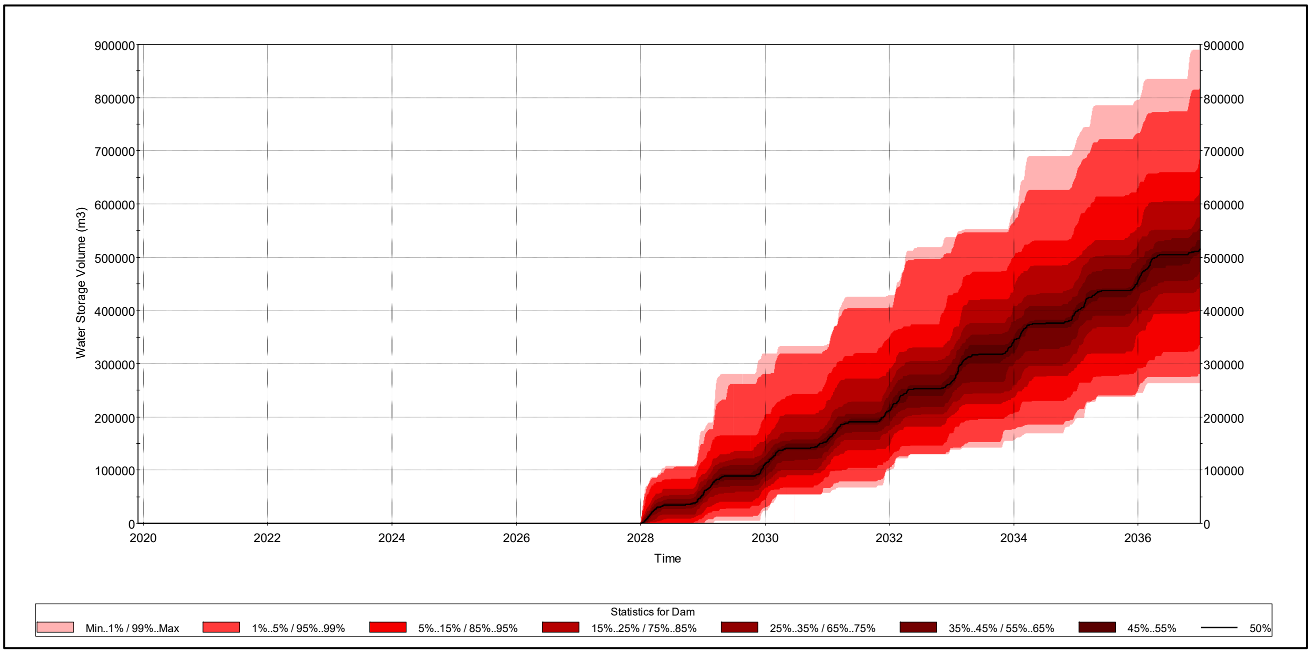


Figure 35: Plot of simulated water volumes stored in the South pit

The average water balance for the opencast operation was calculated over the simulation period using the model results. The average balance is shown in Figure 36.

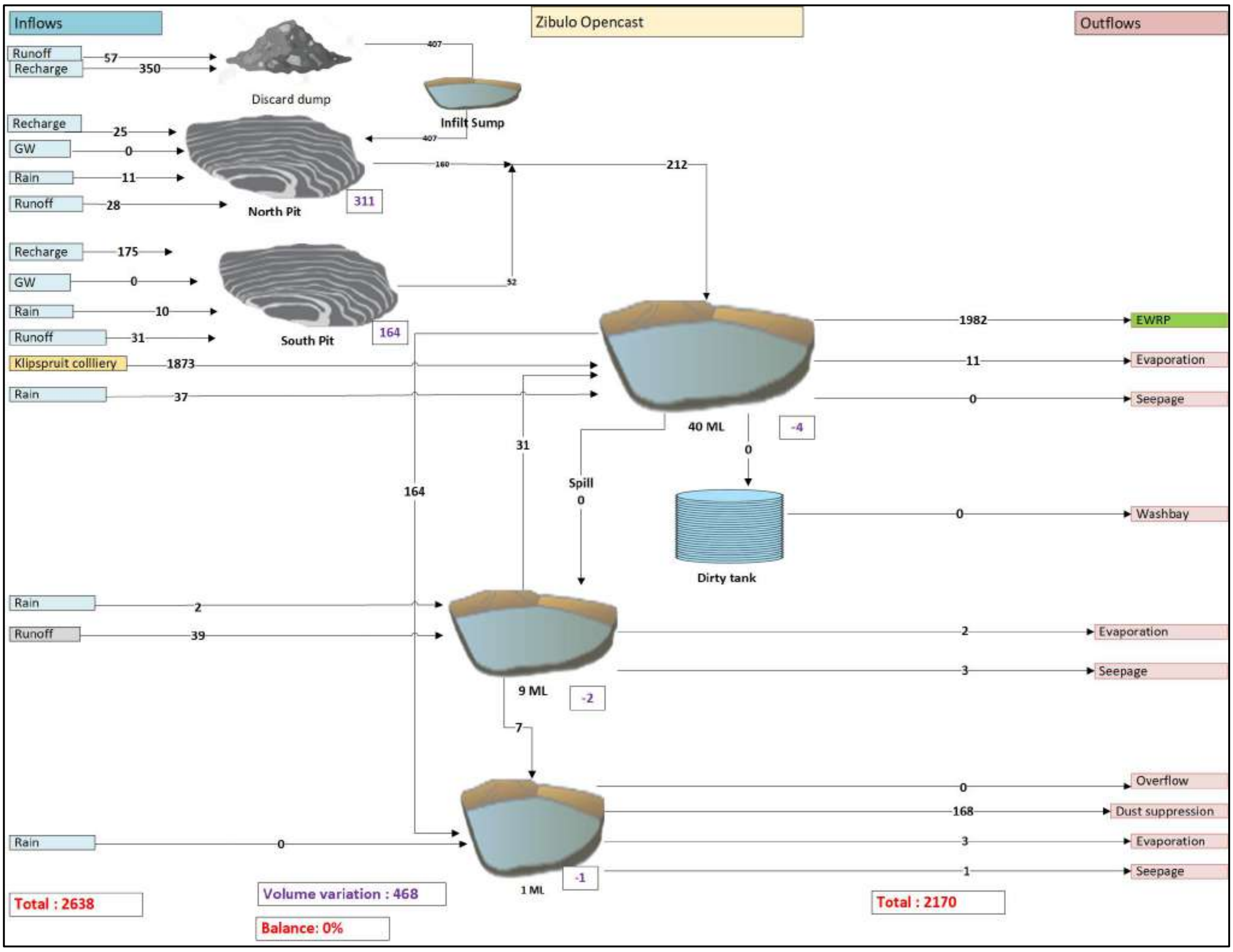


Figure 36: Average daily water balance for Zibulo Opencast

The following conclusions can be made as a result of the model simulations:

- The simulation results plotted in Figure 33 shows that the 40ML Dam had one year in which a spill occurred in the 1500 years simulated and meets the Regulation 704 requirement of 1 spill in 50 years. The additional stormwater runoff from the discard dump reporting to the workings can be successfully managed in the current system.
- The simulation showed that the South Pit will not have filled by the time the life of the discard dump has been reached.
- The probability that the North pit will fill by 2037 is small. Only one of the 100 realizations resulted in the pit filling before the end of the life of the discard dump. For this realization, the water was pumped from the pit to the 40 ML Dam to maintain the pit water level below the ECL.
- The Zibulo Colliery is expanding the monitoring system to include the monitoring of water volumes in the pits to action the in-pit pumping systems when the water level reaches the ECL.
- The operational water management system only has to manage the water pumped from the South Pit while the pit is being mined. The North Pit will be filling while the South Pit is being mined and will not contribute to the water balance. Once mining of the South Pit is finished, the only water that will have to be managed is the water pumped from Klipspruit Colliery to the 40 ML Dam.

4.4 Post Closure

The approach to managing the excess mine water from the North and South Pits post closure is to pump water from the pits to maintain the pit water level below the ECL. The excess water will be pumped to the EWRP via the 40ML Dam. The average water volumes that will need to be managed post closure is given in Table 17. The total volume that will need to be pumped to EWRP from the North and South Pits is estimated to be 1030 m^3/d. The total if the Klipspruit Colliery 2000 m^3/d is included, is 3030 m^3/d which is in line with the capacity of the current water supply infrastructure from the 40 ML Dam to EWRP.

Table 17: Average water volumes to be managed Post Closure

Water Source	Volume (m^3/d)
North Pit	851 – as per groundwater model
South Pit	179
Total Pits	**1030**
Klipspruit Colliery	2000
Total	**3030**

5.0 STORMWATER MANAGEMENT PLAN

A storm water management model (SWMM) was prepared for the discard facility using the PCSWMM modelling software. The objectives of the SWMM are to:

- Delineate clean and dirty storm water sub-catchments;
- Locate alignments for clean and dirty storm water conveyance channels;
- Determine cross-sections and vertical profiles of storm water conveyance channels; and
- Determine dimensions of clean and dirty storm water channels to convey storm water runoff resulting from the design storm event.

The guiding principles for the above work are taken from government regulation No. 704 of 4 June 1999 – Regulations on use of Water for Mining and related activities aimed at the Protection of Water Resources (National Water Act No. 36 of 1998) (Department of Water Affairs and Forestry, 4 June 1999), specifically clause 6. The regulation is commonly referred to as GN704.

5.1 Methodology

The United States Environmental Protection Agency Storm Water Management Model (EPA SWMM) was used to construct the rainfall-runoff model – refer https://www.epa.gov/water-research/storm-water-management-model-swmm. The Computation Hydraulics International (CHI Water – www.chiwater.com) PCSWMM model was used as the software interface for coding and running the EPA SWMM model. The model uses the US Soil Conservation Service rainfall distributions (Type I to Type IV), adapted for South African conditions (Schimdt & Schulze, 1987a). The project falls in a region of South Africa having a Type III rainfall distribution.

A topographic survey was received from the client. The survey was processed in CAD software to obtain digital elevation model (DEM) of the study area. The discard facility was developed in CAD and a DEM developed from the elevation analysis of the discard facility design. This DEM was used to obtain watershed boundaries defining the local sub-catchments.

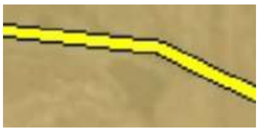
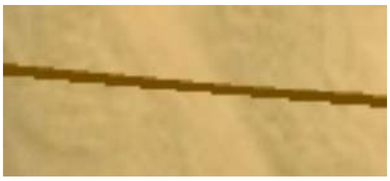
A channel layout was designed to intercept clean and dirty runoff from the corresponding sub-catchments separately. The design rainfall analysis (refer Section 2.4) was used to develop rain gauges which were then applied to the sub-catchments. The analysis was run using the 1-in-50-year recurrence interval storm event following GN-704 regulation. Parameters, relating to the catchment response to rainfall, were applied to the sub-catchments. The model was run, necessary adjustments made to optimise, and finalised.

The surface topography of the discard facility currently drains to the north. Once completed, the discard facility's surface is planned to drain towards the north as well. The intention of the stormwater management for the facility is to collect the contaminated runoff from the catchment using a concrete-lined perimeter channel around the boundary of the facility which directs water northwards towards a void in the pit. A series of bench channels are placed at 45 m horizontal intervals (5 m vertical) along the side slopes of the facility. This is to reduce the catchment sizes and hence the runoff to the respective channels. The accumulation of energy and shear forces along the slopes, which results in erosion, is therefore also fragmented. These channels are constructed out of the discard material and hence have the same hydraulic properties as the facility's sub-catchments. The bench channels are sloped southward and join the perimeter channel. At the junction of the bench channels and the perimeter channel, energy dissipators must be installed to reduce the incoming flow velocities and allow the water to change flow direction. All contaminated runoff reports to the void at the northern base of the facility. The void has not been sized as part of the stormwater assessment.

5.2 Model Layout

The key in Table 18 applies to the symbols use in the model imagery to represent the stormwater management of the discard facility:

Table 18: Key to Model Symbols

SYMBOL	DESCRIPTION
	Clean water channel, river diversion
	Discard bench channel
	Concrete-lined perimeter channel
	Berm
	Clean sub-catchment

SYMBOL	DESCRIPTION
	Dirty sub-catchment

Figure 37 shows the model layout and the sub-catchments which are relevant to the proposed infrastructure.

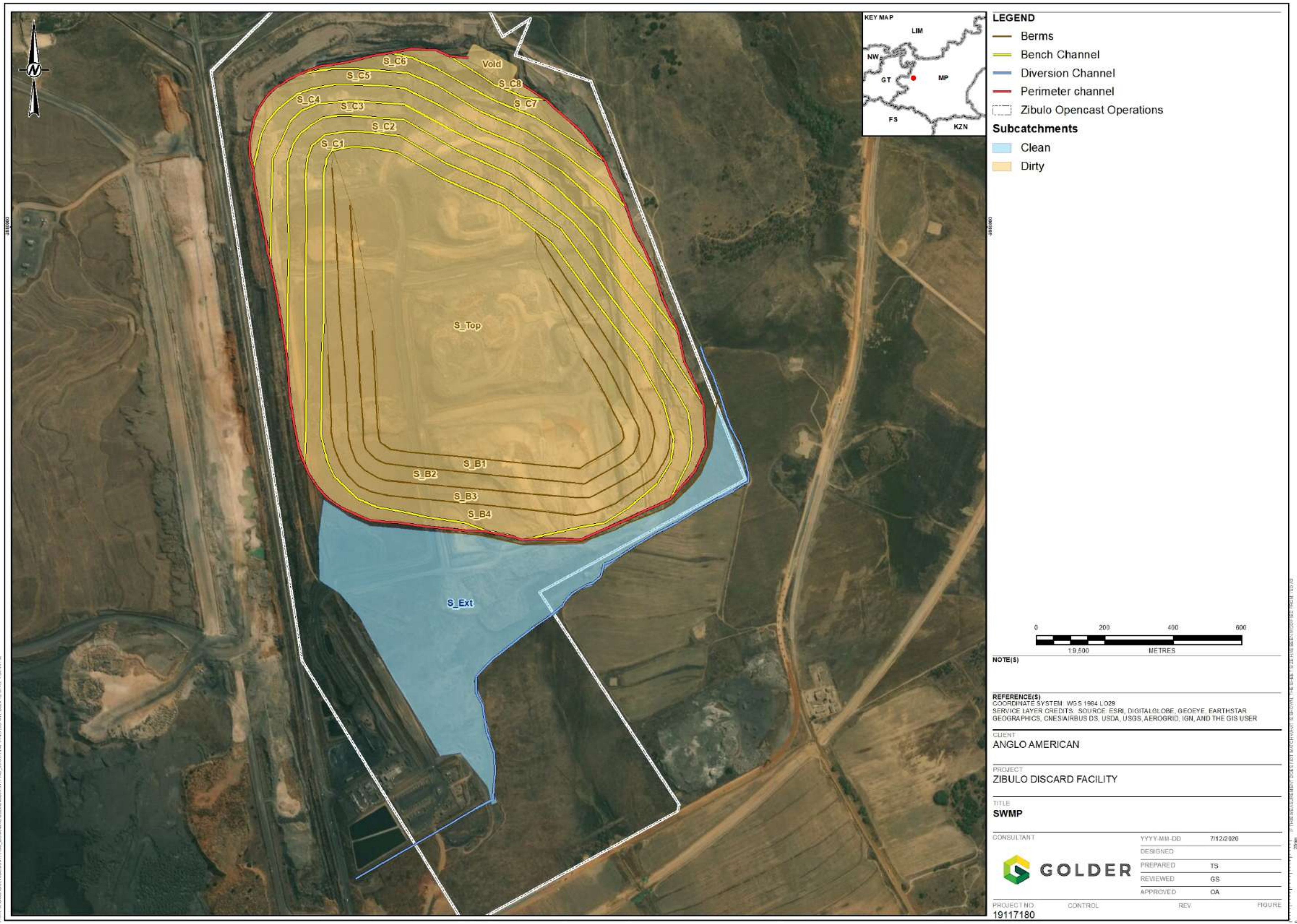


Figure 37: Zibulo Discard Facility Stormwater management plan layout

5.3 Input Parameters

Detail layouts and tables of input parameters are presented in APPENDIX C. Design rainfall used for the model was determined as described in Section 2.4. The 1:50-year return interval rainfall depth for the site is 110 mm, and the SCS-SA rainfall distribution is Type III. The resulting rainfall intensity distribution is shown in Figure 38.

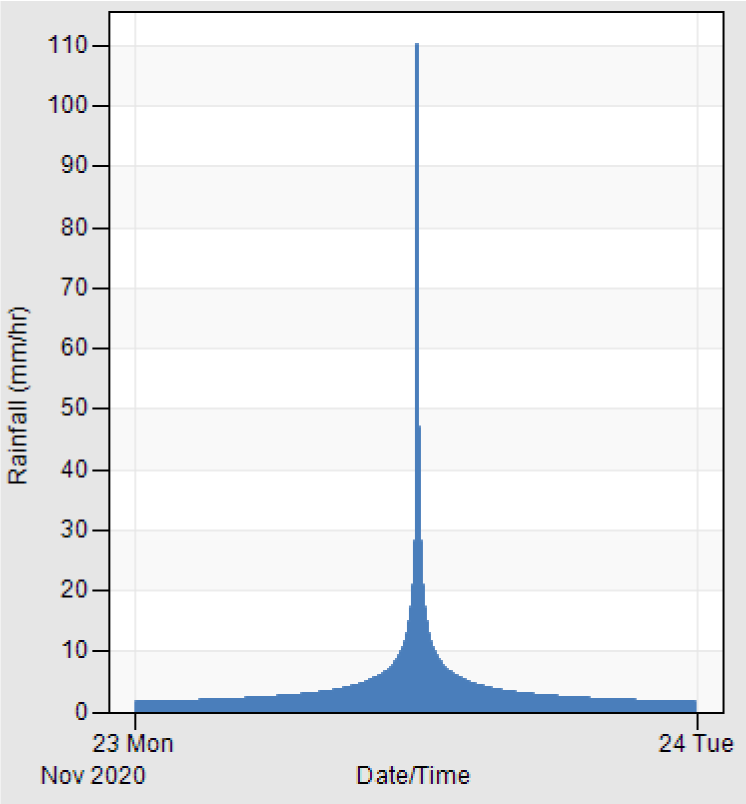


Figure 38: 1-in-50-year return interval SCS-SA Type III design rainfall distribution

Roughness of sub-catchments and channels affect time of concentration of runoff from the sub-catchments, which in turn influences the peak flow reporting from the catchment. Roughness estimations for different land uses are estimated in studies and published in tables in literature. Tables distinguish between roughness values for overland flow (sheet flow) and channelized flow (concentrated flow). (Chow, 1959) and (United States Environmental Protection Agency, May 2017) were consulted for roughness estimates for the catchments and channels. The manning's n, a roughness factor, for the discard facility was taken as 0.035. The concrete channel's Manning's n was taken as 0.015. The sub-catchment details are given in detail in Table 25 under APPENDIX C.

Abstractions remove water from the runoff in the form of depression storage and infiltration. Exact determination of depression storage is not practical and is based on estimates and experiential judgements. However, the magnitude thereof is insignificant in the large design event used for these models, and therefore high-level estimates are adequate, and are taken in the order of 0.5 mm for rough areas and 0.05 mm for impervious areas e.g., concrete, hardstand, roofs, etc. The EPA-SWMM model offers a variety of infiltration models. For this model, the Modified Green-Ampt model was selected. It takes account of soil hydraulic characteristics based on soil type. The model uses three parameters:

- Suction head (mm);
- Conductivity (mm/hr); and

- Initial deficit (fraction).

The soil type of the discard facility is assumed to represent a loamy sand with high infiltration ability. The parameters in Table 19 were therefore applied to the infiltration model.

Table 19: Provisional estimates of soil parameters for Green-Ampt Infiltration. Loamy sand was chosen for the soil type of the discard facility (United States Environmental Protection Agency, May 2017)

USDA Soil Texture Classification	Avg. Capillary Suction	Saturated Hydraulic Conductivity	Initial Moisture Deficit for Soil (Vol. of Air / Vol. of Voids, expressed as a fraction)	
	(mm)	(mm/hr)	Moist Soil Climates (Eastern US)	Dry Soil Climates (Western US)
Sand	49.5	235.6	0.346	0.404
Loamy Sand	**61.3**	**59.8**	**0.312**	**0.382**
Sandy Loam	110.1	21.8	0.246	0.358
Loam	88.9	13.2	0.193	0.346
Silt Loam	166.8	6.8	0.171	0.368
Sandy Clay Loam	218.5	3.0	0.143	0.250
Clay Loam	208.8	2.0	0.146	0.267
Silty Clay Loam	273.0	2.0	0.105	0.263
Sandy Clay	239.0	1.2	0.091	0.191
Silty Clay	292.2	1.0	0.092	0.229
Clay	316.3	0.6	0.079	0.203

The average slopes of the sub-catchments were determined from the DEM.

The benched channels were designed as trapezoidal channels with a berm on the outer side to ensure that water does not spill into the downslope strip as shown schematically in Figure 39 below.

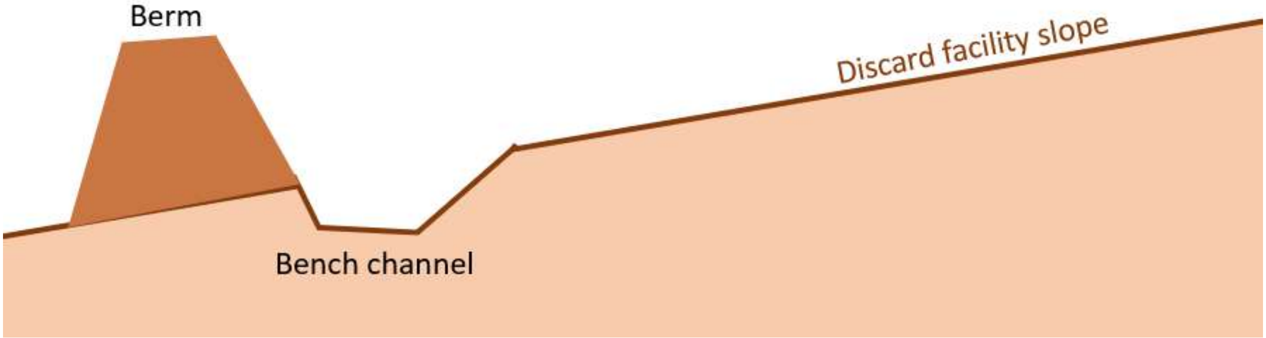


Figure 39: Bench channel cross-section schematic

The perimeter channel is a concrete-lined trapezoidal channel with a berm on the outer end to prevent clean water entering the channel from the sides. The channel has two legs which extend around the discard facility and meet at the void to the north of the facility. A schematic cross section of the channel is shown in Figure 40 below.

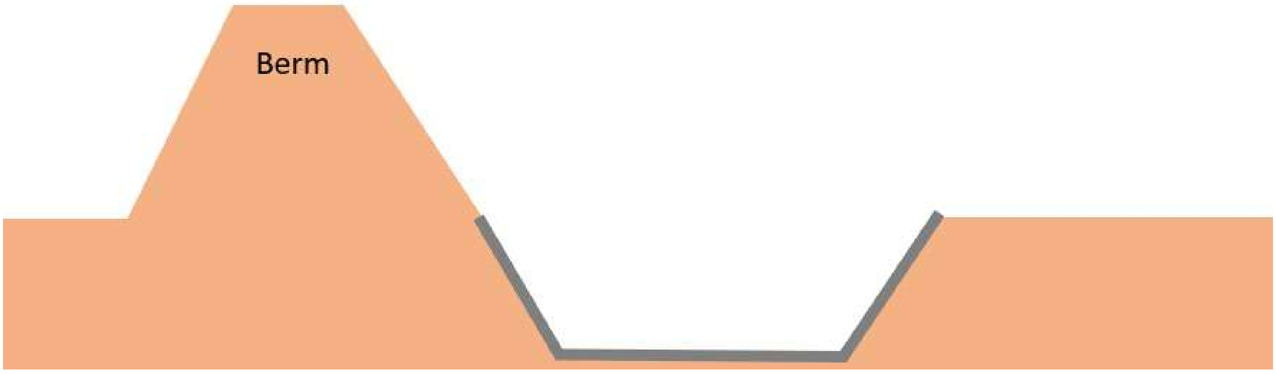


Figure 40: Perimeter channel cross-section schematic

One meter high rockfill berms with side slopes of 1:2 are proposed on the southern end of the discard facility side slopes to attenuate the runoff reducing the flow velocity reporting into the perimeter channel at the base of the facility. The berms are to be designed as a cascading system water filtering through the rockfill voids with the intention to increase the flow lag and increase the flow length which in turn will reduce the energy of runoff from the southern end. These berms are displayed in the stormwater management layout in **Figure 37** above.

There is currently a diversion channel which directs clean water towards the west of the Zibulo site and away from the discard facility. A one-meter berm with 1:2 side slopes is proposed to the southwest of the discard facility to ensure that any clean runoff from the clean sub-catchment shown in **Figure 37**is directed away from the dirty channels and contributes to the existing clean diversion channel. Following planned mining southward of the discard facility, this diversion channel is to be re-routed and re-sized which falls out of the scope of this project.

5.4 Results

Detail layouts and tables of results are presented in APPENDIX C. The hydraulic profile of the east and west legs of the perimeter channel (as proposed) are shown in Figure 41 and Figure 42 respectively. In the figures, the high point represents the south of the discard facility which slopes northward, and the low point is the void where the contaminated runoff is directed towards. The channel sizes and the respective velocities and flow rates are given in Table 26 under APPENDIX C.

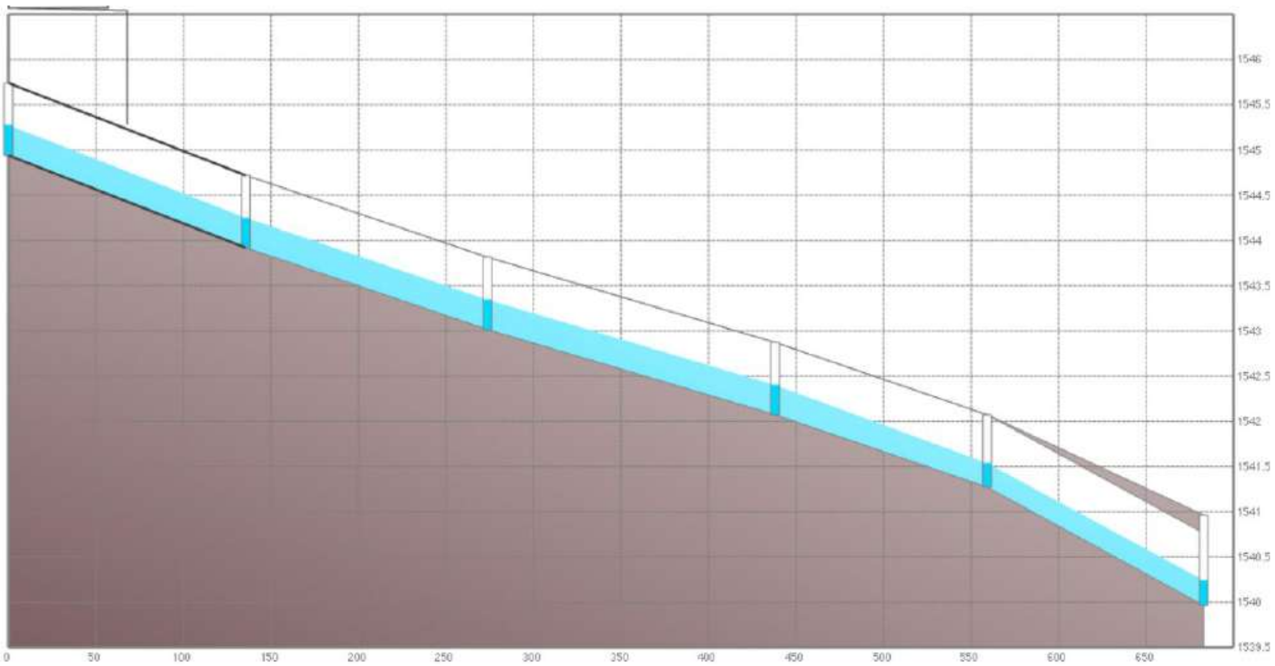


Figure 41: Eastern leg of the concrete-lined perimeter channel with water the water depth displayed in blue (units in meters)

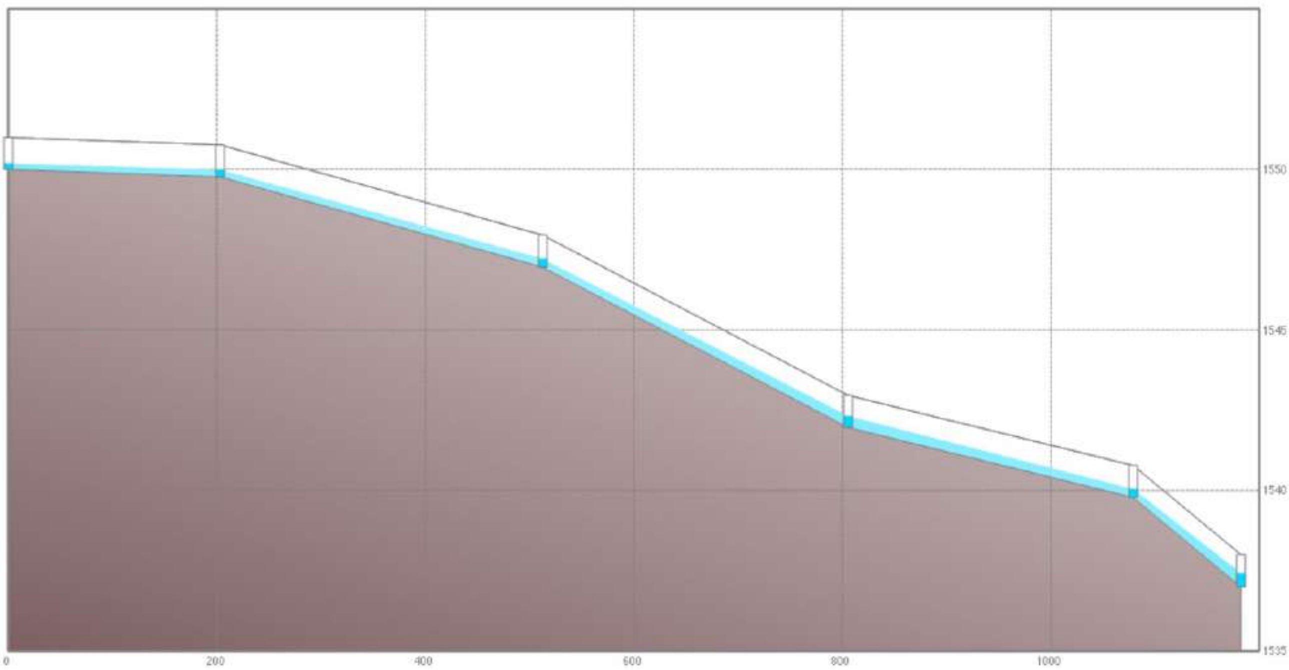


Figure 42: Western leg of the concrete-lined perimeter channel with water the water depth displayed in blue (units in meters)

The trapezoidal bench channels were sized to be 0.7 m high with a left side slope of 1:2 and a right slope of 1:9 to represent the slope of the facility. The trapezoidal perimeter channel is sized to be one meter high, with a bottom width of 2 m and 1:2 side slopes. The channel details are shown in APPENDIX C.

Due to the high velocities of the runoff in the bench and perimeter channels it is recommended that energy dissipators be installed at the junction of the bench channels and the perimeter channels as well as at the discharge points into the voids. A combination of drop chutes and stilling basins is recommended to reduce the energy for the runoff and hence reduce the flow velocities. The contour channels will also require erosion protection such as rip-rap or similar.

6.0 GEOCHEMICAL CHARACTERISATION OF DISCARD

Geochemical characterisation was undertaken on 14 discrete samples collected from the existing Klipspruit discard facility during 2015 (spatially distributed to capture any compositional variability), as well as one composite filter cake sample from the filter press and one composite coarse discard sample from Phola Plant (on a day when only Zibulo ROM coal was being processed to determine whether discard from Zibulo was materially different from the 2015 samples).

6.1 Chemical Properties

Sulphide content of discard materials varied between 0.76% and 3.6%. The least sulphide content was measured in fine discard sample from the plant. Sulphate sulphur (0.04%-0.51%) and organic sulphur (0.38%-1.4%) were also present (Table 20). The relatively higher sulphate levels in discard from the Discard dump (0.04-0.51%) than in the coarse and fine discard from the Plant (0.04%–0.05 %) suggests that samples from the dump were oxidised before analyses, due to exposure to air and water in the Discard dump. Sulphate precipitates were observed on surfaces on old sections of the Discard dump.

Bulk NP varied between 11 kg $CaCO_3$ eqv t^{-1} and 25 kg $CaCO_3$ eqv t^{-1} and was lower than CaNP (12 kg $CaCO_3$ eqv t^{-1} to 384 kg $CaCO_3$ eqv t^{-1}) in five of the six samples suggesting that siderite is the dominant carbonate mineral. The Bulk NP was similar to CaNP in the fine discard sample from the Plant indicating that calcite and dolomite are the dominant sources of NP in this sample. The paste pH was near-neutral to slightly alkaline indicating sufficient reactive NP to buffer acidity generated by the initial oxidation of sulphides during the testing procedure. There is generally insufficient buffering capacity in discard materials as Bulk NP is exceeded by SAP in all the discard samples. (*See notes after Table 20 for abbreviations*).

Table 20: Discard acid base accounting results (Golder 2015)

Parameter	Units	Plant	KPS Discard dump					
		Fine Discard	Coarse Discard					
		KPSPFD	KPSPCD	KPCDFC1	KPCDFC2	KPCDFC3	KPCDFC4	KPS - HC1♯
Paste pH	s.u	7.6	6.5	6.6	6.8	6.8	7.3	7.0
Total- S	%	1.2	4.6	3.5	2.8	5.7	3.2	2.8
Sulphide-S		0.8	3.6	2.2	1.7	3.9	2.3	2.1
Sulphate-S		0.039	0.052	0.47	0.51	0.47	0.053	0.52
Organic-S		0.38	0.97	0.77	0.61	1.42	0.85	0.22
C-Total		53	23	42	34	32	29	37
C-Inorganic		0.15	0.49	4.6	4.0	3.8	3.1	36

Parameter	Units	Plant	KPS Discard dump					
		Fine Discard	Coarse Discard					
		KPSPFD	KPSPCD	KPCDFC1	KPCDFC2	KPCDFC3	KPCDFC4	KPS - HC1♯
C-Organic		53	22	37	30	29	26	0.90
Bulk NP*	kg $CaCO_3t^{-1}$	15	11	21	21	25	14	30
CaNP*		12	41	384	335	318	262	75
SAP**		24	112	70	54	120	72	64
SNNP***		-8.8	-101	-49	-33	-95	-58	-34
SNPR‡	no units	0.63	0.10	0.30	0.39	0.21	0.19	0.47
Classification based on SNPR		PAG‡‡	PAG	PAG	PAG	PAG	PAG	PAG

**Bulk NP is NP measured by Sobek titration, CaNP is NP calculated on the basis of inorganic carbon LECO analysis. Measured NP is used for the NPR calculation*

***SAP - acid potential based on sulphide sulphur; TAP - acid potential based on the total sulphur content*

****SNNP - the difference between bulk NP and SAP; TNNP - the difference between bulk NP and TAP*

‡SNPR - Ratio of SAP and bulk NP; TNPR - Ratio of TAP and bulk NP

‡‡PAG – Potentially acid generating; Non-PAG – not potentially acid generating

♯ Humidity cell composite sample

Classification of acid rock drainage (ARD) potential per the guidelines of Morin and Hutt (2007) and MEND (2009) (**Figure 44**) shows that all the discard samples are potentially acid-generating (PAG). Classification using the guidelines of Price et al. (1997) and Soregaloli and Lawrence (1997) also shows the discard materials have a potential to generate ARD due to high total sulphur content. The NAG pH and SNPR also classifies the samples as PAG.

6.1.1 Chemical composition of the leachate

Synthetic precipitation leaching procedure (SPLP) and net acid generation (NAG) leach tests were carried out (Golder, 2015). These are short-term leach tests that measure readily soluble components of geological materials but do not predict long term water quality. Water-rock interactions often develop over periods of time that are much greater than can be represented in an 18 to 24-hour extraction test (INAP, 2010).

Leachate generated by net acid generation (NAG) leach tests represents complete and instantaneous oxidation and leaching of all reactive minerals. These tests were done to assess the maximum (worst case) quality of drainage from the discard co-disposal facility. Under field conditions, sulphide oxidation and release of elements will occur gradually and concentrations in mine drainage are expected to be lower than NAG leachate chemistry at any given time. The results indicate that the discard materials are likely to produce near-neutral, saline drainage with low concentration of metals upon exposure to rainfall. The SPLP leachate results show that the following analytes are likely to be elevated in drainage from the discard dump (Golder, 2015):

- Electrical conductivity, total dissolved solids, manganese, sulphate, calcium, magnesium, and fluoride.

The NAG results indicated that when exposed to oxidation conditions for a long period of time, the discard materials will produce acidic (ARD) drainage with elevated levels of metals. The following elements are likely to be elevated (Golder, 2015):

- pH (acidic), electrical conductivity, total dissolved solids, sulphate, sodium, nitrate, phosphate, magnesium, aluminium, cobalt, iron, molybdenum, manganese, calcium, vanadium and sodium absorption ratio (SAR).

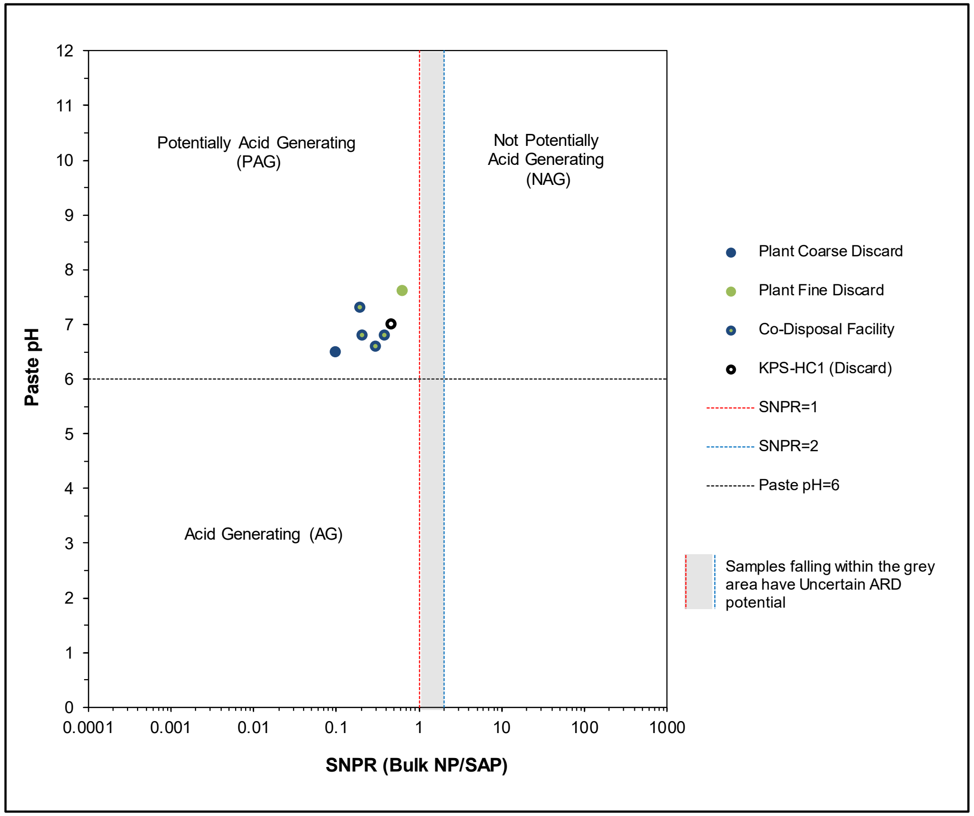


Figure 44: Plot of net potential ratio (SNPR) versus sulphide sulphur content (%S) for discard samples (Golder, 2015)

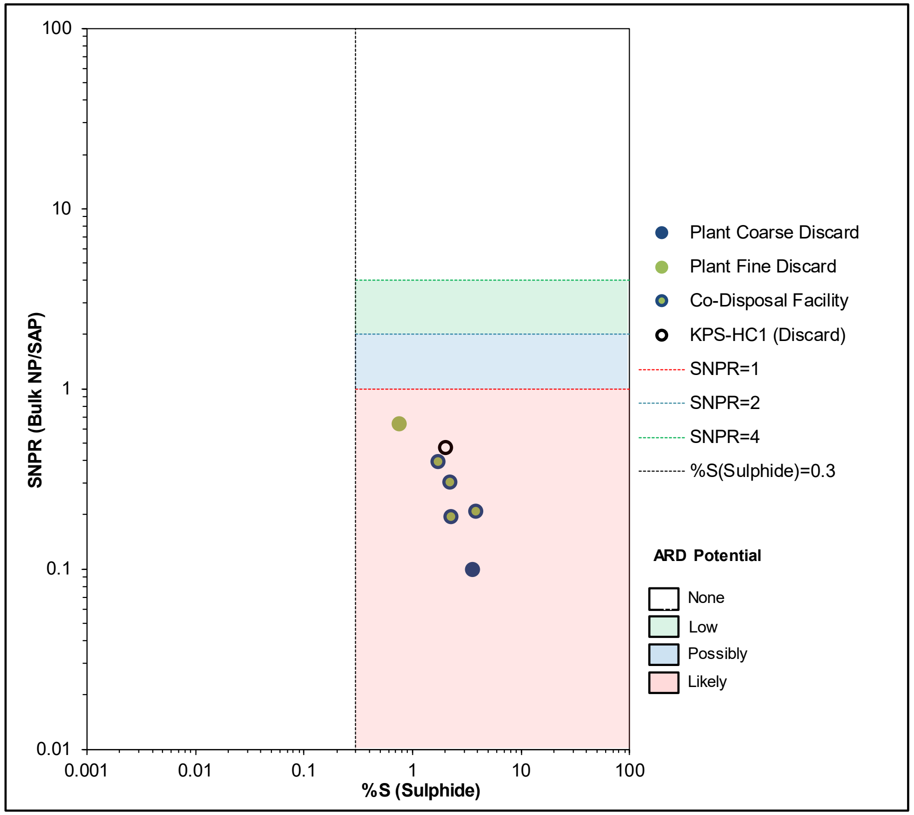


Figure 43: Plot of net potential ratio (SNPR) versus sulphide sulphur content (%S) for discard samples (Golder, 2015)

7.0 IMPACT ASSESSMENT

7.1 Key areas of concern

In respect of the discard dump the following potential surface and groundwater impacts are noted:

1) Erosion and riparian vegetation disturbance during the construction of the conveyor;
2) Surface water contamination during the operational phase;
3) Groundwater contamination during the operational phase; and
4) Decant of contaminated water to the surface water resources post closure.

7.2 Impact assessment methodology

The significance of the identified impacts was determined using the approach outlined below (terminology from the Department of Environmental Affairs Guideline document on EIA Regulations, April 1998). This approach incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows:

Occurrence		Severity	
Probability of occurrence	Duration of occurrence	Scale/ extent of impact	Magnitude (severity) of impact

To assess each of these factors for each impact, the following four ranking scales are used (Table 21):

Table 21: Impact Matrix

Probability (P) of occurrence		Duration (D)		Scale (S)/ Geographic extent		Magnitude (M)	
5	Definite / Don't know	5	Permanent	5	International	10	Very High / Don't know
4	Highly Probable	4	Long-term (impact ceases after the operational life of the activity)	4	National	8	High
3	Medium Probability	3	Medium-term (5-15 years)	3	Regional	6	Moderate
2	Local Probability	2	Short-term (0-5 years)	2	Local	4	Low
1	Improbable	1	Immediate	1	Site only	2	Minor
0	None			0	None		

Once these factors have been ranked for each impact, the significance of the two aspects, occurrence, and severity, were assessed using the following formula:

SP (significance points) = (magnitude + duration + scale) x probability

The maximum value is 100 significance points (SP). The environmental effects are then rated as of **High**

(>75 SP), **Moderate** (30 - 75 SP) or **Low** (<30 SP) significance, both with and without mitigation measures and for both occurrence and severity, on the following basis:

SP >75	Indicates high environmental significance	Where it would influence the decision regardless of any possible mitigation. An impact which could influence the decision about whether to proceed with the project.
SP 30 - 75	Indicates moderate environmental significance	Where it could have an influence on the decision unless it is mitigated. An impact or benefit which is sufficiently important to require management. Of moderate significance - could influence the decisions about the project if left unmanaged
SP <30	Indicates low environmental significance	Where it will not have an influence on the decision. Impacts with little real effect and which should not have an influence on or require modification of the project design or alternative mitigation

For the methodology outlined above, the following definitions were used:

- **Magnitude** is a measure of the degree of change in a measurement or analysis (e.g., the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, moderate or high. The categorization of the impact magnitude may be based on a set of criteria (e.g., health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely-recognised standards are to be used as a measure of the level of impact.
- **Scale/ geographic extent** refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international.
- **Duration** refers to the length of time over which an environmental impact may occur: i.e., immediate/transient, short-term (1 to 3 years), medium term (4 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project), or permanent.
- **Probability of occurrence** is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

7.3 Construction Phase Impacts

While the discard dump will be placed on an existing facility there may still be construction activities specifically related to the construction of a new conveyor.

The proposed new conveyor will lie immediately north of the existing conveyor and cross the R545 road on a dedicated bridge crossing. Soon after the crossing of the R545, the conveyor will turn north to the opencast pit for final discard disposal. The entire extent of the conveyor route is confined to mine property belonging to either South32 or AAIC.

Because the conveyor will be constructed very close to the existing conveyor and is in an already highly impacted area, it is unlikely that construction of the conveyor will have any further impact on the area.

7.4 Operational Phase Impacts

Operational phase impacts for surface and groundwater relate to the impacts to groundwater and surface water chemistry. The geochemical studies have indicated the following in respect of the discard:

i) Pyrite was found to be the only sulphide mineral identified during XRD analysis. Calcite and dolomite were found to be present in minor quantities, with their presence likely providing neutralisation potential for acidity that is formed during pyrite oxidation.

ii) Zibulo discard was classified as potential acid generating (PAG), with a net acid generation (NAG) < 4.5 and a total neutralisation potential ratio (TNPR) < 1.

iii) ARD Classification of Zibulo discard material is comparable to that of the discard samples collected from Phola Plant (Golder, 2017, Golder, 2020). Both materials classified as PAG when considering MEND (2009) and likely to produce acidic drainage when considering Price *et al*., (1997) guidelines.

iv) The average results from the two Zibulo discard samples showed higher sulphide acid potential levels than the discard samples collected from Phola Plant, but much bulk higher neutralisation – this meant that the Zibulo discard average has a less negative net neutralisation potential (SNNP -95 kg $CaCO_3$ eqvt./t compared to -101) and a higher neutralisation potential ratio (SNPR 0.37 compared to 0.10) (Golder, 2020). In summary, while all the discard materials are acid generating, the average Zibulo discard is less so.

v) Short-term leach (SPLP) results for the Zibulo discard sample are comparable to that of the discard samples collected from Phola Plant (Golder, 2017; 2020). The following chemical constituents exceeded the WQPL for the Wilge Catchment guidelines: Electrical conductivity, Total Dissolved Solids, calcium and magnesium.

vi) Kinetic testing for the Klipspruit discard samples indicated that neutralisation potential (NP) will be depleted in the long term (Golder, 2017; 2019a). Using the Klipspruit kinetic results as analogue for the proposed Zibulo discard facility, there is a risk of acid seepage in the long term that could mix with the in-pit spoil material and result in deterioration of the post closure decant quality.

vii) All discard classified as **Type 3 waste** based on the waste classification assessment.

7.4.1 Surface water contamination

The up and downstream tributaries of the Saalboomspruit (also occasionally referred to as the Saalklapspruit) are already highly contaminated with elevated electrical conductivity, total dissolved solids, calcium, magnesium, as well as aluminium, iron, and manganese. The 95-percentile data of historical data indicate values that will have an impact on ecological and human health.

The discard facility will add additional load to the river if the stormwater management is not well designed and maintained. Increased load may impact the downstream domestic and agricultural users. The impact significance is rated as moderate.

Nature of the impact		Significance of potential impact BEFORE mitigation					
		P	D	E	M	Significance	
ACTIVITY: Disposal of discard							
Contaminated stormwater runoff to the receiving watercourses	-	4	4	3	6	**52**	**Moderate**

7.4.1.1 Mitigation

Mitigation in the form of implementing an adequately designed stormwater management system as described in Section 5.0 and APPENDIX C to meet the GN 704 requirements of separating clean and dirty water, will assist in ensuring that only clean water from the eastern sub-catchment drains to the Saalboomspruit and ultimately helps to achieve the legislated requirements at EWR 4 in the Wilge River. It is also important that

South32 (Klipspruit Colliery) and AAIC (Zibulo Opencast) work together to rehabilitate existing areas of concern and ensure cleaner mine areas to improve the quality of the run-off to the catchment right from the upper catchment. Experience has indicated that there will still be some contamination to the surface water resources, however, this will be considerably reduced, should the mentioned mitigation measures be implemented, changing the significance rating to low.

Mitigation Measures	Significance of potential impact AFTER mitigation					
	P	D	E	M	Significance	
ACTIVITY: Disposal of discard						
Ensure stormwater system is designed to meet GN704 to limit contaminated water entering the tributaries and diverting clean water on the eastern side of the pit to the Saalboomspruit.	3	4	2	2	**24**	**Low**

7.4.2 Groundwater contamination

Groundwater quality within the backfilled opencast areas, including the overlying discard dump, is expected to deteriorate due to acid mine drainage and other chemical interactions between the geological and the groundwater regime. The resulting groundwater pollution plume will migrate along the new local and regional hydraulic gradients as the water table rebounds. Based on the topographic setting of the mine and the post-closure topography including the discard dump, the rebounding water table will lead to surface decant of mine water of approximately 620 m^3/d (0.62 ML/d). Based on the current mine plan, the expected critical level to prevent surface decant is estimated at 1 527 mamsl, while the Environmental Critical Level (ECL) to prevent diffuse decant will be at a lower level and depends on the actual weathering depth around the pit perimeter (assumed to be 15 m for the model simulations).

While a limited spreading of leachate from the backfilled pit (with or without the discard dump) into the weathered aquifer is expected for its western, southern, and eastern edges, the migration of the plume towards the north is significant and may trigger potential off-site migration.

Nature of the impact		Significance of potential impact BEFORE mitigation					
		P	D	E	M	Significance	
ACTIVITY: Disposal of discard							
Contaminated recharge to the groundwater	-	4	4	2	6	**48**	**Moderate**

7.4.2.1 Mitigation

Seepage from the discard will be managed by the existing pit water management system in place. Excess mine water make intercepted at the pit is currently sent to the eMalahleni Water Reclamation Plant (EWRP) for treatment. It is important that the current boreholes are augmented by additional proposed boreholes included in the Monitoring Programmes.

Rehabilitation of the discard facility will require the construction of a cover that will be installed during ongoing rehabilitation.

The cover will allow for a growth medium suitable for the establishment of vegetation to limit erosion, and limit seepage into the discard facility. Soil for the cover will be sourced from on site.

Implementation of the mitigation will reduce the impact significance to low.

Mitigation Measures	Significance of potential impact AFTER mitigation					
	P	D	E	M	Significance	
ACTIVITY: Disposal of discard						
Excess mine water interception and treatment at EWRP	3	4	2	2	**24**	**Low**

7.5 Impacts at closure/ post closure

7.5.1 Decant of contaminated water to the surface water resources post closure

At closure the groundwater quality, specifically sulphate, in the pit area is expected to have deteriorated significantly to concentrations > 4 000mg/L for both the capped and uncapped scenarios, and the pollution plume at 50 and 100 years is expected to extend 570 and 800 m respectively for the uncapped scenario and 480 and 700 m for the capped scenario. Decant is expected to be at an estimated rate of 818 m^3/d for the uncapped scenario and 620 m^3/d for the capped scenario.

In this respect the decant could add significant contaminant load to the surface water resources and is rated as having a high impact significance.

Nature of the impact	Significance of potential impact BEFORE mitigation					
	P	D	E	M	Significance	
ACTIVITY: Discard facility closure						
Contaminated recharge to the groundwater and subsequent decant to the surface water	5	5	2	10	**85**	**High**

7.5.1.1 Mitigation

To prevent the decant, boreholes will be pumped and the contaminated water treated at the EWRP. This mitigation will ensure that the impact significance is reduced to low.

Nature of the impact	Significance of potential impact AFTER mitigation					
	P	D	E	M	Significance	
ACTIVITY: Discard facility closure						
Contaminated recharge to the groundwater and subsequent decant to the surface water	2	5	2	4	**22**	**Low**

8.0 MONITORING PROGRAMMES

The surface and groundwater monitoring programmes must be maintained and improved if necessary, as circumstances might change.

8.1 Surface Water Monitoring

The surface water monitoring programme must include monthly sampling at the sampling points described in Table 22 for the parameters set out in Table 23.

Table 22: Surface Water Monitoring Sites

Site ID	Latitude	Longitude	Description
ZC1	-25.96756	29.02706	Most downstream point in Saalboomspruit downstream of Phola
ZC2	-26.005407	29.02587	Saalboomspruit on the R545 crossing near Phola
ZC3	-26.02106	29.02753	Small tributary downstream of Klipspruit Opencast on N12
ZC4	-26.04488	29.04836	Canal from Ogies to Zibulo Opencast (Upstream Locality)
ZC5	-26.0276717	29.05469167	Tributary east of Zibulo Opencast
ZC6	-26.0258767	29.05585	Tributary east of Zibulo Opencast at road crossing
ZC7	-26.02272	29.051617	Combined ZC5 and ZC6 tributaries downstream of Zibulo Opencast
ZC8	-26.022928	29.046566	Tributary draining north, downstream of Zibulo Opencast, to the unnamed tributary that flows through Phila to the Saalboomspruit

Table 23: Parameters to be measured

Variable	Units
pH	
Electrical Conductivity	mS/m
Total Dissolved Solids	mg/L
Calcium	mg/L
Magnesium	mg/L
Sodium	mg/L
Potassium	mg/L
Alkalinity	mg/L
Chloride	mg/L
Sulphate	mg/L
Nitrate	mg/L
Nitrite	mg/L
Fluoride	mg/L
Aluminium	mg/L
Iron	mg/L
Manganese	mg/L
Ammonium	mg/L
Acidity	mg/L
Total Hardness	mg/L
Orthophosphate as P	mg/L

In addition to the above-mentioned parameters, the Upper Olifants Integrated Water Quality Management Plan (DWS, 2016a) propose that the following key pollutants also be measured. It is therefore proposed that these parameters be measured quarterly for the surface water sites.

- Antimony
- Lead
- Arsenic
- Mercury
- Barium
- Nickel
- Beryllium
- Selenium
- Bromide
- Thallium
- Cadmium
- Uranium
- Cobalt
- Vanadium

8.2 Groundwater Monitoring

Groundwater monitoring must include:

- Monthly borehole level monitoring, and
- Quarterly water quality analyses, for at least the parameters included in Table 23.

Table 24: Boreholes to be monitored

Borehole ID	Latitude	Longitude
BSW01		
BSW02		
BSW03		
BSW04		
BSW05		
BSW06		
BSW07		
BSW08		
BSW09		
WSW14		
BSW10	29.04714	-26.03952
BSW11	29.05106	-26.03579
BSW12	29.05214	-26.03479
BSW13p	29.04694	-26.04282
BSW14p	29.04555	-26.04349
BSW15p	29.04558	-26.04001
BSW16	29.04898	-26.02725
BSW17	29.04493	-26.02294
BSW18	29.03772	-26.031474

9.0 CONCLUSIONS

From a surface and groundwater perspective, the impacts from a discard facility constructed on the Zibulo Opencast pit area could have a moderate to high impact on the water resources, however, should mitigation be put in place then the impacts should be reduced.

10.0 REFERENCES

Department of Water and Sanitation (DWS) (2016) Development of an Integrated Water Quality Management Plan for the Olifants River System: Water Quality Planning Limits Report. Study Report No. 3, Report No: P WMA 04/B50/00/8916/4

Department of Water and Sanitation (DWS) (2016a) Development of an Integrated Water Quality Management Plan for the Olifants River System: Upper Olifants Sub-catchment Plan. Study Report No. 7. Report No: P WMA 04/B50/00/8916/8

Delta-H (2020) (In Progress) Zibulo Colliery Open Cast. 2019/2020 Hydrogeological Investigation. Technical Memo no. Delh.2019.011-9_D (v1)

Golder (2020) Zibulo Discard Seepage Assessment. Technical Memorandum. 19117180 Memo 005 Draft

Golder (2015) Preliminary Engineering Design of the Discard Dump at Klipspruit Colliery. Report Number: 12614564-297594-2

Signature Page

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https://golderassociates.sharepoint.com/sites/104294/project files/6 deliverables/19117180-337629-10_hydrology/19117180-337629-10_hydrologyhydrogeology_final_12apr2021.docx

APPENDIX A

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GOLDER ASSOCIATES AFRICA (PTY) LTD

APPENDIX B

Delta H Memo

Delta-H Water Systems Modelling PTY (Ltd)
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ZIBULO COLLIERY (DISCARD DUMP) – GROUNDWATER FLOW AND TRANSPORT MODEL SCENARIOS

1. BACKGROUND

Delta-H (Delta-H Water System Modelling PTY Ltd) have been responsible for a number of geohydrological tasks for the Zibulo Colliery since 2015, which included the development of site-specific groundwater flow and transport models for both the underground as well as the open cast workings near Ogies. The last model update for the Zibulo open cast was done in October 2020 to assess potential water ingress into the new Southern Box cut (including further mining in the southern section).

Delta-H was appointed by Golder to update this latest groundwater flow model to assess the potential long-term impact from the proposed Zibulo coal discard facility. A summary of the scope of work is provided below:

1.1. Scope of work

The following actions were listed for the open cast geohydrological investigation.

- Use the existing Southern Box-cut model and convert it into a contaminant transport model for the coal discard facility.
- Incorporate the discard dump source term (leachate concentrations and seepage rates) provided by Golder for various scenarios into the model.
- Numerical groundwater flow model update to assess:
    - LOM Inflow Simulation (use existing results).
    - Estimate the water management level in the pits below which the water must be managed to limit plume development.
    - Closure scenarios including the discard facility with and without a soil cover.
    - Additional closure scenarios including abstraction scenario to keep water levels below decant elevation.
- Technical memo documenting results.

2. DATA COLLATION

2.1. WATER QUALITY

The sample number and median concentrations of selected constituents of groundwater samples from the Zibulo open cast monitoring data are given in Table 2.1. The results indicate that the pollution plume is essentially limited to the open cast area itself, as the pits act as a sink and plume movement is towards the pit. Based on the results, the local groundwater quality at the Zibulo open cast mine is classified as near neutral (pH in the range of 5.8 to 8.0) with generally low Total Dissolved Solids (TDS) contents, ranging from around 24 to 204 mg/L. Apart from borehole BSW04 located adjacent to the Pollution Control Dam (PCD), the samples are within the specified WUL limits.

Table 2.1: Median groundwater quality results of the open cast monitoring boreholes.

Parameter	SANS 241-1 (2015)	DWAF, 1996 (Class 2)	Zibulo OC IWUL	BSW01	BSW02	BSW03	BSW04	BSW05	BSW06	BSW07	BSW09	WSW14
No. of samples				15	24	22	22	20	40	17	17	14
Latest Sample				Mar-17	Nov-18	Sep-19	Sep-19	Mar-19	Jun-19	Jun-19	Dec-16	Mar-16
pH	5 - 9.7	4-5 or 9.5-10	6.2 to 8.0	8.0	6.7	7.5	5.8	7.2	6.5	7.7	7.0	7.3
EC mS/m	170	150-370	54	13.2	5.2	36.9	31.8	18.1	0.8	26.6	13.9	8.3
TDS mg/L	1200	1000-2400	344	68.5	25.5	227.5	185.5	104.0	24.0	156.0	80.5	37.0
Tot Hardness mg/L			-	51.0	10.0	134.0	116.0	62.5	9.0	111.5	27.0	29.0
Ca mg/L	150	150-300	71	11.6	1.9	31.0	23.4	16.5	1.7	28.0	5.8	6.7
Mg mg/L	70	70-100	16	5.6	1.3	14.3	14.0	5.4	1.1	10.2	3.1	3.0
Na mg/ L	200	200-600	40	3.7	2.2	21.4	12.8	12.3	3.6	11.4	17.9	2.2
K mg/L	-	50-100	8	5.9	3.9	7.4	3.3	4.1	1.1	6.5	3.0	2.9
TALK $CaCO_3$/L	-		272	61.1	17.3	144.5	11.0	96.2	13.9	143.0	73.2	34.1
Cl mg/L	300	200-600	29	2.3	2.3	11.1	6.6	1.9	3.3	5.2	1.3	2.0
SO4 mg/L	250/500	400-600	20	1.1	2.0	12.5	99.9	1.4	0.6	1.0	0.4	0.8
F mg/L	1.5	1-1.5	6.6	0.35	0.43	0.27	0.18	0.36	0.33	0.63	0.24	0.16
NO_3-N mg/L	11	10-20	-	0.28	0.34	0.74	4.77	0.34	0.61	0.31	0.28	0.24
NH_4-N mg/L	1.5		-	1.49	0.21	0.09	0.06	0.08	0.29	1.00	0.14	0.08
PO4 mg/L			-	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Al mg/L	0.3	0.15-0.5	0.66	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.003
Fe mg/L	0.3 / 2	0.2-2	47	0.006	0.009	0.006	0.005	2.810	0.009	0.006	3.430	0.003
Mn mg/L	0.5	0.1-1	0.59	0.002	0.027	0.012	0.004	0.003	0.042	0.058	0.251	0.013
Zn mg/ L	5		-	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002

The Pollution Control Dams (PCDs) of both the Zibulo underground (UG) and open cast (OC) sections are identified as potential sources of groundwater pollution and as good indicators of the dewatered mine water qualities. The sample number and median concentrations of selected constituents of groundwater samples from the Zibulo open cast process water monitoring data are given in Table 2.2. The main constituents of concern (acidity and sulphate concentrations) are indicative of acid mine drainage from sulphur enriched waste rocks (OC) or exposed host rocks (UG). The water quality samples of the open cast PCD show an increasing trend in sulphate concentrations (Figure 2-1).

Table 2.2: Median water quality results of the PCDs located at the open cast sections (Jan-2015 to Sep-2019.

	Zibulo OC IWUL	ZC PC1	ZC PC2
No. of samples		32	33
pH	6.2 to 8.0	8.1	8.3
EC mS/m	54	170.5	204.0
TDS mg/L	344	1433.0	1662.0
TotHardness mg/L	-	948.0	1025.5
Ca mg/L	71	179.0	215.0
Mg mg/L	16	86.1	87.5
Na mg/L	40	71.1	137.0
K mg/L	8	12.0	11.5
TALK $CaCO_3$/L	272	156.0	269.0
Cl mg/L	29	11.7	14.0
SO_4 mg/L	20	843.0	882.0
F mg/L	6.6	2.13	3.95
NO_3-N mg/L	-	0.88	0.77
NH_4-N mg/L	-	0.15	0.14
PO4 mg/L	-	0.02	0.06
Al mg/L	0.66	0.003	0.003
Fe mg/L	47	0.003	0.003
Mn mg/L	0.59	0.076	0.060
Zn mg/L	-	0.002	0.002

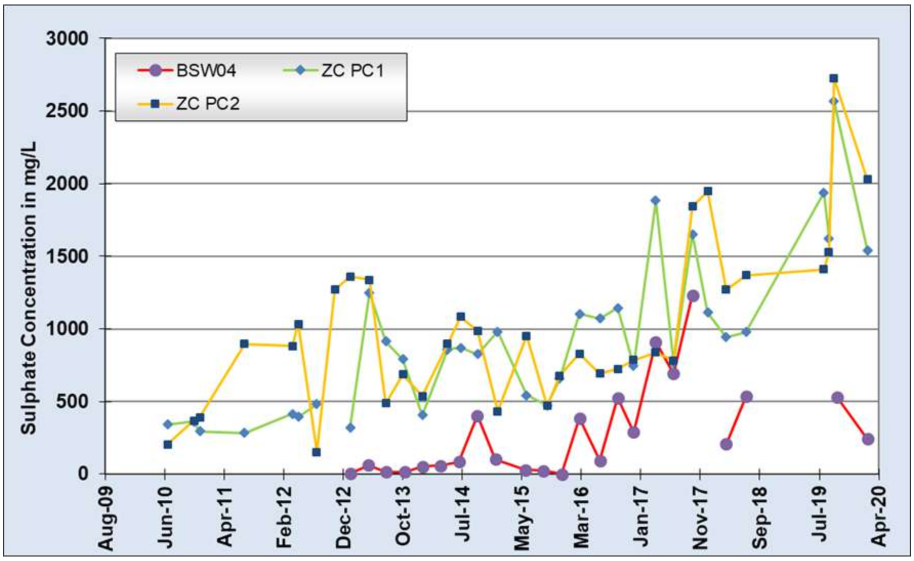

Figure 2-1: Sulphate trends for the Zibulo open cast PCDS and borehole BSW4 (June-2010 to Apr-2020).

2.2. WATER LEVELS

Water levels range from 3.5 mbgl (metres below ground level) to 24.2 mbgl based on the data collated from the Zibulo monitoring data (Table 2.3). Water levels were also collated from the SFF responsible for water level monitoring for the Ogies 'old' underground workings (Table 2.4). A summary of the collated water levels is shown in Table 2.3. Groundwater levels range from 2.8 mbgl to 8.39 mbgl within the shallow aquifer. Deeper groundwater levels of up to 68.9 mbgl are measured in the deeper piezometers representing the deeper fractured rock aquifer and the influence of the 'old' underground mine workings. As part of the Zibulo Southern Box-cut project additional monitoring and aquifer characteristics boreholes were drilled. Three boreholes were drilled to assess the potential for upfront dewatering of the proposed southern box-cut. A further three boreholes were drilled along the perimeter of the Zibulo open cast and the Ogies Strategic Fuel Fund (SFF) underground bunker/mine workings. A summary of the water levels is provided in Table 2.5. Borehole water level locations are shown in Figure 3-1 (refer to section 3.1).

Table 2.3: Summary of water levels for the Zibulo open cast monitoring boreholes.

Borehole ID	Median WL (mbgl)	Last measurement
BSW01	5.8	Mar-17
BSW02	7.4	Nov-18
BSW03	24.2	Mar-19
BSW04	14.7	Jun-18
BSW05	6.7	Mar-19
BSW06	5.6	Mar-19
BSW07	3.5	Mar-19
BSW09	7.4	Dec-16
WSW14	8.6	Sep-16

Table 2.4: Summary of water levels for the old Ogies underground workings (received from the SFF[1]).

Borehole ID	Median WL (Deep) (mbgl)	Median WL (Shallow) (mbgl)	Last measurement	Count
CSIR-1	-		Vandalised	-
CSIR-2	2.90	2.80	Jun-19	16
O11-RRA	7.47	-	blocked	5
O11A	7.94	-	Dry	1
O11C	-	6.15		18
O12	5.60		Jun-19	16
O18	52.97	7.67	Vandalised	9
O20	42.97	6.30	Jun-19	18
O22	68.92	6.45	Jun-19	15
O27	18.21	8.39	Jun-19	15

Table 2.5: Summary of water levels for the newly drilled Zibulo open cast boreholes.

BH ID	Longitude	Latitude	BH Depth (mbgl)	Drill diameter (mm)	Casing Diameter (mm)	Solid Casing (m)	Screened Casing (m)	Water Strike	Water Level (m bgl)	
									June-20	Sep-20
BSW10	29.04714	-26.03952	50	203	217	6	-	none	-	37.6
BSW11	29.05106	-26.03579	50	203	217	0-12	-	none	8.43	8.1
BSW12	29.05214	-26.03479	55	203	217	0-12	-	none	28.94	14.37
BSW13p	29.04694	-26.04282	55	203	217	0-12	-	none	collapsed	
BSW14p	29.04555	-26.04349	55	203	217	0-12	-	none	11.41	
BSW15p	29.04558	-26.04001	40	203	217 and 140	0-1,3-5	1-3,5-40	1 m	14.47	

2.3. WATER BALANCE

The average open cast mine pumping rates from January 2018 to July 2019 are shown in Figure 2-2. The graph also indicates the water pumped from the PCD to Phola. Recent flow meter reports[2] show very little data from the Zibulo open cast, but based on the (limited) available long-term records (2018 to current) an average volume of 855 m^3/d (or ~0.9 ML/d) is pumped from the pit.

[1] E-mail Correspondence: – 30 July 2019, Enoch Makunyane (EnochM@strategicfuelfund.co.za).
[2] E-mail Correspondence: – 3 November 2020, Nxumalo, Nsuku (Nsuku.Nxumalo@angloamerican.com).

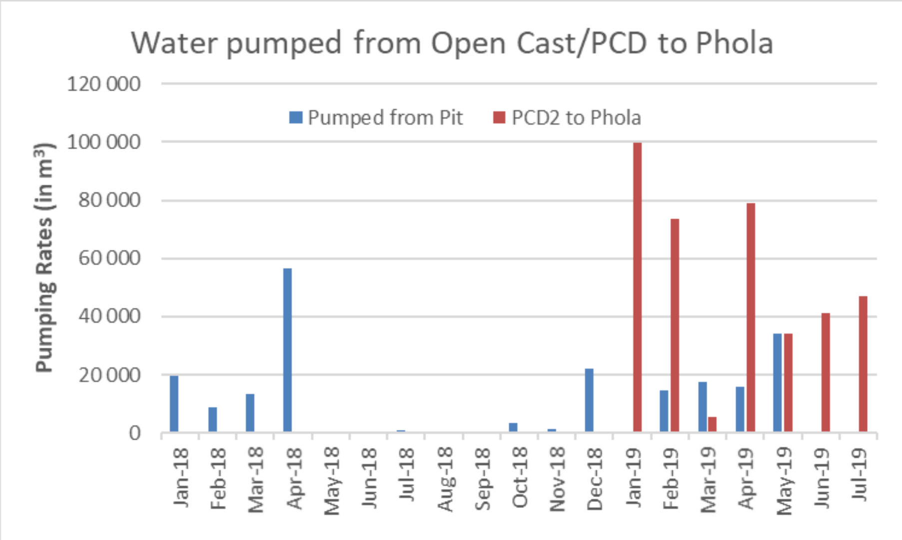

Figure 2-2: Open cast monthly pumping rates.

2.4. Recharge/Seepage

A higher proportion of rainfall infiltration and recharge may occur in areas where the natural vegetation is reduced and the natural permeability is increased such in stripped or backfilled areas, areas of inward draining or areas of increased fracturing (and potentially subsidence) associated with mining. Considering the substantial uncertainty associated with recharge/seepage estimates in general and for mining influenced areas in specific, Delta H moderated the different values and used the estimates as given in Table 2.6. The percentage values are generally used in Anglo Coal groundwater model applications.

Table 2.6: Estimated recharge rates for the Zibulo open cast.

Unit	Life of Mine		Post-closure	
	(% of MAP)	(mm/a)	(% of MAP)	(mm/a)
Weathered Karoo and Alluvium	3%	22	3%	22
Open cuts	20%	143	na	na
Unrehabilitated spoils	15%	105	na	na
Rehabilitated spoils	8%	57	8%	57

3. OPEN CAST AND DISCARD IMPACT MODELLING

3.1. Existing mine inflow simulation

The current mining areas, as contained in the digital elevation model supplied by the client (Zibulo 2019-04-29 DTM.asc), were integrated into the model domain by altering the local elevation and assigning a free seepage boundary to the respective areas. It is assumed that any groundwater entering the cuts is removed (pumped out) instantaneously and that the pits represent therefore net groundwater drains. In other words, groundwater can seep freely into the box cuts and is instantaneously removed from there, with subsequent development of cones of dewatering. No groundwater storage, flow within or seepage from the pits into the underlying aquifer is considered.

The simulations of future mine inflows over life of mine require a representation of planned box cuts. The future box cuts were therefore represented in the digital elevation model by aligning the surface elevation of the respective cut to the floor of the targeted coal seam and assigning a free seepage boundary to the respective areas. The LoM mine schedule is shown in Figure 3-1.

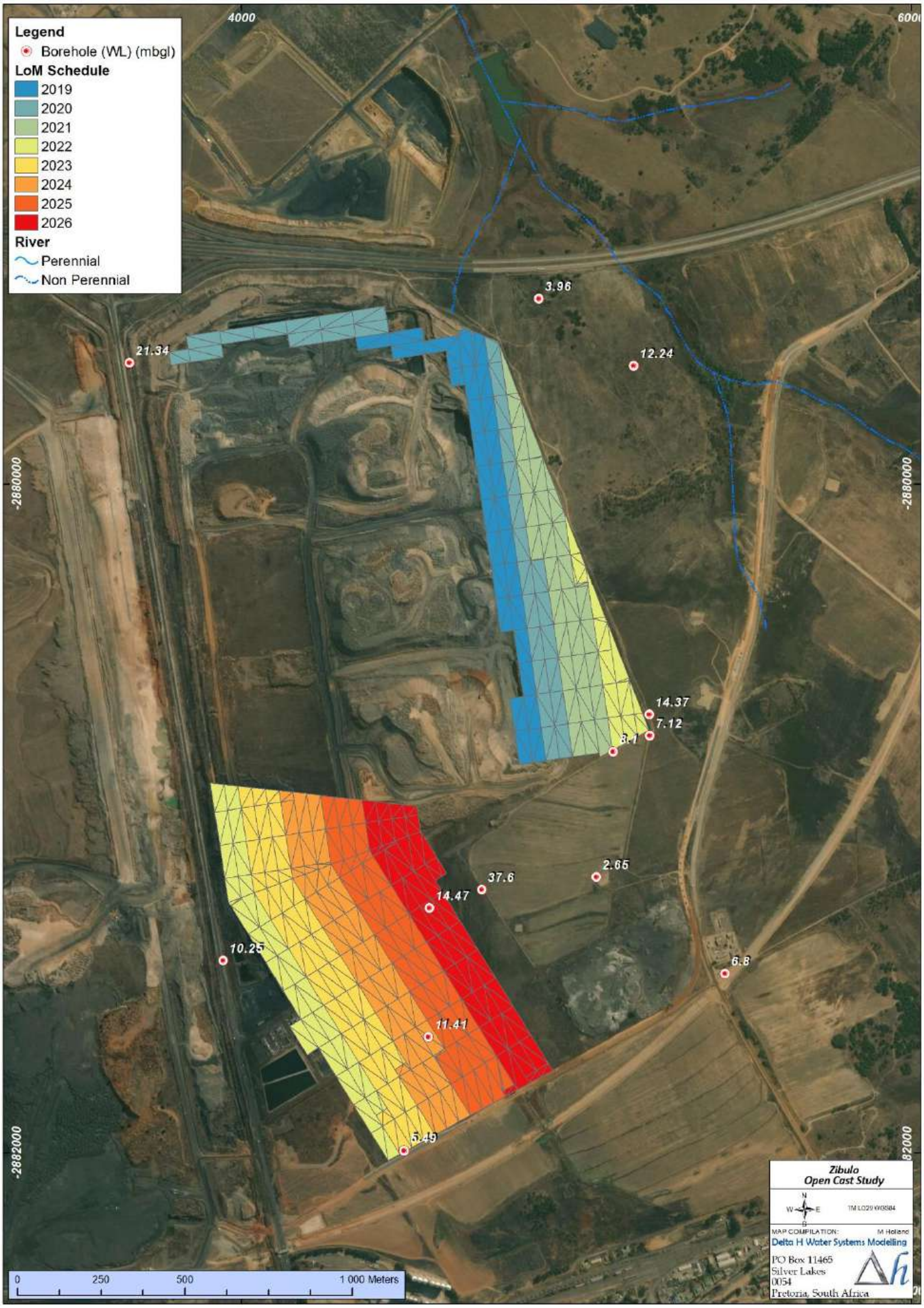

Figure 3-1: LoM period plan of the Zibulo open cast (points indicate borehole locations recent water levels).

The future backfilled opencast mine workings for a given year were equally incorporated into the model by “back-filling” the box cuts of the previous model year up to the envisaged post-closure topography. This was achieved by adjusting the surface elevation of the previous box-cut areas to the envisaged post-closure topography and assigning higher permeabilities (2E-05 m/s), porosities (20%) and recharge rates (57 mm/a, Table 2.6) to these areas. This process was iteratively repeated for each simulation year until the end of planned life of mine was reached for the respective open cast mining area. The simulated life of mine inflows for the Zibulo open cast are given in Table 3.1.

Table 3.1: Simulated mine inflows for the Zibulo open cast (current and LoM).

Year	m^3/day
Current	1 207
2021	1 289
2022	1 500
2023	1 362
2024	1 154
2025	1 271
2026	1 300

3.2. POST-CLOSURE SIMULATION

3.2.1. Base case (No Discard)

To reduce the overall water, make at the end of life of mine, Anglo Coal envisages reshaping the surface topography of the backfilled areas to maximise free draining areas. Thus, for the backfilling of the Zibulo open cast area, a drainage system will be re-created in the place of the existing relict wetland system that will transport all surface runoff water to the wetland in the north. The backfilled areas will also be top soiled and seeded to enhance vegetation growth and thereby minimising the infiltration of rainwater recharging the spoils material.

The following digital elevation model (refer to figure) of the envisaged post-closure topography were considered in the post closure simulations:

- 18March2015_Zibulo_Wetland re-establishment_post closure topography.dxf

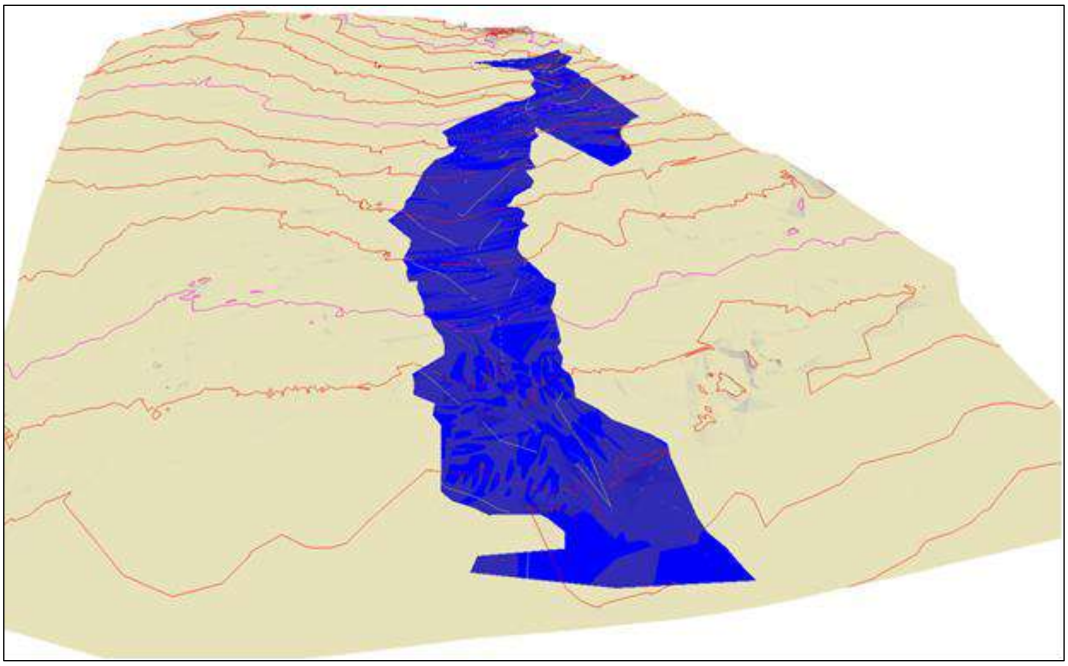

Figure 3-2: Post closure surface drainage plan for the Zibulo open cast.

To identify and quantify potential decant from the backfilled areas, a free seepage boundary was assigned to the surface of the backfilled areas. It is assumed that any decanting water will contribute to surface run-off only (i.e. removed from the groundwater flow system) and not re-infiltrate into the aquifer again. This simplification neglects potential surface-groundwater interactions downstream of decant points. The predictive post-closure simulation was performed as a transient simulation with a monthly time step width over a period of 100 years to provide an estimation of the post-closure rebound of the water table.

No post-closure water qualities were formally predicted for the Zibulo open cast (backfill material). The Zibulo site monitoring data (more specifically the PCDs) as well as the sampled open cast Ramp water qualities (Delta-H, 2020) were therefore used as proxies for the likely sulphate (source) concentrations of 2 500 mg/L.

Figure 3-3 shows the base case (no discard) pollution plume (with a cut-off value of 250 mg/l sulphate, which is the aesthetic health (SANS 241-1:2015) limit) 50- and 100-years post-closure. The 500 mg/l sulphate contour is also shown, which represent the acute health (poses an immediate unacceptable health risk) (SANS 241-1:2015) limit. Note that for comparison purposes of the model scenarios, all plumes are shown with an equal scale.

The pollution plume from the Zibulo open cast spoils extends 50 years post-closure approximately 400 m north north-east towards the surface water drainage line. Smaller plume extents are predicted towards the north northwest. After 100 years the plume has migrated approximately 650 m north north-east. Only a limited spreading of leachate from the backfilled pit into the weathered aquifer is expected for its western, southern, and eastern edges.

Surface decant is expected to occur at the most north north-eastern edge of the pit. The timing of decant is subject to rehabilitation periods as well as rebounding rate of in-pit water levels. The simulated head rebound to surface decant elevation is shown in Figure 3-5, while the long-term decant rate is shown in Figure 3-5. Long-term (base case) decant rates is estimated at around 540 m^3/d (or ~0.54 ML/d).

Based on the current mine plan, the preliminary critical level to prevent surface decant is <u>1527 mamsl</u>, while the Environmental Critical Level (ECL) to prevent diffuse decant into the shallow weathered aquifer will be at a lower level (depending on the actual weathering depth from the pit walls).

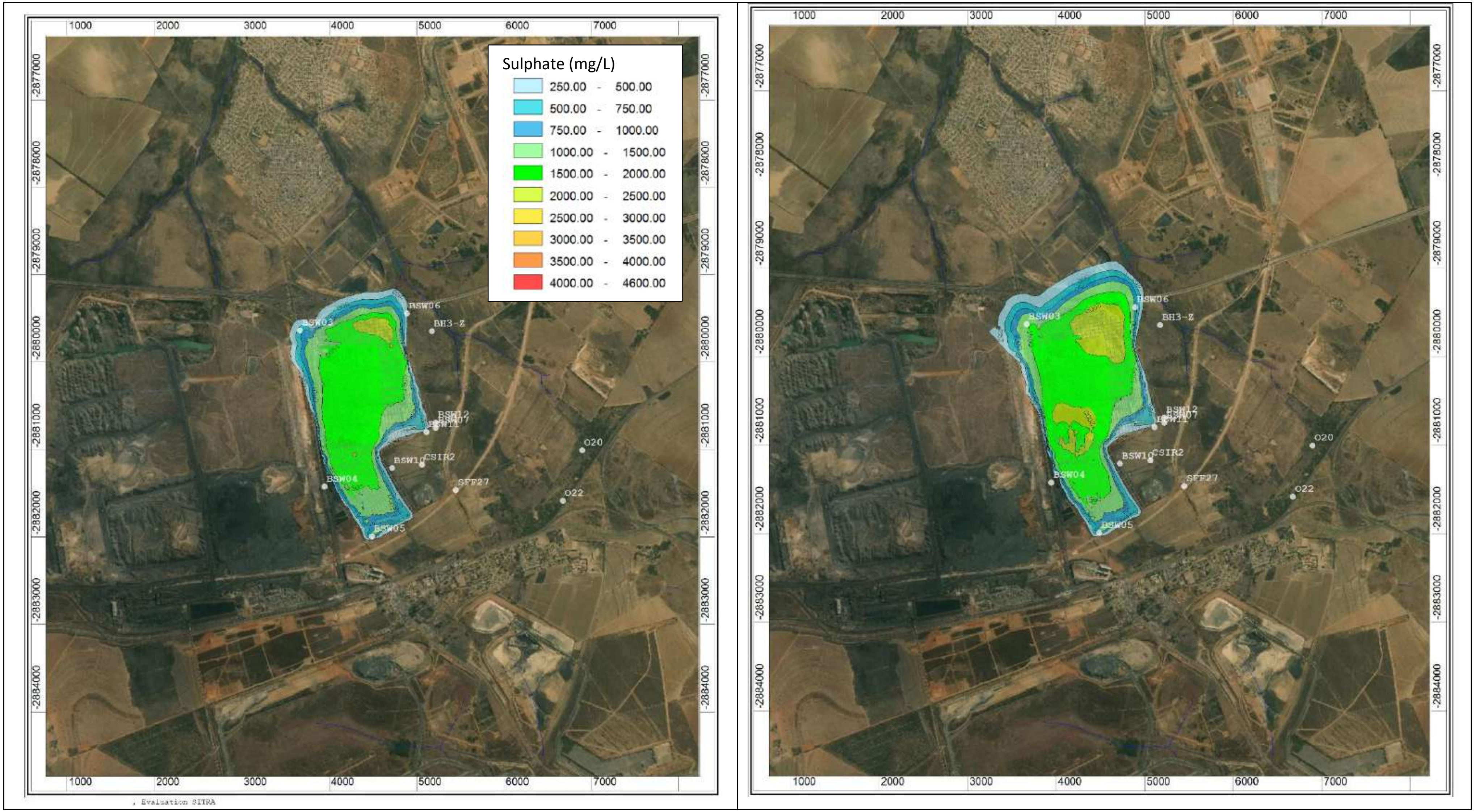

Figure 3-3: Simulated sulphate concentrations for the base case (no discard) scenario after 50- and 100-years post-closure.

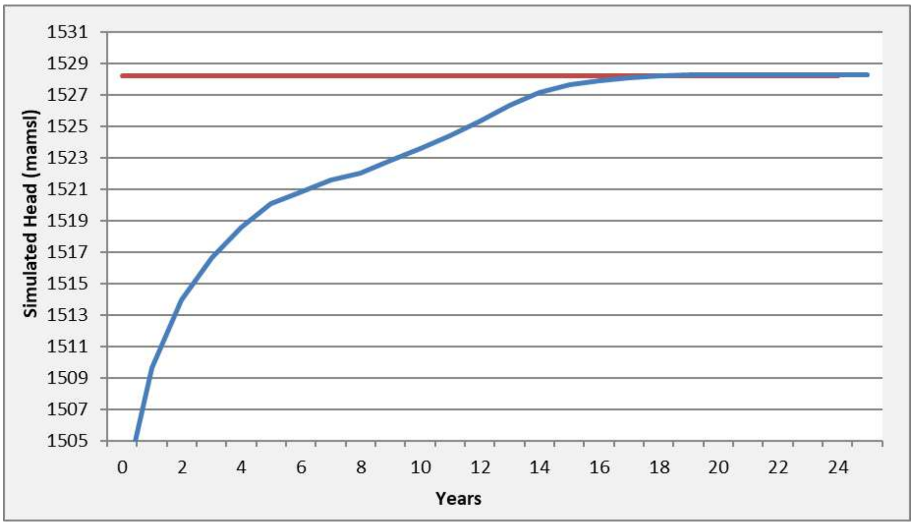

Figure 3-4: Simulated head rebound in the north north-eastern edge of the Zibulo open cast.

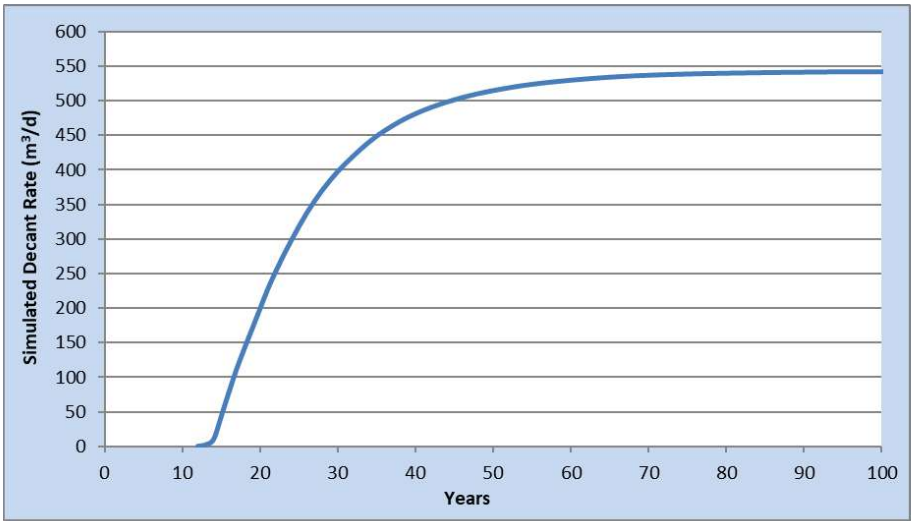

Figure 3-5: Simulated post-closure decant rate for the Zibulo open cast (base case).

3.2.2. Zibulo discard facility

A coal discard facility is required at Zibulo Colliery to service the discard requirement for a Life of Mine (LoM) of 14 years. The proposed site for the new discard facility will be at the current opencast pit at Zibulo (Figure 3-6). The discard dump will be designed such that it will be placed within and over the backfilled pit.

Two post-closure transport model scenarios consider an 'uncapped' and 'capped' (~600 mm)' discard dump (DD) cover. Table 3.2 provides the sulphate concentrations and seepage rates developed by Golder for the Klipspruit discard dump, which serves as a proxy for the proposed Zibulo discard dump. The source term, i.e. the leachate concentrations and seepage rates for the two model scenarios (uncapped and capped (600 mm) DD) were provided by Golder Associates (Golder, 2020) and applied in the model scenarios as provided without scrutiny.

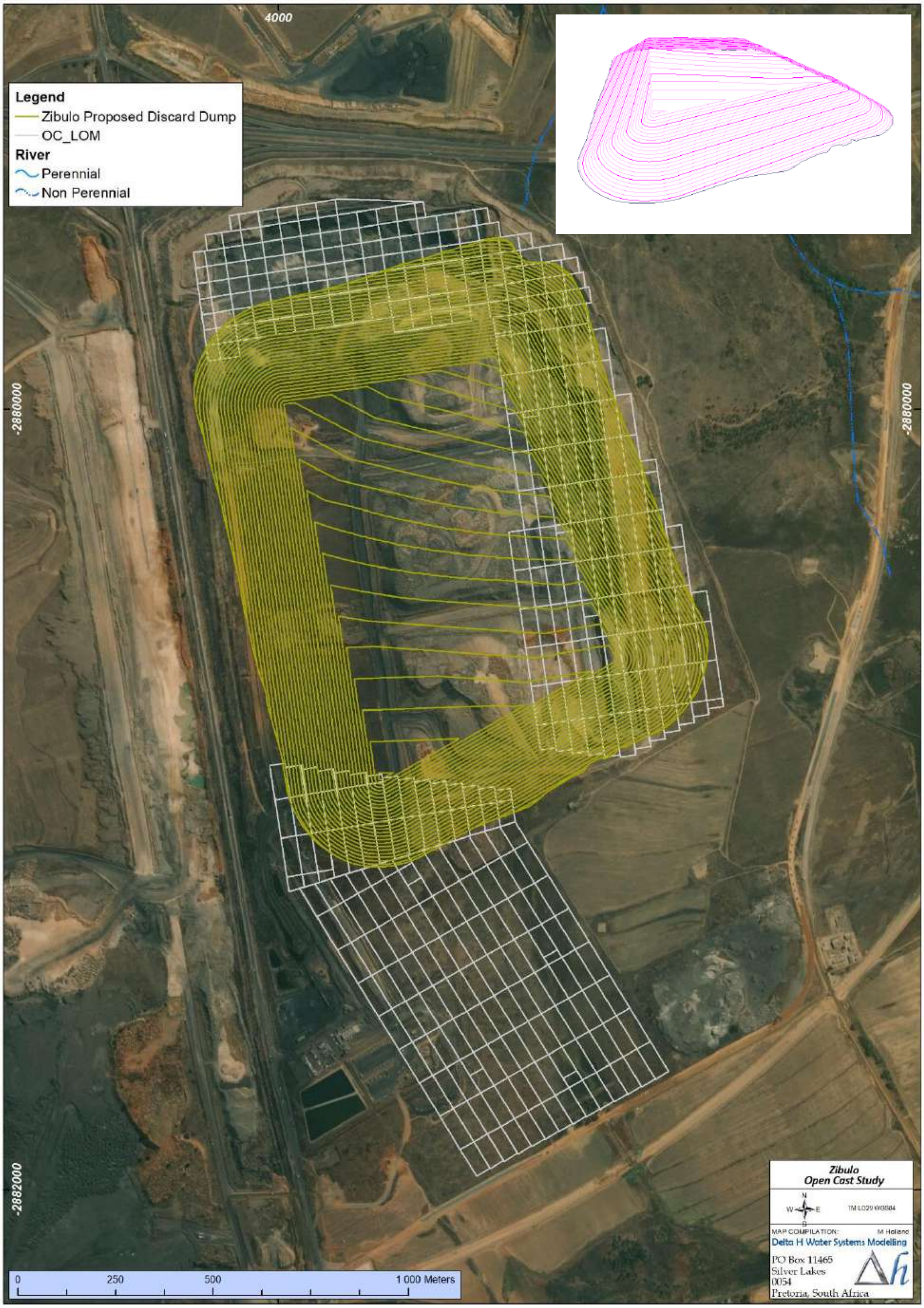

Figure 3-6: Proposed Zibulo discard dump.

Table 3.2: Modelled long-term sulphate concentrations for the Klipspruit discard dump (Golder, 2020).

Cover	Recharge Rate %	Modelled Sulphate (mg/L)
Uncapped*	25	4376
Capped DD (600 mm cover)*	14	4522
Capped DD (700 mm cover)	13.33	4527
Capped DD (800 mm cover)	12.73	4531
Capped DD (900 mm cover)	12	4537

* - Contaminant transport model scenarios

Figure 3-7 and Figure 3-8 show the pollution plumes for the uncapped and capped predictive scenarios. The pollution plume from the Zibulo discard dump extends 50 years and 100 years post closure approximately 570 m and 800 m north, respectively.

The pollution plume for the capped scenario, with an assumed lower seepage rate (but similar sulphate concentration) is expectedly smaller and extends 50 years and 100 years post closure approximately 480 m and 700 m.

Since the expected critical level to prevent surface decant or Environmental Critical Level to prevent diffuse decant into the weathered aquifer are dependent on the pit layout and weathering depth around the perimeter of the pit only, they remain unchanged from the base scenario.
However, since the estimated recharge rate of the discard dump (Table 3.2) is higher than the rate estimated for rehabilitated spoils (Table 2.6), the long-term decant rates are higher than for the base case scenario and estimated at approximately

- 818 m^3/d (or ~0.82 ML/d) for the uncapped scenario, and
- 620 m^3/d (or ~0.62 ML/d) for the capped scenario.

A mitigated model scenario considered four abstraction boreholes to manage the backfill water levels below and ECL of 1512 mamsl (for an assumed average weathering depth of 15 m) to prevent surface and diffuse decant. The boreholes were implemented in the model as constant head boundary conditions with heads iteratively adjusted until plume containment was achieved. The required number and drawdown of such abstraction boreholes will obviously have to be based on actual field drilling and hydraulic test results for the backfill material.

Once the water levels are managed below ECL, hydraulic gradients are mostly reversed inwards and plume migration (Figure 3-9) contained. Since the cone of dewatering 'pulls' additional water from the surrounding aquifer into the backfilled pit area, required dewatering rates will exceed predicted decant rates.

A combined long-term abstraction rate of approximately 851 m^3/d (or ~0.85 ML/d) (Figure 3-10) from the four abstraction boreholes (up-gradient from the decant area) is predicted for the capped scenario (in comparison to a predicted decant rate of 620 m^3/d).

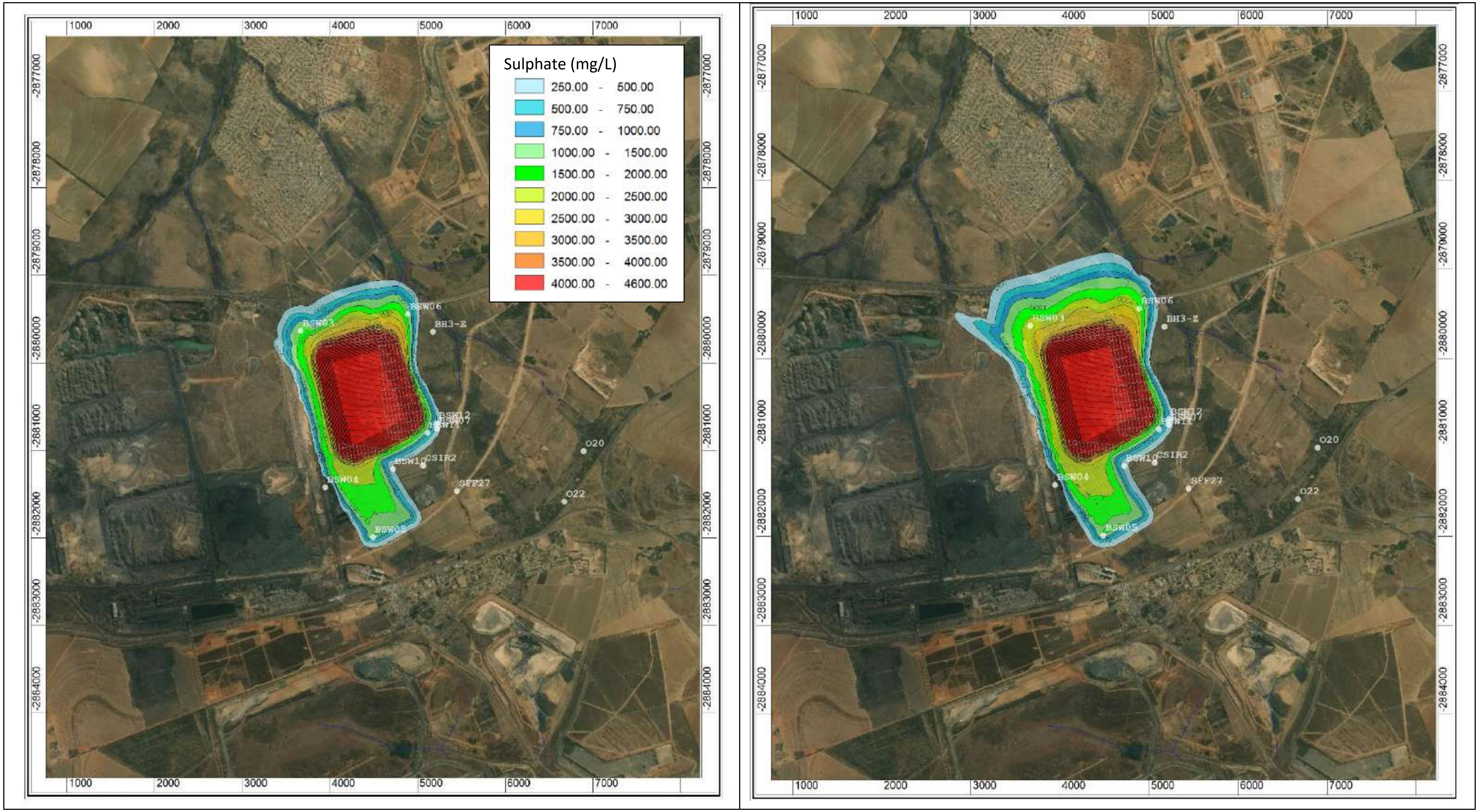

Figure 3-7: Simulated sulphate concentrations for the uncapped scenario after 50- and 100-years post-closure.

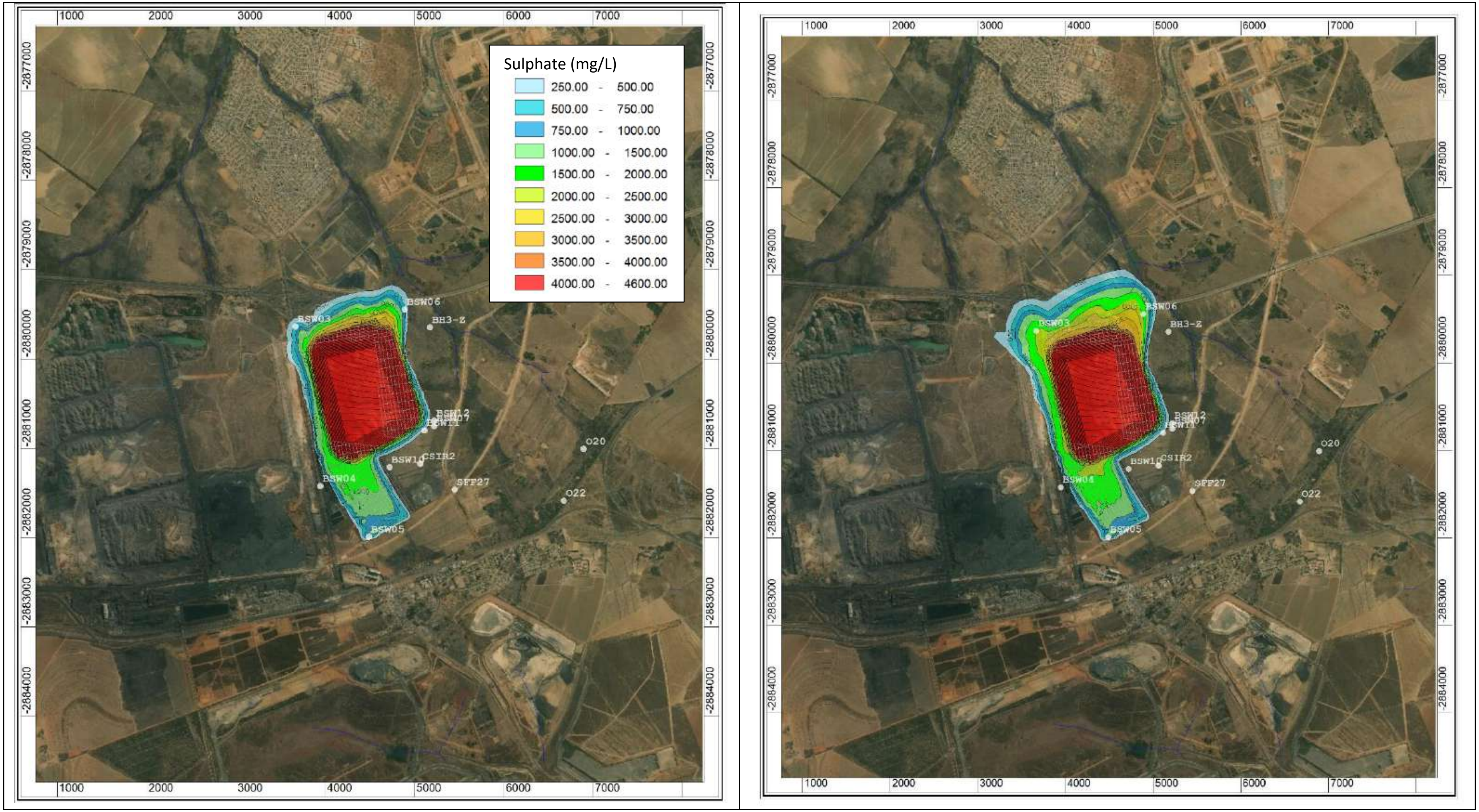

Figure 3-8: Simulated sulphate concentrations for the capped scenario after 50- and 100-years post-closure.

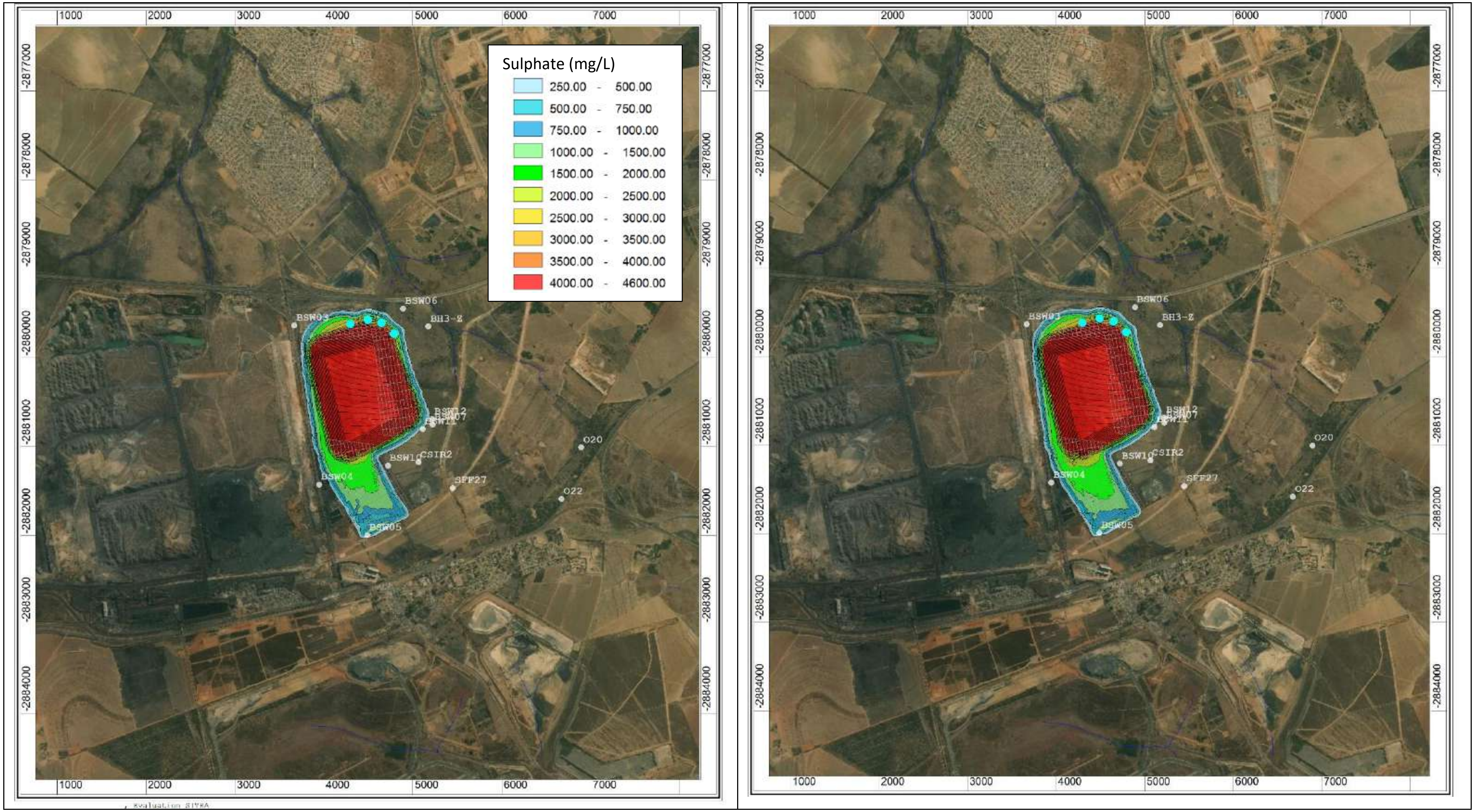

Figure 3-9: Simulated sulphate concentrations for the capped (and pumping) scenario after 50- and 100-years post-closure (light blue dots showing abstraction borehole positions).

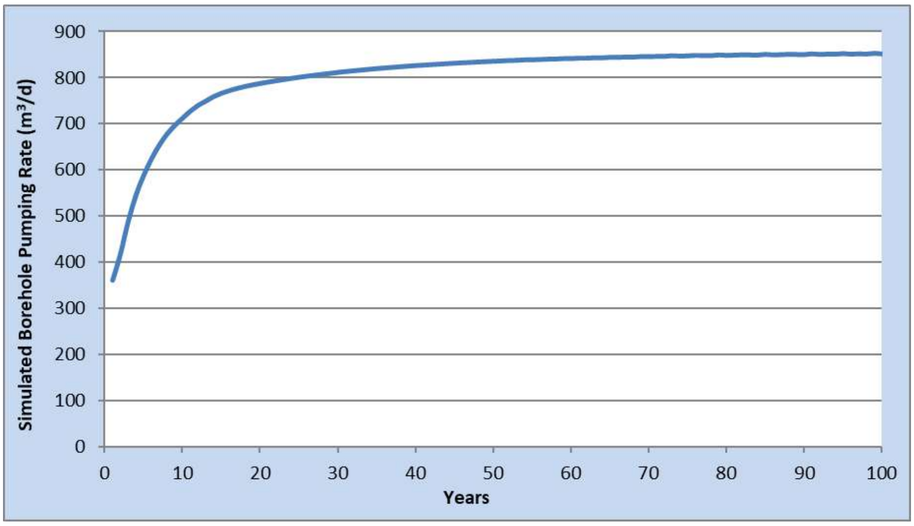

Figure 3-10: Simulated borehole pumping rate post-closure to prevent surface decant and limit diffuse decant.

4. CONCLUSION

Groundwater quality within the backfilled opencast areas (including the overlying discard dump) is expected to deteriorate due to acid mine drainage and other chemical interactions between the geological and the groundwater regime. The resulting groundwater pollution plume will migrate along the new local and regional hydraulic gradients as the water table rebounds. Based on the topographic setting of the mine and the post-closure topography (with the discard dump), the rebounding water table will lead to the surface decant of mine water (of approximately 620 m^3/d or 0.62 ML/d). Based on the current mine plan, the expected critical level to prevent surface is estimated at 1527 mamsl, while the Environmental Critical Level (ECL) to prevent diffuse decant will be at a lower level and depends on the actual weathering depth around the pit perimeter (assumed to be 15 m for the model simulations).

While a limited spreading of leachate from the backfilled pit (with or without discard dump) into the weathered aquifer is expected for its western, southern, and eastern edges, the migration of the plume towards the north is significant and may trigger potential off-site migration.Post closure water levels within the backfilled pit (with or without discard dump) and surrounding aquifer should be monitored and pit water levels managed below environmentally critical levels (i.e. weathered aquifer elevation within the downstream area of the backfilled pit) to prevent potential decant of mine water to surface or into the weathered aquifer. Potentially abstracted groundwater should be treated, re-used, or discharged into the environment.

Three discard dump monitoring boreholes to augment the existing Zibulo open cast monitoring network were identified as part of the Zibulo Southern Box-Cut project. The coordinates are provided in Table 4.1. Note: Monitoring borehole BSW18 located in-between the Klipspruit open cast and the Zibulo open cast was completed, the remaining two are yet to be drilled.

Table 4.1: Proposed discard dump monitoring boreholes.

Borehole ID	Longitude	Latitude	Target Area
BSW16	29.04898	-26.02725	East
BSW17	29.04493	-26.02294	North
BSW18	29.03772	-26.031474	West

In the short term, Zibulo open cast needs to further augment its current monitoring program with the drilling of boreholes into backfilled areas to retrieve samples for geochemical analysis and to monitor the actual water quality in the backfilled cuts as they become saturated. Continuous assessment of geochemical properties of the discard material as part of a ARD assessment programme of the site and to inform management decisions and post-closure planning is recommended.

5. REFERENCES

Delta-H (2017). Zibulo Colliery Open Cast Water Use License Recommendations. Technical Memo no. Delh.2016.011-9.

Delta-H (2020) (In Progress). Zibulo Colliery Open Cast. 2019/2020 Hydrogeological Investigation. Technical Memo no. Delh.2019.011-9_D (v1).

Golder (2020). Zibulo Discard Seepage Assessment. Technical Memorandum. 19117180 Memo 005 Draft.

APPENDIX C

Stormwater Management Plan Data

Table 25: Discard Facility sub-catchments details

Name	Tag	Area (ha)	Flow Length (m)	Zero Imperv (%)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)	Infiltration (mm)	Runoff Depth (mm)	Runoff Volume (ML)	Peak Runoff (m^3/s)	Runoff Coefficient
S_Top	Top Area	48.6302	972.604	25	61.3	59.8	0.4	104.46	5.47	2.66	0.69	0.05
S_B1	South	7.9728	159.456	25	61.3	59.8	0.4	82.46	27.35	2.18	0.58	0.249
S_B2	South	10.7782	215.564	25	61.3	59.8	0.4	97.46	32.59	3.51	0.87	0.25
S_B3	South	10.9678	219.356	25	61.3	59.8	0.4	105.31	36.54	4.01	1.01	0.257
S_B4	South	6.1551	123.102	25	61.3	59.8	0.4	100.06	74.91	4.61	1.46	0.428
S_C1	North	15.541	310.82	25	61.3	59.8	0.4	71.69	38.14	5.93	1.69	0.347
S_C2	North	12.2368	244.736	25	61.3	59.8	0.4	71.15	38.72	4.74	1.47	0.352
S_C3	North	9.1742	183.484	25	61.3	59.8	0.4	82.46	27.34	2.51	0.66	0.249
S_C4	North	8.0836	161.672	25	61.3	59.8	0.4	70.34	39.58	3.2	1.16	0.36
S_C5	North	6.5121	130.242	25	61.3	59.8	0.4	82.46	27.36	1.78	0.48	0.249
S_C6	North	4.2461	84.922	25	61.3	59.8	0.4	82.46	27.38	1.16	0.32	0.249
S_C7	North	2.742	54.84	25	61.3	59.8	0.4	82.46	27.39	0.75	0.21	0.249
S_C8	North	0.6298	12.596	25	61.3	59.8	0.4	82.44	27.47	0.17	0.05	0.25
Void	Void	0.8109	16.218	25	61.3	59.8	0.4	68.92	41.24	0.33	0.18	0.375

Table 26: Channel flow results for the stormwater management plan

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Perimeter channel	C143	285.777	1	2	2	2	0.00728	1.458	2.19	0.27
Perimeter channel	C144	310.471	1	2	2	2	0.01057	1.457	2.45	0.24
Perimeter channel	C145	223.755	1	2	2	2	0.01484	1.446	2.74	0.22
Perimeter channel	C146	184.49	1	2	2	2	0.01947	1.435	2.56	0.24
Perimeter channel	C147	212.323	1	2	2	2	0.01365	1.78	2.98	0.24
Perimeter channel	C148	149.97	1	2	2	2	0.02916	1.853	3.14	0.24
Perimeter channel	C149	249.051	1	2	2	2	0.01503	1.929	2.71	0.28
Perimeter channel	C150	112.773	1	2	2	2	0.01055	1.953	2.57	0.29
Perimeter channel	C153	106.575	1	2	2	2	0.01822	0.059	0.32	0.09
Perimeter channel	C154	259.811	1	2	2	2	0.00223	0.244	0.77	0.14
Perimeter channel	C155	143.157	1	2	2	2	0.00216	0.239	0.7	0.15
Perimeter channel	C156	203.172	1	2	2	2	0.00115	0.234	0.61	0.17
Perimeter channel	C157	309.35	1	2	2	2	0.00908	1.034	1.8	0.23
Perimeter channel	C158	292.864	1	2	2	2	0.01704	1.893	2.46	0.3
Perimeter channel	C159	273.491	1	2	2	2	0.00797	2.079	2.69	0.3
Perimeter channel	C160	103.615	1	2	2	2	0.02689	2.405	2.77	0.33
Perimeter channel	C161	162.134	1	2	2	2	0.00524	2.402	1.93	0.43
Perimeter channel	C162	79.316	1	2	2	2	0.00189	2.402	2.14	0.4
Perimeter channel	C163	271.101	1	2	2	2	0.01176	2.473	3.05	0.31

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Perimeter channel	C164	176.684	1	2	2	2	0.02109	2.498	3.89	0.26
Perimeter channel	C165	119.753	1	2	2	2	0.04628	2.511	4.6	0.22
Bench Channel	C181	89.127	0.8	0.5	9	2	0.00745	0.133	0.47	0.24
Bench Channel	C182	107.36	0.8	0.5	9	2	0.00298	0.106	0.39	0.23
Bench Channel	C183	80.005	0.8	0.5	9	2	0.0092	0.1	0.53	0.19
Bench Channel	C184	64.581	0.8	0.5	9	2	0.00697	0.097	0.5	0.23
Bench Channel	C185	123.864	0.8	0.5	9	2	0.01081	0.161	0.62	0.23
Bench Channel	C186	115.45	0.8	0.5	9	2	0.00377	0.128	0.42	0.24
Bench Channel	C187	124.402	0.8	0.5	9	2	0.00414	0.122	0.42	0.27
Bench Channel	C188	147.395	0.8	0.5	9	2	0.01162	0.305	0.73	0.3
Bench Channel	C189	93.786	0.8	0.5	9	2	0.0046	0.276	0.54	0.33
Bench Channel	C190	140.411	0.8	0.5	9	2	0.00504	0.246	0.55	0.3
Bench Channel	C191	82.903	0.8	0.5	9	2	0.00645	0.228	0.54	0.31
Bench Channel	C192	88.949	0.8	0.5	9	2	0.00605	0.231	0.61	0.3
Bench Channel	C193	153.299	0.8	0.5	9	2	0.00485	0.121	0.46	0.22
Bench Channel	C194	137.784	0.8	0.5	9	2	0.01018	0.104	0.56	0.19
Bench Channel	C195	152.041	0.8	0.5	9	2	0.00376	0.087	0.37	0.21
Bench Channel	C196	74.246	0.8	0.5	9	2	0.00194	0.078	0.26	0.25
Bench Channel	C197	128.771	0.8	0.5	9	2	0.00952	0.615	0.89	0.39
Bench Channel	C198	135.622	0.8	0.5	9	2	0.00752	0.535	0.78	0.39

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C199	138.023	0.8	0.5	9	2	0.00655	0.507	0.72	0.39
Bench Channel	C200	164.35	0.8	0.5	9	2	0.00574	0.486	0.68	0.4
Bench Channel	C201	121.237	0.8	0.5	9	2	0.0066	0.447	0.73	0.36
Bench Channel	C202	123.654	0.8	0.5	9	2	0.01058	0.426	0.82	0.33
Bench Channel	C203	118.711	0.8	0.5	9	2	0.00648	0.539	0.69	0.45
Bench Channel	C204	145.714	0.8	0.5	9	2	0.00361	0.499	0.61	0.43
Bench Channel	C205	121.931	0.8	0.5	9	2	0.00869	0.499	0.8	0.37
Bench Channel	C206	117.518	0.8	0.5	9	2	0.00773	0.495	0.76	0.38
Bench Channel	C207	91.555	0.8	0.5	9	2	0.00493	0.458	0.53	0.48
Bench Channel	C208	103.368	0.8	0.5	9	2	0.00208	0.445	0.57	0.42
Bench Channel	C215	150.212	0.8	0.5	9	2	0.0068	0.576	0.76	0.41
Bench Channel	C216	103.776	0.8	0.5	9	2	0.00618	0.527	0.73	0.4
Bench Channel	C217	123.834	0.8	0.5	9	2	0.00462	0.483	0.65	0.41
Bench Channel	C218	156.725	0.8	0.5	9	2	0.00912	0.471	0.81	0.35
Bench Channel	C219	143.025	0.8	0.5	9	2	0.01196	0.467	1.01	0.34
Bench Channel	C220	93.211	0.8	0.5	9	2	0.00643	0.498	0.65	0.42
Bench Channel	C228	151.89	0.8	0.5	9	2	0.00223	1.272	0.66	0.69
Bench Channel	C229	84.904	0.8	0.5	9	2	0.00438	1.226	0.84	0.59
Bench Channel	C230	78.387	0.8	0.5	9	2	0.01045	1.232	1.08	0.52
Bench Channel	C231	97.042	0.8	0.5	9	2	0.01024	1.215	0.78	0.65

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C232	151.121	0.8	0.5	9	2	0.00218	1.179	0.71	0.64
Bench Channel	C233	229.88	0.8	0.5	9	2	0.00941	1.113	0.8	0.6
Bench Channel	C234	194.177	0.8	0.5	9	2	0.00445	1.12	1.4	0.5
Bench Channel	C235	187.803	0.8	0.5	9	2	0.00034	0.334	0.38	0.46
Bench Channel	C236	124.909	0.8	0.5	9	2	0.00689	0.311	0.67	0.31
Bench Channel	C237	168.862	0.8	0.5	9	2	0.01154	0.299	0.77	0.31
Bench Channel	C238	247.041	0.8	0.5	9	2	0.00481	0.295	0.56	0.33
Bench Channel	C239	166.071	0.8	0.5	9	2	0.00633	0.289	0.62	0.31
Bench Channel	C240	232.704	0.8	0.5	9	2	0.0094	0.293	0.74	0.29
Bench Channel	C241	183.788	0.8	0.5	9	2	0.00992	0.244	0.78	0.25
Bench Channel	C242	155.484	0.8	0.5	9	2	0.00527	1.231	0.83	0.62
Bench Channel	C243	149.603	0.8	0.5	9	2	0.00511	1.147	0.87	0.56
Bench Channel	C244	70.868	0.8	0.5	9	2	0.01359	1.124	0.83	0.59
Bench Channel	C245	143.204	0.8	0.5	9	2	0.0033	1.123	0.74	0.6
Bench Channel	C246	121.639	0.8	0.5	9	2	0.00836	1.083	0.83	0.59
Bench Channel	C247	207.841	0.8	0.5	9	2	0.00443	1.103	0.79	0.58
Bench Channel	C248	415.675	0.8	0.5	9	2	0.0083	1.044	0.97	0.5
Bench Channel	C249	93.55	0.8	0.5	9	2	0.01189	0.993	1.53	0.38
Bench Channel	C250	196.638	0.8	0.5	9	2	0.00375	0.186	0.47	0.28
Bench Channel	C251	116.93	0.8	0.5	9	2	0.00942	0.167	0.63	0.22

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C252	152.661	0.8	0.5	9	2	0.00845	0.154	0.55	0.24
Bench Channel	C253	252.836	0.8	0.5	9	2	0.00371	0.128	0.42	0.24
Bench Channel	C254	148.82	0.8	0.5	9	2	0.0053	0.121	0.46	0.23
Bench Channel	C255	191.085	0.8	0.5	9	2	0.00629	0.115	0.49	0.21
Bench Channel	C256	137.913	0.8	0.5	9	2	0.01054	0.11	0.48	0.22
Bench Channel	C257	265.684	0.8	0.5	9	2	0.00433	0.104	0.42	0.21
Bench Channel	C258	174.19	0.8	0.5	9	2	0.01731	0.098	1.12	0.11
Bench Channel	C259	147.243	0.8	0.5	9	2	0.00791	0.429	0.74	0.36
Bench Channel	C260	136.614	0.8	0.5	9	2	0.00344	0.347	0.5	0.4
Bench Channel	C261	59.094	0.8	0.5	9	2	0.00288	0.321	0.56	0.35
Bench Channel	C262	104.151	0.8	0.5	9	2	0.01219	0.314	0.72	0.32
Bench Channel	C263	304.022	0.8	0.5	9	2	0.00519	0.287	0.58	0.32
Bench Channel	C264	211.551	0.8	0.5	9	2	0.00762	0.267	0.66	0.29
Bench Channel	C265	297.402	0.8	0.5	9	2	0.00652	0.237	0.45	0.35
Bench Channel	C266	141.435	0.8	0.5	9	2	0.00125	0.195	0.38	0.33
Bench Channel	C267	135.915	0.8	0.5	9	2	0.01088	0.197	0.69	0.23
Bench Channel	C268	255.806	0.8	0.5	9	2	0.01468	0.192	0.88	0.2
Bench Channel	C269	154.87	0.8	0.5	9	2	0.00364	0.061	0.36	0.18
Bench Channel	C270	158.773	0.8	0.5	9	2	0.00441	0.106	0.42	0.25

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REPORT

Mineral Residue Risk Assessment for Zibulo Colliery Discard Facility

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Declaration of Independence by Specialist

I, David Love, declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the proposed Rietspruit Closure Project;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity; and
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document.

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TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Golder Associates Africa (Golder) has been appointed by Anglo American Inyosi Coal (AAIC) to undertake the engineering design and environmental impact assessment for the proposed discard facility for Zibulo Colliery. The proposed discard facility will be built on the backfilled Zibulo opencast pit. Geochemical characterisation and assessment for the Zibulo discard material is required in support of the engineering design and numerical groundwater model (Delta H, 2019).

This report documents the Mineral Residue Risk Assessment for Zibulo discard.

2.0 OBJECTIVES

The objectives of this geochemistry assessment are:

- To assess the geochemical differences of the Zibulo and Klipspruit discard material generated by Phola Coal Processing Plant (PCPP);
- To conduct the risk assessment for Zibulo discard material to comply with the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation (GN R. 632 of 2015); and
- To confirm the use of the Klipspruit source-term model as representative of the Zibulo discard facility seepage quality estimates.

3.0 LEGAL FRAMEWORK

The environmental aspects of the design and management of mine residues (i.e. dumps or stockpiles of waste rock, overburden, discard, tailings, ROM and low grade material) are governed by the National Environmental Management: Waste Act (NEM: WA). The *Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation* (GN R. 632 of 2015) provide for the characterisation of mine residues (all forms of mine waste and stockpiles) as the basis for a risk assessment (Figure 1).

GN R. 632 of 2015 additionally provided that the by the *Waste Classification and Management Regulations* (GN R. 634-636 of 2013), based upon the leachable and total concentrations of specified constituents of concern. The amendment of GN R. 632 of 2015 on 21 September 2018, requires that the pollution control barrier system be driven by a risk assessment based upon the characterisation as opposed to pollution control barrier system designs driven by the *Waste Classification and Management Regulations* (GN R. 634-636 of 2013).

Waste classification and assessment for the Zibulo discard materials that will be generated by the operations (and PCPP) has been done as part of the risk assessment. According to GN R.634, waste classification and assessments should be repeated every 5 years. The available material characterisation results (Golder, 2017) for Klipspruit discard and the co-disposal discard dump have been included in this risk assessment for comparison.

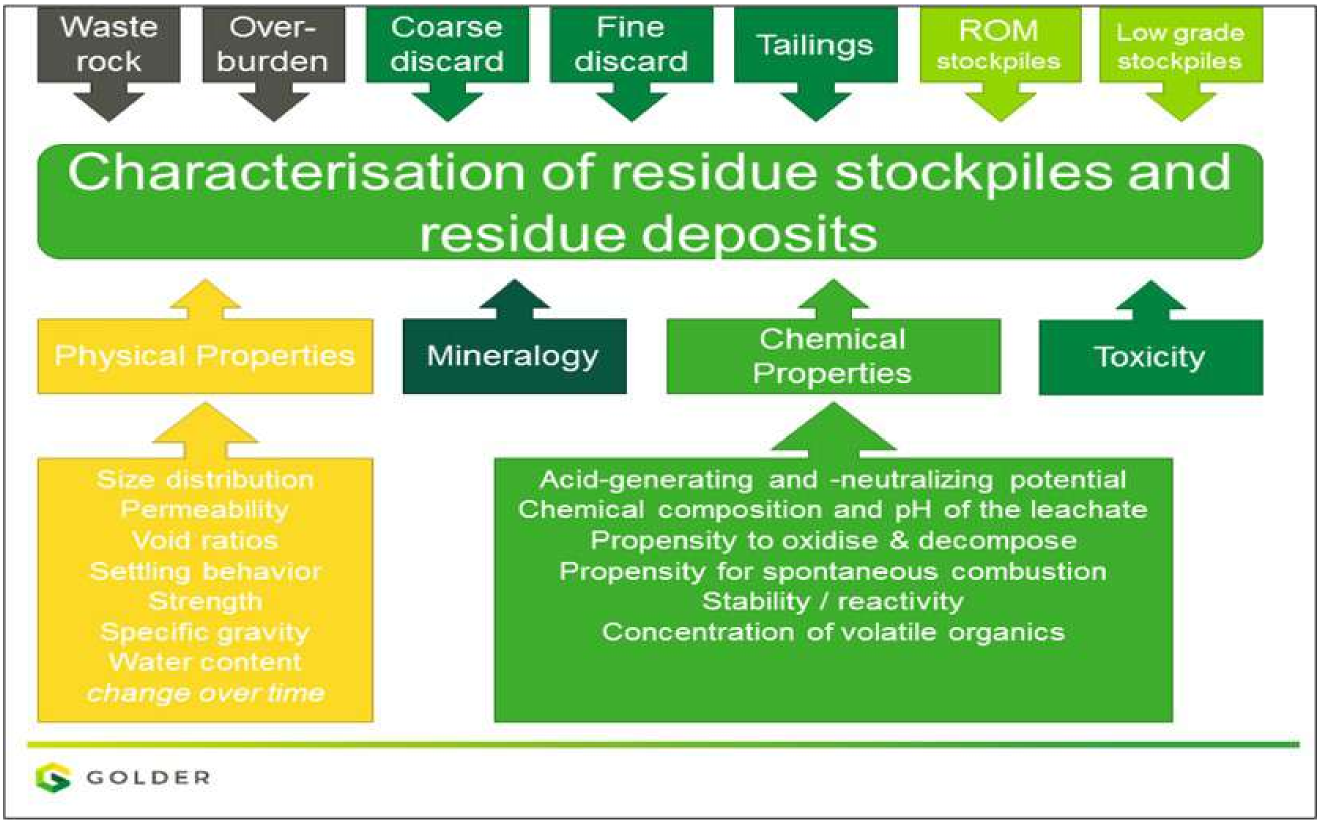

Figure 1: Flowchart for mine residue characterisation in terms of GN R. 632 of 2015

4.0 SITE DESCRIPTION

4.1 Project Location

Anglo American Inyosi Coal's (AAIC) Zibulo Colliery is situated adjacent to Ogies in the Mpumalanga Province. Zibulo Colliery is located in proximity to the town of Ogies, Mpumalanga. The mine comprises an underground section located approximately 20 km south south-west of the town and an opencast section to the immediate north-west of the town. The discard facility is to be built on top of the opencast section. The colliery falls within the upper reaches of the Olifants Water Management Area.

4.2 Geology

4.2.1 Introduction

The Zibulo Colliery is located close to the north-western margin of the Witbank coalfield basin. The Zibulo Colliery coal seams are contained within the Vryheid Formation of the Karoo Supergroup. The sequence was deposited on paleo-highs, and areas that had been eroded, so not all the coal seams are always fully developed throughout the resource area. The stratigraphy of the Zibulo resource area is typical of the eMalahleni coalfield, with five main coal seams present i.e. No.1 seam (deepest), No. 2 seam, No. 3 seam, No. 4 seam and No. 5 seam (most shallow). The Zibulo resources are contained in the No. 2, No. 4 and No. 5 seams. Sediments of shale, siltstone and sandstone overlie and separate the various coal seams. The sequence is underlain by Pre-Karoo diamictite. Figure 3 shows typical stratigraphic sequence at the opencast mine workings.

4.2.2 Opencast Resource

No. 4 seam top is mostly weathered away in the north and north-east of the resource area, except in the lower portion of the resource area. The seam is a fairly thin sub-seam and comprises bright coal with pyrite lenses. Interburden between No. 4 seam and No. 3 seam comprises of fine-grained sandstone and is approximately 3m thick. The interburden between No. 3 seam and the top of No. 2 seam comprises inter-bedded shale and sandstone, with a thick carbonaceous mudstone occurring just above the contact of the No. 2 seam. The No. 2 seam is generally a bright coal underlain by fine-grained sandstone. The No.1 seam is a thin bright coal seam and is overlain by thin inter-bedded shale and sandstone parting.

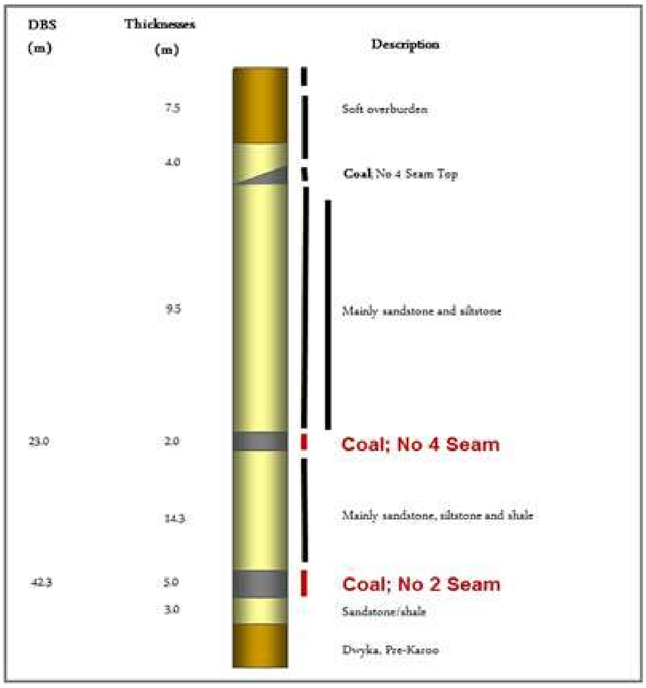

Figure 2: Zibulo Opencast resource stratigraphy

4.2.3 Underground Resource

All coal seams, except for No. 5 seam, are present in the underground mining operations. The No. 1 seam (at the bottom of the sequence) is generally absent in the area, with limited deposition in the central part of the basin. The No. 2 seam is the economic target horizon at Zibulo Colliery, with a maximum thickness of 11 m although only the basal portion of the seam contributes to the resources considered. The No. 3 seam has no economic significance and only attains a maximum thickness of 0.5 m although it is widespread throughout the entire Zibulo area. The No. 4 seam attains a maximum thickness of 13 m underground, with a selected portion considered economic as Eskom type coal.

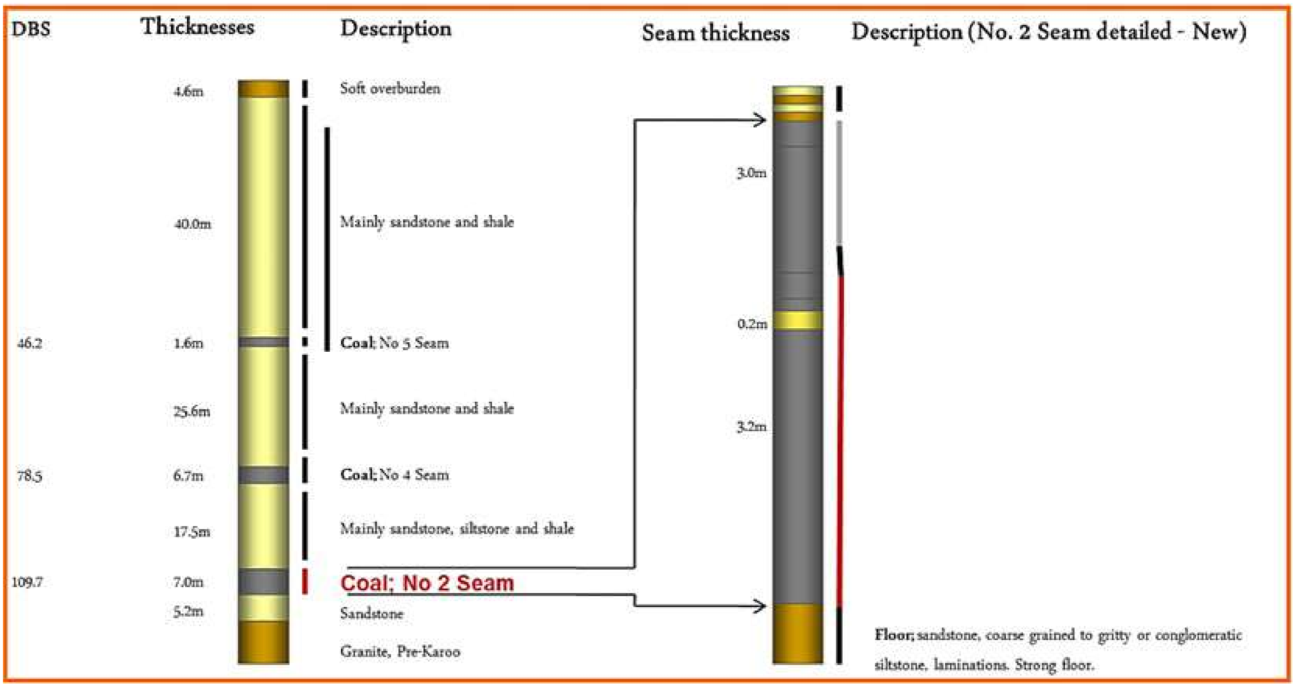

Figure 3: Zibulo Underground resource stratigraphy

4.3 Drainage

The Zibulo Colliery falls in the upper reaches of the Olifants Water Management Area. The open cast workings fall within quaternary catchment B20G (Figure 4) within the Wilge River catchment (Department of Water and Sanitation (DWS) Wilge River Management Unit 20) within the Limpopo-Olifants primary drainage region.

From the Zibulo Opencast Section, the area drains to the Saalklapspruit via an unnamed tributary, which in turn drains into the Wilge River. The Wilge River drains into the Olifants River immediately above the Loskop Dam. After Loskop Dam the Olifants River flows through Mpumalanga and the central part of the Kruger National Park to Mozambique.

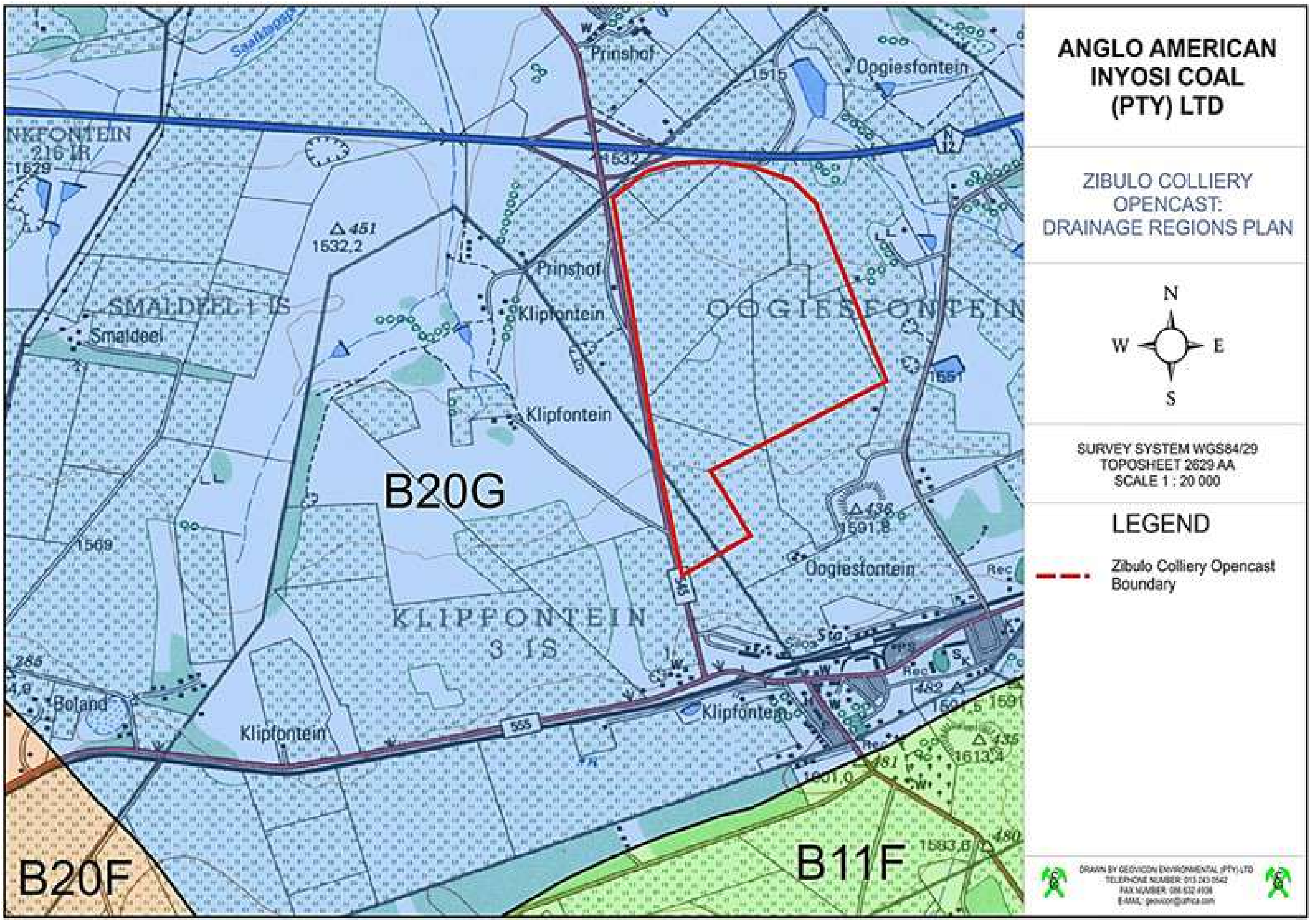

Figure 4: Zibulo colliery drainage region (Geovicon, 2019)

4.4 Hydrogeology

Three different aquifer types occur in the resource area:

- Shallow perched aquifers;
- Shallow weathered zone Karoo aquifers; and
- Deep fractured Karoo aquifers.

The perched aquifer usually displays unconfined conditions; the shallow weathered zone aquifer displays unconfined to semi-unconfined conditions, while the deep aquifer predominantly displays confined conditions. Ground water flow in all three aquifer types is essentially horizontal. However, interconnection between the aquifer types can introduce vertical flow components.

Groundwater monitoring has been conducted at Zibulo since January 2012 (Delta-H, 2017b). The current groundwater monitoring programme includes ten boreholes at the Zibulo Opencast Section (Figure 5).

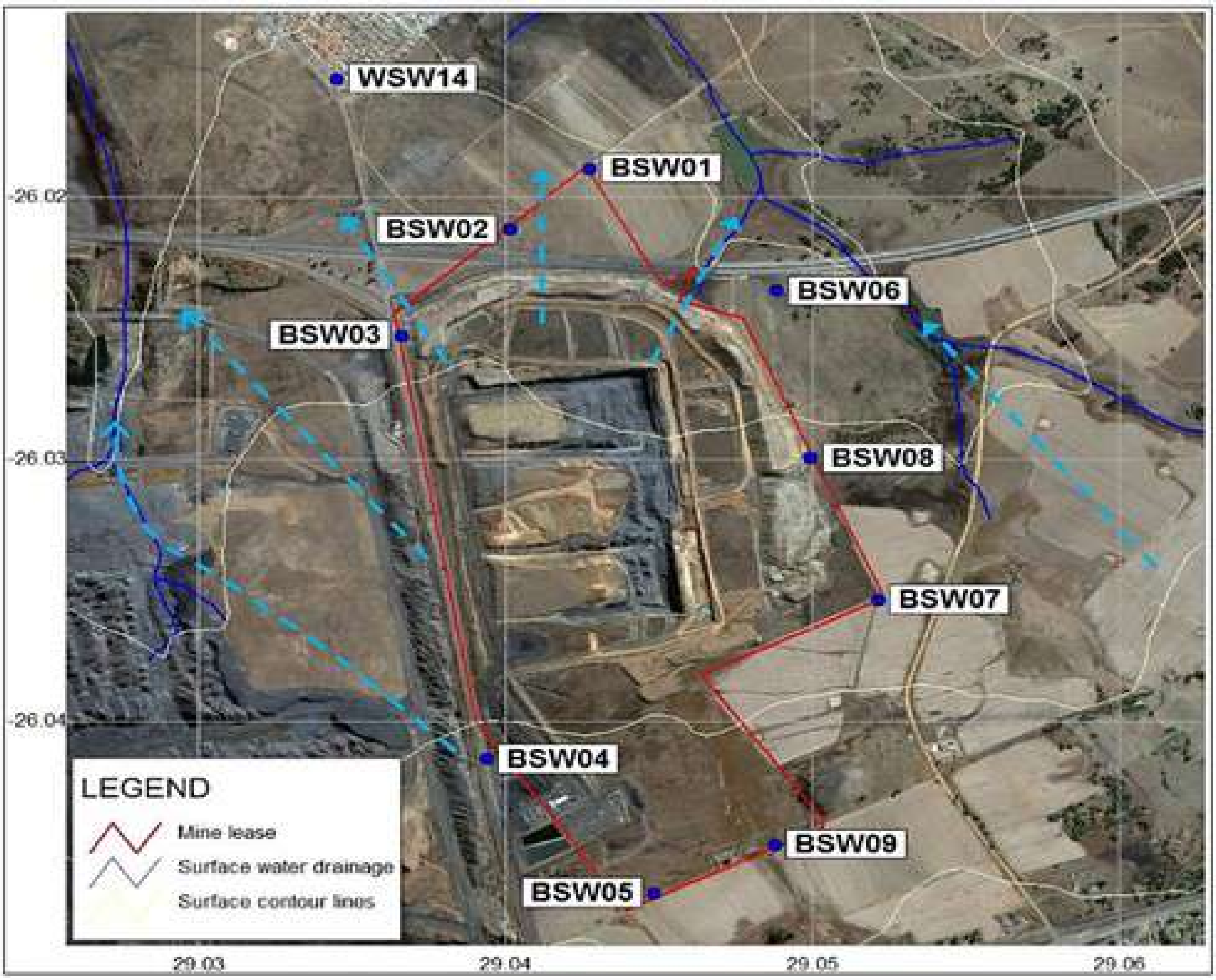

Figure 5: Location of groundwater monitoring boreholes, Zibulo opencast (Groundwater Complete, 2016)

Delta-H (2017a) reported the average seepage or decant rates for a 100 year simulation period as 0.63 Ml/day for the opencast pit. The simulated heads at the end of life of mine (year 2024) were used as starting heads for the post closure simulations. Table 1 summarises the simulated inflows for the Zibulo opencast life of mine and seepage rates over time are shown in Figure 6. Seepage was reported to be likely to start once dewatering ceases, with the decant rates stabilising asymptotically 30 to 40 years post closure. The decant and potential off-site migration is located at the north-eastern edge of the opencast and follows the pre-mining surface drainage lines.

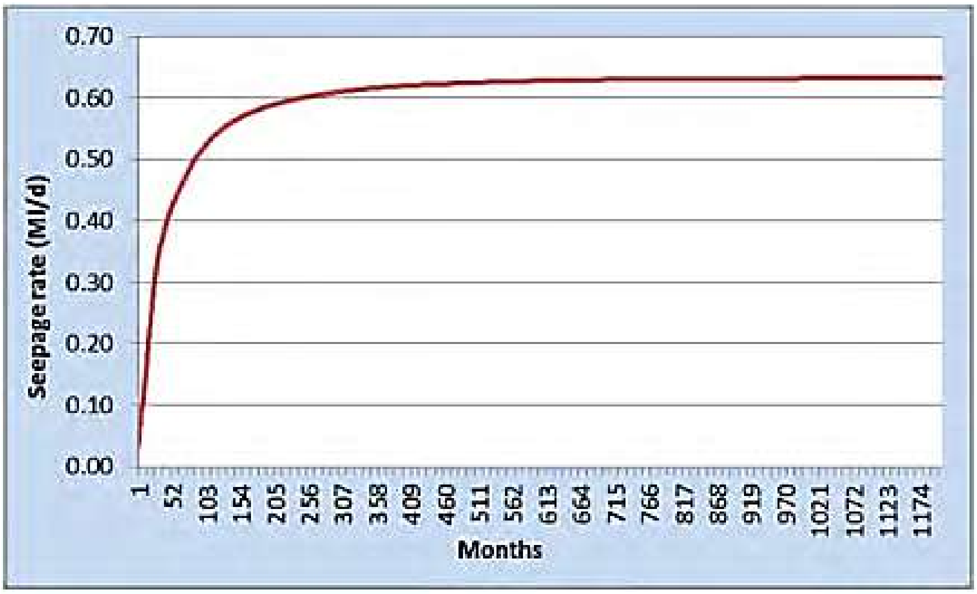

Figure 6: Simulated post-closure seepage rates for the Zibulo opencast (Delta-H, 2017a)

Table 1: Simulated mine inflows for the Zibulo opencast life of mine (Delta-H, 2017a)

Year	l/s	Ml/day
2016	17.4	1.5
2017	22.1	1.91
2018	20.8	1.79
2019	18.3	1.58
2020	19.3	1.66
2021	20.1	1.74
2022	20.5	1.78
2023	22.2	1.92
2024	8.9	0.77

4.5 Previous material characterisation studies

A number of previous material characterisation studies for the Zibulo Colliery were reviewed:

- Delta-H (2017a). Geochemical characterisation on composite spoil samples from the Zibulo opencast mine.
- Delta-H (2017b). Delta-H developed a groundwater and geochemical model for the prediction of mine water inflows, excess volume generation and water chemistry evolution over the life of mine and post-closure for the Zibulo Colliery within the north-western Witbank Coalfield.
- Delta-H (2018). Three composite geochemical samples (discard and soil) from the opencast workings. The study formed part of the 2018 groundwater model update coupled with further geochemical assessment of the Zibulo Colliery.

- Golder (2017) Static and kinetic tests, and ARD block modelling on mixed discard samples from the Phola coal processing plant, as part of a study for Klipspruit Colliery.
- Golder (2019a) Further characterisation on mixed discard samples from the Phola coal processing plant, as part of a study for Klipspruit Colliery.

The main geochemical findings are presented in Table 2, and a summary of results is provided in APPENDIX A.

Table 2: Summary of geochemical findings in previous studies conducted at the Zibulo Colliery

Study	Material sampled	Analyses conducted	Comments
Delta H (2017a)	■ Overburden/ interburden/ coal from borehole drilling (N= 20) ■ Spoils material (N= 3)	■ Acid Base Accounting (ABA) ■ Mineralogy ■ Total elemental analysis ■ Distilled water leach tests (1:20	■ The composited spoil samples classified as potentially acid generating (PAG), with the Ramp 3 sample classifying as having uncertain acid generating potential ■ Abundance of quartz and silicate minerals (kaolinite, microcline and muscovite) and high pyrite content. ■ Classified as Type 3 waste due to the total concentration threshold TCT0 for barium and fluoride.
Delta-H (2017b)	■ Clastic sedimentary rocks (N= 10) ■ Coal (N= 14)	■ XRD analysis ■ Acid Base Accounting	■ ABA results showed insufficient NP to buffer acidity produced. Acidic drainage predicted. ■ Highest pyrite content and acid-generating potential found in the coal seams and adjacent carbonaceous clastic units
Delta H (2018)	■ Ramp 2 soil sample (N= 1) collected before box cut ■ Spoils material (N= 2)	■ ABA ■ Net Acid Generation (NAG) ■ Sulphur speciation ■ Distilled water leach tests (1:20 and 1:4) ■ Aqua regia digestion for total elemental concentration	■ Spoils classified as PAG (NPR<1) and Ramp 2 soil sample with NPR>4 classifying as NPAG. ■ Ramp 4 spoils material classified as Type 3 waste.
Golder (2017)	■ Discard samples from Co-Disposal facility (N= 14) ■ Filter cake (N= 1 composite ■ Coarse discard (N= 1 from Phola Plant) ■ Zibulo ROM (N= 1)	■ Kinetic test work by humidity cell method ■ Multi-acid digestion & ICP-MS for total trace elements concentration ■ ABA and sulphur speciation ■ NAG ■ Deionised water leach tests ■ Mineralogy	■ Pyrite (0.58-1.3 wt%) present in coal samples from Zibulo stockpiles ■ Calcite (0.68-1 wt%) and dolomite (0.6-1.03 wt%) are neutralising minerals in coal samples ■ Zibulo RoM classified as Non PAG due to low sulphide S=0.19% ■ Phola Plant coal sample classified as having uncertain acid-generating potential ■ The discard material and coal from the Zibulo stockpiles classified as Type 3 waste, requiring a Class C barrier.
Golder (2019a)	■ Discard samples from Phola Plant (N= 2) ■ Discard samples from	■ ABA ■ Leach Tests ■ Mineralogy ■ NAG	■ Discard samples classified as PAG ■ The Bulk NP n the fine discard material from the Phola Plant from calcite and dolomite neutralising minerals

Study	Material sampled	Analyses conducted	Comments
	Klipspruit colliery discard dump (N= 5)	■ Ecotoxicity testing on 1 coarse discard and 1 fine discard filter cake	■ NAG and deionised water leach test indicated near-neutral to saline drainage with low concentration of metals. ■ Ecotoxicology tests classified the discard samples (coarse discard and filter cake) as slight acute hazardous material. ■ The ecotoxicology tests were carried out on discard samples: Both coarse discard and filter cake fine discard samples are classified as Level II Hazard (Persoone et al.., 2003) slight acute hazard.

Notes *NP- Neutralisation Potential; AP- Acid-generating PAG – Potentially acid generating; Non-PAG – not potentially acid generating*

5.0 CONCEPTUAL UNDERSTANDING OF THE DISCARD FACILITY

5.1 Coal Processing

Zibulo Colliery produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections and the remaining one million tonnes from its opencast pit. Coal from the underground operations and the opencast operations are transported to the Phola Coal Processing Plant. The plant is a 50:50 joint venture between Anglo American and South32 and processes the Zibulo coal and South32's Klipspruit coal. PCPP produces two waste streams: coarse discard and fine discard slurry which is taken to a filter press for removal of water dry, with an expected moisture content of 20 - 23%. The coarse discard and filter cake are currently disposed in a surface discard facility on top of Klipspruit Main Pit. The facility is reaching capacity (110 ha) and by 2021 an alternative discard facility may be required by AAIC.

Figure 8 provides the projected cumulative volume of the Zibulo coarse and fine material to be placed on the discard facility (Golder, 2019b).

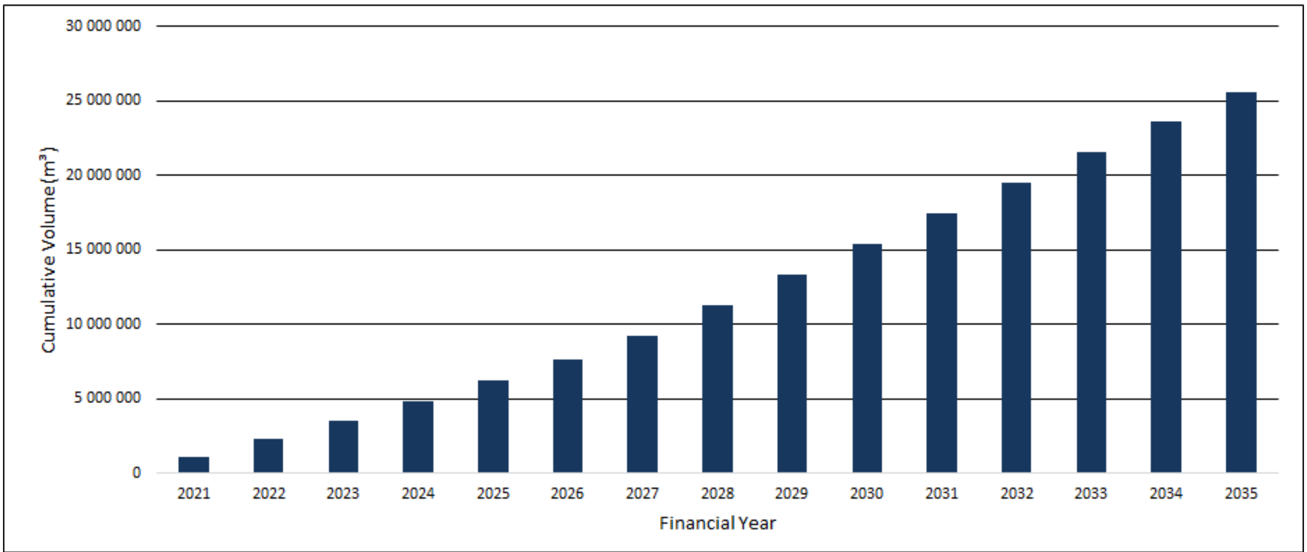

Figure 7: Predicted Zibulo Production Schedule over the Life of Mine

5.2 Discard Facility Design

The alternative discard facility required to service the discard requirement of Zibulo Colliery is designed to have a Life of Mine (LoM) of 15 years, with discard deposition due to commence on Q3 of 2021. The proposed discard facility will be constructed in the footprint of the Zibulo opencast pit. The discard will be developed on top of spoils backfill with the possibility of some discard fill to ramps, see Figure 8.

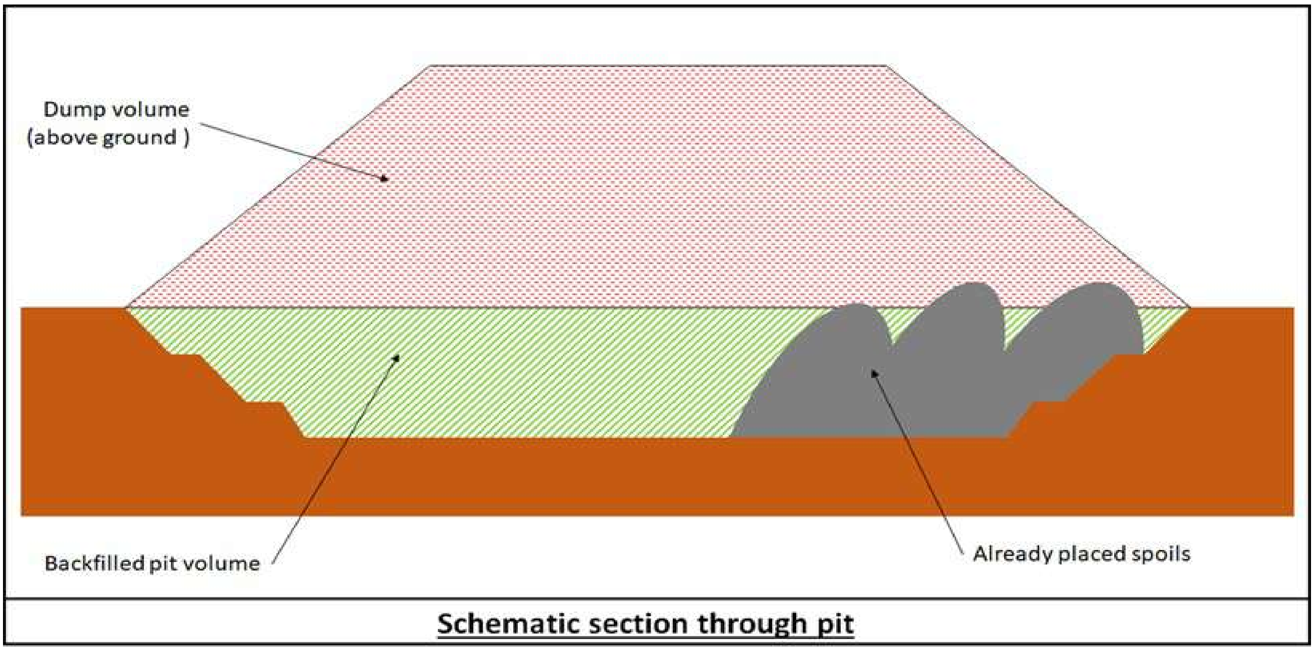

Figure 8: Zibulo Discard facility proposed concept (Golder 2020)

Seepage from the discard will be managed by the existing pit water management system in place for the mine. Excess mine water make intercepted at the pit is currently sent to the eMalahleni Water Reclamation Plant (EWRP) (via the Klipspruit Colliery's balancing dam) for treatment.

5.3 Discard Properties

Coal processing involves crushing, grinding and sizing, followed by physical separation of pyrite and other waste (discard) materials by gravity or floatation. The discard material from the coal washing process generally contains higher acid generation potential than the coal itself since the sulphide minerals contained in the coal rejects and carbonaceous waste rock are concentrated in the discard after the coal beneficiation process. At Zibulo, the discard material has been designed with a dry density of 1435 kg/m^3 and the infiltration rate (from double ring infiltrometer) was reported as 3.7 m/day (Golder, 2019b).

Golder has carried out two studies that address the geochemistry of discard material from the PCPP (Golder, 2017; Golder 2019a – see Table 2). The samples tested in these studies were discard output from Phola Plant when it was receiving ROM coal from both Zibulo and Klipspruit Colliery this is a discard sample from blended coal.

Given that the same coal seams are mined at Zibulo and at Klipspruit, and also the proximity of the two collieries (Klipspruit colliery lies immediately west of Zibulo opencast, and Zibulo underground is 16 km southwest of Klipspruit), it is to be expected that there is similarity between discard produced at PCPP from blended Zibulo and Klipspruit RoM coal, and discard produced from Zibulo RoM coal only. If this is the case, then technical work done on discard material from the PCPP using blended coal can be used as a proxy for stand-alone Zibulo discard material.

To test this assertion, discard material was collected from PCPP in November 2019, during a period when only Zibulo RoM coal was being processed. The results of the analyses of this material were then compared to the existing data on discard material from the PCPP (i.e., to data from discard produced from blended coal from the two mines).

(note that there is no independent data on the geochemistry of discard material from the PCPP when producing discard from Klipspruit RoM coal alone).

6.0 COAL DISCARD MATERIAL CHARACTERISATION

6.1 Sample availability

A composite sample of Zibulo discard material was collected on a day when only Zibulo ROM coal was being processed at the Plant. Two subsamples (Zibulo Discard A and B) were prepared by splitting the composite sample received using a sample splitter. Static geochemical tests and aquatic toxicology screening was conducted on the subsamples as part of the analytical laboratory programme.

The results for Zibulo discard subsamples are provided in the sections that follow, along with results from discard from blended coal (Golder 2017; 2019a). Appendix A (Figure A1) provides the location from which the Klipspruit discard samples were collected (Golder, 2017).

Laboratory certificates for the Zibulo subsamples are provided in Appendix D.

6.2 Chemical Properties

6.2.1 Total Elemental Composition

The extent of elemental enrichment in the Zibulo discard material was assessed using the geochemical abundance index (GAI). GAI compares the measured concentration of an element with the estimated median crustal abundance after Fortescue (1992) and Price (1997), using the equation:

GAI= $\log_2[Cn/1.5 \times Bn]$,

Where Cn is the concentration of the element in the samples and Bn is the crustal abundance of that element. The GAI is expressed in integer increments from 0 through to 6, where GAI where a GAI of 0 indicates the element is present at a concentration similar to or less than the crustal abundances; GAI of 3 corresponds to a 12-fold; and so forth, up to a GAI of 6, which indicates a 96-fold or greater enrichment above the median crustal abundances. The elements that were found to be enriched in the discard samples are tabulated in Table 3 and APPENDIX B (Table B1). The following elements had GAI values >3: As, B, Bi, Hg, Li, Mo, Pb, Sb, Se, Sc.

Table 3: Geochemical Abundance Index for Zibulo discard samples

Sample Name	Rock Type	Elements with GAI>03
Zibulo Discard A	Discard	As, B, Bi, Hg, Li, Mo, Se, Sn, Te
Zibulo Discard B	Discard	As, B, Bi, Hg, Li, Mo, Se, Te
Plant/Discard facility (Golder, 2015)	Coarse and fine discard	As, B, Bi, Hg, Li, Mo, Pb, Sb, Sc, Te

Enrichment of elements in the discard samples over crustal concentrations was also determined. The Zibulo discard material is enriched (>10 times the average crustal abundance) includes, As, Bi, Hg, Mo, Se and Te. These elements and the elements identified with GAI> (Table 3) are identified as potential constituents of concern (PCoC) and could likely be mobilised into the environment depending on the rate of oxidation and weathering extent.

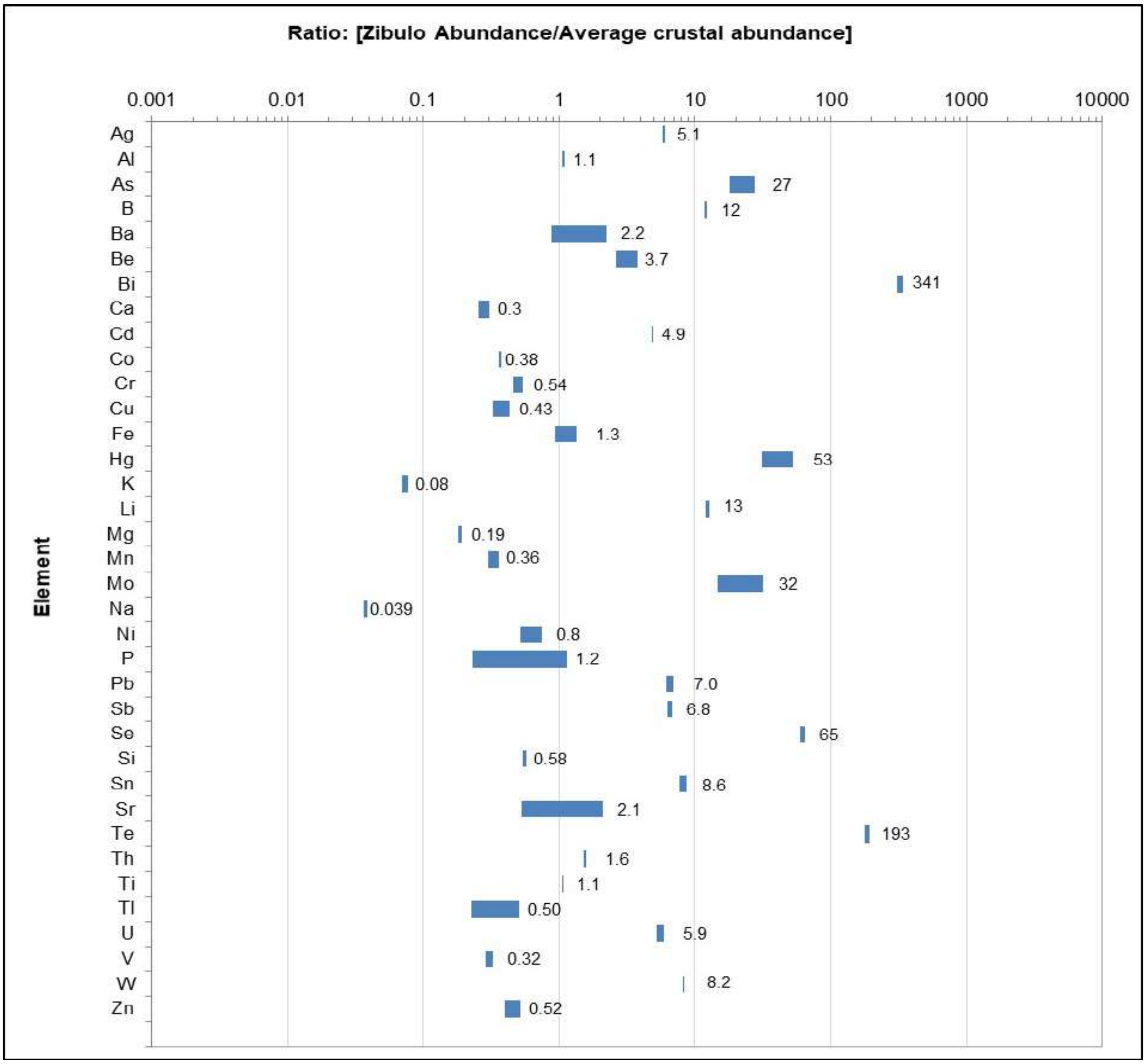

Figure 9: Ratios of Zibulo coal discard's elemental concentrations against average crustal concentration (Data label is the maximum ratio)

6.2.2 Mineralogy

A summary of mineralogical results for discard material is illustrated in Figure 3 and Table 4 and indicates the following:

- Kaolinite (22-46 wt%) was reported as a major to dominant mineral phase in the discard material, with quartz (8-23 wt%) detected as a minor to major mineral phase;
- Other silicate mineral detected in the XRD included augite (0.23-1.7 wt%) was recorded as a rare to accessory mineral phase; microcline 1.8-3.7 wt%) and muscovite (1.1-4.7 wt%) were recorded as accessory to minor mineral phases; and
- Carbonate minerals comprising the discard material are calcite (0.3-2.4 wt%) and dolomite (0.42-6.7 wt%) and are fast reacting minerals (Table 4) that contribute to the Neutralisation Potential (NP) of the discard material. It should be noted that the Zibulo sub-sample have an order of magnitude higher dolomite mineral concentration (average value = 5.8 %) present compared to the samples of discard from blended coal.

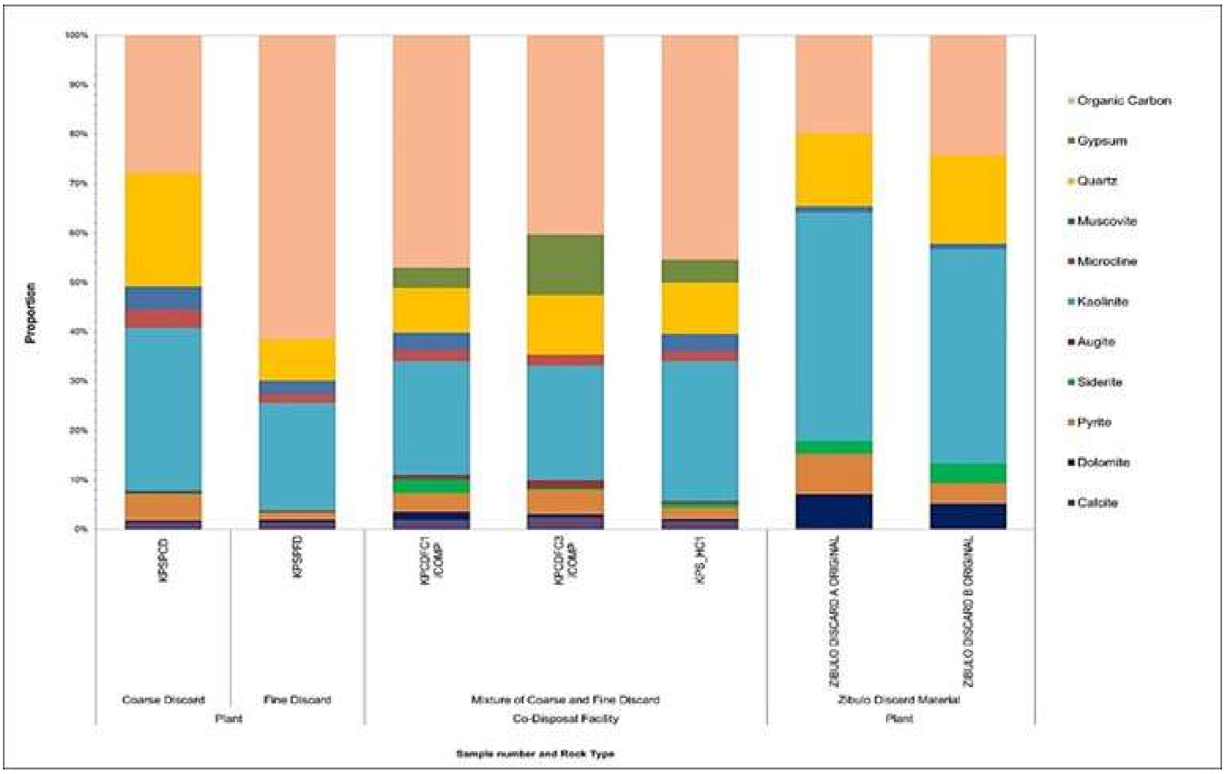

Figure 10: Mineralogical distribution of discard material

Table 4: Summary of Minerology (XRD) Results

Weathering Rate (Bowell, 2000)	Mineral	Approximate Formula	Discard from Blended Coal					Zibulo Discard Material		
Sample ID			KPSP-CD	KPSP-FD	KPCD-FC1	KPCD-FC3	KPS-HC1	Zibulo A	Zibulo B	Zibulo average
Acid Forming Minerals			**Proportion (%)**							
Fast weathering	Pyrite	FeS_2	5.3	1.5	3.9	4.9	2.3	8.1	4.1	6.1
Acid Neutralising Minerals			**Proportion (%)**							
Dissolving	Calcite	$Ca(CO_3)$	1.4	1.5	1.9	2.4	1.7	0.4	0.3	0.35
	Dolomite	$CaMg(CO_3)_2$	0.49	0.49	1.6	0.66	0.42	6.7	4.9	5.8
Fast weathering	Siderite	$Fe(CO_3)$	0.24	0.11	2.7	0.27	0.78	2.6	4.0	3.3
Intermediate Weathering	Augite	$(Ca,Mg,Fe)_2 Si_2O_6$	0.41	0.23	0.87	1.7	0.53	nd	nd	nd
Slow weathering	Kaolinite	$Al_2Si_2O_5(OH)_4$	33	22	23	23	28	46	43	45
Very Slow Weathering	Microcline	$K(AlSi_3O_8)$	3.7	1.8	2.3	2.2	2.04	nd	nd	nd
	Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	4.7	2.8	3.5	trace	3.5	1.2	1.1	1.15
Other minerals			**Proportion (%)**							
Inert	Quartz	SiO_2	23	8.4	9.1	12	10	15	18	16
Secondary mineral	Gypsum	$Ca(SO_4)\cdot 2H_2O$	nd	nd	4.01	12.1	4.64	nd	nd	nd
Organic matter	Organic Carbon		28	62	47	40	45	20	24	22

nd- Not detected

- Siderite (0.11-4.0%) was found present in all discard samples and does not contribute to the NP since under aerobic condition the subsequent oxidation and hydrolysis of Fe2+ generated equivalaent acidity as consumed initially be $FeCO_3$ consuming acidity;

- Pyrite was recorded as an accessory to minor mineral phase (1.5-8.1 wt%) with the highest pyrite content (8.1 wt%) was recorded in the Zibulo discard material (Sample A). The average pyrite content for Zibulo discard (6.1%) is comparable to pyrite content (5.3%) for Klipspruit coarse discard; and

- The heterogeneity of the two Zibulo discard subsamples (Zibulo Discard A and Zibulo Discard B) is evident from the distribution of minerals, most notably pyrite (8% vs 4%). Despite the two subsamples having been prepared from a single sample from the plant by splitting using a rifle splitter, the pyrite and dolomite mineral proportions differ indicating heterogeneity.

6.2.3 Acid generation and neutralisation potential

6.2.3.1 Acid Base Accounting

A summary of Acid Base Accounting (ABA) results obtained from previous studies conducted on PCPP discard, Klipspruit Co-disposal facility and Zibulo discard material are summarised in Table 5. The following can be concluded from the ABA results:

- Sulphide S is the dominant sulphur species in all the discard samples collected. The Sulphide S concentration recorded in the Zibulo discard material (3.3-6.0 %S) is consistent with the pyrite concentration reported during XRD analysis. Figure 11 indicates a 1:1 correlation for Total S and Sulphide S;
- The average Total S (8.3%) and Sulphide S (6.0%) content of the Zibulo discard is 2 to 3 times higher than the discard from blended coal;

- The circum-neutral paste pH (6.6 -7.7) confirms the presence of fast reacting carbonate minerals in all samples. Dolomite and calcite as detected by XRD analysis (Section 6.2.2) provide the neutralisation Potential (NP). The NP of these Zibulo subsamples is 2 to 3 times higher than the discard from blended coal;

- The Acid Potential (AP) calculated using total sulphur (TAP) and sulphide sulphur (SAP) is indicated in Figure 13.The SAP (24-187 kg $CaCO_3$/ton) and TAP (38-260 kg $CaCO_3$/ton) is greater than the Bulk NP (11-53 kg $CaCO_3$/ton) in all the discard samples, both from discard from Zibulo coal and discard from blended coal, due to the % Total S or Sulphide S%.

- The negative Net Neutralisation Potential (TNNP and SNNP) suggest that there may be insufficient NP to buffer acidity generated; and

- Zibulo B discard sample has the highest sulphide S and the most negative SNNP, but the Zibulo A discard sample falls well within the range of discard from blended coal, and is towards the end with less negative SNNP (see Figure 13).

6.2.3.2 Net Acid Generation

The NAG-leach procedure uses a strong oxidant (hydrogen peroxide) to rapidly oxidise sulphide minerals in a crushed sample of the entire rock/ tailings (AMIRA, 2002). The NP of the sample can then be directly titrated against the acidity generated by rapidly oxidising sulphides. If the sample has sufficient available NP, the alkalinity will not be entirely depleted, and the system is expected to remain circumneutral. If there is inadequate available NP, then the pH of the test solution will fall below 4.5 due to a net acidity. Figure 14 shows that the samples of discard from Zibulo coal had net acidity, as did half of the samples of discard from blended coal.

Table 5: Summary of Acid Base Accounting results

Data Source		Sample ID	Paste pH	Total S %	Sulphide S	Sulphate S	Organic S	Total C	Inorganic C	Organic C	Bulk NP[1]	CaNP	SAP[2]	TAP	SNNP[3]	TNNP	SNPR[4]	TNPR
			-	%							kg $CaCO_3$ eqvt./tonne							
Phola Discard from Blended Coal	Golder (2017) Discard Dump	Plant and CDF Discard	6.9	3.5	2.4	0.26	0.83	36	2.7	33	18	225	75	110	-57	-92	0.3	0.2
	Golder (2019a) Plant	KPSP-FD	7.6	1.2	0.8	0.039	0.38	53	0.15	53	15	12	24	38	-8.8	-23	0.63	0.4
		KPSP-CD	6.5	4.6	3.6	0.052	0.97	23	0.49	22	11	41	112	144	-101	-133	0.1	0.08
	Golder (2019a) Discard Dump	KPCDF-C1 KPS	6.6	3.5	2.2	0.47	0.77	42	4.6	37	21	384	70	109	-49	-88	0.3	0.19
		KPCDF-C2 KPS	6.8	2.8	1.7	0.51	0.61	34	4.0	30	21	335	54	88	-33	-67	0.39	0.24
		KPCDF-C3 KPS	6.8	5.7	3.9	0.47	1.42	32	3.8	29	25	318	120	178	-95	-153	0.21	0.14
		KPCDF-C4 KPS	7.3	3.2	2.3	0.053	0.85	29	3.1	26	14	262	72	100	-58	-86	0.19	0.14
		KPS-HC1	7.0	2.8	2.1	0.52	0.22	37	36	0.9	30	75	64	88	-34	-58	0.47	0.34
Discard from Zibulo Coal	Golder (*this study*)	Zibulo Discard A	7.7	4.6	3.3	0.010	1.3	25	3.90	20.7	48	65	103	145	-55	-97	0.46	0.33
		Zibulo Discard B	7.5	8.3	6.0	0.009	2.3	20	3.70	16.5	53	62	187	260	-134	-207	0.28	0.20
		Zibulo Discard Average	7.6	6.5	4.6	0.01	1.3	22	3.8	19	50	63	144	202	-95	-151	0.37	0.27

Bulk NP is NP measured by Sobek titration; CaNP is NP calculated based on inorganic carbon LECO analysis. Measured NP is used for the NPR calculation;

[2]SAP - acid potential based on sulphide sulphur; TAP - acid potential based on the total sulphur content

[3]SNNP - the difference between Bulk NP and SAP; TNNP - the difference between Bulk NP and TAP

[4]SNPR - Ratio of SAP and bulk NP; TNPR - Ratio of TAP and Bulk NP PAG – Potentially acid generating; Non-PAG – not potentially acid generating; NA- Not Analysed

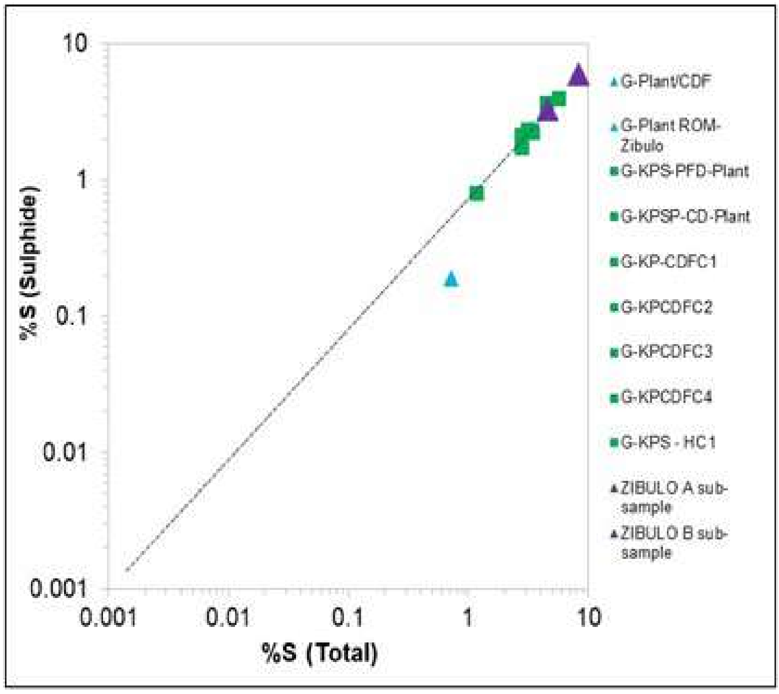

Figure 11: Total S compared to Sulphide S for discard material (G=Golder studies of discard from blended coal)

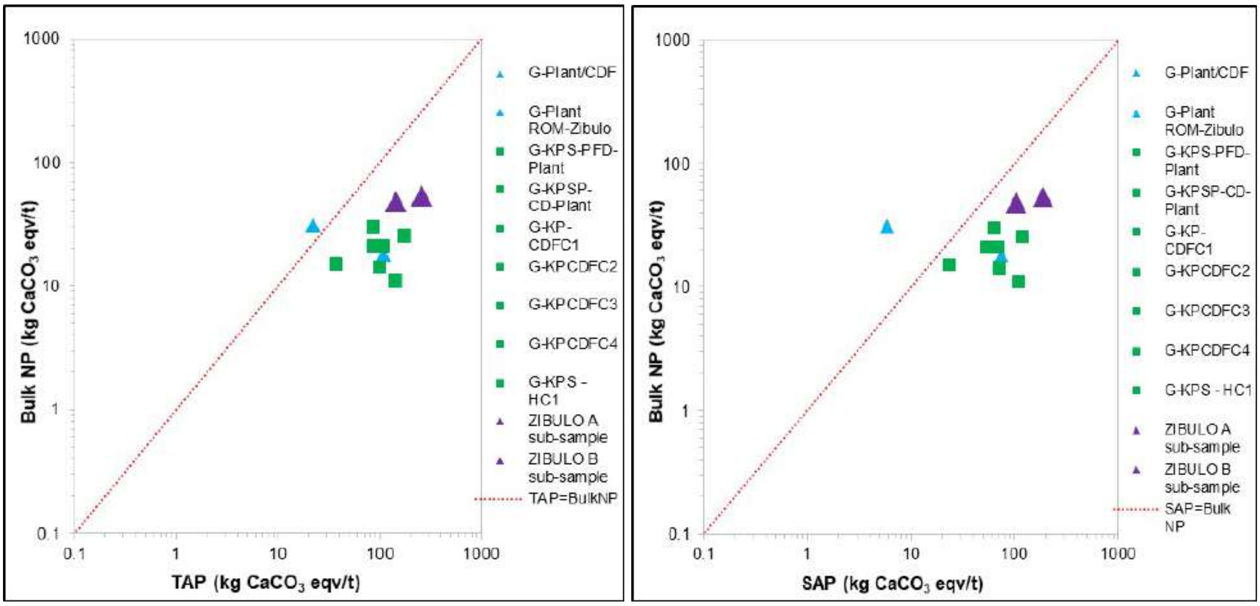

Figure 12: Total Sulphur Acid Potential (TAP) and Sulphide Sulphur Acid Potential (SAP) compared to Bulk NP for Zibulo discard material (G= G=Golder studies of discard from blended coal)

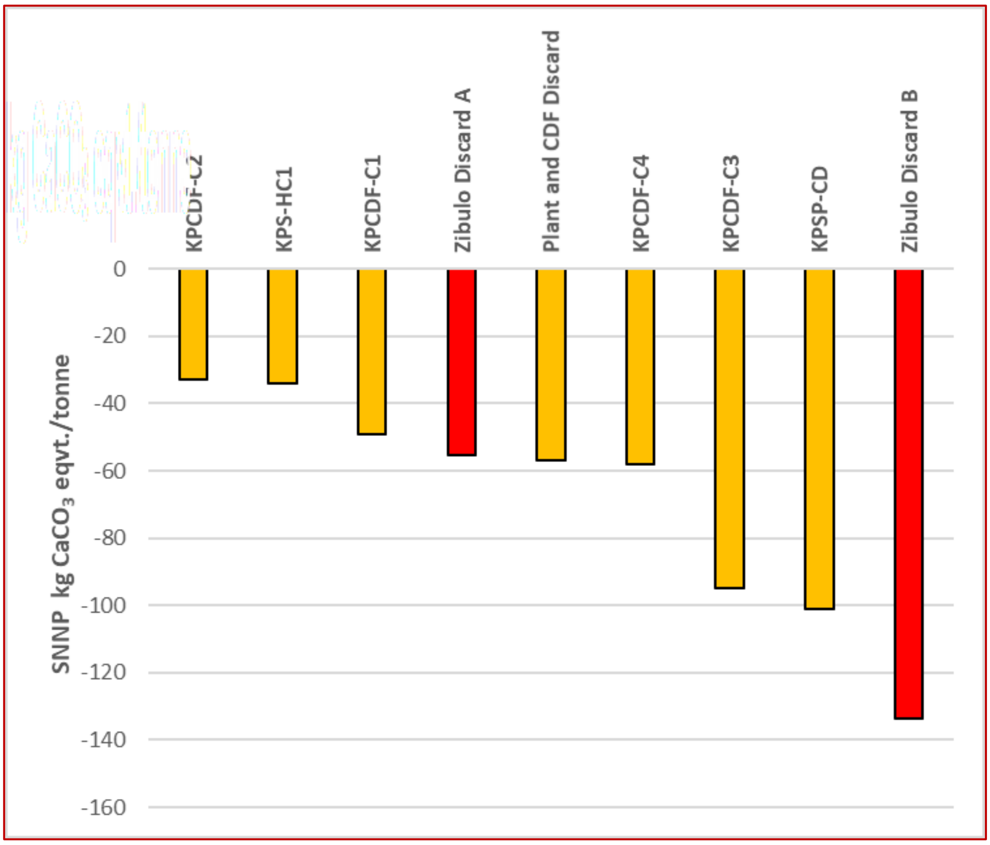

Figure 13: Net Neutralisation potential of discard from blended coal (orange) and discard from Zibulo coal (red)

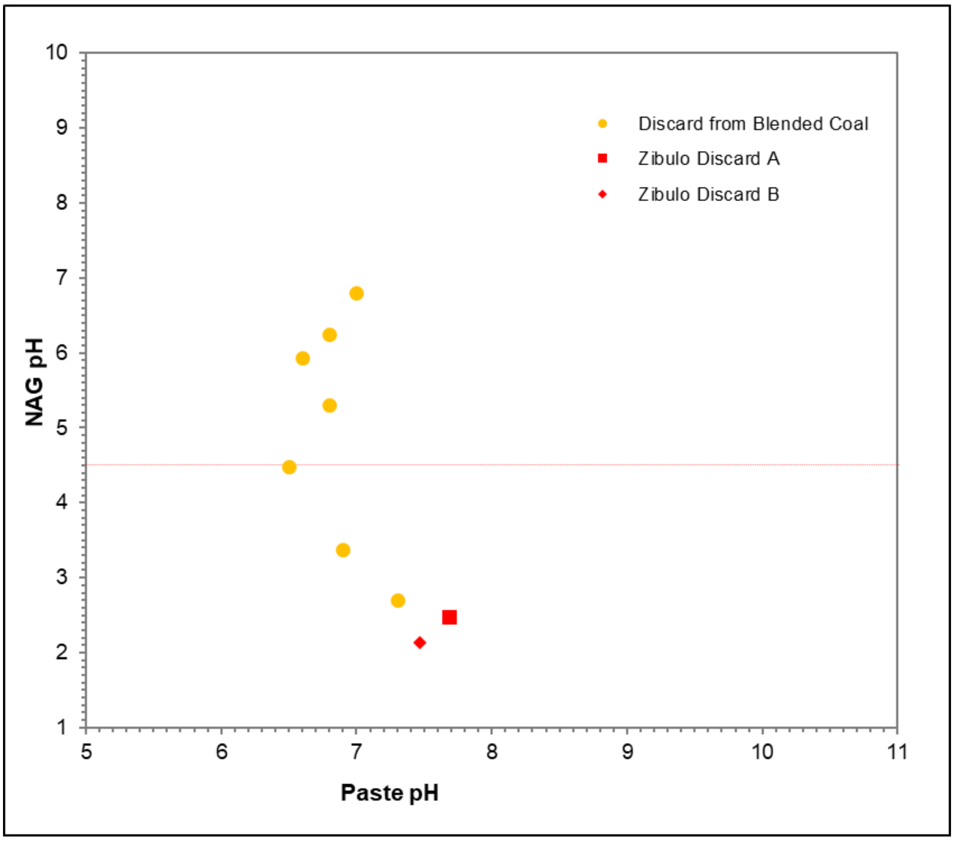

Figure 14: NAG pH versus paste pH for discard from blended coal (orange) and discard from Zibulo coal (red)

6.2.3.3 ARD Risk Classification

Guidelines outlined in Table 6 were used to assess the Acid Rock Drainage (ARD) risk for the discard material.

Table 6: ARD potential guidelines as provided by MEND (2009), Price et al (1997) & Soregaroli and Lawrence (1997)

MEND (2009) * guidelines		
ARD Potential	Criteria	Comments
PAG	NPR<1	Potentially acid generating material, unless sulphide minerals are non-reactive, or NP is preferentially exposed on surfaces.
Non-PAG	NPR>2	Non-potentially acid generation material, unless NP is insufficiently reactive, extremely reactive sulphides are present, or preferential exposure of sulphides is found in the material.
Uncertain	1<NPR<2	Possibly PAG if NP is insufficiently reactive or is depleted at a faster rate than sulphides.

Guidelines from Price *et al*. (1997) and Soregaroli and Lawrence (1997)			
Sulphide sulphur	NPR (Bulk NP /SAP)	Potential for ARD	Comments
<0.3%	----	None	No further ARD testing required provided there are no other metal leaching concerns. *Exceptions:* host rock with no basic minerals, sulphide minerals that are weakly acid soluble.
>0.3%	<1	Likely	Likely to be ARD generating.
	1-2	Possibly	Possibly ARD generating if NP is insufficiently reactive or is depleted at a rate faster than that of sulphides.
	2-4	Low	Not potentially ARD generating unless significant preferential exposure of sulphides occur along fractures or extremely reactive sulphides are present together with insufficiently reactive NP.
	>4	None	No further ARD testing required unless materials used as a source of alkalinity.

Both guidelines show similar risk from both of the samples of discard from Zibulo coal and all of the samples of discard from blended coal:

- MEND (2009): Potentially Acid Generating (Figure 15); and
- Price *et al* (1997) and Soregaroli and Lawrence (1997): likely acid rock drainage (Figure 16).

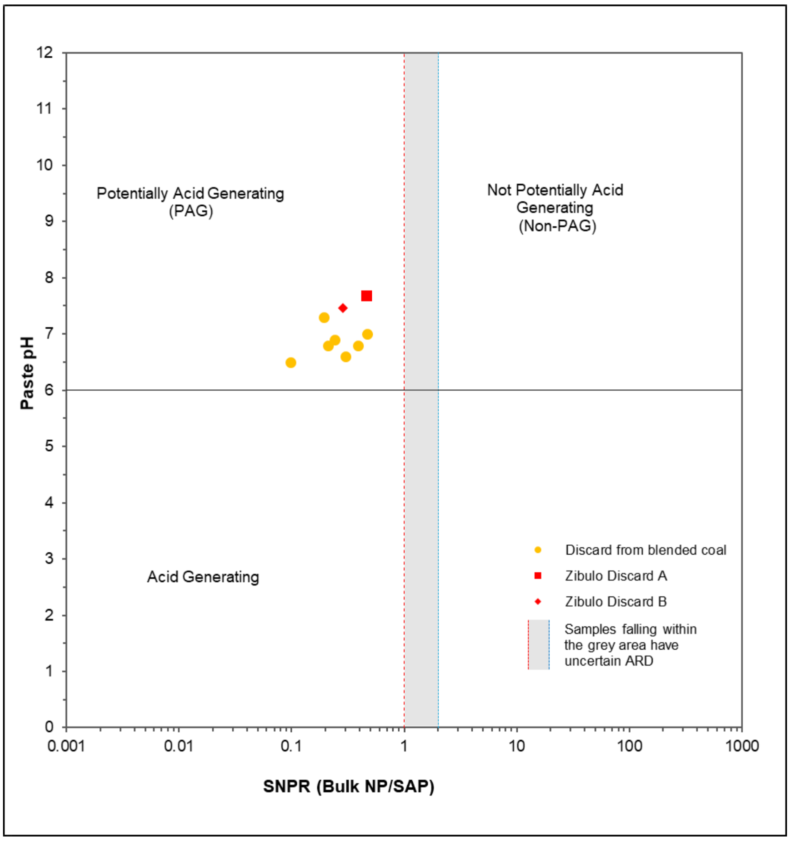

Figure 15: Classification (MEND, 2009) for discard from blended coal (orange) and discard from Zibulo coal (red)

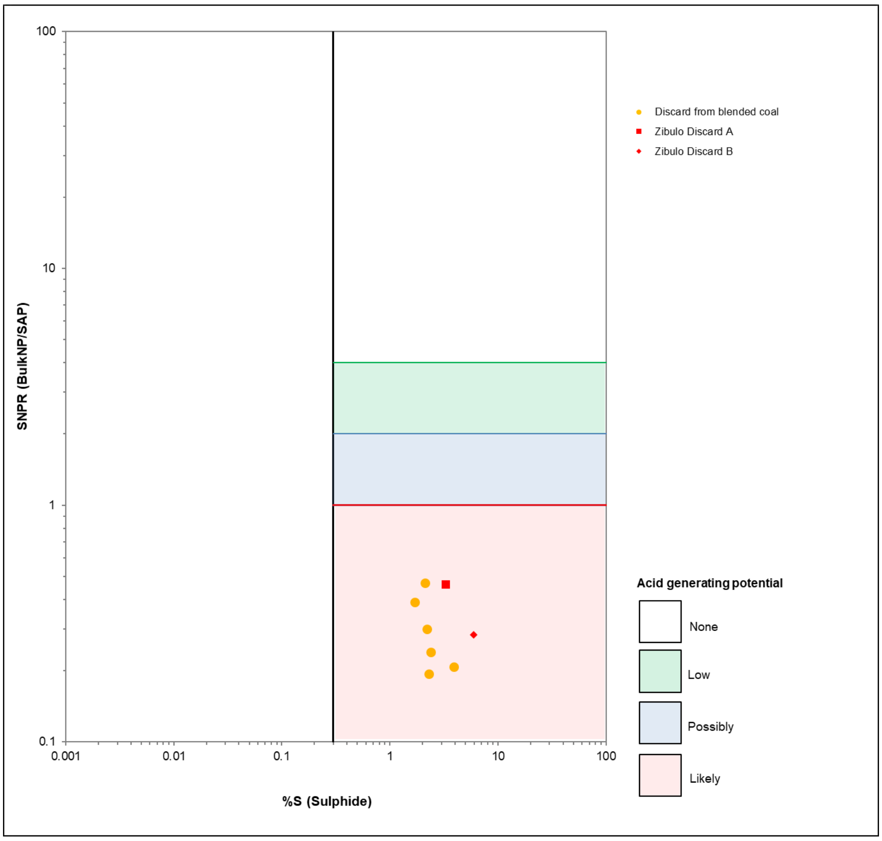

Figure 16: Classification (Price *et al.*, 1997) for discard from blended coal (orange) and discard from Zibulo coal (red)

6.2.4 Leachate Characteristics

Australian Standard Leach Procedure leach with reagent water at 1:20 solid:liquid ratio (Table 7) showed:

- Circum-neutral pH in all samples
- Higher levels of TDS, sulphate, manganese, calcium and magnesium in leachate from discard from blended coal; and
- Higher levels of sodium, chloride and aluminium in leachate from discard from Zibulo coal.

Table 7: Deionised leach (1:20 ASLP) results showing parameters substantially higher for discard from blended coal (orange) and discard from Zibulo coal (red)

Chemical Parameter	Units	Discard from blended coal						Discard from Zibulo coal	
		KPSPCD	KPSPFD	KPCDFC1	KPCDFC2	KPCDFC3	KPCDFC4	Zibulo Discard A	Zibulo Discard B
pH	s.u	7.6	7.6	7.6	7.7	7.8	7.9	7.7	7.5
TDS	mg/l	254	188	928	1090	754	248	92	104
EC	mS/m	38	27	111	121	91	35	17	15
Alkalinity	mg/l $CaCO_3$	45	24	59	52	57	44	46	36
Fluoride	mg/l	0.32	0.70	0.63	0.62	0.44	0.52	0.51	0.45
Chloride	mg/l	0.39	0.22	BDL	BDL	0.33	0.	0.73	0.64
Nitrate as N	mg/l	0.08	0.19	0.09	0.15	0.07	0.09	0.22	0.17
Sulphate	mg/l	145	111	639	730	497	137	28	18
Aluminium	mg/l	BDL	0.013	BDL	0.013	BDL	BDL	0.12	0.35
Arsenic	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001
Calcium	mg/l	67	40	220	217	172	54	11	9
Cobalt	mg/l	0.012	0.001	0.002	0.002	0.002	0.003	BDL	BDL
Copper	mg/l	0.004	BDL	0.002	BDL	BDL	0.001	BDL	BDL
Iron	mg/l	0.010	BDL	0.020	0.020	0.020	0.020	0.004	0.007
Lead	mg/l	0.001	0	0.001	BDL	BDL	BDL	0.001	BDL
Magnesium	mg/l	7.4	7.1	31	53	22	7.2	2.3	1.8
Manganese	mg/l	0.24	0.02	0.35	0.62	0.18	0.09	0.002	BDL
Mercury	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.0003	0.0001
Molybdenum	mg/l	0.006	0.008	0.001	0.001	0.002	0.009	0.002	0.002
Nickel	mg/l	0.017	0.002	0.009	0.010	0.013	0.006	0.003	0.002
Potassium	mg/l	1.50	1.30	0.65	1.10	0.89	1.60	1.35	1.15
Selenium	mg/l	0.004	0.001	0.002	0.003	0.002	0.001	BDL	0.002
Sodium	mg/l	1.2	4.0	7.2	3.6	4.9	5.3	17.6	16.1
Uranium	mg/l	0.0002	0.0004	0.0005	0.0006	0.0006	0.0009	0.0004	0.0002
Zinc	mg/l	0.031	0.002	0.028	0.02	0.008	0.008	0.003	0.003

6.3 Aquatic Toxicology Properties

Screening aquatic ecotoxicology tests were conducted on Zibulo discard sample B. The screening report is provided in Appendix E and concluded that no acute toxic effects greater that 50% within the four bioassays. Therefore, the EC/LC50 value would be greater than 100 mg/L for these four trophic levels. This does not indicate acute toxicity.

6.4 Physical Properties

Particle size for discard material from PCPP coal discard (sample 1-4) and Zibulo discard ranges from coarse sand/silt to gravel-sized particles (Figure 18), with 16-21% passing 5 mm. The Zibulo discard A indicates lower fraction of fine discard materials with 0.19% passing 300 µm vs the rest of the samples recorded with 2-3% passing 300 µm.

Coal discard from the eMalahleni coalfield is known to have a risk of spontaneous combustion, due to exothermic ARD reactions (heat is generated during the oxidation of pyrite) and from the heat of rewetting of dry or oxidised pyrite (Falcon, 1986). There is no information available regarding spontaneous combustion tests on discard from this site.

The sulphide-containing discard materials oxidise in the process of ARD generation.

The sulphide-containing discard materials react with oxygen and water in the process of ARD generation.

No information is available on the levels of volatile organic compounds (VOCs) in the discard material, but the processes at the plant do not generate VOCs.

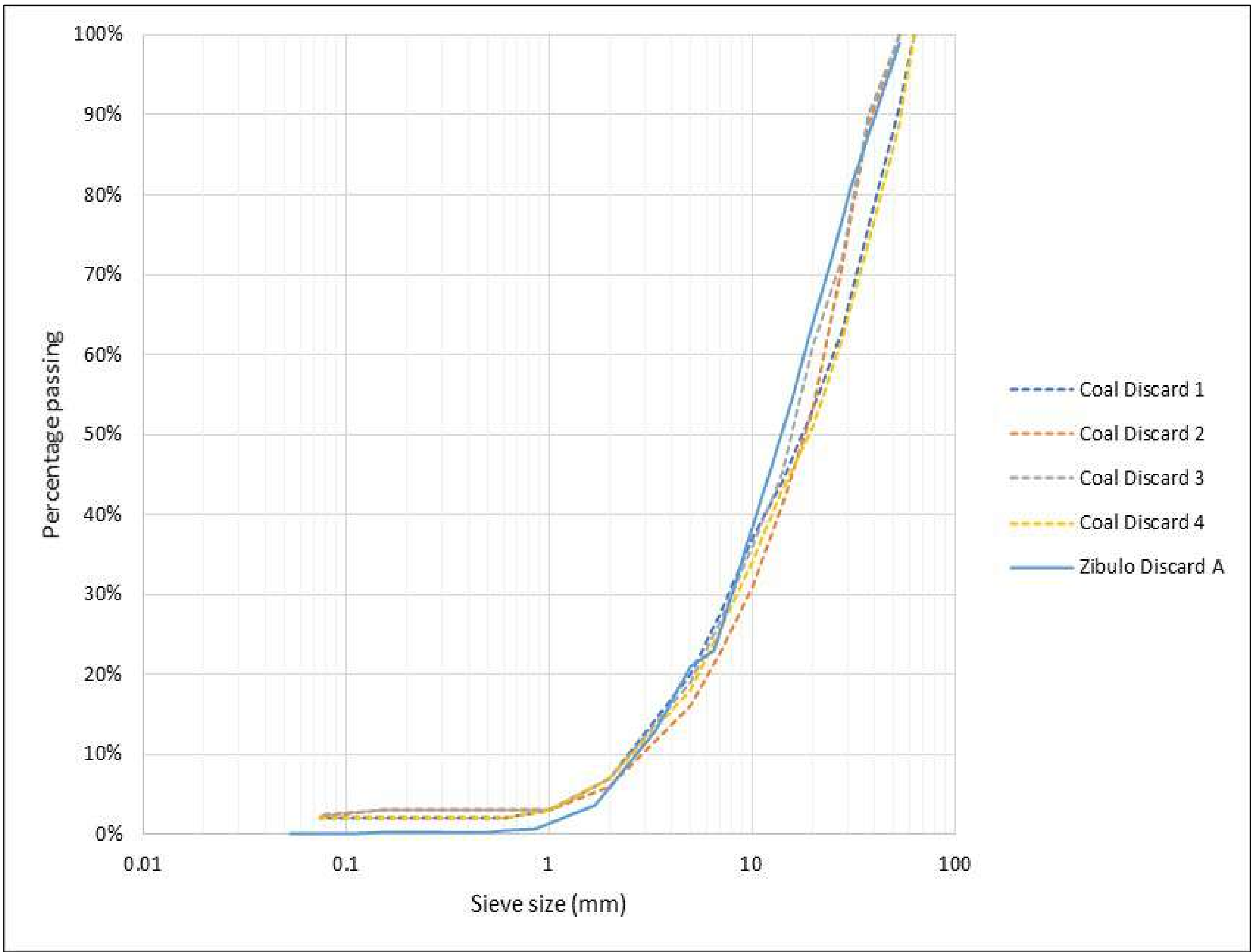

Figure 17: Particle size distribution for coal discard material (Golder, 2019a: discard from blended coal) and discard from Zibulo coal

7.0 COMPARISON OF DISCARD TYPES

Considering the expectation that there is likely to be a similarity between discard produced at PCPP from blended Zibulo and Klipspruit coal, and discard produced from Zibulo coal only, the following is considered:

- One sample of discard from Zibulo coal had slightly more acid-generating pyrite than the range of pyrite content in the samples of discard from blended coal, and the other sample of discard from Zibulo coal was within the range;
- Both samples of discard from Zibulo coal had more acid-neutralising dolomite than the range of dolomite content in the samples of discard from blended coal;
- Both samples of discard from Zibulo coal and all samples of discard from blended coal were potentially acid-generating; and
- Leachate from discard from blended coal had higher levels of TDS, sulphate, manganese, calcium and magnesium, while leachate from discard from Zibulo coal had higher levels of sodium, chloride and aluminium.

On the basis of the above, the geochemical risk profile of discard from Zibulo coal is broadly similar to that of discard from blended Zibulo and Klipspruit coal, although the overall salinity and sulphate concentrations in seepage from discard from Zibulo coal may be somewhat lower than seepage from discard from blended coal.

Therefore, it is reasonable that technical work done on discard material from the PCPP using blended coal can be used as a proxy for discard produced from Zibulo coal. In this context, and in the absence of kinetic tests carried out on discard from Zibulo coal, the results of kinetic tests carried out on discard from blended coal are considered:

- KPS-HC1, which had a high proportion of coarse discard (gravel size); and
- KPS-HC3, which had a mixture of coarse discard and fine discard (milled fraction of the coarse discard).

Appendix D provides a summary of the Golder (2019a) kinetic results.

The two cells gave different results with HC3 turning acidic suggesting depletion of the NP (Figure 17), suggesting that there is a long-term risk of acidic seepage generated from the discard facility under fully oxidizing conditions from the finer material comprising the discard dump.

Based on the kinetic results an engineered cover to reduce oxygen and infiltration into the Zibulo discard dump is required to prevent ARD in the long-term.

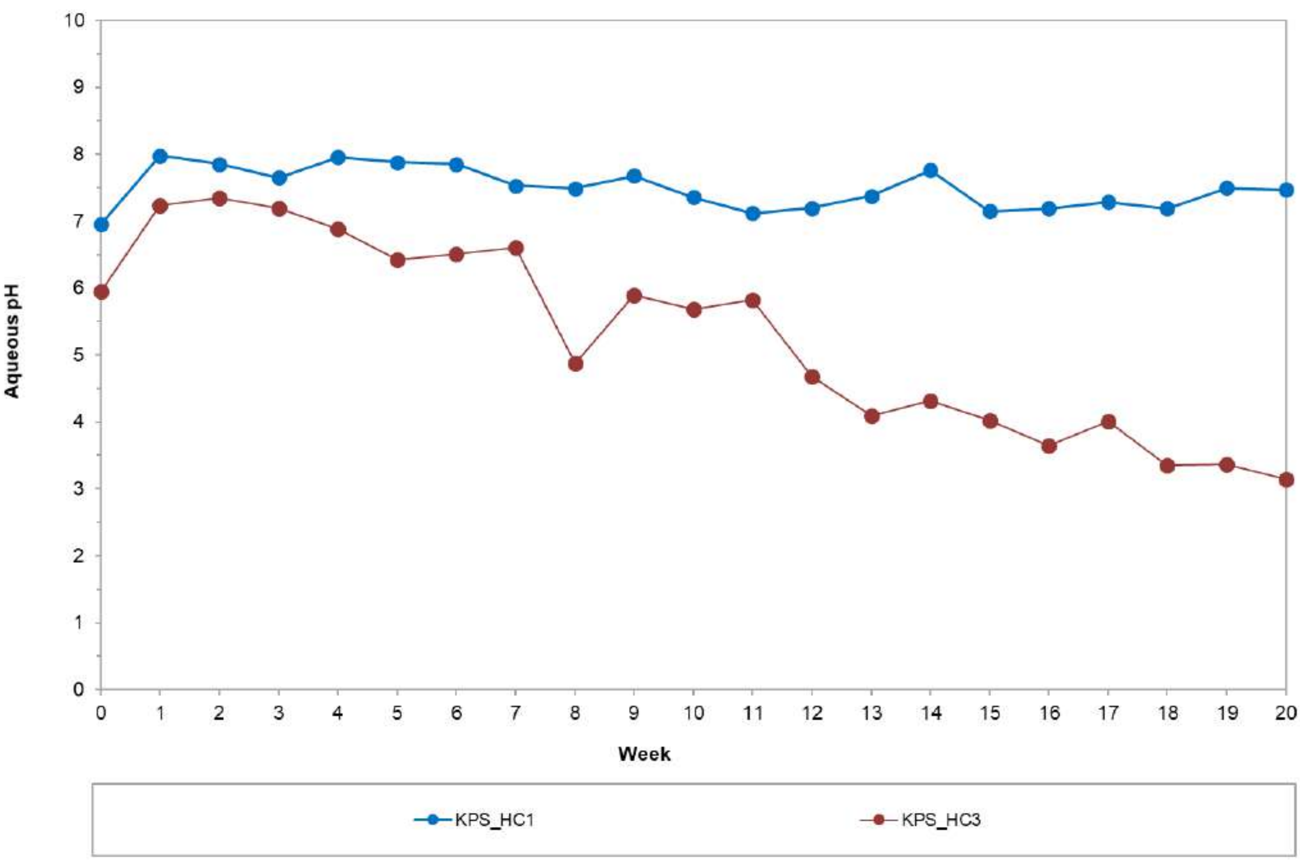

Figure 18: Variation of pH in discard humidity cell leachate samples

8.0 WASTE ASSESSMENT AND CLASSIFICATION

8.1 Waste Classification

8.1.1 Methods

According to section 4(2) of GN R.634 of 2013, all waste generators must ensure that their waste is classified in accordance with SANS 10234 (based on the Global Harmonised System) within 180 days of generation, except if it is listed in Annexure 1 (*Wastes that do not require Classification and Assessment*) of the GN R.634. Furthermore, waste must be re-classified every 5 years.

Waste classification according to SANS 10234 (based on the Global Harmonised System) indicates physical, health and environmental hazards. The SANS 10234 covers the harmonised criteria for classification of potentially hazardous substances and mixtures, including wastes, in terms of its intrinsic properties/hazards.

The chemical test results as well as intrinsic properties of the waste streams were used for the SANS 10234 classification. Constituents present in concentrations exceeding 1% are used for classification in terms of health hazards, except when the constituent is known to be toxic at lower concentrations (carcinogens etc.) (Table 2)

Where specific South African guidance is lacking, classification takes cognisance of European Regulation (EC) No. 1272/2008 on the Classification, Labelling and Packaging of Substance and Mixture (CLP Regulation) which adopts, within the European community, the GHS as published United Nations Social and Economic Council.

Table 8: Cut-off values/concentration limits for hazard classes (SANS10234)

Hazard Class	Cut-off value (Concentration limit) %
Acute toxicity	> 1.0
Skin corrosion	> 1.0
Skin irritation	> 1.0
Serious damage to eyes	> 1.0
Eye irritation	> 1.0
Respiratory sensitisation	> 1.0
Mutagenicity: **Category 1** **Category 2**	 > 0.1 > 1.0
Carcinogenicity	> 0.1
Reproductive toxicity	> 0.1
Target organ systematic toxicity	> 1.0
Hazardous to the aquatic environment	>1.0

8.1.2 Classification Results

- Physical Hazards - The discard material is not explosive, is not corrosive to metal, oxidising and does not release toxic gases when in contact with water or acid, and is therefore **not hazardous in terms of its physical characteristics**.

- Health Hazards- Constituents recorded above 1% (threshold for carcinogens) include Al (8.9-9.1%), Ca (1.2-1.4%), Fe (5.8-8.3%), and Si (14.6-15.7%). These constituents **do not pose a health risk** in their current form (solids and low leachability).
- Environmental Hazard- None of the analysed leachable constituents were recorded above the 1% threshold. However kinetic testing indicated acidic seepage condition will prevail for the discard facility since NP will be consumed under accelerated oxidation and weathering conditions. On this basis the discard material **could pose a risk to the environmental** in terms of SANS 10234. Under acid conditions the ARD products TDS, Fe and SO_4^{2-} >1% and could pose a risk to aquatic environments.

Accordingly, the discard from Zibulo coal is classified as Hazardous.

8.2 Waste Assessment

8.2.1 Methods

A GN R.635 waste assessment is performed to determine the Type of waste and the correct barrier design requirements for disposal. The assessment of waste must be done in terms of the procedures stipulated in GN R. 635 of 23 August 2013 where the potential level of risk associated with disposal of materials/wastes can be determined by following the prescribed and appropriate leach test protocols. The results must be assessed against the four levels of thresholds for leachable and total concentrations, which in combination, determines the waste type and associated barrier design / liner requirements (see Figure 1). The terminology is as follows:

- LC = leachable concentration of a particular contaminant in a waste, expressed as mg/l.
- TC = total concentration of a particular contaminant in a waste, expressed as mg/kg.
- LCT = leachable concentration thresholds of a particular contaminant in a waste (LCT0, LCT1, LCT2, LCT3).
- TCT = total concentration thresholds of a particular contaminant in a waste (TCT0, TCT1, TCT2).

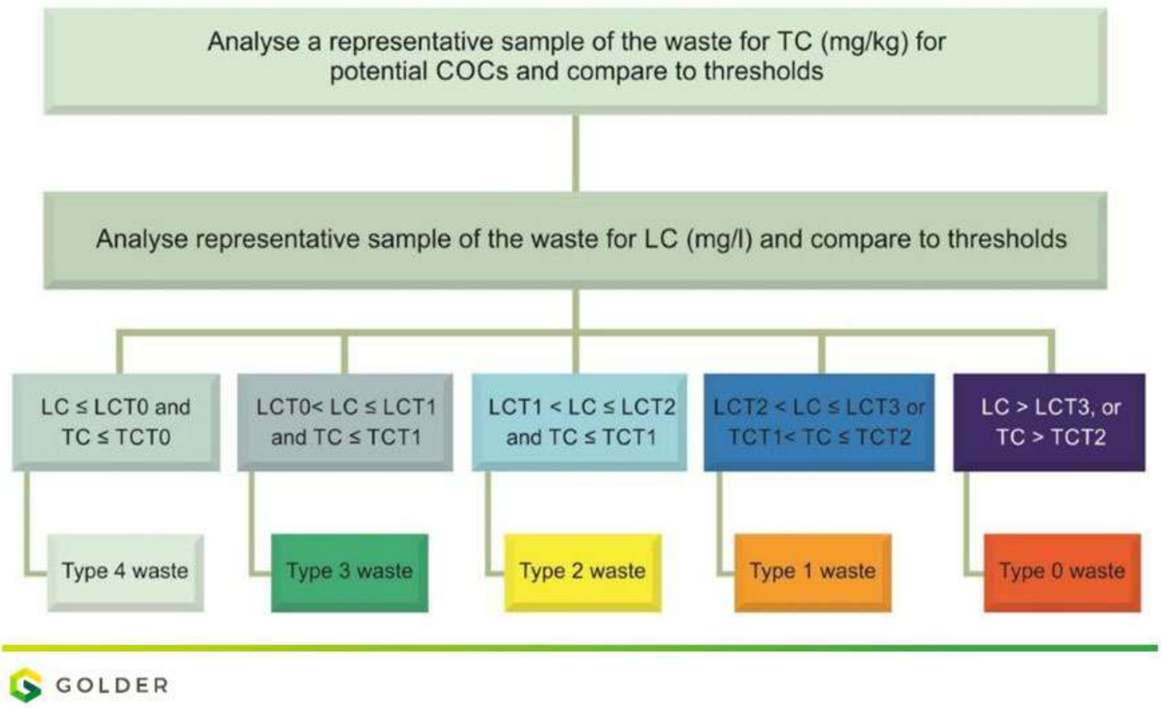

Figure 19: Flow diagram for waste assessment according to the GN R. 635

8.2.2 Waste Assessment Results

Total and leachable concentrations of constituents were compared to TCT threshold (Table 9) and LCT thresholds respectively (Table 10), showing that:

- Total concentrations of As, Ba, Cu, Hg and Pb exceeded TCT0;
- None of the leachable concentrations were reported above LCT0.

Zibulo discard material is assessed as a **Type 3 waste**, although the risk from leachable parameters is low.

Table 9: Total concentrations (mg/kg) of constituents for discard material screened against thresholds

Chemical parameter	GN R.635 thresholds			Discard from Zibulo coal	
	TCT0	TCT1	TCT2	DISCARD A	DISCARD B
As	5.8	500	2000	32	49
B	150	15000	60000	107	111
Ba	62.5	6250	25000	345	877
Cd	7.5	260	1040	0.79	0.77
Co	50	5000	20000	10	11
Cr	46000	800000	N/A	56	66
Cu	16	19500	78000	29	22
Hg	0.93	160	640	2.7	4.5
Mn	1000	25000	100000	377	315
Mo	40	1000	4000	18	38
Ni	91	10600	42400	51	75
Pb	20	1900	7600	80	91
Sb	10	75	300	1.4	1.3
Se	10	50	200	3.2	3.0
V	150	2680	10720	44	39
Zn	240	160000	640000	39	30

Notes: *Total concentrations above TCT0 highlighted in grey*

Table 10: Leachable concentrations (mg/l) of constituents for discard material screened against thresholds

Chemical parameter	GN R.635 thresholds				Discard from Zibulo coal	
	LCT0	LCT1	LCT2	LCT3	DISCARD A	DISCARD B
As	0.01	0.5	1	4	BDL	BDL
B	0.5	25	50	200	0.408	0.371
Ba	0.7	35	70	280	0.408	0.371
Cd	0.003	0.15	0.3	1.2	BDL	BDL
Co	0.5	25	50	200	BDL	BDL
Cr	0.1	5	10	40	BDL	BDL
Cr(VI)	0.05	2.5	5	20	BDL	BDL
Cu	2	100	200	800	BDL	BDL
Hg	0.006	0.3	0.6	2.4	0.0003	0.0001
Mn	0.5	25	50	200	0.002	BDL
Mo	0.07	3.5	7	28	0.002	0.002

Chemical parameter	GN R.635 thresholds				Discard from Zibulo coal	
	LCT0	LCT1	LCT2	LCT3	DISCARD A	DISCARD B
Ni	0.07	3.5	7	28	0.003	0.002
Pb	0.01	0.5	1	4	0.001	BDL
Sb	0.02	1	2	8	BDL	BDL
Se	0.01	0.5	1	4	BDL	0.002
SO_4^{2-}	250	12500	25000	100000	28	18
V	0.2	10	20	80	BDL	BDL
Zn	5	250	500	2000	0.003	0.003
TDS	1000	12500	25000	100000	92	104
Cl^-	300	15000	30000	120000	0.73	0.64
F^-	1.5	75	150	600	0.51	0.45
NO_3^- as N	11	550	1100	4400	0.97	0.77

Notes: *BDL-Below Detection Limit*

9.0 RISK ASSESSMENT

Regulation 5 of GN R. 632 of 2015, as amended 21 September 2018, requires that a risk assessment of the proposed mine residue facility be conducted. Based upon the requirements of Regulation 9, Golder has developed a transdisciplinary framework for mining residue facility environmental risk assessment:

1) Characterisation of the mining residue waste streams in terms of Regulation 4:
    a) Geochemical characteristics;
    b) Physical characteristics; and
    c) Toxicity.
2) Determination of the impact on the receiving groundwater and surface water environment, considering:
    a) The characterisation of the mining residues,
    b) The vulnerability of the local aquifer(s),
    c) The presence of vulnerable ecosystems, and
    d) The predicted runoff and seepage chemistry, with classification of the predicted mine water in terms of baseline water quality, DWAF (1996) water use guidelines and the water quality planning limits (WQPL) applicable to the receiving water bodies;
3) Determination of the impact on biodiversity based upon the impact on groundwater and surface water;
4) Prevention of pollution in order to satisfactorily mitigate the impact on groundwater and surface water and on biodiversity, such prevention measures to potentially include:
    a) The minimisation of runoff and seepage – e.g. through dewatering and compaction,
    b) The interception of runoff and seepage – this is the pollution control barrier system, which may be a:
        - Physical barrier like a liner or stormwater berm, or
        - Pressure barrier created in groundwater by a pumping well, prevents groundwater flow and decant, and
    c) The reuse or treatment and release of intercepted mine waters.

The risk assessment are shown in Table 6

Table 11: Zibulo Discard Risk Assessment

Aspect	Properties	Risk
Chemical	Acid-base accounting	Likely acid generating based on SNPR <1 and Sulphide S of 3.3 to 6.0%
	Chemical composition of leachate (short-term)	Leachate likely to contain elevated levels of chloride, aluminium and sodium.
	Chemical composition of leachate (long-term)	Long-term oxidation is likely to result in acidic leachate.
	Propensity for spontaneous combustion	Likely (Coal discard from the eMalahleni coalfield is known to have a risk of spontaneous combustion) but not tested
	Propensity to oxidise and decompose, stability and reactivity	The sulphide-containing discard materials react with oxygen and water in the process of ARD generation.
	Concentration of volatile organics	Not applicable
Mineralogy	Acid-forming minerals	The pyrite content of Zibulo discard subsamples varied between 4.1 wt% and 8.1 wt%
	Acid-neutralising minerals	Calcite and dolomite were rare to accessory phases
Waste	Physical hazards	Often flammable, not explosive, generally oxidising and does not release toxic gases when in contact with water or acid
	Health hazards	Total concentration of multiple parameters exceeded 1% but none of these parameters exceed 1% in leachate [1]
	Environmental hazard	Total concentration of multiple parameters 1% but none of these parameters exceed 1% in leachate However, acidic seepage is expected
	Classification	Potentially hazardous (in terms of SAN10234) to the environment in medium to long term due to acidic seepage generated under oxidising conditions
	Total concentrations	TCT0 < TC (As,Ba,Cu,Hg,Pb) < TCT1
	Leachable concentrations	LCT0 ≤ LC
	Assessment	Type 3, although risk from leachable parameters is low
Toxicity		Not acute toxicity
Physical Properties		The material is sand to gravel-sized and has a high infiltration rate (3.7 m/day).

[1] 1% is 10 000 mg/L and 0.1% is 1,000 mg/L

Aspect	Properties	Risk
Vulnerability of the water resource		Decant from the pit would immediately impact the Saalklapspruit River
Prevention of pollution in order to satisfactorily mitigate the impact on groundwater and surface water and on biodiversity		■ Decreasing seepage through the use of a cover; ■ Interception of seepage by means of a pressure barrier created in groundwater by pumping wells, which prevents decant from the pit; and ■ Treatment of the intercepted pit water.

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11.0 CLOSING REMARK

This report is based upon work carried out by Aviwe Mgoqi and Dr Koovila Naicker Pr.Sci.Nat, Please contact the undersigned for discussion of any aspect of the report.

Signature Page

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APPENDIX A

Summary of previous spoil (Delta H) and discard (Golder 2015/2019) material characteristics

Table A1: Summary of ARD classification for Zibulo samples (Delta-H, 2017)

Sample ID	Lithology	Classification
Ramp 2 Composite spoil	Composite spoil	**PAG**
Ramp 3 Composite spoil	Composite spoil	**Uncertain**
Ramp 4 Composite spoil	Composite spoil	**PAG**

Table A2: Zibulo samples mineralogical data (Delta-H, 2017)

Mineral	Ideal Composition	Ramp 2 Composite Spoil	Ramp 3 Composite Spoil	Ramp 4 Composite Spoil
Kaolinite	$Al_4(OH)_8(Si_4O_{10})$	46.27	50.99	49.15
Magnetite	Fe_3O_4	1.49	1.23	2.29
Microcline	$KAlSi_3O_8$	6.72	6.01	6.18
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	8.6	8.91	
Pyrite	FeS_2	0.85	0.23	4.03
Quartz	SiO_2	34.78	31.54	37.04
Rutile	TiO_2		1.08	1.31

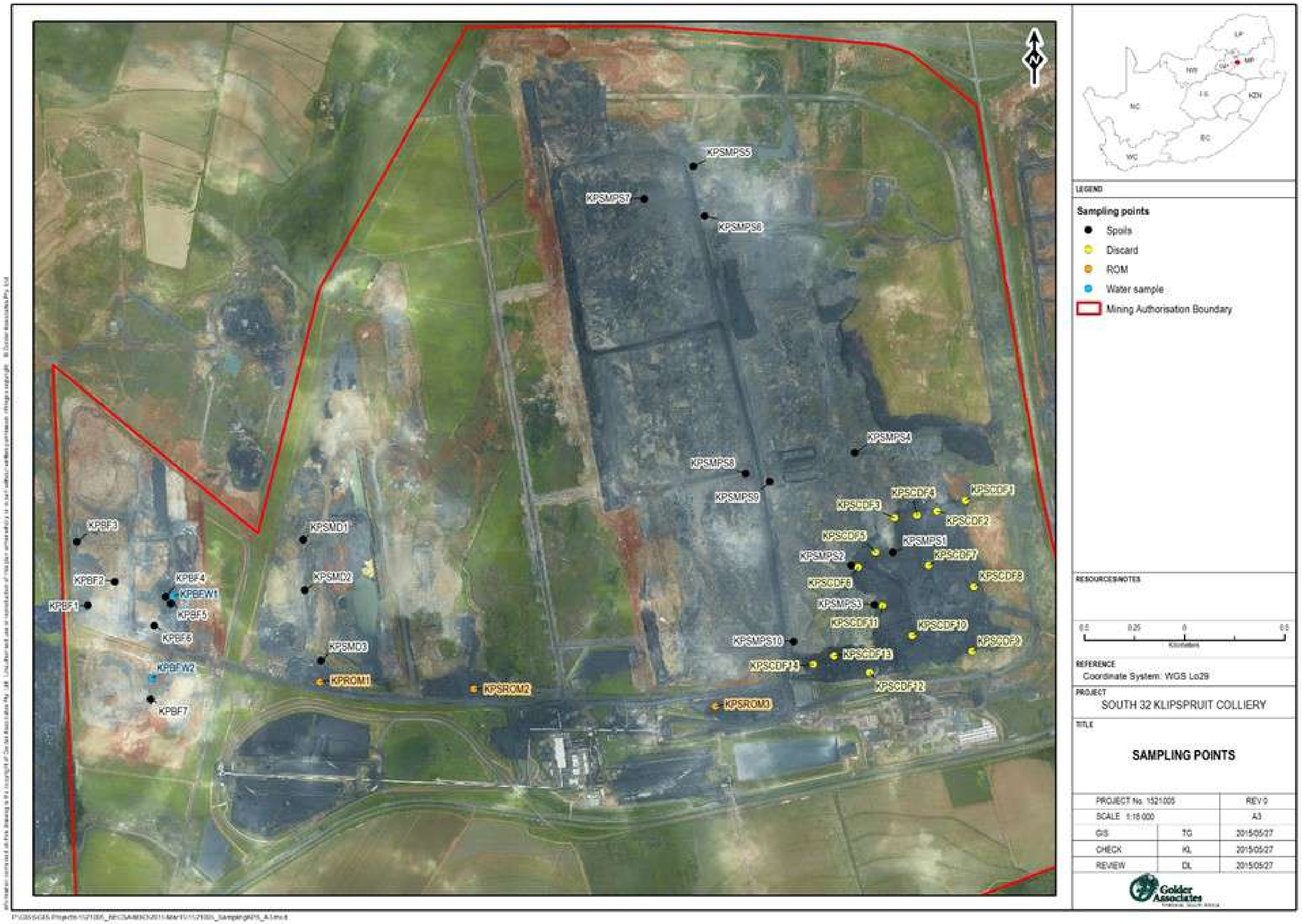
Table A3: Summary of ABA data for Zibulo spoils samples analysed (Delta-H, 2018)

Sample ID		Ramp 2 (New Development)	Ramp 3	Ramp 4	Ramp 4 (Duplicate)
Sulphur Speciation	Total Sulphur (%)	0.18	0.35	0.74	0.74
	Sulphate Sulphur as S (%)	0.16	0.21	0.74	0.73
	Sulphide Sulphur (%)	0.02	0.14	<0.01	0.01
Net Acid Generation (NAG)	pH 4.5 NAG (pH)	9	3.3	5	5
	pH 4.5 NAG (kg H_2SO_4/t)	<0.01	2.7	<0.01	<0.01
	pH 7 NAG (pH)	9	4.5	5	5
	pH 7 NAG (kg H_2SO_4/t)	<0.01	11	12	13
Acid Base Accounting	Paste pH	7.2	3.8	6.2	6.3
	Acid Potential (AP) (kg/t)	5.6	11	23	23
	Sulphide Acid Potential (SAP) (calc) (kg/t)	0.6	4.4	<0.3	0.3
	Neutralising Potential (NP) (kg/t)	53	-6.3	2.9	3.2
	Net Neutralisation Potential (NNP)	47	-17	-20	-20
	Neutralisation Potential Ratio (NPR)	9.51	0.57	0.13	0.14
ARD Classification		Non-PAG*	PAG	PAG	

Table A4: Acid Base Accounting of discard material (Golder, 2019a)

Parameter	Units	Plant	KPS Discard dump					
		Fine Discard	Coarse Discard					
		KPSPFD	KPSPCD	KPCDFC 1	KPCDFC 2	KPCDFC 3	KPCDFC 4	KPS - HC1#
Paste pH	s.u	7.6	6.5	6.6	6.8	6.8	7.3	7
Total- S	%	1.2	4.6	3.5	2.8	5.7	3.2	2.8
Sulphide-S		0.8	3.6	2.2	1.7	3.9	2.3	2.1
Sulphate-S		0.039	0.052	0.47	0.51	0.47	0.053	0.52
Organic-S		0.38	0.97	0.77	0.61	1.42	0.85	0.22
C-Total		53	23	42	34	32	29	37
C-Inorganic		0.15	0.49	4.6	4	3.8	3.1	36
C-Organic		53	22	37	30	29	26	0.9
Bulk NP*	kg $CaCO_3$/t	15	11	21	21	25	14	30
CaNP*		12	41	384	335	318	262	75
SAP**		24	112	70	54	120	72	64
SNNP***		-8.8	-101	-49	-33	-95	-58	-34
SNPR‡	no units	0.63	0.1	0.3	0.39	0.21	0.19	0.47
Classification based on SNPR		PAG‡‡	PAG	PAG	PAG	PAG	PAG	PAG

Figure A.1: Location of sampling points for discard samples collected in 2015 (samples IDs starting KPSCD)



APPENDIX B

GAI values for Zibulo subsamples

Table B1: GAI calculations for Zibulo discard sub samples

Sample Name	Material Type	Mine	Sample ID	Al GAI	Ag GAI	As GAI	B GAI	Ba GAI	Be GAI	Bi GAI	Ca GAI	Cd GAI	Co GAI	Cr GAI	Cs GAI	Cu GAI	Fe GAI	Ga GAI
ZIBULO DISCARD A CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	-1	2	4	3	-1	1	8	-3	2	-2	-1	-5	-2	-1	2
ZIBULO DISCARD B CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	0	2	4	3	1	1	8	-2	2	-2	-1	-6	-2	0	2

Sample Name	Material Type	Mine	Sample ID	Ge GAI	Hf GAI	Hg GAI	K GAI	La GAI	Li GAI	Mg GAI	Mn GAI	Mo GAI	Na GAI	Nb GAI	Nd GAI	Ni GAI	P GAI	Pb GAI
ZIBULO DISCARD A CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	1	2	4	-4	-1	3	-3	-2	3	-5	1	-5	-2	-3	2
ZIBULO DISCARD B CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	1	2	5	-4	-2	3	-3	-2	4	-5	1	-5	-1	0	2

Sample Name	Material Type	Mine	Sample ID	Rb GAI	Sb GAI	Sc GAI	Se GAI	Sn GAI	Si GAI	Sr GAI	Ta GAI	Te GAI	Th GAI	Ti GAI	Tl GAI	U GAI	V GAI	W GAI
ZIBULO DISCARD A CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	-5	2	-1	5	2	-1	-1	1	7	0	-1	-2	2	-2	2
ZIBULO DISCARD B CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	-6	2	-1	5	3	-1	0	1	7	0	-1	-3	2	-2	2

Sample Name	Material Type	Mine	Sample ID	Y GAI	Zn GAI	Zr GAI
ZIBULO DISCARD A CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	-2	-2	1
ZIBULO DISCARD B CRUSH ONLY >6.3mm	Discard	Zibulo	ZIBULO DISCARD	-3	-2	1

APPENDIX C

Laboratory Certificates

ANALYTICAL REPORT: Particle Size Distrubution

To: Golder Associates (Pty) Ltd
Attention: Keretia Lupankwa
Project ID: 19117180
Site Location: Zibulo
Order No:

Date of Request:

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6

Fax: (012) 665 4294

Certificate of analysis: 31280

Note: No unauthorised copies may be made of this report.

Lims ID	Sample ID	Sieve Diameter (mm)	Mass of Empty Sieve	Mass of Sieve + Soil Retained	Mass of Soil Retained	Percent Retained	Percent Passed
		mm	g	g	g	%	%
702912	ZIBULO DISCARD A	31.0	1638	2020	382	18.6	81.4
		25.0	1846	2050	204	9.91	71.5
		19.0	1452	1650	198	9.62	61.9
		16.0	1652	1796	144	7.00	54.9
		12.5	1730	1918	188	9.14	45.8
		9.5	1738	1942	204	9.91	35.9
		8.0	1694	1818	124	6.03	29.8
		6.5	1814	1960	146	7.09	22.7
		5.0	2056	2092	36	1.75	21.0
		3.4	1912	2082	170	8.26	12.7
		1.7	1574	1762	188	9.14	3.60
		0.850	1536	1598	62	3.01	0.58
		0.600	1496	1500	4.0	0.19	0.39
		0.500	1400	1402	2.0	0.10	0.29
		0.300	1348	1350	2.0	0.10	0.19
		0.212	1466	1466	0.0	0.00	0.19
		0.150	1458	1458	0.0	0.00	0.19
		0.106	1452	1454	2.0	0.10	0.10
		0.075	1436	1436	0.0	0.00	0.10
		0.053	1478	1478	0.0	0.00	0.10
		-0.053	1376	1378	2.0	0.10	0.00
					2058	99.42	

Method: Particle Size Distribution
Instrument: Analytical Balance, Sieve Shaker

Date: 29.04.2020
Analysed by: Black/MA Motsepe

Date: 29.04.2020
Authorised : JJ Oberholzer

ANALYTICAL REPORT: C & S Speciation

To:	**Golder Associates (Pty) Ltd**	Date of Request: 11.02.2020	UIS Analytical Services
Attention:	**Keretia Lupankwa**		Analytical Chemistry
Project ID:	**19117180**		Laboratories 4, 6
Site Location:	**Zibulo**		
Order No:			Fax: (012) 665 4294

uis analytical services

Certificate of analysis: 31280

Note: No unauthorised copies may be made of this report.

Lims ID	**Sample ID**	**Total Sulphur**	**S (sulphide)**	**S (sulphate)**	**Total Carbon**	**Organic Carbon**	**Inorganic Carbon**
		%	%	%	%	%	%
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	4.63	3.30	0.010	24.6	20.7	3.90
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	8.31	5.98	0.009	20.2	16.5	3.70
702912 QC	**Duplicate**	4.55	3.29	0.010	24.1	20.3	3.80

		Chemical elements:	C(total), C(organic), C(inorganic), S (total), S (sulphide), S (sulphate)
		Instrument:	ICP-OES LECO CS 230
Date:	16.03.2020	Date:	18.03.2020
Analysed by:	MA Motsepe	Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Acid / Base Accounting (ABA)

To:	**Golder Associates (Pty) Ltd**	Date of Request: 19/02/2020	UIS Analytical Services
Attention:	**Keretia Lupankwa**		Analytical Chemistry
Project ID:	**19117180**		Laboratories 4, 6
Site Location:	**Zibulo**		
Order No:			Fax: (012) 665 4294

Certificate of analysis: 31280

Note: No unauthorised copies may be made of this report.

Lims ID	Sample ID	Paste pH	Total Sulphur	Acid Potential (AP)	Neutralization Potential (NP)	Nett Neutralization Potential (NNP)	Neutralising Potential Ratio (NPR) (NP : AP)	Total Carbon
			%	kg CaCO3/t	kg CaCO3/t	kg CaCO3/t	NP:AP	%
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	7.68	4.63	145	47.7	-97.0	0.33	24.6
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	7.47	8.31	260	53.1	-207	0.20	20.2
702912 QC	**Duplicate**	NA	4.55	142	47.5	-94.7	0.33	24.1

Note: Negative NP values are obtained when the volume of NaOH(0.1N) titrated (pH:8.3) is greater than the volume of HCl(1N) to reduce the pH of the sample to 2.0-2.5. Any negative NP values are corrected to 0.00

Chemical elements:	ABA
Instrument:	Methohm Titrino, LECO CS 230
Method	EPA 600 Modified Sobek

Date:	24.03.2020	Date:	24.03.2020
Analysed by:	L van der Walt	Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Net Acid Generation (NAG)

To:	**Golder Associates (Pty) Ltd**	Date of Request: 19/02/2020	UIS Analytical Services
Attention:	**Keretia Lupankwa**		Analytical Chemistry
Project ID:	**19117180**		Laboratories 4, 6
Site Location:	**Zibulo**		
Order No:			Fax: (012) 665 4294

analytical services

Certificate of analysis: 31280

Note: No unauthorised copies may be made of this report.

Lims ID	**Sample ID**	**NAG pH: (H_2O_2)**	**NAG at pH 4.5**	**NAG at pH 7.0**
			kg H2SO4 / t	**kg H2SO4 / t**
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	2.48	10.4	29.1
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	2.14	31.1	48.6

		Chemical elements:	Net Acid Generation (NAG)
		Instrument:	Methohm Titrino
		Method:	Single addition NAG test
Date:	24.03.2020	Date:	24.03.2020
Analysed by:	L van der Walt	Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Total Trace elements

To: Golder Associates (Pty) Ltd
Attention: Keretia Lupankwa
Project ID: 19117180
Site Location: Zibulo
Order No:

Date of Request : 11.02.2020

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6
Tel: (012) 665 4291
Fax: (012) 665 4294

Certificate of analysis: 31280

Note: all results in parts per million (mg/kg) unless specified otherwise

Lims ID	Sample ID	Ag	As	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Ga	Ge	Hf	Hg	Ho	La	Li	Mn	Mo
	Total trace elements	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	0.385	32.4	107	345	7.49	2.53	0.79	32.9	10.5	72.4	0.14	29.5	91.2	4.76	15.5	2.70	0.40	19.6	214	399	17.5
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	0.407	49.3	111	877	5.25	2.80	0.77	24.9	10.9	75.6	0.06	22.2	94.3	4.96	16.6	4.52	0.23	14.4	231	327	37.9
702912 QC	**Duplicate**	0.371	33.2	109	349	7.74	2.56	0.80	32.8	11.3	76.0	0.13	29.1	97.3	4.97	15.4	2.61	0.41	20.2	220	395	16.8

Lims ID	Sample ID	Nb	Nd	Ni	Pb	Rb	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Tl	U	V	W	Y	Zn	Zr
	Total trace elements	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	64.03	2.23	51.4	80.4	4.26	1.37	16.4	3.23	16.3	204	3.96	0.72	12.8	0.36	12.1	44.7	9.88	10.3	39.2	370
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	63.91	1.74	74.5	91.0	2.55	1.25	17.0	3.01	18.2	806	4.12	0.77	12.3	0.16	13.5	40.4	9.88	5.58	29.9	378
702912 QC	**Duplicate**	62.03	2.15	53.7	78.4	4.60	1.33	17.1	3.23	16.1	205	3.84	0.74	13.6	0.35	12.2	43.3	10.1	11.0	37.3	374

Chemical elements: Ag, , As, Au, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, Hg, Ho, Ir, La, Li, Mn, Mo, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Tl, U, V, W, Y, Zn, Zr
Instrument: ICP-MS,
Method: Trace Elements in soil by ICP-MS

Date: 16.03.2020
Analysed by: MA Motsepe

Date: 16.03.2020
Authorised : JJ Oberholzer

ANALYTICAL REPORT: Water Leach

To:	Golder Associates (Pty) Ltd	Date of Request :11.02.2020	UIS Analytical Services
Attention:	Keretia Lupankwa		Analytical Chemistry
Project ID:	19117180		Laboratories 4, 6
Site Location:	Zibulo		
Order No:			Fax: (012) 665 4294

analytical services

Certificate of analysis: 31280

Note: all results in parts per million (ppm) unless specified otherwise

Lims ID	Sample ID	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	<0.0001	<0.001	<0.001	<0.001	<0.001
702090	ZIBULO DISCARD WATER LEACH A	<0.001	0.121	<0.001	<0.001	0.408	0.408	<0.001	<0.001	10.8	<0.0001	<0.001	<0.001	<0.001	<0.001
702090 QC	Duplicate	<0.001	0.121	<0.001	<0.001	0.419	0.419	<0.001	<0.001	10.8	<0.0001	<0.001	<0.001	<0.001	<0.001
702914	ZIBULO DISCARD WATER LEACH B	<0.001	0.346	0.001	<0.001	0.371	0.371	<0.001	<0.001	8.46	<0.0001	<0.001	<0.001	<0.001	<0.001

Lims ID	Sample ID	Cu	Fe	Ga	Ge	Hf	Hg	Ho	Ir	K	La	Li	Mg	Mn	Mo	Na	Nb
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	<0.001	<0.001
702090	ZIBULO DISCARD WATER LEACH A	<0.001	0.004	<0.001	<0.001	<0.001	0.0003	<0.001	<0.001	1.35	<0.001	0.007	2.28	0.002	0.002	17.6	<0.001
702090 QC	Duplicate	<0.001	0.005	<0.001	<0.001	<0.001	0.0003	<0.001	<0.001	1.38	<0.001	0.007	2.08	<0.001	0.002	17.5	<0.001
702914	ZIBULO DISCARD WATER LEACH B	<0.001	0.007	<0.001	<0.001	<0.001	0.0001	<0.001	<0.001	1.15	<0.001	0.009	1.77	<0.001	0.002	16.1	<0.001

Lims ID	Sample ID	pH	pH Temp	TDS	EC	TDS by Sum	TDS by EC	P Alk.	M Alk.	F	Cl	NO2	NO3	NO3 as N	PO4
	WATER LEACH 1:20		Deg C	mg/l	mS/m	mg/l	mg/l	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	5.72	25.1	<30	0.87	n/a	6.09	<0.6	<3.5	<0.1	<0.25	<0.2	<0.3	<0.1	<0.8
702090	ZIBULO DISCARD WATER LEACH A	7.73	24.5	92.0	16.7	94.0	117.0	<0.6	45.9	0.51	0.73	<0.2	0.97	0.22	<0.8
702090 QC	Duplicate	7.75	24.5	92.0	16.7	92.3	117.0	<0.6	45.2	0.46	0.72	<0.2	0.91	0.21	<0.8
702914	ZIBULO DISCARD WATER LEACH B	7.47	24.5	104	15.4	73.9	107.8	<0.6	36.0	0.45	0.64	<0.2	0.77	0.17	<0.8

Lims ID	Sample ID	SO4	Sum of Cations	Sum of Anions	Ion Balance	NH4	NH3	Acidity to pH8.3	CN (free)	CN (Total)	Cr 6+	TSS	TOC	Paste pH
	WATER LEACH 1:20	mg/l	me/l	me/l	%	mg/l	mg/l	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	
	Leach Blank	<0.3	n/a	n/a	n/a						<0.05			
702090	ZIBULO DISCARD WATER LEACH A	28.3	1.58	1.49	2.91						<0.05			
702090 QC	Duplicate	27.4	1.57	1.45	3.84						<0.05			
702914	ZIBULO DISCARD WATER LEACH B	18.4	1.38	1.12	10.2						<0.05			

Chemical elements: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, Ho, Ir, K, La, Li, Mg, Mn, Mo, Na, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn Anions, pH, EC, NH4, Alkalinity, CN, Cr6+

Instrument: ICP-MS Perkin Elmer NexION 300D Ion Chromatography Spectrophotometer Ion Selective Probe, Photometer

Date:	13.03.2020	Date:	13.03.2020
Analysed by:	UIS Waterlab/MA Motsepe	Authorised :	JJ Oberholzer

To:	**Golder Associates (Pty) Ltd**
Attention:	**Keretia Lupankwa**
Project ID:	**19117180**
Site Location:	**Zibulo**
Order No:	

analytical services

Lims ID	Sample ID	Nd	Ni	Pb	Pt	Rb	Sb	Sc	Se	Si	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.17	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
702090	**ZIBULO DISCARD WATER LEACH A**	<0.001	0.003	0.001	<0.001	0.001	<0.001	<0.001	<0.001	1.09	<0.001	0.107	<0.001	<0.001	<0.0001	0.011	<0.001	0.0004	<0.001	<0.001	<0.001	0.003	<0.001
702090 QC	**Duplicate**	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.01	<0.001	0.108	<0.001	<0.001	<0.0001	0.011	<0.001	0.0004	<0.001	<0.001	<0.001	0.004	<0.001
702914	**ZIBULO DISCARD WATER LEACH B**	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	1.23	<0.001	0.086	<0.001	<0.001	0.0001	0.053	<0.001	0.0002	<0.001	<0.001	<0.001	0.003	<0.001
	WATER LEACH 1:20																						
	Leach Blank																						
702090	**ZIBULO DISCARD WATER LEACH A**																						
702090 QC	**Duplicate**																						
702914	**ZIBULO DISCARD WATER LEACH B**																						

Date: 13.03.2020

Analysed by: UIS Waterlab/MA Motsepe

Dr Sabine Verryn

m: 083 548 0586
f: 086 565 7368
e: sabine.verryn@xrd.co.za

XRD Analytical and Consulting cc
75 Kafue Street, Lynnwood Glen,
0081, South Africa

CLIENT: UIS

DATE: 04 March 2020

SAMPLES: 2 Samples (Request 31280)

ANALYSIS: Qualitative and quantitative XRD

The material was prepared for XRD analysis using a back loading preparation method. Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software
The relative phase amounts (weight %) were estimated using the Rietveld method.

Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- The samples seem to contain organic carbon and amounts were estimated using the C-values supplied by the customer – quantification should be viewed as semi-quantitative, resulting in overall semi-quantitative results.
- Traces of additional phases such as organic carbon may be present.
- Amorphous phases, if present, were not taken into consideration during quantification.

If you have any further queries, kindly contact me.

Dr. Sabine Verryn (Pr.Sci.Nat)

Samples will be stored for 3 months after which they will be discarded.

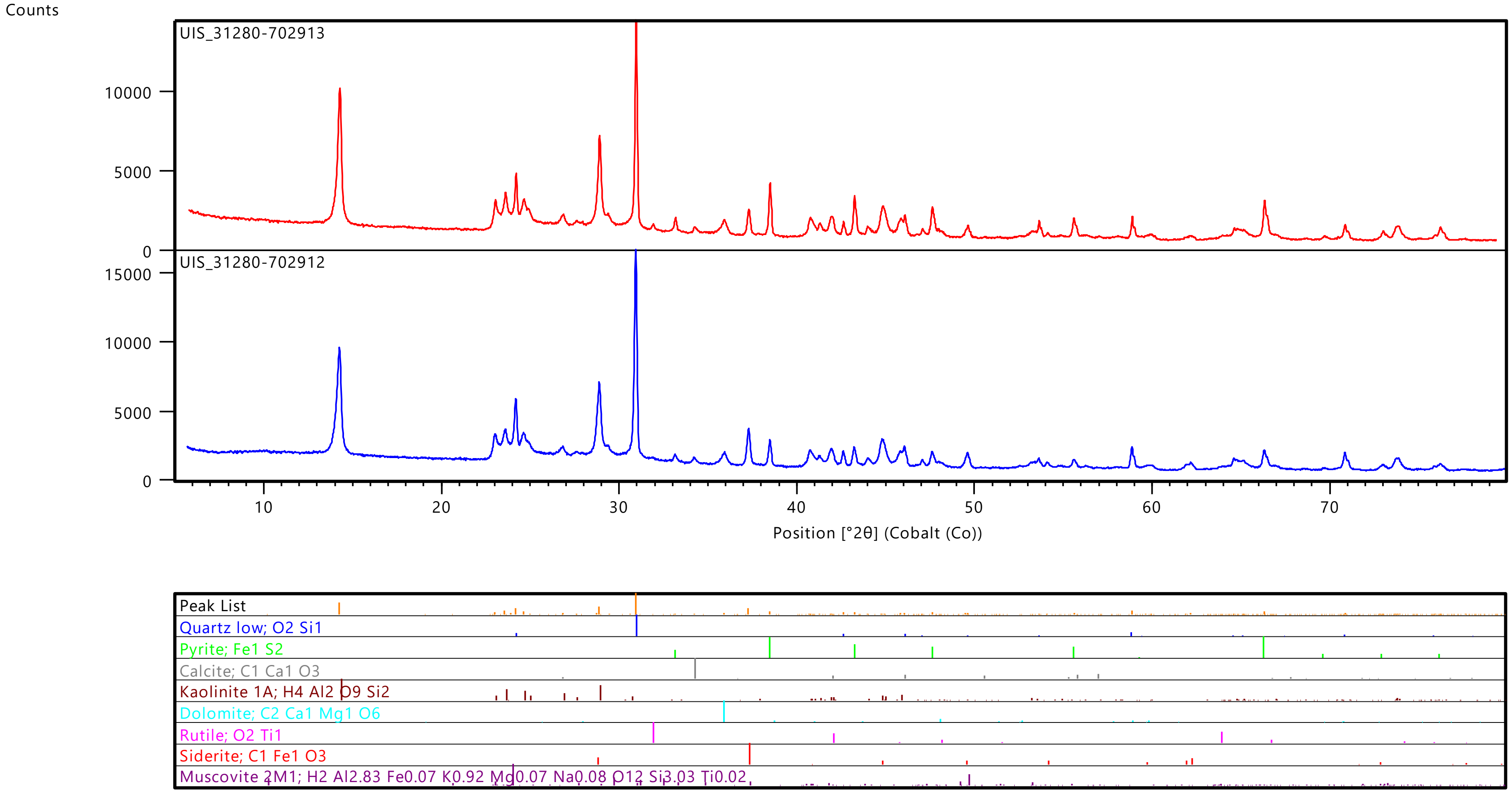
	Quartz	Pyrite	Calcite	Kaolinite	Dolomite	Rutile	Siderite	Muscovite	Organic Carbon
UIS_31280-702913	14.7	8.1	0.4	46.1	6.7	0.3	2.6	1.2	19.8
UIS_31280-702912	17.8	4.1	0.3	43.3	4.9	0.2	4	1.1	24.3

0 = n.d. – not detected above the detection limit of 0.5-3 weight per cent

Sample List:

ZIBULO DISCARD A ORIGINAL	702912
ZIBULO DISCARD B ORIGINAL	702913

XRD Analytical and Consulting cc



Limitation of Liability: Although every effort is made to provide reliable and accurate results, by use of the results the client agrees that “XRD Analytical and Consulting cc” and/or its staff can only be held liable for the cost of the analysis.

ANALYTICAL REPORT:

To:	**Golder Associates (Pty) Ltd**
Attention:	**Keretia Lupankwa**
Project ID:	**19117180**
Site Location:	**Zibulo**
Order No:	

Date of Request: 11.02.2020

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6
Tel: (012) 665 4291
Fax: (012) 665 4294

Certificate of analysis: 31280

Lims ID	Sample ID	SiO2	Al2O3	Fe(tot)	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	MnO	P2O5	Ba	Cr	Cu	Ni	Sr	V	Zn	LOI	Ash
	Major elements in Coal	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
702912	**ZIBULO DISCARD A CRUSH ONLY >6.3mm**	33.6	16.7	5.78	8.27	1.10	1.65	0.819	0.111	0.170	0.049	0.059	0.031	0.006	0.002	0.001	0.019	0.004	0.003	37.5	62.5
702913	**ZIBULO DISCARD B CRUSH ONLY >6.3mm**	31.3	17.3	8.34	11.9	1.11	2.00	0.882	0.118	0.156	0.041	0.295	0.090	0.007	0.001	0.004	0.074	0.004	0.001	34.4	65.6
702912 QC	**Duplicate**	33.6	16.5	5.75	8.22	1.10	1.64	0.810	0.114	0.173	0.048	0.052	0.031	0.006	0.002	0.002	0.019	0.004	0.003	37.5	62.5

note: Analysis done on samples as received before drying

note: L.O.I. does not include moisture

Chemical elements:	Si, Al, Fe, Ti, Ca, Mg, Na, K, Mn, P, Ba, Cr, Cu, Ni, Sr, V, Zn, C, S
Instrument:	ICP-OES, LECO CS 230
Method	Soil/Ore Samples by ICP-OES

Date:	16.03.2020	Date:	16.03.2020
Analysed by:	MA Motsepe	Authorised :	JJ Oberholzer

APPENDIX D

Klipspruit Discard Kinetic Summary (Golder, 2019)

Table D1: Summary Kinetic Testing (Humidity Cell Method) for Klipspruit discard material

Chemical Parameter (mg/l)	KPS_HC31																					DWAF (1996) Water Quality Standards			RWQO for Management Units in the Wilge River catchment
	WK0	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	WK12	WK13	WK14	WK15	WK16	WK17	WK18	WK19	WK20	Domestic Use	Livestock	Irriga-tion	
pH	8.3	7.9	7.9	7.7	6.7	7.1	7.9	7.7	7.4	7.7	7.3	7.6	7.4	7.3	7.4	7.3	7.2	7.4	7.5	7.6	7.7	6-9	ng	6.5-8.4	6.5-8.4
Electrical Conductivity (mS/m)	612	21	166	115	22	66	96	60	108	85	123	67	79	122	114	72	52	58	108	35	237	ng	ng	ng	40
Total Dissolved Solids at 180°C	8100	3220	1670	1020	144	514	786	428	856	650	1060	510	606	1080	1010	584	364	414	850	238	1970	450	1000	ng	280
Total Acidity as CaCO3*	<5.00	no result	no result	0.00	no result	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	no result	<5.00	<5.00				
Total Alkalinity as CaCO3	202	204	65	30	4.3	10	42	22	23	31	26	15	24	17	25	13	11	14	17	36	51	ng	ng	ng	120
Chloride as Cl	<0.25	4.1	1.3	<0.25	0.68	1.0	0.53	0.41	0.55	0.45	0.94	0.56	0.53	2.0	1.7	0.81	0.50	0.49	1.2	0.80	1.4	100	1500	ng	20
Sulphate-SO4	5890	1850	905	682	93.4	295	409	295	578	454	717	361	408	702	665	396.421	245	290	610	137	1710	200	1000	ng	60
Fluoride as F	<0.1	0.55	0.30	5.5	0.43	0.69	0.64	0.49	0.63	0.51	0.52	0.43	0.51	0.56	0.70	0.39	0.27	0.22	0.36	2.0	0.69	1	2	2	0.5
Nitrate as N	<0.3	<0.3	<0.3	<0.2	6.3	4.5	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.2	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.2	<0.3	6	100	ng	6
Nitrite as N	<0.2	<0.2	<0.2	<0.3	1.42	<0.2	<0.2	<0.2	<0.2	0.00	<0.2	0.00	<0.3	<0.2	nr	nr	nr	nr	<0.2	<0.3	nr				
Free & Saline Ammonia as N	0.49	<0.010	<0.010	<0.010	<0.010	<0.010	0.62	<0.010	<0.010	0.04	0.04	<0.010	<0.010	<0.010	<0.010	<0.010	0.02	<0.010	<0.010	<0.010	<0.01				
Ag	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	na	na	na	na	na	na	<0.001	na	na	na	<0.001	na	na	na	0.00				
Al	<0.001	0.06	0.02	<0.001	0.04	<0.001	<0.05	<0.05	<0.001	<0.05	0.10	<0.05	0.01	<0.05	<0.05	<0.05	<0.001	21	<0.05	0.05	<0.001	0.15	5	5	0.02
As	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.1	<0.1	na	<0.1	<0.1	<0.1	0.001	<0.1	<0.1	<0.1	<0.001	<0.05	<0.1	<0.1	<0.001	0.01	1	0.1	ng
B	12	1.6	1.5	0.09	0.08	0.07	na	na	na	na	na	na	0.10	na	na	na	0.03	na	na	na	0.38	ng	5	1	0.5

Chemical Parameter (mg/l)	KPS_HC31																					DWAF (1996) Water Quality Standards			RWQO for Management Units in the Wilge River catchment
	WK0	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	WK12	WK13	WK14	WK15	WK16	WK17	WK18	WK19	WK20	Domestic Use	Livestock	Irriga-tion	
Ba	0.11	0.16	0.09	0.13	0.12	0.16	na	na	na	na	na	na	0.13	na	na	na	0.10	na	na	na	0.10	ng	ng	ng	ng
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	na	na	na	na	na	na	<0.001	na	na	na	<0.001	na	na	na	<0.001				
Ca	550	559	409	250	28	49	167	107	200	206	249	116	130	172	202	115	77	99	185	2	388	32	1000	ng	25
Cd	0.001	<0.0001	0.00	<0.0001	<0.0001	0.001	na	na	na	na	na	na	<0.0001	na	na	na	<0.0001	na	na	na	0.00	5	10	10	ng
Co	0.25	0.0100	0.0030	0.0020	0.0020	0.0020	na	na	na	na	na	<0.05	0.002	<0.05	<0.05	<0.05	0.001	<0.1	<0.05	nr	0.02	ng	1	0.05	ng
Cr	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	na	na	na	na	na	na	<0.001	na	na	na	<0.001	na	na	na	<0.001				
Cu	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	na	na	na	na	na	na	0.001	na	na	na	0.003	na	na	na	0.003	1	0.5	0.2	ng
Fe	<0.01	<0.01	0.06	0.04	0.06	0.03	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	1.35	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	0.10	0.1	10	5	1
Hg	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	na	na	na	na	na	na	<0.0001	na	na	na	<0.0001	na	na	na	<0.0001	0.001	1	ng	ng
K	9.7	5.3	2.2	1.6	0.75	1.9	1.5	0.87	1.4	0.26	1.2	0.59	6.5	1.3	1.6	1.3	5.7	1.0	1.5	49	3.4	50	ng	ng	10
Mg	836	177	33	25	5.2	20	22	14	32	23	40	22	25	51	52	31	11	<0.05	52	16	135	30	500	ng	20
Mn	14	1.4	0.41	0.15	0.09	0.10	na	na	na	na	na	<0.05	0.06	0.16	0.17	0.06	0.04	<0.05	0.18	<0.05	135	0.05	10	0.02	0.18
Mo	<0.001	0.002	0.001	0.002	0.001	0.002	na	na	na	na	na	na	0.00	na	na	na	<0.001	na	na	na	0.001	ng	0.01	0.01	ng
Na	157	50	11	7.7	1.9	30	8.6	5.7	7.8	4.2	8.4	4.4	5.2	6.2	6.1	4.8	1.6	3.2	4.6	2.7	8.7	100	2000	70	20
Ni	0.34	0.04	0.02	0.02	0.04	0.05	<0.05	<0.05	0.0280	<0.05	<0.05	<0.05	0.01	<0.05	<0.05	<0.05	0.01	<0.05	<0.05	<0.05	0.16	ng	1	0.2	ng
Pb	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	na	na	na	na	na	na	<0.001	na	na	na	<0.001	na	na	na	<0.001	0.01	0.1	0.2	ng
Sb	0.004	0.005	0.001	0.001	<0.001	0.001	na	na	na	na	na	na	0.001	na	na	na	0.001	na	na	na	0.001				
Se	0.074	0.002	0.001	0.002	0.003	0.005	na	na	na	na	na	na	0.005	na	na	na	0.12	na	na	na	0.01	0.02	50	0.02	ng
Si	1.83	2.51	1.4	1.1	<0.05	0.35	na	na	na	na	na	na	1.9	na	na	na	0.69	na	na	na	2.74				
Sn	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	na	na	na	na	na	na	0.00	na	na	na	0.00	na	na	na	0.00				
Sr	3.8	3.5	1.9	1.4	0.16	0.50	na	na	na	na	na	na	0.84	na	na	na	0.71	na	na	na	3.3				
Ti	0.23	0.25	0.12	<0.05	<0.05	<0.05	na	na	na	na	na	na	<0.05	na	na	na	<0.05	na	na	na	<0.05				
U	<0.0001	0.006	0.002	<0.0001	<0.0001	<0.0001	na	na	na	na	na	na	<0.0001	na	na	na	<0.0001	na	na	na	0.001	ng	ng	0.01	ng
V	0.01	<0.001	<0.001	<0.001	<0.001	0.01	na	na	na	na	na	na	<0.001	na	na	na	<0.001	na	na	na	<0.001	0.1	1	0.1	ng
Zn	1.2	0.04	0.14	0.10	0.69	0.82	na	na	na	na	na	na	0.08	na	na	na	0.10	na	na	na	0.60	3	20	1	ng

APPENDIX E

Aquatic Screening for Zibulo discard material

REPORT

T0384

COA 2020/39

WHOLE EFFLUENT TOXICITY TEST CERTIFICATE OF ANALYSIS

Submitted to:

Aviwe Mgoqi
P.O Box 6001
Halfway House
1685

Submitted by:

Golder Associates Research Laboratory (Pty) Ltd. (GARL)
25 Main Avenue, Cnr Die Ou Pad, Florida, 1709, South Africa
P.O. Box 6001, Halfway House, 1685

+27 11 672 0666/7

GAL2217

03 April 2020

Distribution List

1 Copy - Golder Associates Africa

1 Copy - Golder Associates Research Laboratory (Pty) Ltd

Table of Contents

TABLES

1.0 CUSTOMER DETAILS

Requested by:	Aviwe Mgoqi
Company name:	Golder Associates Africa
Address:	P.O Box 6001
	Halfway House
	1685
Telephone number:	011 254 4800
E-mail:	amgoqi@golder.co.za

2.0 LABORATORY DETAILS

Company name:	Golder Associates Research Laboratory
Division:	Toxicity Division
Physical Address:	25 Main Avenue
	Florida
	1709
Telephone number:	011 672 0666
Registration Number	2006/020508/07

Enclosed please find Test certificate of analysis number COA2020/39. The results only relate to the sample(s) tested. GARL does not accept responsibility for any matters arising from the further use of the results. Tests marked "Not SANAS Accredited" in this Certificate of Analyses are not included in the SANAS Schedule of Accreditation for this laboratory.

No part of the Certificate of Analyses may be quoted in isolation of the rest of the text without the written permission of GARL. Opinions and Interpretations expressed herein are outside the scope of SANAS accreditation.

This Certificate of Analyses supersedes results reported by telephone.

Please contact the laboratory if further information is required. We look forward to being of assistance to you.

Yours faithfully

____

Bridget Shaddock
(Laboratory Manager)

3.0 SAMPLE INFORMATION

3.1 SAMPLE RECEIPT

Sampling technique:	Grab
Name of sampler (s):	Unknown
Description of sample container (s):	Plastic Bottle
Date and time of sample receipt at testing laboratory:	13.03.2020 Time 13:00
Comments:	GAA 19117180 1l of 100mg/l leachate samples prepared using Laboratory prepared Standard Synthetic Hard Water and filtered through 0.45µm.

3.2 SAMPLES RECEIVED

Sample reference name(s):	Collection date and time	Sample reference number(s):
Zibulo Discard Crushed	Unknown	20/286

4.0 INTRODUCTION TO TESTS REQUESTED

License number:	Not applicable
License toxicity testing requirements:	Not applicable
Plant name and / or location:	Not available
Name of receiving water body (s) up and downstream of discharge:	Not available

5.0 REQUESTED ANALYSES

Analyses performed:	Sample reference numbers
15 and 30-minute *Vibrio fischeri* bioluminescent screening test	20/286
72h *Selenastrum capricornutum* growth inhibition screening test	20/286
24 and 48h *Daphnia pulex* acute toxicity screening test	20/286
96h *Poecilia reticulata* acute toxicity screening test	20/286

6.0 METHODOLOGY

Test Conditions

All toxicity tests were conducted in environmentally controlled rooms using standard techniques.

Quality assurance

The GARL Aquatic toxicology laboratory's Policy and Quality Manual, intended to support and maintain all aspects of the Quality System, is based on the application of ISO/IEC 17025. The following Quality Assurance information would be made available on request: in-house reference toxicant test data and control charts, Proficiency Testing Scheme test data, additional lot and batch numbers and raw toxicity test data.

Toxicity units

The toxicity unit (TUa) for each test performed is calculated as 100% (full strength effluent expressed as percentage) divided by the effective concentration or LC_{50} expressed as percentage sample dilution (e.g. *Daphnia pulex* and *Poecilia reticulata* acute toxicity tests) and EC_{50} (e.g. *Vibrio fischeri* bioluminescent test and *Selenastrum capricornutum* growth inhibition test) (Tonkes & Baltus, 1997). If there is not sufficient toxicity in a sample to enable the determination of an EC_{50}/LC_{50} value, then an acute toxicity unit of <1 will be assigned to the sample.

Table 1: Toxicity Units (Tonkes and Baltus, 1997)

Toxicity Unit	Conclusion
< 1	Limited to Not Acutely Toxic
1 - 2	Negligibly Acute Toxic
2 - 10	Mildly Acutely Toxic
10 - 100	Acutely Toxic
> 100	Highly Acutely Toxic

Physical and chemical properties

Parameter	Method	Analysis	Date analysed
pH	M 05	Voltammetry	20.03.2020
Electrical Conductivity	M 09	Ion Exchange	
Dissolved Oxygen	Not SANAS Accredited	Luminescence	
Residual Total Chlorine		Colorimetric	

T 01: *Vibrio fischeri* bioluminescent test, EN ISO 11348-3 (2007)

Test endpoint:	% growth inhibition relative to control and/or EC20 and EC50 values
Exposure period:	15 and 30 minutes
Deviation from reference method:	None
Test chamber type:	Polystyrene cuvettes for luminometer
Test sample volume:	500 ul
Number of replicates per sample:	2
Test temperature:	15°C ±2°C
Test organism species name and source:	Lyophilized *Vibrio fischeri* luminescent bacteria (NRRL B-11177)
Luminescent measurement:	Luminoskan TL, Hygiene Monitoring System
Reagent batch number:	VF5018
Statistical methods used:	Microsoft Excel® and Regression analysis
Date of performance of the test:	24.03.2020

T 02: *Selenastrum capricornutum* growth inhibition test, OECD Guideline 201 (2011)

Test endpoint:	% growth inhibition relative to control and/or EC20 and EC50 values
Exposure period:	72h
Deviation from reference method:	None
Test chamber type:	10 cm path length long cells
Test sample volume:	25 ml
Number of replicates per sample:	2
Test temperature:	23°C±2°C
Test organism species name and source:	*Selenastrum capricornutum*, Printz algae beads (CCAP 278/4 Cambridge, UK)
OD measurement:	Jenway 6300 Spectrophotometer
Algal beads batch number:	SC211119
Statistical methods used:	Microsoft Excel® and Regression analysis
Date of performance of the test:	23.03.2020 – 26.03.2020

T 03: *Daphnia pulex* acute toxicity test, US EPA (2002)

Test endpoint:	% mortality and/or LC10 and LC50 values
Exposure period:	24 and 48h
Deviation from reference method:	None
Test chamber type:	50 ml disposable polystyrene cups
Test sample volume:	25 ml
Number of test organisms per chamber:	5
Number of replicates per sample:	4
Feeding frequency:	None
Test temperature:	21°C±2°C
Test organism species name, age and source:	*Daphnia pulex,* less than 24h old obtained from in-house cultures
Statistical methods used:	Probit software\TSK for definitive exposures
Date of performance of the test:	24.03.2020 – 26.03.2020

T 04: *Poecilia reticulata* acute toxicity test, US EPA (1996)

Test endpoint:	% mortality and/or LC10 and LC50 values
Exposure period:	96h
Deviation from reference method:	None
Test chamber type:	250 ml disposable polystyrene cups
Test sample volume:	200 ml
Number of test organisms per sample:	10
Number of replicates per sample:	2
Feeding frequency:	None
Test temperature:	23°C±2°C
Test organism species name, age and source:	*Poecilia reticulata,* 7-21 days old. Obtained from Internal stock.
Statistical methods used:	Probit software\TSK for definitive exposures
Date of performance of the test:	20.03.2020 – 24.03.2020

7.0 RESULTS

Table 2: 20/286 Toxicity Results

Physical and chemical data	**Method number**	**Sample reference number(s) and description** 20/286 Zibulo Discard Crushed
pH	M 09	7.18
Conductivity (µS/cm)	M 05	295
Dissolved oxygen concentration (mg/l)	Not SANAS Accredited	5.87
Residual Total chlorine (present✓/not present ×)		×
Temperature (˚C)		21.5
Toxicity test results		
15 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-31
30 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))		-27
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)		<1
72h *Selenastrum capricornutum* growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	+55
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)		<1
24h *Daphnia pulex* acute toxicity screening test (% mortality)	T 03	0
48h *Daphnia pulex* acute toxicity screening test (% mortality)		15
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)		<1
96h *Poecilia reticulata* acute toxicity screening test (% mortality)	T 04	0
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)		<1

8.0 ADDITIONAL REQUIREMENTS OR COMMENTS:

A crushed discard sample (Discard B) was received from Golder Associates Africa (Pty) Ltd on the 13th March 2020 and was used to determine potential aquatic acute toxicity effects. The toxicity was determined using a leachate extracted from 100 mg/L which was shaken in laboratory prepared Standard Synthetic Hard Water (SSHW) for 24 hours. The prepared supernatant was filtered through a 0.45 µm filter to isolate the leachate that was used for the bioassay exposures.

Four trophic levels (*Vibrio fischeri, Selenastrum capricornutum, Daphnia pulex* and *Poecilia reticulata*) were exposed to the prepared leachate sample in order to determine acute toxic effects of the dissolved fraction. The exposures to the leachate sample were as undiluted screenings. The leachate prepared will be equivalent to the upper threshold of the Hazard category of 3 for acute toxicity (SANS, 2008. Table 3). The proposed screening exposure will therefore serve as a tier 1 approach to evaluate waste samples against the SANS 10234 (2008) guidelines for substances which have a potential to be hazardous to the aquatic environment.

Table 3: Hazard categories of acute toxicity for substances hazardous to the aquatic environment (SANS 10234, 2008)

1	2	
Hazard category of acute toxicity	**Classification criteria**	
1	96 h LC_{50} (for fish) 48 h EC_{50} (for crustacea) 72 h or 96 h ErC_{50} (for algae or other aquatic plants)	≤1mg/L ≤1mg/L ≤1mg/L
2	96 h LC_{50} (for fish) 48 h EC_{50} (for crustacea) 72 h or 96 h ErC_{50} (for algae or other aquatic plants)	> 1 to ≤10mg/L and/or > 1 to ≤10mg/L and/or > 1 to ≤10mg/L
3	96 h LC_{50} (for fish) 48 h EC_{50} (for crustacea) 72 h or 96 h ErC_{50} (for algae or other aquatic plants)	>10 – ≤100 mg/L and/or >10 – ≤100 mg/L and/or >10 – ≤100mg/L

8.1 Discard B Crushed (20/286)

The Discard B Crushed (20/286) leachate measured a pH of 7.18 which was within the acceptable range (pH 6 – 9) and therefore pH can be excluded as a driving factor for toxicity (USEPA, 1996). This supernatant had an EC of 295 µS/cm. The Dissolved Oxygen (DO) concentration of the leachate was 5.87 mg/L after filtration. The DO value was above the minimum required volume of 4 mg/L which is required for aquatic organisms (USEPA, 1996). Residual total chlorine was not present in the leachate sample.

The leachate extracted from the Discard B Crushed sample indicated 27% inhibition in the *V. fischeri* after the 30 min exposure period. This result exceeded the threshold of the statistically significant percentage effect (20% inhibition) and was therefore different to the control. The leachate sample expressed 55% stimulation in the *S. capricornutum*. This exposure exceeded the 20% threshold and therefore indicates a result that is different to the control. Although this stimulation is not an indication of toxicity, it indicates a potential to cause algal blooms. The *D. pulex* bioassay expressed 15% mortality when exposed to the Discard B Crushed leachate. This sample therefore exceeded the 10% statistical percentage effect threshold and therefore different to the potential control variation. The *P. reticulata* bioassay exposure resulted in 0% mortality. These four bioassay results did not exceed the 50% effect level and could be allocated a toxicity unit of <1TUa for sensitive aquatic bacteria, algae, invertebrate and fish species.

The leachate prepared from the 100 mg/L of the Discard B Crushed sample, indicated no acute toxic effects greater that 50% within the *Vibrio fischeri, Selenastrum capricornutum, Daphnia pulex* and *Poecilia reticulata* bioassays. Therefore, the EC/LC_{50} value would be greater than 100 mg/L for these four trophic levels. These bioassays could therefore be allocated a Hazard category of acute toxicity >3 according to the SANS 10234 criteria (Table 3).

8.2 Conclusion

Based on the Hazard categories of acute toxicity for substances hazardous to the aquatic environment (SANS 10234, 2008), the most sensitive bioassay would determine the category of the sample. The leachate generated from the Discard B Crushed sample was extracted at the threshold criteria (Category 3; 100 mg/L) for the Hazard category of acute toxicity.

Therefore, based on the acute toxicity results of the *Vibrio fischeri, Selenastrum capricornutum, Daphnia pulex* and *Poecilia reticulata*, the Discard B Crushed sample would have a Category allocation of 3. This sample does not indicate acute toxicity and is therefore unlikely to be harmful to aquatic life.

Please note:
Opinions and Interpretations expressed herein are outside the scope of SANAS accreditation.

Due to the mechanism of the DPD colourmetric method to determine the presence of Residual Total Chlorine, there is a potential for false positive chlorine results to be indicated in the presence of any of the additional Group VII Halogen elements (fluorine, bromine, iodine, and astatine).

Any queries regarding the results should be lodged with Mahadi Motsumi within 14 days from the date of certificate of analysis receipt. The samples cannot be retained from the date of this certificate of analysis. Samples will be discarded 1 week after certificate of analyses receipt. If any queries relating to the results associated with these samples are received, then re-sampling will have to take place.

9.0 REFERENCES

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APPENDIX F

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REPORT

Climate Change Specialist Report for the Proposed Discard Facility at Zibulo Colliery

Anglo American Inyosi Coal (Pty) Ltd

Submitted to:

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1 x electronic copy to SharePoint Site

Executive Summary

This climate change assessment was undertaken as part of the Scoping and Environmental Impact Reporting process for the proposed Zibulo Colliery Discard Dump.

Baseline Climatic Conditions

In the Ogies region, average annual temperatures are approximately 15.6°C. Monthly average temperatures range between 20.1°C in January and 9.8°C in June and July. Average annual rainfall is approximately 687 mm. Average monthly rainfall ranges between 118 mm in November and 5 mm in July.

Climate Change Projections

With climate change, average annual temperatures are projected to increase by 0.92°C to 1.14°C in the medium term (2020-2039) and by 1.5°C to 2°C in the in the long term (2040-2059). Increases in monthly average temperatures range from 0.8°C to 1.28°C in the medium term and 1.34°C to 2.5°C in the long term.

The number of hot days, where temperatures exceed 35°C, are projected to increase by 4 days in the medium term and by 9 to 12 days in the long term.

Average annual precipitation is projected to decrease by 13 mm to 14 mm (2% change) in the medium term, and by 34 mm (5% change) to 51 mm (7% change) in the long term. In general, there will be a decrease in monthly average rainfall in most months, and particularly in September and October.

The percentage change in the amount of rainfall from very wet days is projected to increase by 8% to 19% in the medium term and 6% to 26% in the long term. Interestingly, there is projected to be a greater increase in the amount of rainfall from very wet days in the low-medium emissions scenario (RCP4.5) when compared to the high emissions scenario (RCP8.5).

Impact Assessment

Table E1 presents a summary of the potential impacts of climate change on the proposed Zibulo Colliery Discard Dump with and without mitigation.

Table E1: Summary of potential climate change impacts with and without mitigation

Potential Impact	Significance without mitigation	Significance with mitigation
1. Operational Phase		
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	Low	Low
With an increase in the percentage of rainfall from very wet days, there will be an increase in accelerated runoff from the coal discard, which if not properly managed, can potentially contaminate soil, surface water, and groundwater resources.	Low	Low
A decrease in average annual precipitation, coupled with an increase in average monthly temperatures and evaporation rates, will increase the	Moderate	Low

Potential Impact	Significance without mitigation	Significance with mitigation
dust coming off the facility, which can impact negatively on human health, well-being, and the environment.		
2. Decommissioning and Closure Phase		
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	Moderate	Low

Recommended Adaptation Measures

The recommended adaptation measures are listed below:

- Compaction of the discard to limit oxygen ingress, and in particular on the windward sides where forced ventilation through prevailing winds takes place;
- Undertaking an annual thermographic survey of the facility to identify potential ‘hotspots. Survey must be undertaken during the warmest months (November to February). These surveys must be undertaken annually during the operations and for a minimum five years post closure;
- Design of stormwater management system should take into consideration the projected increases in the percentage of rainfall from very wet days;
- Construction of diversion channels around the facility to prevent mixing of ‘clean’ and ‘dirty’ stormwater runoff;
- Implementing dust control and suppression measures, such as the application of water or surfactants;
- Monitoring dust fallout around the facility; and
- Application of a cover, with minimum layer of 500 mm, in order to minimise the exposed surface area for exothermic reactions, and to prevent the ingress of oxygen and moisture.

DETAILS OF THE SPECIALIST

Specialist Information	
Name:	Michael Van Niekerk
Designation:	Environmental scientist
Telephone number:	+27 11 254 4800
Email:	micvanniekerk@golder.co.za
Qualifications:	Master of Science Geography and Environmental Management, University of KwaZulu-Natal, Durban, South Africa, 2008 Refer to Appendix B for CV of the specialist.
Summary of experience:	Michael is an environmental scientist with over 12 years consulting experience in environmental management. He specialises in climate change assessment, greenhouse gas emissions assessments, energy audits, and waste management in the mining, O&G, manufacturing, and industrial sectors.

Declaration of Independence by Specialist

I, Michael Van Niekerk, declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the proposed Discard Facility at Zibulo Colliery Opencast Operations;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity; and
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document

APPENDIX 6 OF THE EIA REGULATIONS, 2014

Where applicable, this baseline report has been written in compliance with Appendix 6 of the EIA Regulations, 2014 (as amended).

Section	Requirements	Section addressed in report
1.(1)	A specialist report prepared in terms of these Regulations must contain	
(a)	Details of	
(i)	the specialist who prepared the report; and	See above
(ii)	the expertise of that specialist to compile a specialist report including a curriculum vitae	See above, and Appendix B
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority	See above
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 1.0
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 4.0
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 4.2
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	n/a
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 4.0
(f)	details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Section 3.0
(g)	an identification of any areas to be avoided, including buffers;	n/a
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	n/a
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 7.0

Section	Requirements	Section addressed in report
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity **(including identified alternatives on the environment)** or activities;	Section 4.2
(k)	any mitigation measures for inclusion in the EMPr;	Section 4.3
(l)	any conditions for inclusion in the environmental authorisation;	Section 4.3
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 4.3
(n)	a reasoned opinion—	
(i)	**(as to)** whether the proposed activity, activities or portions thereof should be authorised;	Section 6.0
(iA)	regarding the acceptability of the proposed activity or activities; and	
(ii)	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	n/a
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	
(q)	any other information requested by the competent authority.	n/a
2.	Where a government notice *gazetted* by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	n/a

Abbreviations

Acronym / Abbreviation	Description
AAIC	Anglo American Inyosi Coal (Pty) Ltd
CMIP5	Coupled Model Intercomparison Project
Facility (or Project)	Zibulo Colliery Discard Dump
$GtCO_2e$	Gigatonnes carbon dioxide equivalent
Golder	Golder Associates Africa (Pty) Ltd.
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
PCPP	Phola Coal Processing Plant
RCP	Representative Concentration Pathways
S&EIR	Scoping and Environmental Impact Assessment Reporting

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APPENDICES

1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd. ("Golder") has been appointed by Anglo American Inyosi Coal (Pty) Ltd (AAIC) to undertake a Scoping and Environmental Impact Assessment Reporting ("S&EIR") process for the proposed Zibulo Colliery Discard Dump ("Facility" or "Project").

The purpose of this report is to provide a specialist opinion on the potential influence of climate change on the proposed Facility in the medium term (2020 to 2039) and long term (2040 to 2059). This specialist opinion will be used to inform the S&EIR.

2.0 PROJECT DESCRIPTION

Zibulo Colliery is situated approximately 25 km south-east of Ogies, with the province of Mpumalanga. The Colliery currently produces an annual eight million run-of-mine tonnes of export thermal coal, with seven million tonnes per annum coming from its underground operations and the remaining one million tonnes from its opencast pit.

Coal from the underground operations are transported to the Phola Coal Processing Plant (PCPP) via a 16-kilometre-long conveyor. The Plant is a 50:50 joint venture between AAIC and global resources company South32. The coarse and fine discard produced by the PCPP is currently stored in a surface discard facility owned by South32. The facility is reaching capacity (110 ha) by 2021 and an alternative discard facility is required to service the discard requirement of the Zibulo Colliery.

With the current facility reaching capacity an alternative arrangement is required to allow for disposal of the discard material from the Zibulo Colliery.

3.0 BASELINE CLIMATIC CONDITIONS

The following section presents an overview of baseline climatic conditions of the Ogies region in which the proposed Facility will be located.

Figure 1 presents the average monthly temperatures and precipitation for the Ogies region for the period 1901 to 2016 (World Bank, 2020). Average annual temperatures are approximately 15.6°C. Monthly average temperatures range between 20.1°C in January and 9.8°C in June and July. Average annual rainfall is approximately 687 mm. Average monthly rainfall ranges between 118 mm in November and 5 mm in July.

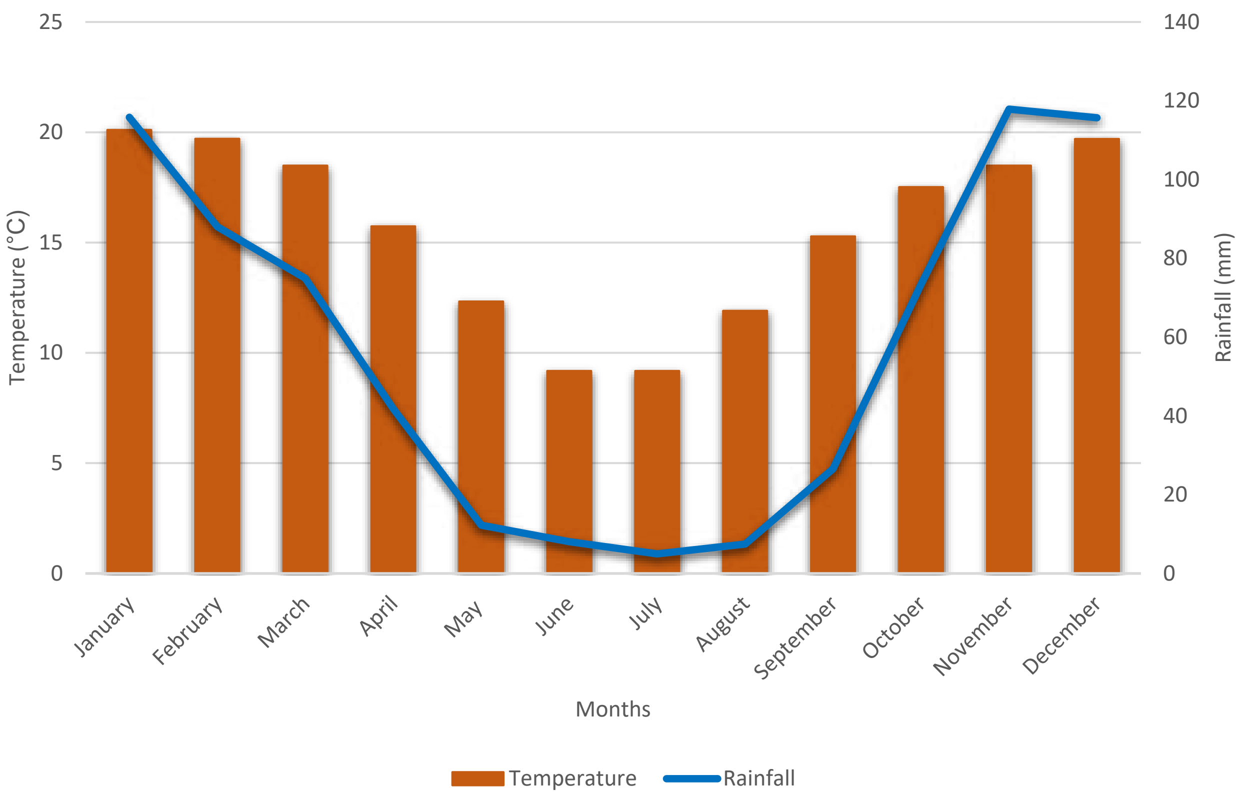


Figure 1: Average monthly temperature and rainfall for the Ogies region for 1901-2016 (World Bank, 2020)

4.0 CLIMATE CHANGE PROJECTIONS

Several climate models have been developed in recent years to simulate future climate change and the associated impacts. The predictions presented in this assessment are based on the 5th Phase of the Coupled Model Intercomparison Project (CMIP5), which comprises 35 global climate change models. CMIP5 is one of the most widely used models and is included in the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report.

Anthropogenic greenhouse gas (GHG) emissions are mainly driven by factors, such as population size, economic activity, land use patterns, and technology. Climate change models use different scenarios, referred to as Representative Concentration Pathways (RCPs), for making predictions based on these factors. The following four RCPs are generally used:

- **RCP2.6:** Low emissions scenario, which aims to keep global warming below 2°C above pre-industrial temperatures;
- **RCP4.5:** Low - medium emissions scenario;
- **RCP6.0:** Medium – high emissions scenario; and
- **RCP8.5:** High emissions or business as usual scenario with no additional efforts to constrain emissions.

Figure 2 (left) presents the trajectory of historical anthropogenic GHG emissions (shown as a black line) and the predicted emissions for each scenario or RCP. With RCP2.6, annual GHG emissions are predicted to be 0 gigatonnes carbon dioxide equivalent ($GtCO_2e$) by 2100, with cumulative anthropogenic CO_2 emissions ($GtCO_2e$) of 430 to 480 parts per million. At these concentrations, the temperature rise relative to pre-industrial levels is predicted to increase by 1.5°C to 2°C (Figure 2 - right). With RCP8.5, annual GHG emissions are predicted to be greater than 100 $GtCO_2e$ by 2100, with cumulative anthropogenic CO_2 emissions ($GtCO_2e$) of more than 1 000 parts per million. At these concentrations, the temperature rise relative to pre-industrial levels is predicted to increase by more than 4°C.

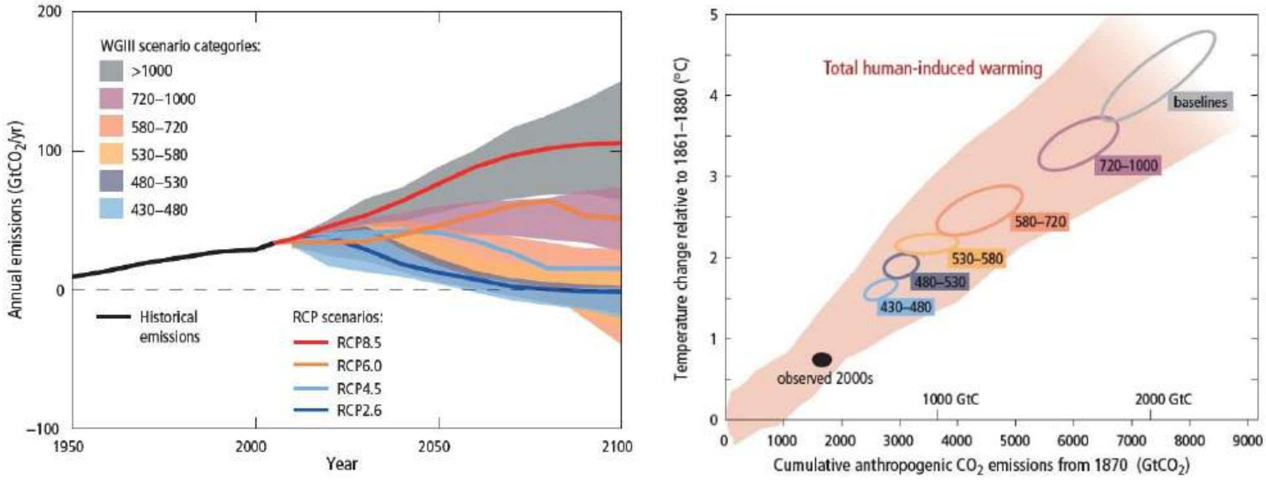


Figure 2: Annual anthropogenic GHG emissions (left) and warming versus cumulative anthropogenic GHG emissions (right) (IPCC, 2014)

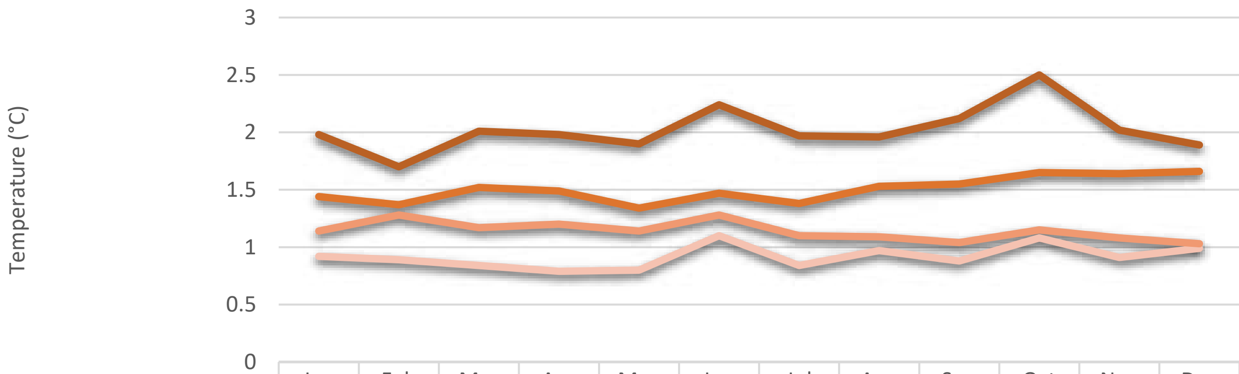
The following section presents an overview of climate change projections for the Ogies region in medium term (2020 to 2039) and long-term (2040 to 2059) under two GHG mitigation scenarios (RCP 4.5 low-medium emissions and RCP8.5 high emissions). This includes changes in average monthly temperatures and precipitation, as well as the number of hot days (>35°C) and percentage of rainfall from very wet days.

4.1.1 Temperature

4.1.1.1 Average Monthly Temperatures

Figure 3 presents the projected changes in average monthly temperatures for the Ogies region in medium term (2020 to 2039) and long term (2040 to 2059), under low-medium (RCP4.5) and high (RCP8.5) emissions scenarios (World Bank, 2020). Note that:

- Average annual temperatures are projected to increase by 0.92°C in the medium term (2020 to 2039) under the low-medium emissions scenario (RCP4.5). Increases in monthly average temperatures range between 0.8°C and 1.1°C;
- Average annual temperatures are projected to increase by 1.14°C in the medium term (2020 to 2039) under the high emissions scenario (RCP8.5). Increases in monthly average temperatures range between 1.1°C and 1.28°C;
- Average annual temperatures are projected to increase by 1.5°C in the long term (2040 to 2059) under the low-medium emissions scenario (RCP4.5). Increases in monthly average temperatures range between 1.34°C and 1.66°C; and
- Average annual temperatures are projected to increase by 2°C in the long term (2040 to 2059) under the high emissions scenario (RCP8.5). Increases in monthly average temperatures range between 1.7°C and 2.5°C.



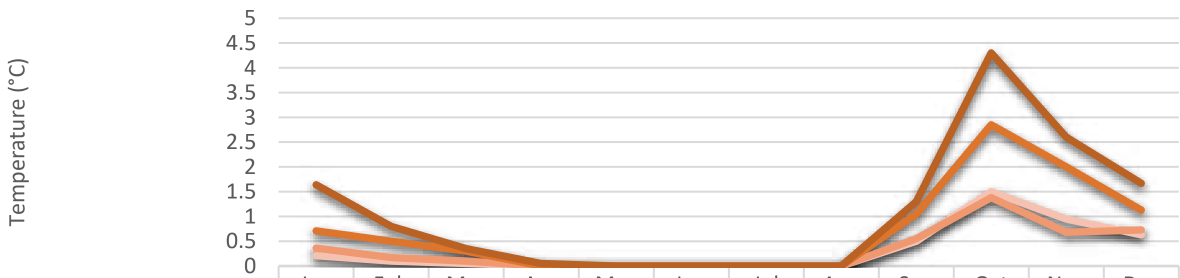
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RCP4.5 (2020-2039)	0.92	0.89	0.84	0.79	0.8	1.1	0.84	0.97	0.88	1.08	0.91	0.99
RCP8.5 (2020-2039)	1.14	1.28	1.17	1.2	1.14	1.28	1.1	1.09	1.04	1.15	1.08	1.03
RCP4.5 (2040-2059)	1.44	1.37	1.52	1.49	1.34	1.47	1.38	1.53	1.55	1.65	1.64	1.66
RCP8.5 (2040-2059)	1.98	1.7	2.01	1.98	1.9	2.24	1.97	1.96	2.12	2.5	2.02	1.89

Figure 3: Projected change in average monthly temperatures for the Ogies region for 2020 to 2039 and 2040 to 2059 (World Bank, 2020)

4.1.1.2 Hot Days (>35°C)

Figure 4 presents the predicted changes in number of hot days where temperatures will rise above 35°C at the Ogies region in medium term (2020 to 2039) and long term (2040 to 2059), under low-medium (RCP4.5) and high (RCP8.5) emissions scenarios. Note that:

- The number of hot days are projected to increase by 4 days in the medium term (2020 to 2039) under the low-medium emissions scenario (RCP4.5) and the high emissions scenario (RCP8.5);
- The number of hot days are projected to increase by 9 days to 13 days in the long term (2040 to 2059) under the low-medium emissions scenario (RCP4.5) and high emissions scenario (RCP8.5), respectively; and
- The increases in the number of hot days are projected to only occur in the summer months (September to March), and in particular October.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RCP4.5 (2020-2039)	0.21	0.1	0.05	0	0	0	0	0	0.5	1.5	0.95	0.63
RCP8.5 (2020-2039)	0.36	0.17	0.1	0	0	0	0	0	0.55	1.38	0.68	0.73
RCP4.5 (2040-2059)	0.71	0.5	0.3	0	0	0	0	0	1.05	2.85	2	1.13
RCP8.5 (2040-2059)	1.64	0.8	0.35	0.05	0	0	0	0	1.3	4.3	2.6	1.67

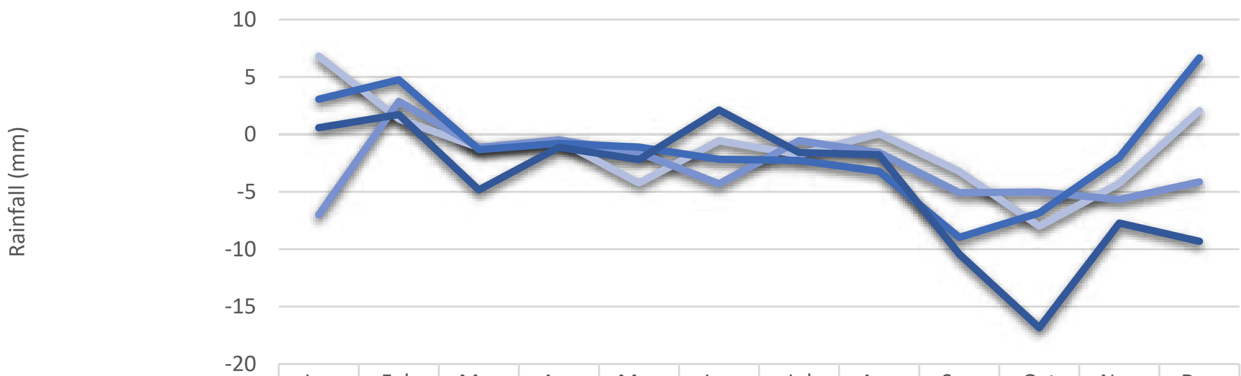
Figure 4: Projected change in number of hot days for the Ogies region for 2020-2039 and 2040-2059 (World Bank, 2020)

4.1.2 Precipitation

4.1.2.1 Average Monthly Precipitation

Figure 5 presents the projected changes in average monthly precipitation for the Ogies region in medium term (2020 to 2039) and long term (2040 to 2059), under low-medium (RCP4.5) and high (RCP8.5) emissions scenarios. Note that:

- Under the low-medium emissions scenario (RCP4.5), average annual precipitation is projected to decrease by 13 mm (2% change) in the medium term (2020 to 2039) and 14 mm (2% change) in the long term (2040 to 2059). There is a marginal increase in average monthly rainfall in December, January, and February. There is a decrease in average monthly rainfall in all other months, with the greatest decreases in September and October; and
- Under the high emissions scenario (RCP8.5), average annual precipitation is projected to decrease by 34 mm (5% change) in the medium term (2020 to 2039) and 51 mm (7% change) in the long term (2040 to 2059). There is a marginal increase in average monthly rainfall in February. There is a decrease in average monthly rainfall in all other months, with the greatest decreases in September and October.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RCP4.5 (2020-2039)	6.82	1.34	-1.15	-0.54	-4.24	-0.55	-1.77	0.06	-3.22	-8	-4.26	2.06
RCP8.5 (2020-2039)	-7	2.87	-1.14	-0.48	-1.58	-4.3	-0.55	-1.58	-5.07	-5.02	-5.68	-4.14
RCP4.5 (2040-2059)	3.06	4.75	-1.34	-0.79	-1.11	-2.17	-2.27	-3.22	-8.97	-6.85	-2.01	6.66
RCP8.5 (2040-2059)	0.58	1.72	-4.84	-1.13	-2.2	2.12	-1.58	-1.78	-10.44	-16.84	-7.73	-9.32

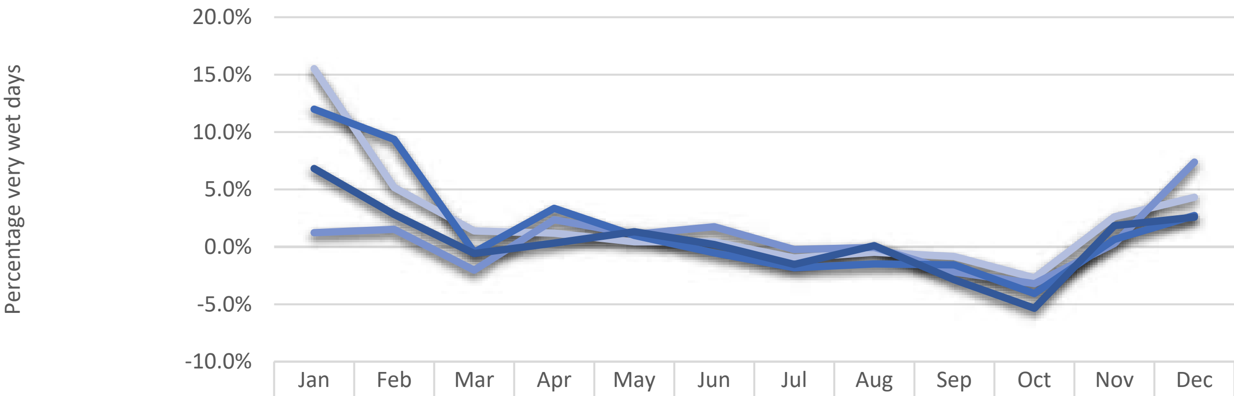
Figure 5: Projected change in monthly precipitation for the Ogies region for 2020 to 2039 and 2040 to 2059 (World Bank, 2020)

4.1.2.2 Very Wet Days

Figure 6 presents the percentage change in the amount of rainfall from very wet days for the Ogies region in medium term (2020 to 2039) and long term (2040 to 2059), under low-medium (RCP4.5) and high (RCP8.5) emissions scenarios. Very wet days are days where the daily precipitation rate exceeds the local 95th percentile of daily precipitation intensity. The higher the percentage, the more rainfall is concentrated with a larger proportion of annual rainfall falling in heavy rainfall events. Conversely, the lower the percentage, the more evenly rainfall is distributed with a lower proportion of annual rainfall falling in heavy rainfall events. Note that:

- Under the low-medium emissions scenario (RCP4.5), the percentage change in the amount of rainfall from very wet days is projected to increase by 26% in the medium term (2020 to 2039) and 19% in the long term (2040 to 2059). There is generally an increase in the percentage of rainfall from very wet days from November to June, with decreases in the percentage of rainfall from very wet days from July to October; and

- Under the high emissions scenario (RCP8.5), the percentage change in the amount of rainfall from very wet days is projected to increase by 8% in the medium term (2020 to 2039) and 6% in the long term (2040 to 2059). There is generally an increase in the percentage of rainfall from very wet days in all months, with the exception March, July, September, and October.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RCP4.5 (2020-2039)	15.5%	5.2%	1.4%	1.2%	0.4%	0.4%	-1.0%	-0.5%	-0.9%	-2.7%	2.6%	4.3%
RCP8.5 (2020-2039)	1.2%	1.5%	-2.0%	2.4%	1.1%	1.8%	-0.2%	-0.1%	-2.2%	-3.2%	0.3%	7.4%
RCP4.5 (2040-2059)	12.0%	9.4%	-0.5%	3.4%	1.0%	-0.5%	-1.8%	-1.5%	-1.6%	-4.1%	0.6%	2.7%
RCP8.5 (2040-2059)	6.8%	2.8%	-0.6%	0.3%	1.3%	0.2%	-1.5%	0.1%	-2.9%	-5.4%	1.8%	2.6%

Figure 6: Projected change in percentage of rainfall from very wet days for the Ogies region for 2020 to 2039 and 2040 to 2059 (World Bank, 2020)

4.2 Impact Assessment

4.2.1 Approach to Impact Assessment

The impact assessment was undertaken using a matrix selection process, the most used methodology, for determining the significance of potential environmental impacts/risks. This methodology incorporates two aspects for assessing the potential significance of impacts, namely severity and probability of occurrence, which are further sub-divided as follows (Table 1).

Table 1: Impact assessment factors

Severity			Probability
Magnitude of impact	Duration of impact	Scale/extent of impact	Probability of occurrence

To assess these factors for each impact, the following four ranking scales are used (Table 1):

Table 2: Impact assessment scoring methodology

Value	Description
Magnitude	
10	Very high/unknown
8	High
6	Moderate
4	Low
2	Minor

Value	Description
Duration	
5	Permanent (Impact continues post-closure)
4	Long term (Impact ceases after decommissioning and closure)
3	Medium-term (Impact ceases after the operational phase)
2	Short-term (Impact ceases after the construction phase)
1	Immediate (less than one year)
Scale	
5	International
4	National
3	Regional
2	Local
1	Site Only
0	None
Probability	
5	Definite/Unknown (impact will definitely occur)
4	Highly Probable (most likely, 60% to 90% chance)
3	Medium Probability (40% to 60% chance)
2	Low Probability (5% to 40% chance)
1	Improbable (less than 5% chance)
0	None

Significance Points = (Magnitude + Duration + Scale) x Probability.

Table 3: Significance of impact based on point allocation

Points	Significance	Description
SP>75	High environmental significance	An impact which could influence the decision about whether or not to proceed with the project regardless of any possible mitigation.
SP 30 – 75	Moderate environmental significance	An impact or benefit which is sufficiently important to require management, and which could have an influence on the decision unless it is mitigated.
SP<30	Low environmental significance	Impacts with little real effect and which will not have an influence on or require modification of the project design.
+	Positive impact	An impact that is likely to result in positive consequences/effects.

For the methodology outlined above (Table 2), the following definitions were used:

- **Magnitude** is a measure of the degree of change in a measurement or analysis (e.g. the severity of an impact on human health, well-being, and the environment), and is classified as none/negligible, low, moderate, or high;
- **Scale/Geographic extent** refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international;
- **Duration** refers to the length of time over which an environmental impact may occur i.e. immediate/transient, short-term, medium term, long-term, or permanent; and
- **Probability** of occurrence is a description of the probability of the impact actually occurring as improbable, low probability, medium probability, highly probable or definite.

4.2.2 Construction Phase

Given that construction is likely to start in the very near future, it is expected that the climatic conditions at the time will be very similar to the baseline climatic conditions presented in Section 4.0. The potential impacts of climate change during the construction phase has therefore not been considered in this assessment as these changes are only likely to manifest in the medium-term and long-term.

4.2.3 Operational Phase

Table 4 presents a summary of the potential impacts during the operational phase.

4.2.3.1 Rising Temperatures Increase Risk of Spontaneous Combustion

It is projected that average annual temperatures will increase by 0.92°C to 1.14°C in the medium term (2020 to 2039) and 1.5°C to 2°C in the long term (2040 to 2059). Furthermore, the annual number of hot days are projected to increase by four (4) days in the medium term and nine (9) to 13 days in the long term.

Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions and the risk of the coal discards igniting or burning. The rate of exothermic reactions is directly related to the temperature, where each 10°C rise in temperature leads to an almost doubling of the oxidation process (Falcon, 1986). Spontaneous combustion of the coal discards poses a risk to the safety of workers. The burning coal discards will also produce smoke which can negatively affect ambient air quality.

Without mitigation, the significance of this impact is likely to be moderate. The magnitude of this impact is expected to be high, however, with short-term duration, extent limited to the site only, and a medium probability of occurrence. With mitigation, the significance of this impact can be reduced to low due to a decrease in the probability of occurrence from medium to low, should the below mitigation measures be implemented.

The proposed mitigation measures are as follows:

- Compaction of the discard to limit oxygen ingress, and in particular on the windward sides where forced ventilation through prevailing winds takes place;
- Undertake progressive rehabilitation to limit areas exposed to oxygen and rainfall;
- Undertake an annual thermographic survey of the Facility to identify potential ‘hotspots. Survey must be undertaken during the warmest months (November to February); and
- It is recommended that a thermographic survey be undertaken following several consecutive hot days (>35°C).

4.2.3.2 Increased Risk of Contaminated Runoff

It is projected that the percentage of rainfall from very wet days will increase by 8% to 26% in the medium term (2020 to 2039) and by 6% to 19% in the long term (2040 to 2059).

Geochemical characterisation of samples from the Zibulo underground mine workings indicates that the coal discards have acid generation potential due to the measurable sulphur contents and insufficient neutralisation potentials. Precipitation coming into direct contact with the coal discards, may therefore become highly acidic. With an increase in the percentage of rainfall from very wet days, there will be an increase in accelerated runoff from the coal discards, which if not properly managed, can potentially contaminate soil, surface water, and groundwater resources.

Without mitigation, the significance of this impact is likely to be low. The magnitude of this impact is expected to be high (significant impact on environment), with medium-term duration, local extent, and low probability of occurrence. With mitigation, the significance of this impact will be reduced even further, due to a decrease in the probability of occurrence from low to improbable.

The proposed mitigation measures are as follows:

- Design of stormwater management system should take into consideration the projected increases in the percentage of rainfall from very wet days; and
- Construction and maintenance of diversion channels around the Facility to prevent mixing of ‘clean’ and ‘dirty’ stormwater runoff.

4.2.3.3 Decreasing Precipitation Increases Likelihood of Dust

It is projected that there will be a decrease in average annual rainfall by 13 mm (2% change) to 34 mm (5% change) in the medium term (2020 to 2039), and by 14 mm (2% change) to 51 mm (7% change) in the long term (2040 to 2059). It is also projected that average annual temperatures will increase by 0.92°C to 1.14°C in the medium term and 1.5°C to 2°C in the long term, thereby increasing evaporation rates.

A decrease in average annual precipitation, coupled with an increase in average monthly temperatures and evaporation rates, will increase the dust coming off the Facility, which can impact negatively on human health, well-being, and the environment.

Without mitigation, the significance of this impact is likely to be moderate. The magnitude of this impact is expected to be moderate, with medium-term duration, regional extent, and medium probability of occurrence. With mitigation, the significance of this impact is likely to be low due to a decrease in the probability of occurrence from medium to low.

The proposed mitigation measures are as follows:

- Implement dust control and suppression measures, such as the application of water or surfactants; and
- Monitor dust fallout around the Facility.

4.2.4 Closure Phase

Table 4 presents a summary of the potential impacts during the closure phase.

4.2.4.1 Rising Temperatures Increase Risk of Spontaneous Combustion

It is projected that average annual temperatures will increase by 0.92°C to 1.14°C in the medium term (2020 to 2039) and 1.5°C to 2°C in the long term (2040 to 2059). Furthermore, the annual number of hot days are projected to increase by four (4) days in the medium term and nine (9) to 13 days in the long term.

Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions and the risk of the coal discards igniting or burning. As mentioned previously, the rate of exothermic reactions is directly related to the temperature, where each 10°C rise in temperature leads to an almost doubling of the oxidation process. Spontaneous combustion of the coal discards poses a risk to the safety of workers during the closure phase, and users of the site post-closure. The burning discards will also produce smoke which can negatively affect ambient air quality. Note that the rate of exothermic reactions is also a function of the exposed surface area (internal surface area for exothermic reactions), oxygen levels, and moisture (removes oxidised products on internal surfaces, thereby re-exposing the surfaces for oxidation), which is the reason that coal discard facilities are required to be capped at closure.

Without mitigation, the significance of this impact is likely to be moderate. The magnitude of this impact is expected to be high (can be life threatening), with long-term duration (extends post-closure), extent limited to the site only, and medium probability of occurrence. With mitigation, the significance of this impact is likely to low, due to a decrease in the probability of occurrence from medium to low.

The proposed mitigation measures are as follows:

- Covering the Facility with minimum layer of 500 mm, in order to minimise the exposed surface area for exothermic reactions, and to prevent the ingress of oxygen and moisture; and
- Annual thermographic surveys of the Facility to identify ‘hotspots’ for minimum five years post closure.

Table 4: Summary of potential impacts during the operational and closure phases

Potential Impact	Impact Assessment Factors		Probability	Significance without mitigation	Impact Assessment Factors		Probability	Significance with mitigation
1. Operational Phase								
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	Magnitude: Duration: Scale:	High Short-term Site	Medium	Moderate	Magnitude: Duration: Scale:	High Short-term Site	Low	Low
With an increase in the percentage of rainfall from very wet days, there will be an increase in accelerated runoff from the coal discards, which if not properly managed, can potentially contaminate soil, surface water, and groundwater resources.	Magnitude: Duration: Scale:	High Medium-term Local	Low	Low	Magnitude: Duration: Scale:	High Medium-term Local	Improbable	Low
A decrease in average annual precipitation, coupled with an increase in average monthly temperatures and evaporation rates, will increase the dust coming off the Facility, which can impact negatively on human health, well-being, and the environment.	Magnitude: Duration: Scale:	Moderate Medium-term Regional	Medium	Moderate	Magnitude: Duration: Scale:	Moderate Medium-term Regional	Low	Low
2. Closure Phase								
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	Magnitude: Duration: Scale:	High Long-term Site	Medium	Moderate	Magnitude: Duration: Scale:	High Long-term Site	Low	Low

4.3 Recommended Adaptation Measures

Table presents a summary of the high-level recommendations for reducing the potential impacts of climate change on the proposed Facility.

Table 5: Summary of the recommended adaptation measures

Impact	No.	Detailed Actions	Timeframes	Responsibility
1. Operational Phase				
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	1.1	Compaction of the discard to limit oxygen ingress, and in particular on the windward sides where forced ventilation through prevailing winds takes place.	Duration of operational phase	Operations
	1.2	Undertake an annual thermographic survey of the Facility to identify potential ‘hotspots. Survey must be undertaken during the warmest months (November to February).	Annual basis	Metallurgy
With an increase in the percentage of rainfall from very wet days, there will be an increase in accelerated runoff from the coal discards, which if not properly managed, can potentially contaminate soil, surface water, and groundwater resources.	1.4	Design of stormwater management system should take into consideration the projected increases in the percentage of rainfall from very wet days.	Prior to construction	Engineering
	1.5	Construction of diversion channels around the facility to prevent mixing of ‘clean’ and ‘dirty’ stormwater runoff.	During construction phase	Engineering
A decrease in average annual precipitation, coupled with an increase in average monthly temperatures and evaporation rates, will increase the dust coming off the Facility, which can impact negatively on human health, well-being, and the environment.	1.6	Implement dust control and suppression measures, such as the application of water or surfactants.	Duration of operational phase	Operations
	1.7	Monitor dust fallout around the Facility.	Duration of operational phase	Metallurgy
2. Closure Phase				

Impact	No.	Detailed Actions	Timeframes	Responsibility
Marked increases in daily or seasonal temperatures will increase the rate of oxidation, thereby increasing exothermic reactions, and the risk of the coal discard igniting or burning.	2.1	Cover the Facility with minimum layer of 500 mm, in order to minimise the exposed surface area for exothermic reactions, and to prevent the ingress of oxygen and moisture.	During closure phase	Operations
	2.2	Annual thermographic surveys of the Facility to identify 'hotspots' for minimum five years post-closure.	Annually for five (5) years	Metallurgy

5.0 GREENHOUSE GAS EMISSIONS

According to the IPCC (2006), the major sources of GHG emissions from both surface and underground coal mines are:

- **Mining emissions:** Release of carbon dioxide and methane stored in the coal and surrounding strata during mining operations; and
- **Post mining emissions:** Release of carbon dioxide and methane during the handling, processing, and transportation of the coal. The coal will continue to emit GHGs even after being mined, but at a much slower rate than during the coal breakage stage.

As the mining of the coal is outside of the scope of this assessment, only the annual GHG emissions from the handling, processing, and transportation of the coal discard will be considered. The annual in-situ GHG emissions from the Zibulo Colliery Discard Dump was estimated using the annual tonnage profile and generic IPCC emissions factors (low and high emissions estimate).

As shown in Table 6, the in-situ GHG emissions from the handling, processing, and transportation of the coal discard deposited at the Facility is estimated to range between 77.04 and 301.52 tCO_2e per annum, with total in-situ emissions ranging between 1 540.84 and 6 03.47 tCO_2e.

Table 6: Estimates of in-situ GHG emissions from the handling, processing, and transportation of coal discard

Year	Annual tonnage	Low emissions estimate		High emissions estimate	
		Emissions factor ($kgCO_2e/t$)	GHG emissions (tCO_2e)	Emissions factor ($kgCO_2e/t$)	GHG emissions (tCO_2e)
2021	2 237 808	0.03	73.79	0.13	288.81
2022	2 237 441	0.03	73.78	0.13	288.76
2023	2 390 744	0.03	78.84	0.13	308.55
2024	2 393 356	0.03	78.92	0.13	308.89
2025	2 377 385	0.03	78.40	0.13	306.83
2026	2 420 369	0.03	79.81	0.13	312.37
2027	2 297 016	0.03	75.75	0.13	296.45
2028	2 336 303	0.03	77.04	0.13	301.52
2029	2 336 303	0.03	77.04	0.13	301.52
2030	2 336 303	0.03	77.04	0.13	301.52
2031	2 336 303	0.03	77.04	0.13	301.52
2032	2 336 303	0.03	77.04	0.13	301.52
2033	2 336 303	0.03	77.04	0.13	301.52
2034	2 336 303	0.03	77.04	0.13	301.52
2035	2 336 303	0.03	77.04	0.13	301.52
2036	2 336 303	0.03	77.04	0.13	301.52

Year	Annual tonnage	Low emissions estimate		High emissions estimate	
		Emissions factor ($kgCO_2e/t$)	GHG emissions (tCO_2e)	Emissions factor ($kgCO_2e/t$)	GHG emissions (tCO_2e)
2037	2 336 303	0.03	77.04	0.13	301.52
2038	2 336 303	0.03	77.04	0.13	301.52
2039	2 336 303	0.03	77.04	0.13	301.52
2040	2 336 303	0.03	77.04	0.13	301.52
Total	**46 726 058**		**1540.84**		**6030.47**
Average	**2 336 303**		**77.04**		**301.52**

6.0 CONCLUSION

In conclusion, it is projected that there will be changes in climate at the proposed Zibulo Colliery Discard Dump in the medium term and long term, and under different climate change scenarios. These changes are however not projected to be significant and will have a low impact on the Facility, provided that the recommended mitigation measures are implemented.

With the emission of GHGs, the proposed Facility will contribute to climate change. The contribution of the Project's GHG emissions are however deemed to be insignificant, especially when considering that these emissions will occur regardless of whether or not the proposed Facility is constructed (i.e., continue to use South32's discard facility).

7.0 LIMITATIONS

Golder has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report.

No other warranty expressed or implied is made. In developing this report, Golder has relied in good faith on information provided by the client.

The client acknowledges that the nature of the work undertaken is stochastic with substantial inherent uncertainly around any given data points and also acknowledge that the uncertainty associated with any projections or forecasts is increased with the duration of the projected period and is subject to future developments or intervening acts which may manifest in the interim period.

Also see Golder's standard document limitations which area attached as APPENDIX B.

8.0 REFERENCES

Falcon R.M. (1986). Spontaneous Combustion of the Organic Matter in Discards from the Witbank Coalfield. *Journal of the South African Institute of Mining and Metallurgy*. Vol. 86. No. 7. pp. 243-250

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change. Japan

World Bank Group (2019). Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/ [accessed on 21 July 2020].

Golder Associates Africa (Pty) Ltd.

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MvN/BB/mc

APPENDIX A

CV of Specialist

Education

MSc Geography and Environmental Science, University of KwaZulu-Natal, Durban, 2009

BSc (Honours) Geography and Environmental Science (Cum Laude), University of KwaZulu-Natal, Durban, 2006

BSc Geography and Environmental Management (Dean's Commendation), University of KwaZulu-Natal, Durban, 2005

Certifications

IEMA Certified Carbon Footprint Analyst, July 2018

Languages

English – Fluent

Afrikaans – Fluent

Johannesburg

Environmental Practitioner

Michael is an environmental scientist with over 12 years of experience in environmental management.

He has considerable experience in energy auditing, GHG emissions assessments, and climate change assessments. Much of that experience has been with IFC and the Equator Principles, through ESIAs in South Africa and the rest of Africa. As a result, he is very familiar with the both the South African legislation regulating GHG emissions, as well as the requirements of the IFC and the Equator Principles.

Having undertaken a number of energy audits in the past, Michael is also familiar with the significant energy uses responsible for GHG emissions.

Michael is also experienced in bespoke excel-based model development for a number of projects in a wide range of sectors, including GHG emissions reporting, Carbon tax liability calculations, energy audits, waste flow modelling, and mine closure costs.

Employment History

FutureWorks – Kloof

Senior Environmental Consultant (2008 to 2015)

Michael joined FutureWorks in 2008 after completing his MSc at the University of KwaZulu-Natal. During his 6 years at FutureWorks, Michael worked on a number of EIAs, BAs, WMLs, S24G applications, and amendment applications, strategic planning projects (e.g. EMFs, SDFs and LAPs), and ecosystem services assessments.

PROJECT EXPERIENCE – SUSTAINABLE DEVELOPMENT

Greenhouse Gas and Climate Change Assessment for the Grootegeluk, Thabametsi and Turfvlakte Projects South Africa (Ongoing)	Undertake a GHG and Climate Change Assessment for the existing Grootegeluk and proposed Thabametsi and Turfvlakte coal mining projects, located in Lephalale, South Africa.
Greenhouse Gas and Climate Change Assessment for the Ahafo North Project Ghana	Undertake a GHG assessment as part of the Bankable Feasibility Study for the Ahafo North Project, a proposed gold mine, located in the Ahafo region, Ghana.
GHG Assessment: Kamoa-Kakula Project (work in progress) Democratic Republic of Congo	Determine the potential GHG emissions from the proposed Kamoa-Kakula Project during the construction, operational, and closure phases. This included an assessment of the estimated GHG emissions against pre-determined thresholds, the contribution of GHG emissions to DRC's national GHG emissions, and product unity intensity.
GHG Assessment: Vesuvius South Africa Johannesburg, South Africa	Determine the GHG emissions of Vesuvius's South African operations and their potential carbon tax liability.
Climate Change and GHG Assessment: Chirano, Damang, and Tarkwa Power Plants (work in progress)	Determine the GHG emissions from upgrades to the existing Chirano, Damang, and Tarkwa Power Plants, and the construction of a gas pipeline to supply these plants. Included a qualitative assessment of the potential impacts of climate change on these projects.
Climate Change and GHG Assessment: Coalbrook Lifex Project Free State, South Africa	Determine the GHG emissions of the Coalbrook Lifex Project during the operational phase, and the potential impacts of climate change on the project.
GHG Assessment: Mozambique Gas-to-Power Project Inhambane, Mozambique	Determine the potential GHG emissions from the proposed Mozambique Gas-to-Power Project during the construction, operational, and closure phases. This included an assessment of the estimated GHG emissions against pre-determined thresholds, the contribution of GHG emissions to Mozambique's national GHG emissions, and product unity intensity.
Developing a Framework for Analysing the Economic Impacts of Climate Change on Coastal Systems in the Western Indian Ocean Western Indian Ocean	Develop a framework for analysing the economic impacts of climate change on coastal systems in the Western Indian Ocean which can be used by affected countries to leverage climate change mitigation and adaptation funding. This included identification of potential impacts of climate change on affected countries and the potential costs associated with these impacts.

Durban Climate Change Strategy
eThekwini Municipality, KwaZulu-Natal, South Africa

Develop the Durban Climate Strategy for the eThekwini Municipality, which includes an overview of Durban's GHG emissions, projected changes in climate, the vision, goals, objectives and responses of the strategy, as well as an implementation plan, and monitoring and evaluation plan. Importantly, this strategy was developed in consultation with relevant stakeholders through a series of sector-specific or theme workshops.

KwaZulu-Natal Green Economy Strategy
KwaZulu-Natal, South Africa

Prepare the KZN Green Economy Strategy for the KZN Department of Economic Development and Tourism. This strategy was developed in collaboration with the various provincial departments that will ultimately be responsible for implementation of the strategy.

Unlocking the Green Economy in KwaZulu-Natal
KwaZulu-Natal, South Africa

Research project for the KZN Department of Economic Development and Tourism to determine best practice for unlocking the green economy in KZN. This included literature review of international best practice and series of focus group meeting and workshops with key stakeholders from selected sectors.

COP17/CMP7 Responsible Accommodation Campaign
eThekwini Municipality, KwaZulu-Natal, South Africa

Co-authored toolkit developed for the COP17/CMP 7 Responsible Accommodation Campaign, an initiative by the eThekwini Municipality to encourage hospitality businesses to be more responsible i.e. energy efficient, conserve water and manage waste sustainably. This included series of workshops with selected key stakeholders.

Guideline for Designing Green Roof Habitats
eThekwini Municipality, KwaZulu-Natal, South Africa

Co-authored guideline document entitled "Guideline for Designing Green Roof Habitats". This guideline profiled the lessons learned from EPCPD's pilot green roof project, which was developed as part of eThekwini's Municipal Climate Change Protection Programme.

Guide to Durban’s Nature Attractions and Outdoor Experiences
eThekwini Municipality, KwaZulu-Natal, South Africa

Co-authored guideline document entitled "Guide to Durban’s Nature Attractions and Outdoor Experiences", which was developed as part of the greening programme for COP17/CMP7 held in Durban in 2011.

Green Landscaping Guideline
eThekwini Municipality, KwaZulu-Natal, South Africa

Co-authored Green Landscaping Guideline, which together with the Energy Efficiency Guideline, Water Conservation Guideline, and Sustainable Waste Management Guideline were developed as part of the Greening Durban 2010 Programme for the 2010 FIFA World Cup.

PROJECT EXPERIENCE – ENERGY

Implementation of ISO 50001 at Transnet Pipelines
South Africa

Assist Transnet Pipelines, which owns, operates, manages and maintains a network of 3800 km of high-pressure petroleum and gas pipelines in implementing ISO 50001 certified Energy Management System.

RECP Assessment of Value Logistics
Durban and Cape Town, South Africa

Resource Efficiency and Cleaner Production (RECP) assessment of four Value Logistics warehousing facilities in Durban and Cape Town. Also included the identification, high-level costing and prioritisation of energy and water saving opportunities

RECP Assessment of Iso Moulders and Rising Sun
Durban, KwaZulu-Natal, South Africa

Resource Efficiency and Cleaner Production (RECP) assessment of Iso Moulders, a polystyrene packaging producer, and Rising Sun, a local community newspaper printer. Also included the identification, high-level costing and prioritisation of energy and water saving opportunities.

Detailed Energy Audit of Corruseal Packaging
Durban, KwaZulu-Natal, South Africa

Identify the key energy sources and significant energy users at Corruseal, a large corrugated card producer in Durban. Also included the identification, high-level costing and prioritisation of energy saving opportunities.

Detailed Energy Audit of Nampak Glass
Johannesburg, Gauteng, South Africa

Identify the key energy sources and significant energy users at Nampak Glass, one of the largest glass bottle producers in South Africa. Also included the identification, high-level costing and prioritisation of energy saving opportunities.

Detailed Green Technology Report for Broadway Sweets
Johannesburg, Gauteng, South Africa

Prepare a detailed green technology report and resource efficiency assessment for Broadway Sweets in Johannesburg as part of grant application from the Department of Trade and Industry.

Energy Savings Review Follow-Up Services
eThekwini Municipality, KwaZulu-Natal, South Africa

Provide follow-up services for a number of companies that have previously undertaken an energy savings survey or review. Companies include Jonday Foods, Duys Component Manufacturers, Spunprint (Pty) Ltd, and Eston Brick and Tile. This includes tracking progress in implementation of recommended energy saving opportunities and evaluation of available financing options.

Energy Efficiency Policy and Strategy for RBCT
Richards Bay, KwaZulu-Natal, South Africa

Develop energy efficiency policy and strategy for Richards Bay Coal Terminal as part of the NBI PSEE Programme. This included the development and rollout of an energy awareness campaign.

Pre-Feasibility Assessment for Implementation of Daylight Saving Time in the eThekwini Municipality
eThekwini Municipality, KwaZulu-Natal, South Africa

Pre-Feasibility Assessment for implementation of Daylight Saving Time in the eThekwini Municipality. This included best practice literature review of daylight saving time implementation in countries around the world, and high-level assessment of potential socio-economic impacts of implementation of daylight saving time in Durban.

Local Government Toolkit for Financing Energy Efficiency and Renewable Energy
South Africa

Prepare a toolkit to guide local government in financing energy efficiency and renewable energy initiatives. This includes a high-level description of available financing mechanisms, an assessment of these mechanisms, and tools for unlocking project financing.

Guideline on Energy Efficiency in Municipal Water and Wastewater Infrastructure
South Africa

Prepare guideline document on energy efficiency and renewable energy in municipal water and wastewater infrastructure. The guideline provides motivation for investing in energy efficiency and renewable energy, suggestions for planning and implementing initiatives, and case examples.

Energy Strategies for King Sabata Dalindyebo, Mbombela, Rustenburg and Polokwane Municipalities
Eastern Cape, Mpumalanga, North West and Limpopo, South Africa

Develop Energy Strategies for King Sabata Dalindyebo, Mbombela, Rustenburg and Polokwane Municipalities. Each strategy generally included an overview of current energy context, vision, principles, and objectives, and implementation plan, The development of each strategy generally involved an extensive engagement process with relevant municipal departments to raise awareness and build capacity around energy efficiency and renewable energy.

Case Study on Energy Savings in Commercial & Residential Buildings in Durban
eThekwini Municipality, KwaZulu-Natal, South Africa

Profile manufacturing, retail, and hospitality businesses, as well as schools and private residences that have made significant reductions in energy use. This included preparation of two guideline documents to create awareness on potential energy savings.

TRAINING

Carbon Footprint Analyst Course
Terra Firma Academy, 2018

Programme in Project Management
USB-ED University of Stellenbosch Business School, 2011

Training Course on Real World EIA
Vicki King of Metamorphosis Environmental, 2008

PUBLICATIONS

Web Documents

Blignaut, J.N., Diederichs, N., Van Niekerk, M., McKenzie, M. and Botes, A. (2014). Local Government Toolkit: Financing Energy Efficiency and Renewable Energy. SALGA, Pretoria.
http://www.cityenergy.org.za/uploads/resource_263.pdf

Diederichs, N., Van Niekerk, M, and McKenzie, M. (2014). Guideline on Energy Efficiency and Renewable Energy in Municipal Water and Wastewater Infrastructure. SALGA, Pretoria.
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Van Niekerk M. and Maganlal M. (2011), COP 17 / CMP 7 Responsible Accommodation Campaign: Toolkit, eThekwini Municipality.

Van Niekerk M., Bellingham C. and Diederichs N. (2009), Saving Electricity in Commercial and Industrial Buildings and Operations: A Guide to Reducing Costs and Helping Avoid Load Shedding, eThekwini Municipality, Durban

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APPENDIX B

Document Limitations

DOCUMENT LIMITATIONS

This document has been provided by Golder Associates Africa Pty Ltd (“Golder”) subject to the following limitations:

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REPORT

Atmospheric Impact Report for the Zibulo Colliery Discard Dump Facility

Anglo American Inyosi Coal (Pty) Ltd

Submitted to:

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Declaration of Independence by Specialist

I, Novania Reddy declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the proposed discard facility and associated conveyor;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity; and
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document.

EXECUTIVE SUMMARY

Overview

Anglo American Inyosi Coal (Pty) Limited Zibulo Colliery (Zibulo) proposes to develop a discard facility on the footprint of its opencast mine located north-west of the town of Ogies in Mpumalanga. Golder Associates Africa (Pty) Ltd (Golder) has been appointed by Zibulo to undertake the Air Quality Impact Assessment (AQIA) for the proposed discard dump and associated conveyor.

The AQIA (this report) included a baseline assessment, impact assessment and recommended mitigation measures to reduce emissions on the surrounding environment from the proposed discard dump and associated conveyor.

Baseline assessment

The baseline assessment included an identification of key pollutants associated with the proposed operations and an overview of available meteorological and ambient air quality data. Key pollutants associated with the proposed activities (material handling, including conveyor transfer points, and wind erosion from the discard dump) were identified as total suspended particulates (TSP) (in the form of dust fallout) and particulate matter of aerodynamic diameters less than 10 and 2.5 microns (PM_{10} and $PM_{2.5}$, respectively).

Meteorological data

To assess ambient meteorological conditions (temperature and rainfall), the meteorological station based in the town of Ogies (located 1.5 km's south-south-east of Zibulo) was utilized to provide an understanding of the air dispersion characteristics. Due to the very close proximity of this station to Zibulo, the experienced meteorological conditions at this station are anticipated to be almost identical to that experienced at Zibulo.

Temperature and rainfall are key influencing factors in ambient air quality:

- Historically, rainfall is typically much higher during the spring and summer months, where approximately 90% of the annual precipitation occurs between October through to April. Little rainfall occurs during the autumn and winter months between May to September. The driest month is usually July. Precipitation usually reaches its peak in January; and
- Zibulo falls within semi-arid climatic conditions, where temperatures are generally warm and temperate with warm summers and cold winters usually associated with frost.

To assess wind conditions, site-specific modelled MM5 meteorological data was obtained from Lakes Environmental Software for the period January 2016 to December 2018 (three-year data set).

- Winds at Zibulo are predominantly from the northern and south-easterly sectors. Wind speeds are moderate, averaging ±3 to 5 m/s with a low percentage (±13%) of calm conditions (<1 m/s).

Ambient air quality data

For the purpose of this study, reference has been made to the most current and available monitoring data, for the period 2019.

- Particulate matter at Zibulo is currently monitored at the Ogies School, using a Topas monitor mounted on a solar-powered monitoring trailer.
  - For the period May to December 2019, the PM_{10} annual average (51 µg/m³) was non-compliant with the annual average PM_{10} standard (40 µg/m³), whilst the $PM_{2.5}$ annual average (16 µg/m³) was compliant with the annual average $PM_{2.5}$ standard (20 µg/m³) using the data from the Topas. Such

concentrations are however representative of the current baseline conditions in the Highveld Priority Area (HPA).

- Dust fallout monitoring at Zibulo is currently conducted at six monitoring locations, consisting of one directional (oil office monitoring location) bucket and six single buckets (oil office, WHBO office, offramp, west of opencast, Phola and Ogies School monitoring locations, of which only Phola an Ogies School are residential locations).
  - For the period January to December 2019 a 12-month residential and non-residential network average of 521 mg/m^2/day and 928 mg/m^2/day, respectively (below the Residential and Non-Residential Dust Control Regulations) was noted over the period.

Impact Assessment

The impact assessment comprised of an emissions inventory and subsequent dispersion modelling simulations. An emissions inventory was developed using site-specific data and emission factors which were sourced from either the United States Environmental Protection Agency (USEPA) AP42 (USEPA, 1995) or the Australian Government National Pollutant Inventory (NPI, 2012) database. This emissions inventory was input into a Level 2 atmospheric dispersion model, AERMOD, together with prognostic MM5 meteorological data (for the period 2016 to 2018), to predict ambient air concentrations at specified sensitive receptors of the key pollutants associated with the proposed operations. Sensitive receptors are identified as areas that may be impacted negatively due to emissions from the proposed operations.

The assessment of construction air quality impacts was not applicable as the footprint of the proposed dump and conveyor offloading area are part of existing operations and consequently does not require any footprint preparations as part of a formal construction phase.

Long-term (annual) and short-term (24-hour average) concentrations for the pollutants of concern for the operational phase were compared with the applicable South African ambient air quality standards and the South African Dust Control Regulations.

Dispersion modelling simulations for the mitigated operational phase indicated that:

- Dust Fallout:
  - Predicted dust fallout rates are well below the South African Residential Dust Control Regulations at all sensitive receptors; and
  - Cumulative dust fallout rates at all sensitive receptors are below the South African Residential Dust Control Regulations.
- PM_{10} Concentrations:
  - Predicted PM_{10} concentrations are well below the ambient air quality standard for PM_{10} at all sensitive receptors for all assessment periods; and
  - Cumulative annual average PM_{10} concentrations are expected to be non-compliant with the annual average ambient air quality standard for PM_{10} at all sensitive receptors.
    - It must be noted that this is a result of the high existing PM_{10} background concentrations and is not a result of the proposed discard dump facility operations. Additionally, the PM_{10} concentrations at each of the sensitive receptors contribute marginally to the overall cumulative concentrations.

- $PM_{2.5}$ Concentrations:
  - Predicted $PM_{2.5}$ concentrations are well below the ambient air quality standard for $PM_{2.5}$ at all sensitive receptors for all assessment periods; and
  - Cumulative annual average $PM_{2.5}$ concentrations are expected to be compliant with the annual average ambient air quality standard for $PM_{2.5}$ at all sensitive receptors.

All impacts of the proposed project were also evaluated using a risk matrix, which is a semi-quantitative risk assessment methodology.

- Construction Phase:
  - The proposed discard dump facility (including conveyor) does not require any footprint preparations as part of a formal construction phase as the discard will simply be deposited within the existing footprint. Assessment of construction air quality impacts is thus not applicable.
- Operational Phase:
  - With the implementation of mitigation measures such as water sprays, the magnitude of the impact from the proposed discard dump and conveyor operations is anticipated to be low, with a low probability of occurrence. This is further substantiated by the fact that the short-term and long-term PM_{10} and $PM_{2.5}$ concentrations and dust fallout rate, as discussed within the predicted modelling results section, are predicted to be below the relevant ambient air quality standard and South African Residential Dust Control Regulations at all sensitive receptors. The impact is expected to be medium-term in duration (as the operations are expected to last for 15 years), but is likely to be limited to a local extent, resulting in a “low” significance; and
  - Combustion emissions associated with spontaneous combustion was not quantitatively assessed as no suitable site-specific emission factors are available. Qualitatively, the combustion emissions from spontaneous combustion onsite are anticipated to have a negative impact on the ambient air quality. The occurrence of spontaneous combustion onsite will need to be managed carefully (through e.g. concurrent rehabilitation) to ensure the operations are compliant with the ambient air quality standards.
    - With the implementation of mitigation measures, the magnitude of the impact is anticipated to be low, with a low probability of occurrence. The impact of the duration is expected to remain the same, but is likely to be limited to site only, resulting in a “low” significance.
  - Without mitigation, the magnitude of the air quality impact is likely to exacerbate.
- Closure Phase:
  - With the implementation of mitigation measures, the magnitude of the impact is anticipated to be minor and is likely to be improbable. The impact of the duration is expected to remain the same, but is likely to be limited to site only, resulting in a “low” significance; and
  - Without mitigation, the magnitude of the air quality impact is likely to exacerbate.

Conclusion and Recommendations

Given the low impacts predicted on the sensitive receptors during the operational and closure phases of the project, Golder’s professional opinion is that this project be recommended for authorisation, with the recommended mitigation measures being implemented accordingly.

ACRONYMS AND ABBREVIATIONS

Abbreviation	Explanation
AEL	Atmospheric Emission License
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DJF	December, January, February
EIA	Environmental Impact Assessment
HPA	Highveld Priority Area
JJA	June, July, August
MAM	March, April, May
MM5	Fifth Generation NCAR/Penn State Mesoscale Model
NAAQS	National Ambient Air Quality Standard
NEM: AQA	National Environmental Management: Air Quality Act (Act no. 39 of 2004)
NO	Nitric oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
O_3	Ozone
Pb	Lead
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 µm
ptn.	Portion
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxides
SON	September, October, November
SR	Sensitive Receptor
TSP	Total Suspended Particulates
WHO	World Health Organisation

UNITS OF MEASURE

Abbreviation	Explanation
%	Percentage
°C	Degree Celsius
µg	Microgram
$µg/m^3$	Micrograms per Cubic Metre
km	Kilometre
M	Metre
m/s	Meters per Second
mamsl	Metres Above Mean Sea Level
mg	Milligrams
$mg/m^2/day$	Milligrams per Square Metre per Day
mg/Nm^3	Milligrams per Normal Square Metre
mm	Millimeters
ppb	Parts per Billion
ppm	Parts per Million

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1.0 INTRODUCTION

Anglo American Inyosi Coal (Pty) Limited Zibulo Colliery (Zibulo) proposes to develop a discard facility on the footprint of its opencast mine located north-west of the town of Ogies in Mpumalanga. Golder Associates Africa (Pty) Ltd (Golder) has been appointed by Zibulo to undertake an Air Quality Impact Assessment (AQIA) for the proposed discard dump and associated conveyor.

1.1 Location and extent of colliery

Zibulo is located approximately 1.5 km north-north-west of Ogies, directly adjacent to the intersection of the National Road 12 (N12) and Regional Road 545 (R545). The Colliery lies within the greater Nkangala District Municipality, in the eMalahleni Local Municipality in the Mpumalanga province, South Africa. The location and extent of the facility is described in Table 1 and illustrated in Figure 1.

Table 1: Location and extent of Zibulo

Enterprise Name	Anglo American Coal (Pty) Ltd – Zibulo Colliery
Description of Site (Erf)	Zibulo Colliery Opencast Section
Coordinates of Approximate Centre of Operations	26° 2'0.02"S 29° 2'47.98"E
Extent (km²)	2.75
Elevation Above Mean Sea Level (m)	±1 552 m
Province	Mpumalanga
Metropolitan/District Municipality	Nkangala District Municipality
Local Municipality	eMalahleni Local Municipality
Designated Priority Area	Highveld Priority Area

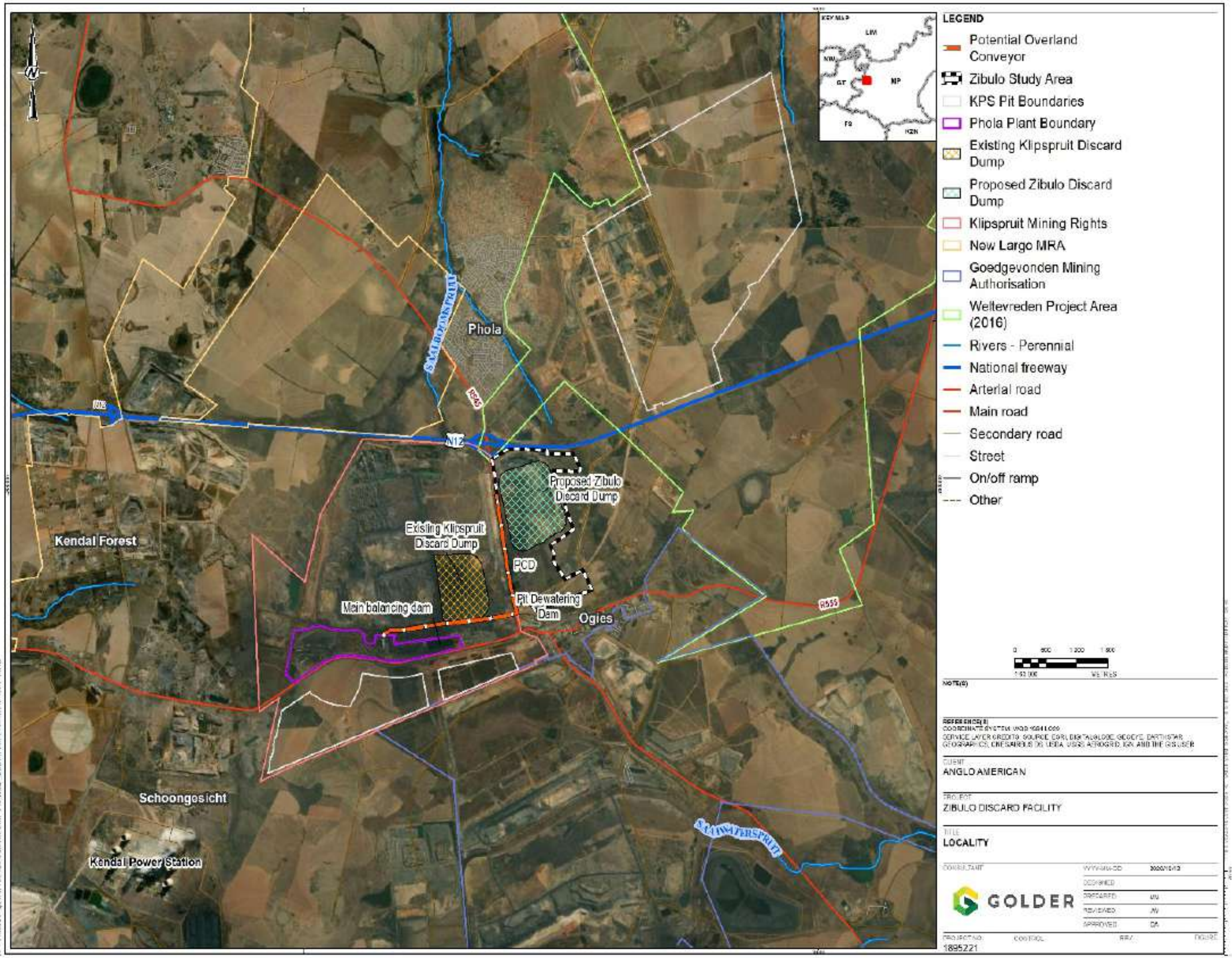


Figure 1: Map indicating the location of Zibulo Colliery, the proposed discard facility and conveyor route

1.2 Description of surrounding land use

The proposed discard facility will be developed within the footprint of the existing opencast operation, and the proposed conveyor will largely follow the alignment of the existing conveyor linking the South32 Klipspruit extension project to the Phola Coal Processing Plant (PCPP). The study area is heavily developed with mining, power generation and agriculture dominating the surrounding land uses. Klipspruit Expansion Project lies to the north-east of the site and the Vlakfontein opencast lies to the north-west. In addition, the New Largo opencast which will supply Kusile Power Station lies to the north-west and will be a large-scale opencast operation once commissioned. The town of Ogies is located to the south-east of the opencast area while Phola is located to the north-west and separated from the site by the N12 National Road. The dominant land uses surrounding Zibulo are shown in Figure 2.

Sensitive receptors are defined by the United Stated Environmental Protection Agency (USEPA) as areas where occupants are more susceptible to the adverse effects of exposure to pollutants. These areas include but are not limited to:

- Residential areas;
- Hospitals/clinics;
- Schools and day care facilities; and
- Elderly housing.

For the purpose of this study the following sensitive receptors within close proximity of Zibulo were identified and are presented in in Table 2 and Figure 3. Figure 3 also depicts the topography in the area which is typically described as undulating with numerous ridges and shallow valleys.

Table 2: Sensitive receptors (SR) within a 10km radius of Zibulo

No.	Sensitive Receptor Name	Sensitive Receptor Type	GPS Location		Distance from Site Boundary (km)	Direction from Site
			East	South		
1	Residential	Residential	29.0489	-26.1207	8.18	South
2	Residential	Residential	29.0364	-26.1208	8.20	South
3	Residential	Residential	29.0971	-26.0210	4.78	East-north-east
4	Residential	Residential	29.0618	-25.9606	6.76	North
5	Residential	Residential	29.0238	-25.9626	6.53	North-north-west
6	Residential	Residential	29.0081	-25.9625	7.16	North-north-west
7	Residential	Residential	29.0001	-25.9624	7.58	North-north-west
8	Residential	Residential	28.9936	-25.9612	8.07	North-north-west
9	Residential	Residential	28.9861	-25.9762	7.35	North-north-west
10	Residential	Residential	28.9620	-26.0067	7.72	North-west
11	Residential	Residential	28.9622	-25.9884	8.45	North-west
12	Residential	Residential	28.9507	-26.0536	8.98	West-south-west
13	Residential	Residential	28.9500	-26.0567	9.11	West-south-west
14	Phola Clinic	Clinic	29.0358	-26.0081	1.40	North
15	Mabande Secondary School	School	29.0316	-26.0046	1.95	North
16	Mehlwana Secondary School	School	29.0388	-25.9945	2.75	North

No.	Sensitive Receptor Name	Sensitive Receptor Type	GPS Location		Distance from Site Boundary (km)	Direction from Site
			East	South		
17	Residential	Residential	29.0458	-26.0520	0.59	South
18	Residential	Residential	29.0478	-26.0542	0.89	South
19	Residential	Residential	29.0109	-25.9881	4.68	North-north-west
20	Residential	Residential	28.9957	-26.0141	4.25	North-west
21	Thembelihle Primary School	School	29.0454	-26.1110	7.09	South
22	Gekombineerde Skool Ogies	School	29.0683	-26.0489	1.90	East-south-east
23	Imbalenhle Primary School	School	28.9722	-26.0412	6.64	West
24	Thuthukani Primary School	School	29.0387	-26.0094	1.15	North
25	Hlanga Phala Primary School	School	29.0326	-26.0072	1.65	North
26	Ogies Clinic	Clinic	29.0559	-26.0502	0.90	South-east
27	Ogies District Surgeon	Surgeon	29.0568	-26.0498	0.93	South-east
28	Residential	Residential	29.0354	-26.0077	1.45	North
29	Residential	Residential	29.0841	-25.9771	6.24	North-north-east
30	Residential	Residential	29.0847	-25.9915	5.21	North-north-east
31	Residential	Residential	29.1066	-25.9923	6.92	North-east
32	Residential	Residential	29.0741	-26.0187	2.71	North-east
33	Residential	Residential	29.0718	-26.0235	2.31	East-north-east
34	Residential	Residential	29.0084	-26.0667	4.17	South-west
35	Residential	Residential	28.9694	-26.0611	7.36	West-south-west
36	Residential	Residential	28.9669	-26.0604	7.58	West-south-west
37	Residential	Residential	28.9583	-26.0590	8.36	West-south-west
38	Residential	Residential	29.0219	-26.1165	8.01	South-south-west
39	Residential	Residential	28.9755	-26.0794	7.71	South-west
40	Residential	Residential	28.9503	-26.0124	8.73	West-north-west
41	Residential	Residential	29.0366	-25.9741	5.02	North
42	Residential	Residential	29.0494	-25.9741	5.03	North
43	Residential	Residential	29.0770	-26.0487	2.74	East-south-east
44	Residential	Residential	28.9627	-26.0400	7.56	West
45	Residential	Residential	28.9955	-26.0816	6.18	South-west
46	Residential	Residential	29.0045	-26.0894	6.14	South-west
47	Residential	Residential	29.0587	-26.1185	8.05	South-south-east

1.3 Atmospheric emission licence

Zibulo does not have any listed activities on site and thus no Atmospheric Emission License (AEL) is applicable to the operation. Furthermore, the proposed development of the discard facility including conveyor are not listed activities triggering an AEL process.

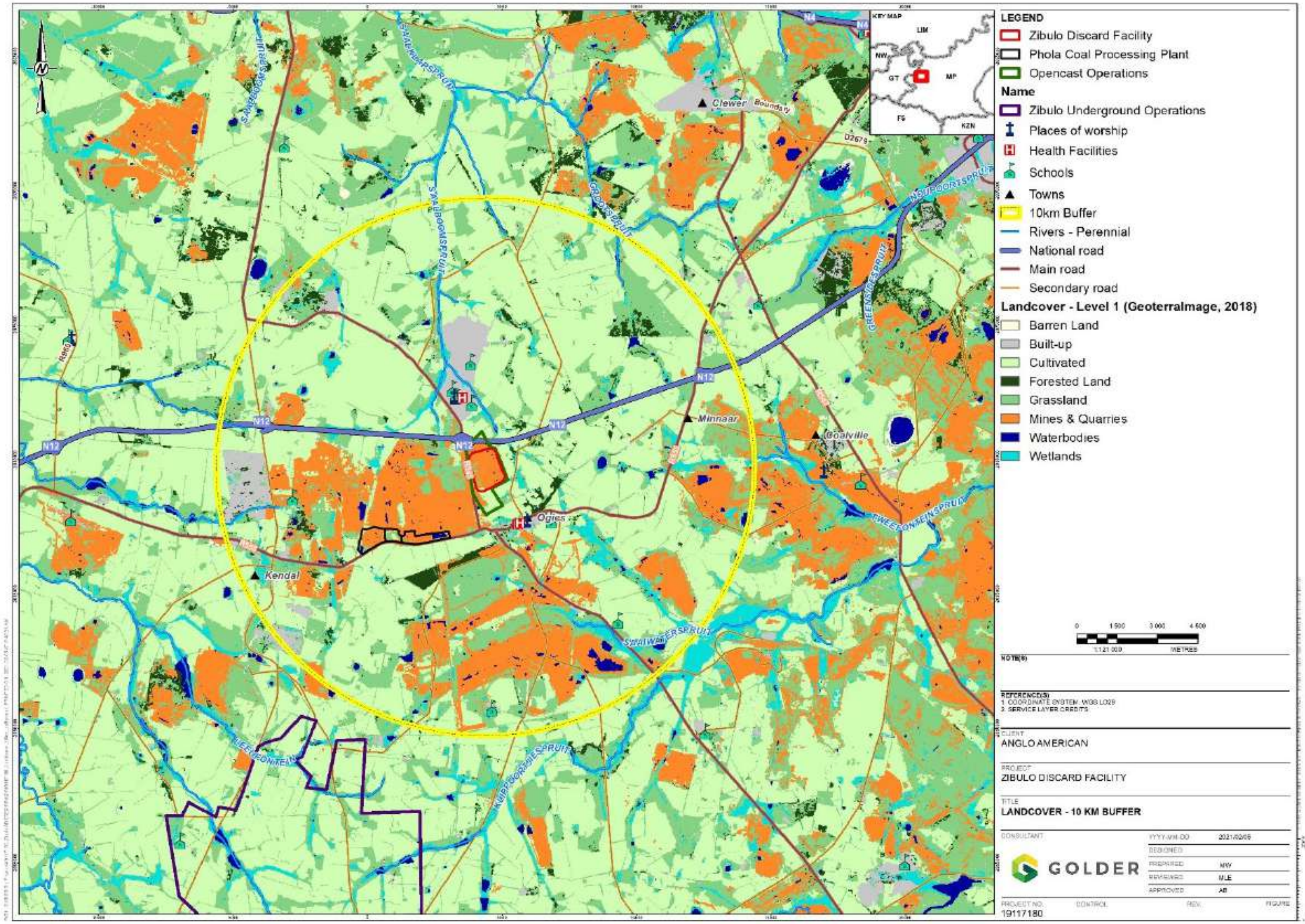


Figure 2: Local land use and cover within a 10 km radius of Zibulo

Note: Figure 2 land cover is based on available datasets from the regulator. Variance to the current on the ground land-use may be expected

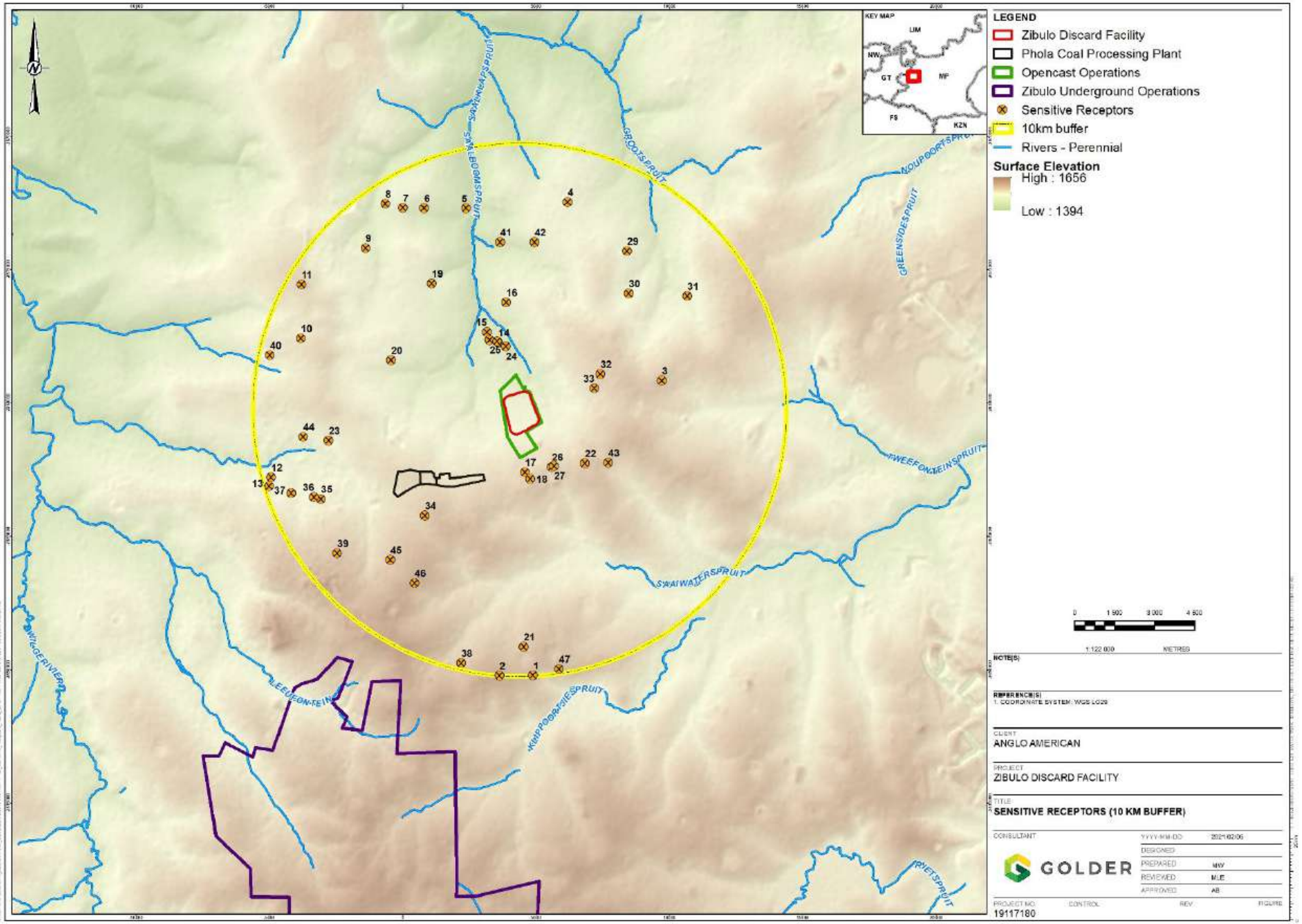


Figure 3: Local topography and sensitive receptors (10 km radius) of Zibulo

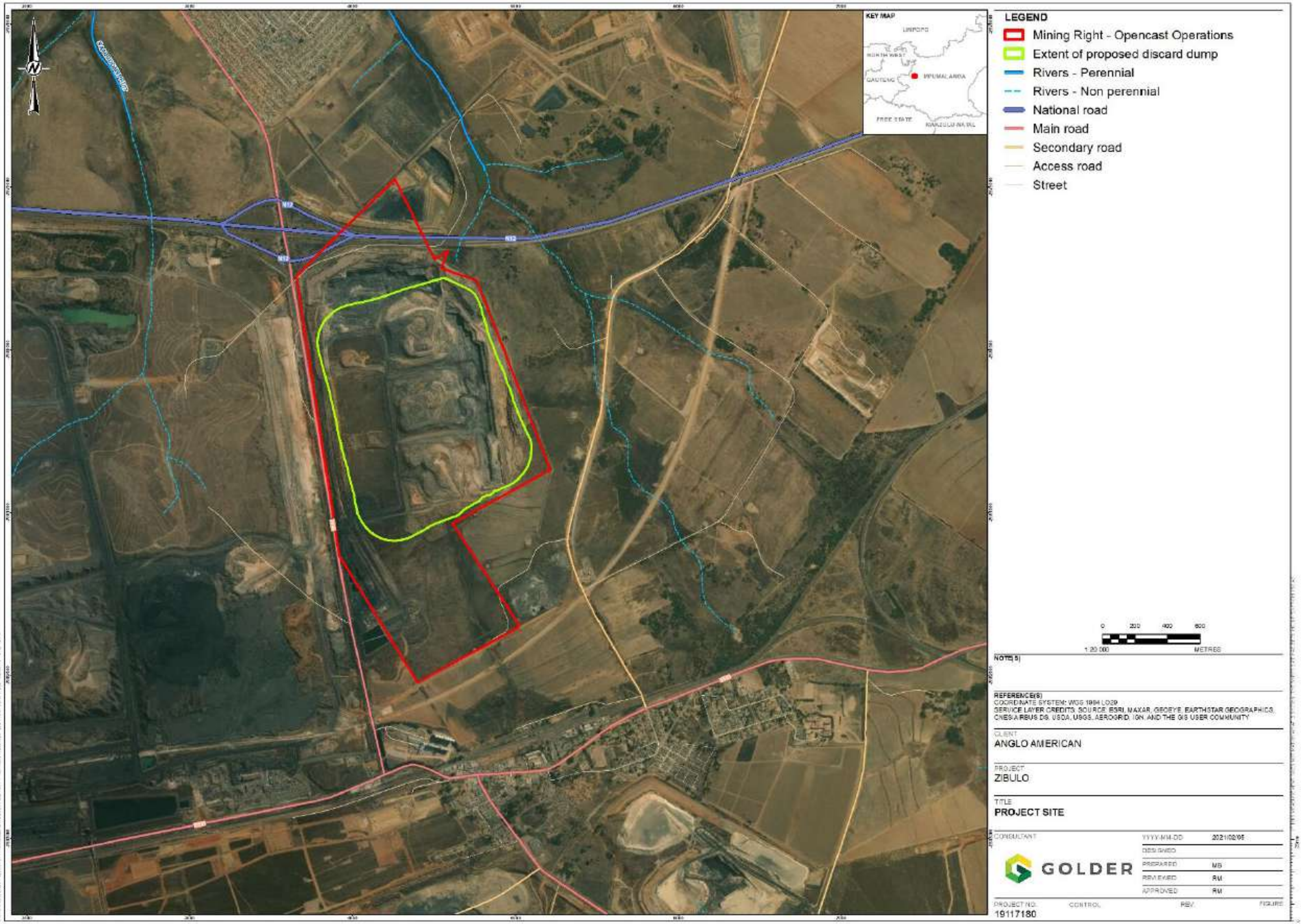


Figure 4: Layout of the proposed Zibulo discard facility

2.0 NATURE OF THE PROCESS

2.1 Process description

Zibulo seeks to develop a discard dump that will be confined within the footprint of the existing opencast mining operation. The discard will be brought to site via a conveyor linking the opencast site to the PCPP. From the conveyor the discard will be hauled and placed by truck. Figure 4 illustrates the site layout.

The unit processes associated with Zibulo are tabulated below in Table 3.

Table 3: Unit processes at Zibulo

Unit Process	Unit Process Function	Batch or Continuous Process
Discard facility	Storage of coarse and fine coal discard	Continuous
Conveyor transfer	Transport of coal and fine coal discard	Continuous

3.0 TECHNICAL INFORMATION

3.1 Raw material used

Table 4 provides the raw materials used at Zibulo.

Table 4: Raw materials used at Zibulo

Raw Material Type	Maximum Permitted Consumption Rate (Quantity)	Units (Quantity / period)
Discard	2 336 303	Tonnes/annum

3.2 Appliances and abatement equipment control technology

There are no appliances and abatement equipment control technology applicable to the Zibulo discard dump operations.

4.0 ATMOSPHERIC EMISSIONS

4.1 Point Sources

There are no point sources applicable for this assessment.

4.2 Point source maximum emission rates (normal operating conditions)

Given that there are no point sources applicable for this assessment, point source maximum emission rates are not required for this assessment.

4.3 Point source maximum emission rates (start-up, shut-down, upset and maintenance conditions)

No special start-up, maintenance or shut-down conditions are applicable to the Zibulo process, as there are no point sources applicable for this assessment.

4.4 Fugitive emissions (area/line sources)

4.4.1 Emission estimation

An emission factor is a value representing the relationship between an activity and the rate of emissions of a specified pollutant. These emission factors have been developed based on test data, material mass balance studies and engineering estimates.

Emission factors are always expressed as a function of the weight, volume, distance or duration of the activity emitting the pollutant. The general equation used for the estimation of emissions is:

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

Where:

E = emission rate

A = activity rate

EF = emission factor

ER= overall emission reduction efficiency (%)

Emission rates for the proposed activities associated with the discard dump facility were calculated using the USEPA AP-42 and the Australian Government National Pollutant Inventory (NPI) emission factors. The following USEPA AP-42 and NPI references, been used:

- USEPA AP-42 Chapter 13.2.4: Aggregate Handling and Storage Piles; and
- NPI Emission Estimation Technique Manual for Mining Version 3.1.

The emission calculations and resultant emission rates are discussed in the sections below using the equation presented above and information provided by the Client.

4.4.1.1 Construction phase

The footprint of the proposed dump and conveyor offloading area is part of existing operations. The proposed operations consequently does not require any footprint preparations as part of a formal construction phase as the discard will simply be deposited within the proposed discard facility footprint. The assessment of construction air quality impacts is thus not applicable and therefore not been included in this report.

4.4.1.2 Operational phase

Fugitive emissions at the proposed dump may arise from materials handling, including conveyor transfer points and wind erosion.

4.4.1.2.1 Material handling

Materials handling operations predicted to result in fugitive dust emissions include the transfer of material by means of tipping, loading and offloading. The quantity of dust which will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are more readily disaggregated and released to the atmosphere during the material transfer process as a result of exposure to strong winds. Increase in the moisture content of the material being transferred would decrease the potential for dust emissions since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles (USEPA, 2006).

The following equations were used to calculate particulate emissions respectively:

$$E_{TSP} = 0.74 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4} \; kg/ton$$

$$E_{PM10} = 0.35 \times 0.0016 \times \left(\frac{\text{U}}{2.2}\right)^{1.3} \times \left(\frac{\text{M}}{2}\right)^{-1.4} kg/ton$$

$$E_{PM2.5} = 0.053 \times 0.0016 \times \left(\frac{\text{U}}{2.2}\right)^{1.3} \times \left(\frac{\text{M}}{2}\right)^{-1.4} kg/ton$$

Where:

U = mean wind speed (3.4 m/s (as per AERMET-ready data))

M = material moisture content (2.5% as per average recommended by USEPA AP-42)

The particle size multiplier varies with aerodynamic particle sizes. For total suspended particulates (TSP), PM_{10} and $PM_{2.5}$ the fraction is 74%, 35% and 5.3% respectively (USEPA, 2006).

Physical parameters and calculated emission rates for materials handling are given in Table 5 and Table 6. Various control measures are applied to most materials handling activities (NPI, 2012).

Table 5: Source parameters for materials handling for the discard dump operations

Source	Control Efficiency (%)	Total Throughput (Tons/annum)
Loading of discard from truck/shovel	0% - no control for loading trucks	2 336 303
Offloading of discard on conveyor	70% - water sprays	2 336 303
Offloading of discard onto site	70% - water sprays	2 336 303
Loading of discard into truck/shovel	0% - no control for loading trucks	2 336 303
Offloading of discard onto dump	70% - water sprays	2 336 303

Table 6: Emission rates for materials handling for the discard dump operations

Source	Emission Rate (g/s)		
	TSP	PM_{10}	$PM_{2.5}$
Loading of discard from truck/shovel	2.21E-01	1.05E-01	1.58E-02
Offloading of discard on conveyor	6.64E-02	3.14E-02	4.75E-03
Offloading of discard onto site	6.64E-02	3.14E-02	4.75E-03
Loading of discard into truck/shovel	2.21E-01	1.05E-01	1.58E-02
Offloading of discard onto dump	6.64E-02	3.14E-02	4.75E-03

4.4.1.2.2 Wind erosion

Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded (Cowherd *et al.*, 1988; EPA, 1995). The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Any factor which binds the erodible material or otherwise reduces the availability of erodible material on the surface, thus decreases the erosion potential of the surface. Studies have shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material (Cowherd *et al.*, 1988).

The default emission factors for wind erosion over open areas are calculated using the below equation (USEPA, 1998):

$$E_{TSP} = 0.4 \text{ kg}/ha/hour$$

$$E_{PM10} = 0.2 \text{ kg}/ha/hour$$

Source parameters for areas subject to wind erosion are given in Table 7. Emission rates were applied to the various stockpiles and are presented in Table 8. $PM_{2.5}$ emissions were assumed to equal 15% of TSP (USEPA, 2006) in the absence of a $PM_{2.5}$ emission factor. A 50% control efficiency for the use of wet suppression was applied as an environmentally conservative approach (NPI, 2012).

Table 7: Source parameters for the discard dump subject to wind erosion

Source	Height (m)	Area (m^2)	Control efficiency (%)
Wind erosion of the discard dump	30	1 610 700	50%

Table 8: Emission rates for wind erosion for the discard dump

Source	Emission Rate ($g/s/m^2$)		
	TSP	PM_{10}	$PM_{2.5}$
Wind erosion of the discard dump	5.56E-06	2.78E-06	4.17E-07

4.4.1.2.3 Spontaneous combustion

Coal can ignite spontaneously when exposed to oxygen which causes it to react exothermically when there is insufficient ventilation for cooling. At about 65.5°C to 149°C, coal begins to liberate aerosols, hydrogen gas, and carbon dioxide which are precursors to spontaneous combustion (USDEA, 1993). At approximately 400°C to 427°C degrees, the coal will reach ignition temperature and spontaneous combustion will occur (USDEA, 1993).

Should spontaneous combustion occur at the proposed discard facility (in the future), the following risks may occur:

- Reduction and/or production losses due to operational stoppages and standing time associates with the combusting discard facility;
- Instability within the discard facility and an increased risk of collapses due to voids being formed as the discard burns within the facility;
- Increased risk of occupational injuries and/or losses of equipment due to burns, smoke inhalation, and/or collapse;
- Increased levels of fugitive emissions (i.e. air pollution) and noncompliance with the NEM: AQA when the ambient air quality standards are exceeded; and
- Increased occupational exposures to the combustion gasses.

There are no available emission factors to assess spontaneous combustion, however it is recommended that Zibulo manage the occurrence of spontaneous combustion at the discard facility to ensure that the above risks are minimised.

5.0 IMPACT OF THE PROJECT ON THE RECEIVING ENVIRONMENT

5.1 Analysis of emissions impact on human health

5.1.1 General overview of key pollutants and associated health effects

Please note that section 5.1.1 provides a generic overview of the possible impacts to human health as a result of exposure to elevated levels of atmospheric pollutants from the proposed Zibulo discard facility. This section, *in no way infers impact levels as a result of Zibulo's operations. Please refer to the impact assessment section for clarification on the anticipated impacts of the proposed Zibulo discard facility on the surrounding environment.*

5.1.1.1 Particulate Matter

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) (Harrison and van Grieken, 1998). The fine particles contain the secondarily formed aerosols such as combustion particles, sulphates, nitrates, and re-condensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dusts from roads and industries (Fenger, 2002).

The impact of particles on human health is largely dependent on the particle characteristics, particle size, chemical composition, the duration, frequency and magnitude of the exposure/s. Typically, particulate air pollution is associated with respiratory complaints (WHO, 2000). Particle size is important because it controls where in the respiratory system a given particle deposits. Fine particles are thought to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs, compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extra-thoracic part of the respiratory tract, while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

5.1.1.1.1 Acute exposure

Studies have proven that acute exposure to particulate matter at both high and low concentrations is associated with health effects. Various studies undertaken during the 1980s to 1990s have investigated the relationship between daily fluctuations in particulate matter and mortality at low levels of acute exposure. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000). Morbidity effects associated with acute exposures to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung functioning.

5.1.1.1.2 Chronic exposure

Chronic exposure to low concentrations of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung functioning (WHO, 2000). An association between lung function and chronic respiratory disease and airborne particles has been indicated through several studies. Using chronic respiratory disease data, Schwartz (1993) determined that the risk of chronic bronchitis increased with increasing particulate concentrations, with no apparent threshold. Few studies have been undertaken documenting the morbidity effects of chronic exposure to particulates. Recently, the Harvard Six Cities Study showed increased respiratory illness rates among children exposed to increasing particulate, sulphate and hydrogen ion concentrations. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10 $\mu g/m^3$ increase in annual average particulate concentrations.

5.2 Applicable legislation, guidelines and standards

5.2.1 National Environmental Management: Air Quality Act (Act No. 39 of 2004)

The National Environmental Management: Air Quality Act (NEM: AQA) approach to air quality management is based on the control of the receiving environment. The main objectives of the act are to protect the environment by providing reasonable legislative and other measures that (i) prevent air pollution and ecological degradation, (ii) promote conservation and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development alignment with Sections 24a and 24b of the Constitution of the Republic of South Africa.

5.2.2 Ambient air quality standards

The ambient air quality standards for common pollutants prescribe the allowable ambient concentrations of pollutants which are not to be exceeded during a specified time period in a defined area (Table 9). If the standards are exceeded, the ambient air quality is defined as poor and potential adverse health impacts are likely to occur. As such, the Zibulo discard facilities emission contributions to the ambient air quality levels must not exceed or cause exceedances of the ambient air quality standards. The only applicable pollutant, under the ambient air quality standards, for the proposed Zibulo discard facility is particulate matter.

Table 9: Ambient Air Quality Standards for criteria pollutants

Pollutant	Averaging Period	Limit Value ($\mu g/m^3$)	Frequency of Exceedance	Compliance Date
NO_2 (a)	1 hour	200	88	Immediate
	1 year	40	0	Immediate
PM_{10} (b)	24 hours	75	4	Immediate
	1 year	40	0	Immediate
$PM_{2.5}$ (c)	24 hours	40	4	1 January 2016 – 31 December 2029
	24 hours	25	4	1 January 2030
	1 year	20	0	1 January 2016 – 31 December 2029
	1 year	15	0	1 January 2030
O_3 (d)	8 hours	120	11	Immediate
Lead (Pb) (e)	1 year	0.5	0	Immediate
CO (f)	1 hour	30 000	88	Immediate
	8 hours	10 000	11	Immediate
Benzene (C_6H_6) (g)	1 year	5	0	Immediate
SO_2 (h)	10 minutes	500	526	Immediate
	1 hour	350	88	Immediate
	24 hours	125	4	Immediate
	1 year	50	0	Immediate

Notes:

a) The reference method for the analysis of NO_2 shall be ISO 7996
b) The reference method for the determination of the PM_{10} particulate matter fraction of suspended particulate matter shall be EN 12341
c) The reference method for the analysis of $PM_{2.5}$ shall be EN14907
d) The reference method for the analysis of ozone shall be the UV photometric method as described in ISO 13964
e) The reference method for the analysis of lead shall be ISO 9855
f) The reference method for analysis of CO shall be ISO 4224
g) The reference methods for benzene sampling and analysis shall be either EPA compendium method TO-14 A or method TO - 17
h) The reference method for the analysis of SO_2 shall be ISO 6767

5.2.3 National dust control regulations

On 1 November 2019, the National Dust Control Regulations came into effect under the NEM: AQA, 2004 and published in the Government Gazette No. 41650. The dust fall standard defines acceptable dust fall rates in terms of the presence of residential areas (Table 10).

Table 10: Acceptable dust fall rates

Restriction Areas	Dust Fall Rate (mg/m²/day over a 30-day average)	Permitted Frequency of Exceedance
Residential areas	Dust fall <600	Two within a year, not sequential months
Non-residential areas	Dust fall ≤1 200	Two within a year, not sequential months

Note: *Standard test method ASTM D1739, latest method*

The National Dust Control Regulations are applicable to Zibulo's operations and the proposed discard facility.

5.2.4 Listed activities and minimum emissions standards

The NEMA: AQA makes provision for the setting and formulation of national ambient air quality and emission standards. On a provincial and local level, these standards can be set more stringently if the need arises. The control and management of emissions in NEMA: AQA relates to the listing of activities that are sources of emission and the issuing of AELs. In terms of Section 21 of the NEMA: AQA, a listed activity is an activity which 'results in atmospheric emissions that are regarded to have a significant detrimental effect on the environment, including human health'.

Zibulo does not have any listed activities onsite. Furthermore, the proposed development of the discard facility does not trigger any listed activities and/or minimum emission standards.

5.3 Baseline assessment

5.3.1 Regional climatic overview

Zibulo lies within Southern Africa. The atmospheric circulation of Southern Africa plays a major role in determining regional climates (Figure 5).

Southern Africa is situated in the subtropical high-pressure belt. The mean circulation of the atmosphere over the subcontinent is anticyclonic throughout the year (except for near the surface) (Preston-Whyte and Tyson, 1997). The synoptic patterns affecting the typical weather experienced in the region owe their origins to the subtropical, tropical and temperate features of the general atmospheric circulation over Southern Africa.

The subtropical control is introduced via the semi-permanent presence of the South Indian Anticyclone (HP cell), Continental High (HP cell) and the South Atlantic Anticyclone (LP cell) located in the high-pressure belt located approximately 30°S of the equator (Preston-Whyte and Tyson, 1997). The tropical controls are introduced via tropical easterly flows (LP cells) (from the equator to the southern mid-latitudes) and the occurrence of the easterly wave and lows (Preston-Whyte and Tyson, 1997). The temperature control is introduced by perturbations in the westerly wave, leading the development of westerly waves and lows (LP cells) (i.e. cold front from the polar region, moving into the mid-latitudes) (Preston-Whyte and Tyson, 1997).

Seasonal variations in the positioning and intensity of the HP cells determine the extent to which the westerly waves and lows impact the atmosphere over the region:

- In winter, the high-pressure belt intensifies and moves northward while the westerly waves in the form of a succession of cyclones or ridging anticyclones moves eastwards around the South African coast or across the country. The positioning and intensity of these systems are thus able to significantly impact the region; and
- In summer the anticyclonic HP belt weakens and shifts southwards and the influence of the westerly waves and lows weakens.

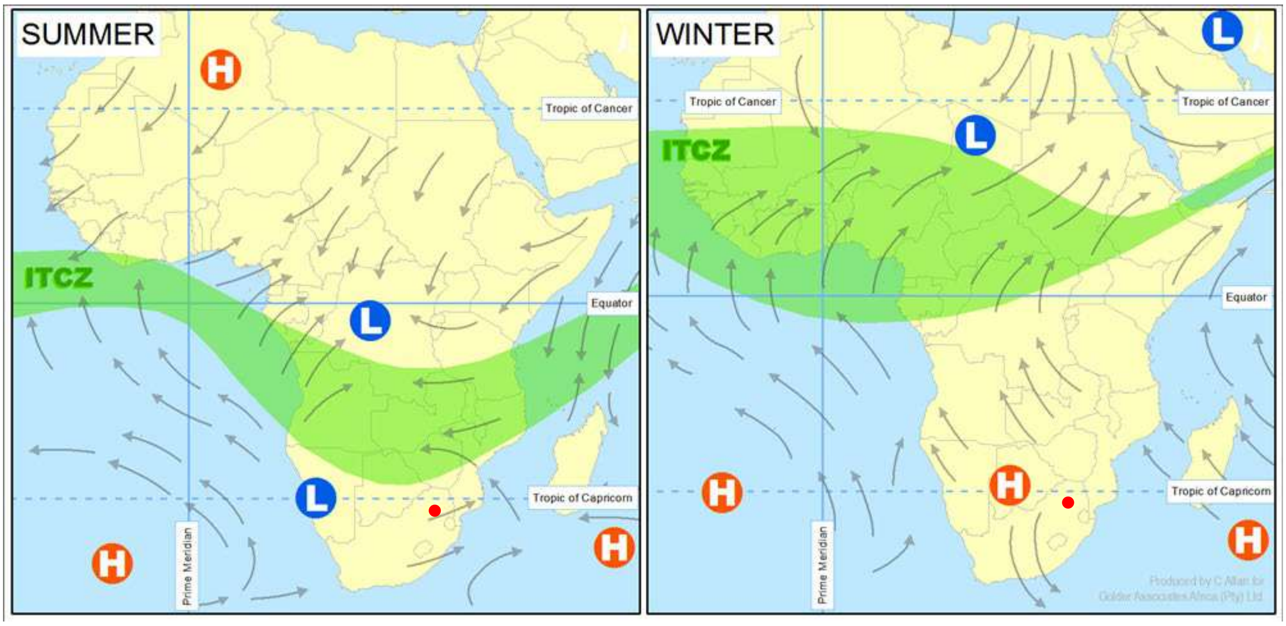


Figure 5: Seasonal circulation patterns affecting the regional climate. The red dot indicts the approximate location of Zibulo

5.3.2 Meteorological overview

5.3.2.1 Temperature and rainfall

To assess ambient meteorological conditions (temperature and rainfall), the meteorological station based in the town of Ogies (located 1.5 km's south-south-east of Zibulo) was utilized to provide an understanding of the air dispersion characteristics. Due to the very close proximity of this station to Zibulo, the experienced meteorological conditions at this station are anticipated to be almost identical to that experienced at Zibulo. The South African National Accreditation System (SANAS, 2012) TR 07-03 standards stipulate a minimum data recovery of 90% for the dataset to be deemed representative of conditions during a specific reporting period. The percentage recovery for parameters recorded exceeded 90% and is thus considered reliable for use in this assessment.

Temperature and rainfall are key influencing factors in ambient air quality:

- Rainfall is an effective removal mechanism of atmospheric pollutants as when it falls, it brings pollutants down with it. Rainfall further reduces the erosion potential by increasing the moisture content of erodible materials; and
- Historically, rainfall is typically much higher during the spring and summer months, where approximately 90% of the annual precipitation occurs between October through to April. Little rainfall occurs during the autumn and winter months between May to September. The driest month is usually July. Precipitation usually reaches its peak in January, where in 2019 there was an average of 92 mm. Figure 6 depicts the monthly average rainfall data as observed at Ogies over 2019.

Ambient air temperature affects both plume buoyancy and the development of mixing and inversion layers. Furthermore, the greater the difference in temperature between the plume and the ambient air, the higher the plume is able to rise.

- Ogies and Zibulo fall within semi-arid climatic conditions, where temperatures are generally warm and temperate with warm summers and cold winters usually associated with frost. The annual average temperature is approximately 16°C. The temperature in January (i.e. during the summer season) averages approximately 20°C, however daily maximum temperatures may exceed 27ºC on occasion (Table 11).

June and July are the coldest months (i.e. the winter season), with temperatures averaging approximately 9°C (https://en.climate-data.org/africa/south-africa/mpumalanga/ogies-189664/,19/05/2019) (Table 11).

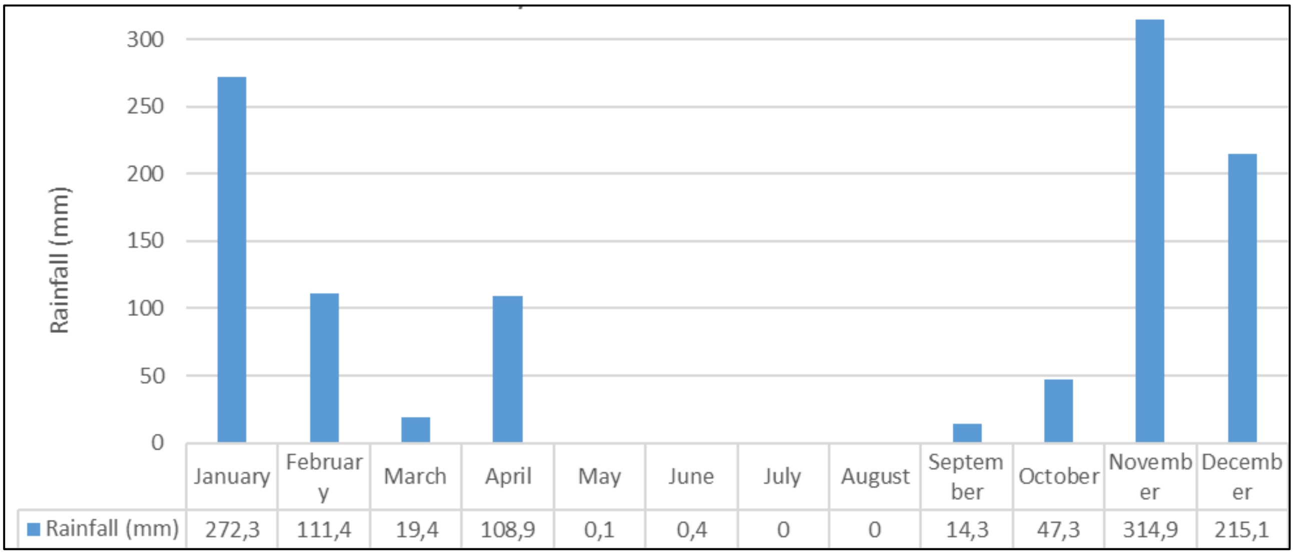


Figure 6: Monthly rainfall at Ogies during 2019 (Source: https://www.worldweatheronline.com/ogies-weather-averages/mpumalanga/za.aspx, 19/05/2019)

Table 11: Annual average temperature at Ogies (https://en.climate-data.org/africa/south-africa/mpumalanga/ogies 189664/, 19/05/2019)

Temperature (°C)	January	February	March	April	May	June	July	August	September	October	November	December	Total
Average	20.1	19.7	18.4	15.5	12.1	8.9	8.9	11.6	15.3	17.8	18.6	19.7	**15.6**
Minimum	13.7	13.4	11.7	8.1	3.7	0	0	2.5	6.7	10.2	11.9	13.2	**7.9**
Maximum	26.6	26.1	25.2	22.9	20.5	17.8	17.9	20.8	23.9	25.4	25.4	26.3	**23.2**

5.3.2.2 Wind field

To assess wind conditions, site-specific modelled MM5 meteorological data was obtained from Lakes Environmental Software for the period January 2016 to December 2018 (three-year data set). The data coverage was centred over the adjacent Klipspruit Colliery discard facility (approximately 1.5 to 2 km to the south-west of the proposed Zibulo discard facilities centre) (anemometer height of 14 m) with a grid cell dimension of 12 km x 12 km over a 50 km x 50 km domain. Due to the very close proximity, the experienced meteorological conditions are anticipated to be almost identical to that experienced onsite at Zibulo. The South African National Accreditation System (SANAS, 2012) TR 07-03 standards stipulate a minimum data recovery of 90% for the dataset to be deemed representative of conditions during a specific reporting period. The percentage recovery for parameters recorded was 100% and is thus considered reliable for use in this assessment. The wind conditions for the site using the modelled MM5 data is discussed below.

Wind roses summarise the occurrence of winds at a specified location by representing their strength, direction and frequency. Calm conditions are defined as wind speeds of less than 1 m/s which are represented as a percentage of the total winds in the centre circle. Each directional branch on a wind rose represents wind originating from that specific cardinal direction (16 cardinal directions). Each cardinal branch is divided into segments of different colours which represent different wind speed classes.

Winds at Zibulo are predominantly from the northern and south-easterly sectors (Figure 7). Wind speeds are moderate, averaging ±3 to 5 m/s with a low percentage (±13%) of calm conditions (<1 m/s). A significant diurnal variation in wind was observed during the monitoring period (Figure 8). A significant seasonal variation in wind was also observed during the monitoring period (Figure 9).

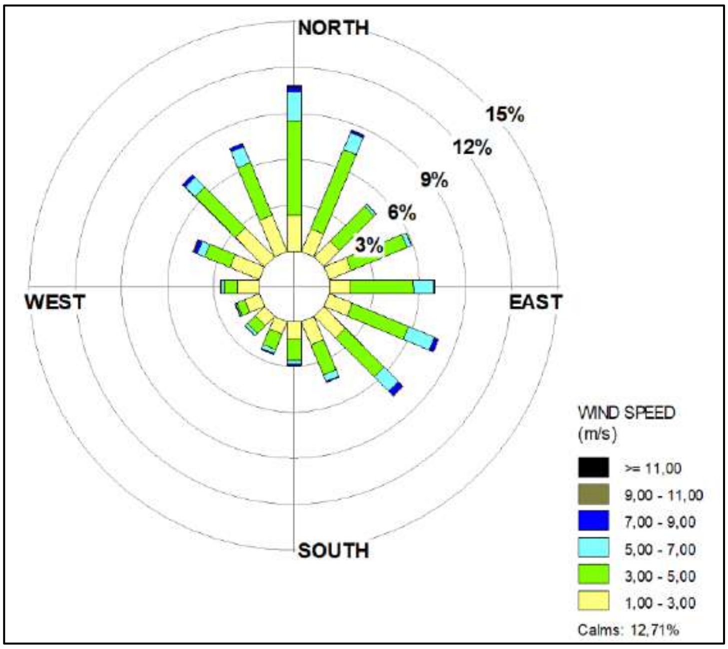
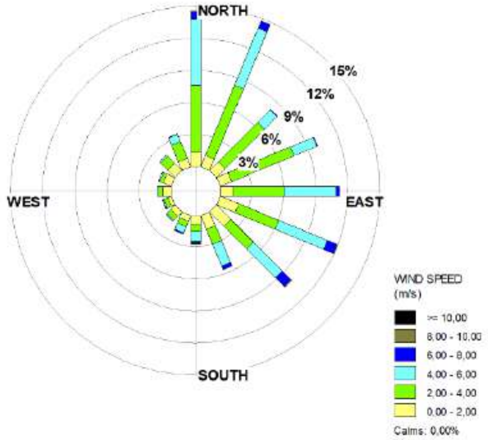
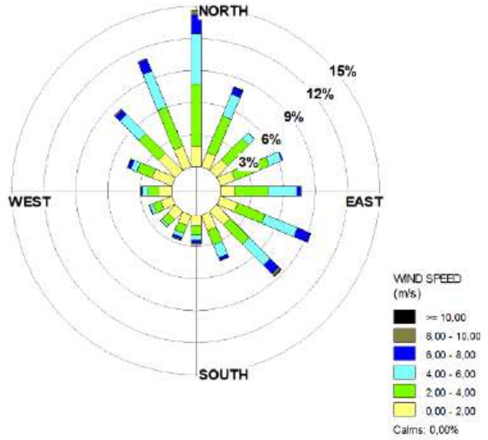


Figure 7: Modelled annual wind rose for Zibulo (2016-2018)



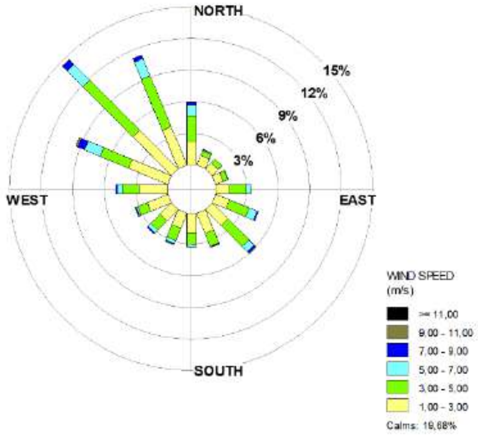
00:00 to 05:59

Northerly and south easterly sectors



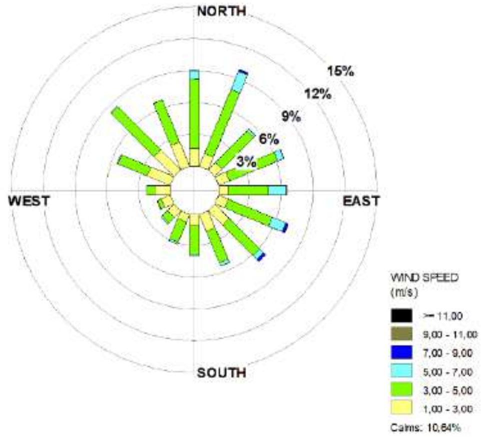
06:00 to 11:59

Northerly and south easterly sectors



12:00 to 17:59

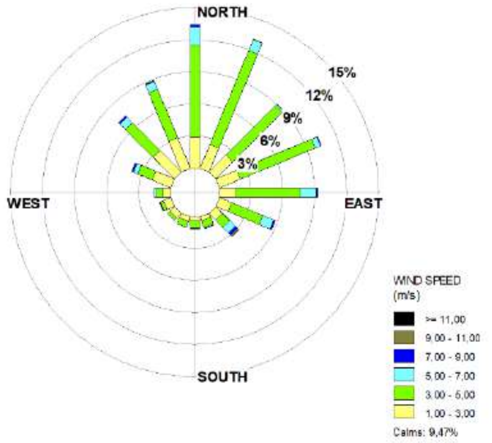
North westerly sector



18:00 to 23:59

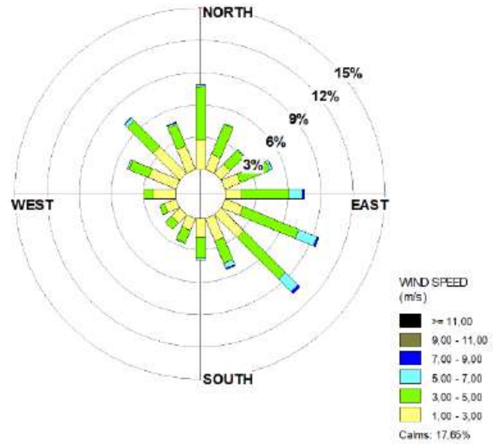
North-westerly to south easterly sectors

Figure 8: Modelled diurnal wind roses for Zibulo with predominant wind directions for 2016-2018



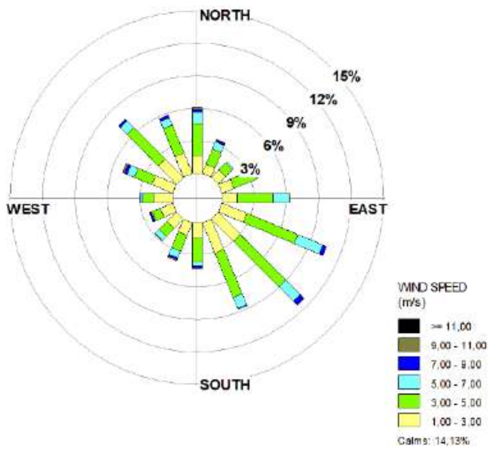
Summer (DJF)

North westerly to easterly sectors



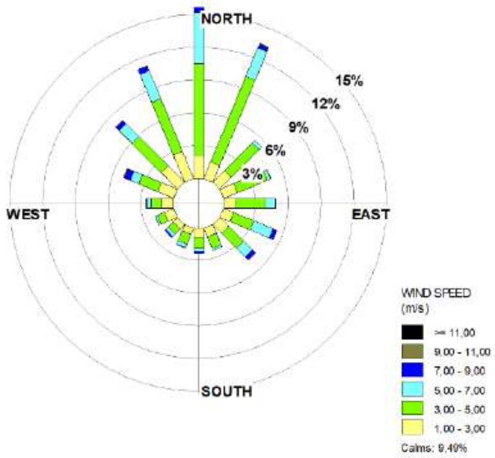
Autumn (MAM)

South easterly sector and north westerly sectors



Winter (JJA)

South easterly and north westerly sectors



Spring (SON)

Northerly sector

Figure 9: Modelled seasonal wind roses for Zibulo with predominant wind directions for 2016-2018

5.3.3 Regional ambient air quality overview

Zibulo and the surrounding areas fall within the Highveld Priority Area (HPA) and are therefore subject to its Air Quality Management Plan (AQMP) (DEA, 2015). This was put in place to help alleviate the large amounts of air pollution that the region was experiencing. Exceedances of fine particulate matter with an aerodynamic diameter ten microns (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) have often been recorded in the pollution hotspots of the eMalahleni, Kriel, Steve Tshwete, Ermelo, Secunda, Ekurhuleni, Lekwa, Balfour and Delmas areas (DEA, 2015). Despite the implementation of the HPA AQMP there continue to be exceedances in:

- PM_{10} and fine particulate matter with an aerodynamic diameter 2.5 microns ($PM_{2.5}$) in particular, areas proximate to significant industrial operations as well as residential areas where domestic coal burning is occurring;
- SO_2 in eMalahleni, Middelburg, Secunda, Ermelo, Standerton, Balfour, and Komati due to a combination of emissions from the different industrial sectors, residential fuel burning, motor vehicle emissions, mining and cross-boundary transport of pollutants into the HPA adding to the base loading;
- NO_2 in the eMalahleni, Steve Tshwete and Ekurhuleni areas where anthropogenically induced and naturally occurring biomass fires occur throughout the HPA at all times of the year and contribute NO_2; and
- O_3 in Kendal, Witbank, Hendrina, Middelburg, Elandsfontein, Camden, Ermelo, Verkykkop and Balfour thought to be due to biomass burning.

5.3.4 Local ambient air quality overview

Potential sources of air pollution within vicinity of the Zibulo have been identified to include:

- Agricultural activities;
- Biomass burning;
- Domestic fuel burning;
- Mining activities;
- Vehicle emissions (tailpipe and entrained emissions); and
- Power generation.

5.3.4.1 Agricultural activities

Emissions from agricultural activities are difficult to control due to the seasonality of emissions and the large surface area producing emissions (USEPA, 1995). Most of the agricultural activities in the region appear to be the commercial farming dedicated to crops and to a smaller extent grazing, which is common in the region. Despite the large-scale presence of agricultural activities within the area, agricultural emissions are not expected to significantly influence the air quality in the area. This is due to HPA AQMP stating that industrial sources are by far the largest contributor of emissions, accounting for 89% of PM_{10}, 90% of Nitrogen Oxides (NO_x) and 99% of SO_2. Particulate emissions may increase during the frequent periods where the Highveld grasslands are subjected to wildfires.

5.3.4.2 Biomass burning

Biomass burning may be described as the incomplete combustion process of natural plant matter with Carbon Monoxide (CO), Methane (CH_4), NO_2 and PM_{10} being emitted during the process. During the combustion process, approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. In comparison to the nitrogen emissions, only small amount of SO_2 and sulphate aerosols are emitted. With all biomass burning, visible smoke plumes are typically generated. These plumes are created by the aerosol content of the emissions and are often visible for many kilometres from the actual source of origin.

The extent of emissions liberated from biomass burning is controlled by several factors, including:

- The type of biomass material;
- The quantity of material available for combustion;
- The quality of the material available for combustion;
- The fire temperature; and
- Rate of fire progression through the biomass body.

Crop-residue burning and general wildfires represent significant sources of combustion-related emissions associated with agricultural areas. Given that the region has significant agricultural activities rather, controlled burning related to the agricultural activities contribute to air quality.

5.3.4.3 Domestic fuel burning

Domestic fuel burning of coal emits a large amount of gaseous and particulate pollutants including sulphur dioxide, heavy metals, total and respirable particulates, inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a) pyrene. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a) pyrene and formaldehyde. The main pollutants emitted from the combustion of paraffin are nitrogen dioxide, particulates, carbon monoxide and polycyclic aromatic hydrocarbons.

The density of housing in the region is relatively low with most residential areas being confined to small local towns such as Phola, Wilge and Ogies. In addition to these small residential areas, individual farms/homesteads are scattered throughout the region and comprise of formal and informal residential structures. It is thus highly likely that certain households within the communities are likely to use coal, wood and paraffin for space heating and/or cooking purposes. Emissions from these communities and/or the individual residences/homesteads are not anticipated to have a significant impact on the regional air quality due to their low density and dispersed nature.

5.3.4.4 Vehicle emissions

Air pollution generated from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly to the atmosphere as tail-pile emissions, whereas secondary pollutants are formed in the atmosphere as a result of atmospheric chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The primary pollutants emitted typically include Carbon Dioxide (CO_2), CO hydrocarbons (including benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons), SO_2, NO_x and particulates. Secondary pollutants formed in the atmosphere typically include NO_2, photochemical oxidants such as O_3, hydrocarbons, sulphur acid, sulphates, nitric acid, sulphates, nitric acid and nitrate aerosols.

The quantity of pollutants emitted by a vehicle depends on specific vehicle related factors such as vehicle weight, speed and age; fuel-related factors such as fuel type (petroleum or diesel), fuel formulation (oxygen, sulphur, benzene and lead replacement agents) and environmental factors such as altitude, humidity and temperature (Samaras and Sorensen, 1999).

Given the population density in the region, and the distribution of the mining activities, it is anticipated that vehicle exhaust emissions and their contribution to ambient air pollutant will be relatively insignificant.

5.3.4.5 Mining activities

Dust and fine particulate emissions associated with mining operations include wind erosion from waste rock dumps, tailings facilities, open mining pits, blasting emissions, ore processing and refining, sintering operations, unpaved mine access roads and other exposed areas. Factors which influence the rate of wind erosion include surface compaction, moisture content, vegetation, shape of storage pile, particle size distribution, wind speed and rain. Emissions from the mining activities are anticipated to be one of the dominant emissions influencing and impacting on the regional air quality.

Numerous significant mining operations are present in the region (I.e. Klipspruit Colliery, Mbali Colliery, Goedgevonden Mine, Khutala Colliery, Wescoal Khanyisa Colliery, Ogies Mine, Kendal Mine etc.). Mining, along with contributions from power stations, are likely to be the largest sources of particulates (PM_{10}, $PM_{2.5}$, Total Suspended Particulates - TSP) within the region, with smaller contributions from industry and biomass burning.

5.3.4.6 Power generation

South Africa mainly relies on its extensive coal reserves as its primary source of energy. A large amount of CO_2, CO, SO_2, sulphur trioxide (SO_3), NO_2 and nitric oxide (NO), some traces of heavy metals and particulates such as PM_{10} are released whenever coal is burned at the power stations (Munawer, 2017). These power stations are one of the key emission sources and contribute significantly to the level of air pollution within the region. Several coal fired power stations are in close proximity to Zibulo including Kendal, Kriel, Duvah and the Matla power station.

5.3.5 Local ambient air quality monitoring

Dust fallout and particulate matter-monitoring for Zibulo Colliery dates as far back as 2010. For the purpose of this study, reference has been made to the most current and available monitoring data, for the period 2019.

5.3.5.1 PM_{10} monitoring

Particulate matter at Zibulo is currently monitored at the Ogies School, using a Topas monitor mounted on a solar-powered monitoring trailer. Particulate matter was historically monitored at the Zibulo opencast offices using an E-Sampler monitor. The E-sampler unit however was an old monitor with continuous faults, yielding low data recoveries. Subsequently, the E-sampler was decommissioned in June 2019.

Given the historically low data recovery rates from the E-sampler, the Topas unit was used to determine the particulate matter annual averages. Data recovery for the monitoring period using the Topas was above the minimum requirement of 90% as stipulated by the SANAS, 2012 TR 07-03 standards.

For the period May to December 2019, the PM_{10} annual average (51 $\mu g/m^3$) was non-compliant with the annual average PM_{10} standard (40 $\mu g/m^3$), whilst the $PM_{2.5}$ annual average (16 $\mu g/m^3$) was compliant with the annual average $PM_{2.5}$ standard (20 $\mu g/m^3$) using the data from the Topas. Such concentrations are however representative of the current baseline conditions in the HPA.

5.3.5.2 Dust fallout monitoring

Dust fallout monitoring at Zibulo is currently conducted at six monitoring locations, consisting of one directional (oil office monitoring location) bucket and six single buckets (oil office, WHBO office, offramp, west of opencast, Phola and Ogies School monitoring locations, of which only Phola an Ogies School are residential locations).

For the period January to December 2019 a 12-month residential and non-residential network average of 521 $mg/m^2/day$ and 928 $mg/m^2/day$, respectively (below the Residential and Non-Residential Dust Control Regulations) was noted over the period.

5.4 Dispersion modelling

5.4.1 Model type

Dispersion modelling is an effective tool for predicting the ambient air concentrations from pollutants emitted to the atmosphere from a variety of processes.

As per the Regulations Regarding Air Dispersion Modelling, this assessment is considered a Level 2 assessment as emissions are from sources where the greatest impacts are in the order of a few kilometres (less than 50 km), downwind. As such, the AERMOD modelling software was used to determine likely ambient air pollutant concentrations from the proposed Zibulo discard operations, for comparison against ambient air quality standards. The AERMET pre-processor was used to process MM5 modelled regional meteorological data for input into AERMOD. The AERMOD modelling software calculates likely changes in dispersion plume trajectory and concentrations in response to changes in local terrain, meteorology and source data. Model inputs are verified before the model is executed.

5.4.2 Model input

Data input into the model includes modelled MM5 surface and upper air meteorological data with wind speed, wind direction, temperature, pressure, precipitation, cloud cover and ceiling height for January 2016 to December 2018. Terrain data at a resolution of 90 m (SRTM3) was also input into the model. A modelling domain of 20 km × 20 km was used (Table 12), with multi-tier Cartesian grid receptor spacing's of 50 (1 km metre from source), 100 (5 km metre from source) and 250 m (10 km metre from source). A receptor spacing of 50 m was also located along the boundary of Zibulo.

Table 12: Modelling domain coordinates

Domain Point	UTM East (m)	UTM South (m)
North-Eastern Point	726818.52	7138944.78
South-Western Point	680739.94	7091944.62

5.4.3 Model settings

A summary of the model settings into AERMOD used in this assessment is provided in Table 13.

Table 13: Summary of model settings

Parameter	Setting	
Assessment Level	Level 2	
Default Regulatory Settings Utilised	Yes	
Dispersion Model	Aermod 9.6.5	
Supporting Models	Aermet and Aermap	
Pollutants modelled	Dust Fallout, PM_{10} and $PM_{2.5}$	
Scenarios	Proposed Scenario	
Flag Pole Height	1.5 m	
Building Downwash	N/A	
Chemical Transformation	N/A	
Exponential Decay	N/A	
Terrain Settings (simple, flat, elevated)	Elevated	
Terrain Data	SRTM3	
Terrain Data Resolution (m)	90	
Elevation Data	The WebGIS Shuttle Radar Topography Mission (STRM) Terrain data was used with a resolution of 90 m	
Land Use Characterisation	Cultivated Land (characterised based on aerial imagery and land use data)	
Cultivated Land	Bowen Ratio	0.75

Parameter	Setting	
	Surface Albedo	0.28
	Surface Roughness	0.0725
Number of Sectors	1	
Modelling Domain Centre (UTM)	704528.60 mE, 7118917.39 mS	
Modelling Domain (km)	20 x 20	
Property Line Resolution (m)	50	
Fine Grid Resolution (m)	50	
Medium Grid Resolution (m)	100, 250	

5.4.4 Modelling scenarios

Only one scenario has been modelled for the proposed Zibulo discard operations, using the worst case, maximum production profile throughput that will be achieved in 2035.

Various statistical outputs that have been generated, are described below:

- Long term averages: Annual average (long-term) outputs, which is calculated by averaging all hourly concentrations. The calculation is conducted for each grid point within the modelling domain; and
- Short-term averages: The short-term scenario refers to the 99th percentile (P99) concentrations, which are recommended for short-term assessment with the National Standards, as per the Modelling Regulations (Government Gazette 37804).

It must be noted that, as defined in the Regulations Regarding Air Dispersion Modelling, ambient air quality objectives are applied to areas outside the facility fenceline (i.e. beyond the facility boundary). Within the facility boundary, environmental conditions are prescribed by occupational health and safety criteria.

5.4.5 Results and discussion

This section presents the results of the atmospheric dispersion modelling conducted for the operational phase of the proposed Zibulo discard facility for dust fallout, PM_{10} and $PM_{2.5}$ concentrations. Concentration results at specified sensitive receptors are presented in tabular format, while concentration isopleths are presented graphically to indicate the dispersion of pollutants. Comparison of the predicted dust fallout and PM_{10} and $PM_{2.5}$ concentrations was made with the relevant National Ambient Air Quality Standard (NAAQS) or limits to determine compliance.

The National Framework for Air Quality Management in South Africa calls for air quality assessment in terms of cumulative impacts rather than the contributions from an individual facility. Compliance with the NAAQS is to be determined by taking into account all local and regional contributions to background concentrations. For the different facility locations and averaging times, the comparisons with NAAQS must be based on recommendations in Table 14. As such, the cumulative impact from the proposed discard dump facility has also been determined (where data is available), and are presented in tabular format. Comparison of the cumulative dust fallout and PM_{10} and $PM_{2.5}$ concentrations (where data is available) was also made with the relevant NAAQS or limits to determine compliance. It must be emphasised that the isopleths presented in this section are from the proposed discard dump facility operations only (i.e. not the cumulative operations).

Table 14: Summary of recommended procedures for assessing compliance with NAAQS

Facility Location	Annual NAAQS	Short-term NAAQS (24 hours or less)
Isolated facility not influenced by other sources, background concentration (C_B) insignificant*.	Highest predicted conetration (C_P)must be less than the NAAQS, no exceedances allowed.	99th percentile concentrations must be less than the NAAQS. Wherever one year is modelled, the highest concentrations shall be considered.
Facilities influenced by background sources e.g. in urban areas and priority areas.	Sum of the highest C_P and background concentrations must be less that the NAAQS, no exceedances allowed.	Sum of the 99th percentile concentrations and background C_B must be less than the NAAQS. Wherever one year is modelled, the highest concentrations shall be considered.

Note: For an isolated facility influenced by regional background pollution C_B must be considered.

5.4.5.1 Dust fallout

Predicted and cumulative dust fallout concentrations associated with the proposed discard dump operations (including conveyor operations) for the highest offsite concentration and at each sensitive receptor are presented in Table 15. Figure 10 shows the plume isopleths for the predicted dust fallout concentrations only.

- Predicted modelled concentrations:
  - The maximum predicted offsite dust fallout rate of 678 mg/m^2/day is above the NEM: AQA Residential Dust Control Regulations of 600 mg/m^2/day. This exceedance is approximately 195 m north-east of the site boundary. However, there are no sensitive receptors located in this area; and
  - Predicted dust fallout rates are well below the NEM: AQA Residential Dust Control Regulations at all sensitive receptors.
- Cumulative concentrations:
  - The measured background dust fallout rate of 521 mg/m^2/day was assumed to be representative of the existing residential background dust fallout rate in the area and has therefore been used to assess the cumulative impacts from the proposed discard dump facility;
  - The maximum cumulative offsite dust fallout (1200 mg/m^2/day) is above the NEM: AQA Residential Dust Control Regulations of 600 mg/m^2/day;
  - It must be noted that this is a result of the maximum predicted offsite dust fallout rate of 678 mg/m^2/day which is already above the NEM: AQA Residential Dust Control Regulations; and
  - Cumulative dust fallout rates at all sensitive receptors are however, below the NEM: AQA Residential Dust Control Regulations.

Table 15: Predicted dust fallout rates at the sensitive receptor locations

No.	Dust Fallout Standard ($mg/m^2/day$)	Predicted Dust Fallout ($mg/m^2/day$)	Cumulative Dust Fallout ($mg/m^2/day$)
1	600	1.29	522.29
2	600	2.04	523.04
3	600	3.94	524.94
4	600	1.77	522.77
5	600	2.44	523.44
6	600	1.94	522.94
7	600	1.81	522.81
8	600	1.42	522.42
9	600	2.05	523.05
10	600	2.81	523.81
11	600	2.76	523.76
12	600	1.15	522.15
13	600	1.20	522.20
14	600	36.53	557.53
15	600	27.65	548.65
16	600	10.60	531.60
17	600	16.57	537.57
18	600	14.31	535.31
19	600	6.55	527.55
20	600	6.77	527.77
21	600	2.08	523.08
22	600	12.37	533.37
23	600	3.03	524.03
24	600	34.74	555.74
25	600	35.86	556.86
26	600	18.26	539.26
27	600	16.71	537.71
28	600	36.24	557.24
29	600	1.69	522.69
30	600	3.24	524.24
31	600	1.40	522.40
32	600	8.17	529.17
33	600	11.02	532.02
34	600	7.39	528.39

No.	Dust Fallout Standard (mg/m^2/day)	Predicted Dust Fallout (mg/m^2/day)	Cumulative Dust Fallout (mg/m^2/day)
35	600	2.64	523.64
36	600	2.45	523.45
37	600	1.51	522.51
38	600	2.08	523.08
39	600	1.66	522.66
40	600	1.86	522.86
41	600	3.53	524.53
42	600	2.97	523.97
43	600	8.69	529.69
44	600	2.22	523.22
45	600	3.83	524.83
46	600	3.02	524.02
47	600	1.62	522.62
Highest offsite concentration	600	**678.38**	**1199.38**

Note: A blanket value of 521 mg/m^2/day (12-month average) from the dust fallout monitoring results (deemed to be representative as a residential background deposition rate) was utilized for the background dust fallout rate

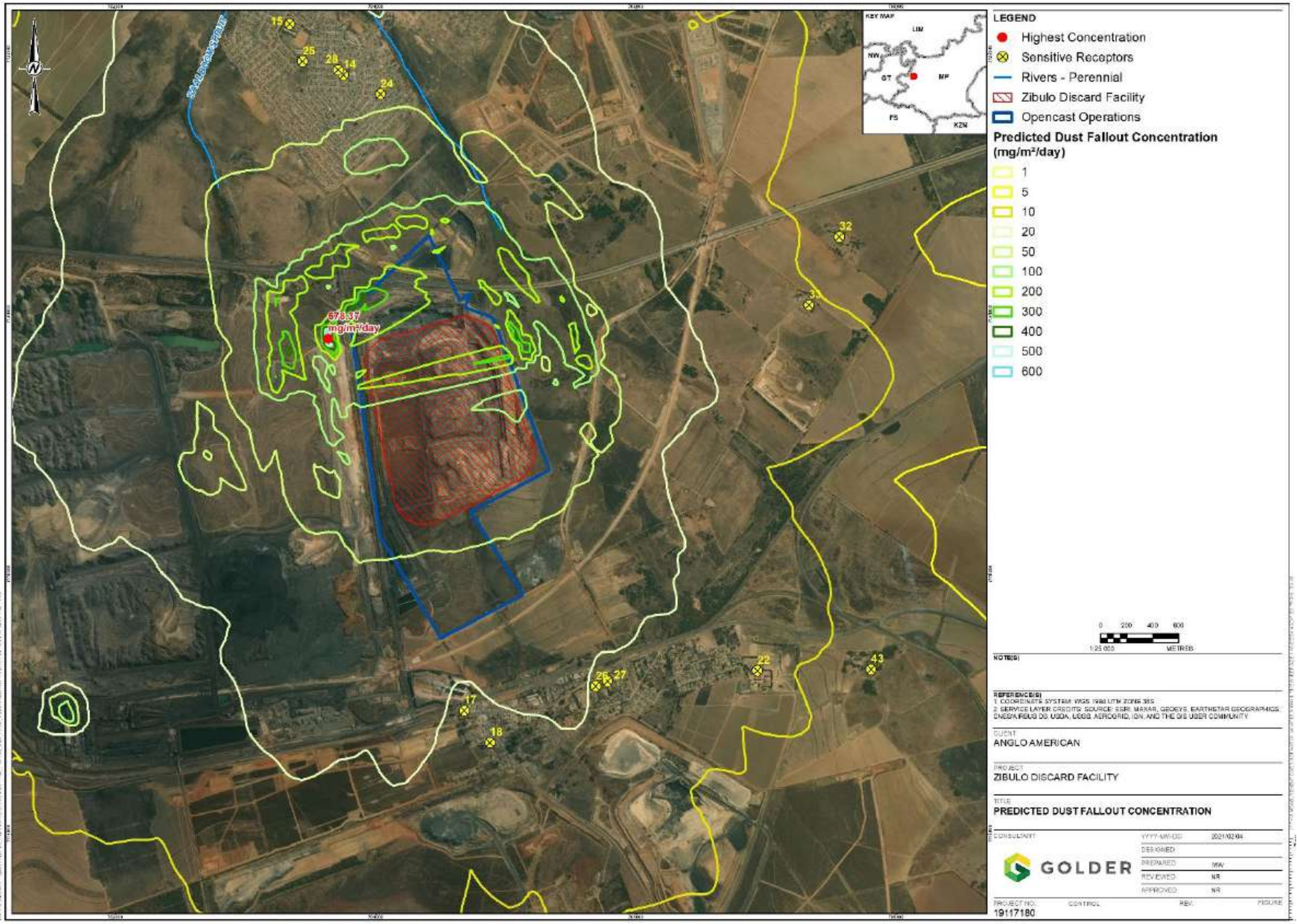


Figure 10: Predicted dust fallout from the proposed discard dump facility (mg/m^2/day)

5.4.5.2 Particulate matter (PM_{10}) concentrations

Predicted and cumulative P99 24-hour average and annual average PM_{10} concentrations associated with the proposed discard dump operations for the highest offsite concentration and at each sensitive receptor are presented in Table 16. Figure 11 and Figure 12 shows the plume isopleths for the predicted PM_{10} concentrations only.

- Predicted modelled concentrations:
  - The highest predicted offsite PM_{10} concentrations are compliant with the NAAQS for PM_{10} for all assessment periods; and
  - Predicted PM_{10} concentrations are well below the NAAQS for PM_{10} at all sensitive receptors for all assessment periods.
- Cumulative concentrations:
  - The measured background PM_{10} concentration of 51 µg/m^3, for the annual average was assumed to be representative of the existing background PM_{10} concentrations in the area and has therefore been used to assess the cumulative impacts from the proposed discard dump facility;
  - Cumulative annual average PM_{10} concentrations are expected to be non-compliant with the annual average NAAQS for PM_{10} at all sensitive receptors; and
  - It must be noted that this is a result of the high existing PM_{10} background concentrations and is not a result of the proposed discard dump facility operations. Additionally, the PM_{10} concentrations at each of the sensitive receptors contribute marginally to the overall cumulative concentrations.

Table 16: Predicted PM_{10} concentrations at the sensitive receptor locations (exceedances are highlighted in bold red)

No.	PM_{10} 24-Hour Average NAAQS (µg/m³)	24-Hour Average Concentrations (µg/m³)	PM_{10} Annual Average NAAQS (µg/m³)	Annual Average Concentrations (µg/m³)	
		Predicted Concentration (P99)		Predicted Concentration	Cumulative Concentration
1	75	0.65	40	0.08	**51.08**
2	75	0.62	40	0.10	**51.10**
3	75	0.43	40	0.04	**51.04**
4	75	1.51	40	0.11	**51.11**
5	75	1.57	40	0.15	**51.15**
6	75	2.14	40	0.18	**51.18**
7	75	2.87	40	0.22	**51.22**
8	75	2.22	40	0.21	**51.21**
9	75	2.56	40	0.26	**51.26**
10	75	4.74	40	0.37	**51.37**
11	75	1.60	40	0.19	**51.19**
12	75	1.67	40	0.22	**51.22**
13	75	2.73	40	0.26	**51.26**
14	75	4.21	40	0.46	**51.46**
15	75	3.45	40	0.42	**51.42**
16	75	2.86	40	0.27	**51.27**
17	75	2.37	40	0.46	**51.46**
18	75	1.85	40	0.32	**51.32**
19	75	3.40	40	0.34	**51.34**
20	75	3.15	40	0.44	**51.44**
21	75	0.68	40	0.10	**51.10**
22	75	1.72	40	0.19	**51.19**
23	75	2.80	40	0.33	**51.33**
24	75	4.15	40	0.44	**51.44**
25	75	3.89	40	0.48	**51.48**
26	75	2.19	40	0.30	**51.30**
27	75	2.21	40	0.30	**51.30**
28	75	4.17	40	0.46	**51.46**
29	75	1.33	40	0.08	**51.08**
30	75	2.18	40	0.12	**51.12**
31	75	1.02	40	0.07	**51.07**
32	75	0.80	40	0.06	**51.06**
33	75	1.29	40	0.11	**51.11**
34	75	1.34	40	0.17	**51.17**

No.	PM10 24-Hour Average NAAQS (µg/m³)	24-Hour Average Concentrations (µg/m³)	PM10 Annual Average NAAQS (µg/m³)	Annual Average Concentrations (µg/m³)	
		Predicted Concentration (P99)		Predicted Concentration	Cumulative Concentration
35	75	4.77	40	0.39	**51.39**
36	75	4.11	40	0.37	**51.37**
37	75	2.16	40	0.26	**51.26**
38	75	1.03	40	0.18	**51.18**
39	75	0.68	40	0.09	**51.09**
40	75	5.55	40	0.34	**51.34**
41	75	1.71	40	0.15	**51.15**
42	75	2.01	40	0.14	**51.14**
43	75	1.59	40	0.15	**51.15**
44	75	2.11	40	0.27	**51.27**
45	75	1.03	40	0.13	**51.13**
46	75	0.93	40	0.12	**51.12**
47	75	0.68	40	0.09	**51.09**
Highest offsite concentration	75	72.62	40	9.15	**60.15**

Note: A blanket value of 51 µg/m³, for the annual average concentrations from the PM_{10} monitoring results was utilized for the background concentrations

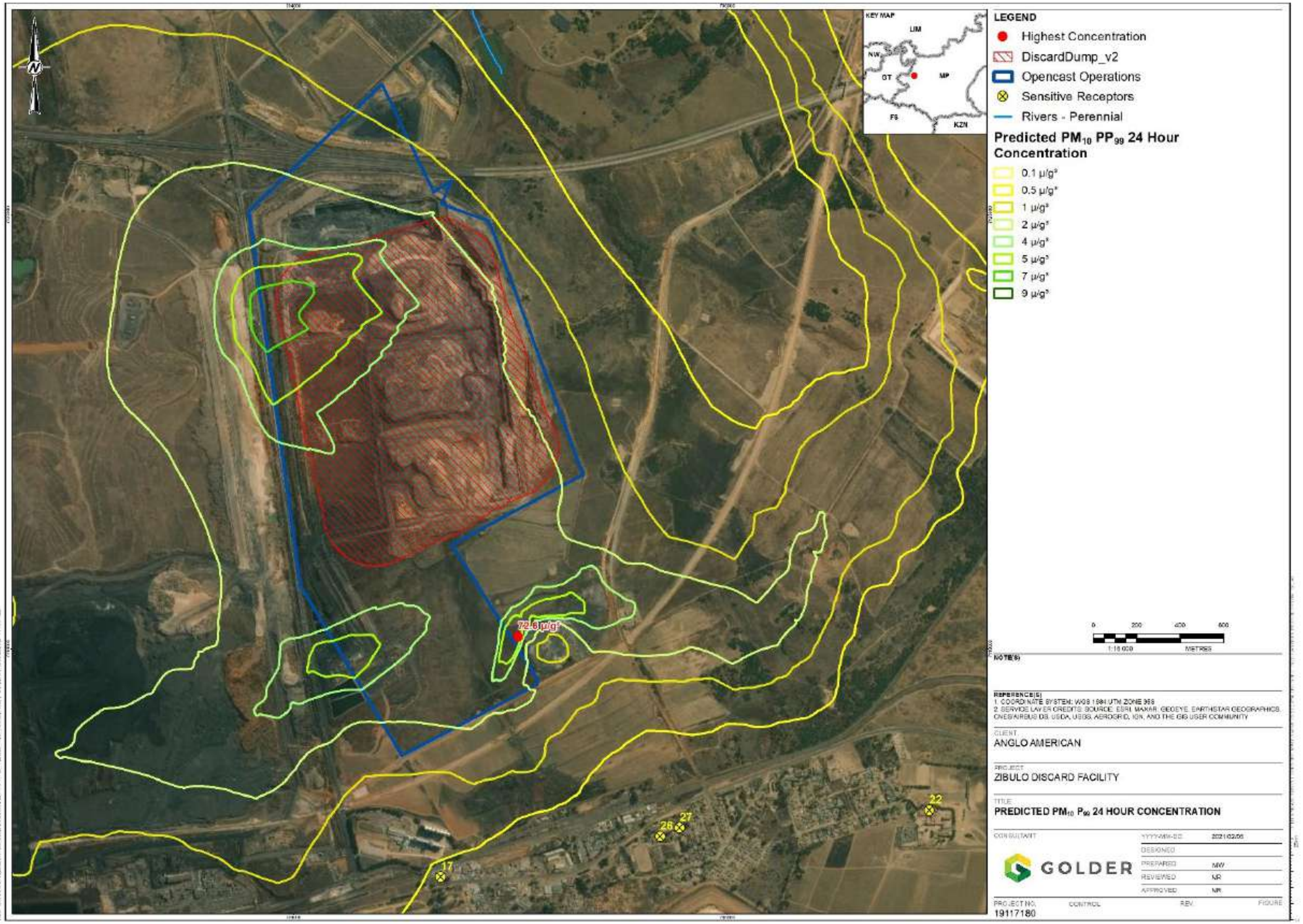


Figure 11: Predicted P99 24-hour average PM_{10} concentrations from the proposed discard dump facility (µg/m^3)

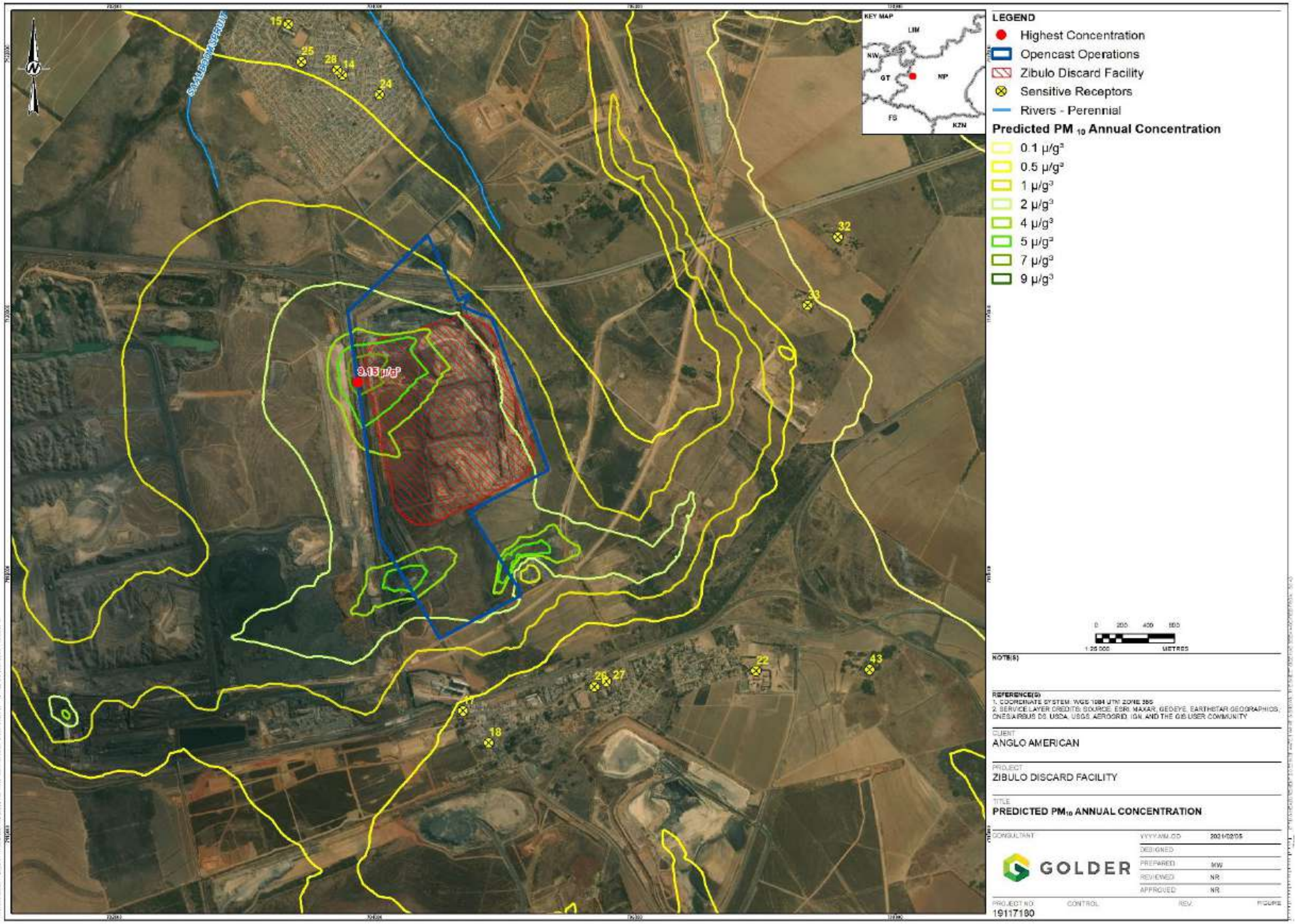


Figure 12: Predicted annual average PM_{10} concentrations from the proposed discard dump facility (µg/m³)

5.4.5.3 Particulate matter ($PM_{2.5}$) concentrations

Predicted and cumulative P99 24-hour average and annual average $PM_{2.5}$ concentrations associated with the proposed discard dump operations for the highest offsite concentration and at each sensitive receptor are presented in Table 17. Figure 13 and Figure 14 shows the plume isopleths for the predicted PM_{10} concentrations only.

- Predicted modelled concentrations:
  - The highest predicted offsite $PM_{2.5}$ concentrations are compliant with the NAAQS for $PM_{2.5}$ for all assessment periods; and
  - Predicted $PM_{2.5}$ concentrations are well below the NAAQS for $PM_{2.5}$ at all sensitive receptors for all assessment periods.
- Cumulative concentrations:
  - The measured background $PM_{2.5}$ concentration of 16 µg/m^3, for the annual average was assumed to be representative of the existing background $PM_{2.5}$ concentrations in the area and has therefore been used to assess the cumulative impacts from the proposed discard dump facility;
  - The maximum cumulative annual average $PM_{2.5}$ concentration is expected to be slightly above the annual average NAAQS for $PM_{2.5}$; and
  - Cumulative annual average $PM_{2.5}$ concentrations are expected to be compliant with the annual average NAAQS for $PM_{2.5}$ at all sensitive receptors.

Table 17: Predicted $PM_{2.5}$ concentrations at the sensitive receptor locations

No.	$PM_{2.5}$ 24-Hour Average NAAQS (µg/m³)	Predicted P99 24-Hour Concentration (µg/m³)	$PM_{2.5}$ Annual Average NAAQS (µg/m³)	Predicted Annual Concentration (µg/m³)	Cumulative Annual Concentration (µg/m³)
1	40	0.10	20	0.01	16.01
2	40	0.09	20	0.02	16.02
3	40	0.07	20	0.01	16.01
4	40	0.25	20	0.02	16.02
5	40	0.25	20	0.02	16.02
6	40	0.33	20	0.03	16.03
7	40	0.47	20	0.04	16.04
8	40	0.34	20	0.03	16.03
9	40	0.39	20	0.04	16.04
10	40	0.71	20	0.06	16.06
11	40	0.25	20	0.03	16.03
12	40	0.26	20	0.04	16.04
13	40	0.43	20	0.04	16.04
14	40	0.65	20	0.08	16.08
15	40	0.61	20	0.07	16.07
16	40	0.44	20	0.04	16.04
17	40	0.36	20	0.07	16.07
18	40	0.28	20	0.05	16.05
19	40	0.55	20	0.05	16.05
20	40	0.50	20	0.07	16.07
21	40	0.10	20	0.02	16.02
22	40	0.26	20	0.03	16.03
23	40	0.46	20	0.06	16.06
24	40	0.69	20	0.07	16.07
25	40	0.66	20	0.08	16.08
26	40	0.36	20	0.05	16.05
27	40	0.34	20	0.05	16.05
28	40	0.65	20	0.08	16.08
29	40	0.22	20	0.01	16.01
30	40	0.38	20	0.02	16.02
31	40	0.16	20	0.01	16.01
32	40	0.12	20	0.01	16.01
33	40	0.21	20	0.02	16.02
34	40	0.21	20	0.04	16.04
35	40	0.73	20	0.06	16.06
36	40	0.68	20	0.06	16.06

No.	$PM_{2.5}$ 24-Hour Average NAAQS (µg/m³)	Predicted P99 24-Hour Concentration (µg/m³)	$PM_{2.5}$ Annual Average NAAQS (µg/m³)	Predicted Annual Concentration (µg/m³)	Cumulative Annual Concentration (µg/m³)
37	40	0.34	20	0.04	16.04
38	40	0.16	20	0.03	16.03
39	40	0.11	20	0.02	16.02
40	40	0.84	20	0.06	16.06
41	40	0.26	20	0.02	16.02
42	40	0.33	20	0.02	16.02
43	40	0.24	20	0.02	16.02
44	40	0.35	20	0.05	16.05
45	40	0.17	20	0.02	16.02
46	40	0.14	20	0.02	16.02
47	40	0.10	20	0.01	16.01
Highest offsite concentration	40	15.43	20	4.14	**20.14**

Note: A blanket value of 16 µg/m³, for the annual average concentrations from the $PM_{2.5}$ monitoring results was utilized for the background concentrations

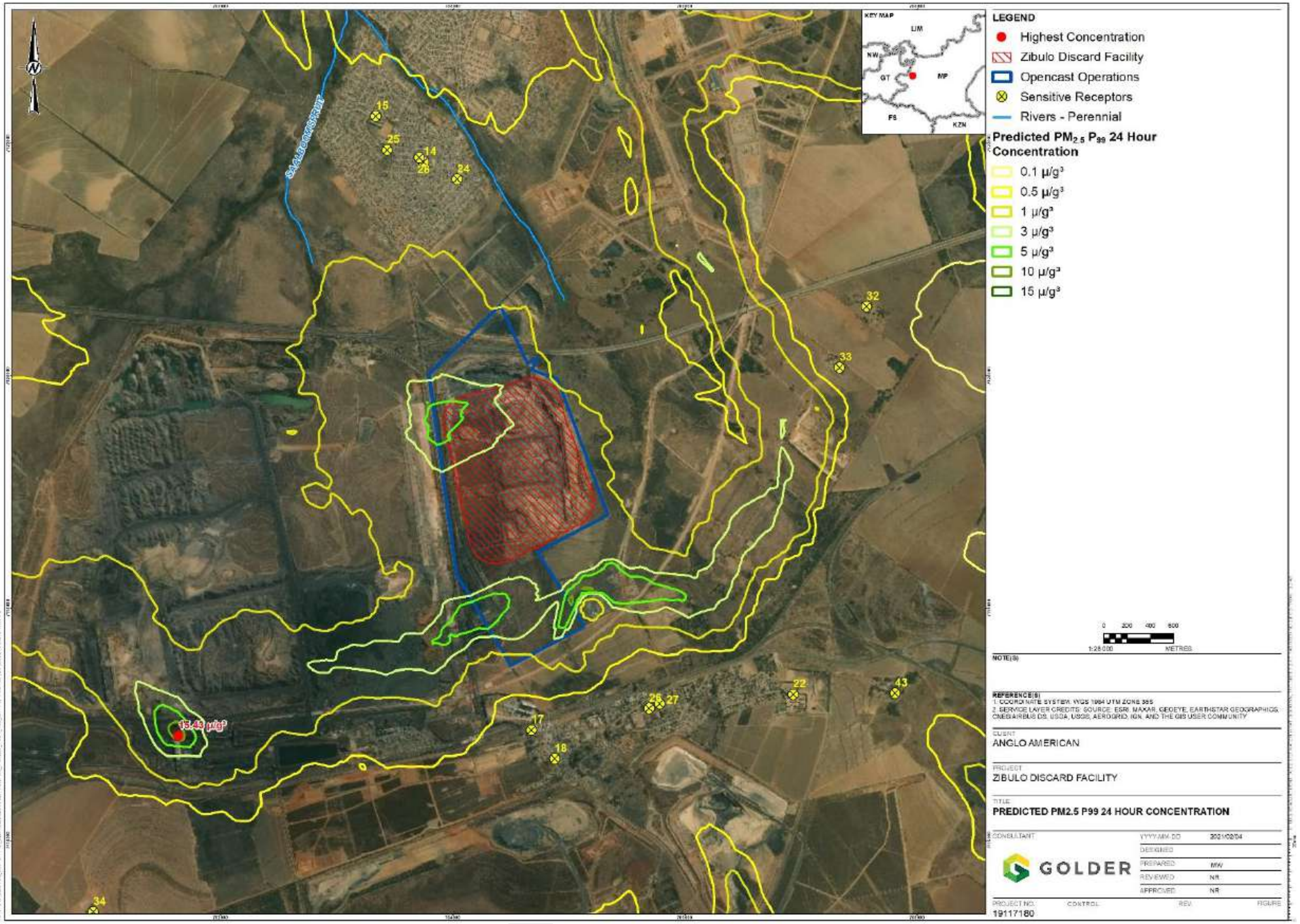


Figure 13: Predicted P99 24-hour average $PM_{2.5}$ concentrations from the proposed discard dump facility (µg/m³)

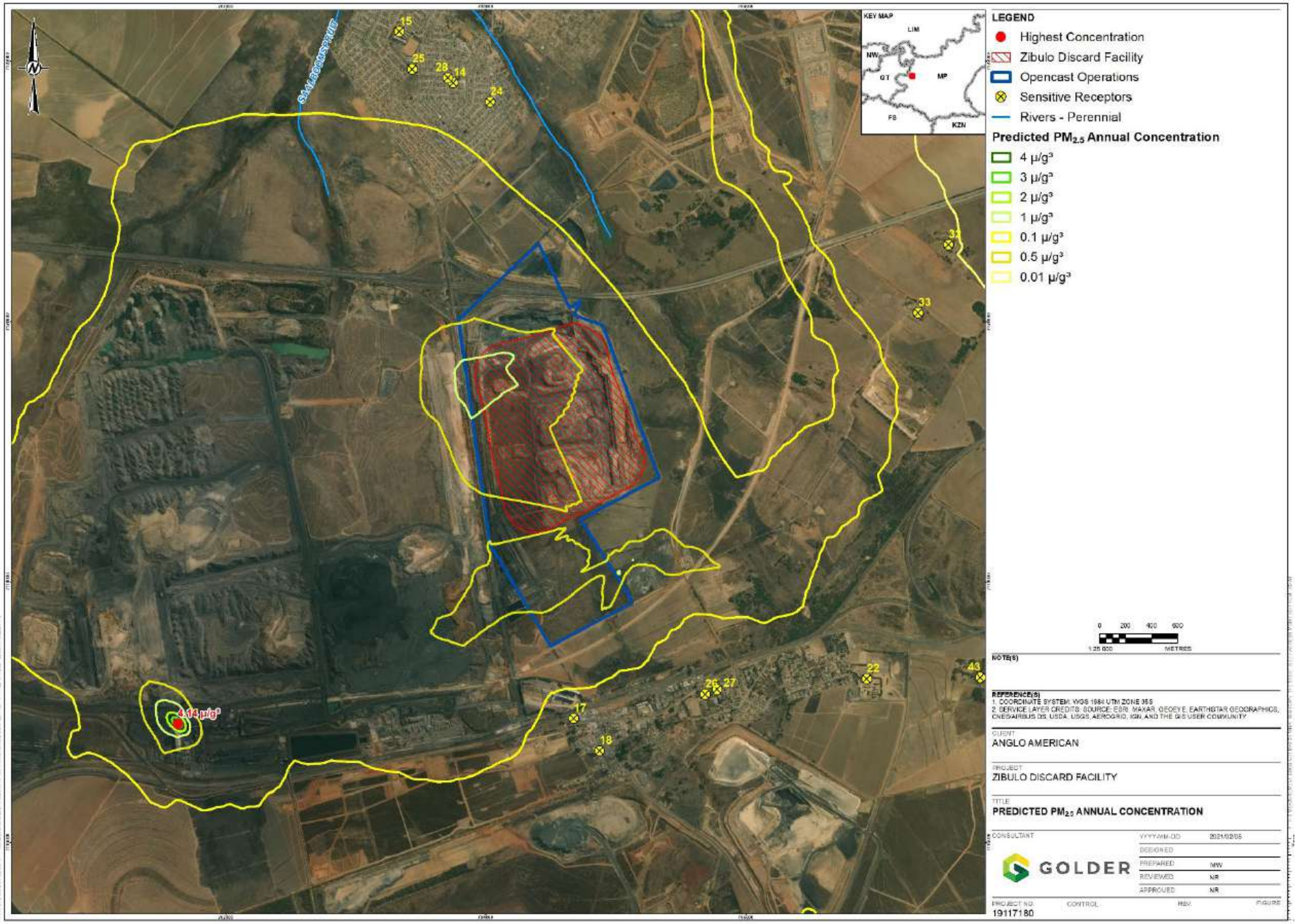


Figure 14: Predicted annual average $PM_{2.5}$ concentrations from the proposed discard dump facility (µg/m³)

5.4.5.4 Assumptions and limitations

- Due to the proximity of the Ogies weather station to Zibulo, the meteorological conditions experienced at this station are anticipated to be almost identical to that experienced at Zibulo, and was used for this assessment, in the absence of data from Zibulo at the time of the assessment;
- The proposed discard facility (including conveyor) does not require any footprint preparations as part of a formal construction phase as the discard will simply be deposited within the existing footprint. As such, the construction phase air quality impacts are thus not applicable and have therefore not been included in this assessment;
- A mean wind speed of 3.4 m/s and a material moisture content of 2.5%, as per the average recommended by USEPA AP-42 (USEPA, 2006), was used for the material handling activities. A control measure of 70% was applied to the offloading activities as per the recommended NPI (NPI, 2012) mitigation control techniques;
- For wind erosion, $PM_{2.5}$ emissions were assumed to equal 15% of TSP (USEPA, 2006) in the absence of a $PM_{2.5}$ emission factor. A 50% control efficiency was applied as an environmentally conservative approach (NPI, 2012) for water sprays; and
- No available site-specific emission factors for the Zibulo Colliery are available regarding spontaneous combustion and as such, has not been determined in this assessment.

5.5 Impact assessment

The objective of this assessment is to identify the potential impacts posed by the proposed Zibulo operations on the air quality climate of the area.

All impacts of the proposed project were evaluated using a risk matrix, which is a semi-quantitative risk assessment methodology. This system derives an environmental impact level on the basis of the magnitude, duration, scale, probability and significance of the impacts, based on a clear understanding of the potential mitigatory measures that can be implemented and changes in risks as a result of implementation of these mitigatory measures. A full description of the risk rating methodology is presented in Appendix A. Outcomes of the AQIA are contained within Table 18. A detailed description of the impacts is provided below.

5.5.1 Construction phase

The proposed discard dump facility (including conveyor) does not require any footprint preparations as part of a formal construction phase as the discard will simply be deposited within the existing footprint. Assessment of construction air quality impacts is thus not applicable.

5.5.2 Operational phase

The degeneration of the ambient air quality due to increased dust and fine particulate levels from the proposed discard dump facility may occur. Daily emissions will vary according to the level of activity, the type of operation and the meteorological conditions at the time.

Dust is anticipated to fall out rapidly with distance from the source. PM_{10} and $PM_{2.5}$ are predicted to disperse further and can therefore have a negative impact on ambient air quality beyond the boundary.

With the implementation of mitigation measures such as water sprays, the magnitude of the impact is anticipated to be low, with a low probability of occurrence. This is further substantiated by the fact that the short-term and long-term PM_{10} and $PM_{2.5}$ concentrations and dust fallout rate, as discussed within the predicted modelling results section, are predicted to be below the relevant NAAQS and NEM: AQA Residential Dust Control Regulations at all sensitive receptors. The impact is expected to be medium-term in duration (as the operations are expected to last for 15 years), but is likely to be limited to a local extent, resulting in a “low” significance.

Without mitigation, the magnitude of the air quality impact is anticipated to exacerbate and as such, will likely be moderate. The impact of the duration will remain the same, but could reach a regional capacity. Additionally, a medium probability of occurrence is predicted, resulting in a “moderate” significance.

Combustion emissions associated with spontaneous combustion were not quantitatively assessed as no suitable site-specific emission factors are available. Qualitatively, the combustion emissions from spontaneous combustion onsite are anticipated to have a negative impact on the ambient air quality. The occurrence of spontaneous combustion onsite will need to be managed carefully (through e.g. concurrent rehabilitation) to ensure the operations are compliant with the NEM: AQA ambient air quality standards.

Without mitigation, the magnitude of the air quality impact is anticipated to be moderate. The impact is expected to be medium-term in duration (as the operations are expected to last for 15 years), but is likely to be limited to a local extent, as the volume of the proposed discard can be considered as low to moderate in comparison to the bigger usage of the colliery. Additionally, a medium probability of occurrence is predicted, resulting in a “moderate” significance.

With the implementation of mitigation measures, the magnitude of the impact is anticipated to be low, with a low probability of occurrence. The impact of the duration is expected to remain the same, but is likely to be limited to site only, resulting in a “low” significance.

5.5.3 Closure phase

Final rehabilitation will result in dust and fine particulate emissions associated with shaping the final discard facility to a fairly flat outer slope of probably 1:9, with the main remaining rehabilitation being the placement of the final cover.

Without mitigation, the magnitude of the air quality impact is anticipated to be low. The impact is expected to be short-term in duration (as the impact will cease once the activity ceases), and is likely to be limited to a local capacity. Additionally, a low probability of occurrence is predicted, resulting in a “low” significance.

With the implementation of mitigation measures, the magnitude of the impact is anticipated to be minor and is likely to be improbable. The impact of the duration is expected to remain the same, but is likely to be limited to site only, resulting in a “low” significance.

Table 18: Impact assessment summary

Phase	Activity	Impact	Aspect	Without Mitigation						With Mitigation					
				Magnitude	Duration	Scale	Probability	Significance	Significance	Magnitude	Duration	Scale	Probability	Significance	Significance
Operational phase	Material handling and wind erosion from the proposed discard dump facility	Dust and fine particulate mobilization on sensitive receptors	Ambient air quality	6	3	3	3	36	Moderate	4	3	2	2	18	Low
Operational phase	Spontaneous combustion	Combustion gas mobilization on sensitive receptors	Ambient air quality	6	3	2	3	33	Moderate	4	3	1	2	16	Low
Closure phase	Shaping the final discard facility to a fairly flat outer slope of probably 1:9.	Dust and fine particulate mobilization on sensitive receptors	Ambient air quality	4	2	2	2	16	Low	2	2	1	1	5	Low

Note: This assessment considers the impact of new emissions sources associated with the proposed discard dump facility only

5.6 Mitigation measures

Without the implementation of the mitigation measures, the local ambient air quality may be negatively affected by the emissions from the Zibulo discard operations. This degeneration in the local air quality may impact negatively on the surrounding sensitive receptors. It is therefore recommended that appropriate mitigation measures be implemented and maintained. Mitigation measures for the proposed Zibulo discard operations are outlined below.

5.6.1 Operational phase

5.6.1.1 Truck loading, unloading and transfer point activities

A combination of some of the following techniques can be employed to assist with dust suppression (Katestone, 2011):

- Modifying or ceasing loading activities during dry and windy conditions;
- Avoid double handling of material where possible;
- Minimising the drop height of the material from truck loads/transfer points;
- Using bund walls to shelter and protect tipping operations particulate emissions from being further entrained by wind;
- Using bund walls to shelter and protect temporary and/or permanent stockpiles and dumps from being further entrained by wind erosion;
- Using water carts with boom sprayers or wet suppression systems;
- Ensure that transfer points are tightly enclosed;
- Ensure proper design of transfer points with rubber seals between stationary and moving components;
- Make use of sweepers around transfer points; and
- Implementation of a Triggered Action Response Plan to ensure the timeous/proactive response to a major dust release.

5.6.1.2 Conveyor belts

The following techniques can be considered to assist with dust suppression for conveyor belts:

- For low lying/flat conveyors that are not enclosed, a wind guard in the prevailing wind direction can be fitted;
- To prevent unnecessary airborne dust from the conveyors, it is recommended that the conveyor belts are cleaned on a regular basis with belt scrapers, washers and/or combinations of both; and
- Wetting of conveyor belts and conveyed ore with water aerosol sprayers has also been found to greatly improve airborne dust concentrations around conveyors.

5.6.1.3 Wind erosion and exposed areas

The following techniques can be considered to assist with dust suppression for wind erosion and exposed areas:

- Where re-vegetation is not feasible, areas of concern can be mitigated with the use of water sprays (control efficiency of 50%); and

- Windbreaks in the form of shade cloth screens may be erected at exposed areas. The windbreaks aim to mitigate dust transportation by reducing the wind speed across the surface of the ground (higher wind speeds tend to scour the surface, leading to dust entrainment and subsequent transportation).

5.6.1.4 Spontaneous combustion

All areas of spontaneous combustion should be extinguished. Mitigation actions should be implemented within 48 hours of detection. A spontaneous combustion management plan can be developed which documents standard operating procedures (SOP's) to deal with such incidents.

5.6.1.5 Complaints

Dust related complaints should be directed to the site management and any actions arising from a complaint should be recorded in a complaint register to be maintained by site management.

5.6.2 Closure phase

Final rehabilitation and re-vegetation is to be undertaken once the discard dump reaches final height. The dump will be constructed to a relatively flat outer slope of probably 1:9.

These control measures are summarized in Table 19.

Table 19: Detailed mitigation measures

Phase	Detailed Mitigation Measures	Mitigation Type	Time period for implementation	Standards to be Achieved	Compliance with Standards	Responsible person
Operational	Loading, unloading and transfer activities: ■ Modifying or ceasing loading activities during dry and windy conditions ■ Avoid double handling of material where possible ■ Minimising the drop height of the material from truck loads/transfer points ■ Using bund walls to shelter and protect particulates, from resultant dumps, from being further entrained by wind erosion ■ Using water carts with boom sprayers or wet suppression systems when loading, unloading and transfer activities occur ■ Make use of sweepers around transfer points to remove and collect any spilled materials which may lead to fugitive dust generation ■ Implementation of a Triggered Action Response Plan to ensure the timeous/proactive response to dust release offsite Conveyor belts: ■ For low lying/flat conveyors that are not enclosed, these conveyors can be fitted with wind guards	Minimize control through management	Continuous	Compliance with NAAQS beyond site boundary	Implementing dust control measures at significant emissions sources, the cumulative ambient particulate load will be reduced Implement control measures to ensure no spontaneous combustion onsite	Environmental officer Environmental specialist Production manager

Phase	Detailed Mitigation Measures	Mitigation Type	Time period for implementation	Standards to be Achieved	Compliance with Standards	Responsible person
Operational phase *continued*	■ Conveyor belts should be cleaned on a regular basis through the use of belt scrapers, washers, and or both ■ Wetting of conveyor belts can also improve airborne dust concentrations around conveyors ■ Use of water sprayers at transfer points should they not be sufficiently enclosed ■ Implementation of a Triggered Action Response Plan to ensure the timeous/proactive response to a major dust release Wind erosion: ■ Where re-vegetation is not feasible, areas of concern can be mitigated with the use of water sprays Exposed areas: ■ Windbreaks in the form of shade cloth screens may be erected at exposed areas Spontaneous combustion: ■ All areas of spontaneous combustion should be extinguished. Mitigation actions should be implemented within 48 hours of detection Complaints: Dust related complaints should be directed to the site management and any actions arising from a complaint should be recorded in a complaint register to be maintained by site management					

Phase	Detailed Mitigation Measures	Mitigation Type	Time period for implementation	Standards to be Achieved	Compliance with Standards	Responsible person
Closure	Final rehabilitation and re-vegetation is to be undertaken once the discard dump reaches final height. The dump will be constructed to a fairly flat outer slope of probably 1:9.	Minimize Control through management and monitoring	Continuous	Compliance with NAAQS at the mine boundary	Implementing dust control measures at significant emissions sources, the cumulative ambient particulate load will be reduced	Environmental officer Environmental specialist Production manager

5.7 Monitoring and reporting requirements

Monitoring and reporting requirements for Zibulo are detailed below and are further summarized in Table 20.

5.7.1 Dust fallout monitoring

It is recommended that the existing dust fallout monitoring at Zibulo is ongoing and remains in alignment with the dust regulations. The network currently covers a good spatial distribution, at the fenceline and covering all receptors within the immediate vicinity of the colliery. Furthermore, non-compliances should be reported to the regulators and a dust management plan should be developed if results are exceeding the regulations. Additionally, monthly reporting should be used to identify problem areas/activities to target mitigation.

5.7.2 Continuous particulate matter monitoring

As stipulated by the South African National Accreditation System (SANAS, 2012) TR 07-03 standards, for a dataset to be fully representative, a minimum requirement of 90% recovery should be achieved. As such, the following is recommended for continued particulate matter monitoring in order to achieve this:

- Ensuring data recovery remains high (above 90%). Regular maintenance and calibration of the unit will ensure data recovery meets the required minimum;
- Ensuring monthly maintenance on the unit continues, including flow rate checks, filter changes and inlet cleaning; and
- Ensuring the unit is sent to the supplier on for calibration in alignment with manufactures specifications.

Additionally, monthly reporting should be used to identify problem areas/activities to target mitigation.

5.7.3 Meteorological monitoring

It is recommended that the meteorological station for Zibulo remains fully functional to aid in mitigating further dust releases, given that the assessment of meteorological conditions (predominantly winds) is key in managing site activities. Additionally, monthly reporting of meteorological data within the ambient monitoring reports (dust fallout and PM monitoring) should be used to identify problem areas/activities to target mitigation.

5.7.4 Spontaneous combustion monitoring

Weekly visual monitoring should be undertaken to identify the presence of spontaneous combustion onsite as well as an annual integrated check. If spontaneous combustion commonly occurs onsite, trace gas monitoring of the combustion emissions must be undertaken to determine the impact on the ambient air quality.

Table 20: Monitoring and reporting requirements

Source activity	Impacts requiring monitoring programmes	Functional requirements for monitoring	Roles and responsibilities (for the execution of the monitoring programme)	Monitoring and reporting frequency and time periods for implementing impact management actions
Zibulo	Emissions concentrations causing exceedances of the NAAQS beyond the mine boundary	Continued dust fallout monitoring using single direction dust buckets	Environmental officer Environmental specialist Production manager	Dust fallout monitoring at the current monitoring locations are deemed sufficient Monthly reporting should be used to identify problem areas/activities to target mitigation
		Continued PM_{10} and $PM_{2.5}$ monitoring	Environmental officer Environmental specialist Production manager	Continuous PM_{10} monitoring at the current location is deemed sufficient Monthly reporting should be used to identify problem areas/activities to target mitigation
		Continued meteorological monitoring	Environmental officer Environmental specialist Production manager	It is recommended that the meteorological station remains fully functional to aid in mitigating further dust releases Monthly reporting of meteorological data within the ambient monitoring reports (dust fallout and PM monitoring) should be used to identify problem areas/activities to target mitigation
		Ongoing spontaneous combustion monitoring	Environmental officer Environmental specialist Production manager	Weekly monitoring should be undertaken to identify the presence of spontaneous combustion onsite as well as an annual integrated check If spontaneous combustion commonly occurs onsite, trace gas monitoring of the combustion emissions must be undertaken to determine the impact on the ambient air quality

5.8 Conclusion

Given the low impacts predicted on the sensitive receptors during the operational and closure phases of the project, Golder's professional opinion is that this project be recommended for authorisation, with the recommended mitigation measures being implemented accordingly.

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APPENDIX A

Impact Assessment Criteria

The significance of each identified impact was determined using the approach outlined below (terminology from the Department of Environmental Affairs and Tourism Guideline document on EIA Regulations, April 1998). This approach incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows.

Impact assessment factors

Occurrence		Severity	
Probability of occurrence	Duration of occurrence	Scale/extent of impact	Magnitude of impact

To assess these factors for each impact, the following four ranking scales are used.

Impact assessment scoring methodology

Probability	Duration
5 - Definite/don't know	5 - Permanent
4 - Highly probable	4 - Long-term
3 - Medium probability	3 - Medium-term (8 - 15 years)
2 - Low probability	2 - Short-term (0 - 7 years) (impact ceases after the operational life of the activity)
1 – Improbable	1 – Immediate
0 – None	
Scale	**Magnitude**
5 – International	10 - Very high/don't know
4 – National	8 - High
3 – Regional	6 - Moderate
2 – Local	4 - Low
1 - Site only	2 - Minor
0 – None	

Once these factors are ranked for each impact, the significance of the two aspects, occurrence and severity, is assessed using the following formula:

SP (significance points) = (magnitude + duration + scale) x probability

The maximum value is 100 significance points (SP). The impact significance will then be rated as follows.

Significance of impact based on point allocation

SP >75	Indicates high environmental significance	An impact which could influence the decision about whether or not to proceed with the project regardless of any possible mitigation.
SP 30 – 75	Indicates moderate environmental significance	An impact or benefit which is sufficiently important to require management and which could have an influence on the decision unless it is mitigated.
SP <30	Indicates low environmental significance	Impacts with little real effect and which should not have an influence on or require modification of the project design.
+	Positive impact	An impact that constitutes an improvement over pre-project conditions,

For the methodology outlined above, the following definitions were used:

- ***Magnitude*** is a measure of the degree of change in a measurement or analysis (e.g. the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, moderate or high. The categorization of the impact magnitude may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely recognised standards are to be used as a measure of the level of impact;
- ***Scale/Geographic extent*** refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international;
- ***Duration*** refers to the length of time over which an environmental impact may occur: i.e. immediate/transient, short-term (0 to 7 years), medium term (8 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project), or permanent; and
- ***Probability*** of occurrence is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

APPENDIX B

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APPENDIX C

Formal Declarations

Formal Declarations

Declaration of Accuracy of Information

DECLARATION OF ACCURACY OF INFORMATION - APPLICANT

Name of Enterprise: Zibulo Colliery

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, ____ (duly authorised), declare that the information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Johannesburg on this 05th day of February 2021.

Ambiguous

____

SIGNATURE

____

CAPACITY OF SIGNATORY

Declaration of Independence of Practitioner

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Novania Reddy

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act.

I, Novania Reddy, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer, The information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1) (g) of this Act.

Signed at Johannesburg on this 06th day of February 2021.

SIGNATURE

Environmental Consultant and Modeller at Golder

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