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ENVIRONMENTAL

Environmental Regulatory Process Required to Amend and Consolidate the Sigma Colliery Mooikraal Environmental Management Programme Report, Sasolburg, Free State

Groundwater Report

Project Number:

SAS5175

Prepared for:

Sasol Mining (Pty) Ltd

March 2019

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Project Name:	**Environmental Regulatory Process Required to Amend and Consolidate the Sigma Colliery Mooikraal Environmental Management Programme Report, Sasolburg, Free State**
Project Code:	**SAS5175**

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been requested by Sasol Mining (Pty) Ltd (hereafter Sasol Mining) to carry out a groundwater impact assessment for a combined Basic Assessment and Regulation 31 Amendment Process. The scope involves the amendment and consolidation of the approved Sigma Colliery: Mooikraal (hereafter Mooikraal) Environmental Management Programme Report (EMPr) with the proposed reconfiguration and relocation of the conveyor belt series and relocation of the existing crusher facility located at Sigma Colliery: 3 Shaft (hereafter 3 Shaft). An environmental regulatory process is thus required to obtain the necessary environmental authorisations. Through this process, it is intended that new triggered Listed Activities in terms of the EIA Regulations 2014 (as amended) promulgated under the NEMA be applied for, as well as incorporate existing activities at Mooikraal and 3 Shaft into the existing approved EMPr, so as to ensure that all activities are lawfully executed.

Sigma Colliery consists of two components, namely the operational complexes comprising Sigma Colliery Mooikraal (Mooikraal) and Sigma Colliery 3 Shaft Complex (3 Shaft), and the non-operational Sigma Defunct. This document only considers the Project as relevant to Mooikraal and 3 Shaft.

Current Hydrogeological Conditions at Mooikraal and 3 Shaft

The groundwater levels at Mooikraal are affected by mining activities. This we attribute to the presence of vertical groundwater pathways within the project area. This trend is not observed for all boreholes meaning that the presence of the dolerite sills does restrict impact. Some water levels are also observed to have been affected by pumping for water supply.

Water table at the 3 Shaft range from 4.73 to 31.63 mbgl, with an east to west groundwater flow direction.

The local groundwater quality at Mooikraal is predominantly influenced by the local geology and at 3 Shaft only the intermediate aquifer shows remnants of this characteristic with high alkalinity showing signs of impact from the ash backfilling from the underlying Sigma Defunct mine void. The shallow aquifer at 3 Shaft is a fresh aquifer with recently recharged groundwater. Of all the aquifers assessed, none are impacted by mining related activities (including the mine aquifer however with the exception of the intermediate aquifer at 3 Shaft). This is concluded based on the relatively minimal sulphate concentrations and EC values found in the groundwater.

Mooikraal Activities and Associated Impacts during the Construction Phase

No new construction activities are anticipated at Mooikraal as the colliery has already been established.

3 Shaft Activities and Associated Impacts during the Construction Phase

During the construction phase, site clearance (where required) and construction activities are expected to take place above the water table. The local water table ranges from 4.73 to 31.63 mbgl. No impact on the groundwater is expected if the activities take place above the water table. Should there be a need to excavate below the water table, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

Mooikraal Activities and Associated Impacts during the Operational Phase

Model simulations indicate minimal impacts from the removal of groundwater. This is due to the presence of the dolerite sills which act as aquicludes; restricting impact to the local aquifers in terms of groundwater quantity deterioration. However, there are monocline structures within the western parts of Mooikraal which are preferential flow pathways. These structures were conceptualised to not penetrate the dolerite sills because their formation is understood to have taken place prior the sill intrusions. Thus, the dolerite sills predominantly restrict the extent of the drawdown to the immediate area.

The WRD at Mooikraal is a potential source of contamination; once material is exposed to oxygen and rainfall, leachate generating reaction may occur and introduce contamination into the groundwater environment via seepage. Total concentration analysis identified Ba and Cu as potential elements of concerns however these results are a worst case scenario. Leachable concentration analysis, which is the most representative of the expected leachate at the site, shows no concern within regards to the leachate expected to emanate from the dump.

3 Shaft Activities and Associated Impacts during the Operational Phase

Relocation of the facilities onto the stockpile may generate contaminating leachate at the new location; as rainwater infiltrates through the coal, metals could be dissolved, and leachate may form. The leachate may then seep to the groundwater and migrate by advection within the groundwater environment.

Looking at the current groundwater quality at 3 Shaft area, no mining related impact thus far have been observed, although the existing primary plant area has been operational since 1950. However, the location of the monitoring boreholes needs to be reassessed as they are not located in areas within close proximity to the existing plant area and therefore it is with low confidence that 3 Shaft is deemed as an area that is without contamination. Two boreholes are recommended downstream of the existing primary plant (one borehole at the shallow aquifer and another at the intermediate aquifer).

The stockpile area, however, is much less of a risk to the groundwater environment compared to the current primary plant area. This is because the relocation area (stockpile area) is lined with concrete therefore reducing the potential or rate at which leachate may seep into the underlying unsaturated and saturated zone (aquifer). The stormwater management system will also be upgraded reducing the potential impact even further. Due to these factors, the stockpile area is not observed to be a high risk to the groundwater environment.

Mooikraal Activities and Associated Impacts during the Closure Phase

As mining operation at Mooikraal ceases, groundwater removal will also cease. The hydraulic gradient will then drive for the recovery of the local water levels previously affected by removal of water. A contamination plume has been created within the mine voids which will be filling up with groundwater. From model simulations, the contamination plume was found to be limited in extent due to the depth of the coal seam and thickness of the overlying dolerite sills. However, it was observed that at locations where the coal seam is shallower, the dolerite sill is thinner and the presence of vertical preferential pathways (such as the decline shaft and monoclines structures is found), the plume is expected to migrate further introducing a potential contaminant risk to the shallow aquifer and surface water bodies.

The post-mining model indicated groundwater levels will not fully recover within a 300 year simulation period. The slow recovery, in spite of the underground mine voids being fully flooded, is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill. Therefore, there are uncertainties at this point with regards to the potential of decant. However, for the sake of being conservative in preparation for the worst case scenario, a steady state model was subsequently used to model the fully recovered water levels imposing an equilibrium state and infinite time. The steady state model indicated the northern boundary of the Mooikraal underground mine as the most likely area for decant at an estimated rate of 2.5 m^3/d. The decant rate should be considered only as an initial estimation due to the uncertainty associated with predicting flow.

The WRD is proposed to be backfilled into the shaft therefore it will not exist as a potential contamination source at the surface.

3 Shaft Activities and Associated Impacts during the Closure Phase

All infrastructure will be demolished and removed during decommissioning therefore no impacts are expected post closure.

The following recommendations were concluded for the groundwater studies

General:

- Two monitoring boreholes at 3 Shaft are recommended to be drilled downstream (in addition to the existing) of the current location of the primary plant area, one in the shallow, and one in the intermediate aquifer. These boreholes will serve to acquire groundwater samples in order to quantify the presence or absence of contamination in the existing primary plant vicinity with better accuracy;
- The hydrocensus previously conducted (and not completed) at Mooikraal is recommended to be updated within a 3 km radius of the project boundary;
- A hydrocensus is recommended to be conducted within a 1 km radius of the 3 Shaft area;

- Should any landowner report a reduced yield/ quality from his borehole, the cause of the impact will be investigated by the mine. If there is reasonable cause to believe that the impact is mining related, suitable corrective action will be agreed between the parties; and
- X-Ray Diffraction (XRD), acid base accounting and leachable concentration investigations of the coal seam at Mooikraal are recommended.

Construction phase:

<u>3 Shaft:</u>

- Restrict construction activities to be limited to areas above the water table; and
- If that is not possible, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

Operational phase:

<u>Mooikraal:</u>

- A dewatering network will not be constructed; dry working conditions will be achieved by abstracting groundwater ingress from mine voids during operation, as currently authorised by Mooikraal's approved water use license;
- Water removed from underground should be stored in the North and South pollution control dams (PCD) and reused for mine processes that are not quality sensitive and are authorised by the competent authority. Excess water shall be pumped away to 3 Shaft and Sasolburg Operations to prevent any overflows from the PCDs;
- If overflow from the PCDs should occur, Mooikraal will conduct water quality monitoring downstream of the PCDs and notify the competent authority, should there be a negative impact to surface water bodies, downstream users will be notified and rehabilitation measures will be informed by a professional;
- Should there be an impact to delineated wetlands, ongoing wetland rehabilitation should be conducted as informed by a professional and the Freshwater Impact Assessment Report (Digby, 2018);
- The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation;
- Groundwater monitoring should continue to assess the time series water level and groundwater quality trends as per the approved water use license; and
- All groundwater monitoring, geological, rescue borehole locations must be retained on a register;
- Geological/ exploration boreholes will be sealed and decommissioned during the operational phase, according to the Sasol Mining procedure and the register will reflect the status of the borehole;

- Rescue boreholes that are no longer required/ in use will be sealed and decommissioned as per Sasol Mining Procedure, and the register will reflect the status of the borehole;
- Numerical modelling should be updated every five years based on groundwater monitoring results as to identify any potential concerns that may occur over the years.

<u>3 Shaft:</u>

- Maintenance of the stockpile area must be undertaken by developing an effective stormwater management system;
- Groundwater monitoring must be implemented to assess the time series water level and water quality trends; and
- Due to the fact that no underground mining occurs at 3 shaft, all historical groundwater, geological, rescue borehole locations must be retained on a register and the status of the borehole will be recorded.

Decommissioning and post-closure phase:

<u>Mooikraal:</u>

- All existing boreholes as informed by the registers, with the exception of private water supply boreholes and monitoring boreholes should have been sealed and decommissioned according to Sasol Mining procedure during the operational phase, in order to minimise the chance of decant occurring;
- All shaft adits, ventilation shafts and downcasts will be sealed and decommissioned as guided by a professional;
- Should there be an negative impact to surface water bodies due to decant and baseflow contribution, investigations will occur, and rehabilitation will commence as informed by a professional;
- Should there be an negative impact to delineated wetlands, investigations will ensue, and rehabilitation will commence as informed by a professional;
- The waste rock material which will be backfilled into the shaft should be completely flooded to eliminate exposure to oxygen, this will hinder contamination generating reactions;
- Potential decant should be informed by the numerical model as new data becomes available, should decant be predicted to occur, decant locations should be monitored for decant quality and rate; possible scenarios to manage the decant will be informed by a professional;
- The groundwater monitoring network may be re-assessed and amended to determine the boreholes, to be monitored, necessary to monitor the relevant aquifers sources of contamination and receptors; and

- Groundwater monitoring should be conducted to assess the time series water level and water quality trends.

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1 Introduction

Digby Wells Environmental (Pty) Ltd (hereafter Digby Wells) was appointed by Sasol Mining (Pty) Ltd (hereafter Sasol Mining) to consolidate Sigma Colliery Mooikraal (hereafter Mooikraal) and Sigma Colliery 3 Shaft Complex (hereafter 3 Shaft) groundwater impact assessments for their operations.

Sigma Colliery consists of two components, namely the operational complexes comprising Mooikraal and 3 Shaft, and the non-operational Sigma Defunct. This document only considers the Project as relevant to the Mooikraal and 3 Shaft.

Mooikraal is an underground coal mine located in the Sasolburg area. It currently operates under a consolidated Mining Right (Reference No. FS 30/5/1/2/2/2/1/221) and approved amended Environmental Management Programme (EMPr) (Reference No. 30/5/1/2/3/2/1 (221) EM) granted April 2016. The authorisation permits the undertaking of various activities associated with the underground coal mining operation.

Mooikraal also holds a separate approved Environmental Authorisation (EA) (Reference No. EMB/28/14/43, dated 09 March 2015) for a 10 Mega litre (ML)/day and 7 ML/day water transfer pipeline. The 7 ML/day pipeline will transfer water from the Kleinvlei ventilation shaft to the Pollution Control Dams (PCDs) (North and South PCD) at Mooikraal (Figure 3-1), and the 10 ML/day pipeline will transfer water from the PCDs at Mooikraal to 3 Shaft for dust suppression (dust suppression is conducted at all the areas within 3 Shaft), any excess water from these operations will be sent to Sasolburg Operation (SO). Both pipelines are constructed along mine servitudes.

Mooikraal is now proposing to reconfigure and relocate the conveyor belt series and the crusher facility located at 3 Shaft. In addition, Mooikraal wishes to amend and consolidate the approved Mooikraal EMPr. An environmental regulatory process is thus required to obtain the necessary environmental authorisations.

1.1 Project Description

Dirty water (water contaminated with coal) runoff from the primary plant (crusher, coal bunker area and conveyor belt) at 3 Shaft is currently flowing into the Leeuspruit, which is indicated in the Sigma Defunct water monitoring report dated January 2018 (Ref No. 2018/03/PJHL). This is due to the original siting of the primary plant area (in the 1950s) within a delineated wetland area, the wetland was delineated in 2016. (Figure 3-3). Poor and/or no separation of clean and dirty water management at 3 Shaft, as well as the absence of dirty water management activities at the stockpile area resulted in dirty water runoff entering the water resource.

To rectify these issues, Sasol Mining is proposing to demolish the existing infrastructure of the primary plant area and establish a new crushing facility on the existing stockpile area. This area is well outside of the delineated wetland area but within the 500 meter regulated buffer area. Comprehensive clean and dirty water management activities will be established at and around the stockpile area, as well as dust management activities. The impacted delineated wetland will be remediated.

The relocation of the crusher facility will necessitate the realignment of the MK9 Belt over the shortest distance to convey Run of Mine (ROM) coal directly to the stockpile where the new crusher facility will be located. The proposed conveyor structure, namely the new MK9 Belt, will measure approximately 650 m from the existing MK8 transfer point (MK 9 tail end) to the proposed new primary plant (crusher). The proposed conveyor route will traverse one water resource.

Sasol Mining also intends to drill boreholes for groundwater monitoring and exploration within the Mooikraal Mining Right Area (MMRA). Some of these boreholes (approximately 100) are proposed to be drilled within wetlands, in the vicinity of wetlands (500 m buffer) and/or within 100 m of the Kromelmboogspruit, therefore requiring authorisation in terms of NEMA and the NWA. It should be noted that a WUL (08/C22K/CIGJFAE/ 6981, dated 16 January 2018) has already been authorised for the drilling of these boreholes within 100 m of the wetlands and river courses in terms of the National Water Act (NWA). An application to include the boreholes to be drilled within the 500 m buffer of the wetland must still be applied for. Sasol Mining is investigating options to further maximise the extraction of coal at Mooikraal towards the southern reserves which necessitates diamond core drilling.

In addition to the exploration boreholes, monitoring, downcast and rescue boreholes will also be drilled. The monitoring boreholes will enable the mine to extend its groundwater monitoring programme within the Mooikraal Mining Right area, as well as to incorporate 3 Shaft into the monitoring network.

The downcast and rescue boreholes are intended to be drilled as ventilation structures as well as emergency access points to the underground workings in the event of a disaster respectively, as required by the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).

The above-mentioned proposed activities will introduce new activities to Mooikraal for which an Environmental Authorisation through a Basic Assessment Process is being sought out.

Mooikraal operates under a consolidated mining right (Ref No. FS 30/5/1/2/2/2/1/221) and EMPr (dated 2016), which covers all the current activities associated with the operation. However, although the EMPr contains some management and mitigation measures of 3 Shaft, this area has not been adequately addressed/included in the Mooikraal EMPr.

In addition, some properties associated with the overland conveyor belt trajectory are not included in the Mooikraal EMPr, which this application intends to address.

Mooikraal has a separate environmental authorisation for the 10 ML/day and 7 ML/day transfer water pipelines which is proposed to be incorporated within the Mooikraal EMPr.

Through this application, Sasol Mining intends to incorporate the 3 Shaft, overland conveyor belt properties and water transfer pipelines into the approved Mooikraal EMPr so as to have one consolidated EMPr applicable to the entire operation. This is proposed to be done through a Regulation 31 Amendment Process in terms of NEMA.

A combined Basic Assessment and Regulation 31 Amendment Process in terms of NEMA and associated EIA Regulations 2014 (as amended) will be undertaken to fulfil the project scope.

In summary the key infrastructure/activities, relevant to the groundwater study, for this application include:

- Demolition of the existing conveyor belt, crushing facility and coal bunker, which is currently situated within a wetland at the 3 Shaft (primary plant);
- Relocation/reconstruction the primary plant (crusher facility) on the stockpile area (to remain within the 3 Shaft footprint);
- Proposed upgrade of the stormwater management system at 3 Shaft;
- Drilling of exploration, monitoring and rescue boreholes within the approved Mooikraal Mining Right area and 3 Shaft within 500m from a wetland;
- Incorporate all activities at Mooikraal (including existing and proposed underground mining).

1.2 Objective and Scope

The objective of the groundwater study was to assess potential impacts associated with Mooikraal and 3 Shaft. This included:

- Assessment of the groundwater environment in terms of levels and quality;
- Consolidation of relevant previously conducted groundwater studies;
- Development of an impact assessment (type, degree, extent and probability) related to various project components; and
- Provision of mitigation and management measures for all identified potential impacts.

The scope of work for the groundwater study included:

- Desktop study;
- Review and update of conceptual model;
- Conduct impact assessment based on groundwater quality assessment and the existing numerical model outcomes;
- Provide mitigation and management measures; and
- Provide a specialist report incorporating details of the tasks mentioned above.

2 Details of the Specialist

The following specialists compiled this groundwater report:

Responsibility	**Report Writer**
Full Name of Specialist	Ayabonga Mpelwane
Highest Qualification	MSc Hydrogeology
Years of experience in specialist field	5
Responsibility	**1st Reviewer**
Full Name of Specialist	Carol Hooghiemstra
Highest Qualification	MSc Environmental Management
Years of experience in specialist field	24
Responsibility	**Technical Reviewer**
Full Name of Specialist	Robel Gebrekristos
Highest Qualification	PhD Hydrogeology
Years of experience in specialist field	16

3 Site Description

3.1 Infrastructure

The infrastructure currently present at Mooikraal and 3 Shaft is listed in Table 3-1 and Table 3-2, respectively. The site layout is shown in Figure 3-2 and Table 3-2.

Table 3-1: Infrastructure at Mooikraal

Incline shaft	Waste storage area	7ML/day pipeline from Kleinvlei Shaft to PCDs
Ventilation Shaft (Kleinvlei Shaft) - Downcast	Workshops (cable, boiler and diesel)	Electricity pylons located with the existing servitudes
PCDs (North and South Dams)	Lamp room	Various pipelines (potable and sewerage)
Access roads (including access routes to the rescue boreholes)	Bulk fuel and oil storage area and bunds	Office blocks (including kitchen, security and proto room)
Pump station	Dust suppression storage area and bund	Various walkways
Sumps located at the wash bay, fuel storage, shaft complex and various areas around the mine for stormwater management	Stone dust silo	Tuck-shop (where light meals are prepared)
Explosives magazine	Capital yard	Change houses
Transformers and bunds	Warehouse	Smokers facilities

Clean water channels	Material storage yards	Laundry washing facility
Soil stockpiles	Conveyor belting, associated drive houses, transformers and substations	Security fencing
Waste Rock Dump (WRD)	Coal scanners located on belts	Rescue boreholes
Borrow pits	5 ML/day pipeline from Mooikraal to SSO	-
Sewage Treatment Plant (STP)	10 ML/day pipeline from Mooikraal to SSO	-

Table 3-2: Infrastructure at 3 Shaft

Primary plant area – including crusher facility	Parking area
Stockpile area including stacker reclaimer for ROM and imported coal	Hazardous chemical storage area
Unpaved haul roads	Offices (including security and mine closure offices)
Access roads	Material handling stores
Security fencing	Workshops (diesel and boiler)
Transformers and substations	Various pipelines (potable and sewerage)
Conveyor belt and transfer points	Paint spraying booth
Coal scanners located on the belts	Waste storage area
Bulk fuel storage area	A cement dam for dust suppression (this dam is fed by the 5 ML/day pipeline from Mooikraal)
Wash bay	Contractors storage yard
ABET training centre	Dirty water storage dams
Warehouse	-

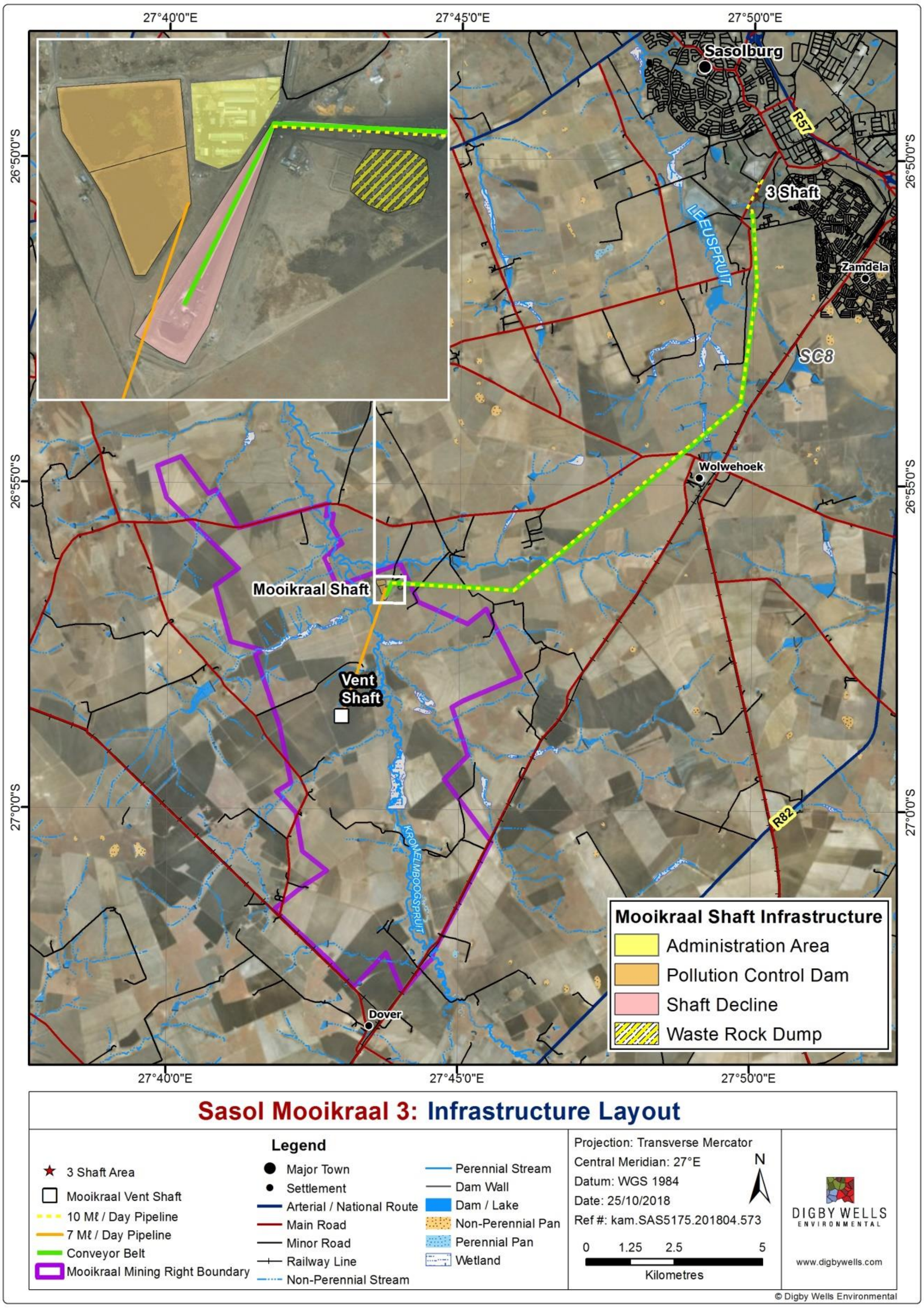

Figure 3-1: Site Layout at Mooikraal

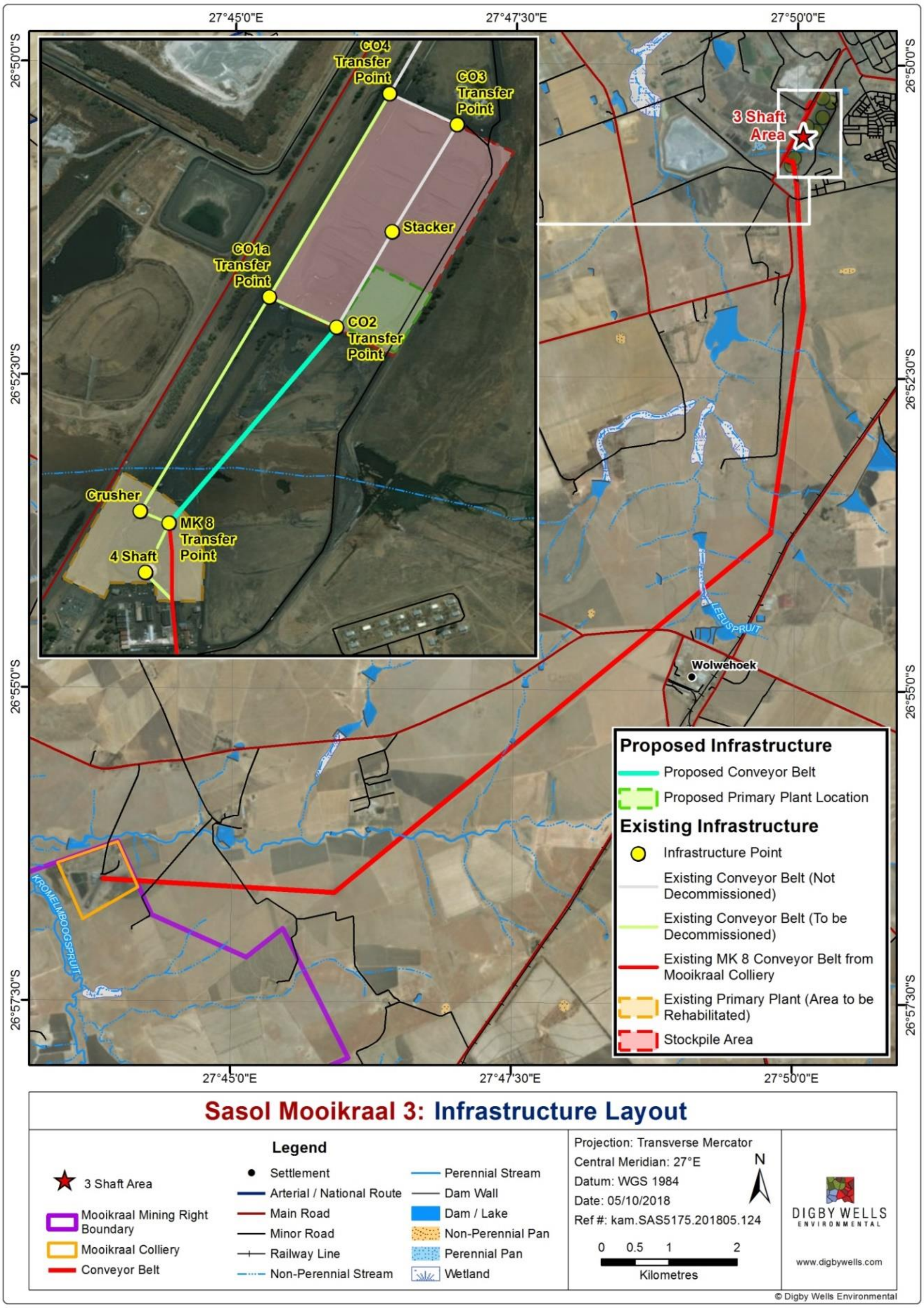

Figure 3-2: Site Layout at 3 Shaft

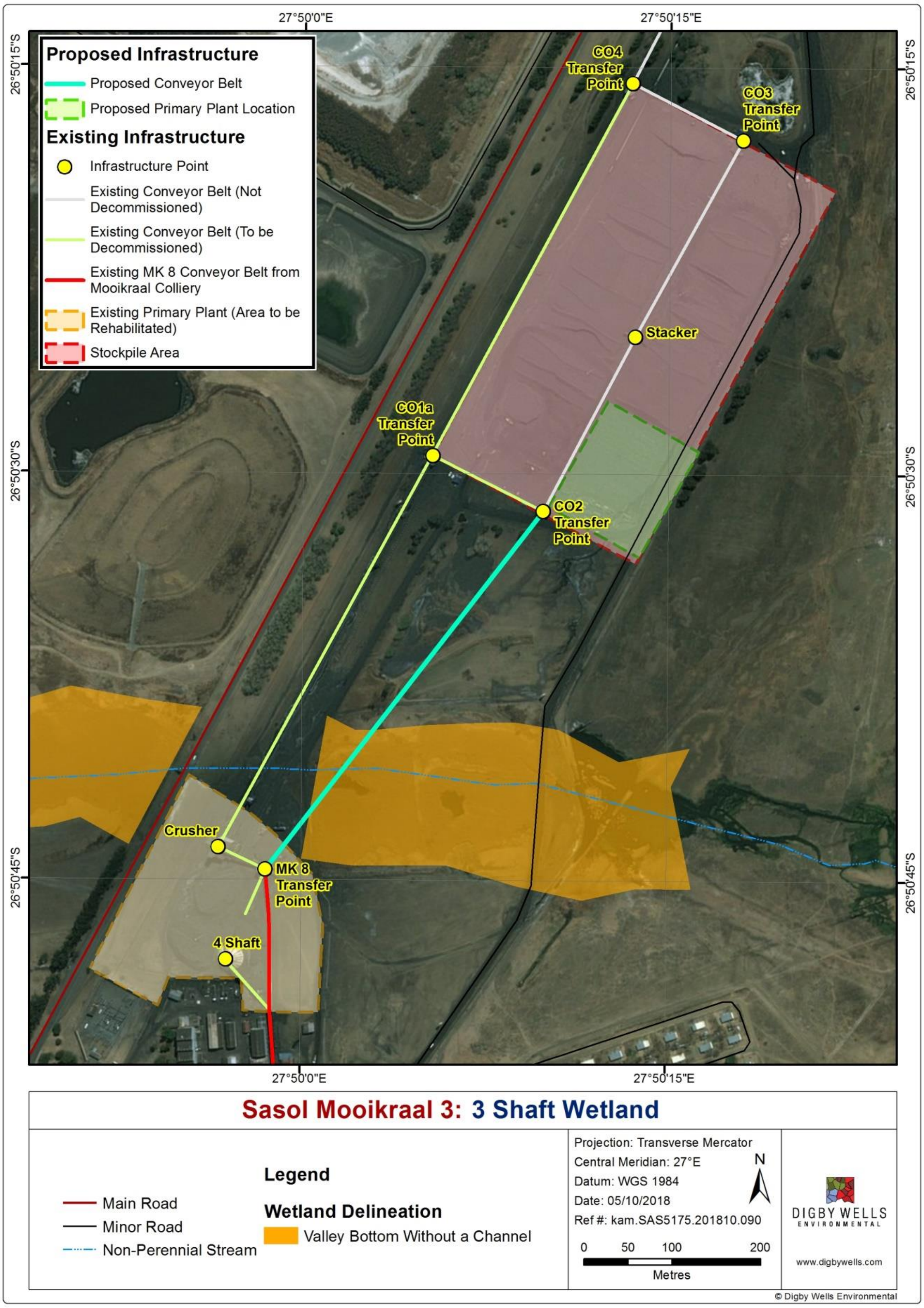

Figure 3-3: Wetland at 3 Shaft

3.2 Topography and Drainage

Mooikraal and 3 Shaft are situated in the Vaal Water Management Area (WMA) as revised in the 2016 Republic of South Africa Government Gazette Vol. 615 no. 40279, previously subdivided into the Lower Vaal, Middle Vaal and Upper Vaal WMA.

Mooikraal is located within quaternary catchment C23B; with topographic elevation ranging from 1498 to 1448 metres above mean sea level (mamsl). The Kromelmboogspruit runs through the middle of the project area in a south to north direction; drainage migrates towards this river which joins the Vaal River further downstream.

3 Shaft is located within quaternary catchment C22K. Elevation at this site ranges from 1466 to 1480 mamsl at 3 Shaft. Drainage at the project area is towards the Leeuspruit, draining into the Vaal River.

3.3 Precipitation

The rainfall within the Mooikraal and 3 Shaft area measured at the Mooikraal Mine, from 1953 to 2017 (Figure 3-4), reflects the following:

- The wet season is experienced predominantly in summer (from October to April), and dry season is experienced from May to September; and
- The area was found to have a mean annual precipitation (MAP) of 667 mm/a.

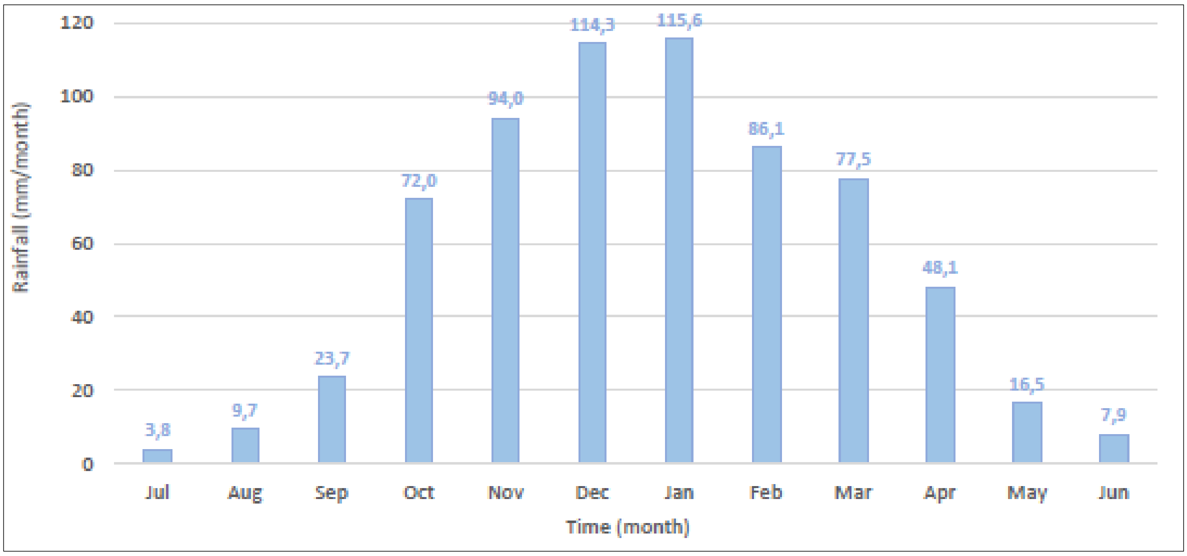

Figure 3-4: Average rainfall measured at the Mooikraal Mine from 1953 to 2017

3.4 Geology

The Mooikraal area comprises of sedimentary lithologies of the Karoo Supergroup, i.e. Vryheid and Volksrust Formations of the Ecca Group. These lithologies were intruded by dolerite, mainly in the form of sills. Two dolerite sills are found in the area, namely the No. 4 and No. 5 sills. The stratigraphy at the area is displayed in Table 3-3.

The Karoo sedimentary lithologies are underlain by the older rocks of the Witwatersrand and Ventersdorp Supergroup. The Witwatersrand Supergroup is highly fractured and fragmented in nature because it was subjected to numerous structural forces, including the emplacement of the Vredefort Dome. With the Karoo sediments deposited on top of the Witwatersrand Supergroup, a number of monocline faults/fractures were created (Figure 3-5 and Figure 3-6).

3 Shaft is observed to have similar stratigraphy; however, the difference was found to be the absence of No. 4 sill and the 3 C coal horizon (Table 3-4). Additionally looking at the distribution of monocline structures being localised, these structures are not expected at 3 Shaft, however, investigations would better conclude this with more certainty.

Table 3-3: Stratigraphic column at the Mooikraal Colliery (IGS, 2018)

DESCRIPTION	
WEATHERED HORIZON	
INTERBURDEN 4	
NR 4 SILL	
INTERBURDEN 3	
NR 5 SILL	
INTERBURDEN 2	
3C HORIZON	FULL 3 SEAM
3 HIGHER HORIZON	
ROOF PARTING	
MINED SEAM	
BOTTOM COAL	
3 LOWER HORIZON	
3A HORIZON	
3 FLOOR HORIZON	
DWYKA	
BASEMENT	

Table 3-4: Stratigraphic column at 3 Shaft

DESCRIPTION	
WEATHERED HORIZON	
INTERBURDEN 3	
NR 5 SILL	
INTERBURDEN 2	
3 HIGHER HORIZON	FULL 3 SEAM
ROOF PARTING	FULL 3 SEAM
MINED SEAM	FULL 3 SEAM
BOTTOM COAL	FULL 3 SEAM
3 LOWER HORIZON	FULL 3 SEAM
3A HORIZON	FULL 3 SEAM
3 FLOOR HORIZON	FULL 3 SEAM
DWYKA	
BASEMENT	

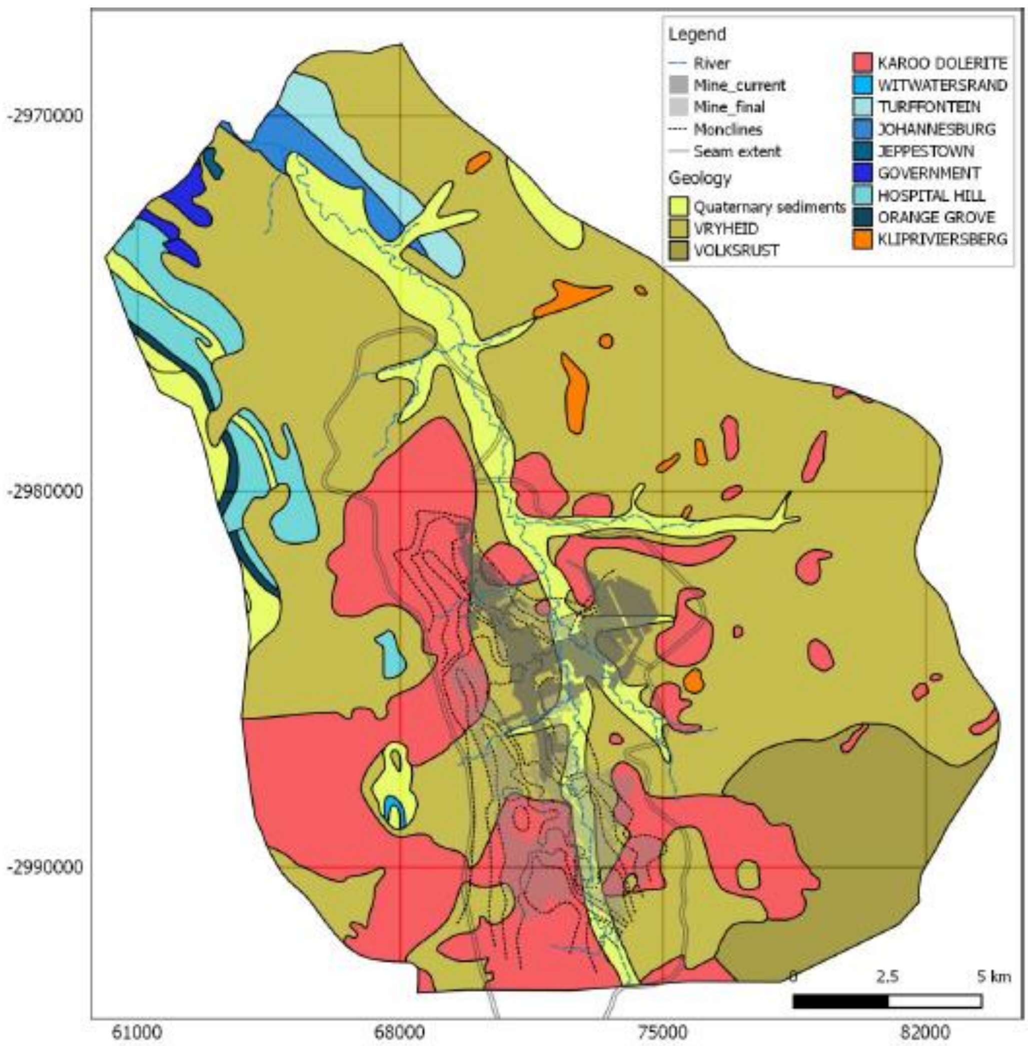

Figure 3-5: Surface geology indicating location of monocline structures

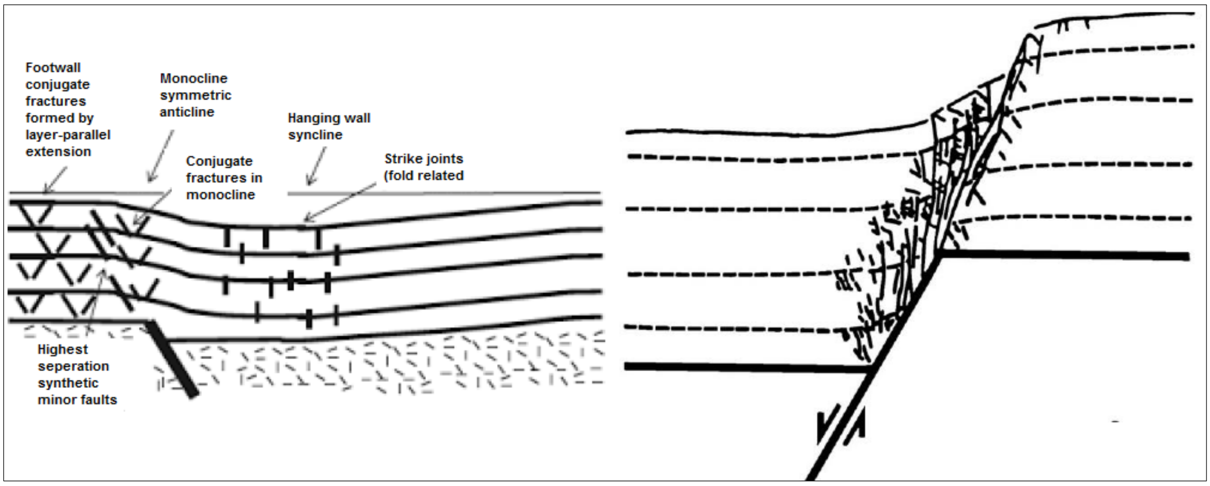

Figure 3-6: Monocline structures

4 Methodology

4.1 Desktop Assessment

During this task, all available data for the project area was collected and reviewed. This included all geological and hydrogeological reports. Information within this report is based on the following groundwater related reports:

- Institute of Groundwater Studies (IGS), 2018. Mooikraal Groundwater Model;
- IGS, 2018. Sigma Colliery: Water Monitoring Report for Mooikraal Colliery; and
- Sasol Mining's Environmental Management Department and Sigma: Mooikraal Operation, 2014. Sasol Mining (Pty) Ltd Sigma Mooikraal Operation's Environmental Management Programme for FS/5/1/2/2/224 MR.

4.2 Waste Classification

Digby Wells collected 2 waste rock samples at Mooikraal (25 January 2019). Fresh samples were collected by digging approximately a metre into the deposited material and a sample weighing approximately 1 kg was acquired from each location. The location of the samples is listed in Table 4-1.

Table 4-1: Waste rock sample location

Sample ID	X co-ordinate	Y co-ordinate
WRDS1	27.733013°	-26.943218°
WRDS2	27.733384°	-26.943246°

The waste rock samples were classified in accordance with the NEM: WA Regulations, by comparison with Total Concentration Threshold (TCT) and Leachable Concentration Thresholds (LCT).

Leachable concentrations were determined using reagent water to simulate the metal and anion leachate potential of the overburden stockpile WRD under neutral conditions, with only neutral water allowing leaching to occur. Total Concentrations were determined by *aqua regia* digestion to provide a measure of the solid-phase levels of various mineral-forming cations that may be of environmental concern. These levels allow for the calculation of metal depletion and can be used as a screening tool to detect constituents which occur in anomalously high concentrations under unfavourable geochemical conditions.

Total Concentration Threshold limits are subdivided into three categories as follows:

- TCT0 limits based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010);
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
- TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

Leachable Concentration Threshold (LCT) limits are subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS) and South African National Standards (SANS);
- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
- LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
- LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

GN R634 identifies waste classes (Waste Types 0 to 4) ranging from high risk to low risk, based on comparison of the Total Concentration (TC) and Leachable Concentration (LC) of individual constituents as shown in Table 4-2. Waste is assessed by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as per Table 4-3.

Table 4-2: Waste Classification Criteria

Waste Type	Element or chemical substance concentration	Disposal
0	LC > LCT3 **OR** TC > TCT2	Not allowed
1	LCT2 < LC ≤ LCT3 **OR** TCT1 < TC ≤ TCT2	Class A or Hh:HH landfill
2	LCT1 < LC ≤ LCT2 **AND** TC ≤ TCT1	Class B or GLB+ landfill
3	LCT0 < LC ≤ LCT1 **AND** TC ≤ TCT1	Class C or GLB- landfill
4	LC ≤ LCT0 **AND** TC ≤ TCT0 for metal ions and inorganic anions **AND** all chemical substances are below the total concentration limits provided for organics and pesticides listed	Class D or GLB- landfill

Table 4-3: Total and leachable concentration threshold limits

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
As, Arsenic	mg/kg	5.8	500	2000	mg/l	0.01	0.5	1	4
B, Boron	mg/kg	150	15000	60000	mg/l	0.5	25	50	200
Ba, Barium	mg/kg	62.5	6250	25000	mg/l	0.7	35	70	280
Cd, Cadmium	mg/kg	7.5	260	1040	mg/l	0.003	0.15	0.3	1.2
Co, Cobalt	mg/kg	50	5000	20000	mg/l	0.5	25	50	200
Cr total	mg/kg	46000	800000	N/A	mg/l	0.1	5	10	40
Cr (IV), Chromium (IV)	mg/kg	6.5	500	2000	mg/l	0.05	2.5	5	20
Cu, Copper	mg/kg	16	19500	78000	mg/l	2	100	200	800
Hg, Mercury	mg/kg	0.93	160	640	mg/l	0.006	0.3	0.6	2.4
Mn, Manganese	mg/kg	1000	25000	100000	mg/l	0.5	25	50	200
Mo, Molybdenum	mg/kg	40	1000	4000	mg/l	0.07	3.5	7	28
Ni, Nickel	mg/kg	91	10600	42400	mg/l	0.07	3.5	7	28
Pb, Lead	mg/kg	20	1900	7600	mg/l	0.01	0.5	1	4
Sb, Antimony	mg/kg	10	75	300	mg/l	0.02	1	2	8
Se, Selenium	mg/kg	10	50	200	mg/l	0.01	0.5	1	4
V, Vanadium	mg/kg	150	2680	10720	mg/l	0.2	10	20	80
Zn, Zinc	mg/kg	240	160000	640000	mg/l	5	250	500	2000
Chloride as Cl	mg/kg	n/a	n/a	n/a	mg/l	300	15000	30000	120000
Sulfate as SO_4	mg/kg	n/a	n/a	n/a	mg/l	250	12500	25000	100000
Nitrate as N	mg/kg	n/a	n/a	n/a	mg/l	11	550	1100	4400
F, Fluoride	mg/kg	100	10000	40000	mg/l	1.5	75	150	600
CN total, Cyanide total	mg/kg	14	10500	42000	mg/l	0.07	3.5	7	28

Notes: n/a: no threshold values

4.3 Impact Assessment

A groundwater impact assessment was conducted based on the outcome of the desktop study inclusive of the numerical model for Mooikraal, with recommended mitigation measures that may be necessary to address groundwater impacts associated with the project.

The impact assessment includes the following:

- Identification of potential hydrogeological impacts;
- Quantification of impacts through the numerical modelling;
- Impact risk rating; and
- Proposed mitigation and management measures.

5 Hydrogeological Environment

5.1 Local Aquifers

The hydrostratigraphic units at the Mooikraal project area are shown in Table 5-1. The units were conceptualized based on the geological stratigraphic units expected on site. Two cross-sections through the project area (from north to south and west to east), are used to illustrate the simplified hydrostratigraphic units, as shown in Figure 5-1, Figure 5-2 and Figure 5-3

The hydrostratigraphy expected at 3 Shaft will be characteristic of the local geology, therefore a similar hydrostratigraphic succession would be expected, with the exception of the No. 4 dolerite sill aquiclude.

Simplified, the Mooikraal and 3 Shaft area are underlain by the aquifers (referred to as groundwater regimes in IGS 2018) listed below:

- Shallow Aquifer, associated with Quaternary deposits of the Karoo Supergroup i.e. alluvium, colluvium and weathered Karoo rocks;
- Intermediate Aquifer, associated with hard fractured Karoo rocks i.e. sandstone and dolerite of the Karoo Supergroup;
- Deep Aquifer, associated with pre-Karoo rocks i.e. karst aquifer comprised of dolomitic rocks of the Transvaal Supergroup; and
- Mine Aquifer (unnatural groundwater regime) is still being developed as a result of mining; underground mining at Mooikraal and underground mining at Sigma (at the 3 Shaft location)

Table 5-1: Hydrostratigraphy at Mooikraal

HYDROSTRATIGRAPHIC UNIT
WEATHERED AQUIFER
FRACTURED AQUIFER
DOLERITE SILL LAYER
FRACTURED AQUIFER
DOLERITE SILL LAYER
FRACTURED AQUIFER
COAL/MINE LAYER

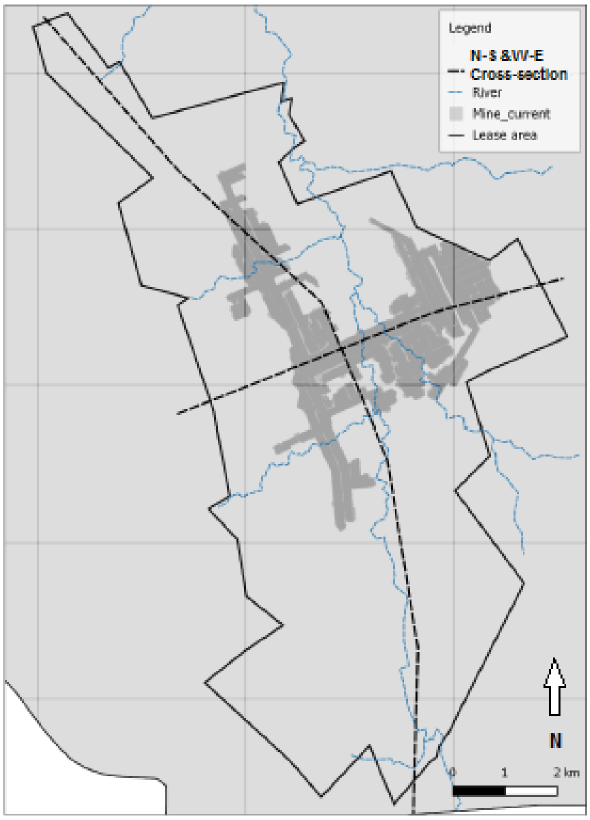

Figure 5-1: Cross-section delineation within project boundary

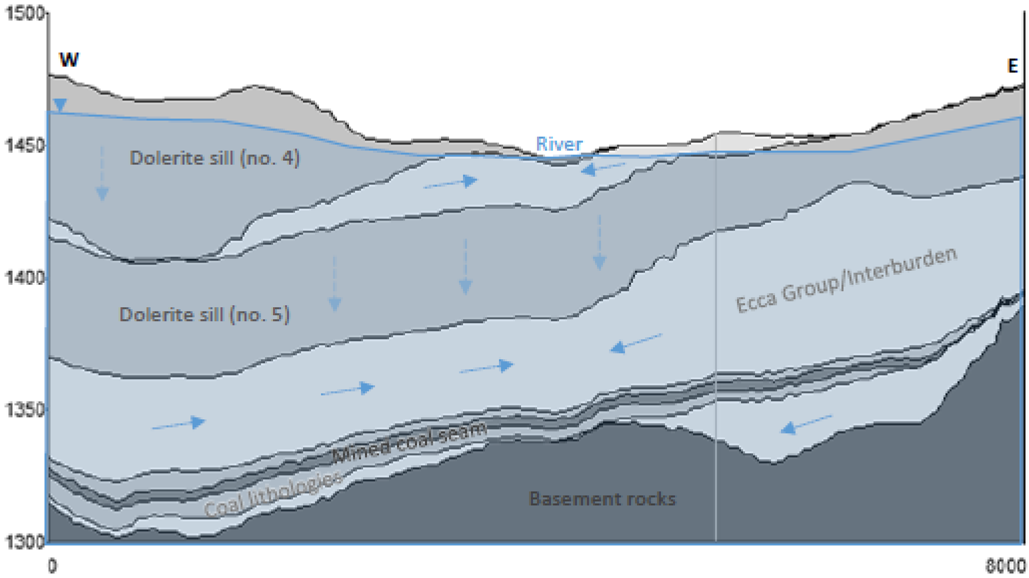

Figure 5-2: W – E cross-section

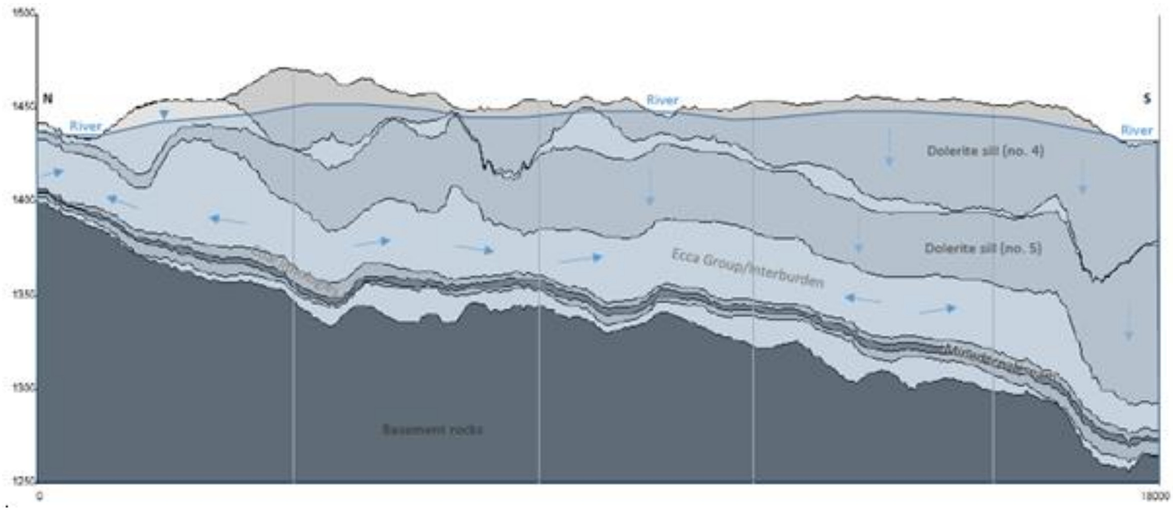

Figure 5-3: N – S cross-section

Aquifer properties for the local hydrostratigraphic units are listed in Figure 5-2, properties such as; hydraulic conductivity, effective porosity and recharge are included. The initial properties listed in the table were obtained from previous hydrogeological investigations conducted by IGS (2009) and Aquisim Consulting (2003). A numerical model was constructed by Aquisim Consulting and later updated by IGS (2018). During the calibration of the model by IGS, water levels observed on site were measured against those observed in the field and this was achieved by altering the aquifer properties within an acceptable range of what was observed on site. The final calibrated aquifer properties are taken to be representative of the hydrostratigraphic units.

Table 5-2: Local aquifer properties (IGS, 2018)

Parameter	Zone	Initial	Final Calibration
Horizontal hydraulic Conductivity (m/d)	Alluvial aquifer	0.1	0.097
	Weathered aquifer	0.02	0.02
	Dolerite sills	0.00001	1.41E-05
	Interburden (Ecca)	0.0004	0.0003
	Coal (mined)	0.0005	0.008
	Coal/siltstone (unmined)	0.0001	0.0011
Vertical Hydraulic Conductivity (m/d)	Alluvial aquifer	0.01	0.0097
	Weathered aquifer	0.002	0.002
	Dolerite sills	0.000001	1.41E-06
	Interburden (Ecca)	0.00004	3.06E-05
	Coal (mined)	0.00005	0.0008
	Coal/siltstone (unmined)	0.00001	0.00011
Porosity (%) (n)	Alluvial aquifer	8	20
	Weathered aquifer	4.5	20
	Dolerite sills	1	20
	Interburden (Ecca)	4	20
	Coal (mined)	13	20
	Coal/siltstone (unmined)	10	20
Recharge(mm/a)	Recharge 1	7	0.00036
	Recharge 2	7	0.0014
	Recharge 3	7	0.00036
	Recharge 4	7	0.00036
	Recharge 5	7	0.00036

5.2 Groundwater Quality

Groundwater quality trends at Mooikraal are observed from quarterly monitoring results (IGS, 2018). The current water levels and quality at 3 Shaft are obtained from newly drilled boreholes (drilled in 2018). Water quality is compared against the Groundwater Resource Quality Objectives (WRQO), according to Water use license no: 08/C22K/CIGJFAE/6981 dated 16 January 2018.

Groundwater quality limits as per Mooikraal WUL (16/01/2018) are given in table below:

Table 5-3 Groundwater quality limits as per Mooikraal WUL 08/C22K/CIGJFAE/6981 (16/01/2018). Borehole locations are presented in Figure 5-4.

Table 5-3: Groundwater quality limits as per Mooikraal WUL 08/C22K/CIGJFAE/6981

Parameter (m/L unless otherwise stated)	Limit	Parameter (m/L unless otherwise stated)	Limit
Electrical conductivity (mS/m)	150	Nitrate	10
Sodium	200	Fluoride	1.0
Magnesium	100	Calcium	150
Chloride	200	pH	5.5-9.5
Sulphate	200	-	-

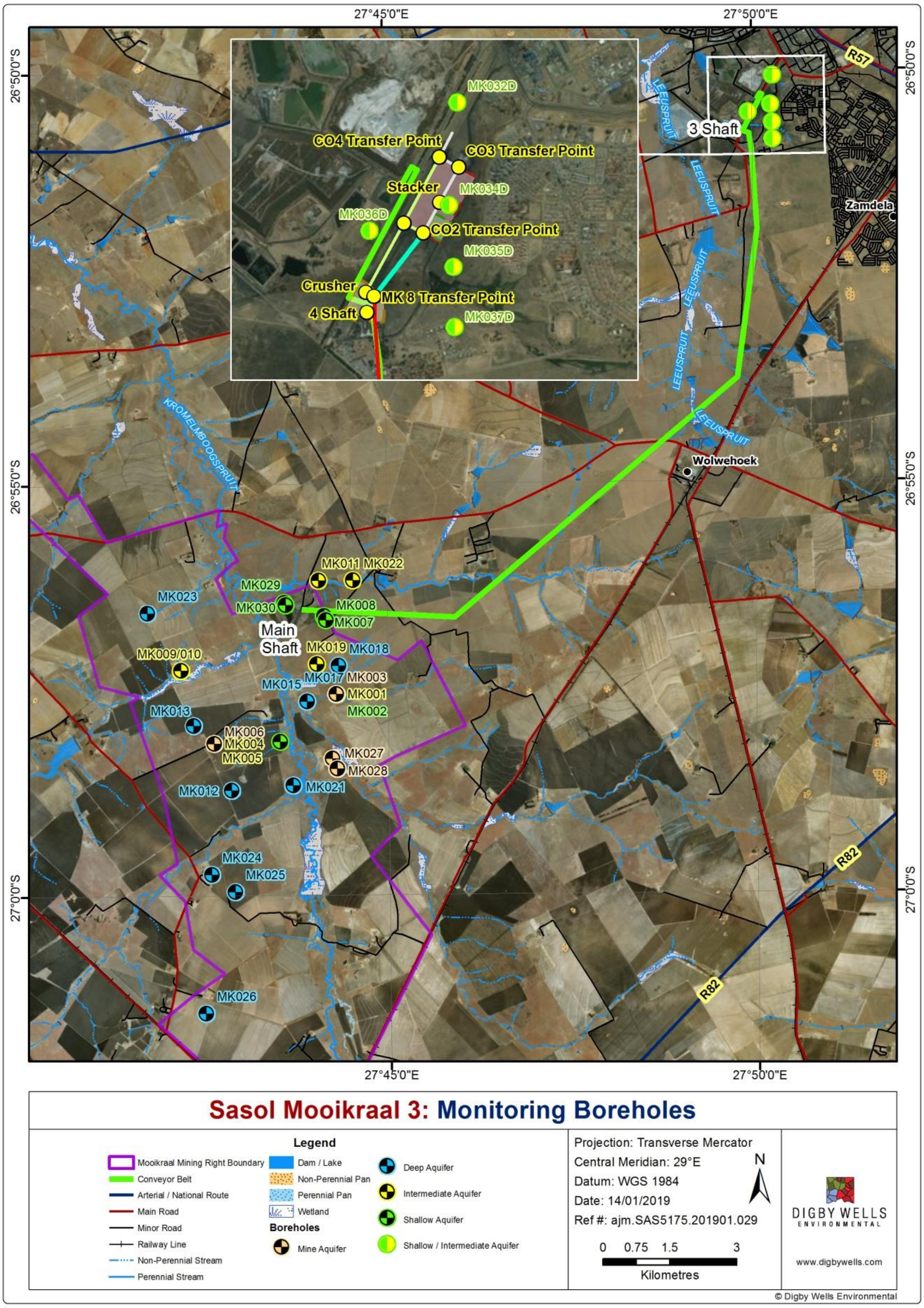

Figure 5-4: Borehole location at Mooikraal and 3 Shaft

5.2.1 Water quality at Mooikraal

5.2.1.1 Shallow Aquifer

The monitoring boreholes within this aquifer are listed below:

- MK002;
- MK007;
- MK008;
- MK029;
- MK030; and
- MK031.

The depths of the boreholes monitoring the shallow aquifer range from 30 to 45 metres below ground level (mbgl).

Water quality trends in the shallow aquifer are presented in Figure 5-5 and Figure 5-6. Electrical conductivity (EC) has been observed to deteriorate for MK002 since 2006. MK007 has improved since operation. The EC of the remaining boreholes has fluctuated throughout operation. However, all boreholes have remained within the prescribed WRQO of 150 mS/m, refer to Table 5-3, since operation. Nitrate has been observed to be in excess in MK008 since operation, however, drastic improvements have occurred since 2014; fluctuations have occurred since, however, currently nitrate concentrations are within the prescribed WRQO of 10 mg/L refer to Table 5-3. Chloride and sodium are observed to exceed WRQO in borehole MK002 since 2009; this is attributed to the local geology. Chloride and sodium in MK007 were observed to rise in 2004 and improved in 2006, they have since remained relatively stable up to date, with slight increases over time. Sulphate was found to fluctuate since operation, with a period of stability between 2006 and 2011, since 2011 trends were observed to fluctuate until stability was reached in 2015 and has remained constant since. Sulphate concentrations have remained within WRQO for all boreholes throughout operation.

Low sulphate concentrations are indicative of very minimal or no influence from mining. The shallow aquifer quality is of natural Karoo groundwater, found to have elevated alkalinity and chloride, typical of this area.

Water characterisation according to the Stiff Diagram (Figure 5-7) shows that the current water quality within this aquifer is indicative of bicarbonate type water. This type of water is characteristic of recently recharged groundwater.

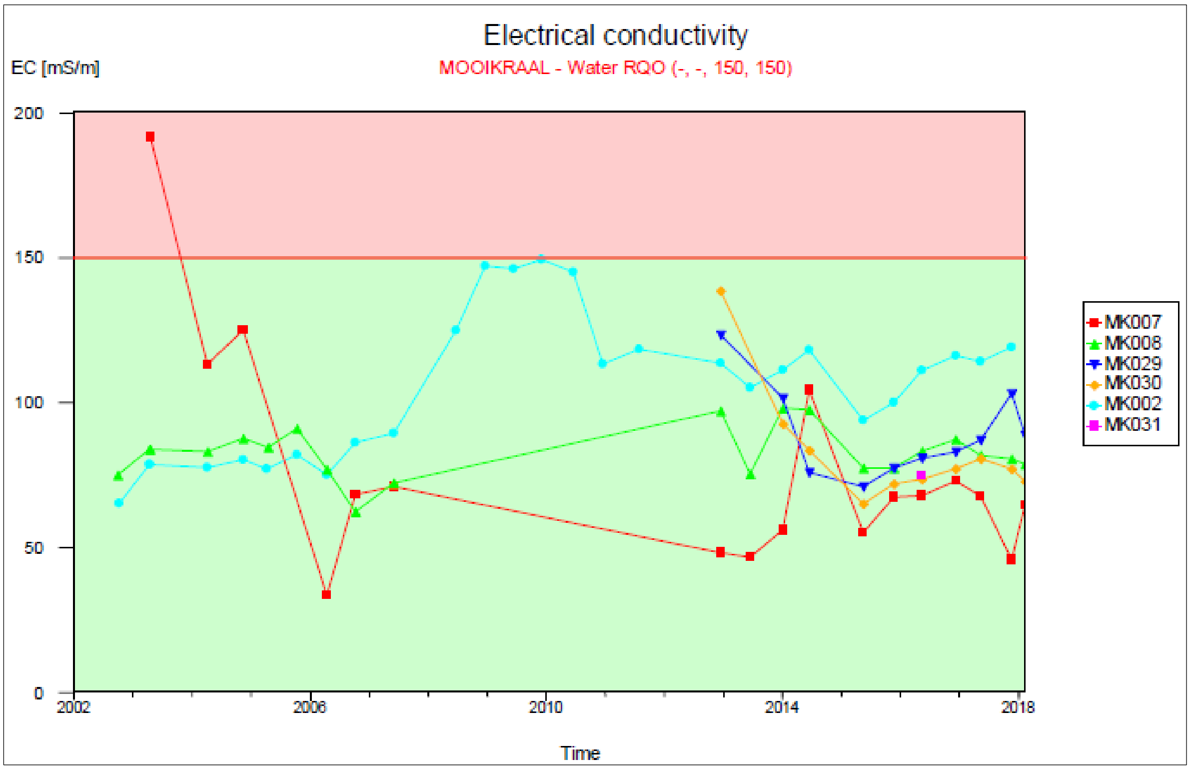

Figure 5-5: Electrical conductivity trends within the shallow aquifer

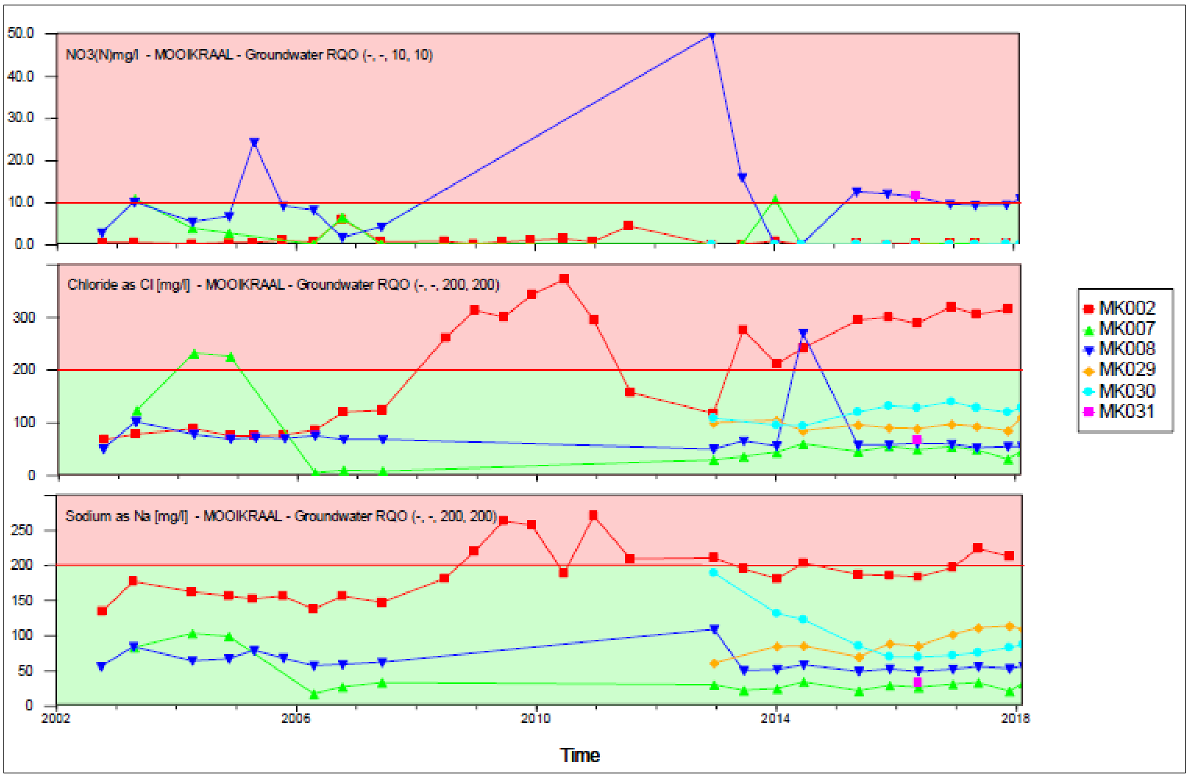

Figure 5-6: Nitrate, chloride and sodium concentration trends within the shallow aquifer

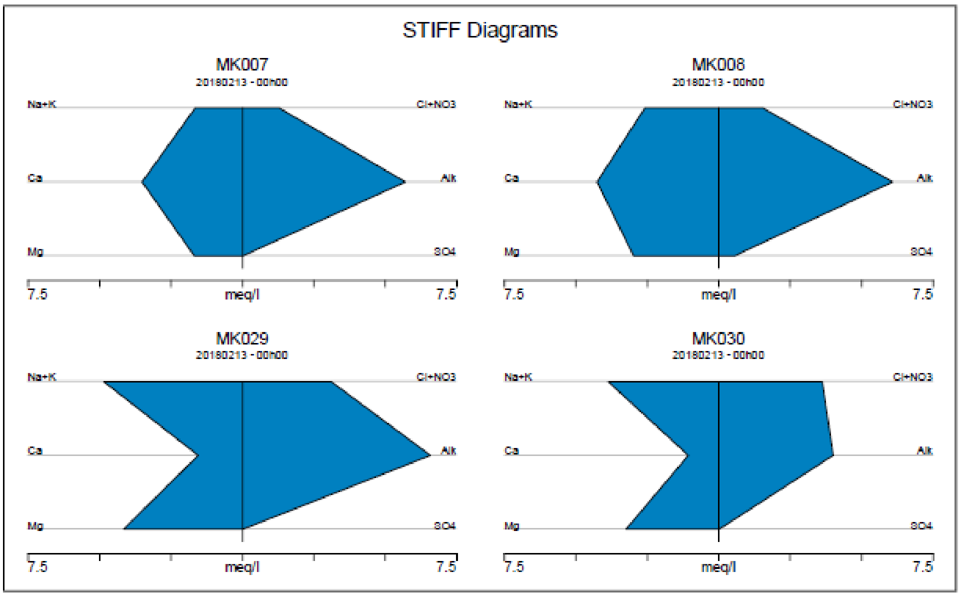

Figure 5-7: Stiff Diagram of the Shallow Aquifer within the Mooikraal Area

5.2.1.2 Intermediate Aquifer

The monitoring boreholes within this aquifer are listed below:

- MK001;
- MK004;
- MK005;
- MK009;
- MK010;
- MK011;
- MK019; and
- MK022.

The depths of the boreholes monitoring the intermediate aquifer range from 70 to 108 mbgl.

Water quality trends in the intermediate aquifer are presented in Figure 5-8. Electrical conductivity is observed to fluctuate for all the boreholes, showing relative improvements since 2014. Particularly erratic behaviour is observed for MK005 since 2005; this is attributed to surface water inflows into the borehole which is caused by an absence of a sanitary seal within the borehole. EC has remained within the WRQO for all the boreholes since monitoring was initiated (prior to the commencement of operation). Nitrate has been found to exceed the WRQO in boreholes MK004 (in years 2006, 2011, 2014 and 2016), MK009 (prior to operation till 2007 and again in 2014), and MK010 (2014 and 2015). However, improvements have been observed since then, remaining below the WRQO. Chloride is elevated, however, not in excess of the WRQO (with the exception of MK00 in 2009); the elevated concentration is attributed to underlying geology.

Sodium was found to be within the WRQO with the exception of MK010 (prior operation, showing a distinct rise in concentration in 2013 and drop below the WRQO in 2014).

Water characterisation according to the Stiff Diagram (Figure 5-9) shows that the dominating cations vary between magnesium, calcium and sodium, indicating mixed water with an influence of ion exchange with the host geology. The water is bicarbonate type and is typical of Karoo aquifer waters. Chloride is also mostly elevated due to ion exchange with the host geology.

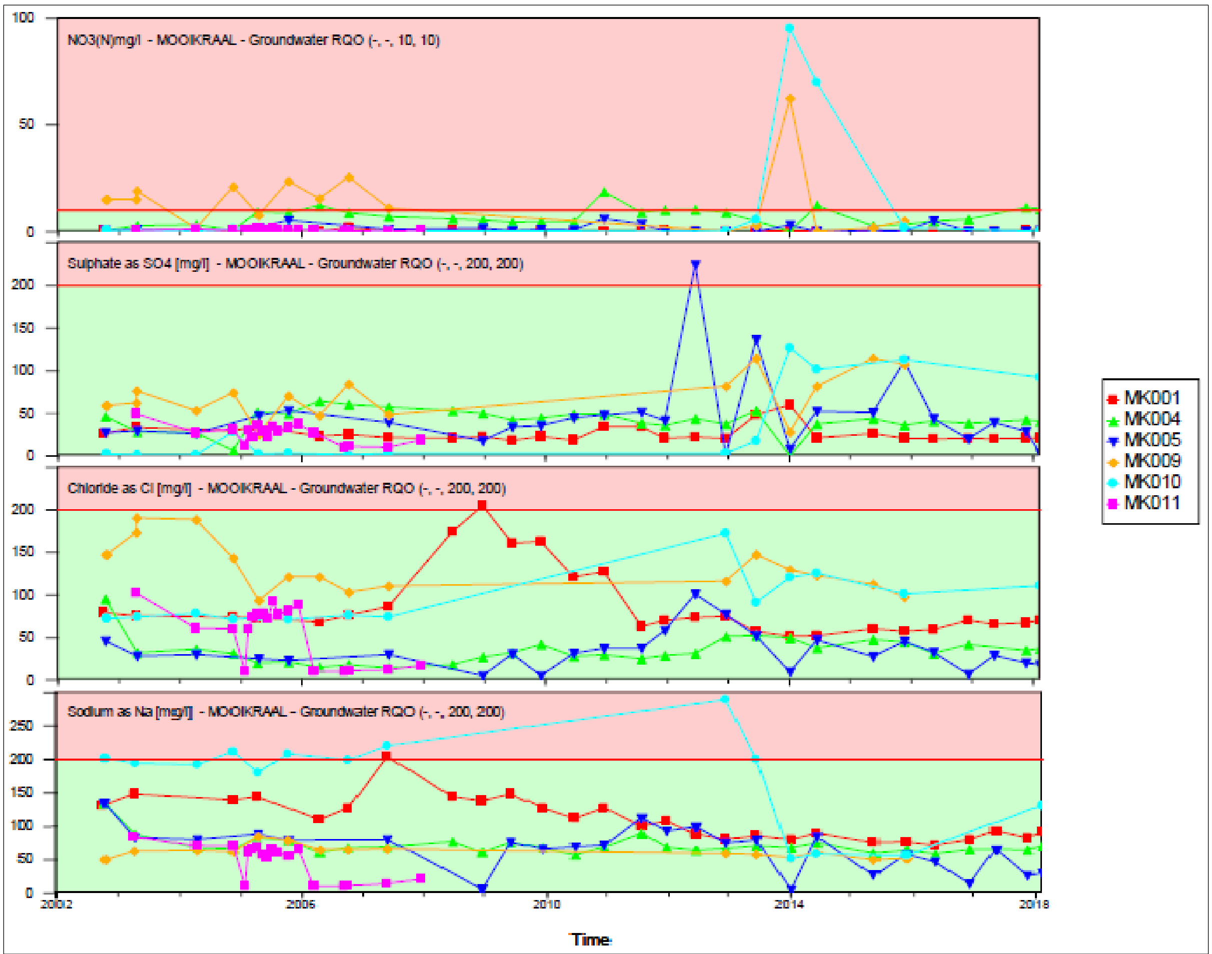

Figure 5-8: Nitrate, sulphate, chloride and sodium concentration trends within the intermediate aquifer

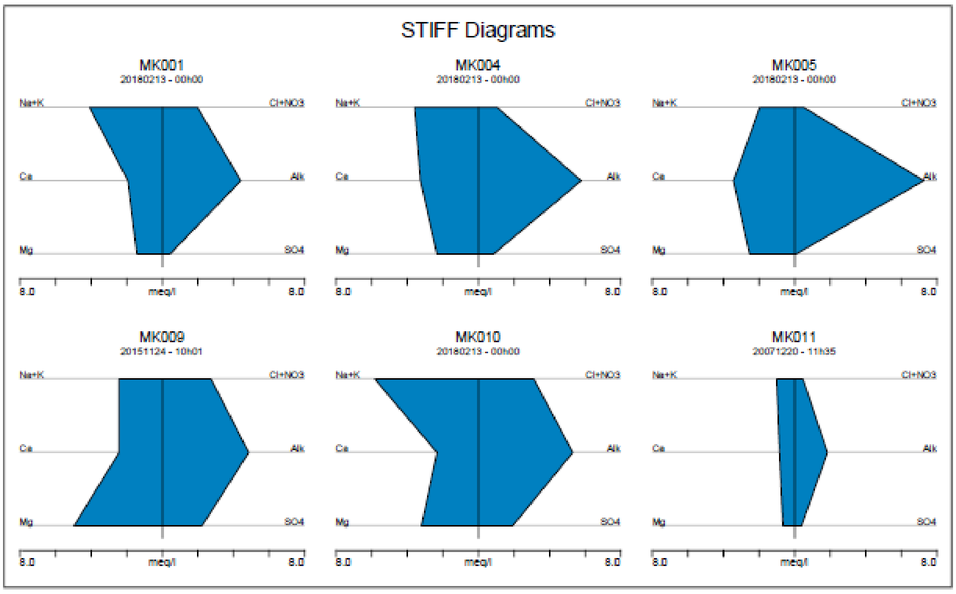

Figure 5-9: Stiff Diagram of the Intermediate Aquifer within the Mooikraal Area

5.2.1.3 Deep Aquifer

The monitoring boreholes within this aquifer are listed below:

- MK012;
- MK013;
- MK015;
- MK017;
- MK018;
- MK021;
- MK023;
- MK024;
- MK025; and
- MK026.

The deep aquifer boreholes range from a depth of 114 to 192 mbgl.

Water quality trends in the deep aquifer are presented in Figure 5-10 and Figure 5-11. Electrical conductivity is observed to be relatively stable, with the exception of MK012 and MK026 which have exceeded the WRQO. However, MK026 has been found to be below the WRQO since 2015. Nitrate has been observed to be in excess in boreholes MK012 and MK023 which initiated during the operation of the mine, drastic improvements have occurred since 2015, however, remain above the WRQO. Chloride exceeded the prescribed WRQO since 2005 in boreholes MK012 and 2007 in MK026. Sodium has been found to exceed the WRQO since monitoring commenced in borehole MK026.

Water characterisation according to the Stiff Diagram (Figure 5-12) shows mostly calcium/sodium-chloride signatures, indicating the influence of ion exchange with the host geology. No mining related influences are observed.

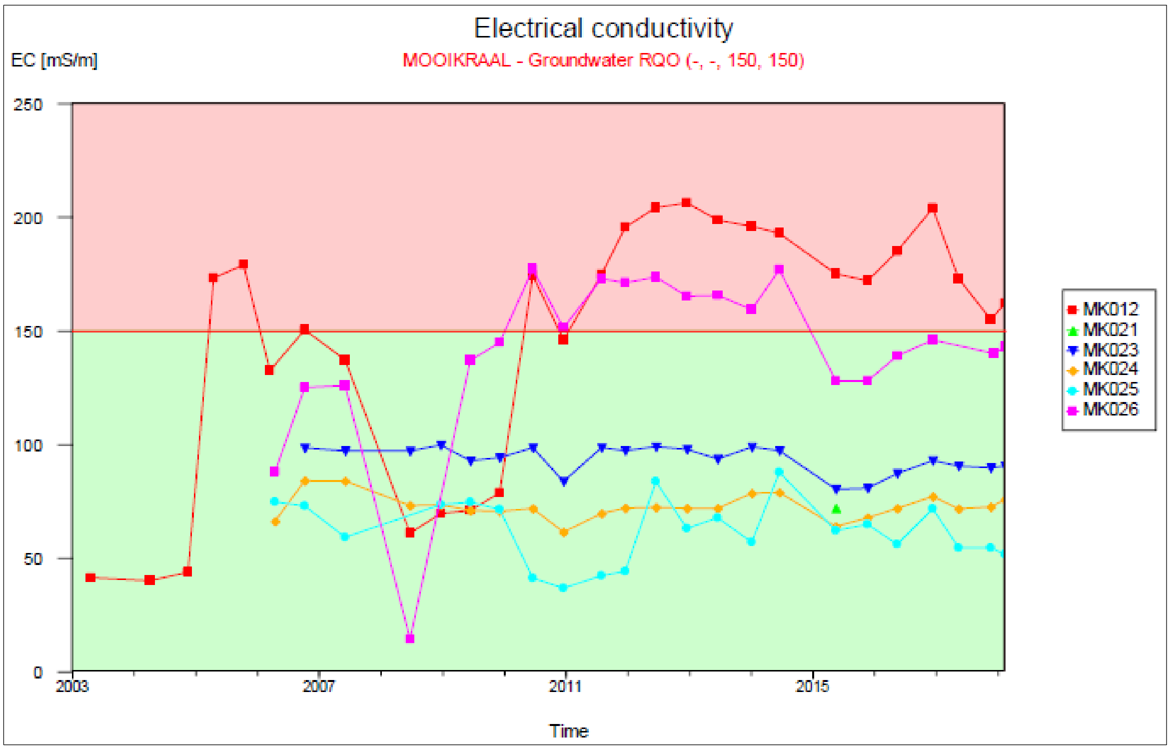

Figure 5-10: Electrical conductivity trends within the deep aquifer

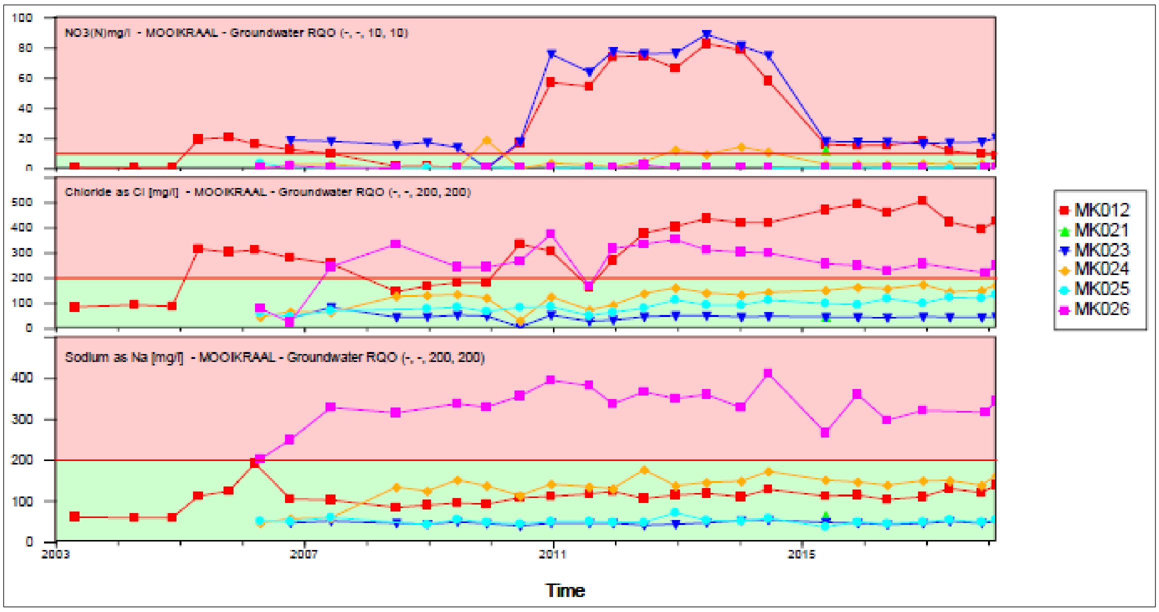

Figure 5-11: Nitrate, chloride and sodium concentration trends within the deep aquifer

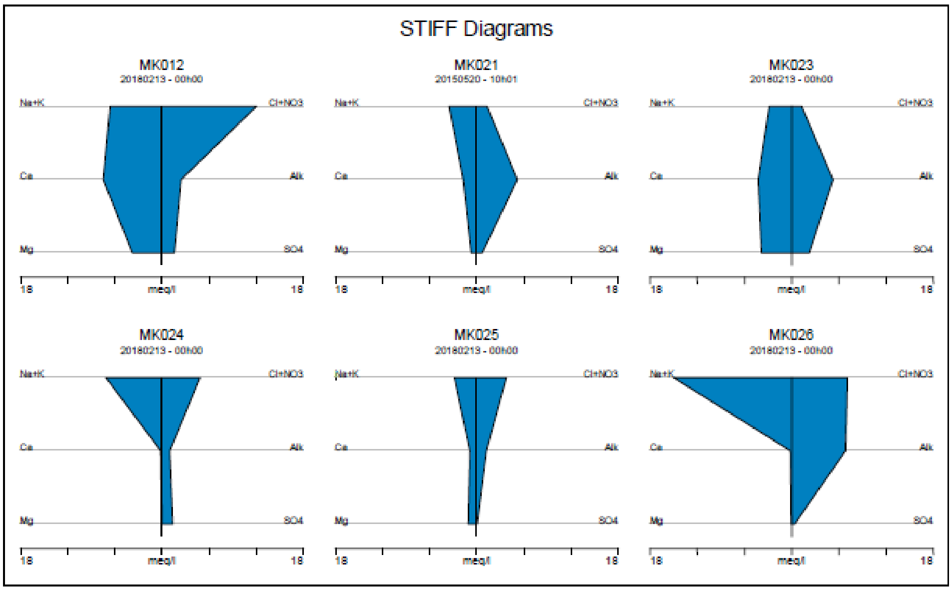

Figure 5-12: Stiff Diagram of the Deep Aquifer within the Mooikraal Area

5.2.1.4 Mine Aquifer

The monitoring boreholes within this aquifer are listed below:

- MK003;
- MK006;
- MK027; and
- MK028.

The mine aquifer boreholes range from a depth of 110 to 265 (mbgl).

Water quality trends in the mine aquifer are presented in Figure 5-13 and Figure 5-14. Electrical conductivity has exceeded the WRQO in borehole MK006 since the commencement of monitoring in 2002, prior to operation. Sodium has been found to exceed the WRQO since 2002 in borehole MK006. It has also been found to be in excess of the WRQO in MK028 since monitoring was initiated in 2017 therefore pre-mining condition is unknown at that location. All other parameters are within the WRQO showing relative stability.

Water characterisation according to the Stiff Diagram (Figure 5-15) shows the groundwater to be sodium bicarbonate; with MK006 having significantly high concentrations. This indicates the influence of ion exchange between the groundwater and the host geology, without any mining related influences.

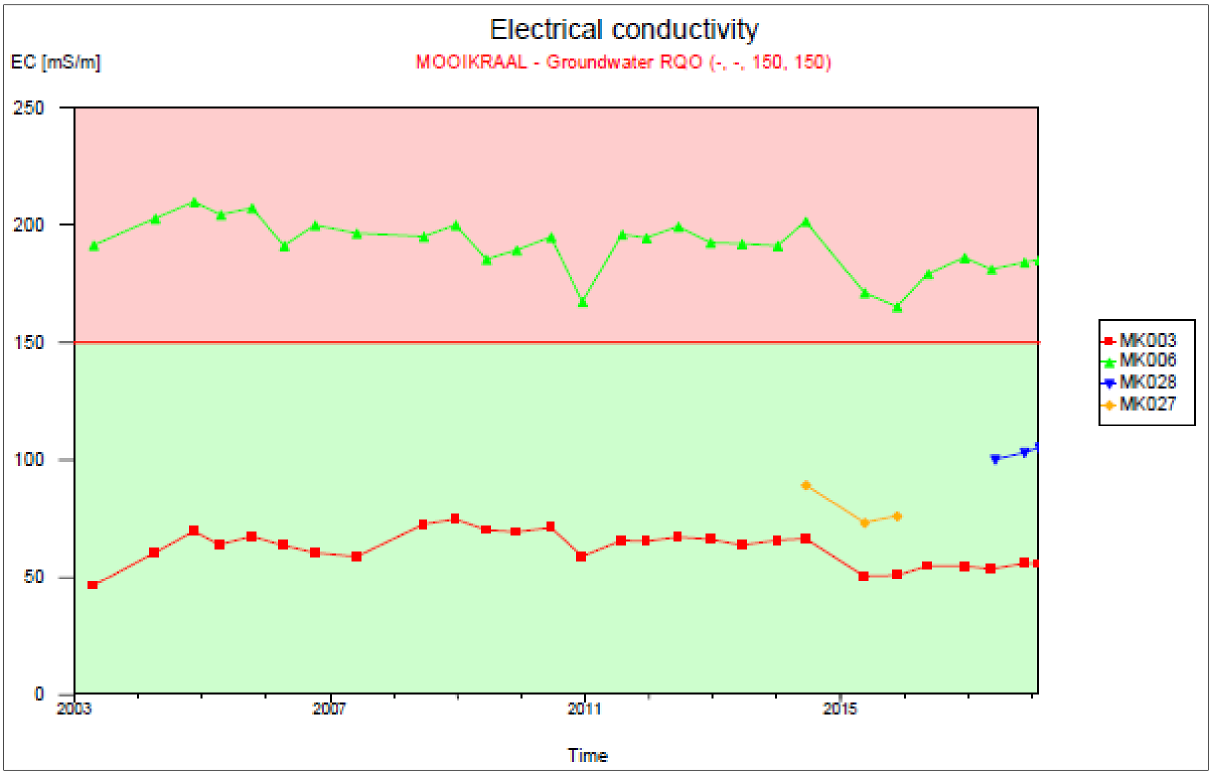

Figure 5-13: Electrical conductivity trends within the mine aquifer

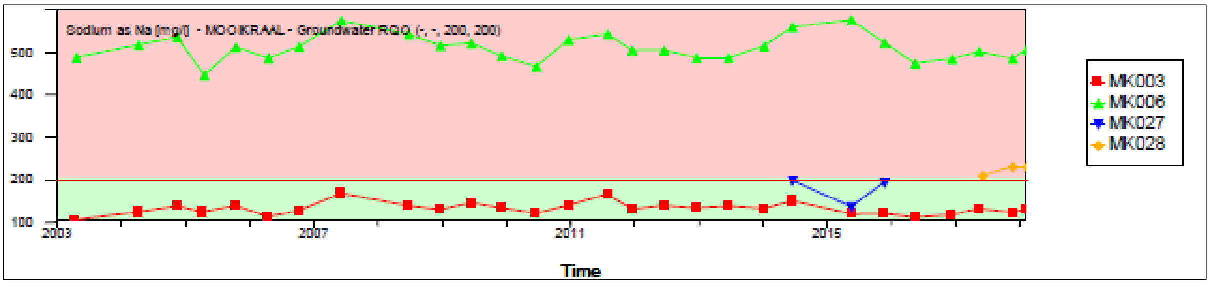

Figure 5-14: Sodium concentration trends within the mine aquifer

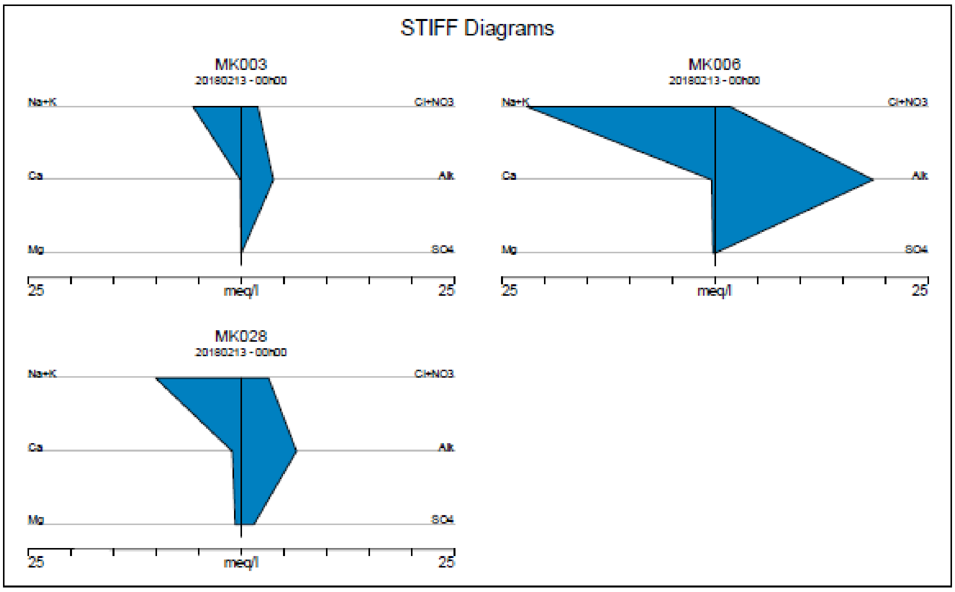

Figure 5-15: Stiff Diagram of the Mine Aquifer within the Mooikraal Area

5.2.2 Water quality at 3 Shaft

Shallow and deep boreholes were drilled at 3 Shaft in 2018. The shallow boreholes were drilled to a depth of 49 m and the deep boreholes drilled to a depth of 89 m; intercepting the shallow and intermediate aquifer respectively.

The comparison of the groundwater quality at 3 Shaft to the WRQO is listed in Table 5-4 and discussed in the subsections below.

Table 5-4: Groundwater quality compared against WRQO

Sample ID		pH	EC (mS/m)	Na (mg/l)	Mg (mg/l)	SO_4 (mg/l)	Cl(mg/l)	$N0_3$ (mg/l)	F (mg/l)	Ca (mg/l)
WRQO	**Date**	**5.5 to 9.5**	**150**	**200**	**100**	**200**	**200**	**10**	**1**	**150**
Shallow Aquifer										
MK034S	25/10/2018	7.88	31.6	27.1696	10.1413	1.7741	2.5994	-0.05	0.9073	29.2604
MK036S	25/10/2018	7.65	54.2	55.5129	14.9851	32.1358	18.2219	2.9985	0.1474	47.0192
MK037S	25/10/2018	7.09	36.5	19.3372	11.4156	4.756	4.5205	1.3127	0.0386	45.4591
Intermediate Aquifer										
MK034D	25/10/2018	9.91	33.6	73.8065	0.096	7.4179	6.3393	0.0625	0.1567	0.4762
MK035D	25/10/2018	7.72	39.1	33.5006	11.8544	4.6795	3.8764	0.5884	0.0352	41.3627
MK036D	25/10/2018	8.78	33.2	72.8309	0.9625	17.8878	5.8689	0.3757	0.1257	2.6423
MK037D	25/10/2018	8.19	30.2	57.249	2.7184	8.6359	5.7722	-0.05	0.0508	8.4472

5.2.2.1 Shallow Aquifer

The monitoring boreholes within this aquifer are listed below (drilled to a depth of 49 m):

- MK032S;
- MK034S;
- MK035S;
- MK036S; and
- MK037S.

All parameters were found to be within the WRQO therefore currently there are no mining related impacts found within the shallow aquifer (Table 5-4). According to the Stiff Diagram (Figure 5-16) the shallow aquifer is characteristic calcium - bicarbonate type water typical of recently recharged groundwater. This is typical of the shallow aquifer as it receives recharge, it is indicative of no influences from mining related impacts.

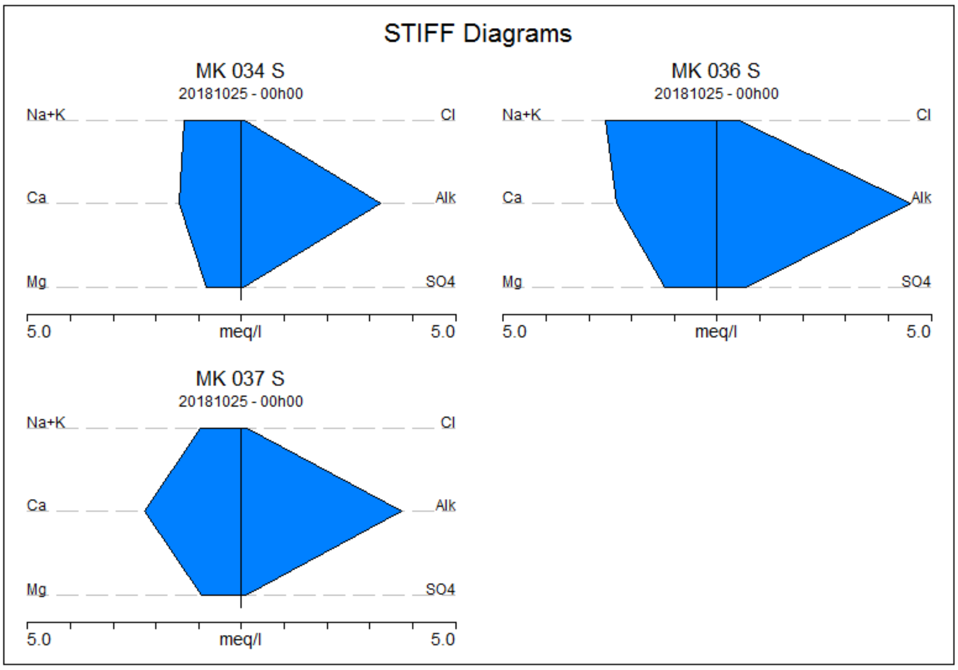

Figure 5-16: Stiff Diagram of the Shallow Aquifer within the 3 Shaft Area

5.2.2.2 Intermediate Aquifer

The monitoring boreholes within this aquifer are listed below (drilled to a depth of 89 m):

- MK032D;
- MK034D;
- MK036D; and
- MK037D.

As shown in the results of the shallow aquifer, the deep aquifer is found to be within WRQO. This is with the exception of the pH in MK034D (Table 5-4).

According to the Stiff Diagram found in Figure 5-17, the intermediate aquifer at 3 Shaft is characterised as sodium bicarbonate type. This type of water is indicative of mixing of long-resident water with recently recharged water, showing no indication of influence from mining related influences. Additionally, the high alkalinity of the water in the intermediate aquifer (ranging between 8.19 and 9.91) is likely a result of the ash backfilling in the mine voids of Sigma Defunct.

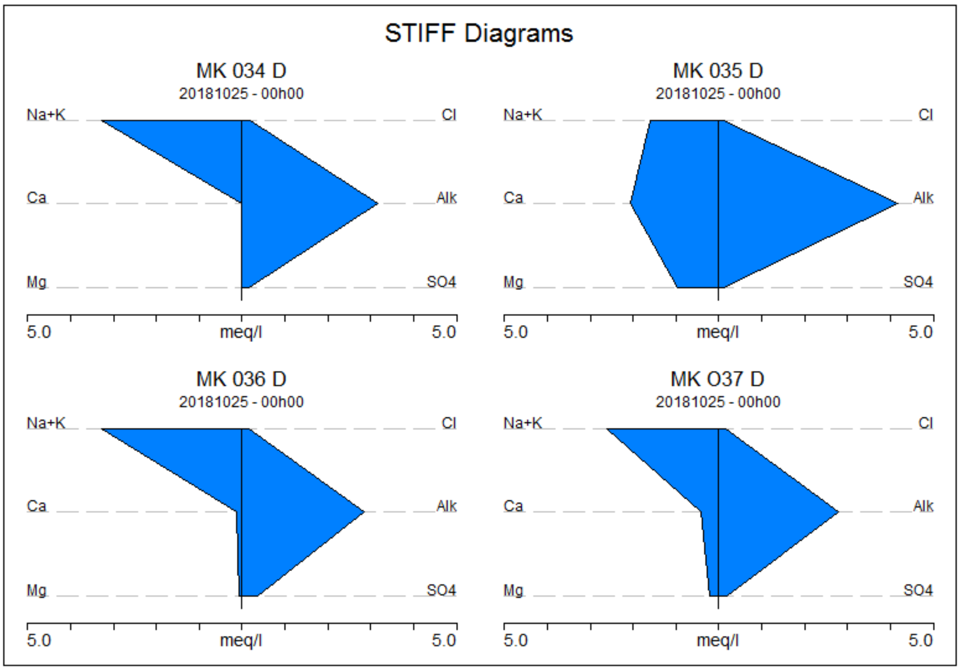

Figure 5-17: Stiff Diagram of the Intermediate Aquifer within the 3 Shaft Area

5.3 Groundwater Levels

5.3.1 Water levels at Mooikraal

5.3.1.1 Shallow Aquifer

Between the years 2008 to 2012, MK002 and MK008 water levels declined by approximately 20 and 7 metres respectively (Figure 5-18), whereas the water level in MK007 has increased. It has been observed, however, that since 2013 water levels have been relatively stable, with a distinct rise from 2016. This was attributed to heavy rainfall events that contributed largely to the groundwater recharge.

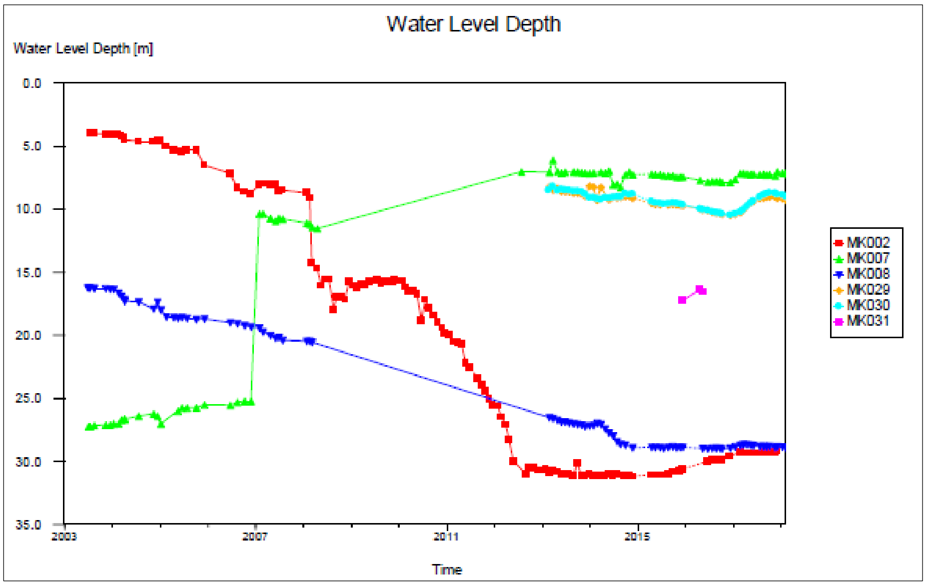

Figure 5-18: Groundwater levels measured at the shallow aquifer

5.3.1.2 Intermediate Aquifer

Water level trends at the intermediate aquifer are shown in Figure 5-19. The water level in boreholes MK009, MK011 and MK022 have been observed to fluctuate, however, generally seen as stable. MK022 is a water supply borehole for the adjacent dairy farm and the erratic water level behaviour is due to pumping.

The water levels in MK001 and MK010 indicate a declining trend since 2008. The decline in water level in these boreholes is a result of mine dewatering activities.

The water levels in MK004 and MK005 have been observed to be very erratic.

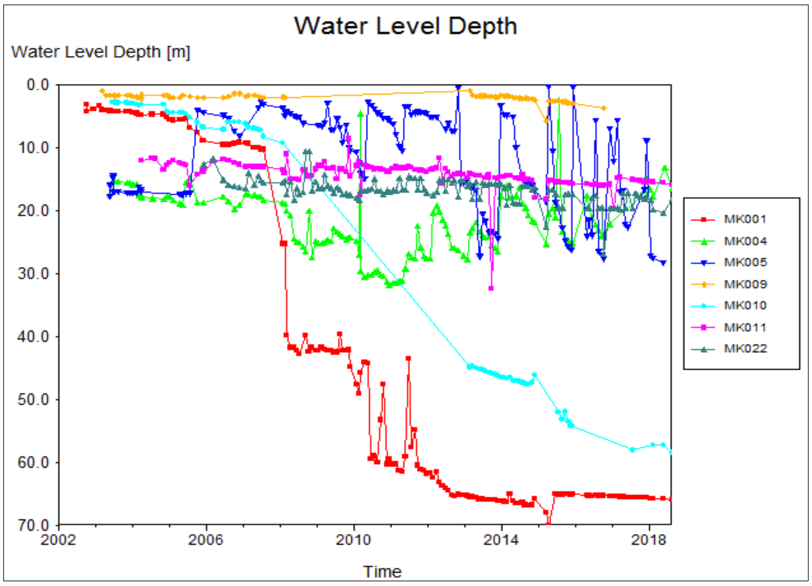

Figure 5-19: Groundwater levels measured at the intermediate aquifer

5.3.1.3 Deep Aquifer

The water level trends in the deep aquifer are illustrated in Figure 5-20. The water level of boreholes MK021 and MK025 have been relatively stable since monitoring commenced. MK021 experienced a rise in February 2017.

The overall water levels in boreholes MK023, MK024 and MK026 indicated a declining trend since 2008. These declining trends can be associated with mine dewatering. However, the water levels in boreholes MK024 and MK026 rose approximately 10 m between 2014 and 2015 (from the ranges of approximately 80 to 70 mbgl), and have since relatively stabilized.

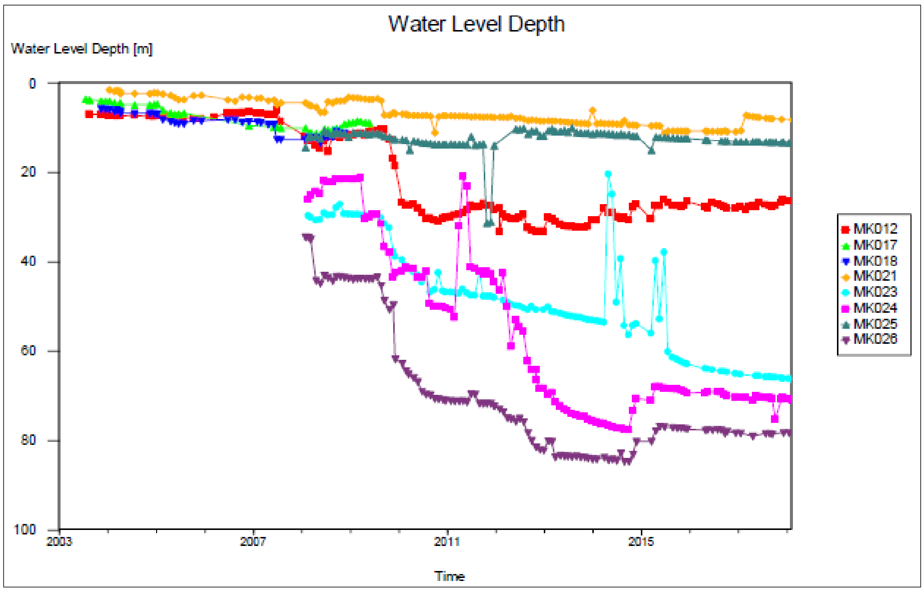

Figure 5-20: Groundwater levels measured at the deep aquifer

5.3.1.4 Mine Aquifer

The mined out area where boreholes MK027 and MK028 are located is currently being utilised for water storage. The water levels for MK027 and MK028 have fluctuated only slightly since monitoring at these locations commenced (2013), suggesting that the water level in the mined out area remains stable.

The water level of borehole MK006 at the western area of the mine indicates a continuous rising trend. The water level of borehole MK003 at the north-eastern area indicated a rising trend until 2008, since then the water levels has declined slightly and since 2012 has stabled.

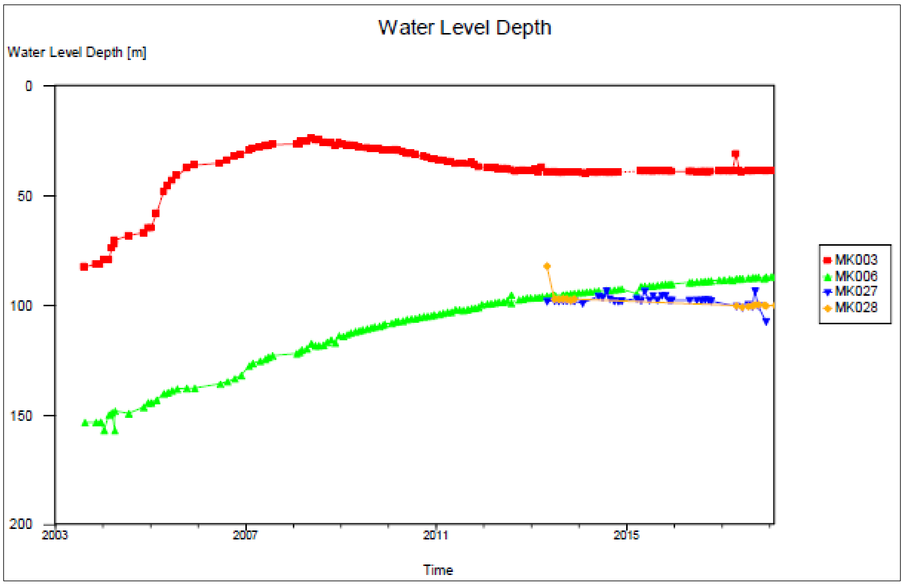

Figure 5-21: Groundwater levels measured at the mine aquifer

5.3.2 Water levels at 3 Shaft

5.3.2.1 Shallow Aquifer

Groundwater levels measured at the shallow aquifer boreholes are listed in Table 5-5.

Table 5-5: Groundwater levels measured at the shallow aquifer

Borehole ID	Water level (mbgl)
MK034S	31.63
MK035S	No water level measured. Found to be muddy
MK036S	24.74
MK037S	4.73

From the water level groundwater flow direction at 3 Shaft is found to be from east to west.

5.3.2.2 Intermediate Aquifer

Groundwater levels measured at the intermediate aquifer boreholes are listed in Table 5-5.

Table 5-6: Groundwater levels at the intermediate aquifer

Borehole ID	Water level (mbgl)
MK034D	32.43
MK035D	33.45

Borehole ID	Water level (mbgl)
MK036D	25.81
MK037D	38.27

5.3.3 Total Concentration Analysis Mooikraal

Coal samples at Mooikraal were obtained and Total Concentration Threshold (TCT) was tested. The samples labelled with the prefix ''SEC'' refers to specific sections underground, whereas the Mooikraal sample represents a composite sample taken along surface belts.

Total Concentrations were determined by *aqua regia* digestion to provide a measure of the elements in the solid-phase. Although not all elements found in the solid-phase will dissolve, these levels provide the elemental composition of the rocks and can be used as a screening tool to detect constituents which occur in anomalously high concentrations under unfavourable geochemical conditions.

The results are compared to threshold concentrations published in the NEM:WA Waste Classification and Management Regulations (Figure 5-6):

- TCT0 limits based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010);
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
- TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

It is important to note that the total concentration values discussed in this section are different from the leachable concentration. Leachable concentrations assessments should be conducted to provide a more accurate prediction on the elements expected to be released from the host rocks.

The analysis shows that TCT0 threshold values of Ba, Cr Cu and Pb are exceeded in majority of the samples. These parameters form part of the quarterly monitoring currently on-going with the exception of Ba, it is recommended to be included as part of analysis going forward.

5.3.4 3 Shaft

No geochemical assessments have been conducted on the coal to be stocked at 3 Shaft therefore little is known about the contamination potential of the material. This is addressed in Section 8.3.2.

Table 5-7: TCT comparison threshold concentrations

Parameter	Unit	TCT 0	TCT1	TCT2	Mooikra al	SECT65_ A	SECT 65_B	SECT69_ C	SECT69_ D	SECT69_ E	SECT67_ F	SECT67_ G	SECT 67_H
As, Arsenic	mg/kg	5.8	500	2000	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
B, Boron	mg/kg	150	15000	60000	37.71	24.29	45.11	28.85	74.43	39.33	51.59	36.29	20.41
Ba, Barium	mg/kg	62.5	6250	25000	102.4	114.6	58.09	114.9	107	109	117.2	137.4	185.4
Cd, Cadmium	mg/kg	7.5	260	1040	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
Co, Cobalt	mg/kg	50	5000	20000	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	4.95	4.42	<4.2
Cr (IV), Chromium (IV)	mg/kg	6.5	500	2000	<4.2	5.17	<4.2	9	<4.2	4.415	4.45	<4.2	<4.2
Cu, Copper	mg/kg	16	19500	78000	24.41	12.46	17.02	21.98	8.21	40.96	18.47	15.98	25.78
Mn, Manganese	mg/kg	1000	25000	100000	80.58	52.27	142.8	16.63	88.09	24.49	75.28	45.72	15.14
Mo, Molybdenum	mg/kg	40	1000	4000	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
Ni, Nickel	mg/kg	91	10600	42400	11.94	12.77	10.62	16.78	4.9	<4.2	53.74	29.21	<4.2
Pb, Lead	mg/kg	20	1900	7600	28.8	54.37	42.74	30.93	11.04	40.1	26.4	8.5	15.73
Sb, Antimony	mg/kg	10	75	300	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
Se, Selenium	mg/kg	10	50	200	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
V, Vanadium	mg/kg	150	2680	10720	20.3	6.13	11.34	20.51	15.14	30.42	26.71	5.84	7.732
Zn, Zinc	mg/kg	240	160000	640000	31.92	30.55	59.85	79.18	20.59	23.52	18.4	15.55	24.2

6 Waste Classification for the Waste Rock Dump at Mooikraal

Results of the TC and LC analysis are shown in Table 6-1 and Table 6-2, respectively. The results are compared to threshold concentrations published in the NEM: WA Waste Classification and Management Regulations.

6.1 Total Concentration Results

The analysis shows that:

- TCT0 threshold values of Ba and Cu are exceeded for both samples from the waste rock material; and
- Based on the outcome of the TCT assessment only; more than one element exceeds the TCT0 limits therefore the material according to the regulations is classified as Type 3 waste, requiring a Class C liner.

6.2 Leachable Concentration Results

The analysis shows that none of the samples leached above the LTC0 threshold. Therefore, based on the LCT results only; the residue from all samples is classified as Type 4, that need to be disposed in an area with a Class D liner.

6.3 Classification

Both TC and LC analysis are used in conjunction with one another therefore the waste rock material is classified as Type 3 waste, requiring a Class C liner or system performing in a similar way. This is based on the TC analysis outcomes.

The WRD is not lined, as it consists of discard rock that was removed when the box cut was removed to form the Mooikraal adit, the stockpile is not in use, no further deposition of rock occurs.

The WRD has been authorised in Mooikraal EMP, the intention is to amend the EMP, hereby doing so, Mooikraal has undertaken a waste classification of the discard rock, to inform monitoring and management actions, as well as decommissioning activities. It further stands to reason that other requirements such as a geotechnical investigation and design of pollution barrier system cannot be achieved as the WRD is already in present.

Additionally, the WRD was constructed in 2002, prior to the promulgation of the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits (2015) under NEM:WA (2008). The law therefore does not apply retrospectively.

Table 6-1: TCT classification

Parameter	Unit	TCT0	TCT1	TCT2	WRDS1	WRDS2
As, Arsenic	mg/kg	5.8	500	2000	0.800	0.400
B, Boron	mg/kg	150	15000	60000	107	36
Ba, Barium	mg/kg	62.5	6250	25000	144	584
Cd, Cadmium	mg/kg	7.5	260	1040	2.80	4.00
Co, Cobalt	mg/kg	50	5000	20000	<10	<10
Cr total	mg/kg	46000	800000	N/A	108	185
Cu, Copper	mg/kg	16	19500	78000	17	19
Hg, Mercury	mg/kg	0.93	160	640	<0.400	<0.400
Mn, Manganese	mg/kg	1000	25000	100000	137	330
Mo, Molybdenum	mg/kg	40	1000	4000	<10	<10
Ni, Nickel	mg/kg	91	10600	42400	42	<10
Pb, Lead	mg/kg	20	1900	7600	18	14
Sb, Antimony	mg/kg	10	75	300	<0.400	<0.400
Se, Selenium	mg/kg	10	50	200	<0.400	<0.400
V, Vanadium	mg/kg	150	2680	10720	81	15
Zn, Zinc	mg/kg	240	160000	640000	34	65
Cr (IV), Chromium (IV)	mg/kg	n/a	n/a	n/a	<5	<5
F, Fluoride total	mg/kg	n/a	n/a	n/a	196	396
CN total, Cyanide total	mg/kg	n/a	n/a	n/a	<0.5	<0.5

Table 6-2: LCT classification

Parameter	Unit	LCT0	LCT1	LCT2	LCT3	WRDS1	WRDS2
As, Arsenic	mg/l	0.01	0.5	1	4	<0.001	0.003
B, Boron	mg/l	0.5	25	50	200	0.235	0.037
Ba, Barium	mg/l	0.7	35	70	280	0.105	<0.025
Cd, Cadmium	mg/l	0.003	0.15	0.3	1.2	<0.003	<0.003
Co, Cobalt	mg/l	0.5	25	50	200	<0.025	<0.025
Cr total	mg/l	0.1	5	10	40	<0.025	<0.025
Cr (IV), Chromium (IV)	mg/l	0.05	2.5	5	20	<0.010	<0.010
Cu, Copper	mg/l	2	100	200	800	<0.010	<0.010
Hg, Mercury	mg/l	0.006	0.3	0.6	2.4	<0.001	<0.001
Mn, Manganese	mg/l	0.5	25	50	200	<0.025	<0.025
Mo, Molybdenum	mg/l	0.07	3.5	7	28	<0.025	<0.025
Ni, Nickel	mg/l	0.07	3.5	7	28	<0.025	<0.025
Pb, Lead	mg/l	0.01	0.5	1	4	<0.010	<0.010
Sb, Antimony	mg/l	0.02	1	2	8	0.001	<0.001
Se, Selenium	mg/l	0.01	0.5	1	4	<0.001	0.002
V, Vanadium	mg/l	0.2	10	20	80	<0.025	<0.025
Zn, Zinc	mg/l	5	250	500	2000	<0.025	<0.025
Chloride as Cl	mg/l	300	15000	30000	120000	4	<2
Sulfate as SO_4	mg/l	250	12500	25000	100000	35	15
Nitrate as N	mg/l	11	550	1100	4400	<0.1	<0.1
F, Fluoride	mg/l	1.5	75	150	600	0.3	<0.2
CN total, Cyanide total	mg/l	0.07	3.5	7	28	<0.02	<0.02

7 Numerical Model

A numerical model was developed by IGS (2018) for Mooikraal and the model outcomes are summarized in this chapter. The model was developed to predict the potential impact posed by the underground mining and associated activities with regards to groundwater flow, mine inflows and possible decant over the period depicted in Figure 7-1. It is important to note that the groundwater model was conservative with regards to the groundwater flow and contamination plume migration; therefore the results presented are a worst-case scenario for the potential impacts to the surface water and shallow aquifer.

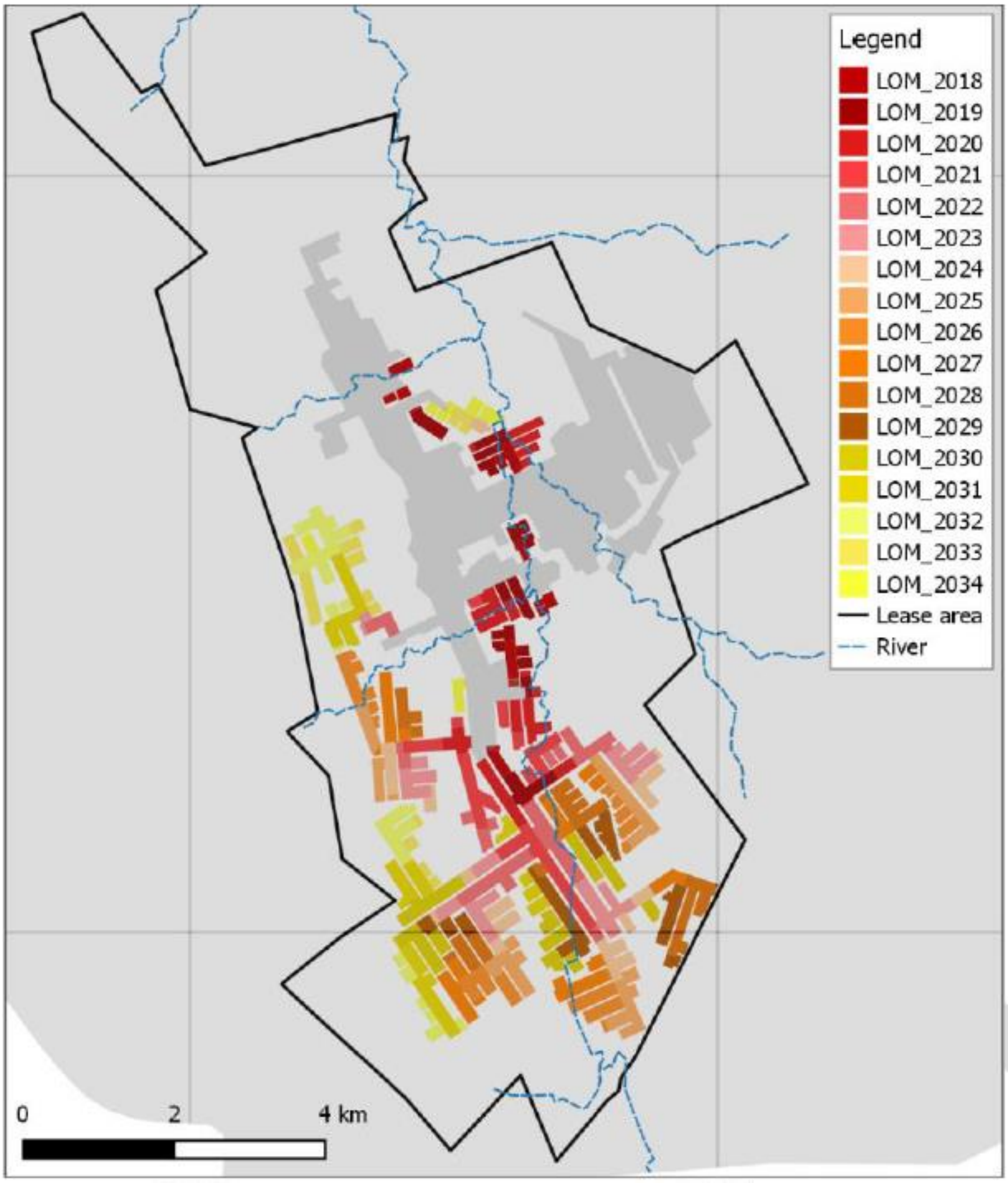

Figure 7-1: Life of Mine (IGS, 2018)

7.1 Model Setup

The model domain was defined by the western, southern and eastern boundary of the catchment divide of C23B quaternary catchment, while the northern boundary is defined by tributaries flowing towards the Kromelmboogspruit.

The hydrostratigraphic units (and the properties) incorporated into the model are those discussed in Section 5.1. A simplified image is shown in Figure 7-3. Monoclines structures as described in Section 3.4 were also include into the model.

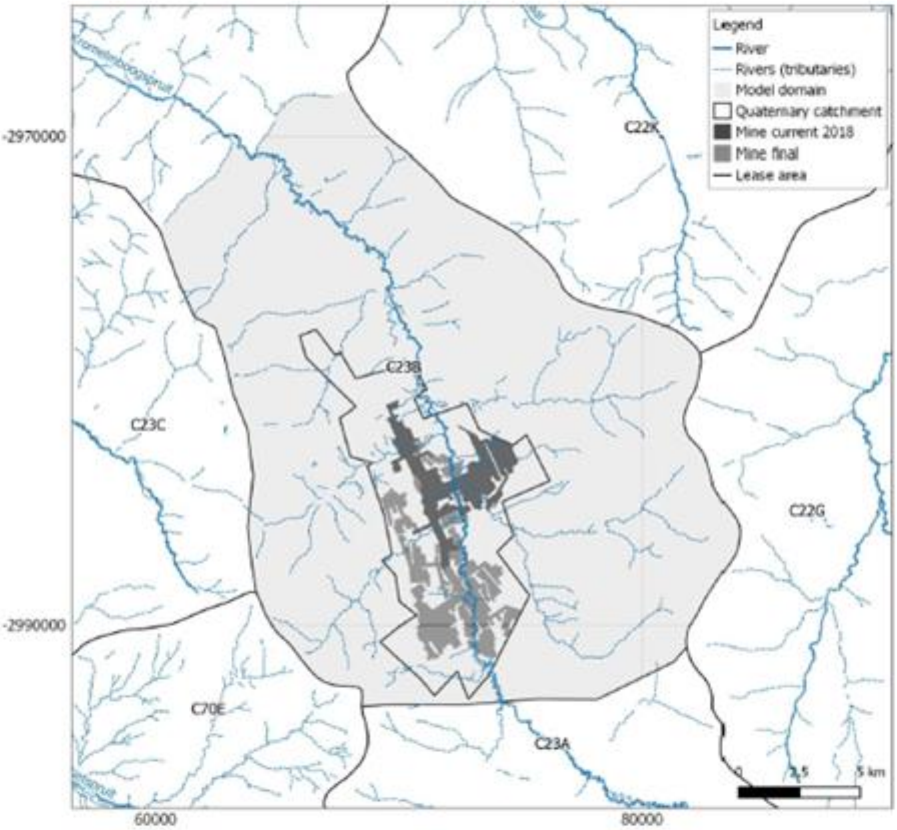

Figure 7-2: Model domain

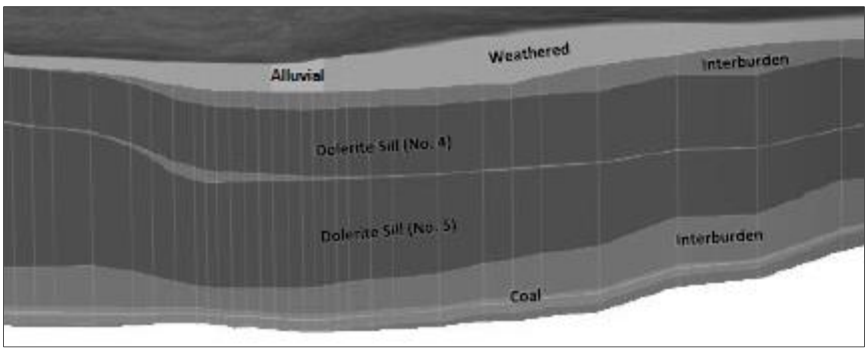

Figure 7-3: Simplified hydrostratigraphic units

7.2 Model Calibration

Model calibration was conducted to create the best possible representation of site conditions within the constructed numerical model. This task provides for predictive results that are within a reasonable range. Calibration was conducted by altering the aquifer properties (i.e. hydraulic conductivity, porosity, storativity and recharge) in order to achieve good correlation between observed water levels generated within the model and water levels measured on site.

Steady state calibration was conducted using groundwater levels measured during 2002 and 2003, before dewatering commenced. Transient state calibration was conducted using water levels measures and dewatering rates during the operational years from 2004 to date (2018).

7.3 Operational Phase

Modelling of the operational phase was initially simulated from 2004 to 2018 this was done in order to compare model results to observe site conditions over the previous years and calibrating the model according to the best fit of the two measurements. The result of this task is a model of increased accuracy. Future operations were then simulated over a life of mine that extends from 2018 to 2034 (anticipated life of mine, LOM), showing the impacts of mining to the groundwater environment.

7.3.1 Groundwater Flow

Future groundwater flow predictions simulated between 2018 and 2034 yield the following results:

- The dewatering rate is presented in Figure 7-4. The simulated rate and total volume show large steps because the LOM plan was simulated per year. Due to the nature of scenario simulation, the model is conservative and is expected to overestimate the required dewatering rates, simulations incorporated roof collapse therefore promoting maximum groundwater inflows. An average of 50 ML/d, reaching 350 ML/d at an absolute maximum for dewatering recommended (Figure 7-4).
- The modelling results show that dewatering impacts are observed at depths within the mine and only slightly affected upper shallow water table. This is confirmed by measured groundwater levels within monitoring boreholes that remain stable or are only slightly affected in spite of being located in close proximity of the active mining.
- There are monocline structures within the western parts of Mooikraal. The monocline structures act as preferential flow pathways. These structures were conceptualised to not penetrate the dolerite sills because their formation is understood to have taken place prior the sill intrusions. Thus, the dolerite sills restrict the extent of the drawdown to the immediate area.
- The model simulates the groundwater level above the underground mine (near the decline shaft; where monocline structures that act as vertical preferential pathways

are prevalent) falling below the dolerite sill by 2025. This could potentially change the aquifer below the dolerite sill from confined to unconfined, potentially altering the response of the aquifer and the mine inflow rates.

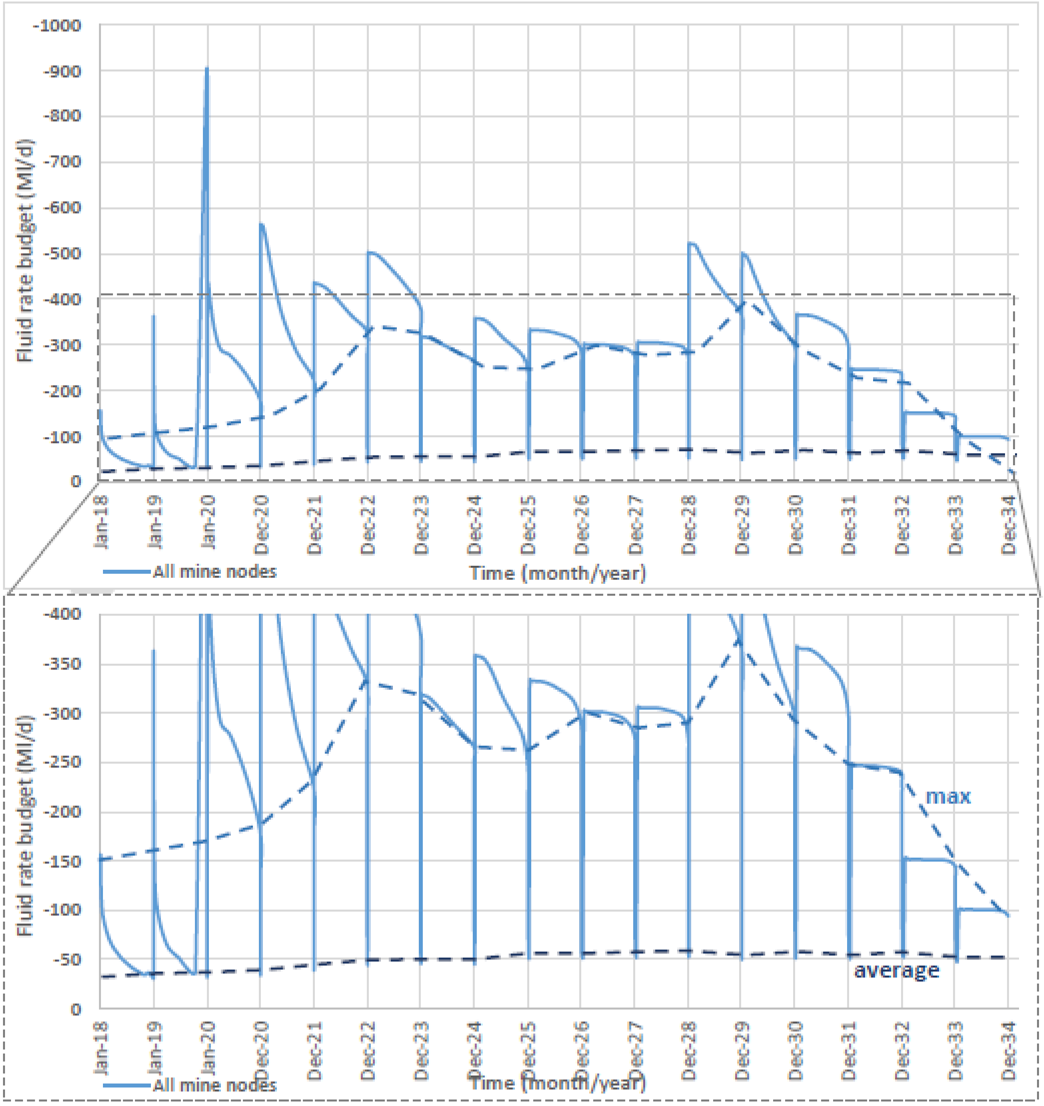

Figure 7-4: Scenario-based simulation of the rate of dewatering for the LOM underground mine voids (2018 – 2034) (IGS, 2018)

7.4 Post Closure Phase

7.4.1 Contamination Plume

The transport of potential contaminants was found to be controlled by the depth of the coal seam, thickness of the overlying dolerite sills and the presence of vertical preferential pathways.

However, at locations where the coal seam is shallow, the dolerite sill is thin and there are vertical preferential pathways such as the decline shaft and monoclines structures. It is at these locations that there is a potential contaminant risk to the shallow aquifer and surface water bodies.

7.4.2 Decant

The post-mining model indicated groundwater levels will not fully recover within a 300 year simulation period. The slow recovery, in spite of the underground mine voids being fully flooded, is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill. A steady state model was subsequently used to model the fully recovered water levels imposing an equilibrium state and infinite time. The steady state model indicated that the northern boundary of the Mooikraal underground mine is the area where decant is most likely to occur (Figure 7-5) due to the highest hydraulic pressure coupled with the lowest topography. The model estimated a decant rate of 2.5 m^3/d, but this value should be considered only as an initial estimation due to the uncertainty associated with predicting flow rates far into the future based on the current groundwater and climatic conditions.

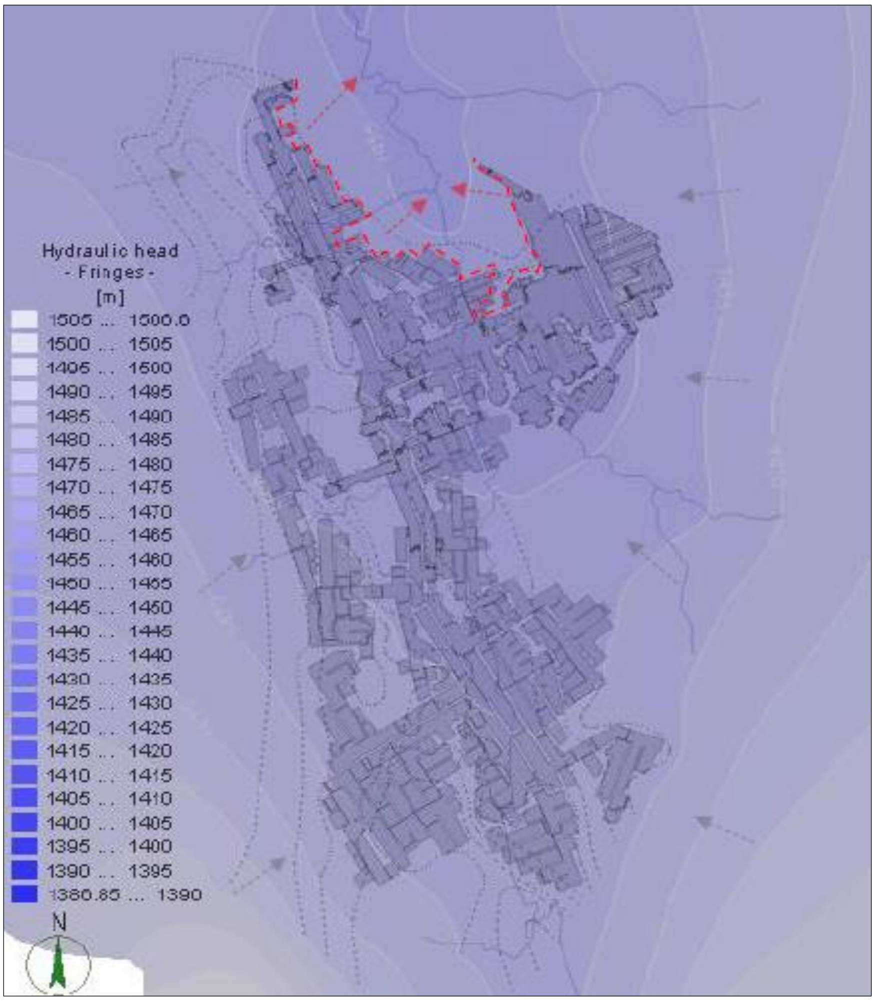

Figure 7-5: Potential decant area (indicated in red)

8 Impact Assessment and Mitigation Plans

8.1 Introduction

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

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

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

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

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

The matrix calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 8-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 8-3).

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

Table 8-1: Impact assessment parameter ratings

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

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

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

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

Table 8-2: Probability/consequence matrix

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

Table 8-3: Significance rating description

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

8.2 Project Facilities Assessed

The project facilities and/or activities that are relevant to the groundwater impact assessment are presented in Table 8-4.

Table 8-4: Description of activities to be assessed

Project Phase	Project Activity	Project Structures
Mooikraal		
Operation	Groundwater removal from the underground mine	Underground mine void
	Contamination generation	WRD
Mine Decommissioning and Closure	Contamination generation and decant	Underground mine void
3 Shaft		
Construction	Demolition and reconstruction of infrastructure	Primary Plant, conveyor belt and stormwater management system upgrade
Operation	Contamination generation	Stockpile

8.3 Impact Overview

8.3.1 Mooikraal Activities and Associated Impacts

The coal seam mined at Mooikraal lies below the water table and intermediate aquifer. As such due to groundwater ingress into the underground mined out voids, the groundwater is pumped from the working sections, for productive and safety purposes, to underground dams, where the underground water is contained behind seal walls. Mooikraal has an approved water use license which authorises the removal of underground water to the pollution control dams at a rate of 9 524 000 m^3/annum or 25.6 Ml/day.

The abstraction of the underground water may potentially impact on the groundwater environment, by lowering the water level by creating a cone of depression around the mined out area, reducing the local aquifer quantity (levels)

A contamination plume migrating away from the mining void is not expected during operation. This is due to the continued removal of groundwater from the mine creating a groundwater gradient that promotes groundwater flow to be towards the mine void during operation. Groundwater quality trends observed since operations commenced in 2005 shows evidence of this, refer to Section 5.2.

The WRD at Mooikraal is a potential source of contamination; once material is exposed to oxygen and rainfall, leachate generating reaction may occur and introduce contamination into the groundwater environment via seepage. Total concentration analysis identified Ba and Cu as potential elements of concern however these results are a worst case scenario. Leachable concentration analysis, which is the most representative of the expected leachate at the site, shows no concern within regards to the leachate expected to emanate from the dump.

During the closure phase, the underground mine void may be a potential source of contamination. The risk of groundwater contamination is likely to occur as groundwater removal from the underground void ceases. The groundwater will then migrate towards reaching recovery. During this process the potential contamination plume may migrate within the local aquifer(s), beyond the project area.

Additionally decant may occur due to hydraulic head potentially being above the topographic elevation.

8.3.2 3 Shaft Activities and Associated Impacts

The following activities which are under assessment will be conducted at 3 Shaft:

- Demolition of the existing conveyor belt, crushing facility and coal bunker which is currently situated within a wetland at the 3 Shaft (primary plant); and
- Relocation/reconstruction the primary plant (crusher facility) on the stockpile area (to remain within the 3 Shaft footprint);

The demolition of the existing conveyor belt, crushing facility and coal bunker (not lined) which are currently situated within a delineated wetland, will reduce the risk to the groundwater environment as the potential source of contamination will be gradually depleted throughout this process. This is a positive action with regards to impact to the groundwater environment.

Relocation of the primary plant facilities onto the stockpile area, introduces the potential of leachate generation at this new location. As rainwater infiltrates through the coal, metals could be dissolved, and leachate may form. The leachate may then seep to the groundwater and migrate by advection within the groundwater environment. However, the stockpile area is lined with cement and groundwater quality has shown no contamination since operation (in the 1950’s); therefore the vulnerability of the groundwater environment in this area is not a concern.

8.4 Impact Assessment – Construction Phase

8.4.1 Mooikraal Activities and Associated Impacts

No new construction activities are anticipated at Mooikraal as the colliery has already been established.

8.4.2 3 Shaft Activities and Associated Impacts

During the construction phase, site clearance (where required) and construction activities are expected to take place above the water table. The local water table ranges from 4.73 to 31.63 mbgl. No impact on the groundwater is expected if the activities take place above the water table. Should there be a need to excavate below the water table, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

The demolition of the infrastructure within the wetland will reduce the risk to the groundwater environment as the potential source of contamination will be gradually depleted throughout this process. This is a positive action with regards to impact to the groundwater environment.

8.4.2.1 Management Actions and Targets

- Restrict construction activities to be limited to areas above the water table; and
- If that is not possible, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

The significance rating of the potential impacts of groundwater contamination during the decommissioning and post-closure is provided in Table 8-10.

Table 8-5: Potential impacts of site clearing and construction during the construction phase at 3 Shaft

Activity & Interaction: Site clearing and construction			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Site clearing and construction for the development of the plant area and associated infrastructure through the demolition of infrastructure within wetland, removal of the top soil and weathered rocks, may result in localised dewatering activities if excavation is required below the water table			
Prior to mitigation/ management			
Duration	Short term: Less than 1 year (2)	Construction activities are expected to be short-lived (i.e. during the construction phase)	Negligible (-15)
Extent	Limited (1)	Site clearing will only occur within and immediately around the project site	
Intensity x type of impact	Negative (-2)	Any dewatering will have minor environmental significance	
Probability	Unlikely (3)	Dewatering during the construction phase (if any) is unlikely to cause environmental impact considering limited rock permeability, the duration and excavation depth.	
Nature	Negative		

Activity & Interaction: Site clearing and construction			
Dimension	**Rating**	**Motivation**	**Significance**
Mitigation/ Management actions			
▪ Restrict construction activities to be limited to areas above the water table; and ▪ If that is not possible, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.			
Post- mitigation			
Duration	Short term: Less than 1 year (2)	Any lowering of the water table during the construction phase is expected to be shallow and recover relatively quickly	Negligible (-8)
Extent	Limited (1)	No impacts are expected, however, if they occur they will be reduced to isolated parts of the mine where site clearing is going to take place	
Intensity x type of impact	Negative (-1)	Considering that the construction phase will be for a short period, the intensity will be minimal	
Probability	Rare (2)	It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plan	
Nature	Negative		

8.5 Impact Assessment – Operational Phase

8.5.1 Mooikraal

Model simulations indicate minimal impacts from the removal of groundwater. This is due to the presence of the sills which act as aquicludes; restricting impact to the local aquifers in terms of groundwater quantity deterioration. It is also observed in the model that the water levels within the shallow aquifer boreholes are stable throughout the mining activities indicating that the shallow aquifer is insignificantly affected by water removal from the mine void.

However, model simulations predict a notable drop in groundwater level (near the decline shaft where monocline structures are most prevalent) falling below the dolerite sill by 2025.

Surface infrastructures that are potential groundwater contamination sources located near the decline shaft were incorporated into the numerical model. The WRD was one of those potential sources. The model outcomes show that the plume emanating from the dump will be limited in extent; predominantly restricted in vertical migration into the deeper aquifers due to the presence of the dolerite sills and restricted in a lateral movement (staying within the project bounary). The WRD is currently not lined and this is because it was constructed in 2002, prior to the promulgation of the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits (2015) under NEM:WA (2008). The law therefore does not apply retrospectively.

8.5.1.1 Management Actions and Targets

- A dewatering network will not be constructed; dry working conditions will be achieved by abstracting groundwater ingress from mine voids during operation, as currently authorised by Mooikraal's approved water use license;
- Water removed from underground should be stored in the North and South pollution control dams (PCD) and reused for mine processes that are not quality sensitive and are authorised by the competent authority. Excess water shall be pumped away to 3 shaft and Sasolburg Operations to prevent any overflows from the PCDs;
- If overflow from the PCDs should occur, Mooikraal will conduct water quality monitoring downstream of the PCDs and notify the competent authority, should there be a negative impact to surface water bodies, downstream users will be notified and rehabilitation measures will be informed by a professional;
- Should there be an impact to delineated wetlands, ongoing wetland rehabilitation should be conducted as informed by a professional and the Freshwater Impact Assessment Report (Digby, 2018);
- The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation;
- Groundwater monitoring should continue to assess the time series water level and groundwater quality trends as per the approved water use license; and
- All groundwater monitoring, geological, rescue borehole locations must be retained on a register;
- Geological/ exploration boreholes will be sealed and decommissioned during the operational phase, according to the Sasol Mining procedure and the register will reflect the status of the borehole;
- Rescue boreholes that are no longer required/ in use will be sealed and decommissioned as per Sasol Mining Procedure, and the register will reflect the status of the borehole;
- Numerical modelling should be updated every five years based on groundwater monitoring results as to identify any potential concerns that may occur over the years.

The significance rating of the potential impacts of groundwater removal before and after mitigation plans is provided in Table 8-6.

Table 8-6: Potential impacts of the waste rock dump at Mooikraal

Activity & Interaction: Groundwater contamination as a result of the WRD			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: A contamination plume may emanate from the WRD and seep into the groundwater			
Prior to mitigation/ management			
Duration	Medium term (3)	Groundwater contamination from the dump (if any) is expected to be minimal and dilution is expected over time.	Minor (-21)
Extent	Limited (2)	The plume is expected to be limited to the project area.	
Intensity x type of impact	Minimal (2)	The intensity of the contamination will be minimal. This is based on the outcomes of the expected leachate quality derived from geochemical analysis.	
Probability	Unlikely (3)	The impact is unlikely to occur.	
Nature	Negative		
Mitigation/ Management actions			
▪ The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation.			
Post management			
Duration	Medium term (3)	Groundwater contamination from the dump (if any) is expected to be minimal and dilution is expected over time.	Negligible (-18)
Extent	Very limited (1)	The plume is expected to be limited to be limited to isolated parts within the immediate vicinity of the dump.	
Intensity x type of impact	Minimal (2)	The intensity of the contamination will be minimal. This is based on the outcomes of the expected leachate quality derived from geochemical analysis.	
Probability	Unlikely (3)	The impact is unlikely to occur.	
Nature	Negative		

The significance rating of the potential impacts of groundwater removal before and after mitigation plans is provided in Table 8-7.

Table 8-7: Potential impacts of groundwater removal at Mooikraal

Activity & Interaction: Groundwater removal			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: As the groundwater is removed from the mine voids, the groundwater resource is depleted in quantity, affecting local aquifers and potentially lowering the water table			
Prior to mitigation/ management			
Duration	Beyond Project Life (6)	The water level will remain below its natural level during the entire operation and for some years post-operation. The slow recovery, in spite of the underground mine voids being fully flooded, is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill.	Minor (-65)
Extent	Local (3)	The extent of influence will mainly be at mining depths due to the existence of the overlying sills. However, localised impacts to the shallow aquifer is expected at the decline shaft area, where the coal seal is shallower, sills are thinner and vertical preferential flow paths exist.	
Intensity x type of impact	Serious (-4)	Groundwater quantity deterioration will be predominantly within the mine aquifer and isolated to some parts of the shallow weathered aquifer. Areas where there may be impacts to the shallow aquifer and surface water bodies bring about concern.	
Probability	Likely (5)	Impact to the shallow aquifer in isolated parts is expected due to the structural geological setting.	
Nature	Negative		
Mitigation/ Management actions			

<table>
<tr><th colspan="4">Activity & Interaction: Groundwater removal</th></tr>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">
A dewatering network will not be constructed; dry working conditions will be achieved by abstracting groundwater ingress from mine voids during operation, as currently authorised by Mooikraal’s approved water use license;
Water removed from underground should be stored in the North and South pollution control dams (PCD) and reused for mine processes that are not quality sensitive and are authorised by the competent authority. Excess water shall be pumped away to 3 shaft and Sasolburg Operations to prevent any overflows from the PCDs;
If overflow from the PCDs should occur, Mooikraal will conduct water quality monitoring downstream of the PCDs and notify the competent authority, should there be a negative impact to surface water bodies, downstream users will be notified and rehabilitation measures will be informed by a professional;
Should there be an impact to delineated wetlands, ongoing wetland rehabilitation should be conducted as informed by a professional and the Freshwater Impact Assessment Report (Digby, 2018);
The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation;
Groundwater monitoring should continue to assess the time series water level and groundwater quality trends as per the approved water use license; and
All groundwater monitoring, geological, rescue borehole locations must be retained on a register;
Geological/ exploration boreholes will be sealed and decommissioned during the operational phase, according to the Sasol Mining procedure and the register will reflect the status of the borehole;
Rescue boreholes that are no longer required/ in use will be sealed and decommissioned as per Sasol Mining Procedure, and the register will reflect the status of the borehole;
Numerical modelling should be updated every five years based on groundwater monitoring results as to identify any potential concerns that may occur over the years.
</td></tr>
<tr><td colspan="4">Post- mitigation</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>The water level will remain below its natural level during the entire operation and post-operation. The slow recovery, in spite of the underground mine voids being fully flooded, is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill.</td><td rowspan="2">Negligible
(-27)</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>With the above stated mitigation methods, the extent is expected to be limited.</td></tr>
</table>

Activity & Interaction: Groundwater removal			
Dimension	**Rating**	**Motivation**	**Significance**
Intensity x type of impact	Minimal (-1)	With the above stated mitigation methods, the intensity is expected to be limited.	
Probability	Unlikely (3)	With the application of the proposed mitigation plans, it is unlikely that the lowering of the water table will have an adverse negative impact.	
Nature	Negative		

8.5.2 3 Shaft

Looking at the current groundwater quality at 3 Shaft area (Section 5.2.2), no mining related impact thus far have been observed although the existing primary plant area has been operational since 1950. However, the location of the monitoring boreholes needs to be reassessed as they are not located in areas within close proximity to the existing plant area and therefore it is with low confidence that 3 Shaft is deemed as an area that is without contamination. Two boreholes are recommended downstream of the existing primary plant (one borehole at the shallow aquifer and another at the intermediate aquifer). The recommended locations are presented in Figure 8-1.

The stockpile area, however, is much less of a risk to the groundwater environment compared to the current primary plant area. This is because the relocation area (stockpile area) is lined with concrete therefore reducing the potential or rate at which leachate may seep into the underlying unsaturated and saturated zone (aquifer).The stormwater management system will also be upgraded reducing the potential impact even further. Due to these factors, the stockpile area is not observed to be a high risk to the groundwater environment.

8.5.2.1 Management Actions and Targets

- Maintenance of the stockpile area must be undertaken by developing an effective stormwater management system;
- Groundwater monitoring must be implemented to assess the time series water level and water quality trends; and
- Due to the fact that no underground mining occurs at 3 shaft, all historical groundwater, geological, rescue borehole locations must be retained on a register and the status of the borehole will be recorded
- Should any negative impact occur, Mooikraal will institute investigations and rehabilitation will be informed by a professional.

The significance rating of the potential impacts of groundwater contamination during the operational phase is provided in Table 8-10.

Table 8-8: Potential impacts of groundwater contamination during the operational phase at 3 Shaft

Activity & Interaction: Groundwater contamination as a result of the coal bunker at the primary plant			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: A contamination plume may occur due to dissolution of heavy metals when the coal interacts with rainfall in the presence of air, forming a contamination plume which may seep into the local aquifer			
Prior to mitigation/ management			
Duration	Beyond project life (6)	Groundwater contamination may occur due to dissolution of heavy metals forming a contamination plume which may seep into the local aquifer which may stay beyond the life of the project.	Minor (-60)
Extent	Local (3)	The contamination is likely to be predominantly within the development area with isolated parts of the plume migrating beyond the project area.	
Intensity x type of impact	Serious (-6)	Groundwater quality deterioration will be predominantly within shallow aquifer and the shallow aquifer is where private borehole (if any) will be located and where surface water bodies receive baseflow. Therefore a serious problem may arise.	
Probability	Likely (4)	Impact to the shallow aquifer is likely to occur should leachate generation and seepage occur.	
Nature	Negative		
Mitigation/ Management actions			
▪ Maintenance of the stockpile area must be undertaken by developing an effective stormwater management system; ▪ Groundwater monitoring must be implemented to assess the time series water level and water quality trends; and ▪ Due to the fact that no underground mining occurs at 3 shaft, all historical groundwater, geological, rescue borehole locations must be retained on a register and the status of the borehole will be recorded.			
Post management			

Activity & Interaction: Groundwater contamination as a result of the coal bunker at the primary plant			
Dimension	**Rating**	**Motivation**	**Significance**
Duration	Project life (5)	Groundwater contamination during the operation of the primary plant at the new location is likely to be present during the project life	Negligible (-27)
Extent	Limited (2)	With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only	
Intensity x type of impact	Minor (-2)	With the implementation of the above stated mitigation methods, impacts of the contamination plume is regarded as minor.	
Probability	Unlikely (3)	The impact is unlikely to occur if the above stated mitigation plans are implemented	
Nature	Negative		

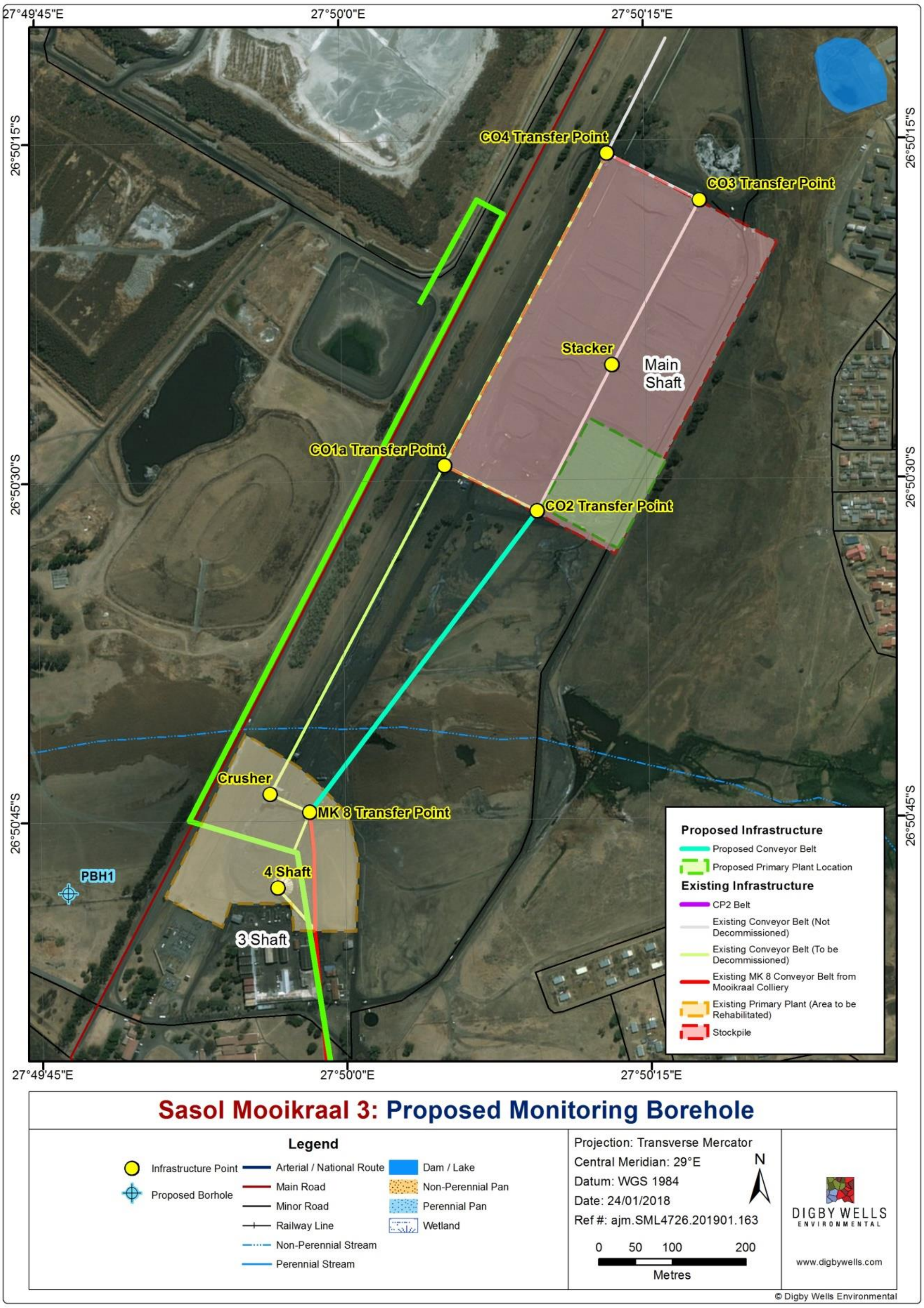

Figure 8-1: Proposed monitoring borehole at the existing primary plant area

8.6 Impact Assessment - Decommissioning and Post-Closure Phases

8.6.1 Mooikraal

As mining operation at Mooikraal ceases, groundwater removal will also cease. The hydraulic gradient will then drive for the recovery of the local water levels previously affected by removal of water. A contamination plume has been created within the mine voids which will be filling up with groundwater. From model simulations, the contamination plume was found to be limited in extent due to the depth of the coal seam and thickness of the overlying dolerite sills. However, it was observed that at locations where the coal seam is shallower, the dolerite sill is thinner and the presence of vertical preferential pathways (such as the decline shaft and monoclines structures is found), the plume is expected to migrate further introducing a potential contaminant risk to the shallow aquifer and surface water bodies.

The WRD is proposed to be backfilled into the shaft therefore it will not exist as a potential contamination source at the surface.

The post-mining model indicated that groundwater levels will not fully recover within a 300 year simulation period. The slow recovery is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill. Therefore there are uncertainties at this point with regards to the potential of decant. However, for the sake of being conservative in preparation for the worst case scenario; a steady state model was subsequently used to model the fully recovered water levels. The steady state model indicated the northern boundary of the Mooikraal underground mine (Section Figure 7-5) as the most likely area for decant at an estimated rate of 2.5 m^3/d.

8.6.1.1 Management Actions and Targets

- All existing boreholes as informed by the registers, with the exception of private water supply boreholes and monitoring boreholes should have been sealed and decommissioned according to Sasol Mining procedure during the operational phase, in order to minimise the chance of decant occurring;
- All shaft adits, ventilation shafts and downcasts will be sealed and decommissioned as guided by a professional;
- Should there be an negative impact to surface water bodies, due to decant and baseflow contribution, investigations will occur, and rehabilitation will commence as informed by a professional;
- Should there be an negative impact to delineated wetlands, investigations will ensue, and rehabilitation will commence as informed by a professional;
- The waste rock material which will be backfilled into the shaft should be completely flooded to eliminate exposure to oxygen, this will hinder contamination generating reactions;

- Potential decant should be informed by the numerical model as new data becomes available, should decant be predicted to occur, decant locations should be monitored for decant quality and rate; possible scenarios to manage the decant will be informed by a professional;
- The groundwater monitoring network may be re-assessed and amended to determine the boreholes, to be monitored, necessary to monitor the relevant aquifers sources of contamination and receptors; and
- Groundwater monitoring should be conducted to assess the time series water level and water quality trends.

The significance rating of the potential impacts of groundwater removal before and after mitigation plans is provided in Table 8-6.

Table 8-9: Potential impacts of the waste rock dump at Mooikraal

Activity & Interaction: Groundwater contamination as a result of the WRD			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Contamination plume in the groundwater during operation			
Prior to mitigation/ management			
Duration	Medium term (3)	Groundwater contamination from the dump (if any) is expected to be minimal, especially considering the extent of the shaft compared to that of the mine void and dilution is expected over time.	Minor (-21)
Extent	Limited (2)	The plume is expected to be limited to the project area	
Intensity x type of impact	Minimal (2)	The intensity of the contamination will be minimal. This is based on the outcomes of the expected leachate quality derived from geochemical analysis.	
Probability	Unlikely (3)	The impact is unlikely to occur.	
Nature	Negative		
Mitigation/ Management actions			
▪ The waste rock material which will be backfilled into the shaft should be completely flooded; to eliminate exposure to oxygen, this will hinder contamination generating reactions.			
Post management			
Duration	Medium term (3)	Groundwater contamination from the dump (if any) is expected to be minimal and dilution is expected over time	Negligible (-16)

Extent	Very limited (1)	The plume is expected to be limited to be limited to isolated parts within the immediate vicinity of the shaft	
Intensity x type of impact	Minimal (1)	The intensity of the contamination will be minimal. This is based on the outcomes of the expected leachate quality derived from geochemical analysis. Additionally, flooding of the shaft will hinder contamination generating reactions	
Probability	Unlikely (3)	The impact is unlikely to occur	
Nature	Negative		

The significance rating of the potential impacts of groundwater contamination during the decommissioning and post-closure is provided in Table 8-10.

Table 8-10: Potential impacts of groundwater contamination and decant during the post-closure phase at Mooikraal

Activity & Interaction: Groundwater contamination and decant as a result of underground mining			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: A contamination plume will originate from the underground mine workings as groundwater recovery commenced and the system moved towards filling up the mine voids			
Prior to mitigation/ management			
Duration	Beyond project life (6)	Groundwater contamination occurs due to dissolution of heavy metals forming a contamination plume even after mine closure.	Minor (-64)
Extent	Beyond local extent (4)	Similar to the nature of the impacts associated with groundwater removal, the extent of influence of the contamination plume is observed to mainly be at mining depths due to the existence of the overlying sills. However, localised impacts to the shallow aquifer are expected at areas where the coal seam is shallower, sills are thinner and vertical preferential flow paths exist, potentially impacting surface water bodies through base flow. Decant may occur based on current modelling simulation, however, there are uncertainties associated with its occurrence and rates. Should it occur, impacts will migrate beyond the local vicinity.	
Intensity x type of impact	Serious (-6)	Groundwater quality deterioration will be predominantly within the mine aquifer and isolated to some parts of the shallow weathered aquifer. Areas where there may be an impact to the shallow aquifer and surface water bodies bring about concern. Should decant occur, it is expected to have serious impact on the surrounding surface water bodies.	
Probability	Likely (4)	Impact to the shallow aquifer in isolated parts is expected due to the structural geological setting.	
Nature	Negative		

<table>
<tr><th colspan="4">Activity & Interaction: Groundwater contamination and decant as a result of underground mining</th></tr>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">
All existing boreholes as informed by the registers, with the exception of private water supply boreholes and monitoring boreholes should have been sealed and decommissioned according to Sasol Mining procedure during the operational phase, in order to minimise the chance of decant occurring;
All shaft adits, ventilation shafts and downcasts will be sealed and decommissioned as guided by a professional;
Should there be an negative impact to surface water bodies, due to decant and baseflow contribution, investigations will occur, and rehabilitation will commence as informed by a professional;
Should there be an negative impact to delineated wetlands, investigations will ensue, and rehabilitation will commence as informed by a professional;
The waste rock material which will be backfilled into the shaft should be completely flooded to eliminate exposure to oxygen, this will hinder contamination generating reactions;
Potential decant should be informed by the numerical model as new data becomes available, should decant be predicted to occur, decant locations should be monitored for decant quality and rate; possible scenarios to manage the decant will be informed by a professional;
The groundwater monitoring network may be re-assessed and amended to determine the boreholes, to be monitored, necessary to monitor the relevant aquifers sources of contamination and receptors; and
Groundwater monitoring should be conducted to assess the time series water level and water quality trends.
</td></tr>
<tr><td colspan="4">Post management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to mine disturbance will continue even after mine closure.</td><td rowspan="5">Negligible (-30)</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only.</td></tr>
<tr><td>Intensity x type of impact</td><td>Minor (-2)</td><td>The contamination plume is expected to impact isolated parts of the shallow aquifer, however, impact is expect predominantly deep within the mine void. Mining simulations show an unlikelihood for decant, however, this should be further investigated.</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>The impact is unlikely to occur if the above stated mitigation plans are implemented</td></tr>
<tr><td>Nature</td><td colspan="2">Negative</td></tr>
</table>

8.6.2 3 Shaft

All infrastructures will be demolished and removed during decommissioning therefore no impacts are expected post closure.

9 Unplanned Events and Low Risks

The unplanned events that may happen at the project site and the proposed mitigation plans are listed in Table 9-1.

Table 9-1: Unplanned events, low risks and their management measures

Unplanned event	Potential impact	Mitigation / Management / Monitoring
Hydrocarbon spills from bulk storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities at fuel bay.	▪ Hydrocarbon contamination of the groundwater	▪ Hydrocarbons and hazardous materials must be stored in bunded areas and refuelling should take place in contained areas; ▪ Ensure that oil and silt traps are well maintained; ▪ Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills; ▪ Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place; ▪ Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes; and ▪ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable disposal facility. The excavation should be backfilled with soil of good quality.
Spills / leaks from the dewatering pipeline.	▪ Contamination of groundwater	▪ Regular inspections of the pipeline should be conducted for any leaks. Seeping pipeline should be sealed.

10 Environmental Management Plan

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

10.1 Project Activities with Potentially Significant Impacts

Potentially significant impacts that require mitigation or management are listed in Table 10-1.

Table 10-1: Potentially significant impacts

Activity	Aspects	Potential Significant Impacts
Mooikraal underground mine development	Groundwater removal	▪ Depletion of the groundwater resource and subsequent lowering of water table; and ▪ Reduction of the flow rate of the streams due to reduced baseflow.
	Groundwater contamination	▪ Dissolution of heavy metals, contamination plume generation and deterioration of groundwater quality.
Decant at Mooikraal	Surface water	▪ Deterioration of surface water quality.
3 Shaft demolishing existing conveyor belt, crushing facility and coal bunker and relocating the primary plant	Groundwater contamination	▪ Dissolution of heavy metals, leachate generation and seepage; and consequent deterioration of groundwater quality.

10.2 Summary of Mitigation and Management

Table 10-2 to

Table 10-3 provide a summary of the proposed project activities, environmental aspects and impacts on the receiving environment. Information on the frequency of mitigation, relevant legal requirements, recommended management plans, timing of implementation, and roles / responsibilities of persons implementing the EMP.

Table 10-2: Objectives and Outcomes of the EMP

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Compliance with standards	Time period for implementation
Mooikraal Underground mine development - Dewatering	Groundwater and surface water depletion	Groundwater quantity	Operation	▪ A dewatering network will not be constructed; dry working conditions will be achieved by abstracting groundwater ingress from mine voids during operation, as currently authorised by Mooikraal's approved water use license; ▪ Water removed from underground should be stored in the North and South pollution control dams (PCD) and reused for mine processes that are not quality sensitive and are authorised by the competent authority. Excess water shall be pumped away to 3 shaft and Sasolburg Operations to prevent any overflows from the PCDs; ▪ If overflow from the PCDs should occur, Mooikraal will conduct water quality monitoring downstream of the PCDs and notify the competent authority, should there be a negative impact to surface water bodies, downstream users will be notified and rehabilitation measures will be informed by a professional; ▪ Should there be an impact to delineated wetlands, ongoing wetland rehabilitation should be conducted as informed by a professional and the Freshwater Impact Assessment Report (Digby, 2018); ▪ The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation; ▪ Groundwater monitoring should continue to assess the time series water level and groundwater quality trends as per the approved water use license; and ▪ All groundwater monitoring, geological, rescue borehole locations must be retained on a register; ▪ Geological/ exploration boreholes will be sealed and decommissioned during the operational phase, according to the Sasol Mining procedure and the register will reflect the status of the borehole; ▪ Rescue boreholes that are no longer required/ in use will be sealed and decommissioned as per Sasol Mining Procedure, and the register will reflect the status of the borehole; ▪ Numerical modelling should be updated every five years based on groundwater monitoring results as to identify any potential concerns that may occur over the years.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering. ▪ WUL guidelines.	▪ During operation

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Compliance with standards	Time period for implementation
Mooikraal Underground mine development - Dewatering	Groundwater contamination and decant	Groundwater quality	Post-closure	▪ All existing boreholes as informed by the registers, with the exception of private water supply boreholes and monitoring boreholes should have been sealed and decommissioned according to Sasol Mining procedure during the operational phase, in order to minimise the chance of decant occurring; ▪ All shaft adits, ventilation shafts and downcasts will be sealed and decommissioned as guided by a professional; ▪ Should there be an negative impact to surface water bodies, due to decant and baseflow contribution, and rehabilitation will commence as informed by a professional; ▪ Should there be an negative impact to delineated wetlands, investigations will ensue, and rehabilitation will commence as informed by a professional; ▪ The waste rock material which will be backfilled into the shaft/ adit should be completely flooded to eliminate exposure to oxygen, this will hinder contamination generating reactions; ▪ Potential decant should be informed by the numerical model as new data becomes available, should decant be predicted to occur, decant locations should be monitored for decant quality and rate; possible scenarios to manage the decant will be informed by a professional; ▪ The groundwater monitoring network may be re-assessed and amended to determine the boreholes, to be monitored, necessary to monitor the relevant aquifers sources of contamination and receptors; and ▪ Groundwater monitoring should be conducted to assess the time series water level and water quality trends.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering. ▪ WUL guidelines.	▪ Post-closure
3 Shaft demolishing existing conveyor belt, crushing facility and coal bunker (primary plant). Reconstruction of primary plant at new location.	Groundwater contamination	Groundwater quality	Construction	▪ Restrict construction activities to be limited to areas above the water table; and ▪ If that is not possible, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.	▪ n/a	▪ Construction
Relocating the primary plant	Groundwater contamination at stockpile area	Groundwater quality	Operation	▪ Maintenance of the stockpile area must be undertaken by developing an effective stormwater management system; and ▪ Groundwater monitoring must be implemented to assess the time series water level and water quality trends.	▪ SANS. ▪ South African water quality guidelines for drinking, irrigation and livestock watering. WUL guidelines.	During operation

Table 10-3: Prescribed Environmental Management Standards, Practice, Guideline, Policy or Law

Specialist field	Applicable standard, practice, guideline, policy or law			
Groundwater	▪ National Water Act, 1998 (Act No. 36 of 1998). ▪ National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended (NEMA), GNR 544 and GNR 545 (Section 24 (1)). ▪ Water Services Act 108 of 1997. ▪	▪ Department of Water and Sanitation (DWS) (formerly DWAF). Government Gazette, No. 704 (GN 704). 1999. Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources (Vol. 408, No. 20119). 4 June 1999.	▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G3: Water Monitoring Systems. ▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G1: Storm Water Management.	▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline A4: Pollution Control Dams.

10.3 Monitoring Plan

Current groundwater monitoring network for Mooikraal is seen as sufficient and should be maintained. The newly drilled boreholes at 3 Shaft are recommended to form part of the current ongoing monitoring plan. Reference can be made to Section 5.2 for the location of the monitoring boreholes.

10.3.1 Water Level

Groundwater levels are recommended to be recorded on a quarterly basis, in order to continue to detect any changes or monitor trends in groundwater elevation and flow direction.

10.3.2 Water Sampling and Preservation

When sampling, the following procedures are proposed:

- One litre plastic bottles with a cap are required for the sampling exercises;
- Collected samples must be stored in cooler box or fridge while on site; and
- Sample bottles should be marked clearly with the borehole name, date of sampling and the sampler's name and submitted to a laboratory that analyses in accordance with the methods prescribed by the South African Bureau of Standards in terms of the Standards Act, Act 30 of 1982.

10.3.3 Sampling Frequency

Groundwater migrates at a relatively slow rate and drastic changes in the groundwater quality rarely encountered, unless a groundwater preferential flow path is present in the vicinity of a contamination plume. Quarterly monitoring is recommended; in accordance to the WUL guidelines additionally it has been observed sufficient over the years of monitoring groundwater level and quality trends.

Samples should be collected by using Water Research Commission (WRC), 2007, Groundwater Sampling: A Comprehensive Guide for Sampling Methods and submitted to a laboratory that analyses in accordance with the methods prescribed by the South African Bureau of Standards in terms of the Standards Act, Act 30 of 1982.

It is suggested that quarterly samples be collected, extending up to two years post closure and based on the result trends it can be adjusted until a sustainable situation is reached and after it has been signed off by the authorities.

10.3.4 Parameters to be Monitored

- Should be informed by the authorised water use license, additional suggested parameters include:
- TDS, Alkalinity, Chemical Oxygen Demand; Major ions i.e. K, NH_3, , NO_2, PO_4,; and

- Minor and trace metals, including As, Al, B, Co, Cr, Zn, Cd, Cu, Pb, Fe, Ni, Mn.

11 Consultation Undertaken

Not applicable.

12 Conclusions

The following conclusions were reached during the baseline groundwater quality assessment:

The groundwater levels at Mooikraal are affected by mining activities; this is attributed to the presence of vertical groundwater pathways occurring within the project area. This trend is not observed for all boreholes meaning that the presence of the sills do restrict impact. Some water levels may be affected by pumping for water supply.

Water levels at the 3 Shaft range from 4 to 31 mbgl, with an east to west groundwater flow direction.

The local groundwater quality at Mooikraal is predominantly influenced by the local geology and at 3 Shaft only the intermediate aquifer shows remnants of this characteristic with high alkalinity showing signs of impact from the ash backfilling from the underlying Sigma mine void. The shallow aquifer at 3 Shaft is a fresh aquifer with recently recharged groundwater. Of all the aquifers assessed, none are impacted by mining related activities (including the mine aquifer however with the exception of the intermediate aquifer at 3 Shaft). This is concluded based on the relatively minimal sulphate concentrations and EC values found in the groundwater.

12.1 Mooikraal Activities and Associated Impacts during the Construction Phase

No new construction activities are anticipated at Mooikraal as the colliery has already been established.

12.2 3 Shaft Activities and Associated Impacts during the Construction Phase

During the construction phase, site clearance (where required) and construction activities are expected to take place above the water table. Since the local water table ranges from 4.73 to 31.63 mbgl, no impact on the groundwater is expected if the activities take place above the water table. Should there be a need to excavate below the water table, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

The demolition of the infrastructure within the wetland will reduce the risk to the groundwater environment as the potential source of contamination will be gradually depleted throughout this process. This is a positive action with regards to impact to the groundwater environment.

12.3 Mooikraal Activities and Associated Impacts during the Operational Phase

Model simulations indicate minimal impacts from the removal of groundwater. This is due to the presence of the sills which act as aquicludes; restricting impact to the local aquifers in terms of groundwater quantity deterioration. It is also observed in the model that the water levels within the shallow aquifer boreholes are stable throughout the mining activities therefore indicating that the shallow aquifer is insignificantly affected by water removal within the mine void.

However, there is a presence of monocline structures within western parts of Mooikraal. It is important to note that the effect of the monocline structures is that they act as preferential flow pathways. These structures were conceptualised to not penetrate the dolerite sills because their formation is understood to have taken place prior the sill intrusions. Thus, the dolerite sills predominantly restrict the extent of the drawdown to the immediate area.

Additionally a notable drop in groundwater level is observed (near the decline shaft where monocline structures are most prevalent) falling below the dolerite sill by 2025. This could potentially change the aquifer below the dolerite sill from confined to unconfined, potentially altering the response of the aquifer and the mine inflow rates.

The WRD at Mooikraal is a potential source of contamination; once material is exposed to oxygen and rainfall, leachate generating reaction may occur and introduce contamination into the groundwater environment via seepage. Total concentration analysis identified Ba and Cu as potential elements of concern however these results are a worst case scenario. Leachable concentration analysis, which is the most representative of the expected leachate at the site, shows no concern within regards to the leachate expected to emanate from the dump.

<u>3 Shaft Activities and Associated Impacts during the Operational Phase</u>

Looking at the current groundwater quality at 3 Shaft area, no mining related impact thus far have been observed although the existing primary plant area has been operational since 1950. However, the location of the monitoring boreholes needs to be reassessed as they are not located in areas within close proximity to the existing plant area and therefore it is with low confidence that the plant area is deemed as an area that is without contamination. Two boreholes are recommended downstream of the existing primary plant (one borehole at the shallow aquifer and another at the intermediate aquifer).

The stockpile area, however, is much less of a risk to the groundwater environment compared to the current primary plant area. This is because the relocation area (stockpile area) is lined with concrete therefore reducing the potential or rate at which leachate may seep into the underlying unsaturated and saturated zone (aquifer).The stormwater management system will also be upgraded reducing the potential impact even further. Due to these factors, the stockpile area is not observed to be a high risk to the groundwater environment.

12.4 Mooikraal Activities and Associated Impacts during the Closure Phase

As mining operation at Mooikraal ceases, groundwater removal will also cease. The hydraulic gradient will then drive for the recovery of the local water levels previously affected by removal of water. A contamination plume has been created within the mine voids which will be filling up with groundwater. From model simulations, the contamination plume was found to be limited in extent due to the depth of the coal seam and thickness of the overlying dolerite sills. However, it was observed that at locations where the coal seam is shallower, the dolerite sill is thinner and the presence of vertical preferential pathways (such as the decline shaft and monoclines structures are found), the plume is expected to migrate further introducing a potential contaminant risk to the shallow aquifer and surface water bodies.

The post-mining model indicated groundwater levels will not fully recover within a 300 year simulation period. The slow recovery, in spite of the underground mine voids being fully flooded, is attributed to the partial depressurisation of the confined aquifer system below the No. 5 dolerite sill. Therefore there are uncertainties at this point with regards to the potential of decant. However, for the sake of being conservative in preparation for the worst case scenario; a steady state model was subsequently used to model the fully recovered water levels imposing an equilibrium state and infinite time. The steady state model indicated the northern boundary of the Mooikraal underground mine as the most likely area for decant at an estimated rate of 2.5 m^3/d. The decant rate should be considered only as an initial estimation due to the uncertainty associated with predicting flow.

12.5 3 Shaft Activities and Associated Impacts during the Closure Phase

All infrastructure will be demolished and removed during decommissioning therefore no impacts are expected post closure.

13 Recommendations

General:

- Two monitoring boreholes at 3 Shaft are recommended to be drilled downstream (in addition to the existing) of the current location of the primary plant area, one in the shallow, and one in the intermediate aquifer. These boreholes will serve to acquire groundwater samples in order to quantify the presence or absence of contamination in the existing primary plant vicinity with better accuracy;
- The hydrocensus previously conducted (and not completed) at Mooikraal is recommended to be updated within a 3 km radius of the project boundary;

- A hydrocensus is recommended to be conducted within a 1 km radius of the 3 Shaft area;
- Should any landowner report a reduced yield/ quality from his borehole, the cause of the impact will be investigated by the mine. If there is reasonable cause to believe that the impact is mining related, suitable corrective action will be agreed between the parties; and
- X-Ray Diffraction (XRD), acid base accounting and leachable concentration investigations of the coal seam at Mooikraal are recommended.

Construction phase:

3 Shaft:

- Restrict construction activities to be limited to areas above the water table; and
- If that is not possible, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains the same as prior to construction activities.

Operational phase:

Mooikraal:

- A dewatering network will not be constructed; dry working conditions will be achieved by abstracting groundwater ingress from mine voids during operation, as currently authorised by Mooikraal's approved water use license;
- Water removed from underground should be stored in the North and South pollution control dams (PCD) and reused for mine processes that are not quality sensitive and are authorised by the competent authority. Excess water shall be pumped away to 3 shaft and the Sasolburg Operations to prevent any overflows from the PCDs;
- If overflow from the PCDs should occur, Mooikraal will conduct water quality monitoring downstream of the PCDs and notify the competent authority, should there be a negative impact to surface water bodies, downstream users will be notified and rehabilitation measures will be informed by a professional;
- Should there be an impact to delineated wetlands, ongoing wetland rehabilitation should be conducted as informed by a professional and the Freshwater Impact Assessment Report (Digby, 2018);
- The WRD should be maintained with slopes that reduce pooling of water, to reduce the amount of leachate generation;
- Groundwater monitoring should continue to assess the time series water level and groundwater quality trends as per the approved water use license; and
- All groundwater monitoring, geological, rescue borehole locations must be retained on a register;

- Geological/ exploration boreholes will be sealed and decommissioned during the operational phase, according to the Sasol Mining procedure and the register will reflect the status of the borehole;
- Rescue boreholes that are no longer required/ in use will be sealed and decommissioned as per Sasol Mining Procedure, and the register will reflect the status of the borehole;
- Numerical modelling should be updated every five years based on groundwater monitoring results as to identify any potential concerns that may occur over the years.

3 Shaft:

- Maintenance of the stockpile area must be undertaken by developing an effective stormwater management system;
- Groundwater monitoring must be implemented to assess the time series water level and water quality trends; and
- Due to the fact that no underground mining occurs at 3 shaft, all historical groundwater, geological, rescue borehole locations must be retained on a register and the status of the borehole will be recorded

Decommissioning and post-closure phase:

Mooikraal:

- All existing boreholes as informed by the registers, with the exception of private water supply boreholes and monitoring boreholes should have been sealed and decommissioned according to Sasol Mining procedure during the operational phase, in order to minimise the chance of decant occurring;
- All shaft adits, ventilation shafts and downcasts will be sealed and decommissioned as guided by a professional;
- Should there be an negative impact to surface water bodies due to decant and baseflow contribution, investigations will occur, and rehabilitation will commence as informed by a professional;
- Should there be an negative impact to delineated wetlands, investigations will ensue, and rehabilitation will commence as informed by a professional;
- The waste rock material which will be backfilled into the shaft should be completely flooded to eliminate exposure to oxygen, this will hinder contamination generating reactions;
- Potential decant should be informed by the numerical model as new data becomes available, should decant be predicted to occur, decant locations should be monitored for decant quality and rate; possible scenarios to manage the decant will be informed by a professional;

- The groundwater monitoring network may be re-assessed and amended to determine the boreholes, to be monitored, necessary to monitor the relevant aquifers sources of contamination and receptors; and
- Groundwater monitoring should be conducted to assess the time series water level and water quality trends.