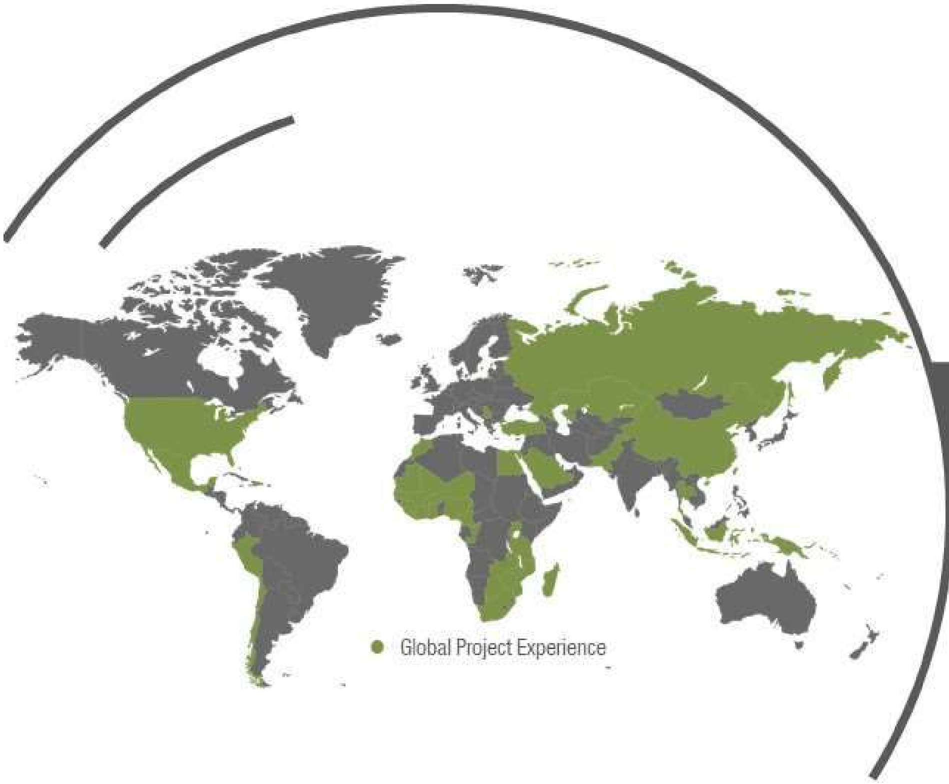

DIGBY WELLS ENVIRONMENTAL

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Dorstfontein East Expansion Project near Kriel, Mpumalanga Province

Hydrogeological Impact Assessment

Prepared for:
Exxaro Coal Central (Pty) Ltd

Project Number:
EXX6358

September 2021

Digby Wells and Associates (South Africa) (Pty) Ltd
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Report Type:	Hydrogeological Impact Assessment
Project Name:	Dorstfontein East Expansion Project near Kriel, Mpumalanga Province
Project Code:	EXX6358

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DECLARATION OF INDEPENDENCE

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I, Arjan van ‘t Zelfde, as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd., has any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Exxaro Coal Central (Pty) Ltd other than fair remuneration for work performed, specifically in connection with the Groundwater Impact Assessment for the Dorstfontein East Coal Mine Expansion Project.

Full Name:	Arjan van ‘t Zelfde
Title/ Position:	Unit Manager: Hydrogeology / Senior Hydrogeologist
Qualification(s):	MSc. Hydrogeology
Experience (Years):	16
Registration(s):	SACNASP 115656

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) was appointed by Exxaro Coal Central (Pty) Ltd to undertake Groundwater Impact Assessment and Update of the Groundwater Model specialist study for the proposed Dorstfontein East Expansion Project. The planned expansion includes underground mining from 2022 onwards at the Dorstfontein Coal Mine East (DCME).

Exxaro Coal Central has existing Environmental Authorisation (EA) for current mining activities. However, additional coal reserves that are not part of the existing authorisation (EMPr) have been identified, and these areas will need to be incorporated in the updated EMPr for approval. The underground mining will be accessed from the existing Pit 2 opencast.

Baseline Assessment

DCME is located 12 km north-east of the town of Kriel, in the Mpumalanga Province of South Africa. The mine is situated within the magisterial district of Bethal under the jurisdiction of Emalahleni Local Municipality (Council). The mine (DCME) falls within a semi-arid climate region of Southern Africa, where rainfall is sparse with high seasonal variations during wet and dry seasons. The wet (or rainy) season occurs during summer months, October to March, and is characterised by short, intense convective storms.

The Mean Annual Precipitation (MAP) for quaternary catchments B11B and B11D is 688 mm and 671 mm, respectively. The average rainfall (70% of events) for the wettest month (January) will likely not exceed 126 mm, while extreme precipitation (10% of the events) will probably not exceed 183 mm. This implies that the region experiences moderate to high rainfall. The area experiences higher evaporation than precipitation, giving rise to dry winters and wet summers with a negative natural water balance. Average daily temperatures of approximately 27°C are experienced during summer months, while average daily temperatures of approximately 4°C are experienced during the winter season. However, daily temperatures may reach up to 36°C in summer while minimum temperatures may fall below -4°C in winter.

The topographical elevation of the project area varies from 1515 meters above mean sea level (mamsl) and 1660 mamsl characterised with gentle slopes and low-lying areas. The topography differs approximately by 50 meters in elevation between the low laying areas (an unnamed tributary of the Steenkoolspruit) and the high lying ridge areas (about 1660 mamsl). The high lying Klein Vaalkop forms the water divide between B11B quaternary catchment in the north-east and B11D in the south-west region. Two western Olifants tributaries overly the western limb of the reserve and the eastern tributary overly the eastern limb. The confluence of the three tributaries takes place on the farm Vlaklaagte 45 IS, just north of the mining concession area.

DCME is located within the Witbank coalfield, which is within the Karoo Supergroup. The Karoo Supergroup within the project area comprises the Ecca Group as well as the Vryheid Formation. The coal reserves located at DCME forms part of the coal-bearing sandstones and siltstones of the Vryheid Formation, which rest either conformably on diamictites and

associated glaciogenic sediments or unconformably on basement rocks of the Lebowa Granite suite, which in turn is underlain by volcanic rocks of the Loskop Formation.

The groundwater system in the Mpumalanga coalfields is composed of three distinct superimposed aquifers. Three principal aquifers are identified in the conceptual geohydrological model for the Mpumalanga coalfields: the upper weathered Ecca aquifer; the fractured Karoo aquifers within the unweathered Ecca sediments and the aquifer below the Ecca sediments (the fractured pre-Karoo aquifer).

The Ecca sediments are weathered to depths between 5 and 12 m below the surface throughout the area. The upper aquifer is associated with this weathered zone, and water is often found within a few meters below the surface. The fractured layer comprises of shale, sandstone, and coal seams in which the groundwater movement is mainly limited to the fractures. The fractured pre-Karoo aquifer consists of basement granites characterised with low permeability. These occur in areas separated from the fractured Karoo aquifer by the Dwyka tillites, which act as an aquiclude. Groundwater movement occurs through fractures or unweathered areas that were not removed during glaciation.

Pre-mining groundwater levels show that the groundwater levels within the area vary between 2.5 mbgl and 20 mbgl, indicating groundwater levels are relatively shallow and mainly located within the weathered aquifer. Generally, groundwater flow directions mostly follow topographical gradients. However, some localised flow can be observed at some borehole due to historical and or current dewatering activities.

The baseline groundwater quality results based on the groundwater monitoring database as well as monitoring trend analysis, indicates reasonably good water quality when compared to drinking water standards, and there are no indications that existing mining activities are impacting private or third-party groundwater sources. However, contamination signs can be observed at DFBH and DFTNM01/DFNM10 showing slightly elevated sulphate concentrations down-gradient of the co-disposal facility. However, both boreholes comply with water quality guidelines.

Geochemical Assessment and Waste Classification

The static tests indicate that the discard materials analysed were classified as Non-Acid Forming (NAF) or the acid-generating potential was uncertain due to high content of neutralising minerals. However, the dynamic leach tests and the waste classification indicated that the coal and waste rock materials are classified as a Type 3 waste and need to be disposed at a Class C landfill site or a facility with a similarly performing liner system.

Hydrogeological Model

The weathered zone hydraulic conductivity values are in the order of 10^{-2} m/d. The fracture zone hydraulic conductivity varies from the top to the bottom of the unit and ranges from 10^{-2} m/d at the upper layers and 10^{-4} m/d at bottom layers. Groundwater recharged occurs through rainfall-infiltration, and the percentage of recharge is estimated to be in the order of 1% to 3%

of the annual rainfall (MAP). Recharge to dolerite sills expected to be less than 1% of MAP due to the higher resistance to weathering of dolerite sills.

The following sources, pathways, and receptors were distinguished:

- Groundwater sources:
  - Seepage from the underground void into the surrounding aquifer post-closure after the mine dewatering has ceased; and
  - Infiltration of contaminated water from the co-disposal into the underlying aquifer through recharge on the co-disposal.
- The pathway:
  - The primary pathway for the underground void is the fractured rock unit and faults and fractures within this rock unit that are sufficiently permeable (effectively porous) to allow water flow; and
  - The primary pathway for the discard dump is the weathered/fractured aquifer units below the co-disposal.
- Groundwater receptors:
  - Groundwater receptors are mainly third-party groundwater users in the surrounding area. Boreholes and springs identified during the hydrocensus were mostly for domestic use and livestock watering for single households and small communities; and
  - Groundwater dependant wetlands and streams in the vicinity of the site were also identified as receptors.

Impact Assessment

- The potential cone of drawdown during the operational phase is largest at the end of life of mine and extends to a maximum radius of ~600 m around the open pits and ~1 200 m for the underground mining areas;
- Historical groundwater inflows into the opencasts fluctuate between ~1 000 m^3/d and ~1 500 m^3/d mainly due to increase in pit size since mining started. Between 2020 and 2027 inflows increase to ~2 100 m^3/d due to the expansion of the underground extension at Pit 1 and mining of the 2-seam and 4-seam underground mining blocks. After 2027 groundwater inflows gradually decrease to about 1 200 m^3/d;
- Based on the simulations no third-party sources are present within the zone of influence. Impacts on wetlands are likely to be low due to most of the expansion being underground mines, and surface runoff to these wetlands will not be impacted upon;
- Base flow to tributaries at the site may reduce during mining, and flows in the tributaries should be monitored;

- During the operational phase groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area;
- The drawdown impacts as a consequence of the proposed mining is expected to result in a minor impact due to the scale and it is unlikely there will be an impact on third party abstraction sources;
- During steady state production the groundwater inflows will likely be in the range of ~1 500 - 2 000 m^3/d. Most of these abstraction volumes will be drawn from the pit areas and as such the impact on groundwater availability will be minor;
- Groundwater levels in the vicinity of the site are expected to take approximately 20 years to recover post-closure. It is expected that the long-term recovery will have a minor impact. It is unlikely that any privately-owned boreholes located in the vicinity of the proposed development will be impacted upon. The contaminant migration indicates that the plumes will flow towards and following local drainage lines located between and to the west and the east of the open pits;
- The contaminant migration calculations indicate that the plumes will mainly flow towards and follow local drainage lines, such as the two tributaries of the Olifants River located to the north and the east of the opencasts (Figure 7 4). These are expected to receive an increased salt load due to the contaminant plume migration. Expected post-closure sulphate concentrations in groundwater close to the western tributary (north of Pit 1) may go up to 2 800 mg/l, while concentrations close to the eastern tributary (east of Pit 2) may go up to 1 500 mg/l. This is expected to have a high impact on the streams and associated wetlands.
- Based on the contaminant transport simulations no third party boreholes are projected to be within the zone of contamination and it is therefore unlikely that any of these boreholes will be impacted.
- Decant from Pit 1 will flow towards the western tributary of the Olifants River; the decant from Pit 2 will flow towards the eastern tributary of the Olifants River. The calculated volumes and quality of the potential decant indicate a high impact on the water quality of the tributaries of the Olifants River, and subsequently the Olifants River itself, if not mitigated.
- Decant could also potentially impact on the hillslope seep and channeled valley bottom wetland associated with the western tributary, and the channeled valley bottom wetland areas associated with the eastern tributary.

- Mitigation should focus on the post-closure contaminant plumes and decant flows. The proposed mitigations in this report should reduce all impacts to minor or negligeble and include:
  - Mining should progress as swiftly as possible to reduce the period of active dewatering and the mining area extent should be kept to a minimum. Dewatering of the mining areas should stop as soon as the mining activities cease;
  - Groundwater levels surrounding the mining areas should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown;
  - Groundwater abstraction should continue for the LoM to maintain a cone of drawdown, and dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as possible;
  - Groundwater levels surrounding the mining areas should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown;
  - Dispose of coal discard slurry at the co-disposal facility only;
  - Pollution control dams and/or ROM coal stockpile areas should be lined, and clean water needs to be diverted away from these infrastructures;
  - Dewatering should cease as soon as possible after mining activities are completed to allow for groundwater level recovery;
  - Groundwater level recovery should be frequently monitored to identify deviations from the predicted recovery rate;
  - Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate. If a contaminant plume is detected from Pit 1 or Pit 2, groundwater may need to be abstracted and treated before release into the environment;
  - Clean water and runoff should where possible be directed towards the open pits to flood these areas as fast as possible;
  - Rehabilitation of the pits and co-disposal facility to reduce infiltration of rainwater into the dump to reduce seepage generation;
  - The post-closure sealing of inter-connections between the mining areas at DCME, especially between the underground mine voids and the opencast pits;
  - Installation of groundwater abstraction boreholes at decant points, or formation of a pit lake, to reduce water level and prevent decant flow, and treatment of the abstracted water;
  - Groundwater level recovery in the rehabilitated open pits should be frequently monitored to create stage curves and predict the final water recovery level.

Considering the extent of expected impacts on the groundwater environment, and taking into account the mitigations as recommended in this report, the proposed activities can be authorised.

Recommendations

The following recommendations are made, and should be included in the Environmental Management Plan report and EA:

- The development of a closure water management plan that assesses the management of a critical water level to minimise contamination of the shallow weathered aquifer. This must be analysed in a financial model to further inform the most effective closure water management options. The groundwater model must be used as a management tool to inform this process;
- Adhere to the mining footprint and avoid unnecessary impacts to areas not currently identified in the layout, progress the mining activities as quickly as possible, and cease dewatering activities as soon as possible after mining has been completed;
- Develop a post mining landform design informed by the end land use objectives, providing design elevations to manage backfilling operations;
- Concurrent rehabilitation of the opencasts as an integrated part of the mining activities, including:
  - Backfilling as mining progresses and preferential handling of material to ensure reactive overburden is placed in the deepest portion of the pit;
  - Backfilling in layers rather than end tipping to provide a level of compaction by the traversing equipment;
  - Placement of softs over hard overburden, combined with the above points will reduce oxygen ingress;
  - Replacement of topsoil stripped ahead of mining and vegetation establishment to reduce recharge and limit erosion; and
  - Implementing topsoil management throughout the life of the operation to limit damage to the physical properties and combat compaction. Compaction can lead to poor quality rehabilitation and increased recharge through the development of preferential pathways.
- Monitoring of groundwater abstraction volumes during operation and the rate of water level recovery in the backfilled open pits and the development of stage curves which will aid in water management during the Post-Closure Phase;
- Update of the groundwater and surface water monitoring network, with frequent surface and groundwater quality monitoring for the operational phase, to continue into the post-closure phase, to be able to discern trends in surface water quality;
- Updating of the geochemical assessment with additional samples from new mining areas and geochemical model update to asses expected long-term AMD formation;
- Updating of the numerical model once every three years or after significant changes in mine schedules or closure plans, by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario; and

- Options to prevent decant flow from the pits, such as pump and treat, or a pit lake, must be considered, and alternatives should compared and included in a closure plan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid Base Accounting
AG	Acid Generating
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
BH	Borehole
Coeff. Var.	Coefficient of Variance
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DWS	Department of Water and Sanitation
EAP	Environmental Assessment Practitioner
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMPr	Environmental Management Programme report
ESIA	Environmental and Social Impact Assessment
GPS	Global Positioning System
GMWL	Global Meteoric Water Line
He	Hectares
Hz	Hertz
ICP	Inductively Coupled Plasma
IPP	Independent Power Producer
IWULA	Integrated Water Use License Application
k	Hydraulic conductivity
km	kilometre
L/s	Litre per second
L/h	Litre per hour
MAE	Mean Annual Evaporation
m amsl	metres above mean sea level
MAP	Mean Annual Precipitation
m bgl	metres below ground level

mg/ℓ	milligrams per litre
mm	millimetre
mm/a	millimetre per annum
ms	milli-seconds
mS/m	milli Siemens per metre
Mtpa	Million ton per annum
m^3	cubic metre
NAG	Net Acid Generating
NEMA	National Environmental Management Act, 1998
NEMWA	National Environmental Management: Waste Act, 2008
NNP	Net Neutralising Potential
NPR	Net Potential Ratio
nT	nanoTesla
NTU	Nephelometric Turbidity Units
PAG	Potential Acid Generating
PCD	Pollution Control Dam
S	Storativity
SANAS	South African National Accreditation System
SPLP	Synthetic Precipitation Leaching Procedure
St. Dev.	Standard Deviation
S_y	Specific yield
TDS	Total Dissolved Solids
T	Transmissivity
WHO	World Health Organisation
WRD	Waste Rock Dump
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
WMA	Water Management Area

1 Introduction

Digby Wells Environmental (hereinafter Digby Wells) was appointed by Exxaro Coal Central (Pty) Ltd to undertake Groundwater Impact Assessment and Update of the Groundwater Model for the proposed Dorstfontein East Expansion Project. The planned expansion includes underground mining from 2022 onwards at the Dorstfontein Coal Mine East (DCME) (Figure 1-1 and Figure 1-2).

Dorstfontein East Coal Mine, has existing Environmental Authorisation (EA) for current mining activities. However, additional coal reserves that are not part of the existing authorisation (EMPr) have been identified, and these areas will need to be incorporated in the updated EMPr for approval. The underground mining will be accessed from the existing Pit 2 opencast (Figure 1-1 and Figure 1-2).

Exxaro Coal Central appointed Digby Wells as the independent Environmental Assessment Practitioner (EAP) to manage the legislated environmental application processes which include the following applications:

- Integrated Environmental Authorisation Application in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA), and the National Environmental Management: Waste Act, 2008 (Act No. 56 of 2008) (NEM: WA) for all current and proposed activities at the operation; and
- An integrated Water Use Licence Application in terms of the National Water Act, 1998 (Act No. 26 of 1998) (NWA) for water-related activities associated with the proposed underground and opencast authorisation activities.

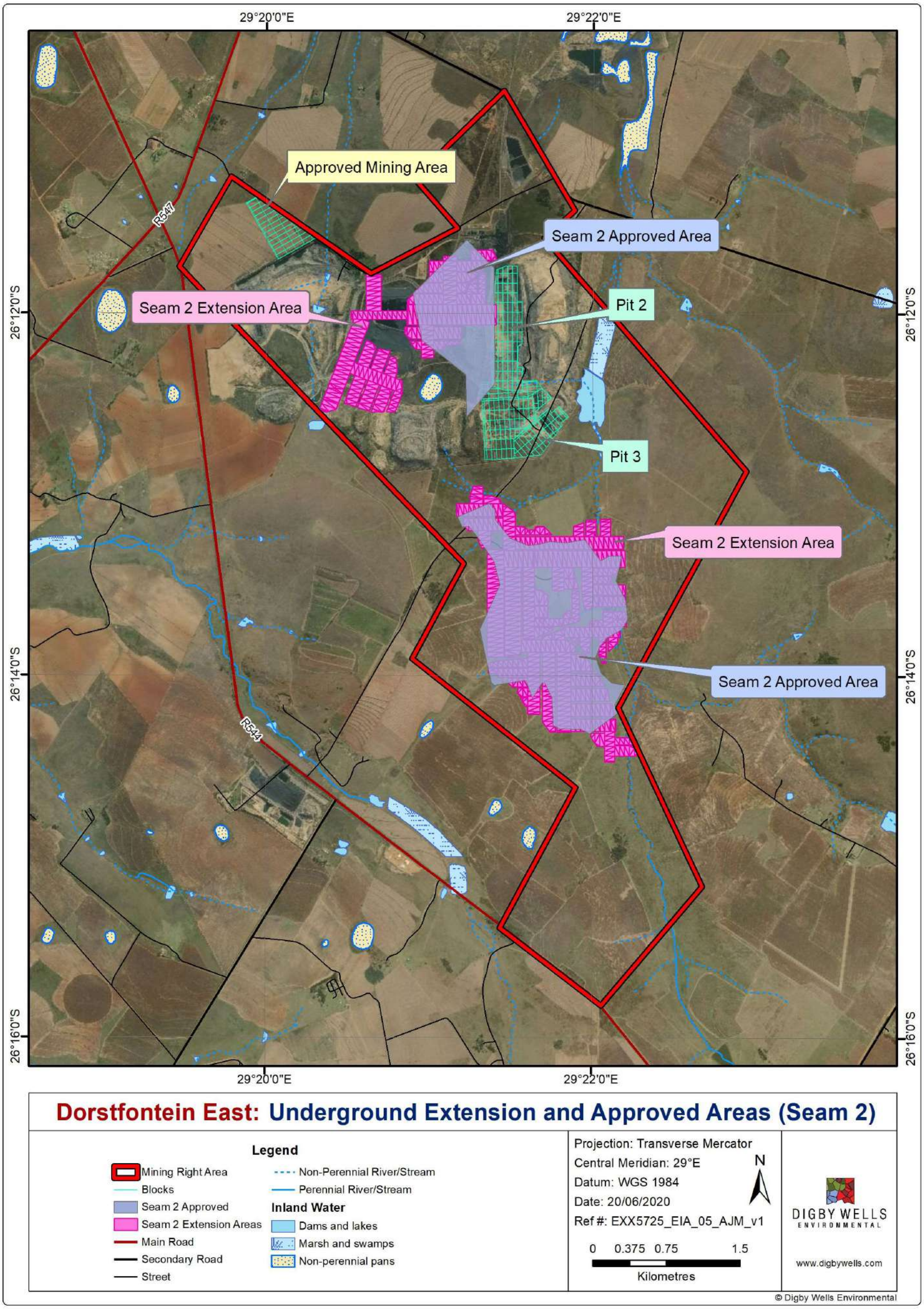


Figure 1-1: Seam 2 current and proposed underground mining

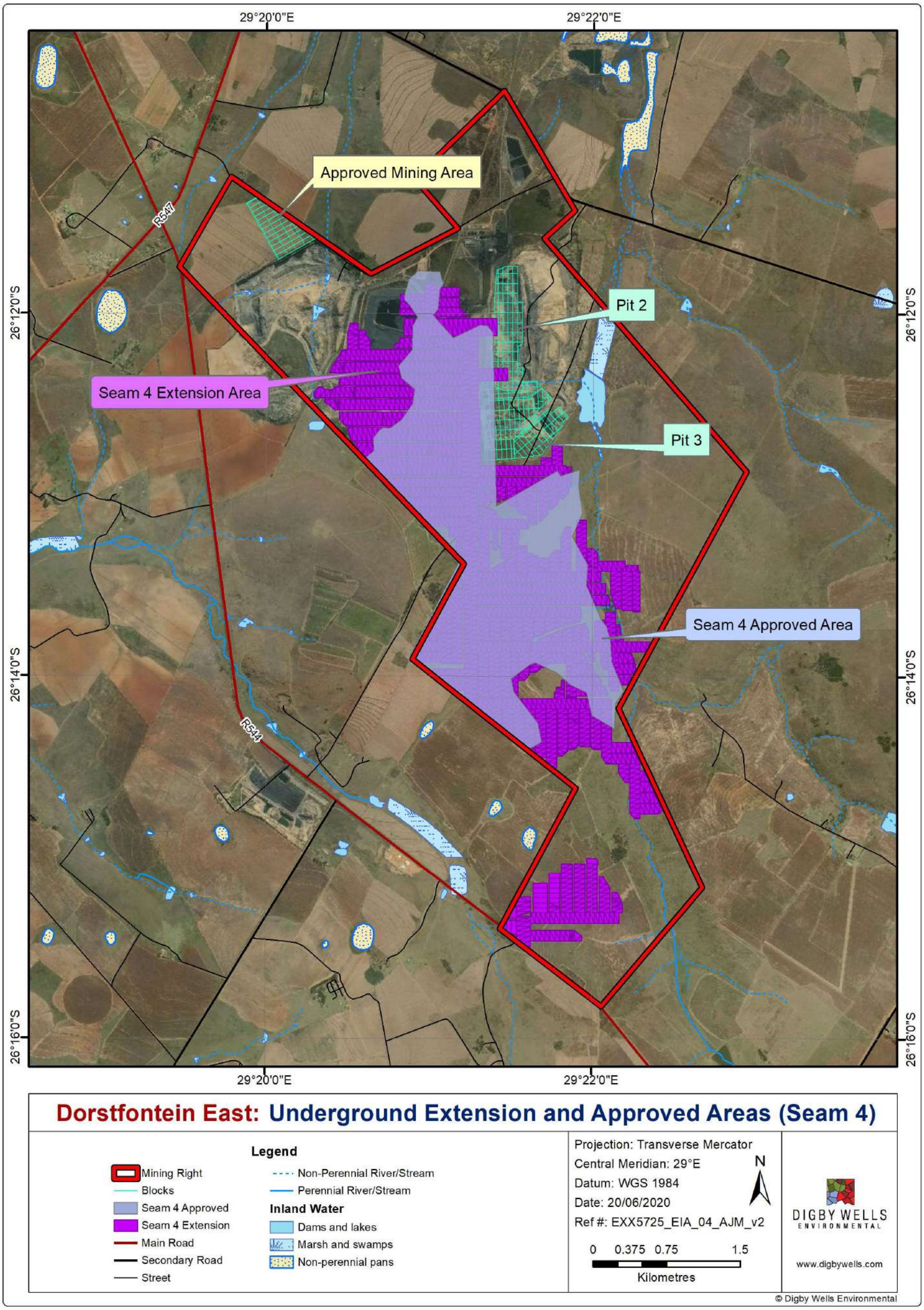


Figure 1-2: Seam 4 current and proposed underground mining

An amendment and consolidated process will ensure that Exxaro Coal Central incorporates all current and future proposed activities associated with the DCME operation. The proposed project activities are presented in Table 1-1. The proposed infrastructure layout throughout the life of mine is shown in Figure 1-3.

The MR includes Portion 2, Portion 3, the Remaining Extent (RE), RE of Portion 54, and RE of Portion 1 of the Farm Fentonia 54 IS; and Portion 4, Portion 5, Portion 10, Portion 11, Portion 12, the RE of Portion 55, RE of Portion 8, RE of Portion 13 and RE of 1 of the Farm Welstand 55 IS; as well as RE of Portion 2, RE of Portion 9 and RE of Portion 1 of the Farm Dorstfontein 71 IS. The proposed mining activities will only take place in the western half of the MR, which covers a surface area of approximately 800 hectares. The eastern portion will not be mined nor accommodate any mining-related infrastructure.

Two mining options have been considered for the proposed DCME expansion project. The underground mining option has been proposed underneath 395.69 ha of wetland area, while the open cast mining option is expected to impact 96.07 ha of wetland habitat directly.

Therefore, to attain the required approval for the proposed Dorstfontein East Expansion Project is undertaking a detailed hydrogeological impact assessment study. As part of the study, a specialist hydrogeological impact assessment study is assumed to provide baseline environmental background (define the groundwater system of the area), to identify and assess potential groundwater impacts that may arise from the proposed development and its associated activities.

Table 1-1: Proposed Project Activities

Project Phase	Project Activity
Operational Phase	Removal of rock (blasting)
	Stockpiling (rock dumps, soils, ROM, discard dump) establishment and operation
	Diesel storage and explosives magazine
	Operating processing plant
	Operating sewage treatment plant
	Water use and storage on-site – during the operation, water will be required for various domestic and industrial applications. A pollution control dam will be constructed that capture water from the mining area which will be stored and used accordingly
	Storage, handling and treatment of hazardous products (including fuel, explosives, and oil) and waste
	Maintenance activities – through the operations maintenance will need to be undertaken to ensure that all infrastructure is operating optimally and does not pose a threat to human or environmental health. Maintenance will include

Project Phase	Project Activity
	haul roads, pipelines, processing plant, machinery, water, and stormwater management infrastructure and stockpile areas.
Decommissioning Phase	Demolition and removal of infrastructure – once mining activities have been concluded, infrastructure will be demolished in preparation for the final land rehabilitation.
	Rehabilitation – rehabilitation mainly consists of backfilling of open pits, profiling of the land, spreading of the preserved subsoil and topsoil, and re-vegetation
	Post-closure monitoring and rehabilitation

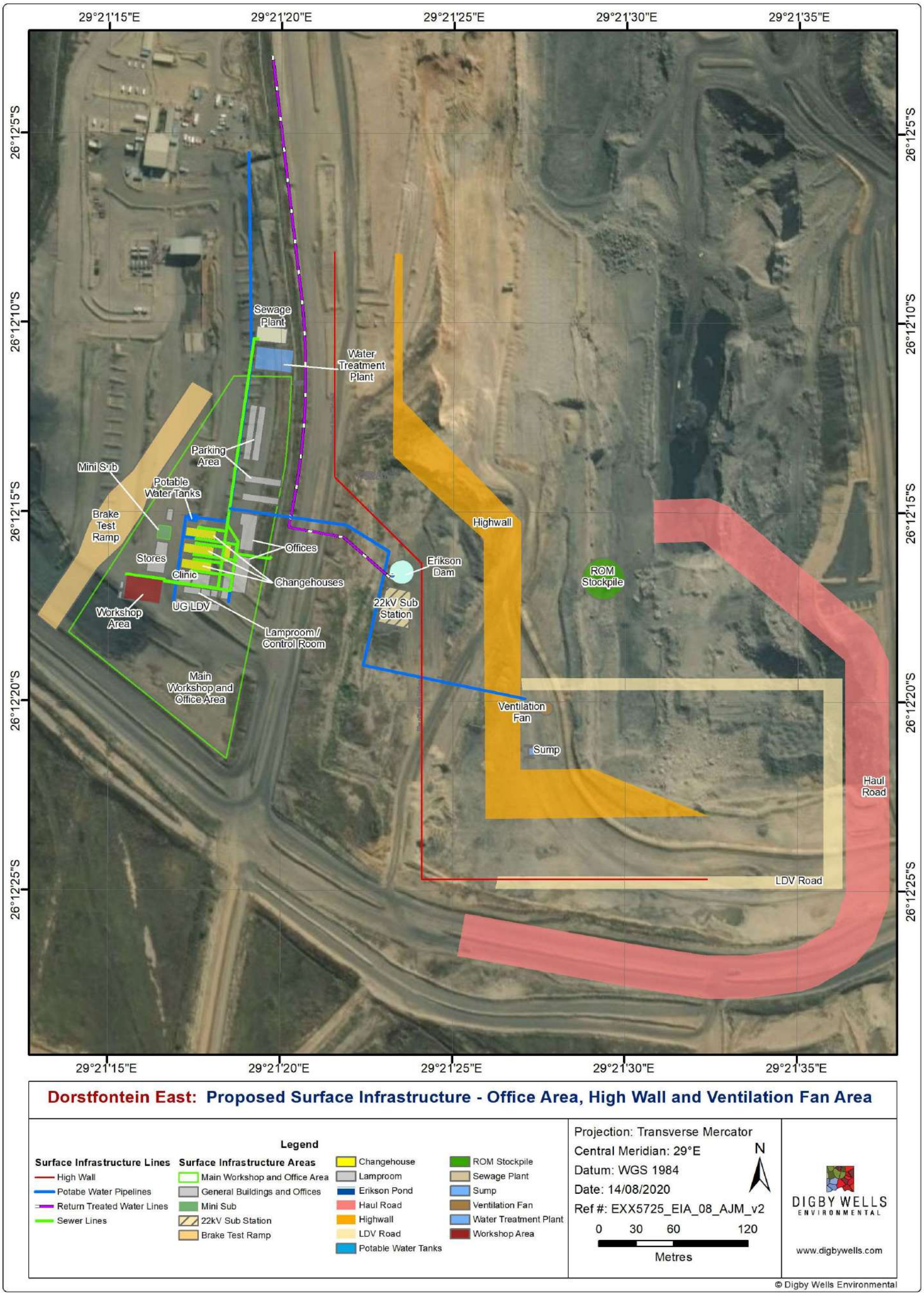


Figure 1-3: Proposed DCME Infrastructure Layout

1.1 Scope and Purpose of the Report

This specialist groundwater impact assessment report provides the baseline hydrogeological characteristics for DCME, including the proposed expansion. Furthermore, the study evaluates the potential impacts of all DCME proposed activities on the quantity and quality of groundwater resources within the Project Area (Mining Right Area) according the hydrogeological characteristics, monitoring data, and process description of the mine operations.

To update the existing ESIA study and to incorporate the newly identified coal reserved into the existing EMPr for the Proposed Dorstfontein East Expansion Project, an additional hydrogeological impact assessment needs to be carried.

1.1.1 Terms of Reference

The following activities have been included in terms of reference (ToR):

- Data collection and desktop review;
- Geochemical Assessment;
- Update Acid-Mine Drainage treatment plan;
- Update hydrogeological conceptual model;
- Numerical Flow and Contaminant Transport Model Update.

Below the scope of work and methodology is described to address the requirements as per the ToR.

1.1.2 Scope of Work

The following scope of work is deemed to be required to carry out the ToR above:

- Groundwater baseline description based on a desktop review of available data;
- Geochemical Assessment including static and dynamic testing;
- Compilation of an Acid Mine Drainage (AMD) treatment plan;
- Conceptual hydrogeological model update;
- Numerical Model update;
  - Construct a numerical groundwater flow and contaminant transport model for the sub-catchment in which the project is situated;
  - To calibrate the model with groundwater levels measured in the newly drilled monitoring boreholes for the project;
- Complete a groundwater impact assessment with the calibrated model that will meet the following objectives:

    - Delineate the radius of influence on groundwater levels as a result of mine dewatering;
    - Identify and quantify the impact of mine dewatering on private groundwater users as well as rivers and streams (receptors);
    - Calculate the volume of groundwater that may seep into the pit during mining;
    - Predict the timing of decant from the pits post closure;
    - Predict the long-term impact of the mining activities on groundwater quality; and
    - Estimate the salt load as a result of the groundwater component to stream baseflow.
- Reporting; and
- Project management.

The study is undertaken in line with the Department of Water and Sanitation (DWS) Best Practice Guideline for Impact Prediction and is guided by following legislative requirements:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA);
- Regulation 636 under the National Environmental Management: Waste Act; National Water Act (Act 36 of 1998) (NWA); and
- NWA amendment of Regulation 704 (GN R 704) of 1999.

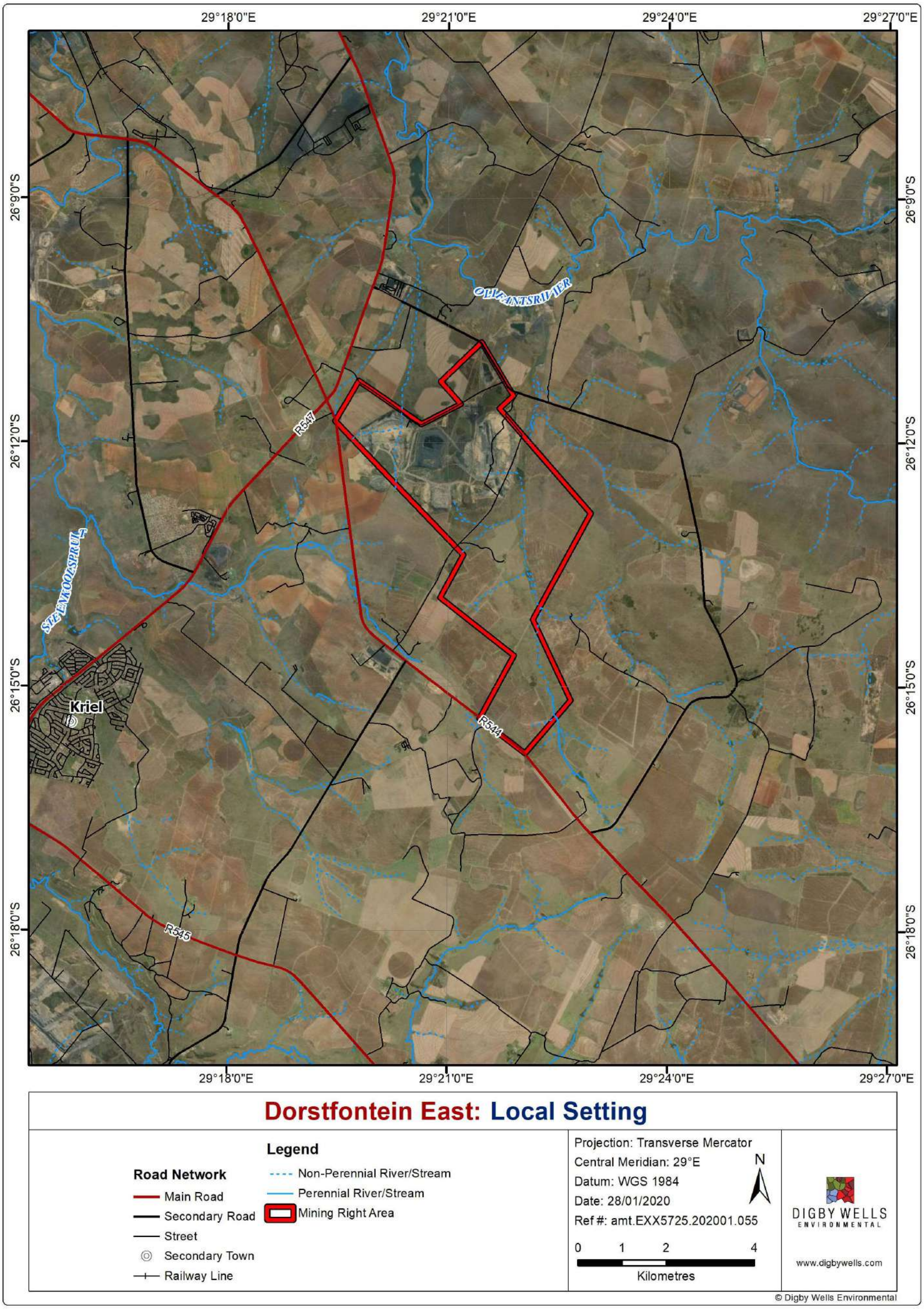


Figure 1-4: Project Location

1.2 Report Structure

The remainder of the report is structured as follows:

- Section 2: Methodology
- Section 3: Baseline Hydrogeological Environment
- Section 4: Geochemical Assessment Update;
- Section 5: Conceptual Hydrogeological Model Update;
- Section 6: Numerical Model Update;
- Section 7: Groundwater Impact Assessment
- Section 8: Groundwater Management Plan; and
- Section 9: Gaps In Knowledge And Limitations
- Section 10: Conclusions and Recommendations

1.3 Expertise of the Authors

Table 1-2 presents a summary of the expertise of the specialists involved in the compilation of this report. The full CVs of these specialists are included in Appendix A.

Table 1-2: Expertise of the Specialists

Team Member	Bio Sketch
Arjan van 't Zelfde Senior Hydrogeologist (MSc. Soil Science)	Arjan van 't Zelfde is a Senior Hydrogeologist at Digby Wells with 16 years' experience in Europe and Africa. He specialises in numerical groundwater flow modelling including multi-species solute and heat transport modelling using the MT3D and SEAWAT modules for Modflow. He has worked for mine sites for various His experience includes hydrogeological investigations for Feasibility Studies, EIA's, mine dewatering, construction dewatering, groundwater management plans, and groundwater monitoring programmes – design and implementation, aquifer thermal energy storage (ATES) impact studies, groundwater contamination studies and risk assessments, environmental management program reports and project management.

Team Member	Bio Sketch
Kgaugelo Thobejane Geochemist (MSc Geochemistry (In Progress))	Kgaugelo Thobejane is a geochemist at the Water Geosciences Department and holds a BSc Honours in Mining and Geology from the University of Limpopo. Kgaugelo is currently registered with the South African Council for Natural Scientific Professions as a candidate. She has less than a year of experience in the mining and environmental industry, working as a geochemist and assisting in the hydrogeology field. Her expertise includes geochemistry assessment, waste classification, hydrocensus, water monitoring programs, drilling supervision, and technical reporting on all aspects.

2 Methodology

This section of the report describes the methodology adopted in determining the baseline hydrogeological characteristics at the Dorstfontein East Coal Mine.

2.1 Baseline Assessment

2.1.1 Desktop Study

In-depth analyses of all relevant and available secondary data such as reports, datasheets, proposals, and maps were utilised to compile a baseline site description that will feed into the Hydrogeological Impact Assessment / EIA specialist report. Part of the assessment was to collate all background information and carry out preliminary fieldwork. Part of the review process included the following reports:

- GCS, 2008. Dorstfontein 4-Seam EMP Study. Hydrogeological Investigation. TCSA .D.07.251;
- GCS, 2016. Dorstfontein East Environmental Impact Assessment – Hydrogeological Investigation. GCS Project Number: 16-0123; and
- GCS, 2019. Dorstfontein East Environmental Impact Assessment – Hydrogeological Investigation. GCS Project Number: 18-1091.

2.1.2 Hydrocensus

A hydrocensus survey was conducted between the 1st and the 30th July 2020. The hydrocensus survey was conducted within a 2 km radius around the DCME site. Further, the survey was undertaken to provide an insight into the baseline hydrogeological conditions in and around the proposed Dorstfontein East Expansion Project mining area. The survey included visits to public water sources, private sources, and springs. A total of 3 springs and 10-20 boreholes were visited. The following information was collected at each of the field sites (where possible):

- Sampling coordinates (X, Y and Z position);
- Static (or rest) water level;
- Primary groundwater use; and
- Field pH, EC, and TDS values.

2.1.2.1.1 Water Level Measurements

During the hydrocensus survey, groundwater levels were estimated by determining the water level elevations at the springs. Further, the groundwater levels were measured by using a dip meter for identified boreholes. Static groundwater levels were measured by measuring the distance between the borehole collar height level above the surface and the water table depth within the borehole. The height of the borehole collar was then subtracted from the measured groundwater level to determine the exact groundwater level in meters below ground level (mbgl). The mbgl measurement was subsequently subtracted from the borehole's surface elevation to use a universal unit of meters above mean sea level (mamsl) for all measurements.

2.1.3 Geochemical Assessment

A geochemical assessment in terms of the National Environmental Management: Waste Act (NEM: WA) 2014 was undertaken to determine the acid-producing potential and leachate capability for coal discard and slurry materials, and at what rate acidic leachate would be generated.

In addition, the study was used to confirm previous geochemical testing and modelling as carried out by GCS in 2016. A total of six discard samples were made available by the client for testing and were used for the assessment of the co-disposal facility expansion and backfilling of discard materials in the opencasts.

The following testing was performed on all samples:

- Acid-base accounting (ABA);
- Net-acid generation (NAG); and
- Paste pH.

The following testing to be performed on 3 selected samples:

- X-ray diffraction (XRD);
- X-ray fluorescence (XRF);
- S speciation.

The following humidity cell testing was carried out for one 6 kg discard sample:

- Kinetic leach testing of one (1) sample including leach water analyses (10 weeks).

The discard and coal disposal samples are decribed in Table 2-1.

Table 2-1: Sample description

No.	Reporting ID	UIS Laboratory ID	Analysis	Description
1	Discard 1	711683	Waste Classification	Roof or Floor Sample of exploration borehole XYZ
2	Discard 2	711684	Waste Classification	Roof or Floor Sample of exploration borehole XYZ
3	Discard 3	711685	Waste Classification	Roof or Floor Sample of exploration borehole XYZ
4	Discard 4	711686	Waste Classification	Roof or Floor Sample of exploration borehole XYZ
5	Discard 5	711687	Waste Classification	Roof or Floor Sample of exploration borehole XYZ
6	PDT 1.1	101764	Waste Classification and Humidity Cell Test	Roof or Floor Sample of exploration borehole XYZ

2.1.4 Hydrogeological Conceptual Model Update

The existing hydrogeological conceptual model was updated using input of the baseline assessment, groundwater levels and quality time series, the updated geochemical assessment, updated mine plans and schedules, as well as the regional geological and hydrogeological setting. The conceptual model was used to identify all potential sources of contamination, preferential pathways and potential receptors, including wetlands that may be affected.

2.1.5 Numerical Model Update

The model grid was re-defined and model boundaries used previously were reviewed. After construction the model was re-calibrated using the latest groundwater levels. Once the model was calibrated it was then used to simulate the current situation and the expected future groundwater impacts associated with the updated project activities.

The deliverables from the modelling phase of the project included an updated, calibrated groundwater flow and contaminant transport model.

2.1.6 Impact Assessment

A groundwater impact assessment was carried out based on the outcome of the numerical model, and recommended mitigation measures were given that are necessary to address groundwater impacts associated with the project on the environmental receptors, including private boreholes.

The final task of the study was to define a network of observation points and implement a monitoring program that would satisfactorily monitor groundwater conditions (levels and quality) before and after commencement of operations. Existing boreholes drilled during the investigations were identified and additional sites were proposed.

2.1.7 Groundwater Management

The groundwater management plan was updated and an AMD treatment plan was included to develop a coherent treatment plan that will be refined and implemented across the Life of Mine (LoM) and into closure. This treatment plan is assumed to be revisited annually in order to incorporate updated information and ensure alignment with operational planning, closure planning and annual rehabilitation planning. A conceptual treatment plan was formalised and included in the management plan.

2.1.8 Reporting

A hydrogeological impact assessment report was compiled and include the following:

- Groundwater baseline description, including updated mine schedules and activities;
- Geochemical assessment;
- Updated Conceptual Hydrogeological Model;
- Updated Numerical Modeling;
- Impact assessment with:
  - potential impacts classified according to the standard risk assessment methodology;
  - discussion of the most significant impacts in detail, including potential impacts on surrounding wetland/s due to the expansion;
- Groundwater Management Plan, including:
  - Actions and mitigations to minimise identified impacts;
  - Input required for the mine Environmental Authorisation;
  - AMD treatment plan; and
  - Groundwater monitoring network.

3 Baseline Hydrogeological Environment

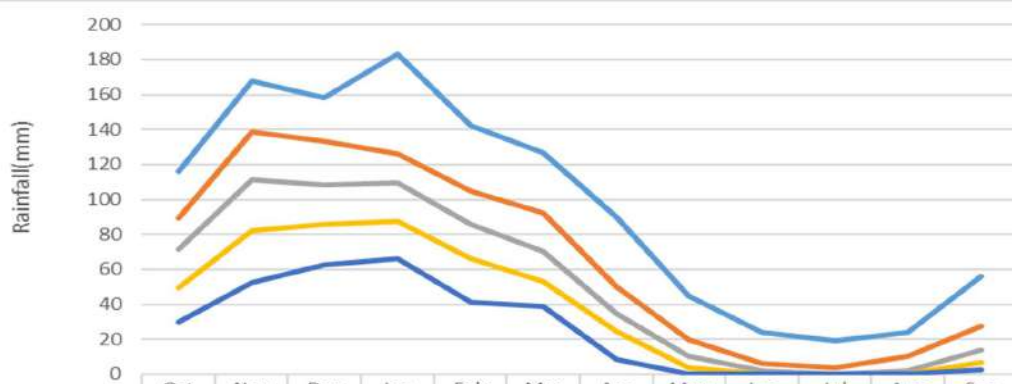
The section below describes the environmental setting of the Project Area with focus on the physiography, climate, land-use and vegetation, surface-water hydrology, geology, and the hydrogeology. The aim is to provide a detailed understanding of hydrogeological characteristics within the proposed mining area.

3.1 Climate

Dorstfontein East Coal Mine falls within a semi-arid climate region of Southern Africa, where rainfall is sparse with high seasonal variations during wet and dry seasons. The wet (or rainy) season occurs during summer months, October to March and is characterised by short, intense convective storms. Such high rainfall contributes to significant parts of recharge into the aquifers (Braune and Xu, 2005). Dry seasons occur during wintertime (April - September) and are characterised by dry cold weather conditions. Governing the variation in seasonal rainfall is the latitudinal movement of the Inter-Tropical Convergence Zone (ITCZ), which migrates to the south of the equator during summer months and back to the north of the equator in winter.

3.1.1 Rainfall

The DCME project site is characterised by a temperate climate with cool dry winters and warm summers. The Mean Annual Precipitation (MAP) for quaternary catchments B11B and B11D is 688 mm and 671 mm, respectively. The combined average MAP for the two quaternary catchments is likely to be distributed as indicated in Figure 3-1. The normal rainfall (70% of events) for the wettest month (January) will likely not exceed 126 mm, while extreme rainfall (10% of the events) will likely not exceed 183 mm. This implies that the region experiences moderate to high rainfall.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90 Percentile	116	168	158	183	143	127	90	45	24	19	24	56
70 Percentile	89	139	133	126	105	92	50	20	6	4	11	27
50 Percentile	71	111	108	109	86	70	35	10	2	0	2	14
30 Percentile	49	82	86	88	66	53	24	4	0	0	0	7
10 Percentile	30	53	63	66	41	39	9	0	0	0	0	3

Figure 3-1: Monthly Rainfall Distribution

3.1.2 Evaporation

The Mean Annual Evaporation (MAE) for the quaternary catchments B11B and B11D is 1587 mm and 1647 mm, respectively. The region experiences higher evaporation than precipitation, giving rise to dry winters and wet summers with a negative natural water balance. The average monthly distribution of potential evaporation and rainfall for both quaternary catchments can be seen in Figure 3-2.

Generally, evaporation exceeds mean annual rainfall by a factor of 2 times which could mean that rainfall recharge into the aquifer could only be possible in times where rainfall is high and evaporation rates are low. This is one of the major factors resulting in dry streams and also on low moisture fluxes recharge the aquifers.

3.1.3 Temperature

Temperature variation is seasonal. Average daily temperatures of approximately 27°C are experienced during summer months while average daily temperatures of approximately 4°C are experienced during the winter season. However, daily temperatures may reach up to 36°C in summer while minimum temperatures may fall below -4°C in winter.

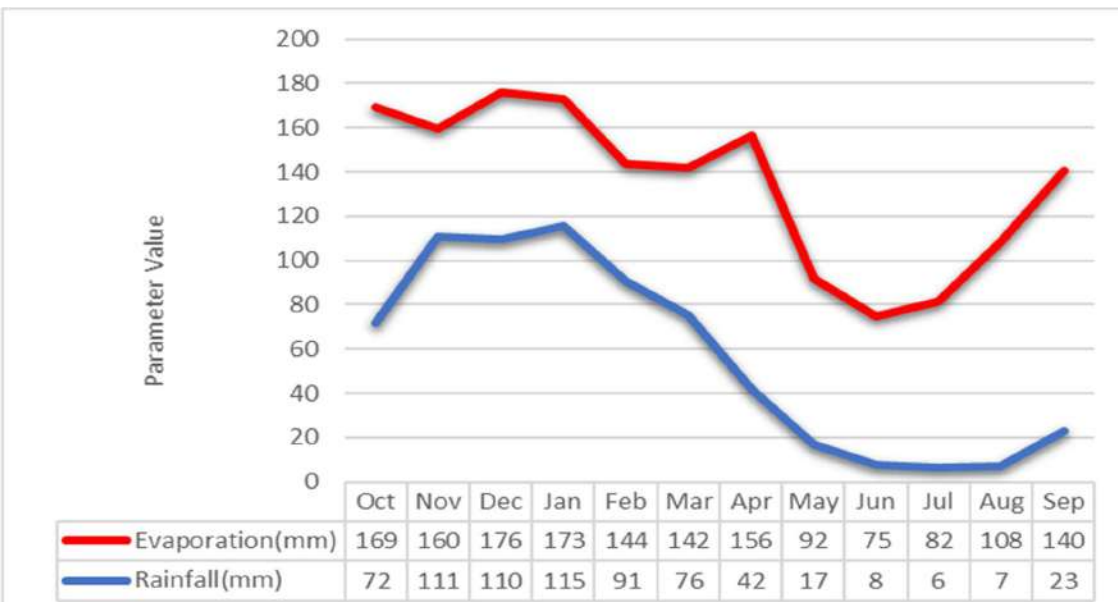


Figure 3-2: Monthly Evaporation and Rainfall

3.2 Topography and Drainage

3.2.1 Topography

The topographical elevation of the project area varies from 1515 meters above mean sea level (mamsl) and 1660 mamsl characterised with gentle slopes and low-lying areas (Figure 3-3). The topography differs approximately by 50 meters in elevation between the low laying areas (an unnamed tributary of the Steenkoolspruit) and the high lying ridge areas (approximately 1660 mamsl). The high lying Klein Vaalkop forms the water divide between B11B quaternary catchment in the north-east and B11D in the south-west region (Figure 3-3). The land undulates gently. There are four (4) valleys present in the larger reserve area, namely:

- the unnamed tributary of the Steenkoolspruit which flows in a westerly direction; and
- Three unnamed tributaries of the Olifants River, which drains in a northerly direction.

Two western Olifants tributaries overly the western limb of the reserve and the eastern tributary overly the eastern limb. The confluence of the three tributaries takes place on the farm Vlaklaagte 45 IS, just north of the mining concession area. The slopes of the valleys vary between 1:20 and 1:40. The topography between the two Olifants River tributaries is less prominent and can be characterised more as a plateau.

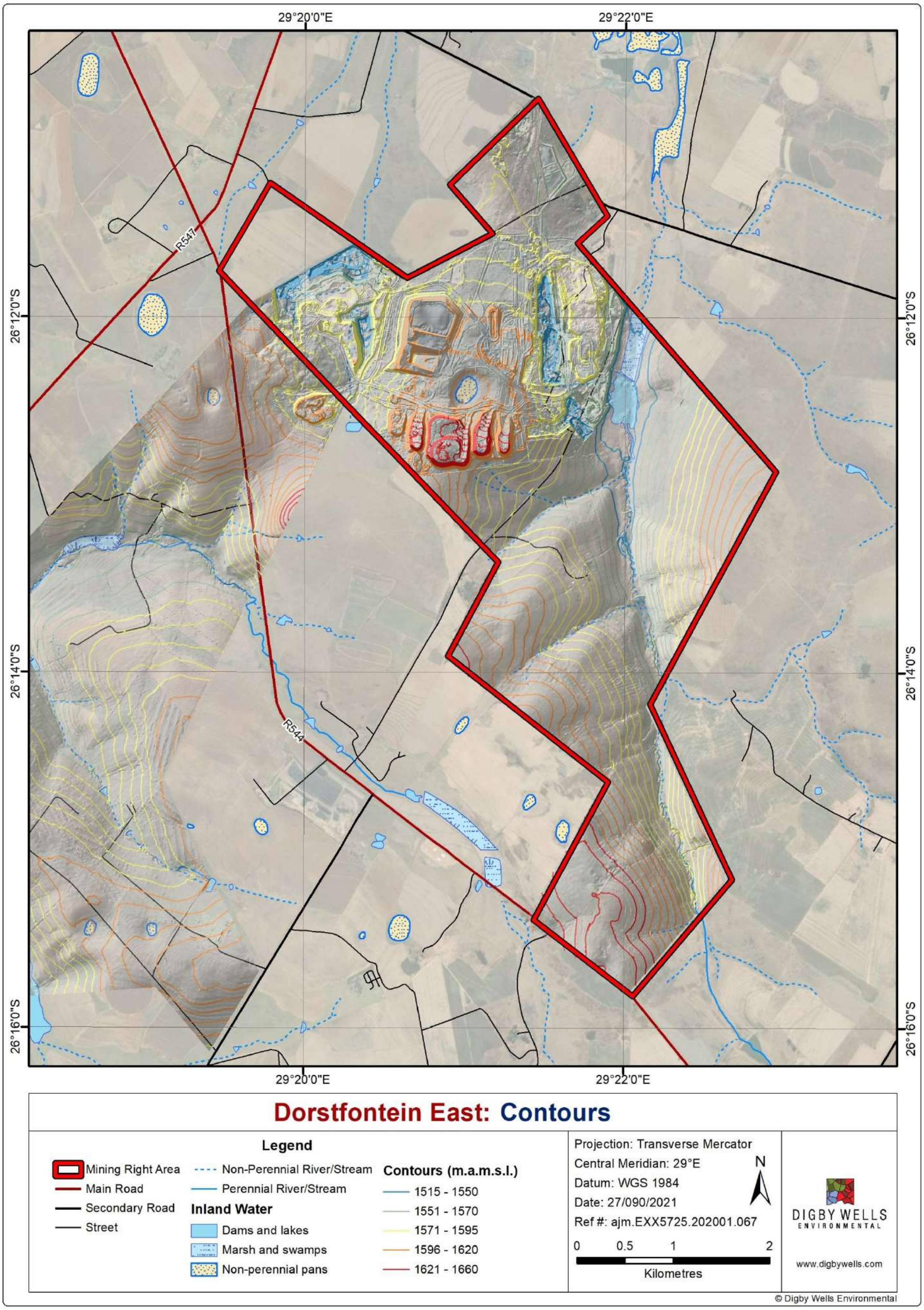


Figure 3-3: Surface Topographical Contours For The DCME Site

3.2.2 Drainage and Catchments

South Africa is divided into 9 Water Management Areas (WMA) (Revised National Water Resource Strategy, 2012) which are made up of quaternary catchments which relate to the drain regions of South Africa. These drainage regions are subdivided into four divisions based on the size. DCME is located within the Olifants Water Management Area (WMA 2) and occurs asymmetrically within the upper catchments of quaternary catchment B11B and B11D as revised in the 2012 water management area boundary descriptions.

As mentioned under Section 3.2.1, the higher-lying Klein Vaalkop forms the water divide between the B11D and B11B quaternary catchments (Figure 3-4). Surface water hydrology within the Dorstfontein East Expansion Project is mainly associated with the upper Olifants River and locates within B11B quaternary catchment in the east. Further south, directly opposite the eye of the western Olifants tributary is a perennial pan.

The other part of DCME is mainly associated with the upper Steenkoolspruit River. Rainfall that occurs within the B11D catchment drains towards the unnamed tributary of the Spookspruit, which flows into a westerly direction towards the Steenkoolspruit. The confluence of the Steenkoolspruit River with the Olifants River occurs north of the mining rights area roughly a kilometre (s) downstream from the proposed project site and these two merges to form an unknown river at quaternary catchment B11F.

3.3 Land-use, Soils and Vegetation Cover

To develop an understanding of the processes governing recharge it is essential to understand both surface and sub-surface complexities defining the rate (movement) and the magnitude of water recharged into the aquifer. Such complexities include the land-use and cover and soils characteristics (such as soil types). The section below provides a short overview of the land-use, soil and vegetation cover within the Project Area.

Data from this section was obtained from the following reports:

- Digby Wells, 2020. Hydropedological Scoping Report for the Dorstfontein East Coal Mine. Hydropedological Assessment. Project Code: EXX5725; and
- Digby Wells, 2020. Scoping Environmental Baseline Biodiversity Specialist Report (Fauna and Flora) in support of Environmental Authorisation to amend the Environmental Impact Programme and Water Use License for Dorstfontein East Mine, near Kriel, Mpumalanga. Project Code: EXX5725.

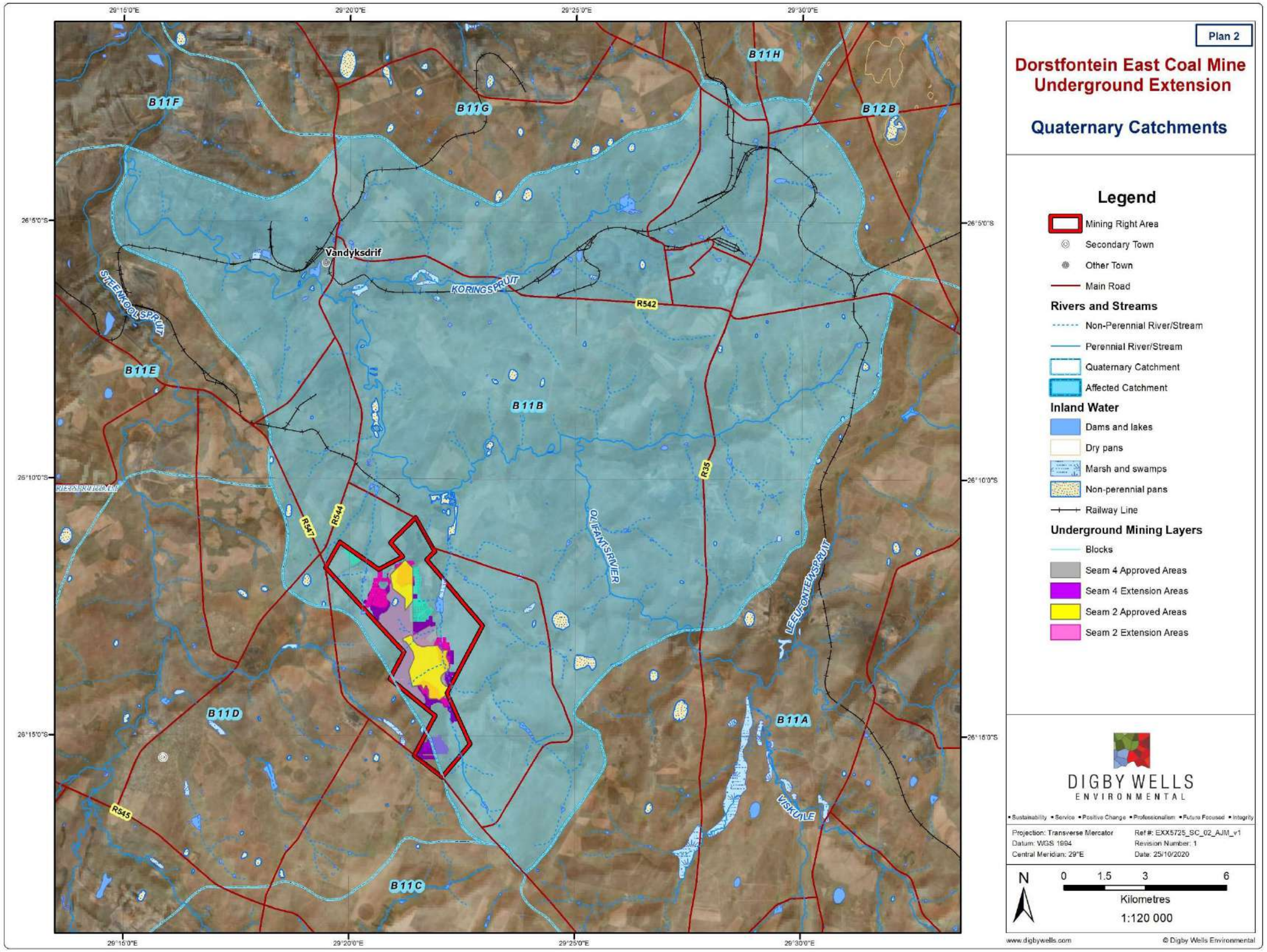


Figure 3-4: Hydrological Setting of the DCME Project Site

3.3.1 Land-Use

The land use of the project area ranges from rural (undeveloped land) to a semi-developed land (rural-urban transition zone) in and around Rietkuil-Kriel located South-East of the Dorstfontein Coal Mine. Specifically, the Dorstfontein Coal Mine area can be characterised as rural with disseminated villages associated with agricultural farming activities. The land use within the project area is mainly crop production and smaller parts as livestock farming. These farming activities largely depend on groundwater abstraction through private boreholes, while some depend on rainfall (rain-fed).

3.3.2 Vegetation Cover

The proposed Dorstfontein underground mining project area is located within the Eastern Highveld Grassland national vegetation type (Mucina & Rutherford, The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, 2011) of the Mesic Highveld Grassland Bioregion. Utmost of the project area consists of disturbed/transformed vegetation as a result of existing structures/developments, agricultural practices and associated infrastructure. Small patches of the study site do consist of recovered natural vegetation.

Generally, the Eastern Highveld Grassland occurs in high rainfall areas on leached soils. The soils of this Eastern Highveld Grassland consist of yellow sandy soils of the Ba (30%) and Bb (65%) land types found on shale and sandstone of the Karoo Supergroup. Approximately 44% of the Eastern Highveld Grassland has been transformed, primarily by cultivation, plantations, mining, urbanisation, and building of dams (Mucina & Rutherford; 2006). Climate and soil type is the major influencing type controlling vegetation type in the region.

3.3.2.1 Hydrological Soil Types and Hillslope Hydrology

The dominant land type within the project boundary is Bb4. Portions of the study area are also occupied by land types Bb5 and Fa8. Based on the diagnostic horizons and materials associated with the expected soil forms, the probable hydrological soil types can be summarised as follows (Digby Wells, 2020):

- Recharge – Hutton, Clovelly;
- Interflow (A/B) – Estcourt, Longlands, Valsrivier, Sterkspruit, Glenrosa;
- Interflow (Soil/Bedrock) - Glencoe, Wasbank, Swartland;
- Responsive (Shallow) – Mispah, Arcadia; and
- Responsive (Saturated) – Avalon, Rensburg, Katspruit, and Kroonstad.

Recharge occurs within the hillslope areas and largely occurs through one-dimensional (vertical) flow and out of the profile into the underlying bedrock as the dominant flow. These soils can either be shallow on the fractured rock with limited contribution to evapotranspiration or deep freely drained soils with significant contribution to evapotranspiration. Interflow is understood to occur within the mid-slope areas through duplex soils where the textural discontinuity facilitates build-up of water in the topsoil as well as soils overlying relatively impermeable bedrock. Foot-slope areas are characterised with Responsive shallow and saturated hydrological soil types. Responsive shallow soils overly relatively impermeable bedrock and characterised with limited storage capacity. On the other hand saturated Responsive soils depicts morphological evidence of prolonged saturation and such soils are sometimes close to saturation during the rainy season and largely contribute to the generation of overland flow due to saturation excess.

3.4 Geology

3.4.1 Regional geology

DCME is located within the Witbank coalfield, which is within the Karoo Supergroup. The Karoo Supergroup within the project area comprises the Ecca Group as well as the Vryheid Formation. The base of the Karoo Supergroup is the Dwyka Group comprising of tillites that are fairly regularly deposited over the basin except for paleo-topographical highs. The Dwyka tillites are overlain by the Vryheid Formation of the Ecca Group which hosts the coal seams.

The Vryheid Formation consists of various sequences of stacked upward-coarsening depositional sequences of sandstone and siltstone with the various coal seams located within the alternating lithofacies (Figure 3-5). The sediments (the coal-bearing sandstones and siltstones) rest either conformably on diamictites and associated glaciogenic sediments of probable Dwyka age, or unconformably on basement rocks (GCS, 2019). The Ecca Group sediments overlie the Dwyka Group. The geology can be stratigraphically classified as indicated in Table 3-1.

During the Jurassic period, a large number of dolerite dykes and sills intruded into the Karoo Supergroup as part of the Karoo dyke swarm (originating from the Karoo Large Igneous Province). These dykes and sills act as important geological structures which divert and impeding groundwater movements. The tendency of dolerite sills to migrate to differing stratigraphic levels has resulted in the coal seam displacement throughout the Karoo Coalfields.

The geological sequence underlying the Olifants River is characterised by alluvium, with minor outcrops of dolerites towards the north, close to the existing RBCT railway line, which could be a result of the Karoo strata being invaded by dolerite dykes and sills during the late Jurassic times.

Table 3-1: Stratigraphy of the regional geology

	Subgroup	Lithology	Formation
Karoo Supergroup	Upper Ecca	Sandstones	Volksrust
	Middle Ecca	Sandstones	Vryheid
		Shales	
		Coal	
	Lower Ecca	Shale	Pietermaritzburg

3.4.2 Local Geology

The economically important coal seams within the Witbank coalfield are the 1, 2, 4 and 5 seams with most mining occurring in the 2 and 4 seams. The thickness and distribution of the seams have been controlled by paleo-topography, pre and syndepositional events, and the later destructive effects of dolerite intrusions. The Dorstfontein Coal Mining area was unaffected by major fluvial events concurrent with peat accumulation, thus modification of seam thicknesses by ancient erosion is minimal.

The structural nature of the coal seam and the overburden formation has resulted in sub outcropping occurring in the north and western areas of the reserve blocks and dipping gently in a southerly direction. This feature of the coalfield allows for relatively easy access to the seam.

The presence of the undulating dolerite sill may have a detrimental effect on the quality of the coal through devolatilisation during the emplacement of the dolerite sill. Sills and dykes are constant sources of seam disturbance where the area is associated with, not only seam destruction by burning (Hagelskamp, 1987 as in GCS, 2008) but vertical movements, as well as geotechnical problems. This results in poor roof conditions occurring in some areas.

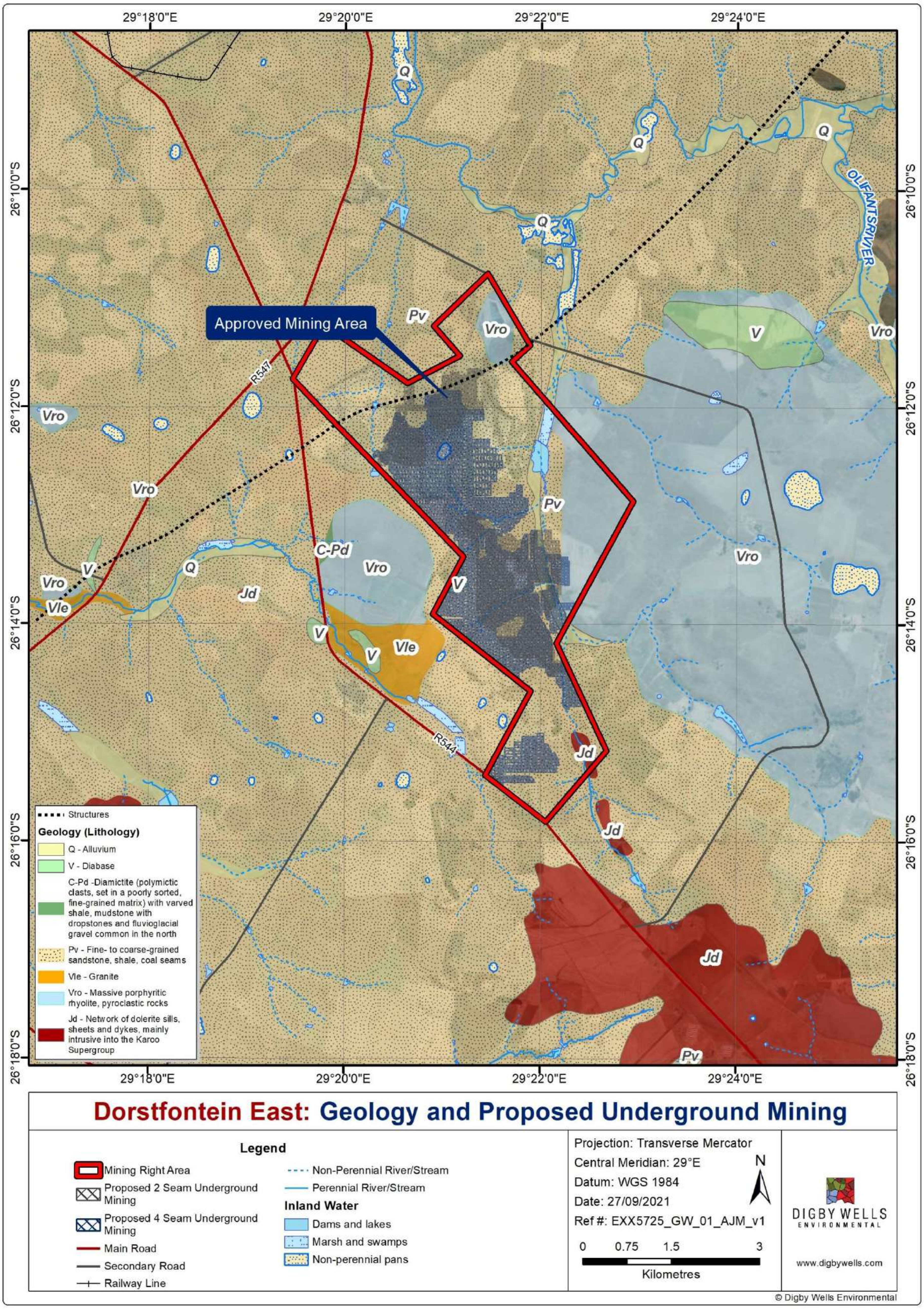


Figure 3-5: Regional Geology Map

3.5 Hydrogeology

3.5.1 General Aquifer Description

The groundwater system in the Mpumalanga coalfields is composed of three distinct superimposed aquifers. Hodgson *et al.* (1998) have classified the aquifer systems in the following manner: they are the upper weathered Ecca aquifer; the fractured Karoo aquifers within the unweathered Ecca sediments and the aquifer below the Ecca sediments (the fractured pre-Karoo aquifer).

3.5.1.1 Weathered Ecca Aquifer

The Ecca sediments are weathered to depths between 5 and 12 m below the surface throughout the area. The upper aquifer is associated with this weathered zone and water is often found within a few metres below the surface. The weathered layer comprises of residual soils and weathered shales and sandstones. This aquifer is recharged by rainfall. The hydraulic conductivity values are in the order of 10^{-2} m/d. The percentage recharge to this aquifer is estimated to be in the order of 1% to 3% of the annual rainfall based on work by Kirchner *et al*. (1991) and Bredenkamp (1995).

It should, however, be emphasised that in a weathered system, such as the Ecca sediments, highly variable recharge values can be found from one area to the next. This is attributed to the composition of the weathered sediments, which range from coarse-grained sand to fine clay.

3.5.1.2 Fractured Ecca Aquifer

The pores within the Ecca sediments are well-cemented and do not allow any significant flow of water. All groundwater movement, therefore, occurs along with secondary structures, such as fractures and joints in the sediments. The fractured layer comprises of shale, sandstone and coal seams in which groundwater movement is mainly limited to the fractures. The fracture density decreases with depth, therefore, permeability decreases with depth. These structures are better developed in competent rocks, such as sandstone; hence the better water-yielding properties of the latter rock type. The hydraulic conductivity varies from the top to the bottom of the unit and ranges from 10^{-2} m/d at the upper layers and 10^{-4} m/d at bottom layers.

It should, however, be emphasised that not all secondary structures are water-bearing. Many of these structures are constricted because of compressional forces that act within the earth's crust, in addition to that fractures sometimes get filled by secondary fluids like silica to form quartz veins.

3.5.1.3 Fractured Pre-Karoo Aquifer

The fractured pre-Karoo aquifer comprises of basement granites characterised with low permeability. These occur in areas separated from the fractured Karoo aquifer by the Dwyka tillites which act as an aquiclude. Groundwater movement occurs through fractures or unweathered areas that were not removed during glaciation.

3.5.2 Aquifer Properties

3.5.2.1 Water Strikes

A summary of water strike depths within DCME monitoring boreholes is given in Table 3-2. For the weathered zone, water strikes were encountered between 2-25 mbgl corresponding to the weathered aquifer. While for the fractured rock units intersected in the boreholes water strikes were observed frequently for depths between 25-57 mbgl corresponding to the fractured Karoo (Ecca) aquifer. None of the boreholes was drilled into the deeper lying fractured pre- Karoo aquifer.

Table 3-2: Water strike frequency within DCME (Source: GCS, 2016)

Borehole ID	Drilled borehole depth (m)	Weathered aquifer water strike position (mbgl)	Fractured aquifer water strike position (mbgl)
DFTNM1	75	15	
DFTNM2	75	24	
DFTNM3	75	2	57
DFTNM4	75	None	56
DFTNM5	40	19	
DFTNM6	85	25	
DFTNM7	85	None	38 & 56
DFTNM8	85	25	None
DFTNM9	85	None	39
DFTNM10	40	17	
DFTNM12	85	None	43
DFTNM13	85	None	None

** mbgl – meters below ground level*

3.5.2.2 Aquifer Hydraulics

Hydraulic parameters were sourced from GCS (2019) report and are summarised below. The Transmissivity (T) and Hydraulic conductivity (K) values for Karoo aquifers determined in previous studies are summarised below:

- The DCME is characterised T values varying between 0.01 and 22.3 m^2/day with an average T value of 3.3 m^2/day (Table 3-3);
- The K values determined by GCS (2008) and GCS (2016) vary between 10^{-2} and 10^{-4} m/day. These correcponded with the expected hydraulic parameters for Karoo aquifers;
- Coal seam No 4 is not highly permeable however some seepage of water can be expected during mining;
- The sandstone between the upper and the lower at coal seam No 4 has low permeability that the fractures within the Vryheid Formation sediments;
- Shale and dolerite at depths exceeding 15 m have a hydraulic conductivity between 0.004 and 0.02 m/day; and
- Generally the T values decrease with depth.

Table 3-3: Statistics for Transmissivity (m^2/day)

Number of observations	36
minimum	0.01
maximum	22.25
average	3.32
geometric mean	0.75
harmonic mean	0.06

3.5.3 Aquifer Classification

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

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

3.5.4 Hydrocensus Survey

A hydrocensus survey was conducted by Digby Wells on 12th and 13th August 2020. The aim of the survey was to obtain the most up-to-date data on current groundwater use in the area and and cross-check water levels and other relevant data that was collected during a hydrocensus conducted by GCS between 25th and 27th August 2016.

The 2020 hydrocensus survey was conducted within an approximate 2 km survey radius of DCME. A total of 15 boreholes were visited. Groundwater levels were measured and in-field parameters were taken, where possible. Boreholes surveyed in 2020 and 2016 are shown in Table 3-4 and Figure 3-6. The hydrocensus survey results are presented below.

3.5.4.1 Borehole Status

- Six (6) monitoring boreholes of which three (3) boreholes are owned by Exxaro Coal Central and the remaining borehole is owned by BHP Billiton. All four boreholes are part of the monitoring network at Dorstfontein Coal Mine;
- Eleven (11) boreholes used for domestic and livestock watering purposes at nearby farm portions; and
- Two (2) boreholes not in use at Portion 2, Boschkrans farm and One (1) borehole also not in use at Jan Dieta farm portion.

3.5.4.2 Groundwater Use

The section below is a summary of findings from the Dorstfontein East Hydrogeological Investigation report (GCS, 2019):

- The main source of water supply in and around the proposed mining area is groundwater. Through several privately own boreholes and springs which are mainly used for domestic and livestock purposes. In some instances, boreholes are used for single and/ or several households for various uses such as domestic (farm workers) and livestock use. Some farmers had previously mentioned that the water is filtered or softened prior consumption due to the elevated salts; and
- Three privately owned springs can be found south-east of the current mining activities:
  - Farm Fentonia 54 IS (DFTNS1 & DFTNS2): Mr Edmund Muller has two fountains that have been excavated and lined with concrete. The overflow from these fountains drains into larger dams, which serve as drinking water for livestock. The yields of these fountains are not known; and
  - Farm Rietkuil 57 IS (DFTNS3): The fountain belongs to Mr Gerhard de Wet and is also lined with concrete. It is used as the source of potable water supply to the farmstead, and as such is still used by farmworkers. The overflow drains into an earth dam which is used for livestock drinking water.

Table 3-4: Hydrocensus Borehole Data – 2020 Update And Previously Collected Data (Source: GCS, 2016)

ID	Coordinates			Owner Information		Bore/Spring Status & Equipment					Hydrogeological Information		In-situ water quality (Aug-20)			
	Easting [m]	Northing [m]	Elevation [m aMSL**]	Owner	Farm Name	Primary Water Application			Equipment	Estimated Abstraction Rate [L/s]	Static Water Level [m bRL]*		EC (mS/cm)	TDS (ppm)	pH	T (C)
						Primary Use	Other Uses									
							Domestic	Stock Watering			Aug-16	Aug-20				
NBH4	29.3405	-26.2387	1610	N.Hirschowitz	Portion RE. Dorstfontein 71 IS	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	0.5	8.7	8.2	0.53	0.26	6.76	16.8
NBH4B	29.3366	-26.2405	1592	N.Hirschowitz	Portion RE. Dorstfontein 71 IS	Unused	(previously domestic)	(previously livestock)	Submersible pump (removed)		-	0.7	-	-		-
NBH5	29.1783	-26.1783	1592	BHP Billiton	North of DCME	Monitoring BH	Not Applicable	Not Applicable	N/A	0	8.6	-	-	-		-
NBH5A	29.3566	-26.1703	1539	BHP Billiton	North of DCME	Monitoring BH	Not Applicable	Not Applicable	N/A	0	11.74	6.3	0.54	0.27	7.14	20.2
D10	29.4032	-26.2182	1635	CJ Lourens	Jan Dieta	Domestic	Yes (Small Scale)	Not Applicable	Submersible pump	0	8.48	-	-	-	-	-
D10A	29.4009	-26.2154	1636	CJ Lourens	Jan Dieta	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	1	7.8	Pumping	0.26	0.13	6.92	18.4
DFTNM3	29.3625	-26.2158	1563	Exxaro Coal Central	Fentonia	Monitoring BH	Not Applicable	Not Applicable	N/A	N/A	20.1	21.0	0.42	0.21	6.69	18.1
DFTNM4	29.3576	-26.2164	1577	Exxaro Coal Central	Fentonia	Monitoring BH	Not Applicable	Not Applicable	N/A	N/A	14.8	13.6	0.43	0.22	7.05	17.3
DFTNM12	29.3246	-26.1954	1588	Exxaro Coal Central	Welstand	Monitoring BH	Not Applicable	Not Applicable	N/A	N/A	7.2	12.2	0.44	0.22	6.19	19.3
WSBH2	29.3239	-26.1831	1593	Mr.Swart	Welstand	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	1	21.9	-	-	-	-	-
WSBH1	29.3233	-26.1851	1589	Mr.Swart	Welstand	Domestic	Yes (Small Scale)	Not Applicable	Submersible pump	1	15.2	Pumping	0.48	0.24	6.64	13.9
WSWP1	29.3221	-26.1185	1550	Mr.Swart	Welstand	Domestic	Yes (Small Scale)	Yes (Small Scale)	Windmill	N/A	20.6	-	-	-	-	-
NBH23	29.3119	-26.1887	1609	IJG De Wet	Portion 2, Rietkuil	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	1	50.7	Pumping	0.48	0.24	6.27	19.6
NBH24	29.3116	-26.1913	1613	IJG De Wet	Portion 2, Rietkuil	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	1	13.2	Pumping	0.45	0.22	6.09	19.6
BHU1	29.3231	-26.1840	1593	BHP Billiton	Welstand	Monitoring BH	Not Applicable	Not Applicable	N/A	0	46.9	15.9	-	-	-	-
D7	29.3906	-26.2465	1634	E.Muller	Portion 2, Boschkrans	Domestic	yes (Small Scale)	Not Applicable	Submersible pump	0	10.7	-	-	-	-	-
D7B	29.3903	-26.2474	1638	E.Muller	Portion 2, Boschkrans	Domestic	yes (Small Scale)	Not Applicable	Submersible pump		-	2.8	-	-	-	-
D7C	29.3929	-26.2499	1642	E.Muller	Portion 2, Boschkrans	Domestic	Yes (Small Scale)	Yes (Small Scale)	Submersible pump	1	-	Pumping	-	-	-	-
D12	29.3568	-26.1783	1558	Unknown	Vlaklaagte	Domestic	yes (Small Scale)	Yes (Small Scale)	Windmill	Unknown	3.1	-	-	-	-	-
D4	29.3813	-26.2768	1652	E.Muller	Portion 2, Boschkrans	Domestic	yes (Small Scale)	Not Applicable	Submersible pump	1l/s	12.2	8.8	0.87	0.41	6.23	19.5
D4A	29.3803	-26.2703	1632	E.Muller	Portion 2, Boschkrans	None	Not Applicable	Not Applicable	N/A	0	3.1	1.0	0.65	0.35	6.49	18.7

***m bRL = meters below reference level (i.e. top of casing or surface level)**

**** m aMSL = meters above mean sea level**

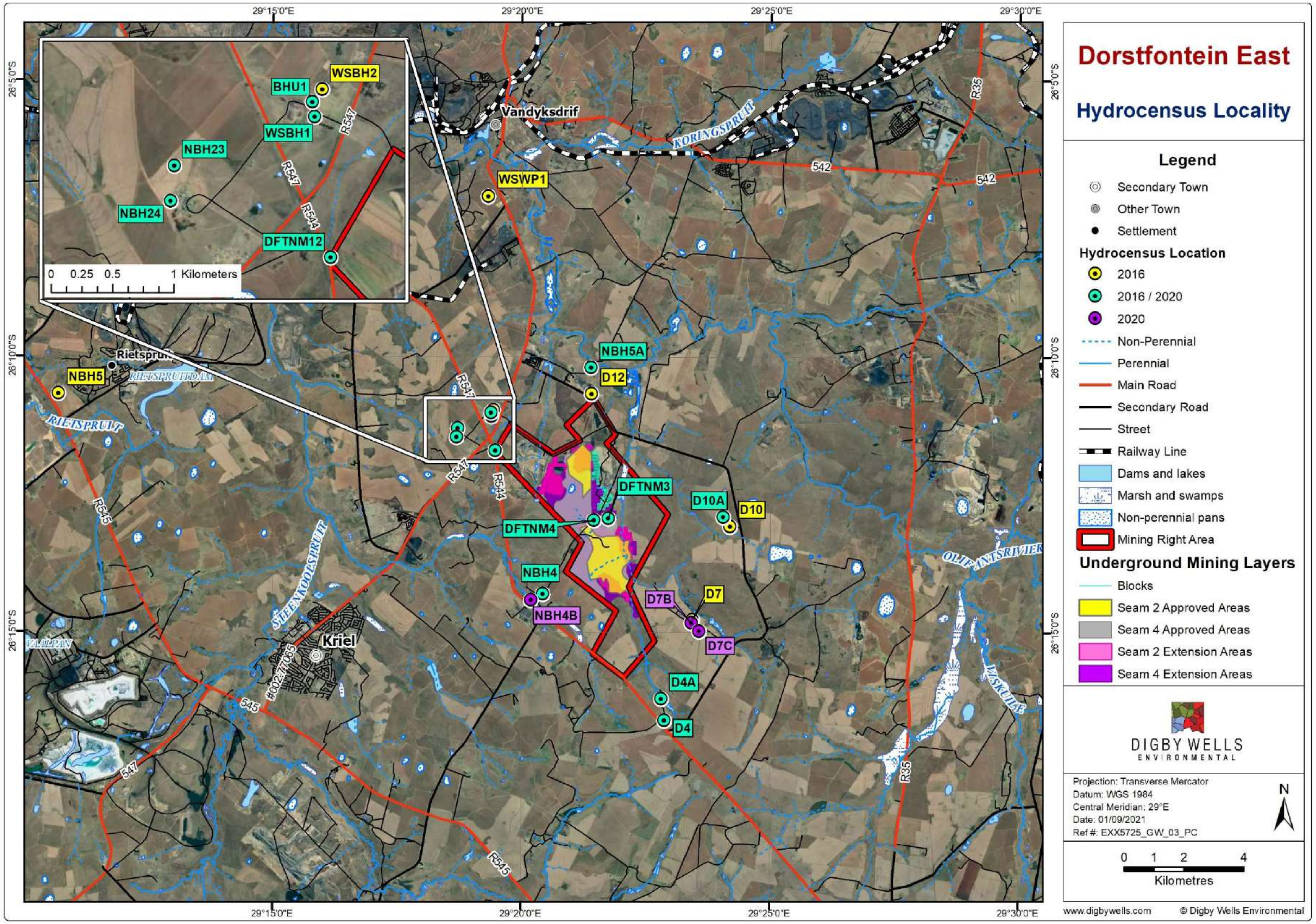


Figure 3-6: Hydrocensus Localities For The 2020 and 2016 Hydrocensus Surveys

3.5.5 Groundwater Levels

3.5.5.1 Historical Data

DCME has a groundwater monitoring network (Figure 3-10). Some boreholes that were part of the monitoring network have been destroyed over time while eactivities where expanding and at current the network consists of eleven (11) operational monitoring boreholes. Water level monitoring is conducted quarterly. For this study results collected during hydrocensus surveys in 2016 and 2020 were combined with monitoring data for the last 10 years (January 2010 and April 2020). The groundwater depth (meters below ground level) and elevation (meters above mean sea level) are given in Figure 3-7 to Figure 3-9.

As is evident from Figure 3-7, pre-mining groundwater levels where relatively shallow and were in general less than 20 mbgl in 2010 and the first half of 2011. At the end of 2011 groundwater levels in some of the boreholes started to decrease, and at the end of 2016 most monitoring boreholes showed a decrease in groundwater levels, between approximately 5 m (DTFNM9) up to 25 m (DFTNM10). However, borehole DFTNM5 showed stable shallow groundwater level varying between 3 mbgl and 6 mbgl.

Boreholes DFTNM3, DFTNM6, DFTNM7 and DFTNM10, all in close vcicinity to the opencasts, were the most impacted by the dewatering activities and showed decreases in water levels between 10 and 25 m; DFTNM4, DFTNM8, DFTNM9, DFTNM12, were less impacted and showed decreases less than 10 m.

After 2016, groundwater levels seem to have stabilised and the decreaing trends shown in Figure 3-7 do not continue in Figure 3-8. This may indicate that at current, the extent of the current cone of drawdown is not significantly expanding.

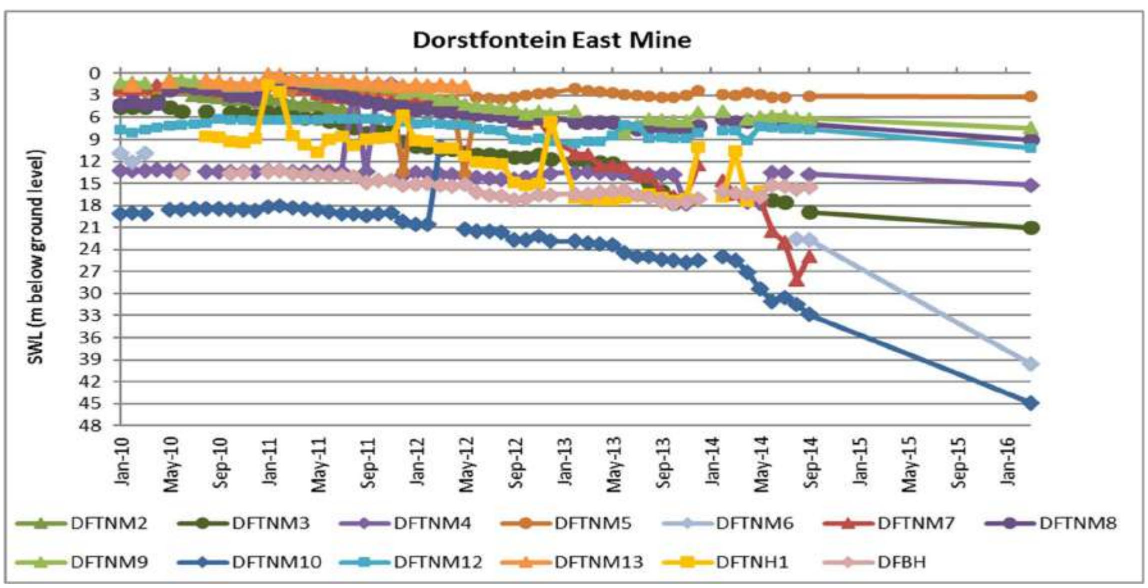


Figure 3-7: DCME Goundwater Levels in mbgl 2010-2015 (source: GCS 2019)

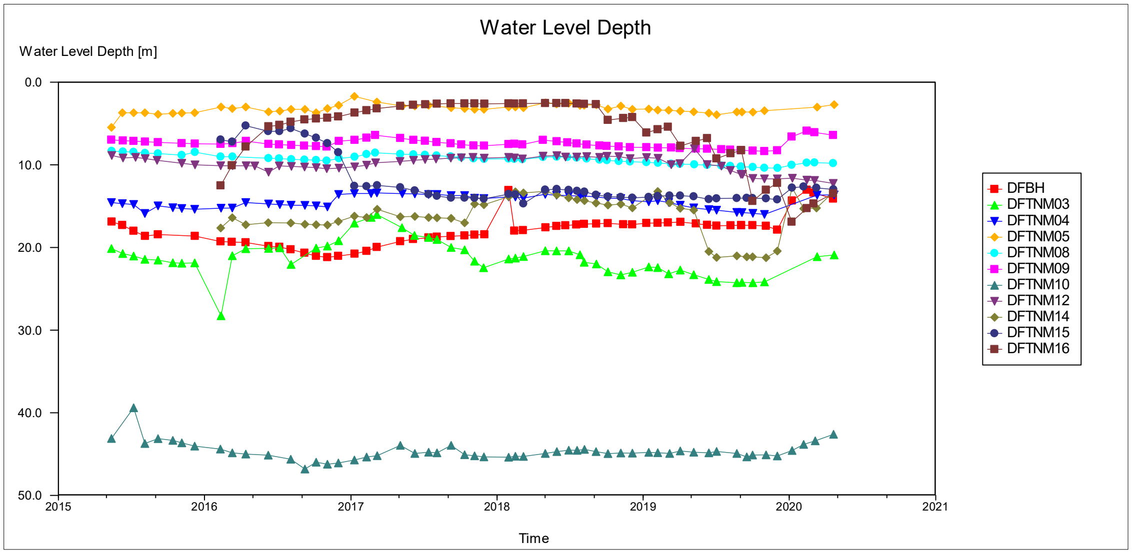


Figure 3-8: DCME Goundwater Levels in mbgl 2016-2020 (Source: DCME)

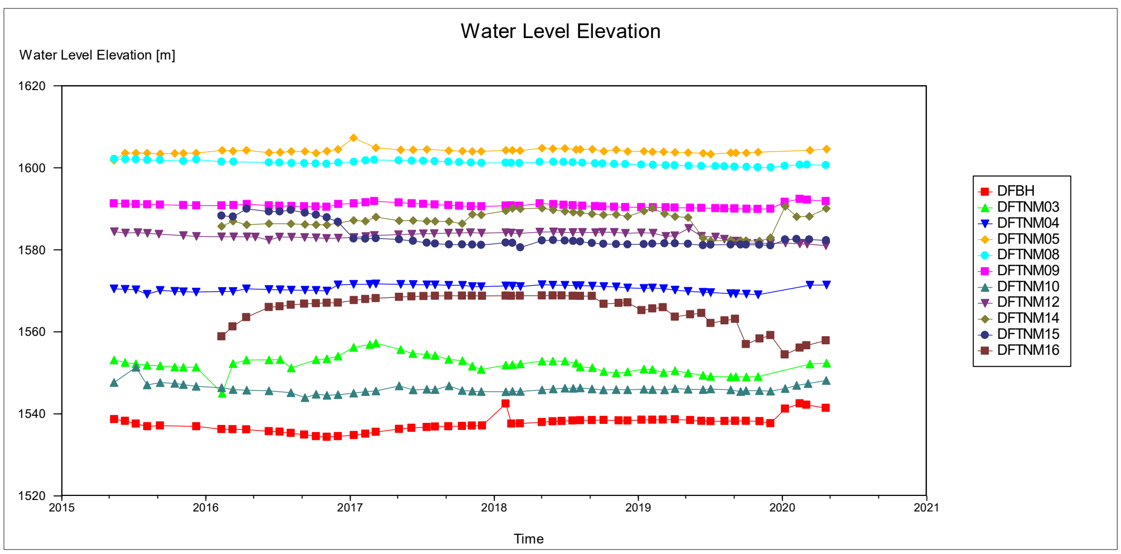


Figure 3-9: DCME Goundwater Levels in mamsl 2016-2020 (Source: DCME)

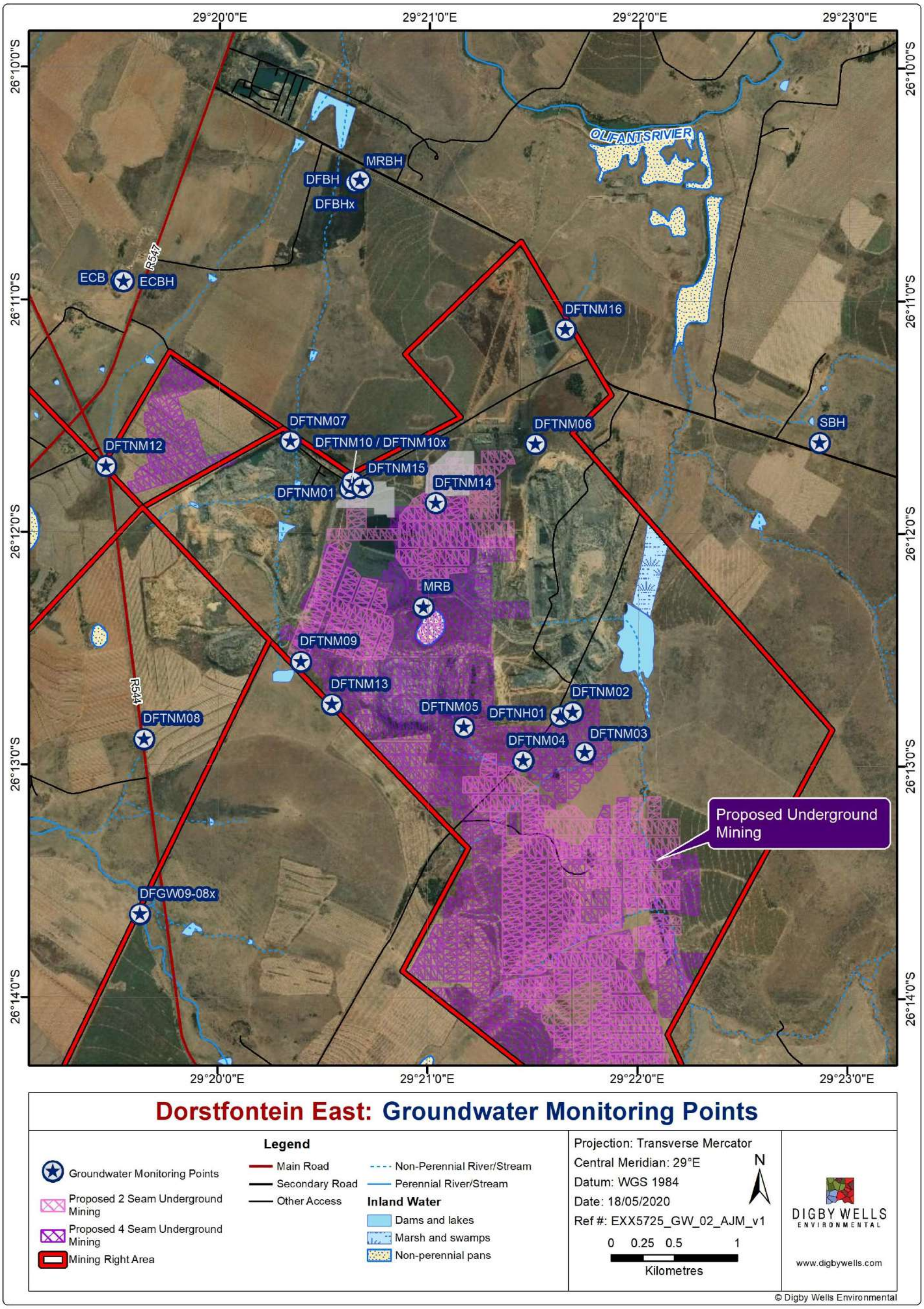


Figure 3-10: DCME Groundwater Monitoring Network

3.5.5.2 Current Groundwater Levels And Flow Directions

Recent water levels for the first quarter in 2020 (Table 3-5) were combined with the 2020 hydrocensus results (water levels of third party boreholes). Groundwater levels in monitoring boreholes ranged between 2.7 mbgl and 46 mbgl (DFTNM10) and between 1541.5 mamsl (at DFBH) and 1604.6 mamsl at (DFTNM05); and groundwater levels in hydrocensus borehols ranged between 0.7 and 21 mbgl and between 1533 and 1643 mamsl.

The recent monitoring and hydrocensus data (Figure 3-11) shows a good correlation (97%) between groundwater levels and surface elevation thus suggesting groundwater levels within the Project Area generally follow topographical gradients, with the exception of the areas in close vicinity to the current opencasts, as shown by DFTNM10 and DFTNM3. For the DCME area, this indicates that the groundwater flow direction is mainly in a northerly direction, however, as the site is situated on a topographical high, local flow directions along the eastern side of the site are east to northeast.

Table 3-5: Groundwater Levels- 2020 Monitoring

BH ID	Jan-20		Feb-20		Mar-20		Apr-20	
	SWL (mbgl)	WL Elevation (mamsl)	SWL (mbgl)	WL Elevation (mamsl)	SWL (mbgl)	WL Elevation (mamsl)	SWL (mbgl)	WL Elevation (mamsl)
DFBH	14.4	1541.3	13.1	1542.6	13.4	1542.2	14.1	1541.5
DFTNM03	-	-	-	-	21.1	1552.2	20.9	1552.4
DFTNM04	-	-	-	-	13.7	1571.4	13.7	1571.4
DFTNM05	-	-	-	-	3.0	1604.3	2.7	1604.6
DFTNM08	10.0	1600.5	9.8	1600.7	9.7	1600.8	9.8	1600.7
DFTNM09	6.6	1591.7	5.9	1592.4	6.1	1592.2	6.4	1591.9
DFTNM10	44.6	1546.2	43.8	1547.0	43.4	1547.4	42.6	1548.2
DFTNM12	11.6	1581.7	11.9	1581.5	11.9	1581.4	12.3	1581.1
DFTNM14	12.8	1590.6	15.3	1588.1	15.2	1588.2	13.3	1590.1
DFTNM15	12.8	1582.5	12.7	1582.6	12.8	1582.5	13.0	1582.3
DFTNM16	16.9	1554.5	15.3	1556.1	14.7	1556.7	13.5	1557.9
GCS02	4.5	1545.5	4.4	1545.6	4.5	1545.5	4.9	1545.1
GCS03	8.5	1552.0	8.5	1552.0	8.5	1552.0	8.6	1551.9
GCS04	-	-	-	-	1.5	1544.2	1.6	1544.1

*WL - Water Level
*SWL - Static Water Level
*mbgl - meters below ground level
*mamsl – meters above mean sea level

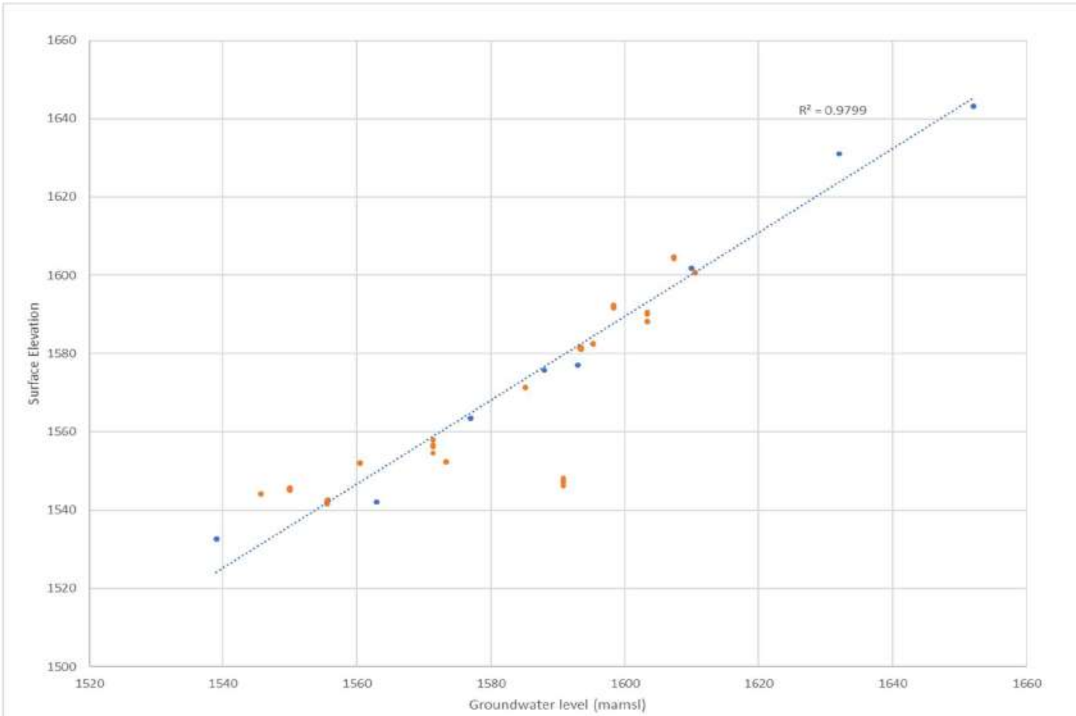


Figure 3-11: Bayesian Correlation For Groundwater Levels In Monitoring Boreholes (Orange) and Hydrocensus Boreholes (Blue).

3.6 Groundwater Quality

The groundwater quality for DCME is being described based on previous baseline studies and current monitoring data as follows:

- Pre-Mining conditions: based on results in (GCS 2008); and
- Current groundwater quality, based on results of groundwater monitoring data for 2020 and trend line analysis of historical and recent monitoring data.

3.6.1 Pre-Mining Groundwater Quality - 2008

3.6.1.1 Groundwater Characterisation

The 2008 baseline groundwater types can be characterised as follows:

- Group 1: Ca-Mg-HCO_3 type groundwater: the groundwater samples falling in this group are enriched with bicarbonate as the dominant anion. Regarding the major cations Ca and Mg are slightly higher than Na or K. Borehole DFTNM4, DFTNM5, DFTNM7, DFTNM9, DFTNM12, DFTNH3 and DFTNH4 represent Ca-Mg-HCO_3 groundwater type. This water type signifies fresh groundwater with limited degree of ion exchange (with some cation mixing) and is not affected by the mining activities;
- Group 2: Na-Cl type groundwater: the second group is characterised by their increased Na-Cl signature (i.e. borehole DFTNH4 and DFTNH7). This groundwater type represent old/stagnant groundwater or Na-Cl source affected groundwater (please refer to Figure 3-12 to Figure 3-13);
- Group 3: SO_4 contamination or a mix of different water types: Borehole DFTNM01 and DFTNH7 plots at the centre of the expanded Durov plot (Figure 3-13) and represent this group. Based on the Piper diagram none of the boreholes plots in the pollution field of the Piper diagram, which currently indicates no mining-related activities impact on the groundwater quality. Therefore, the group 3 groundwater type can be characterised as a mix of different water types with minor elevations in SO_4;
- Group 4: Na+K-HCO_3 type groundwater: the groundwater samples falling in this group are also enriched with HCO_3 as the dominant anion while Na+K is the dominant cation. This group is characterised as fresh groundwater with a high degree of Na ion exchange or Na source (DFTNM2);
- Group 5: SO_4-Na+K groundwater type (DFTNM10): the groundwater samples falling in this group mostly indicate SO_4 and Na contamination.

3.6.1.2 Comparison to WUL limits and Guideline Values

Baseline water quality results were compared to the current WUL as well as the South African Water Quality Guidelines for Domestic Use and Livestock Watering (Department of Water Affairs and Forestry, 1996). The 2008 baseline assessment results are interpreted as follows:

- pH values were between 6.3 and 9.1 All boreholes complied with the targeted water quality guideline range (TWQGR) for Domestic Use as well as WUL limit of 6.5-8.4 except borehole DFTNM2 (9.1) and DFTNH4 (6.3);
- All sampled boreholes complied with the all the recommended water quality guidelines for Ca (except DFTNH5 exceeding the TWQGR limit), Mg, K, SO_4 and NO_3 concentrations and TDS;
- Na concentrations exceeded the recommended WUL limit of 21.12 mg/L for DFTNM1, DFTNM2, DFTNM4, DFTNH4, DFTNH5, DFTNH7 and DFTNM12;
- SO_4 concentrations varied between 4.1 mg/L and 99.3 mg/L and thus complied with the recommended all the recommended water quality guidelines;
- All sampled sboreholes complied with the all the recommended water quality guidelines for F except for DFTNM2 and DFTNM7. Borehole DFTNM2 which exceeded the TWQGR of 1 mg/L for Domestic Use and the TWQGR of 2 mg/L for Livestock Watering;
- All sampled boreholes complied with the TWQGR of 10 mg/L for Fe concentration, however, borehole DFTNM1 (0.17 mg/L), DFTNM5 (0.76 mg/L), DFTNM9 (0.25 mg/L), DFTNM10 (0.88 mg/L), DFTNM12 (0.27 mg/L), DFTNH3 (0.26 mg/L) and DFNH4 (0.23 mg/L) exceeded the TWQGR limit of 0.1 mg/L for Fe concentration;
- All sampled boreholes complied with all the recommended water quality guidelines for Mn concentration except borehole DFTNM1 and DFTNM7. Borehole DFTNM1 (0.16 mg/L) and DFTNM7 (0.06 mg/L) exceeded the Domestic Use TWQGR of 0.05 mg/L for Mn concentration;
- All sampled boreholes complied with the recommended water quality guidelines for Al concentration except borehole DFTNM9 and DFTNM10. Borehole DFTNM9 (0.3 mg/L) and DFTNM10 (1.5 mg/L) exceeded TWQGR of 0.15 mg/L for Al concentration; and
- The slightly elevated Al, Ca, Na, Cl, F, Fe and Mn concentraton is understood to be naturally occurring as a result to the dissolution pre-Karoo minerals.

The baseline groundwater quality results based on the monitoring database indicate good water quality, which does not show any sign contamination from the current mining activities, as noted in the baselines water quality (GCS, 2008) and time series analysis.

Table 3-6: 2008 Groundwater Quality (Source: GCS, 2008)

Parameter (mg/l)	SAWQG TWQGR for Domestic Use	SAWQG TWQGR for Livestock Watering	DCME WUL Water Resource Limits	DFTN M1	DFTN M2	DFTN M4	DFTN M5	DFTN M7	DFTN M9	DFTN M10	DFTN M12	DFTN H4	DFTN H5	DFTN H7	DFTN H3	DFTN H9
pH	6-9	NS	**6.5-8.4**	7.64	9.08	8.30	7.92	7.74	8.41	7.66	7.37	6.27	8.36	7.01	8.41	7.38
TDS	450	1000	**650**	301	239	188	79	193	149	59	209	288	398	276	142	142
EC (mS/m)	NS	NS	**NS**	51.5	41.0	33.3	14.1	33.1	26.2	10.2	36.3	49.6	68.5	49.0	24.0	24.0
Ca	32	1000	**NS**	30.3	1.10	25.3	10.9	29.7	23.7	5.60	19.8	15.6	50.2	14.9	21.8	13.2
Mg	30	500	**NS**	20.8	0.10	9.30	3.30	12.9	8.10	0.60	15.8	13.8	25.2	13.9	8.60	7.30
Na	100	2000	**21.12**	39.7	93.1	27.0	5.30	12.8	15.8	5.80	30.9	43.2	30.4	44.5	13.8	18.0
K	50	NS	**NS**	0.70	0.40	2.20	3.80	3.00	1.70	3.50	3.80	16.7	13.1	3.00	2.80	6.70
Cl	100	1500	**25**	20	10	3	2	10	3	10	6	81	111	104	5	16
SO_4	200	1000	**400**	99.3	5.23	12.3	9.80	8.80	7.00	13.2	6.10	27.7	20.9	17.9	4.10	3.80
Alkalinity	NS	NS	**NS**	120	142	152	54	136	124	16	180	70	144	32	16	76
NO_3 as N	6	100	**NS**	0.66	<0.1	<0.1	0.11	0.09	<0.1	0.22	<0.1	1.59	0.29	0.70	<0.1	2.60
F	1	2	**NS**	1.03	18.2	0.23	<0.01	2.74	0.62	<0.01	0.21	0.11	<0.01	<0.01	0.32	0.02
Fe	0.1	10	**NS**	0.17	0.12	0.11	0.76	0.14	0.25	0.88	0.27	0.23	0.12	0.10	0.26	0.05
Mn	0.05	10	**0.18**	0.16	0.01	0.04	0.11	0.06	0.03	0.01	0.01	0.05	0.04	0.05	0.05	0.01
Al	0.15	5	**0.18**	0.1	0.1	0.1	1.1	0.1	0.3	1.5	0.1	0.1	0.1	0.1	0.1	0.1

*Blue - SAWQG TWQGR for Domestic Use Exceedances; *Green - SAWQG TWQGR for Livestock Watering Exceedences *Orange - WUL Exceedances *NS – No Standard or Guideline Limit

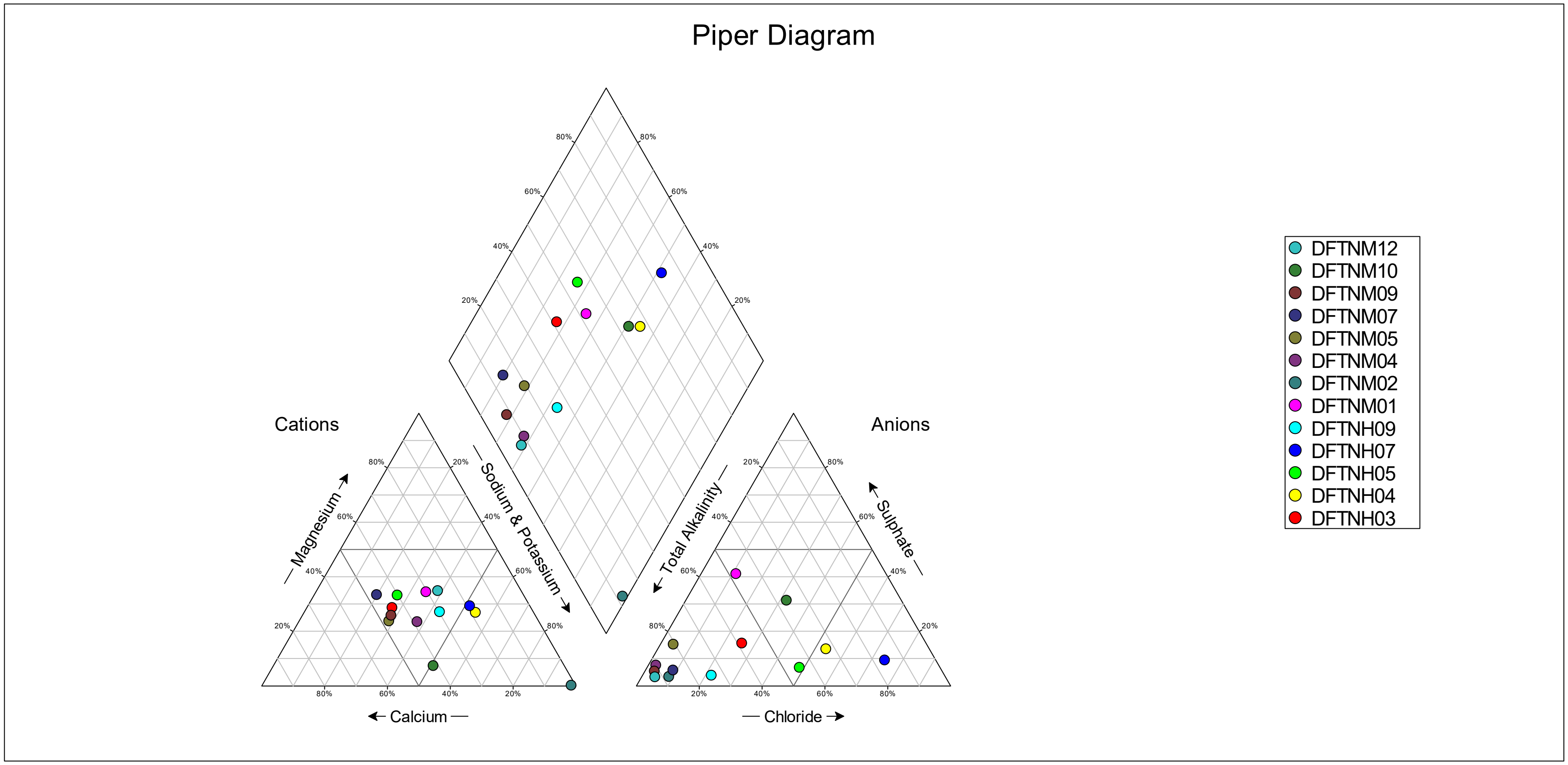


Figure 3-12: Piper Diagram –DCME Monitoring Boreholes – 2008 Results (Source: GCS, 2008)

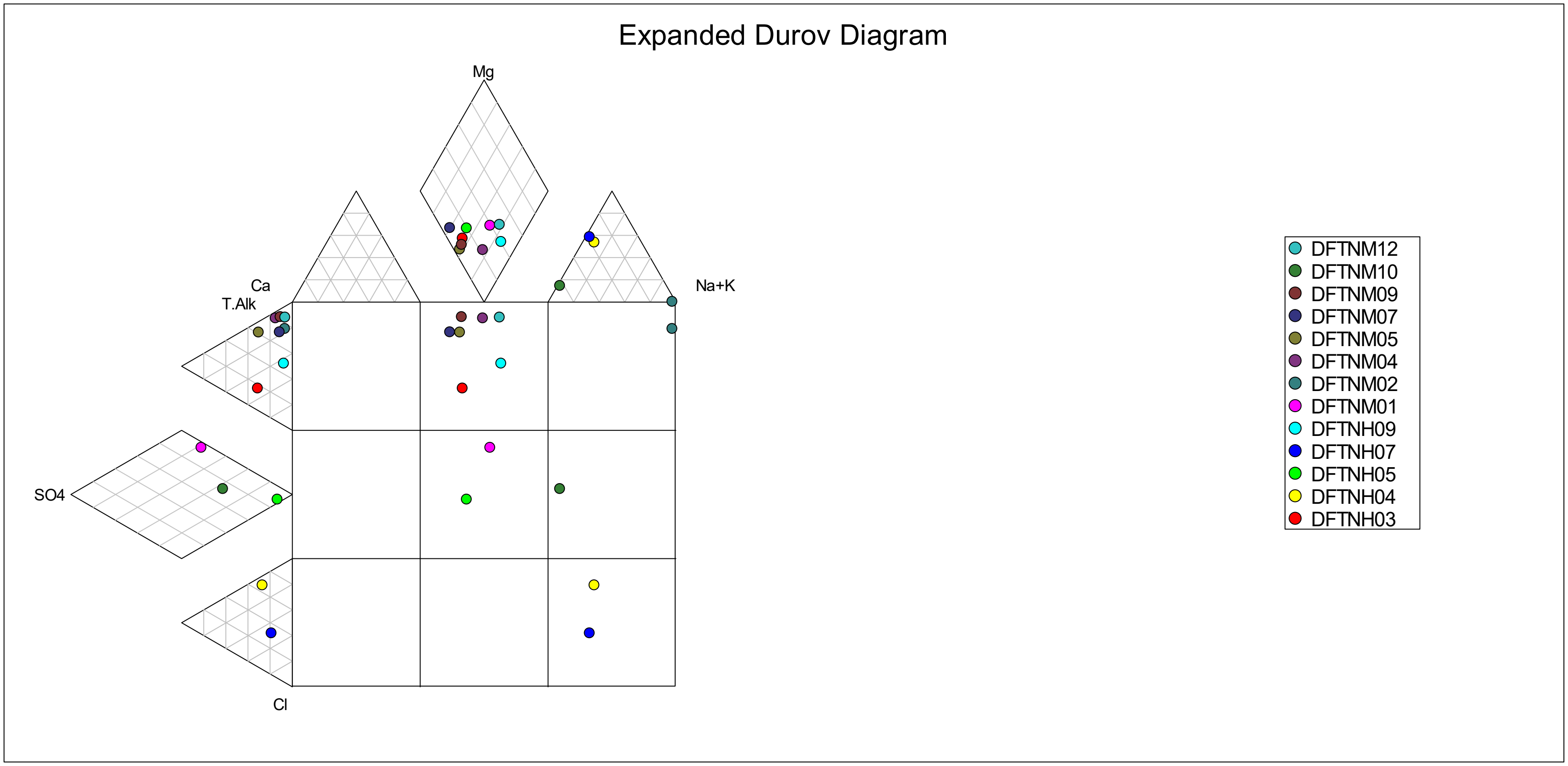


Figure 3-13: Expanded Durov Diagram - –DCME Monitoring Boreholes – 2008 Results (Source: GCS, 2008)

3.6.2 Current Groundwater Quality

The current groundwater quality is described based on data received from the client for the first quarter of 2020.

3.6.2.1 Groundwater Characterisation

Four groundwater types were identified (Figure 3-14 and Figure 3-15):

- Group 1: Ca-HCO_3 type groundwater: The monitoring points falling in this group are enriched in HCO_3 as the dominant anion. Further, all common cations are present, with Ca being slightly more dominant that Mg and Na+K. Borehole DFTNM5 and DFTNS2 are within this group. This groundwater type signifies fresh, recently recharged groundwater;
- Group 2: Ca-Mg-Na-HCO_3 type groundwater: The monitoring points falling in this group are enriched in alkalinity as a dominant anion. All the common cations are present, with Na+K being slightly more dominant. This water type signifies fresh (recently recharged) groundwater with a limited degree of ion exchange (some cation mixing) and is not affected by the mining activities (i.e. DFTNS01, DFTNM3, DFTNM9, DFTNM14, and DFTNM15);
- Group 3: Na-HCO_3 type groundwater: The monitoring boreholes falling in this group are enriched with Na+K as the dominant cation. This water type signifies high residence time within the aquifer or high degree of ion exchange, particularly Na source (i.e. DFTNM4, DFTNM12, and DFTNM16). ;
- Group 4: Mg-SO_4 type groundwater: The fourth group is characterized by their increased SO_4 signature, with Mg as the dominant cation. The absence of alkalinity limits the buffering ability to neutralise acid, therefore, rendering it more acidic with increased sulphate concentration. Borehole DFBH lies within this group;
- Group 5: Ca-Mg-HCO_3-SO_4 type groundwater: The fifth group signifies potential SO_4 contamination or a mix of different water types. Boreholes DFTNM10 is part of this group; and
- Group 6: Na-SO_4 type groundwater: characterized by its increased SO_4 and Na signature and indicates SO_4 and Na contamination. Borehole DFTNS3 is part of this group.

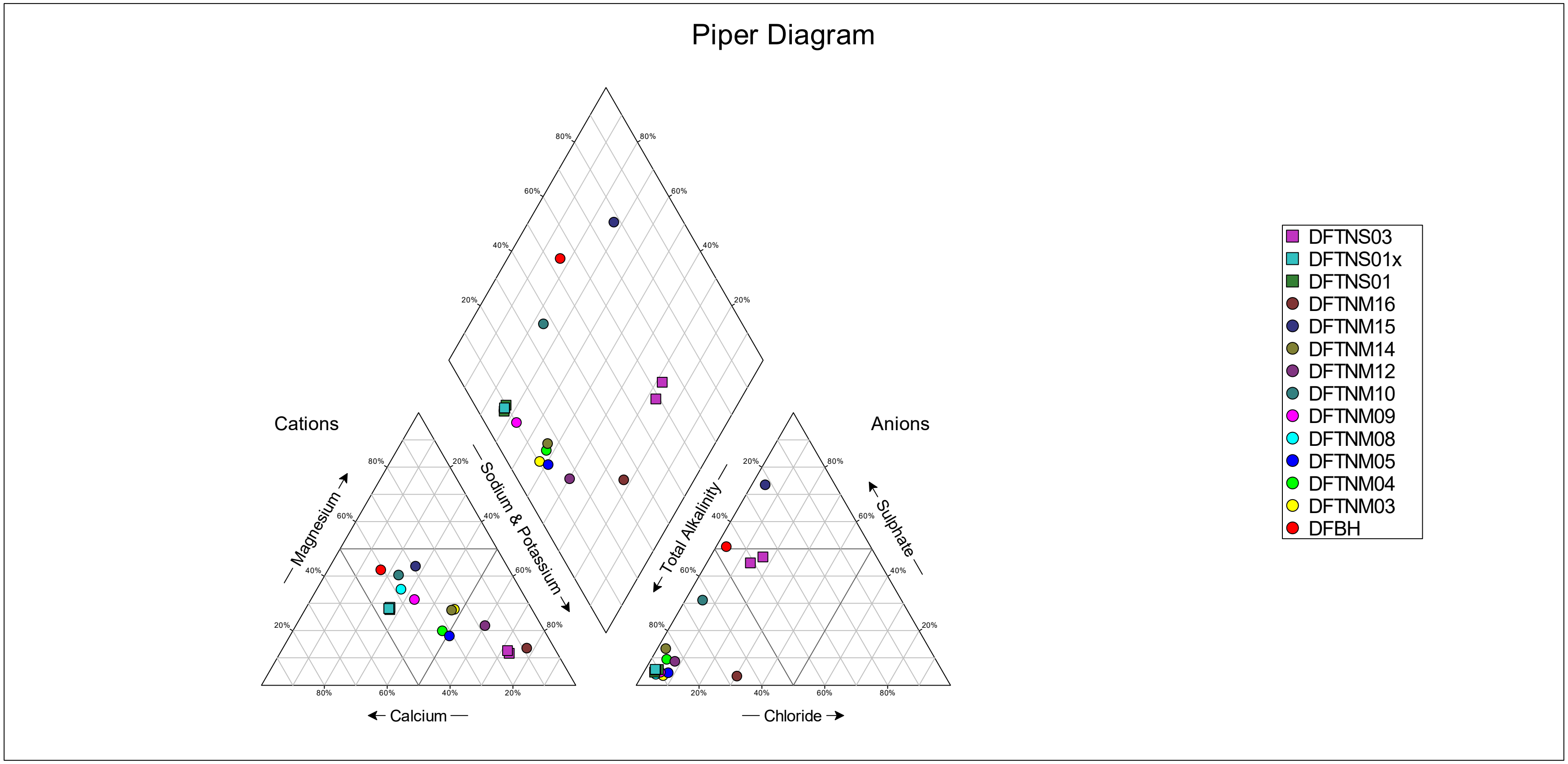


Figure 3-14: Piper Diagram - DCME Monitoring Boreholes – 2020 Results

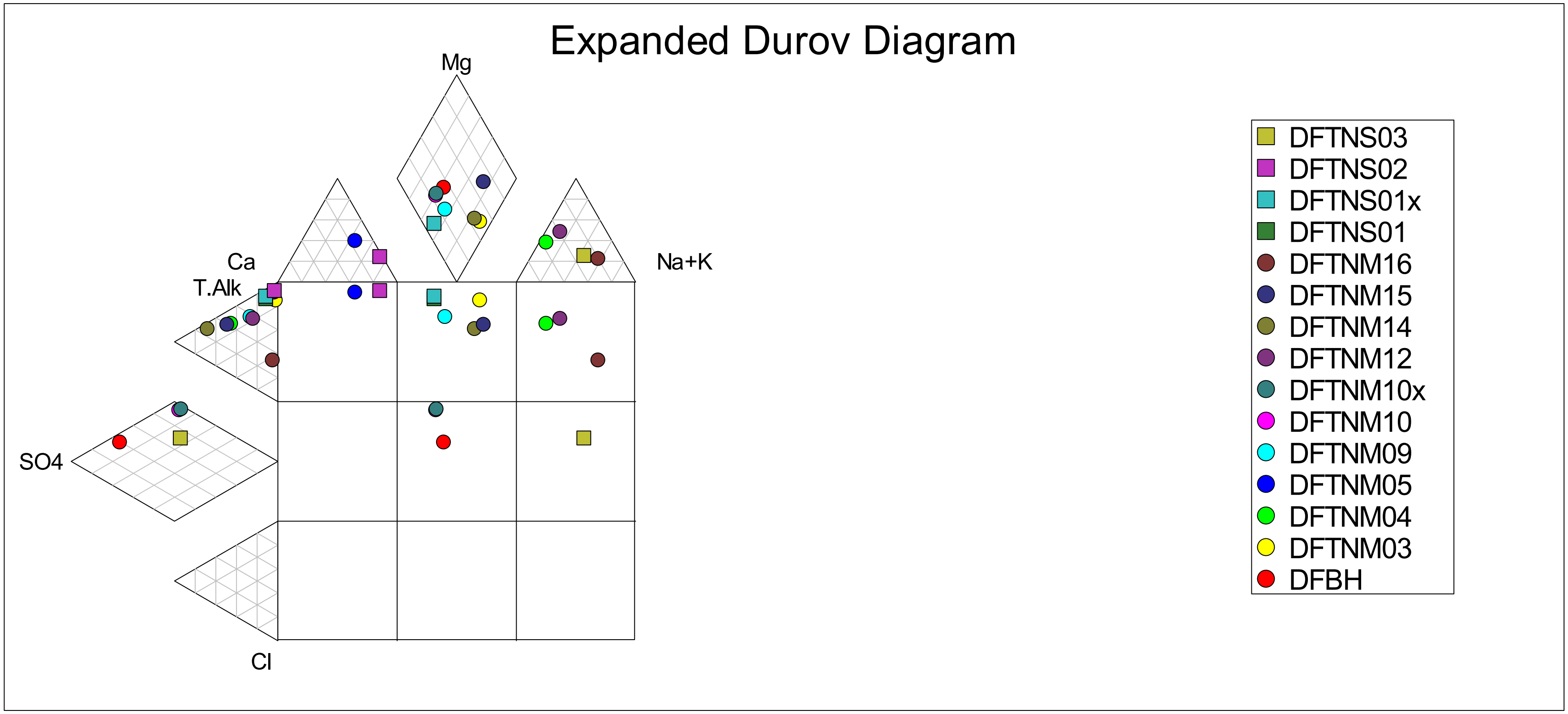


Figure 3-15: Expanded Durov Diagram - DCME Monitoring Boreholes – 2020 Results

3.6.2.2 Comparison to WUL Limits

Groundwater quality (Table 3-7) was from the DCME monitoring database and compared to the limits as per the Water Use License (WUL). The purpose of the interpretation is to determine the current groundwater quality and whether the boreholes have been affected by pollution or not. The following observations were made:

- The pH values vary from 6.6 and 9.8, with an average of 7.8. A pH between 6.6 and 9.8 indicates circumneutral to alkaline waters. All monitoring boreholes are within the recommend WUL of 6.5-8.4 except borehole DFTNM14, DFTNM15, DFTNM16 and
- All boreholes are within the recommended WUL limits for all WUL parameters except aluminium, manganese and sodium concentrations. Sodium and manganese can be naturally elevated in Karoo sediments and could be linked to long residence times of groundwater in the deeper layers of the sedimentary rocks. The source of aluminium is unclear, however, the elevated concentrations were only detected in 2008 and have note been observed since;
- Borehole DFBH, DFTNM5 and SBH exceeded the recommended WUL limit of 0.18 mg/L for manganese concentration. Elevated manganese concentration is not mine-related contaminant and is understood to be naturally occurring as a result of the dissolution of the pre-Karoo minerals;
- Borehole DFBH, DFTNM03, DFTNM04, DFTNM09, DFTNM10, DFTNM10x, DFTNM12, DFTNM14 and DFTNM16 exceeded the recommended WUL limit of 21.12 mg/L for sodium concentration. The slightly elevated sodium concentration is not a mine-related contaminant and is understood to be naturally occurring as a result of the dissolution of minerals in the host rocks.

Table 3-7: Groundwater Quality Results - 2020

Parameter (mg/L)			pH	EC mS/m	TDS	Alkalinity as CaCO3	K	Cl	SO_4	F	NO_3 as N	PO_4	Free & Saline Ammonia as N	Al	Ca	Cr	Fe	Mg	Mn	Na
WUL Water Resource Limits			**6.5-8.4**	**NS**	**650**	**NS**	**NS**	**25**	**400**	**NS**	**NS**	**NS**	**NS**	**0.18**	**NS**	**NS**	**NS**	**NS**	**0.18**	**21.12**
Borehole ID	DFBH	02/03/2020 11:54	7.3	81.5	606	92.0	9.6	13.0	342.0	0.30	0.10	<0.1	0.30	<0.1	58.00	<0.025	<0.025	49.00	0.69	39.00
	DFTNM03	11/03/2020 11:43	7.7	33.9	230	180.0	2.2	10.0	<2	1.20	0.40	<0.1	0.20	<0.1	19.00	<0.025	<0.025	13.00	<0.025	37.00
	DFTNM04	11/03/2020 11:31	7.9	48.1	350	180.0	3.7	11.0	55.0	0.30	0.40	0.10	0.30	<0.1	29.00	<0.025	0.03	12.00	0.05	61.00
	DFTNM05	11/03/2020 10:26	6.8	33.3	144	112.0	8.1	3.0	<2	0.40	0.40	0.80	17.00	<0.1	24.00	<0.025	0.31	5.00	0.52	6.00
	DFTNM09	04/03/2020 11:03	7.5	39	306	124.0	4.2	9.0	20.0	0.30	12.00	<0.1	<0.1	<0.1	30.00	<0.025	<0.025	17.00	<0.025	23.00
	DFTNM10	06/03/2020 10:51	7.4	56.5	446	140.0	4.8	10.0	135.0	1.30	0.40	<0.1	0.10	<0.1	48.00	<0.025	0.03	32.00	0.14	27.00
	DFTNM10x	06/03/2020 10:52	7.4	56.6	454	140.0	4.7	10.0	130.0	1.70	0.40	<0.1	<0.10	<0.1	46.00	<0.025	<0.025	32.00	0.05	26.00
	DFTNM12	04/03/2020 10:27	6.6	39.6	280	164.0	4.9	14.0	24.0	0.40	0.50	<0.1	<0.1	<0.1	16.00	<0.025	0.07	12.00	<0.025	50.00
	DFTNM14	09/03/2020 14:41	8.5	39.1	238	132.0	10.6	4.0	68.0	0.20	0.30	<0.1	<0.1	<0.1	22.00	<0.025	<0.025	15.00	0.07	33.00
	DFTNM15	09/03/2020 14:52	9.4	26.4	162	104.0	7.4	6.0	35.0	<0.2	0.30	<0.1	0.20	<0.1	8.00	<0.025	<0.025	16.00	<0.025	19.00
	DFTNM16	02/03/2020 12:06	9.8	17	78	56.0	3.0	19.0	<2	0.3	<0.1	<0.1	0.70	<0.1	3.00	<0.025	<0.025	2.00	<0.025	25.00
	ECBH	02/03/2020 14:39	7.5	9.8	50	12.0	3.2	10.0	13.0	<0.2	0.10	<0.1	0.10	<0.1	6.00	<0.025	<0.025	3.00	<0.025	6.00
	SBH	02/03/2020 11:18	6.7	16.2	94	68.0	3.7	8.0	<2	0.8	<0.1	<0.1	0.10	<0.1	11.00	<0.025	<0.025	3.00	0.33	17.00

KEY:

Exceeding the WUL limit

No Standard NS

3.6.3 Time Series Analysis

The historical water quality data for DCME was sourced from data from previous hydrogeological reports (GCS (2008), GCS, (2016) and GCS, (2019)) Baseline Hydrogeological Assessment Reports and the DCME monitoring database. For the groundwater localities monitored, the limits stipulated by the Dorstfontein East WUL (number: 04/B11B/ACGIJ/957) for Water Resource Protection were used.

Dorstfontein Coal Mine historical data (groundwater monitoring data) was gathered into Windows Interpretation System for Hydrogeologica (WISH) for trend analysis.

3.6.3.1 *pH*

The pH trend of the groundwater monitoring points is given in Figure 3-16. The trend shows that the pH can vary between 6.02 and 9.9. The trend is relatively stable with most of the monitoring points within the recommended WUL limit. The exception is the fountain DFTNS3 which has a slightly acidic pH and plots below the recommended WUL limit of 6.5. Borehole DFTNM15 and DFTNM16 plot above the recommended WUL limits of 8.4.

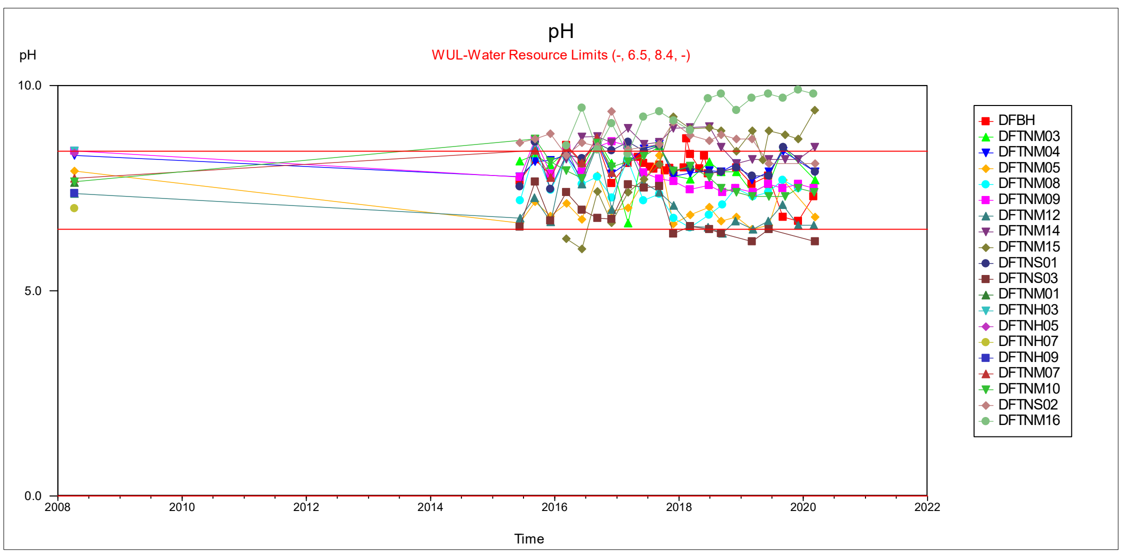


Figure 3-16: pH time series graph for groundwater monitoring boreholes

3.6.3.2 *Total Dissolved Solids*

The total dissolved solids (TDS) graph is illustrated in Figure 3-17. The graph shows relatively stable trends that are slightly increasing. The exception is borehole DFBH, where a number of recent exceedances were recorded. These exceedances can be mainly attributed to elevated Na, Cl and SO_4 concentrations. This borehole is drilled into historical mine voids present to the north of DCME and the elevated parameters are related to the historical mining taking place in the vicinity of the borehole.

Borehole DFTNM15 has shown historic increases in TDS, however, since 2017 TDS complied with the recommended WUL limit of 650 mg/L. As of March 2020, the TDS complies with the recommended WUL limit of 650 mg/L for all WUL monitoring boreholes.

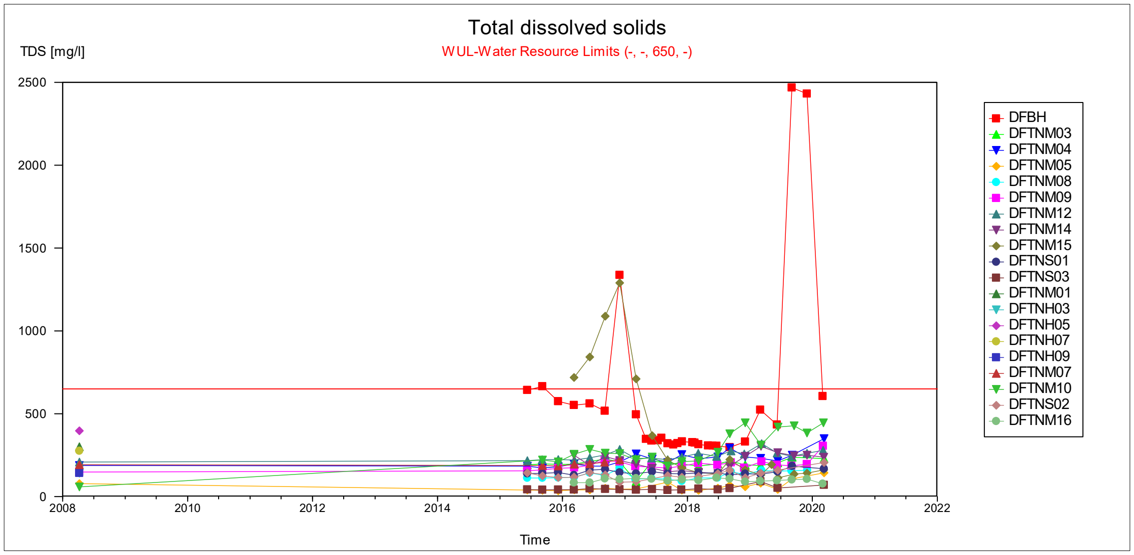


Figure 3-17: TDS Time Series Graph For Groundwater Monitoring Boreholes

3.6.3.3 Sodium

The sodium concentration graph is shown in Figure 3-18. Borehole DFTNM05, DFTNS03, DFTNM08 and DFTNM10 show stable trends.

Borehole DFTNM5, DFTNM8, DFTNS1 and DFTNS3 show reatively stable Na concentration and falls within the recommended WUL limit of 21 mg/L since when the borehole were drilled in 2015. Most of the monitoring boreholes show Na concentration between 21 mg/L and 60 mg/L and thus, exceed the recommended WUL limit of 21 mg/L. The slightly elevated sodium concentration is not a mine-related contaminant and is understood to be naturally occurring as a result of the dissolution of the pre-Karoo rock minerals.

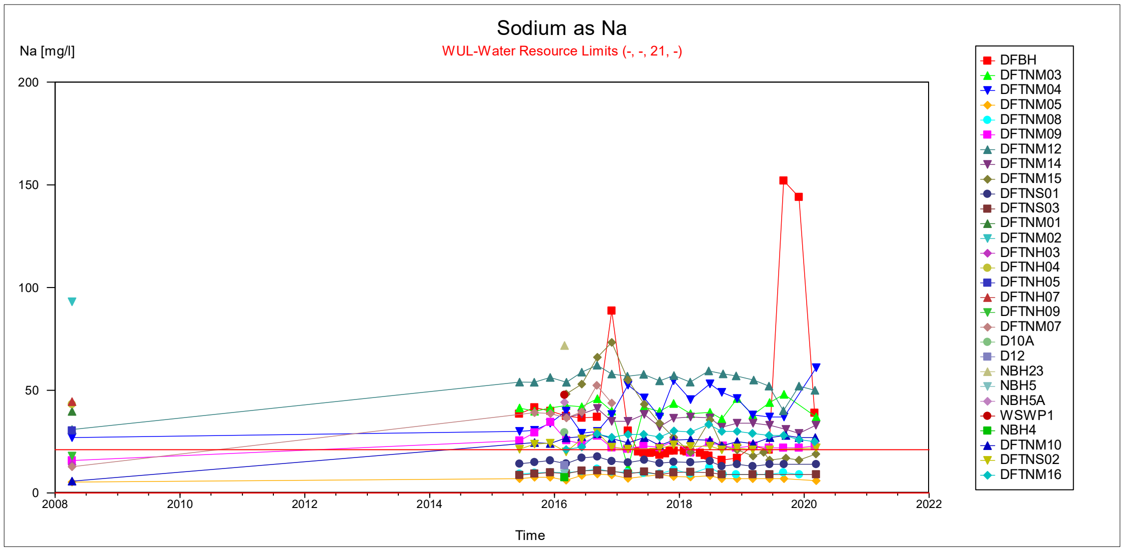


Figure 3-18: Na concentration time graph for groundwater monitoring boreholes

3.6.3.4 <u>Chloride</u>

The chloride concentration time-graph is illustrated in Figure 3-19. The trends are relatively stable for all sites except at DFTNM16 and DFBH. Borehole DFBH and DFTNM15 are located downgradient of the mining activities and thus could be impacted by these. As of March 2020 all groundwater monitoring boreholes comply with the recommended WUL limit of 25 mg/L.

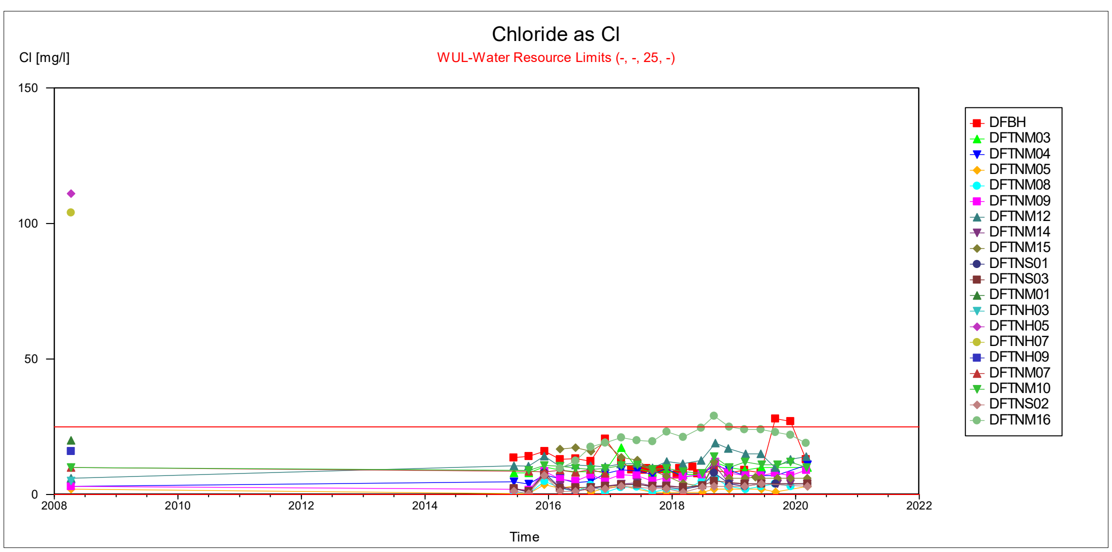


Figure 3-19: Cl concentration time graph for groundwater monitoring boreholes

3.6.3.5 Sulphate

The sulphate concentration time-graph is illustrated in Figure 3-20. The graph shows relative stable trends for most of the boreholes and shows concentrations within the recommended WUL limit of 400 mg/L. The exceptions are boreholes DFBH and DFTNM15, showing a few discrete exceedances. As mention above borehole DFBH and DFTNM15 are located downgradient of the mining activities and thus could be impacted by these. As of March 2020, all monitoring boreholes are within the recommended WUL limit for sulphate.

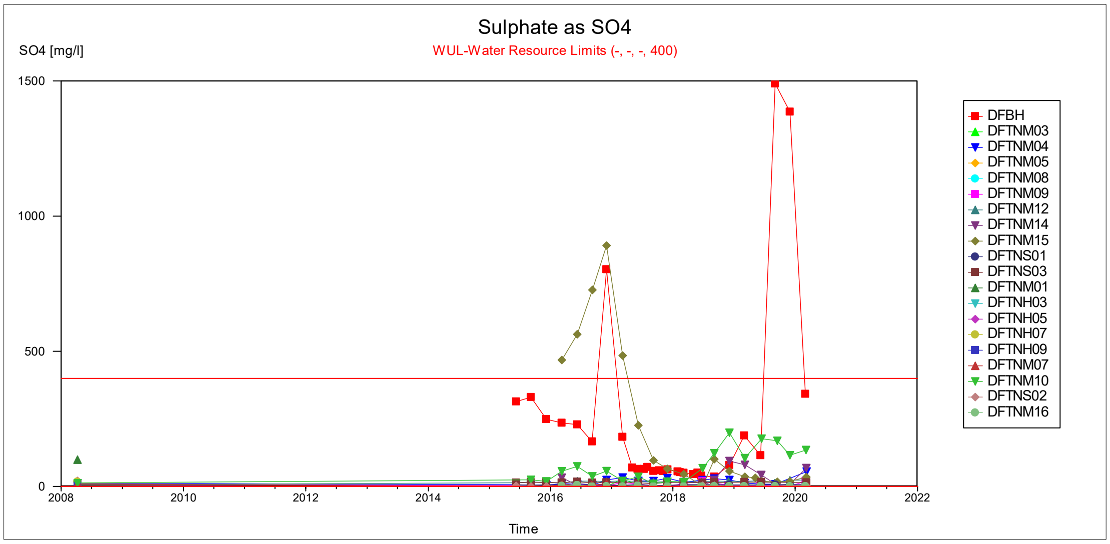


Figure 3-20: SO_4 concentration time graph for groundwater monitoring boreholes

3.6.3.6 Manganese

The manganese concentration time-graph is illustrated in Figure 3-21. The graph show erratic fluctuations with most of the boreholes within the recommended WUL limit of 0.18 mg/L. The slightly elevated manganese concentration is not a mine-related contaminant and is understood to be naturally occurring as a result of the pre-Karoo minerals.

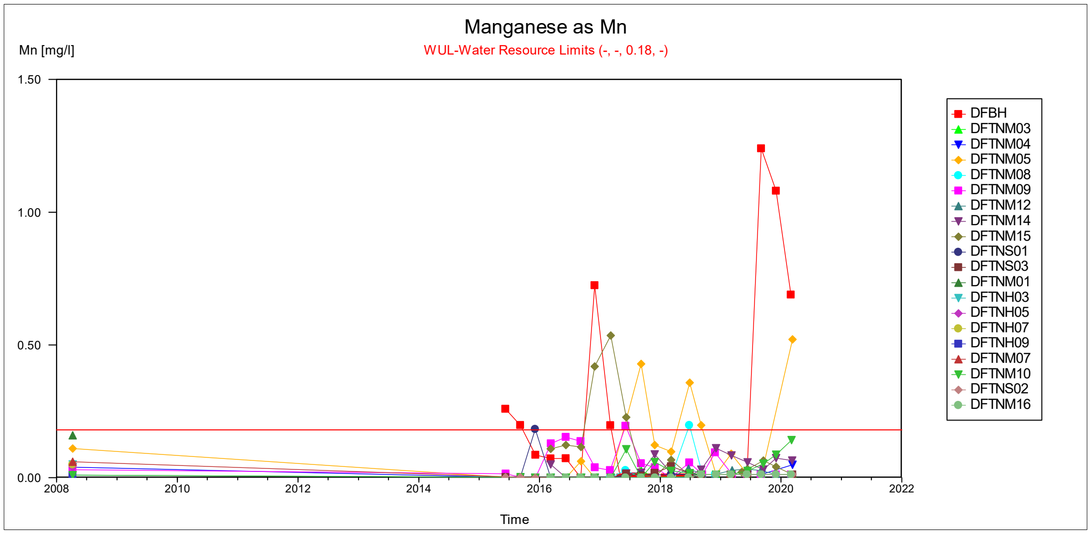


Figure 3-21: Mn concentration time graph for groundwater monitoring boreholes

3.6.3.7 Summary: Trend Analysis

- The pH trend is relatively stable with most of the monitoring boreholes within the recommended WUL limits except for the spring (DFTNS03) which shows deteriorating water quality while DFTNM15 and DFTNM16 also show elevated pH above the recommended WUL limit of 8.4;
- TDS and SO_4 for all WUL sampled boreholes and springs are within the recommended WUL limits. The exceptions are boreholes DFBH and DFTNM15, showing a few discrete exceedances. Borehole DFBH is located downgradient of the mining activities and thus could be impacted by these;
- Elevated Na and Mn concentration is observed in most of monitoring boreholes, however, the slightly elevated sodium and manganese concentration is not a mine-related contaminant and is understood to be naturally occurring as a result of the dissolution of the pre-Karoo minerals; and
- Based on the groundwater monitoring trend analysis the groundwater in and around the mine area does not show any significant mining impacts, however, a contamination plume (based on the elevated elevated SO_4) can observed at DFBH which might have been triggered by mining activities as the boreholes is located downgradient from DCME the mining activities. Activities which might have led to the elevated SO_4 need to me investigated as the borehole is located a couple of meters from an unknown tributary draining into the Olifants River which poses a high risk to the downstream users.

4 Geochemical Assessment and Waste Classification Update

Section below presents a summary of the geochemical assessment and waste classification that was carried out as part of this hydrogeological impact assessment study for the proposed Dorstfontein East Expansion Project (DCME) (please refer to Appendix B for the full geochemical and waste assessment).

Geochemical characterisation and waste classification at the DCME were undertaken to evaluate acid-base generation potential and/or neutralisation potential of the waste rock materials from the proposed expansion project in order to:

- Characterise and classify the acid-generating and non-acid generating waste rock material;
- Assess Acid Rock Drainage/Metal Leaching risk potential of the various geological strata that will be disturbed by the proposed mining operations; and
- Provide an understanding of the potential impacts from the various geological strata to the surrounding environment.

Hence, the DCME geochemical characterisation and waste classification of the discard material will be used to provide the first-order source-term ranges to enhance longer-term groundwater quality prediction.

4.1 Discard Mineralogy and Chemical Composition

The XRD and XRF results are indicated in Table 4-1 and Table 4-2.

A total of five samples were sent for XRD analyses and the discard samples indicated the following:

- Kaolinite is dominant and ranges between 46 and 71 wt. %. This is common as this is a common clay mineral formed through the breakdown of minerals like alkali-feldspar;
- Quartz ranges between 18 and 40 wt. %. This is one of the common minerals on Earth hence its composition is relatively high;
- Carbonate minerals identified included dolomite (excluding Discard 4 sample) and aragonite. The dolomite had a composition ranging between 1 and 9 wt. %, while the aragonite (calcite polymorph) was identified only in Discard 4 and Discard 5 samples with a composition of 2.1 and 2.4 wt. %, respectively;
- Muscovite was also detected in Discard 4 and Discard 5 samples with a composition of 12.1 and 1.9 wt. % respectively,
- Additonal clay minerals were detected and these included Lizardite (at Discard 1 sample) at traces amount of 0.4 wt. %. Further, illite was detected which is part of a group of non-expanding clay minerals and commonly found in soils, clay-rich sedimentary rocks and low-grade metamorphic rocks;

- Spinel group minerals were detected, this comprised Spinel (in Discard 1 at 0.6 wt. %), magnetite (detected in Discard 4 at 5.2 wt. %) and Franklinite as traces in Discard 5 at 0.5 wt. %;
- Titanium oxide anatase was detected in Discard 1 and Discard 3 at 1.6 and 1.4 wt. % respectively; and
- No acid-forming minerals were detected.

XRF results indicated the following:

- TiO_2 is elevated at least 3 to 5 times above the AUC while Al_2O_3 is slightly elevated; and
- Discard 1 indicates that P_2O_5 is 3 to 5 times above the AUC while for the other samples it was slightly elevated.

Table 4-1: XRD Results (In weight %)

Sample ID	Kaolinite	Quartz	Dolomite	Anatase	Spinel	Lizardite	Illite	Muscovite	Magnetite	Aragonite	Franklinite
Discard 1	68.6	20.9	7.9	1.6	0.6	0.4	-	-	-	-	-
Discard 2	70.6	27.5	1.9	-	-	-	5.5	-	-	-	-
Discard 3	46.3	39.8	7	1.4	-	-	-	-	-	-	-
Discard 4	58.9	21.6	-	-	-	-	-	12.1	5.2	2.1	-
Discard 5	68.5	18.2	8.5	-	-	-	-	1.9	-	2.4	0.5

4.2 Acid Mine Drainage

To interpret the ABA results, five characteristics of the materials were assessed namely paste-pH, Neutralisation Potential (NP), Acid Generation Potential (AP) and Neutralisation Potential Ratio (NPR). For the Sulphur-Speciation the following parameters are analysed Total-Sulphur (Total-S), Sulphate-Sulphur (SO_4^{2-}-S) and Sulphide-Sulphur (S^{2-}-S). This is driven by the mineralogy of the materials that are acid buffering/neutralising and other minerals like sulphides that are the main drivers of acid production and AMD under aerobic conditions.

The results are summarised as follows (Table 4-3 and Figure 4-1):

- Paste-pH results are circumneutral;
- All the S^{2-}-S% apart from Discard 4 demonstrates that they are above the 0.3 % mark which normally indicates acid-generation potential. However, looking at the absence of acid-forming minerals and the low concentration of the S^{2-}-S% it can be assumed the samples are NAF as long as the NP minerals do not deplete;

Table 4-2: X-Ray Fluorescence - Major Oxides (In weight %)

Sample ID	Discard 1	Discard 2	Discard 3	Discard4	Discard5	AUC	AUC 3-5 times higher	>5 times
SiO2	56.48	60.33	61.89	60.94	60.85	66.6	-	-
TiO2	2.18	2.5	2.4	2.38	2.7	0.64	1.92	3.2
Al2O3	31.31	31.68	23.56	32.6	27.71	14.4	46.2	77
Fe2O3	3.32	1.57	5.09	1.19	2.05	11.2	33.6	56
MgO	1.38	0.74	1.39	0.57	1.1	2.48	7.44	12.4
MnO	0.03	0.01	0.03	0.02	0.02	0.1	0.3	0.5
CaO	3.52	1.72	3.32	0.69	3.1	3.59	10.8	18
Na2O	<0.01	<0.01	<0.01	<0.01	<0.01	3.27	9.81	16.35
K2O	0.61	0.57	0.59	0.81	0.43	2.8	8.4	14
P2O5	0.52	0.25	0.38	0.15	0.21	0.15	0.45	0.75
Cr2O3	0.03	0.03	0.03	0.03	0.04	-	-	-

****AUC – Average Upper Crust* (Rudnick & Gao, Composition of the Continental Crust, 2003)

- Net Neutralising Potential (NNP) is the difference between Neutralising Potential (NP) and Acid Potential (AP). Positive NNP indicates that there are more NP minerals in the samples as indicated in the samples below; and
- The overall results indicate that Discard 1, Discard 2 and Discard 3 samples have NAF potential. Discard 4 demonstrates the uncertainty of whether it has the acid-forming potential or not.

Table 4-3: ABA Test Results

Sample ID	Discard 1	Discard 2	Discard 3	Discard 4	Discard 5
Paste pH	7.88	8.06	7.96	8.29	8.07
S^{2-}-S%	0.32	0.23	0.56	0.17	0.64
SO_4^{2-}-S (%)	0.046	0.09	0.054	<0.01	0.065
Total %S	0.37	0.32	0.61	0.17	0.71
AP (kg/t)	10.00	7.19	17.50	5.16	20.10
NP CaCO3 kg/t	25.50	20.00	42.80	9.50	41.20
NNP (kg CaCO3/t)	15.50	12.80	25.30	4.34	21.10
NPR	2.55	2.78	2.45	1.84	2.05
Rock Type S^{2-}S%	Rock Type II	Rock Type II	Rock Type I	Rock Type III	Rock Type I
Rock Type NPR	Rock Type III	Rock Type III	Rock Type III	Rock Type II	Rock Type III
Class.: paste-pH	NAF	NAF	NAF	NAF	NAF

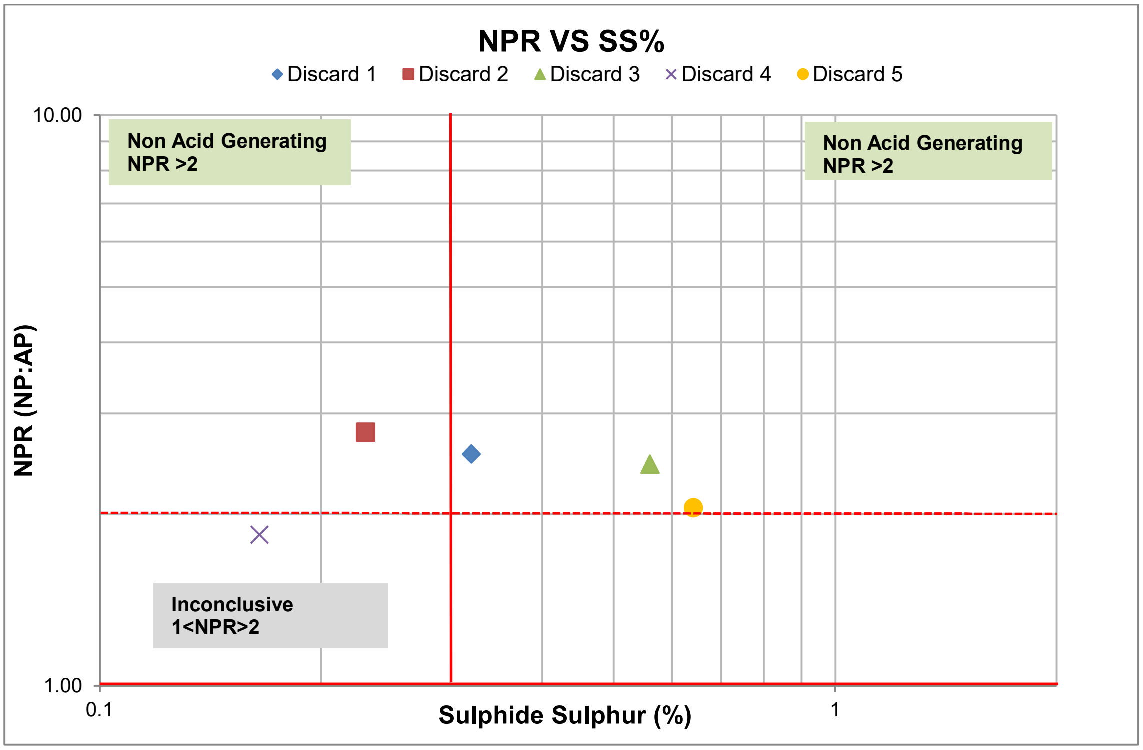


Figure 4-1: Classification of samples in terms of S^{2-}-S and NPR

4.3 Kinetic Column Leachate Test

A subaerial column leaching test was performed on slurry material. A rapid test was performed for the first five days and thereafter the analyses were performed weekly. The results are presented in Figure 4-2. From the kinetic leach test results the following observations could be made:

- During the 73 days of the column leach test, the pH was near neutral with no clear evidence of acidification. The alkalinity indicates an increase from 44.9 mg/L to 121 mg/L then decreases to 56.1 mg/L;
- For the first 5 leaches, EC was above the operational risk for the SANS drinking water standards ranging between 199 to 207 mg/L;
- For the first 10 days the SO_4 concentration in the leachate ranged between 652-1 949 mg/L and was above the SANS drinking water quality of 500 mg/L. Between day 17 and 24 the SO_4 concentration in the leachate was still above the 250 mg/L guideline value. This is demonstrated in Figure 4-2 with the red line indicating the SANS acute health SANS drinking water guideline value for SO_4;
- The highest concentration was observed on day 1 at 1 949 mg/L. The highest concentration as reported in (GCS, 2016) was 198 mg/L measured on day 1;
- Ca, Mg and Mn were above the recommended aesthetic risk of 150 mg/L, 70 mg/L and 0.1 mg/L respectively for the first 4 days. Ca continued to be elevated on day 5, while

Mn of the 10th and 45th day the leach indicated to be above the operational risk. In the GCS report, Pb was the only metal that leached slightly above the SANS parameters after 143 days. While in this study parameters like Ca, Mg, Mn, and Ni were above the SANS drinking water quality at some point during the test;

- Ni was only detected to be above the SANS drinking water quality on day 2 of the test at 0.078 mg/L, which is slightly above the chronic health risk standard from the SANS drinking water standard of 0.07 mg/L. On the other days, the Ni concentration is below the SANS parameters;
- Although no acidification was observed for the duration of the test, the observed concentrations indicate there is high acid-forming potential, and it is expected that the leachate will become acidic after carbonates have been depleted;

4.4 Conclusions

- Although the static leach tests show low acid forming potential, this is due to the initial presence of neutralising minerals. However, these are expected to be depleted over time and hence the acid forming potential will increase over time;
- This was confirmed by the column leach test as part of this study where elevated sulphate concentrations up to 1 900 mg/l were shown to leach from the discard during the first week of dynamic testing;
- As part of the previous study (GCS, 2016) subaerial column tests were also carried out and these column tests were re-done as part of this study. However, due to a lower water to rock ration used in the column tests during the study in 2016, this lead to less time for the water to react with the sample. Therefore, sulphate concentrations were lower then measured during this study;
- However, considering the accumulated concentration of sulphates leached out during the 2016 column tests, the results from these column tests are valid, and confirm the results of the geochemical model as carried out in (GCS, 2016);
- The sulphate concentrations as previously modelled (GCS, 2016) are deemed valid, and confirmed by the high sulphate concentrations as observed in the column test as part of this study.

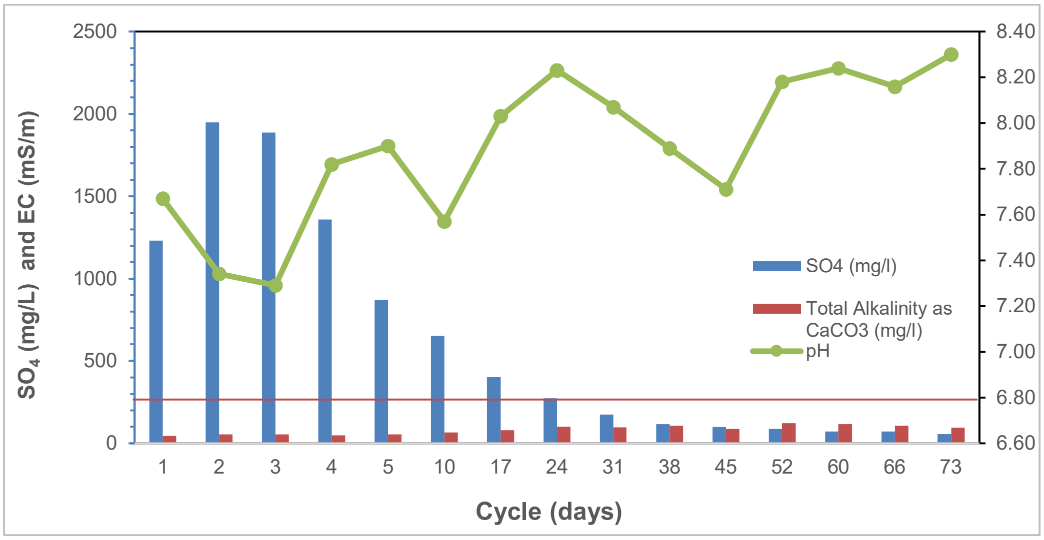


Figure 4-2: Changes In pH, SO_4 and EC for day 1-73 Of The Dynamic Leach testing

Table 4-4: Column Test – Weekly Analyses Of Leachate

Leach	Days	pH	EC (mS/m)	SO_4 (mg/l)	Total Alkalinity (mg/l)	NH_4 as N (mg/l)	Nitrate as N(mg/l)	PO_4 as P(mg/l)	Cl (mg/l)	F (mg/l)
SANS 241: 2015										
Operational		<5; >9.7								
Aesthetic			>170	250			>11		>300	
Acute Health				>500						
Chronic Health										>1.5
0	1	7.67	199	1232	44.9	0.858	0.578	<0.005	16	0.953
1	2	7.34	295	1949	53.70	0.683	0.764	<0.005	22.0	1.310
2	3	7.29	271	1886	54.90	0.482	0.601	<0.005	7.1	1.300
3	4	7.82	207	1359	48.20	0.443	3.580	<0.005	4.3	1.320
4	5	7.90	155	870	53.30	0.421	0.404	<0.005	2.8	1.270
5	10	7.57	122	652	65.50	0.167	0.487	<0.005	2.2	1.220
6	17	8.03	83	401	79.00	0.032	<0.194	<0.005	1.3	1.120
7	24	8.230	64.50	274	99.60	0.03	<0.194	0.021	1.40	0.97
8	31	8.070	53.20	174	96.70	0.04	<0.194	<0.005	2.02	0.90
9	38	7.890	45.00	117	107.00	0.08	0.636	<0.005	0.77	0.88
10	45	7.710	39.20	98	88.00	0.06	0.566	<0.005	0.89	0.87
11	52	8.180	38.70	88	121.00	0.06	<0.194	<0.005	0.63	0.85
12	60	8.240	35.90	73	117.00	0.05	<0.194	<0.005	1.55	0.95
13	66	8.160	30.60	70	108.00	0.07	0.265	<0.005	0.58	0.73
14	73	8.03	30	56.1	94.1	0.14	3.3	<0.005	1.19	0.68

Table 4-5: ICP-OES results in mg/L for discard materials

	Discard															SANS 241-1: 2015			
Leach	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Operational	Aesthetic	Acute	Chronic
Days	1	2	3	4	5	10	17	24	31	38	45	52	60	66	73				
Ag	0.001	0.002	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Al	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.3			
B	0.072	0.096	0.098	0.091	0.071	0.076	0.064	0.054	<0.013	<0.013	<0.013	0.033	0.051	0.050	0.043				2.4
Ba	0.163	0.050	0.034	0.039	0.042	0.044	0.047	0.070	0.062	0.067	0.090	0.095	0.086	0.099	0.102				0.7
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
Bi	0.021	0.033	0.037	0.025	0.019	<0.004	<0.004	0.011	<0.004	<0.004	<0.004	<0.004	0.008	<0.004	<0.004				
Ca	273	410	400	340	220	186	124	101	72.6	59.1	51.2	51.9	46.8	46.7	40.00		150		
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002				0.003
Co	<0.003	0.008	0.009	0.009	0.012	<0.003	0.003	0.005	0.005	<0.003	<0.003	0.007	0.004	<0.003	<0.003				0.5
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003				0.05
Cu	0.06	0.045	0.030	0.01	0.02	0.03	0.02	0.019	0.016	0.011	0.011	0.009	0.008	0.009	0.005				2
Fe	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004		0.3		2
Ga	0.008	0.011	0.011	0.011	0.009	0.021	0.016	0.008	0.006	0.006	0.006	0.006	0.007	0.004	0.006				
K	12	16.30	14.40	11.40	8.37	6.00	4.99	4.60	3.49	3.47	2.88	2.84	2.40	2.31	2.33	50			
Li	0.024	0.031	0.032	0.025	0.019	0.012	0.011	0.010	0.013	0.011	0.010	0.01	0.011	0.009	0.01				
Mg	111	192	178	128	68.70	48	33	30.50	20.30	17.40	15.3	15.10	13.60	13.70	12.40		70		
Mn	0.190	0.128	0.157	0.126	0.088	0.113	0.087	0.077	0.057	0.044	0.177	0.041	0.042	0.050	0.061		0.1		0.4
Mo	0.092	0.215	0.213	0.143	0.150	0.157	0.160	0.142	0.117	0.128	0.09	0.095	0.091	0.084	0.10				
Na	94.2	143	108	63.30	30.8	16.20	11.8	10.1	7.47	6.31	5.50	4.32	3.58	3.02	2.74		200		
Ni	0.049	0.078	0.054	0.042	0.111	0.051	0.055	0.064	0.031	<0.002	0.018	0.030	0.03	0.022	<0.002				0.07
Pb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004				0.01
Rb	0.027	0.036	0.034	0.025	0.015	0.015	0.007	0.009	0.004	0.003	0.004	0.004	0.004	0.003	0.006				
Sr	4.2	6.85	6.78	5.87	4.40	4.4	3.90	3.45	2.86	2.600	2.49	2.54	2.34	2.41	2.30				
Te	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Tl	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037				
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				0.2
Zn	0.062	0.11	0.094	0.087	0.12	1.33	0.139	0.112	0.079	0.005	0.276	0.077	0.066	0.030	0.002		5		

5 Conceptual Model Update

The conceptual model describes the hydrogeological environment and was used to design and construct the numerical model to represent simplified, but relevant conditions of the groundwater system. The conditions were chosen in view of the specific objective of the modelling for the project, including the proposed underground mining expansion at DCME. The conceptual model is based on the source-pathway-receptor principle. From the baseline assessment and available data, the following conceptual model was derived.

5.1 Aquifers

Three principal aquifers are identified in the conceptual hydrogeological model for Dorstfontein East site:

- The upper weathered Ecca aquifer;
- The fractured Karoo aquifers within the unweathered Ecca sediments; and
- Outcrops of pre-Karoo basement rocks (i.e. granite, refer to Figure 3-5):
  - The upper weathered pre-Karoo aquifer; and
  - The deep fractured pre-Karoo aquifer.

Weathering of the Ecca sediments continues to depths of between approximately 5 to 12 mbgl throughout the area. The upper aquifer is associated with this weathered zone, and water is often found within a few meters below the surface. For the weathered zone, water strikes were encountered between 2-25 mbgl corresponding to the weathered aquifer (i.e., borehole DFTNM1, DFTNM2, DFTNM3, DFTNM5 and DFTNM6). The weathered zone hydraulic conductivity values are in the order of 10^{-2} m/d.

The fractured layer comprises of shale, sandstone, and coal seams in which the groundwater movement is mainly limited to the fractures. The fractured rock units intersected in the boreholes water strikes were observed frequently for depths between 25-57 mbgl (i.e., borehole DFTNM4, DFTNM7 and DFTNM12) corresponding to the fractured Karoo (Ecca) aquifer (GCS, 2016). The fracture zone hydraulic conductivity varies from the top to the bottom of the unit and ranges between 10^{-2} m/d for the upper layers and 10^{-4} m/d for the bottom layers.

The fractured pre-Karoo aquifer consists of basement granites are characterised by low permeability. These mainly underly areas where the fractured Karoo aquifer is present. Groundwater movement occurs through fractures or unweathered areas that were not removed during glaciation. Fracturing mainly occurs in the top of the unit and decreases with depth. The hydraulic conductivity for the weathered pre-Karoo aquifer is generally low and in the order of 10^{-3} m/d. Borehole DFTNM13 was drilled into the pre-Karoo basement unit was dry, confirming the low aquifer properties.

5.2 Groundwater Recharge

Groundwater recharged occurs through rainfall-infiltration, and recharge rate for Karoo lithologies are generally low, between 1-5% of MAP. Specifically, the percentage of recharge within the Dorstfontein Coal Mine is estimated to be in the order of 1% to 3% of the annual rainfall (MAP). Recharge to dolerite sills is expected to be less than 1% of MAP due to the higher resistance to weathering.

5.3 Groundwater Level and Flow Direction

Pre-mining groundwater levels show that the groundwater levels within the area vary between 2.5 mbgl and 20 mbgl, indicating groundwater levels are relatively shallow and mainly located within the weathered aquifer. Generally, groundwater flow directions mostly follow topographical gradients. However, some localised flow can be observed at some borehole due to historical and or current dewatering activities.

5.4 Source, Pathways and Receptors

As illustrated in Figure 5-1, an environmental risk exists only if the three components of a conceptual model (source, pathway and receptor) are linked.

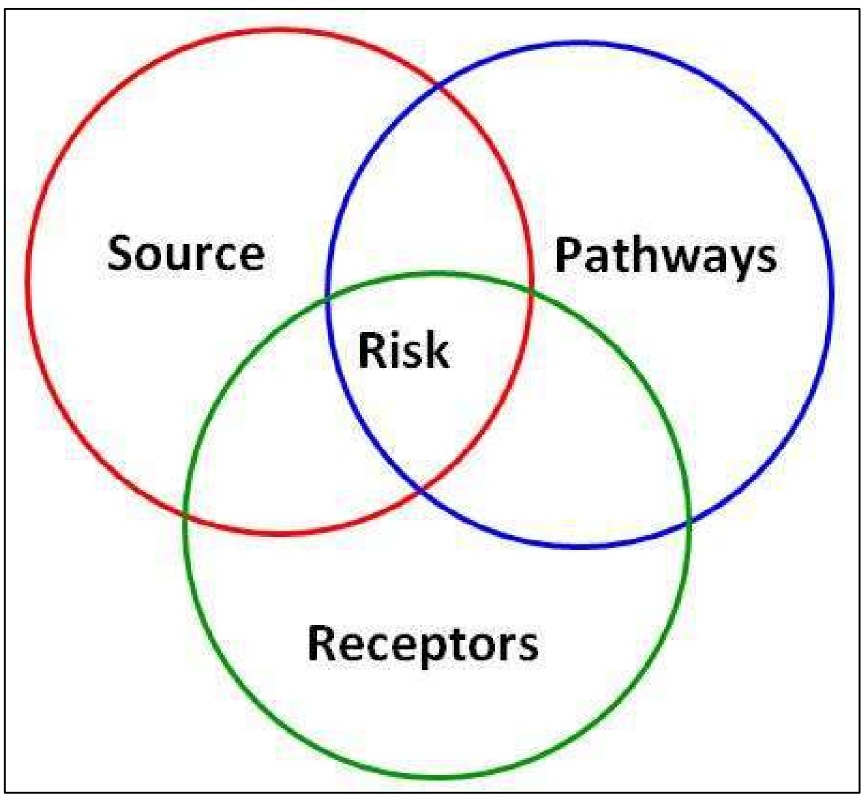


Figure 5-1: A Conceptual Model based Environmental Risk

5.4.1 Potential Contaminant Sources

Potential groundwater contamination sources:

- Co-Disposal Facility (impacts on groundwater quality):
  - Seepage from the underground void into the surrounding aquifer post-closure after the mine dewatering has ceased.
- Product Stockpile Area:
  - Potential for groundwater contamination due to seepages from the stockpiles in terms of volume and water quality leachate (increase salt loading to aquifer).
- Raw, Dirty or Process Water Storage Facilties:
  - Dirty water contains waste water management facilities or dams may impact on groundwater quality by means of seepage to underlying receiving aquifer if not lined and/or not properly maintained;
  - Possible other contaminant sources could be Pollution Control Dams (PCD) if not lined or managed properly.
- Opencast and underground workings:
  - Water inflows into the existing opencasts and proposed underground workings; and
  - Flooded underground voids could discharge contaminated water from any surface connections such as shafts / adits, boreholes, geological features, etc. into surface or ground water resources.

5.4.2 Potential Contaminant Pathways

Potential on-site contaminant pathways:

- The primary pathway for the underground void is the upper weathered and fractured Karoo aquifers. Pathways within the fractures rock unit would only be limited to the fractures that are sufficiently permeable to allow water flow; and
- The primary pathway for the co-disposal if the weathered/fractured aquifer units below the co-disposal.

5.4.3 Potential Contaminant Receptors

- Potential groundwater contamination receptors:
- Groundwater receptors are mainly third-party groundwater users in the surrounding area. Boreholes and springs identified during the previous hydrocensus studies were mainly for domestic use and livestock watering for single households and small communities. These can either be contaminated or ; the water level would decrease while the discharge rates at the springs would lower; and

- Groundwater dependant wetlands in the vicinity and overlying the proposed DCME expansion project. These could either be contaminated or the baseflow into the wetlands would be reduced; and
- Groundwater dependant streams feeding into the Olifants River. These could either be contaminated or the baseflow into the wetlands would be reduced.

6 Numerical Model Update

Following the characterisation of the aquifers, contaminant sources and groundwater receptors, the conceptual model was transformed into a numerical model so that the groundwater flow conditions, and mass transport can be solved numerically. This section outlines the translation of the conceptual model into a numerical flow model.

6.1 Model Objectives

The objective of the model is to determine short-term and long-term pollution potential of the extended co-disposal facility and to conduct necessary tests for such determination. Further, the model intends to determine the quantity and quality that might decant from the the proposed underground workings during post-closure phase once dewatering has ceased.

The deliverables from the modelling phase of the project include an updated, calibrated groundwater flow and contaminant transport model.

6.2 Key Assumptions

The simulations presented here are based on the following assumptions:

- For the geochemical assessment, it was assumed that the additional testing is mainly to verify the current composition of materials and will not require updating of the previous geochemical model;
- The mining schedule and layout used during simulations are presented in Figure 1-1 and Figure 1-2;
- The numerical model update is based on previous numerical modelling reports and available monitoring data;
- The previous impact assessments from modelling exercises in 2016 and 2019 were considered to be correct. These assessments showed that the co-disposal facility and the operational opencasts are considered the main sources of contamination on-site, and this report focussed on updating the infrastructure plans related to the proposed underground extention and co-disposal expansion. This was taken as main input for the model update;
- Based on the existing groundwater models, and based on available groundwater level data, dewatering groundwater levels could be lowered over a relatively large area around the opencasts. However, it is not expected that the dewatering activities will impact negatively on the existing privately-owned boreholes though one spring may have been impacted upon during mining of underground Block AB. The effects on groundwater levels were considered to have a low impact on shallow groundwater levels and therefore dewatering of the underground mine was not included; and
- Inputs for transient flow modelling were derived from values used in previous models in terms of seepage rates and concentrations, sulphate being the main contaminant used

for modelling of contaminant plume movement. However, source input concentrations were based on geochemical dynamic testing and modelling.

6.3 Modeling Code

The numerical model for the project was constructed using GMS 10.4.2 GUI, a pre- and post-processing package for MODFLOW and MT3D. MODFLOW is a modular three dimensional groundwater flow model and MT3D a modular three dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3D uses 3D finite differences discretization and flow codes to solve the governing equations. MODFLOW and MT3D is a widely used simulation code, which is well documented.

6.4 Model Setup

The conceptual model is translated into a numerical model during the model setup. Setting up the numerical model entails:

- Selecting the model domain;
- Defining the model boundary and initial conditions;
- Spatially and temporally discretizing the project data; and
- Preparing the model input data.

The above conditions were used to simulate the groundwater flow in the model domain for pre-mining steady state conditions.

6.4.1 Model Domain

The model domain is defined by the drainage systems between the upper Olifants River and the upper Steenkoolspruit River within DCME (Figure 6-1). The high lying Klein Vaalkop forms the water divide between the two rivers. However, both the merges downstream north of the mining rights.

Further, the model model should be defined by natural geological and hydrogeological boundary conditions, i.e. the model domain should preferably encompass entire hydrogeological structures. The model consists of three layers to represent the weathered and fractured aquifers. The weathered Karoo aquifer consists of one 20 m thick layer represented by an unconfined aquifer. The upper fractured Karoo aquifer with coal seams consists of one 60 m thick layer represented as a semi-confined aquifer. The lower fractured Karoo aquifer consist of 40 m thickness layer represented as a confined aquifer.

6.4.2 Boundary Conditions

Boundary conditions express the way in which the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as the hydraulic head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions.

Boundary condition options in MODFLOW can be specified either as:

- specified head or Dirichlet; or
- specified flux or Neumann; or
- mixed or Cauchy boundary conditions.

Local hydraulic boundaries were identified for model boundaries. They were represented by local perennial and non-perennial water courses and topographical highs and delineated the entire model domain. These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour in an artificial manner. The model boundaries and model grid are shown Figure 6-1 and provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model. Hydraulic boundaries were identified for the model, which are summarised in Table 6-1. A model cross section is shown in Figure 6-2.

Table 6-1: Model Boundary Conditions

Boundary	Description	Condition
Top	Top surface of water table	Mixed type: Recharge is applied consistently to the first layer. Perennial streams are represented by a river package. Non-perennial streams are represented by drain cells.
East	Drainage boundary (Mid-Lower Olifants River) – perennial stream	Drain boundary
North-East	Upper Olifants River boundary condition – perennial stream	River boundary condition
South-East (Edges)	Topographically high boundary condition	No-flow boundary
South-West	Steenkoolspruit River boundary condition - perennial stream	River boundary condition

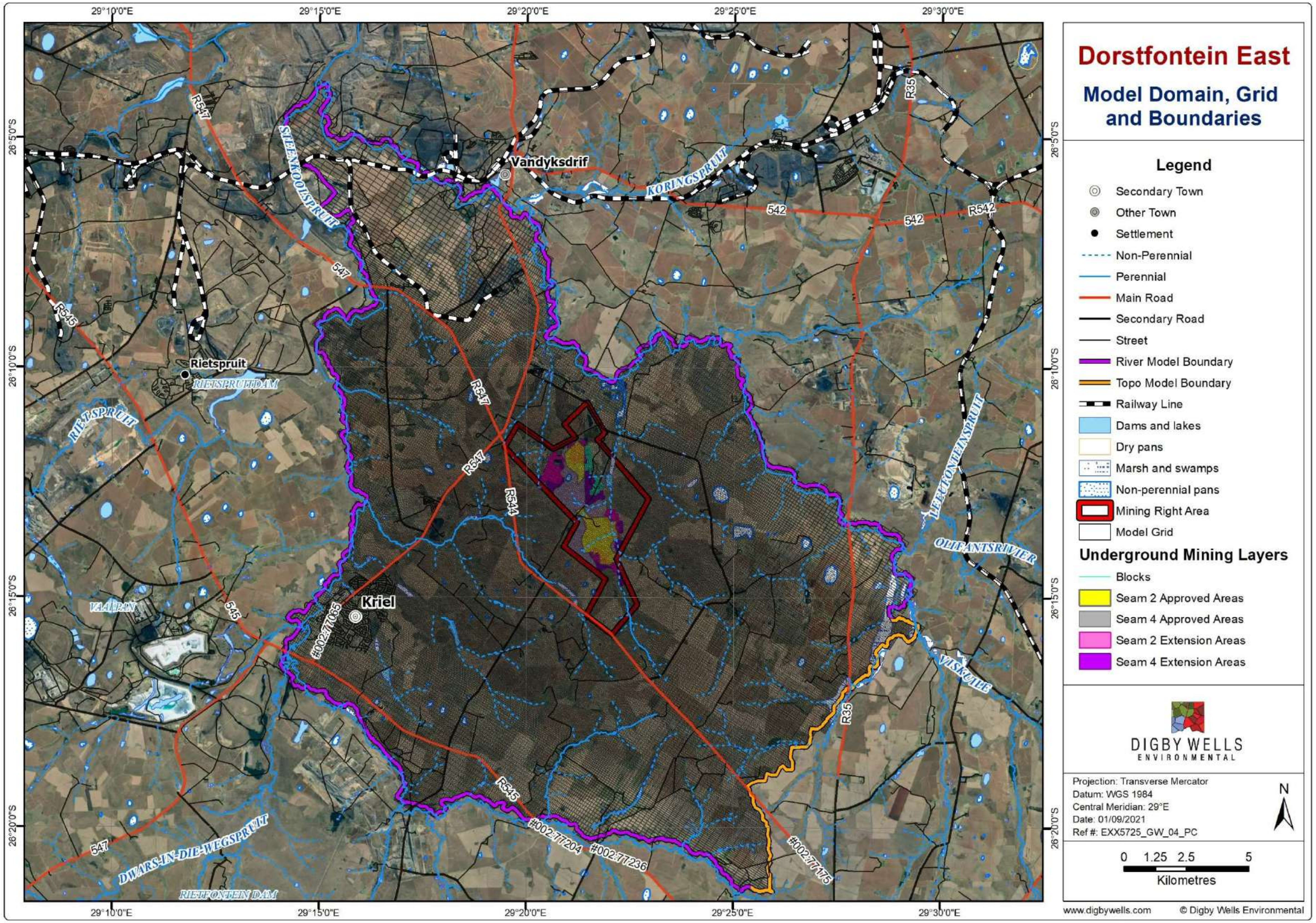


Figure 6-1: Model Domain, Grid and Boundaries

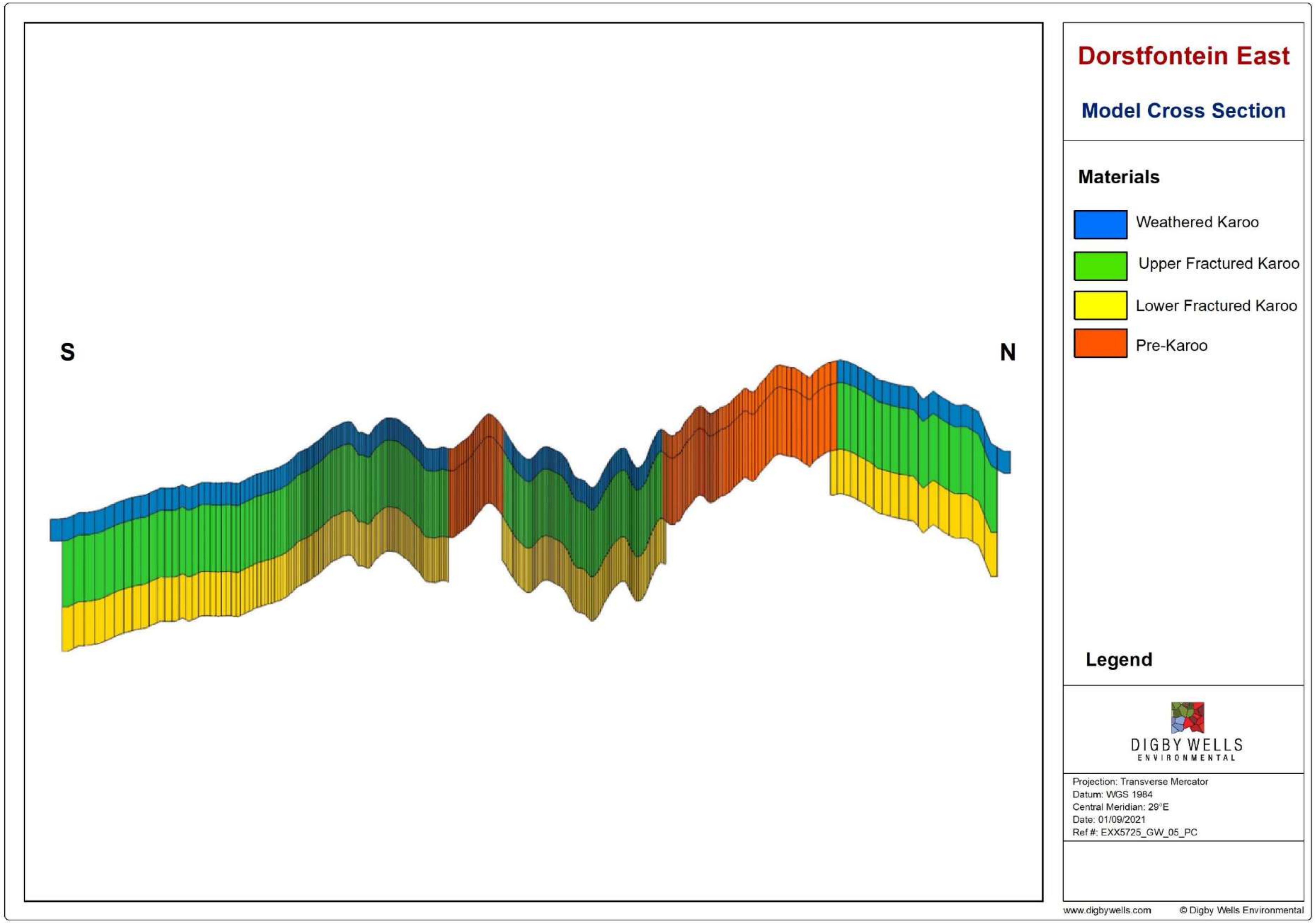


Figure 6-2: Model Cross Section

6.5 Steady State Simulation Update

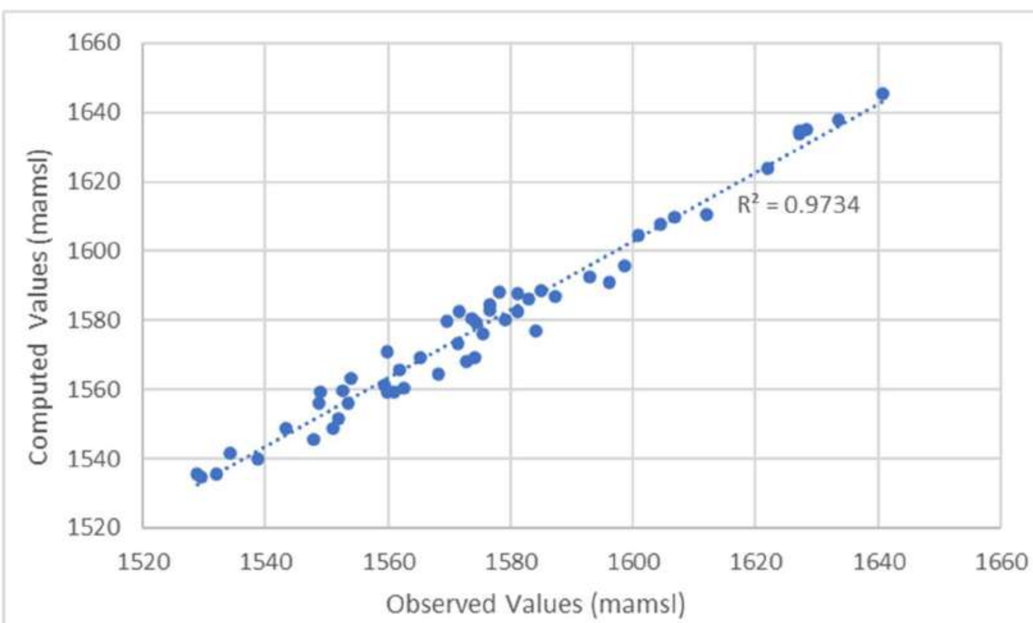
Prior to the simulation of the mining and dewatering activities, a baseline (pre-mining) steady state groundwater flow model was set-up and calibrated. The objective of the steady state model was to simulate the undisturbed groundwater system in the region prior to mining. The impacts of mining activities on the groundwater environment can then be determined by comparing the transient state results with the steady state results.

Digby Wells compiled all the hydrocensus water levels and quality data into a centralised MS Excel database, in a WISH format. Historical water levels were obtained from GCS (2016) and GCS (2019). This data was also added to the WISH database to produce time-series water levels.

The model was calibrated by varying model input data until a realistic, but satisfactory match between simulated and observed water level data was achieved. Since recharge and permeability are dependent on each other, via the measured heads, the model was not calibrated by changing the permeability and recharge simultaneously. The permeability was calibrated based on the aquifer test data while the recharge value was adjusted using the automatic parameter estimation programme - PEST.

A total of 53 observation boreholes were used for the steady state model calibration. Where more than one water level measurement was available, either the mean or one of the values was used. These boreholes are relatively uniformly distributed across the model domain.

After model calibration, an acceptable correlation with $R^2 = 0.97$ (equivalent to a correlation of 97%) was obtained between the simulated and observed groundwater elevation. The calibration was deemed acceptable with a Mean Residual Head of -3.1, a Mean Residual Absolute Head of 4.6 and a Root Mean Square Error (RMSE) of 5.5.



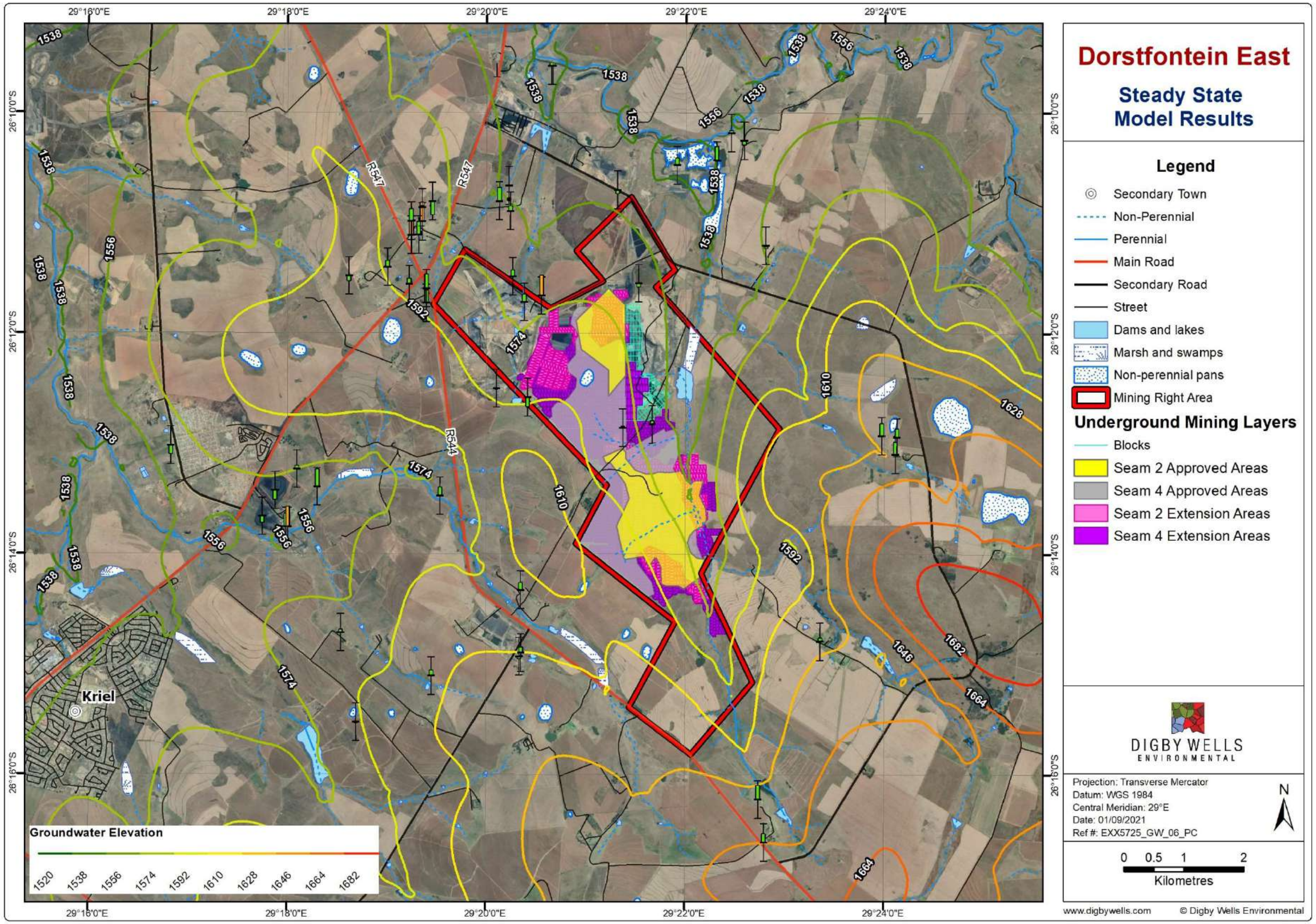


Figure 6-3: Correlation Between Observed And Calculated Heads.

6.5.1 Aquifer Hydraulic Conductivity

Initial estimates of the hydraulic conductivity for the different geological units were obtained from the aquifer test data collected as part of this investigation. These hydraulic conductivity values were assigned to geologic layers in the model area. The initial estimates were used for a combination of PEST and manual calibration. The resulting calibrated hydraulic conductivity and transmissivity values for each layer as summarised in Table 9.3 and Table 9.4. The transmissivity value of the model is in the same order of magnitude as the average transmissivity determined from the aquifer test results as discussed in Section 7.1.3.

Table 6-2: Calibrated Hydraulic Conductivities

Layer	Zone	Hydraulic conductivity (m/day)	
		Horizontal	Vertical
1	Weathered Karoo (Ecca)	3.2×10^{-1}	3.2×10^{-3}
2	Upper fractured Karoo (Ecca)	1.1×10^{-2}	1.1×10^{-3}
3	Lower fractured Karoo (Ecca and Dwyka)	5×10^{-3}	5×10^{-4}
1	Granite (Lebowa)	9×10^{-3}	9×10^{-4}
2	Granite (Lebowa)	5×10^{-3}	5×10^{-4}
3	Granite (Lebowa)	0	0

Table 6-3: Calibrated Hydraulic Conductivities

Layer	Thickness (m)	Lithology	Transmissivity values (m^2/day)
1	20	Weathered Karoo	1.0
2	60	Upper fractured Karoo	0.7
3	40	Lower fractured Karoo	0.2

6.5.2 Other Model Parameters

Recharge values were re-estimated as part of the steady state flow model calibration. An effective large-scale annual recharge value of than 1% of the mean annual precipitation (±700mm) was estimated for the Dorstfontein model. The model was assigned a recharge value of 7 mm/annum for the entire model area. Other model parameters used in the calibrated model were as follows:

- Specific yield (Sy) for the unconfined weathered layers: 0.03 (-);
- Specific storage (Ss) for the confined fractured layers: 1.67x10-6 to 1.67x10-7 (-);
- Rivers:

- Head stage at surface level;
- Bottom elevation at 2 m below surface level;
- Conductance river bottom of 0.86 $m^2/d/m^2$;

- Drains:
  - Drain level at 2 m below surface level;
  - Drain conductance of 0.86 $m^2/d/m^2$;

6.6 Transient State Simulation Update

The impacts of mining activities were assessed in a transient model using different stress periods to simulate changes related to model parameters over time. The transient model setup entails selecting the appropriate time-dependent parameters such as artificial recharge (if any) and mine dewatering. The geometry of the model domain, boundaries, top and bottom of the layers, grid size, layer type and natural recharge remain as defined in the steady state model. The solution of the calibrated steady-state model was used as initial hydraulic head distribution of the transient model.

After the completion of the transient state model setup, the mine plan was incorporated into the model. This was done to estimate the groundwater inflow rates over time and also predict the potential cone of dewatering and environmental impacts associated with the mine plan.

The most important closure impacts were modelled and assessed:

- Expected groundwater abstraction volumes from DCME for the current to the end of the LoM (2037);
- Expected groundwater drawdown at the end of LoM and estimated post-closure water level recovery in the DCME; and
- Potential contaminant plume migration post-closure, including current boreholes – carried out for 50 and 100 year post-closure.

6.6.1 Mass Transport Simulation

In most cases, contaminant transport is driven by advection, i.e. groundwater flow is the main mechanism controlling the movement of solutes in groundwater. Advection implies that contaminants migrate at a rate similar to the groundwater flow velocity and in the same direction as the hydraulic gradient. Therefore, knowledge of groundwater flow patterns and hydraulic parameters can be used to predict solute transport under advection. Other parameters to consider include dispersion, diffusion, effective porosity and the specific yield.

6.6.2 Dispersion and Diffusion

Dispersion of contaminants in groundwater is also important in terms of contaminant transport. Dispersive transport is caused by the tortuous nature of pores or fracture openings that result in variable flow velocity distributions within an aquifer and movement of contaminants due to the difference in concentration gradient.

Dispersion has two components; longitudinal and transversal dispersivities. The longitudinal dispersivity is scale dependent and is usually approximately 10% of the travel distance of the plume (Fetter, 1993). The transversal dispersivity is approximately 10% of the longitudinal dispersivity. The higher the dispersivity, the smaller the maximum concentration of the contaminant, as dispersion causes a spreading of the plume over a larger area.

Considering the coal seam depths and streams, a longitudinal dispersivity of 5 m is estimated. A diffusion coefficient of $1x10^{-5}$ m^2/day was selected, acceptable for Karoo sedimentary rocks.

6.6.3 Effective Porosity and Specific Yield

The percentage of void volume that contributes to groundwater flow is expressed by the term "porosity". Not all pores are interconnected and therefore cannot contribute equally to groundwater flow, leading to the derivation of the term "effective porosity", used to express the interconnected void volume that effectively contributes to groundwater flow and therefore contaminant transport. The higher the effective porosity, the slower the contamination migration rate, because more pore voids have to be filled. The specific yield of a unit volume aquifer is the quantity of water that can be released or drained as a result of gravity. This implies that the specific yield is either equal to or less than the effective porosity.

A specific yield of 0.03 and an effective porosity of 0.01 was applied for the weathered Karoo sedimanents (Layer 1) while a specific yield of 0.02 and an effective porosity of 0.03 was applied for the Upper Fracture Karoo rocks (Layer 2). A specific yield and effective porosity of 0.01 was applied for the Lower Fractured Karoo rocks (Layer 3). A specific yield of 0.001 was applied for the Weathered Pre-Karoo rocks and specific yield of 0.0001 was applied for the fractured Pre-Karoo rocks.

Various parameters (recharge, vertical anisotropy, specific storage etc) were applied across the entire model domain and/ or various mining infrastructure based on transient state model calibration.

6.6.4 Selection of the Contaminant of Concern

As shown in previous studies and confurmed by the updated geochemical assessment as part of this study, the main contaminant of concern is sulphate. Potential contamination plume movement at the project area were simulated using the source concentrations as per

Table 6-4.

Table 6-4: Sulphate Input Concentrations For Transient Modelling

Pit water quality - discard backfill below decant level			
Maximum oxygen infiltration in backfill			
Depth	Short term	Medium term	Long term
	0-20 year	20-50 year	50-200 year
20 m	2500-2800	2800-3100	3100-2900
60 m	2500-2500	2500-3500	3500-3700
Pit water quality - discard backfill below decant level			
Average oxygen infiltration in backfill			
Depth	Short term	Medium term	Long term
	0-20 year	20-50 year	50-200 year
20 m	2500-2700	2700	2700-2400
60 m	2500	2500-2700	2700-2400

7 Groundwater Impact Assessment

The aim of an impact assessment is to strive to avoid damage or loss of ecosystems and services that they provide, and where they cannot be avoided, to reduce, and mitigate these impacts (DEA, 2014). Offsets to compensate for the loss of habitat are regarded as a last resort, after all efforts have been made to avoid, reduce, and mitigate.

The potential impacts of the proposed activities on groundwater resources are shown below per phase of the mine; the impacts were derived based on previous experience and literature review. The impacts shown below take into account the worst-case scenario, however these impacts need to be considered during the planning phase.

7.1 Operational Phase

7.1.1 Groundwater Level Drawdown

The lowest coal floor elevations of the No. 2 Seam are partially below the regional groundwater levels thus causing groundwater inflows into the open mining areas from the surrounding aquifer during operation. The mining areas will have to be actively dewatered to ensure dry working conditions.

Pumping of water that seeps into the open mining areas will cause dewatering of the surrounding aquifer and an associated decrease in groundwater levels within the zone of influence of the dewatering cone. The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifer, the size of the mining area and the aquifer transmissivity, amongst others.

During the operational phase it is expected that the main impact on the groundwater environment will be dewatering of the surrounding aquifer. A numerical groundwater flow model was used to simulate the development of the drawdown cone over time on the Project Site and surrounding area. The mine plan includes mining up to 2037. The potential cone of drawdown is largest at the end of life of mine and extends to a maximum radius of ~200 m around the open pit and underground mining areas.

7.1.1.1 Mitigations

The drawdown impacts as a consequence of the underground expansions is expected to result in a minor impact. To reduce the impact further the mining footprint should be kept as small as possible, mining should progress as quickly as possible, and dewatering activities should cease as soon as possible after mining has been completed.

Frequent groundwater level monitoring should be carried out throughout the operational phase to discern trends in water levels and comparison with calculated drawdowns. Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence and as such it is unlikely there will be an impact on third party abstraction sources.

Table 7-1. Impacts during the Operational Phase – Groundwater Drawdown.

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Activity and Interaction: Mine dewatering causing lowering of groundwater levels</td></tr>
<tr><td colspan="4">Impact Description: Active mine dewatering will be required to ensure dry working conditions in the open pits and underground mining areas. The dewatering will cause ground levels to be drawn down in the vicinity of the mining areaa.</td></tr>
<tr><td colspan="4">Prior to Mitigation/Management</td></tr>
<tr><td>Duration</td><td>6</td><td>Expected for LoM</td><td rowspan="5">Minor (negative) - 42</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to opencast and underground mining areas and surroundings.</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>6</td><td>It is likely that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
<tr><td colspan="4">Mitigation/Management Actions</td></tr>
<tr><td colspan="4">Mining should progress as swiftly as possible to reduce the period of active dewatering
The mining area extent should be kept to a minimum
Dewatering of the open pits and underground voids should stop as soon as the mining activities cease
Groundwater levels surrounding the pits and voids should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown</td></tr>
<tr><td colspan="4">Post-Mitigation</td></tr>
<tr><td>Duration</td><td>5</td><td>Expected for LoM</td><td rowspan="5">Minor (negative) - 39</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to opencast and underground mining areas and surroundings.</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>6</td><td>It is likely that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
</table>

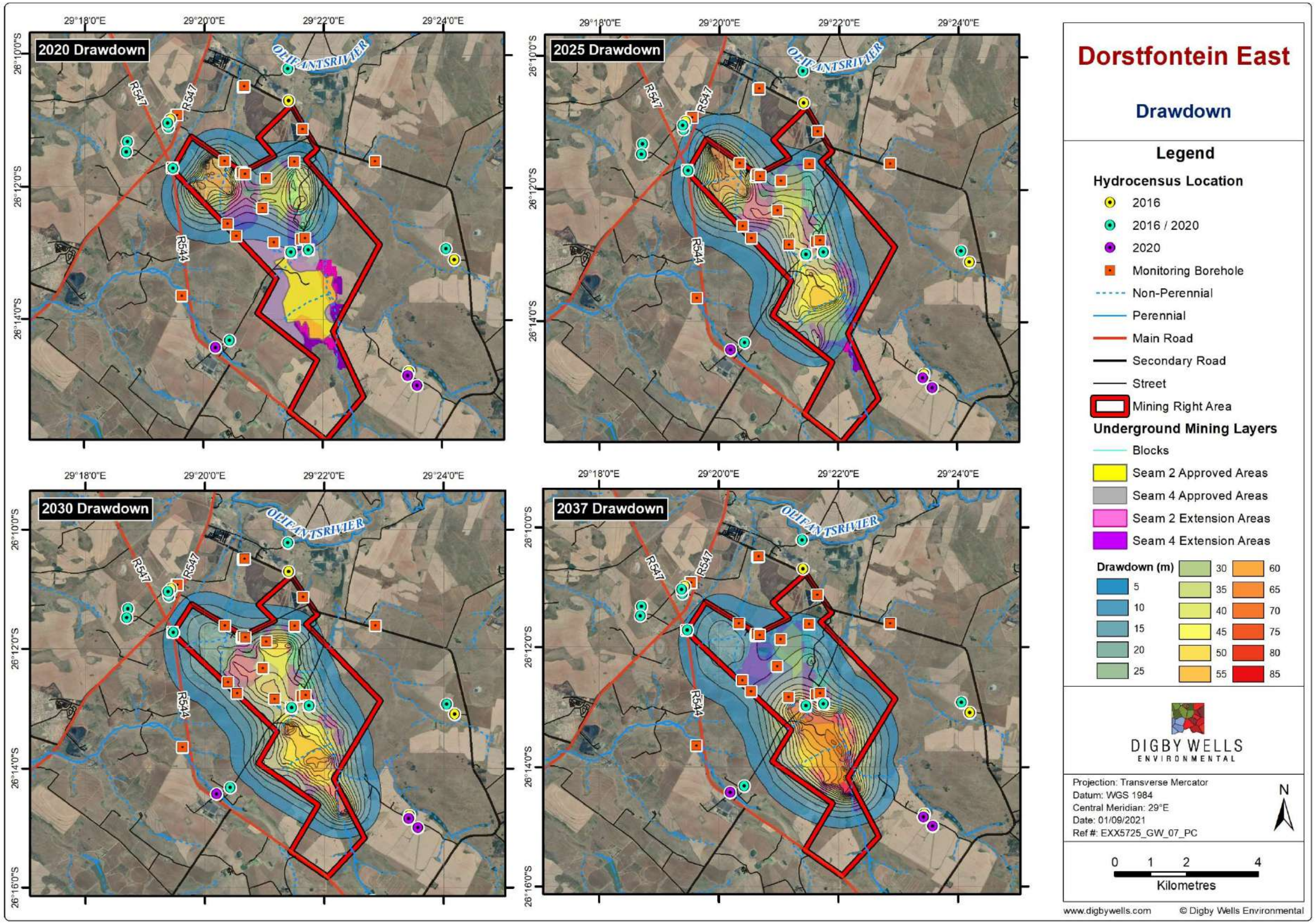


Figure 7-1: Groundwater Cone Of Drawdown During The Operational Phase

7.1.2 Impact On Aquifer Yield (Groundwater Abstraction Volumes)

The numerical model was used to predict groundwater inflows into the proposed mine. The computed inflow into the open pit workings was calculated based on the provided mine schedules and assumptions of the numerical model (refer to Section 6).

The numerical model for the Dorstfontein East mine was used for the prediction of groundwater inflows into the opencast and underground mines. The mine inflow volumes were calculated for the mine schedules obtained from the client for two existing opencast pits, a smaller underground extension at Pit 1 and a large underground block connected to Pit 2. A separate small underground section is proposed in the area where Pit 3 was previously proposed.

Pit 1, Pit 2 and the larger underground mining block all target the 2 and 4 seams; the underground section at the location of Pit 3 and the smaller underground extension at Pit 1 target the 4 seam only.

The predicted groundwater inflows into the opencasts between 2011 and 2020 fluctuate between ~1 000 m^3/d and ~1 500 m^3/d, mainly due to that the opencasts have increased in size since mining started.

Between 2020 and 2027 inflows increase due to the expansion of the underground extension at Pit 1 and as mining of the 2-seam and 4-seam underground mining blocks start. The total groundwater inflows over this period increase to ~2 100 m^3/d. After 2027 groundwater inflows gradually decrease to about 1 200 m^3/d towards the end of life of mine as the aquifers surrounding the underground mining area has been depleted.

The inflow calculations based on the groundwater model represent the correct order of magnitude, and the most likely range of inflow variation based on the uncertainties of the model used has been indicated in Figure 7-2. These calculations were performed excluding evaporation from the opencasts.

7.1.2.1 Mitigations

Mining of all of the proposed areas should progress as swiftly as possible to reduce the period of active dewatering. In addition, the extent of the mining areas should be kept to a minimum to reduce dewatering impacts.

The dewatering of the open pits and underground mines should stop as soon as mining activities cease, or if possible, where certain sections of the underground can be allowed to flood before the end of LoM has been reached, this should be considered to promote groundwater level recovery.

The dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as they are identified.

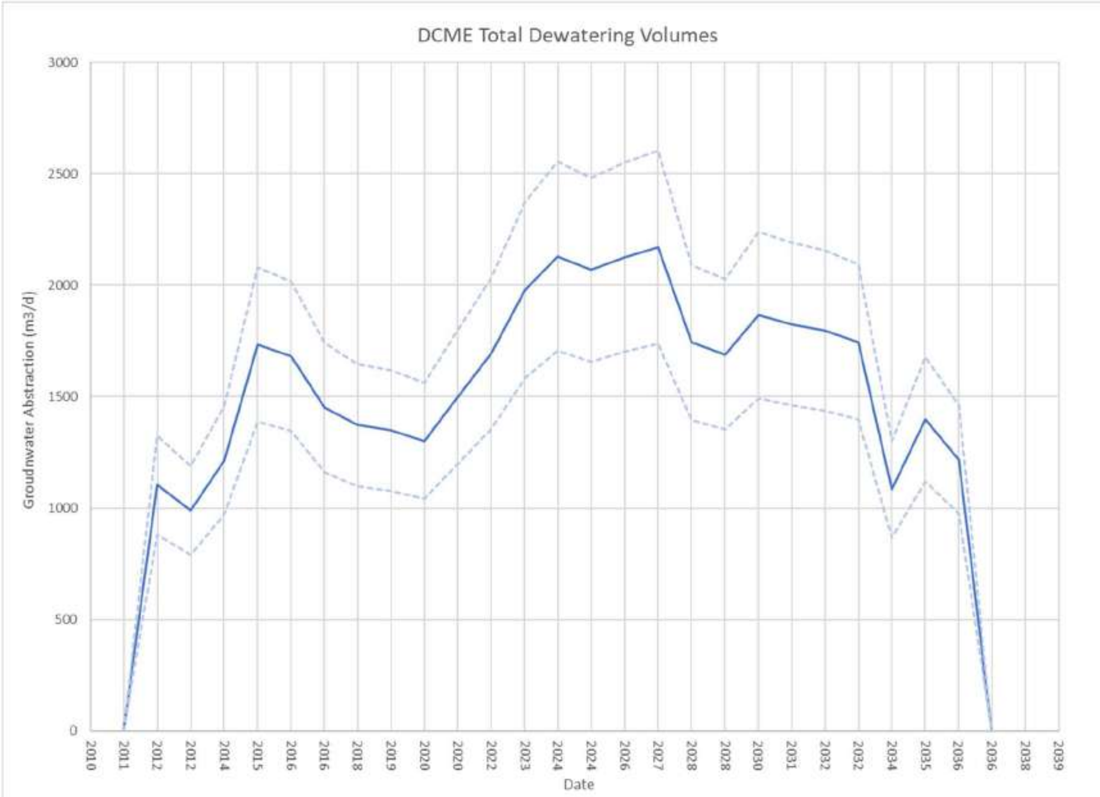


Figure 7-2. Simulated Groundwater Inflows – All Mining Areas

Table 7-2. Impacts during the Operational Phase – Groundwater Abstraction

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Activity and Interaction: Mine dewatering causing a decrease in groundwater reserves</td></tr>
<tr><td colspan="4">Impact Description: Due to active mine dewatering required to ensure dry working conditions in the open pits and underground voids, certain groundwater volumes will be extracted from the open pits and underground mining areas, limiting the groundwater resource.</td></tr>
<tr><td colspan="4">Prior to Mitigation/Management</td></tr>
<tr><td>Duration</td><td>6</td><td>Expected for LoM and a short period post-closure</td><td rowspan="5">Minor (negative) - 36</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Pit 1, Pit 2, proposed underground mining areas and surroundings</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>4</td><td>It is probable that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
<tr><td colspan="4">Mitigation/Management Actions</td></tr>
<tr><td colspan="4">Mining should progress as swiftly as possible to reduce the period of active dewatering
The mining area extent should be kept to a minimum
Dewatering of the open pits and underground voids should stop should as soon as the mining activities cease
Dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as possible</td></tr>
<tr><td colspan="4">Post-Mitigation</td></tr>
<tr><td>Duration</td><td>5</td><td>Expected for LoM</td><td rowspan="5">Negligible (negative) -33</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Pit 1, Pit 2, proposed underground mining areas and surroundings</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>4</td><td>It is probable that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
</table>

7.1.3 Groundwater Quality (Potential Contamination Of Groundwater)

The current mining schedule for the Project Site includes mining up to and including 2036. This allows sufficient time for chemical reactions to take place in the mined-out areas and other potential pollution sources to produce AMD conditions. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area.

7.1.3.1 Mitigations

All discard material and coal slurry should be placed only at the co-disposal facility. Any pollution control dams and/or ROM coal stockpile areas should be lined, thereby preventing contamination of the underlying aquifers. During the operational phase clean water and rainwater needs to be diverted away from these surface infrastructures as much as possible to reduce seepage to groundwater.

Contamination from workshops, sewage treatment plant, wash bay or waste collection areas, if any, should be contained as much as possible by proper construction of hardstanding and bunded areas.

To ensure a cone of drawdown is maintained towards the mining areas, groundwater abstraction should continue for the LoM, and groundwater quality in the area surrounding the mining areas should continue throughout the LoM. Groundwater levels surrounding the pits should be monitored on a regular basis throughout the LoM to verify the extent of the cone.

Table 7-3. Impacts during the Operational Phase – Groundwater Quality

Dimension	Rating	Motivation	Significance
Activity and Interaction: AMD formation in pits, underground voids and co-disposal facility; other surface sources that could cause groundwater contamination			
Impact Description: Due to AMD formation in the mining areas and co-disposal facility, or any seepage from infrastructures, the groundwater quality could be impacted upon.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM and post-closure	Negligible (negative) -22
Extent	2	Limited to opencast and underground mining areas and surroundings	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	3	Based on model results this impact is probable	
Nature	Negative		
Mitigation/Management Actions			
• Groundwater abstraction should continue for the LoM to maintain a cone of drawdown • Monitoring of groundwater quality in the area surrounding the mining areas should continue throughout the LoM • Groundwater levels surrounding the mining areas should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown • Dispose of coal discard slurry at the co-disposal facility only • Pollution control dams and/or ROM coal stockpile areas should be lined, where applicable, and clean water needs to be diverted away from these infrastructures • Contamination from workshops, sewage treatment plant, wash bay or waste collection areas should be contained as much as possible by proper construction of hardstanding and bunded areas			
Post-Mitigation			
Duration	5	Expected for LoM	Negligible (negative) -18
Extent	2	Limited to opencast and underground mining areas and surroundings	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	2	Based on model results this impact is probable	
Nature	Negative		

1.1 Post-Closure Phase

7.1.4 Groundwater Level Recovery

After the end of life of mine pumping of groundwater from the open pits will seize, the voids will be backfiled and groundwater levels are allowed to recover. Groundwater levels in the surrounding area which were drawn down due to the dewatering will subsequently return to close to the natural, pre-mining state. However, due to the low recharge influx and increased porosity of the backfill materials it will take a long time before groundwater levels will return to pre-mining conditions. The numerical model was used to simulate groundwater rebound and indicated the rebound will indeed be slow. Groundwater levels in the vicinity of the site are expected to take approximately 20 years to recover. However, due to the limited scale of the drawdown cone it is expected that the long-term recovery will have a minor impact.

7.1.4.1 Mitigations

Dewatering should cease as soon as possible after mining activities are completed to allow for groundwater level recovery. The groundwater recovery should be frequently (at least quarterly) monitored to identify deviations from the predicted recovery rate, and groundwater quality should be frequently sampled (at least quarterly) to establish if a contaminant plume is migrating. At the start of the post-closure phase, clean water and runoff should be diverted where possible towards the pits to flood these areas as fast as possible after mining has stopped to slow the rate of interaction of the backfilled materials with oxygen.

Table 7-4. Impacts during the Post-Closure Phase – Groundwater Level Recovery

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine Dewatering and residual effect on rebounding groundwater levels			
Impact Description: Due to the dewatering activities during the operational phase, groundwater levels surrounding the mining areas will be subdued at the start of the Post Closure Phase, after it will gradually recover towards pre-mining levels.			
Prior to Mitigation/Management			
Duration	6	Reduced groundwater levels will be fully recovered within 20 years post-closure	Minor (negative) -42
Extent	2	Limited to opencast and underground mining areas and surroundings.	
Intensity	3	Moderate, short-term effects are expected	
Probability	6	This impact is likely to occur	
Nature	Negative		
Mitigation/Management Actions			
• Dewatering should cease as soon as possible after mining activities are completed to allow for groundwater level recovery • Groundwater level recovery should be frequently monitored to identify deviations from the predicted recovery rate Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate • Clean water and runoff should be diverted where possible towards the open pit voids to flood areas as fast as possible after mining has stopped			
Post-Mitigation			
Duration	5	Reduced groundwater levels will be fully recovered within 20 years post-closure	Minor (negative) -39
Extent	2	Limited to opencast and underground mining areas and surroundings.	
Intensity	3	Moderate, short term effects are expected	
Probability	6	This impact is likely to occur	
Nature	Negative		

7.1.5 Groundwater Contamination

Once the mining has ceased, AMD is still likely to form given the partially unsaturated conditions and the consequent contact of water and oxygen in the backfilled pits, underground voids and co-disposal facility. Groundwater contaminants could migrate from these areas once groundwater levels in the mining areas start to recover.

The migration of contaminated water from the mining areas and co-diposal facility was simulated for 50 and 100 years post-closure (Figure 7-3). The maximum extent of the contaminant plume (sulphate >50 mg/l) for the weathered aquifer was calculated to be ~750 m from the mining areas 100 years post-closure.

The contaminant migration indicates that the plumes will mainly flow towards and follow local drainage lines, such as the two tributaries of the Olifants River, located to the north and the east of the opencasts (Figure 7-4) are expected to receive an increased salt load due to the contaminant plumes. Expected post-closure sulphate concentrations in groundwater close to the western tributary (north of Pit 1) may go up to 2 800 mg/l, while concentrations close to the eastern tributary (east of Pit 2) may go up to 1 500 mg/l. This is expected to have a high impact on the streams and associated wetlands.

Based on the contaminant transport simulations no third party boreholes are projected to be within the zone of contamination and it is therefore unlikely that any of these boreholes will be impacted.

7.1.5.1 Mitigations

The dewatering of the pits should cease as soon as possible after mining activities are completed to allow for groundwater level recovery. To mitigate the contaminant plume migration the open pits should be properly rehabilitated, including reduction of recharge to these areas by properly top-soiling and vegetating the areas. This will reduce infiltration of water into the groundwater and reduce plume extents.

Clean water and runoff should be diverted where possible towards the rehabilitated pits immediately after mining has stopped to allow for faster recovery of pit water levels, to reduce the interaction of potentially acid forming materials with oxygen. After completion of the pit rehabilitation surface water runoff should be diverted away from the pits to reduce pit water inflows that may contribute to long-term decant volumes.

Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate If a contaminant plume is detected from Pit 1 or Pit 2, groundwater may need to be captured or actively lowered in Pit 1 and 2 to prevent contaminant plumes to move away from the pits.

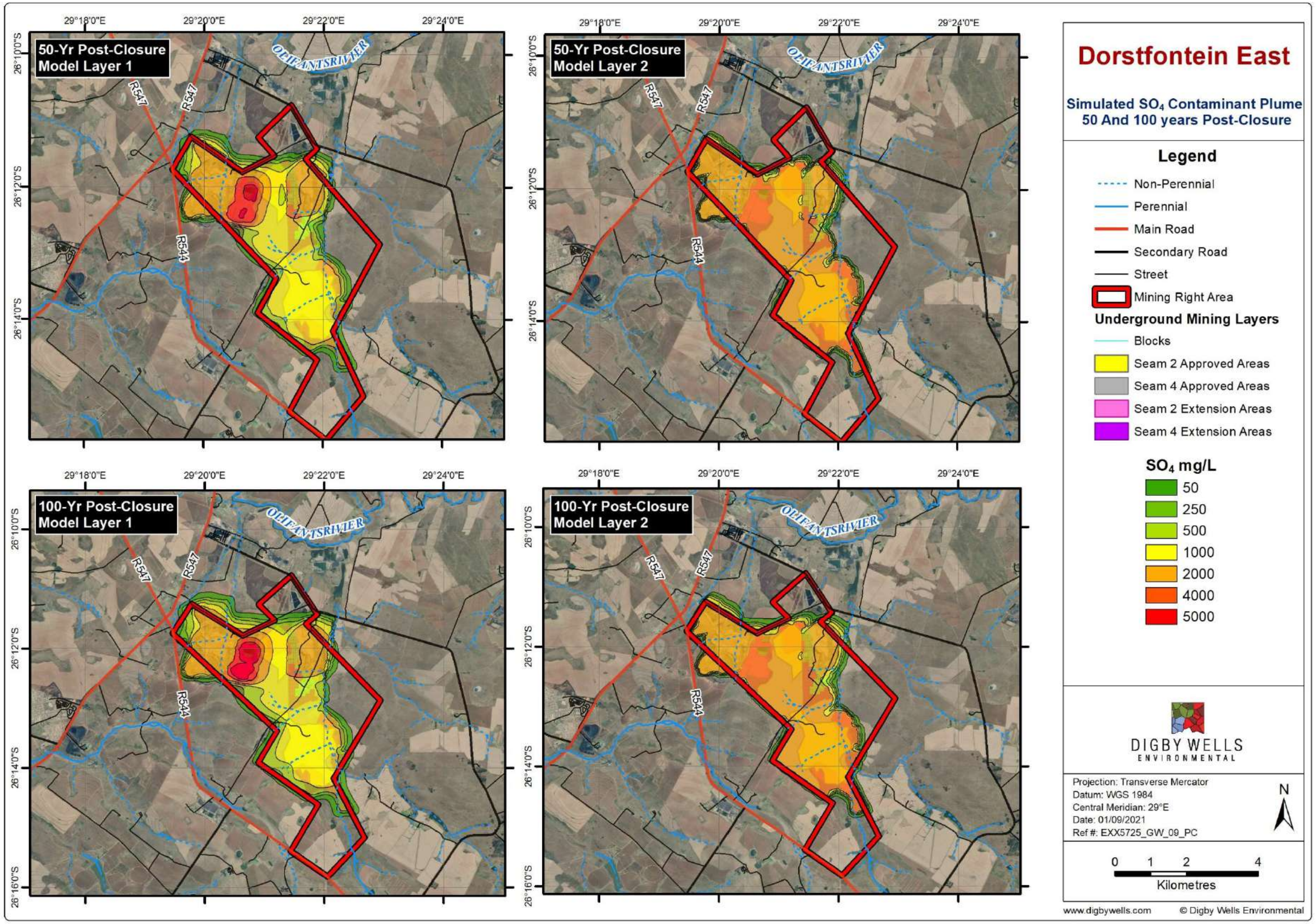


Figure 7-3: Groundwater Contaminant Plumes Post-Closure

Table 7-5. Impacts during the Operational Phase – Groundwater Quality

Dimension	Rating	Motivation	Significance
Activity and Interaction: AMD formation in open pits, underground voids and co-disposal facility.			
Impact Description: Due to AMD taking place within the backfilled open pits and in co-disposal facility, groundwater contamination with elevated sulphate and low pH could occur.			
Prior to Mitigation/Management			
Duration	7	The impact will remain long after the life of the Project and are irreversible.	Moderate (negative) -90
Extent	2	Opencast and underground mining areas and surrounding area.	
Intensity	6	Serious impact on expected on tributaries and associated wetlands.	
Probability	6	This impact will likely occur	
Nature	Negative		
Mitigation/Management Actions			
• Dewatering of the pits should cease as soon as possible after mining activities are completed to allow for groundwater level recovery • Rehabilitation of the pits and co-disposal facility to reduce infiltration of rainwater into the dump to reduce seepage generation • Clean water and runoff should be diverted where possible towards the rehabilitated pits as fast as possible after mining has stopped. • Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate • If a contaminant plume is detected from Pit 1 or Pit 2, groundwater may need to be abstracted and treated before release into the environment			
Post-Mitigation			
Duration	7	The impact will remain long after the life of the Project and are irreversible.	Minor (negative) -60
Extent	2	Opencast and underground mining areas and surrounding area.	
Intensity	4	Reduced impact on expected on tributaries and associated wetlands.	
Probability	6	This impact will likely occur	
Nature	Negative		

7.1.6 Mine Decant

For open pit mining the decant point can be established as the lowest topographical point of the pit outline at the end of life of mine. When the active dewatering of the opencasts and underground voids has ceased, groundwater levels will rebound. As the underground voids and backfilled opencasts flood, decant will occur when the groundwater level recovers to above the lowest surface elevation of the pit. This can occur long after the end of life of mine and is referred to as the time-to-decant.

At Dorstfontein East proposed mining is planned for Pit 1, the Pit 1 extension and Pit 2. Based on the updated historical and proposed mine plans and updated site topography (based on 5 m surface contours) the potential decant points have been determined for each pit (Figure 10.6).

The volume of the opencast mines at Dorstfontein East was based on the depth and extent of the No. 2 and No. 4 coal seams in combination with the updated historical and proposed mine plans. It is assumed the pits will be backfilled.

Decant calculations were carried out for Pit 1, Pit 1 extension and Pit 2. Pit 3 was not taken into consideration for decant calculations as based on the surface elevation of the pit the likelihood of decant is low. In addition, the size of the pit is small and decant from the pit would be negligible when compared to potential decant flows from Pit 1, Pit 1 extension and Pit 2.

Values for porosity and recharge to opencast areas were taken from information on rehabilitation of the DCME opencast areas as obtained from Golder & Associates and du Plessis, J.L., 2010, "Decant Calculations and Groundwater – Surface Water Interaction in an Opencast Coal Mining Environment".

The porosity of the backfill material was taken to be between 15% and 25% of the total mined volume. A recharge rate of between 6.5% and 20% was used for the time-to-decant and decant volume calculations. The lower recharge rate was taken based on the information of the current rehabilitation plan.

The calculations for the opencasts only show that the time-to-decant ranges between approximately 35 and 230 years. Decant volume calculations show discharge rates of between approximately 75 and 450 m3/d.

Table 7-6 Open pit mine volume calculations

Opencast	Total mined volume m3 (below decant position)	Void volume (15% effective porosity)	Void volume (25% effective porosity)
Pit 1	51119000	7667850	12779750
Pit 2	31042000	4656300	7760500

Table 7-7 Time-To-Decant (years).

Opencast	Effective porosity 15%	Effective porosity 25%
	Recharge 20%	Recharge 6.5%
Pit 1	31	161
Pit 2	34	176

Table 7-8 Decant volumes (m^3/d).

Opencast	Pit surface area (m^2)	Recharge 6.5%	Recharge 20%
Pit 1	1649000	218	670
Pit 2	913000	121	371

However, decant discharge rates could be higher if the underground voids stay interconnected with the opencasts. The proposed onderground block northwest of Pit 1 would in that case contribute to the inflow into Pit 1 and groundwater from underground blocks south of Pit 2 would contribute to the flow into Pit 2. This would increase the decant volumes as shown in Table 7-11, with decant volumes expectd for Pit 2 to increase significantly.

Time-to-decant will also decrease if the underground voids stay interconnected with the opencasts due to the additional inflow as shown in Table 7-10. As such, declines, entrances and other connections between the underground voids and the opencasts should be sealed after mining ceases.

Table 7-9 Open pit And Underground Mine Volume Calculations

Opencast + UG	Total mined volume m3 (below decant position)	Void volume (15% effective porosity)	Void volume (25% effective porosity)
Pit 1	51714500	8114475	13226375
Pit 2	40454500	13769925	16874125

Table 7-10 Time-To-Decant (years).

Opencast + UG	Effective porosity 15%	Effective porosity 25%
	Recharge 20%	Recharge 6.5%
Pit 1	32	150
Pit 2	44	74

Table 7-11 Decant volumes (m^3/d).

Opencast +UG	Pit surface area (m^2)	Recharge 6.5%	Recharge 20%
Pit 1	1649000	242	695
Pit 2	913000	639	890

Decant from Pit 1 will flow towards the western tributary of the Olifants River; the decant from Pit 2 will flow towards the eastern tributary of the Olifants River (Figure 7-4).

The calculated volumes and quality of the potential decant indicate a high impact on the water quality of the tributaries (north of Pit 1 and east of Pit 2) of the Olifants River, and subsequently the Olifants River itself, if not mitigated. There is also potential to impact on the hillslope seep and channeled valley bottom wetland associated with the western tributary, and the channeled valley bottom wetland areas associated with the eastern tributary (Figure 7-5).

7.1.6.1 Mitigations

Inter-connections between the mining areas at DCME should be sealed, especially between the underground mine voids and the opencast pits, to prevent additional decant volumes to emanate from the backfilled pits through flooded underground voids. This should focus on the primary pathways between opencast and underground, but also focus on compartmentalising of the underground voids to prevent flow of AMD water from one void to another, and therefore reducing the flows that will report to the backfilled opencasts.

To reduce the impact on surface water quality and wetland areas post-closure, decant capture and treatment will be required to prevent deterioration of the post-closure water quality emanating from Pit 1 and Pit 2.

Table 7-12. Impacts during the Operational Phase – Decant

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine decant causing contamination of groundwater			
Impact Description: If groundwater levels within the open pits recover to elevations higher than surface elevations, this water may then flow from the pit areas and cause groundwater contamination down gradient of the mine.			
Prior to Mitigation/Management			
Duration	7	The impact will remain long after the life of the Project. The impacts are irreversible.	Moderate (negative) -84
Extent	2	Decant points and downgradient	
Intensity	6	Serious, long-term impact o surface water and ecosystems down gradient of the decant points	
Probability	5	This impact is likely to occur	
Nature	Negative		
Mitigation/Management Actions			
• The post-closure sealing of inter-connections between the mining areas at DCME, especially between the underground mine voids and the opencast pits • Installation of groundwater abstraction boreholes at decant points, or formation of a pit lake, to reduce water level and prevent decant flow, and treatment of the abstracted water. • Rehabilitation of the pits and co-disposal facility to reduce infiltration of rainwater into the dump to reduce seepage generation. • Groundwater level recovery in the rehabilitated open pits should be frequently monitored to create stage curves and predict the final water recovery level.			
Post-Mitigation			
Duration	6	The impact will remain long after the life of the Project. The impacts are irreversible.	Minor (negative) -42
Extent	2	Decant points and downgradient	
Intensity	3	Moderate, short-term impact on surface water and ecosystems down gradient of the decant points	
Probability	5	This impact is likely to occur	
Nature	Negative		

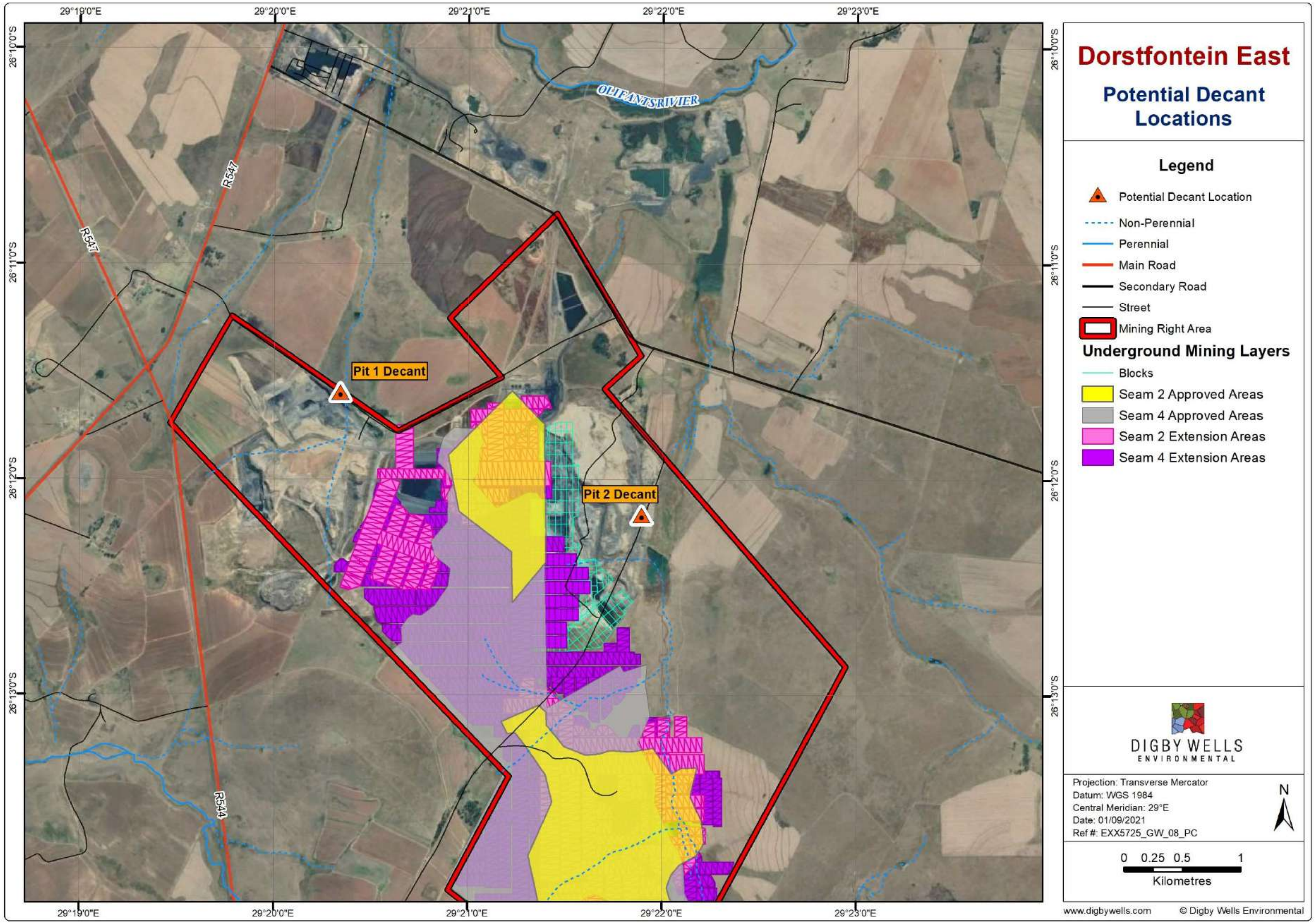


Figure 7-4: Potential Decant Points

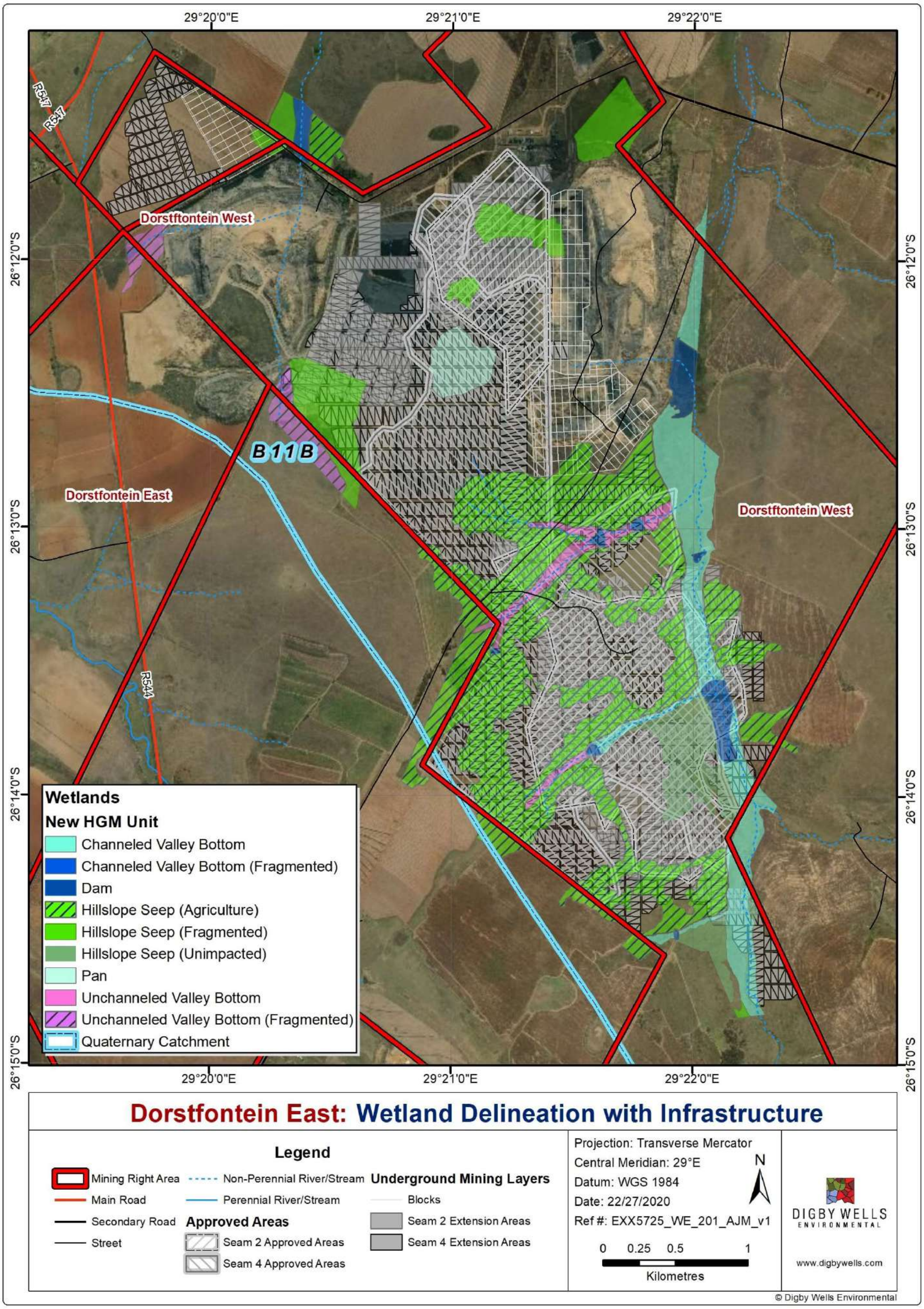


Figure 7-5: Wetland Areas And Drainage Features

7.2 Cumulative Impacts

The main impacts of opencast mining of coal are groundwater resource reduction, drawdown, and contamination. In addition, a risk of decant exists when water levels in the opencasts recover to above the lowest topographical elevation. Other opencast coal mine operations are present within the wider area surrounding the DCME site. These operations are so close they have the potential to impact on groundwater reserves and levels in the areas situated in between the proposed activities, and it may be these areas will be impacted by multiple mining operations.

As such it is expected that groundwater resources and drawdown, and therefore potentially other groundwater users, in the north and west of the Project Area may be impacted upon by at least three mines if simultaneous operation of the mining activities occurs. However, based on the limited extent of the drawdown cone at DCME this cumulative effect may be limited.

Contamination from opencast areas, waste rock dumps and other unlined facilities may also cause a cumulative effect on groundwater quality in areas in between the mining operations, but also may accumulate on down gradient surface water features, if contaminated groundwater increases the salt loads th local streams which then feed into regional rivers, such as the Olifcants River. In the post-closure phase there is a possibility of these contaminant plumes to contribute salt loads to local drainage features and thus impact upon groundwater down gradient of the mines and surface water downstream of the mining operations. This would impact on other groundwater users, groundwater dependant ecosystems and surface waters.

If decant flows towards downgradient streams it can impact on surface water quality, and if multiple decants would occur into the same stream, there would be a cumulative impact on the water quality due to increased salt load. This could be a cumulative impact of high significance, and the possibility of decant for each proposed mining activity and the cumulative effects of these should be properly mitigated.

8 Groundwater Management Plan

8.1 Proposed Actions

8.1.1 Groundwater Management Plan: Actions Operational Phase

8.1.1.1 General

- Static groundwater levels should be monitored to ensure that any deviation of the groundwater flow from the idealised predictions is detected in time;
- The monitoring results must be interpreted annually by a qualified hydrogeologist and network audited annually as well to ensure compliance with regulations;
- A detailed mine closure plan should be prepared during the operational phase, including a risk assessment, water resource impact prediction etc. as stipulated in the DWA Best Practice Guidelines. The implementation of the mine closure plan, and the application for the closure certificate can be conducted during the decommissioned phase;
- A closure water management plan should be developed. This should assess the managed of decant via channelled decant or the management of a critical water level to minimise contamination of the shallow weathered aquifer. The co disposal facility should also be assessed in terms of a remediation action plan should the risk for contaminating on the stream be high. This should all be analysed in a financial model to further inform the most effective closure water management options. The groundwater model should be used as a management tool to inform this process;
- The numerical model should be updated once every three years or after significant changes in mine schedules or plans by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario. Updates to the model should be carried out more frequently if significant changes are made to the mine schedule or plan.
- It is recommended that the geochemical assessment is updated during the life of the mine in order to calibrate and validate its results and to construct an effective closure plan.
- All monitoring boreholes which are to be mined out or are not operational should be grouted and sealed to prevent cross contamination of aquifers;
- If it can be proven that the mining operation is indeed affecting the quantity of groundwater available to certain users, compensation of affected parties should be considered. This may be done through the installation of additional boreholes for water supply purposes, or providing an alternative water supply;
- Should it be proven that the mining activities impact on any boreholes or springs an alternative water supply will need to be provided.

8.1.1.2 Site Water Management

- A proper storm water management should be implemented and maintained. Berms should also be implemented to ensure separation of clean water and dirty water areas;
- During the operational phase the mine water should be used or pumped to dirty water dams or pollution control facilities in order to avoid deterioration of the mine water. The longer the mine water resides in the pit the higher it's TDS will be. It is not foreseen that mine water in contact with the pit material will acidify during the operational phase of the proposed mining but will depend on operational water management;
- Poor quality runoff from dirty areas should be contained and diverted to the pollution control dams for re-use;
- The footprint of dirty water areas like the pollution control dams, water return dam and coal stockpiles, workshops and oil and diesel storage areas should be minimised;

8.1.1.3 Mining Areas

- As much as possible coal must be removed from the opencast/underground mine during the operational phase;
- Keeping the workings dry is necessary for mining and mitigation is not possible. Monitoring boreholes for long term groundwater level monitoring should be maintained over the life of mine to compare measured groundwater levels to calculated impacts;
- Runoff into the opencast pits should be diverted away from the pits as much as possible;
- Fracturing of the overlying strata due to blasting or surface subsidence should be avoided so as to prevent increased infiltration of surface water into the mine workings;
- If a risk of impact on the surface water bodies is established, a remediation action plan should be developed to negate the potential impact.

8.1.1.4 Co-disposal Facility and Other Infrastructure

- Clean water needs to be diverted away from the co-disposal facility as much as possible to reduce seepage to groundwater. Groundwater quality monitoring is proposed;
- Sewage effluent emanating from latrines or ablution blocks, if any, should be treated to acceptable levels before discharge into the environment.

8.1.2 Groundwater Management Plan: Actions Post-Closure Phase

8.1.2.1 General

- Implement as many closure measures during the operational phase, while conducting appropriate monitoring programmes to demonstrate actual performance of the various management actions during the life of mine;
- The closure water management measures should be implemented which may include a decant management system and water treatment plant.

- All old exploration boreholes must be sealed off after closure;
- The drilling of boreholes into mining areas is recommended so that recovery of water can be monitored.
- Multiple-level monitoring boreholes should be constructed to monitor base-flow quality within sensitive zones;
- The results of the monitoring programme should be used to confirm/validate the predicted impacts on groundwater availability and quality after closure;
- Quarterly groundwater sampling should be done to establish a database of plume movement trends, to aid eventual mine closure.
- The monitoring network should be audited annually;
- The existing predictive tools should be updated to verify long-term impacts on groundwater, if required;
- Surface water monitoring of the tributaries will be essential;
- The feasibility and effectiveness of the following measures (Hodgson et al. 2007) at Dorstfontein could be investigated:
  - Select the mining method based on environmental considerations (deep bord-and-pillar mining generates the smallest water volumes, opencast mining the highest);
  - Mine from deep to shallow;
  - Flood the mine workings as soon as possible; and
  - Flush the mines after flooding.

8.1.2.2 *Mining Areas*

- All mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining pyrite;
- During backfill of the opencasts carbonaceous rocks (especially shale) and discard (in the scenario with discard backfill) should be placed in the deepest part of the pit (as far as practical possible) and below the long-term pit water level in order to ensure that it is flooded and that pyrite oxidation is minimized;
- Soft overburden and weathered rock must be placed at the top of the backfill in order to minimize oxygen diffusion into the pit;
- The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas;
- An evapotranspiration cover should be constructed on top of the opencasts. A capillary break should also be constructed between the overburden/clay and top soil. Root depth of grass is usually 0.4 to 0.6 m, therefore the thickness of the top soil should be sufficient to promote root development;

- The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts;
- Intercepting decant by a downstream trench at each decant point is an option to investigate for the Dorstfontein East site;
- Treating of decanting mine water to acceptable water quality levels can be achieved by the installation of a treatment plant. Investigations must continue to establish the most effective way to treat water on site if needed at the end of LoM. The installation of an RO plant should be seen as a last option.
- The level to which the decant water is treated depends on the use of the water after treatment, but should be determined in consultation with the DWA;
- If a risk of impact on the surface water bodies is established, a remediation action plan should be developed to negate the potential impact.

8.1.2.3 Co-Disposal Facility and Other Infrastructures

- Rehabilitation of the co-disposal facility should be undertaken to limit the infiltration of rain water into the facility;
- Rainwater and runoff should be diverted away from the co-disposal facility as much as possible;
- The use of an engineered soil cover should be investigated and implemented if feasible to reduce the infiltration rate of rainwater falling on the facility
- Mitigation measures should be maintained until such a time as seepage water from the co-disposal facility conforms to the relevant standards for aquatic ecosystems.
- The Pollution control dams could be used to intercept polluted seepage water. This should be considered if it is found that streams are indeed negatively affected by pollution.

8.2 Acid Mine Drainage Strategy

Acid Mine Drainage (AMD) also known as acid rock drainage (ARD) is a well-defined process where sulphide minerals (mainly pyrite) are oxidized to produce acidic leachate. This reaction is a two-step process where the first reaction results in sulphuric acid and ferrous sulphate, then with further oxidation ferric hydroxide and more sulphuric acid is formed. Pyrite is a common minor constituent in many mineral deposits, such as coal. In the natural environment this reaction takes place at a very slow rate and as a result naturalization almost always removes the acidity. Mining activities disturb the in-situ rocks and expose pyrite, which accelerates the oxidation reaction.

Where the potential for AMD exists, provisions for prevention of AMD formation is essential and should start in the planning stages of each project. With increased geochemical information and knowledge, the AMD treatment plan process can be integrated into the operational plan which will enhance the closure processes (Figure 9-1). The information will also inform the decision-making process on how to manage the pit closure and mine void management.

The AMD treatment plan will further assist engineering consultants in the final design of mining areas, including pit rehabilitation, the topography surrounding the co-disposal facility, water management plans and the treatment of water.

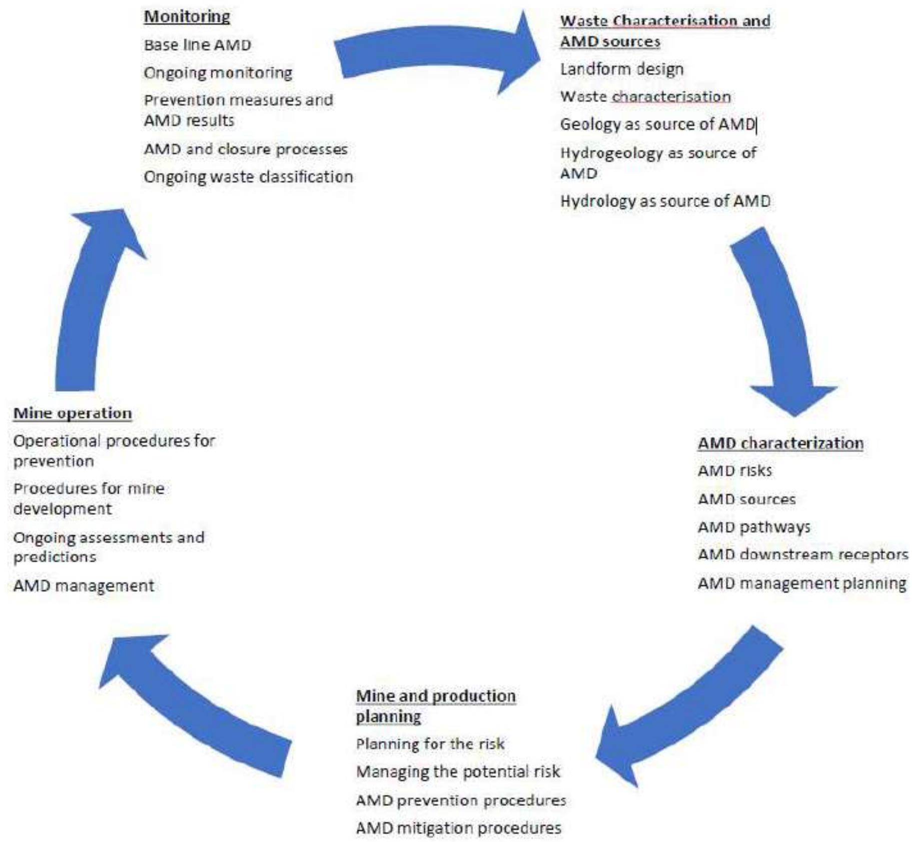


Figure 9-1: Risk-Based AMD Approach (Source: GCS, 2019).

The AMD treatment plan consists of the following management actions:

- Source characterisation: identify all geological units that are/will be disturbed during mining, and determine which of these units are potential acid forming. This is done based on ongoing geochemical assessments;
- Development of a AMD conceptual model. This model will describe the following:
  - Sources – as above;
  - Pathways – what is the most likely pathway for contaminants to migrate off-site and reach potential receptors (surface or groundwater); and
  - Receptors – identify all potential current and future receptors that could be impacted by AMD, during operations but also post-closure.
- AMD prevention: to determine what can be done to prevent AMD from forming. This includes minimisation of contact of acid forming materials with air and/or water;
- AMD reduction: where AMD has already taken place or is expected to take place, and where this cannot be prevented from occurring, the formation should be as minimal as possible;

- AMD control: if AMD is formed, the AMD water should be diverted in such a way that it can be capture in a centralized place to prevent flowing along pathways as described above and reach potential receptors;
- AMD treatment: if the collected or captured AMD water is of such a nature that it cannot be released into the environment, treatment of the water will be required to prevent contamination of groundwater, surface water, water users or ecosystems.

8.2.1 Source Characterisation

8.2.1.1 Geochemical Test Work

Various geochemical assessments and waste characterisations have been carried out for Dorstfontein in 2014, 2016 and 2020 and these have given an outline of the materials that are most acid forming. However, it is important to update these assessments with additional samples from different lithologies from new mining areas, and to re-assess the boundary conditions of the geochemical modelling based on changes in mining and/or closure plans. It is recommended to carry out additional geochemical testing annually or as new sampling material becomes available.

Geochemical test work to predict AMD consists of the following:

- Static testing, such as Acid Base Accounting (ABA). Static test gives an indication of the overall potential that a rock sample will generate acidic leachate. It determines the balance of acid generating and acid neutralizing capacity of a sample. This is a relatively low-cost procedure which can be done in a matter of hours to a few days.
- Kinetic testing, such as humidity cell tests attempt to predict the quality of the leachate over time. Rocks / samples with a net acid generating potential will be subjected to kinetic test. Kinetic test is defined as a group of test work procedure wherein acid generation and metal mobilization from a sample is measured over time. These procedures could take up to 26 weeks to complete.
- Field trails are set up as large-scale column leach tests on-site - under actual field conditions. Laboratory tests need to be converted to field conditions and the best way of “calibrating” the lab results are using these field trails.

As part of the AMD treatment plan for DCME the following geochemical assessment will be continuously updated throughout the operational phase:

- Sample selection. A sample plan should be developed to get information of the disturbed geological units (geochemical analyses) as well as the surface and groundwater quality. The sample plan will determine which materials and locations needs to be sampled;
- Review of the geological units that are disturbed during mining. The geological database will be used to develop conceptual geochemical units of all the disturbed lithologies; determinations of the vilumes of each lithology will be made based on the available information;

- Each geostratigraphical unit will be sampled and submitted for static test work;
- All geostratigraphical units that are potentially acid forming will be submitted for kinetic test work;
- Field trials, such as barrel leach tests, with potentially acid forming lithologies will be set up at the mine;
- Review all (surface and groundwater) hydrochemical data with reference to acidic leachate; and
- Once test results are available, a geochemical assessment report will be produced which will include proposals for the handling and disposal of the potentially acidic materials. This report will inform the closure scenario selections for the various mining voids, and will serve as input into the groundwter model update.

8.2.1.2 Groundwater Contaminant Modelling

Hydrogeological conceptual and numerical modelling is required to determine the risk of contamination of water sources from AMD sources as characterised based on the geochemical assessments. Groundwater flow modelling uses the outcomes of the geochemical test results and modelling to predict the range of possible outcomes for the backfilled open pits and flooded underground voids.

The outcomes of the model will guide further technical studies and site-specific closure plans. Groundwater flow models provide predictions for water level recovery rates and equilibrium levels for the mining areas at closure. The outputs from the modelling guides the AMD treatment plan and informs the environmental impact assessment using the source, pathway, receptor approach.

The numerical groundwater model will be kept up-to-date depending on changes in mine schedules, mine layout, changing mining methods, updated closure plans and backfill designs, geochemical data and characteristics of backfill and capping materials (permeabilities, compaction rates, porosities etc.) that will be used once mining ceases. This will increase the predictions of decant volumes and qualities for the post-closure phase.

8.2.2 AMD Prevention

The most effective and economical method of controlling AMD is to prevent its formation. Once established, acid drainage is often difficult and costly to treat. Because most metal ions are increasingly soluble with decreasing pH, AMD frequently results in elevated heavy metal concentrations. Management by prevention requires characterisation of overburden or waste material and knowledge of the hydrology of the site so that the likely occurrence of acid drainage can be predicted and potentially acid-producing material selectively handled and isolated. Where the potential for AMD exists, provisions for prevention of AMD formation is essential and should start in the planning stages of each project.

Oxygen and water are required for acid formation and prevention methods aim to exclude either reactant from the pyritic material. This involves controlled placement of acid forming materials and appropriate water management strategies. Prevention is dependent on identifying the pyritic material before mining in order to:

- Adopt mining procedures that can selectively handle acid forming materials for placement within mine waste facilities, such as the co-disposal facility. If calcareous strata or other alkaline material, which can neutralise and acidity generated, are available, mining methods and dump construction should enable blending of material within mine waste facilities;
- Control the hydrology of the site to prevent water from contacting pyritic material by diverting surface water away from pyritic material (such as ROM pads, waste rock dumps, etc.) and preventing ponding and subsequent infiltration;
- In case of backfilling of materials onto mined out areas, the acid-forming materials should be submerged. This can be an effective strategy where enough water is available. It has been suggested that a water cover enough to maintain the partial pressure of oxygen below 1% is necessary to inhibit pyrite oxidation; and
- Isolate the pyritic material (whether in a waste rock dump or co-dispocal facility) from water by placing it above the water table and capping with clay or other impermeable materials. The cap can then be covered with soil and vegetation established. This technique reduces infiltration and leaching. Waste rock dumps are unlikely to have an impermeable or semi-impermeable base or sides. The task of reshaping and encapsulation is consequently greater and costlier.

8.2.3 AMD Reduction

8.2.3.1 Closure Landform Designs And Final Topography

Landform re-design is required to include, place and move all new overburden spoils to create a final topography that coincides with the surface drainage areas of the site. The best result of a final topography can be achieved when the landform is designed during the early stages of the operation. Key elements of a successful landform design include:

- the comprehensive characterisation of the properties of soils, overburden and mineral processing wastes to determine their
  - potential erodibility;
  - capacity to support plant growth; and
  - potential to have adverse impacts on water quality (AMD formation);
- the segregation and selective placement of those materials to ensure the creation of a favourable medium for plant growth and the protection of water resources;
- Quantifying the LoM material balance and developing the post mining landform design with the available backfill volumes; and
- Aligning the post mining landform with the site wide surface drainage framework and informing the design with dedicated hydrological and erosion modelling.

Some of the key aspects that require management throughout the mine operation include:

- A final landform design should be developed during the operational phase. The final landform design will benefit the mine as it would influence numerous aspects including the placement of coal discard and slurry materials, waste rock, topsoil and final water management requirements;
- Regularly update the post mining landform design for the open cast pit to replace estimated bulking and compaction values with accurate survey data;
- Backfilled opencasts and waste rock dumps landscaped as raised topographical features will require larger drainage features than existed in the pre-mining setting;
- Long steep slopes and sharp angles typically associated with constructed mine waste facilities should be avoided. Reduced slopes (less than 1:3) constructed to geomorphic principles, covered with suitable growth medium and well vegetated require less maintenance and are more resistant to erosion;
- Where stable slope profiles are not achievable, additional stormwater management measures (contour drains, chutes or benches) should be designed to reduce the velocity of run-off. The engineered solutions should be informed by dedicated storm water and erosion modelling;
- The volume and velocity of the runoff water must be controlled prior to entering the watercourses in surrounding areas. An increase in runoff could result in erosion and increased sedimentation in downstream areas of the catchment;
- Side slopes of rehabilitated areas are to be covered by clay/subsoils/topsoil sourced from the stockpiles which were created during the clearing of specific areas. The cover configuration and functionality should be designed to meet specific closure objectives and agreed to with the relevant authorities (refer to relevant documents and best practice guidelines from the DWAF/DWE/DWS and ICCM);
- The Post-mining landform design must align with the site wide drainage framework and the surrounding macro-topography;
- Each deposit on the mine site requires a specific management plan to ensure that volumes, angles, drainage lines and waterways, are incorporated into the operational site wide surface water manament plan;
- A change management procedure is required to reconsider and amend the post mining landform when the mine plan changes;
- An integrated approach is required to ensure that all aspects of the rehabilitation process is considered during the changes on the mine; and
- Develop a post mining landform design informed by the end land use objectives, providing design elevations to manage backfilling operations;
- Concurrent rehabilitation of waste facility side slopes to reduce infiltration into the waste body and deliver clear surface water runoff back into the catchment;

- Concurrent rehabilitation of the opencasts as an integrated part of the mining activities, including:
  - Backfilling as mining progresses and preferential handling of material to ensure reactive overburden is placed in the deepest portion of the pit;
  - Backfilling in layers rather than end tipping to provide a level of compaction by the traversing equipment;
  - Placement of softs over hard overburden, combined with the above points will reduce oxygen ingress;
  - Replacement of topsoil stripped ahead of mining and vegetation establishment to reduce recharge, limit erosion and deliver clean surface water runoff back into the catchment; and
  - Implementing topsoil management throughout the life of the operation to limit damage to the physical properties and combat compaction. Compaction can lead to poor quality rehabilitation and increased recharge through the development of preferential pathways.

8.2.4 AMD Control

The final site topography and drainage designs will be important to channel AMD waters to a centralised location after which, if required, optimal treatment options need to be considered prior to release into the environment. These designs and options should be focussed on during the operational phase to ensure quality of any potential discharges of waters during operation and for post-closure.

8.2.4.1 Surface Water Management

The design of the site's surface water management should include consideration of AMD requirements. The management of surface water should include options for:

- Managing AMD waters with store and release cover systems;
- Designing of slopes to drain surface water runoff to surrounding water networks; and
- During operation, direct discharges to drainage lines should be avoided where possible by re-directing flows towards PCDs, backfilled mine pits or pit lakes.

Considerations include the fate of the captured water, the potential for surface water recharge to the groundwater system and stability of the impacted landforms to changes in surface water flows.

The selection and design of these alternatives will need to be made over the life of mine with consideration of materials, geochemistry, environmental guideline values and hydrology, and the water management plan should be updated in case any changes to the management system are made or when new information becomes available.

8.2.4.2 Groundwater Management

Groundwater or decant that may emanate from minign areas should also be controlled during the operational and post-closure phases. During the operational phase, the following actions should be adhered to:

- All discard material and coal slurry should be placed only at the co-disposal facility;
- Any pollution control dams and/or ROM coal stockpile areas should be lined, thereby preventing contamination of the underlying aquifers; and
- To ensure a cone of drawdown is maintained towards the mining areas, groundwater abstraction should continue for the LoM, and groundwater quality in the area surrounding the mining areas should continue throughout the LoM. Groundwater levels surrounding the pits should be monitored on a regular basis throughout the LoM to verify the extent of the cone.

For the post-closure phase, the following actions are required:

- The dewatering of the pits should cease as soon as possible after mining activities are completed to allow for groundwater level recovery;
- Clean water and runoff should where possible be directed towards the rehabilitated pits immediately after mining has stopped to allow for faster recovery of pit water levels, to reduce the interaction of potentially acid forming materials with oxygen;
- To minimise contaminant plume migration, the open pits should be properly rehabilitated, including reduction of recharge to these areas by properly top-soiling and vegetating the areas. This will reduce infiltration of water into the groundwater and reduce plume extents;
- After completion of the pit rehabilitation surface water runoff should be diverted away from the pits to reduce pit water inflows that may contribute to long-term decant volumes;
- If AMD contaminated waters are migrating away from Pit 1 or Pit 2, groundwater may need to be captured or actively lowered in Pit 1 and 2 to prevent contaminant plumes to move away from the pits;
- Inter-connections between the mining areas at DCME should be sealed, especially between the underground mine voids and the opencast pits, to prevent additional decant volumes to emanate from the backfilled pits through flooded underground voids. This should focus on the primary pathways between opencast and underground, but also focus on compartmentalising of the underground voids to prevent flow of AMD water from one void to another, and therefore reducing the flows that will report to the backfilled opencasts; and
- Groundwater level recovery in the rehabilitated open pits should be frequently monitored to create stage curves and predict the final water recovery level.

- Rehabilitation of the pits and co-disposal facility to reduce infiltration of rainwater into the dump to reduce seepage generation.
- Installation of groundwater abstraction boreholes at decant points to reduce water level and prevent decant flow, and treatment of the abstracted water.
- Decant capture and treatment will be required to prevent deterioration of the post-closure water quality emanating from Pit 1 and Pit 2.

8.2.5 AMD Treatment

Treatment procedures for dealing with acid leachates will vary according to site conditions. An optimization study based on the AMD treatment plan will be done to determine what are the most suitable options for DCME. Treatment methods previously adopted include the following:

- Incorporation or mixing in of lime or other neutralising materials onto the surface of the co-disposal facility where discard is deposited. The neutralising capacity of the available materials and the “lime demand” of the discard materiasl should be tested to determine feasibility;
- Channelling run-off from the co-disposal facility to selected recharge areas i.e. ponds or ditches filled with alkaline material or areas of the facility where selected materials with high neutralising capacity have been placed;
- Injection of neutralising fluids e.g. sodium carbonate, anhydrous ammonia or caustic soda into the facility to intercept flow paths of acid drainage;
- Collection of acid drainage downstream of the facility and/or decant points for active chemical treatment or inline aeration;
- Directing acid drainage to artificial wetlands where biological production of bicarbonate neutralises the acidic drainage. Metals are removed through hydrolysis and biological formation of insoluble sulphides and carbonates; and
- In areas where evaporation consistently exceeds precipitation, disposal by evaporation may be feasible. Safe disposal of sludge with elevated levels of heavy metals and salts is then required.

8.3 Groundwater Monitoring Plan

The groundwater monitoring network design should comply with the risk-based source-pathway-receptor principle. A groundwater-monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. Both the impact on water quality and water quantity should be catered for in the monitoring system. The boreholes in the network should cover the following: contaminant sources, receptors and potential contaminant plumes. Furthermore, monitoring of the background water quality and levels is also required.Groundwater monitoring will be undertaken to establish the following:

- The impact of mine dewatering on the surrounding aquifers. This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme;
- Groundwater inflow into the mine workings. This will be achieved through monitoring of groundwater levels in the monitoring boreholes as well as measuring water volumes pumped from mining areas;
- Groundwater quality trends. This will be achieved through sampling of the groundwater in the boreholes at the prescribed frequency; and
- The rate of groundwater recovery and the potential for decant after mining ceases. This can be achieved through measuring groundwater levels in the underground mine workings. Stage curves will be drawn to assess the inflow into defunct workings.

It is proposed that groundwater monitoring be undertaken according to the schedule presented in Table 8-1 for the points shown in .

Table 8-1: Groundwater Monitoring Programme

Monitoring position	Sampling interval	Water Quality Standards
Construction, Operational, Decommissioning and Post Closure Phases		
All monitoring boreholes	Quarterly: measuring the depth of groundwater levels	N/a
All monitoring boreholes	Quarterly: sampling for water quality analysis	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	N/a

Laboratory analysis techniques will comply with SANS guidelines. The mine will develop a groundwater monitoring database that will be updated on a monthly or quarterly basis as information becomes available. The database will be used to analyse the information and evaluate trends noted.

An annual compliance report will be compiled and submitted to the authorities for evaluation and comment. The mine will develop a monitoring response protocol after the completion of the Construction Phase of the project. This protocol will describe procedures in the event that groundwater monitoring information indicates that action is required.

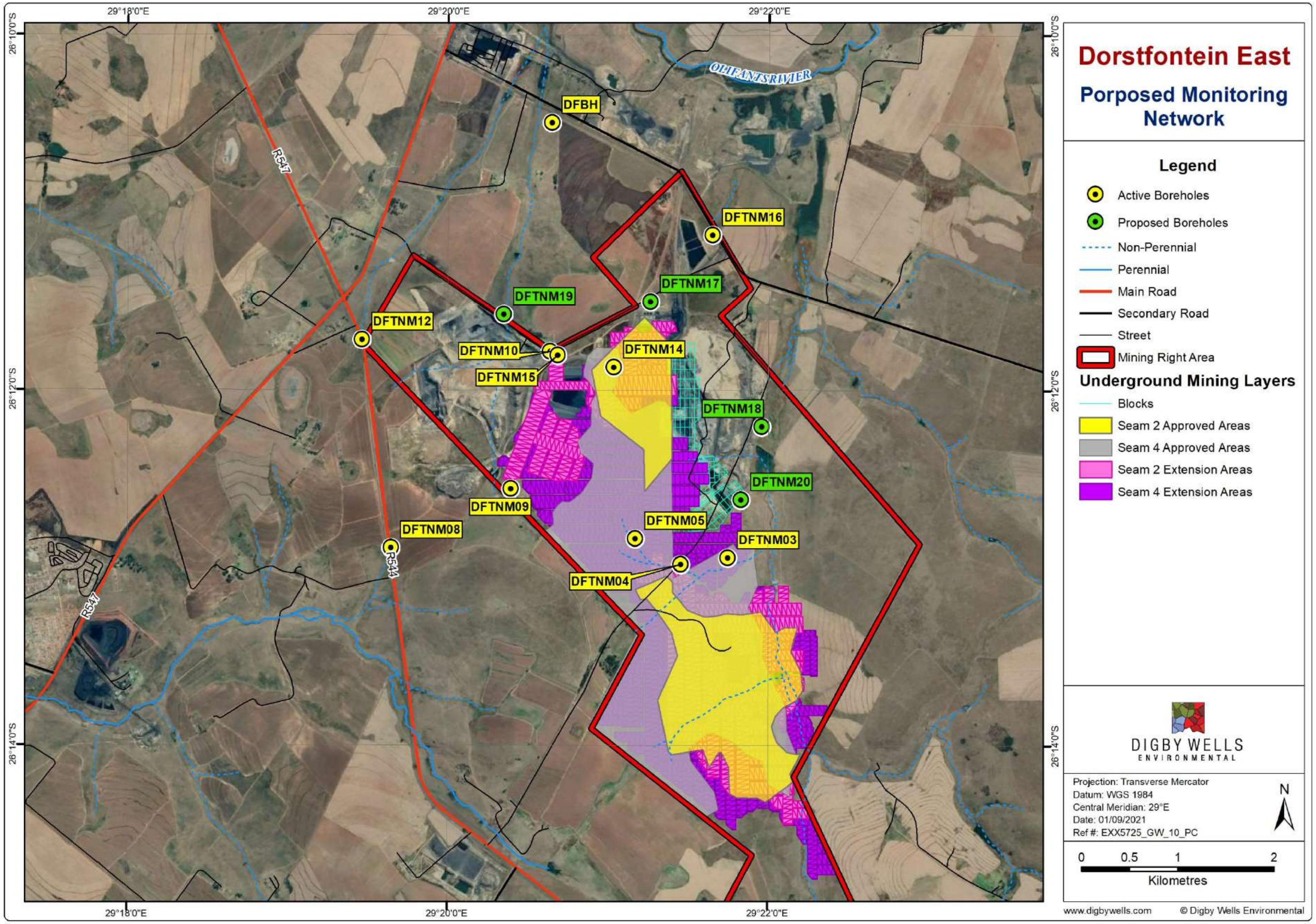


Figure 9-1. Proposed Groundwater Monitoring Network

9 Gaps in Knowledge and Limitations

The following limitations and gaps were identified:

- A model is a simplified representation of reality. This is also the case for numerical groundwater models. Numerical models assume uniform flow within the different aquifer units assigned to the model. In real-life there may be fractured or faulted zones within those units that could enhance groundwater flows. However, the calculated groundwater inflows and drawdowns are considered realistic.
- Porosity values for the aquifers were not available but were chosen based on experience in similar geological settings and values are deemed representative for Karoo strata;
- No in-field verification of dispersion was available for this study. However, representative, generic values for dispersion and parameters have been used as input into the numerical model.
- The model calibration was based on available groundwater levels taken in on-site monitoring and aquifer test holes and accessible third-party boreholes;
- Contaminant plume calculations were based on results of previous geochemical testing and modelling and a limited amount of discard and slurry samples analysed as part of this study for verification. Additional samples of discard and any lithologies to be backfilled into the pits would be recommended to verify the current results and increase the accuracy of the potential seepage concentrations from coal materials.

10 Conclusions and Recommendations

10.1 Conclusions

The following conclusions were made for the site:

- The MAP of region surrounding the site is ~675 mm;
- The topographical elevation of the project area varies from 1515 meters above mean sea level (mamsl) and 1660 mamsl characterised with gentle slopes and low-lying areas;
- The high lying Klein Vaalkop forms the water divide between B11B quaternary catchment in the north-east and B11D in the south-west region. Two western Olifants tributaries run across the western limb and one eastern tributary runs accross the eastern limb of the DCME coal reserves. The confluence of the three tributaries is located on the farm Vlaklaagte 45 IS, just north of the mining concession area;
- The dominant lithologies present in the area are coal-bearing sandstone, mudstone, siltstone, shale and coal seams of the *Vryheid Formation* with dolerite sill type intrusions of the Karoo dolerite Suite. Pre-Karoo lithologies were also identified on-site;
- Based on the mineralogy and AMD results all coal and waste rock materials are classed as NAF or acid generation is uncertain due to high neutralising minerals. However, the dynamic leach test show acidic conditions do form in the discard and /slurry materials with elevated sulphate concentrations noted. This indicates that AMD conditions can develop and are likely to develop in the long-term due to depletion of the neutralising minerals. This is in line with the geochemical assessment as done by GCS, 2016;
- Three principal aquifers are identified for the site: the weathered Karoo aquifer; the fractured Karoo aquifer; and the fractured pre-Karoo aquifer. The aquifers that occur in the area can therefore be classified as minor aquifers (low yielding), but of high importance and are understood to have a low to medium development potential, mostly used for small scale domestic purposes or occasionally for large scale irrigation;
- The shallow aquifer depth at the site ranges varies between 5 and 12 mbgl. In terms of pollution risk and / or susceptibility to pollution, the shallow primary aquifer is understood to be highly susceptible to pollution;
- The main source of water supply in and around the proposed mining area is groundwater which is abstracted using submersible pumps, community handpumps and a windmill. Water is mainly used for domestic use and livestock watering, but also for cut flower and cherry production;
- Pre-mining groundwater levels show that the groundwater levels within the area vary between 2.5 mbgl and 20 mbgl, indicating groundwater levels are relatively shallow and mainly located within the weathered aquifer. Groundwater flow directions generally follow topography and drainage directions;

- The predominant groundwater types found were Mg-HCO_3, Ca-HCO_3 and Na-SO_4. The groundwater is generally of good quality with only a few exceedances over the WUL limits for sodium, manganese and aluminium;
- The potential cone of drawdown during the operational phase is largest at the end of life of mine and extends to a maximum radius of ~600 m around the open pits and ~1 200 m for the underground mining areas;
- Historical groundwater inflows into the opencasts fluctuate between ~1 000 m^3/d and ~1 500 m^3/d mainly due to increase in pit size since mining started. Between 2020 and 2027 inflows increase to ~2 100 m^3/d due to the expansion of the underground extension at Pit 1 and mining of the 2-seam and 4-seam underground mining blocks. After 2027 groundwater inflows gradually decrease to about 1 200 m^3/d;
- Based on the simulations no third-party sources are present within the zone of influence. Impacts on wetlands are likely to be low due to most of the expansion being underground mines, and surface runoff to these wetlands will not be impacted upon;
- Base flow to tributqaries at the site may reduce during mining, and flows in the tributaries should be monitored;
- During the operational phase groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area;
- The drawdown impacts as a consequence of the proposed mining is expected to result in a minor impact due to the scale and it is unlikely there will be an impact on third party abstraction sources;
- During steady state production the groundwater inflows will likely be in the range of ~1 500-2 000 m^3/d. Most of these abstraction volumes will be drawn from the pit areas and as such the impact on groundwater availability will be minor;
- Groundwater levels in the vicinity of the site are expected to take approximately 20 years to recover post-closure. It is expected that the long-term recovery will have a minor impact. It is unlikely that any privately-owned boreholes located in the vicinity of the proposed development will be impacted upon. The contaminant migration indicates that the plumes will flow towards and following local drainage lines located between and to the west and the east of the open pits;
- The contaminant migration calculations indicate that the plumes will mainly flow towards and follow local drainage lines, such as the two tributaries of the Olifants River located to the north and the east of the opencasts (Figure 7-4). These are expected to receive an increased salt load due to the contaminant plume migration. Expected post-closure sulphate concentrations in groundwater close to the western tributary (north of Pit 1) may go up to 2 800 mg/l, while concentrations close to the eastern tributary (east of Pit 2) may go up to 1 500 mg/l. This is expected to have a high impact on the streams and associated wetlands.

- Based on the contaminant transport simulations no third party boreholes are projected to be within the zone of contamination and it is therefore unlikely that any of these boreholes will be impacted.
- Decant from Pit 1 will flow towards the western tributary of the Olifants River; the decant from Pit 2 will flow towards the eastern tributary of the Olifants River. The calculated volumes and quality of the potential decant indicate a high impact on the water quality of the tributaries of the Olifants River, and subsequently the Olifants River itself, if not mitigated.
- Decant could also potentially impact on the hillslope seep and channeled valley bottom wetland associated with the western tributary, and the channeled valley bottom wetland areas associated with the eastern tributary.
- Mitigation should focus on the post-closure contaminant plumes and decant flows. Te proposed mitigations in this report should reduce all impacts to minor or negligeble and include:
  - Mining should progress as swiftly as possible to reduce the period of active dewatering and the mining area extent should be kept to a minimum. Dewatering of the mining areas should stop should as soon as the mining activities cease;
  - Groundwater levels surrounding the mining areas should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown;
  - Groundwater abstraction should continue for the LoM to maintain a cone of drawdown, and dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as possible;
  - Groundwater levels surrounding the mining areas should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown;
  - Dispose of coal discard slurry at the co-disposal facility only;
  - Pollution control dams and/or ROM coal stockpile areas should be lined, and clean water needs to be diverted away from these infrastructures;
  - Dewatering should cease as soon as possible after mining activities are completed to allow for groundwater level recovery;
  - Groundwater level recovery should be frequently monitored to identify deviations from the predicted recovery rate;
  - Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate. If a contaminant plume is detected from Pit 1 or Pit 2, groundwater may need to be abstracted and treated before release into the environment;
  - Clean water and runoff should where possible be directed towards the open pits to flood these areas as fast as possible;

- Rehabilitation of the pits and co-disposal facility to reduce infiltration of rainwater into the dump to reduce seepage generation;
- The post-closure sealing of inter-connections between the mining areas at DCME, especially between the underground mine voids and the opencast pits;
- Installation of groundwater abstraction boreholes at decant points, or formation of a pit lake, to reduce water level and prevent decant flow, and treatment of the abstracted water;
- Groundwater level recovery in the rehabilitated open pits should be frequently monitored to create stage curves and predict the final water recovery level.

- Considering the extent of expected impacts on the groundwater environment, and taking into account the mitigations as recommended in this report, the proposed activities can be authorised.

10.2 Recommendations

The following recommendations are made, and should be included in the Environmental Management Plan report and EA:

- The development of a closure water management plan that assesses the management of a critical water level to minimise contamination of the shallow weathered aquifer. This must be analysed in a financial model to further inform the most effective closure water management options. The groundwater model must be used as a management tool to inform this process;
- Adhere to the mining footprint and avoid unnecessary impacts to areas not currently identified in the layout, progress the mining activities as quickly as possible, and cease dewatering activities as soon as possible after mining has been completed;
- Proper rehabilitation of the open pits, including the installation of a proper cover that reduces recharge to these areas including a proper top-soil layer and vegetation;
- Monitoring of groundwater abstraction volumes during operation and the rate of water level recovery in the backfilled open pits and the development of stage curves which will aid in water management during the Post-Closure Phase;
- Update of the groundwater and surface water monitoring network, with frequent surface and groundwater quality monitoring for the operational phase, to continue into the post-closure phase, to be able to discern trends in surface water quality;
- Updating of the geochemical assessment with additional samples from new mining areas and geochemical model update to asses expected long-term AMD formation;
- Updating of the numerical model once every two years or after significant changes in mine schedules or closure plans, by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario;
- Options to prevent decant flow from the pits, such as pump and treat, or a pit lake, must be considered, and alternatives should compared and included in a closure plan.

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Appendix A: Specialist CVs

KGAUGELO THOBEJANE

Ms Kgaugelo Thobejane

Environmental Geochemistry Interns

Water Geosciences

Digby Wells Environmental

1 Education

- MSc in Geochemistry, University of KwaZulu-Natal, South Africa, still on-going
- BSC Honours in Mining Geology, University of Limpopo, South Africa, 2016
- BSc major in Geology and Chemistry, University of Limpopo, South Africa, 2015

2 Language Skills

Language	Speaking	Reading	Writing
Sepedi	Mother tongue	Good	Good
English	Good	Good	Good
IsiZulu	Good	Fair	Fair
Sesotho	Good	Good	Good

3 Employment

- **Assistant Geochemist**, Digby Wells and Associates, Johannesburg, South Africa (August 2019 to current)
- **Intern Geochemist**, Digby Wells and Associates, Johannesburg, South Africa (March 2019 to July 2019t)
- **Intern,** MGiBA Consulting, Polokwane, South Africa (December 2017-January 2018)
- **XRD Technician**, Geology Division, University of Limpopo, South Africa (January 2017- April 2017)

4 Experience

Kgaugelo just recently joined Digby Wells as an assistant environmental geochemist. She has a year of experience but has been exposed to a variety of fields of studies (hydrogeology, hydrology, public participation). She has recently undertaken a trip to Tanzania to perform a hydrocensus study

5 Project Experience

Geochemistry Projects:

- **Dagsoom Coal Mine (South Africa)** Greenfield Geochemical Assessment and Waste Classification for coal and waste rock
- **Mbuyelo Group (South Africa)** Greenfield Geochemical Assessment and Waste Classification for coal and waste rock
- **Kibali Gold Mine (DRC)** Geochemical Assessment and Waste Classification waste rock and tailings
- **Syama Gold Mine (Mali)** Waste Tailings Classification of copper tailings
- **Palesa Coal Mine (South Africa)** Waste Classification slurry tailings and waste rock
- **Kodal Minerals (Mali)** - Lithium Project Preliminary Waste Rock Geochemistry

Hydrogeology Projects:

- **Dagsoom Coal Mine (South Africa)** percussion drilling supervision
- **Mbuyelo Coal Mine (South Africa)** percussion drilling supervision
- **North Mara Gold Mine (Tanzania)** Hydrocensus
- **Mbali Coal Mine (South Africa)** Water Monitoring Analyses and Reporting
- **Palesa (South Africa)** Water Monitoring Analyses and Reporting
- **Universal Coal (South Africa)** Sampling, Water Monitoring Analyses and Reporting

Public Participation

- Placing of site notices for **IvanPlats** Mine in Mokopane, South Africa
- Placing site notices for **Mbuyelo** Coal Mine in Belfast, Mpumalanga

6 Professional Affiliations

Candidate Natural Scientist with the South African Council for Natural Scientific Professions – Registration Number: 120881/19

Arjan van ‘t Zelfde

Manager: Hydrogeology

Water & Geosciences Department

Digby Wells Environmental

1 Education

- 2003: MSc degree in Soil science (SAQA approved) as part of the BSc/MSc programme Soil, Water and Atmosphere, Wageningen University, The Netherlands. Primary thesis in soil chemistry; secondary thesis in hydrogeology.

2 Language Skills

- Dutch (mother tongue), English (excellent), Afrikaans (good working knowledge), German (good working knowledge), French (reasonable working knowledge)

3 Employment

- April 2019 – current: Digby Wells Environmental, Johannesburg, South Africa
- September 2014 – April 2019: GCS Water & Environmental, Johannesburg, South Africa
- March 2009 – July 2014: Royal HaskoningDHV, Amersfoort, The Netherlands
- O’Neill Groundwater Engineering, Naas, Ireland (January 2004 – December 2008)

4 Experience

Arjan is a Senior Hydrogeologist with over 16 years’ experience in The Netherlands, Ireland, South Africa, Lesotho, Zambia, Mozambique, the DRC and Tanzania. He specialises in numerical groundwater flow modelling and is experienced in multi-species solute and heat transport modelling using the MT3D and SEAWAT modules for Modflow. He has used this software to model complex, fractured, and/or faulted geologies for both open pit and underground mining operations.

In addition, Arjan has vast experience of modelling sedimentary aquifers (including alluvial aquifers) in The Netherlands, including the modelling for major construction works such as for the construction of largest Aquaduct in Europe in a sandy aquifer. He also has experience with construction works and associated dewatering in other sedimentary environments, such as pedestrian/cycling tunnels, water supply and sewage pipelines and other construction works for which grout screens and/or sheet piling was required.

Arjan's experience includes:

- Groundwater investigations for feasibility studies and environmental impact assessments
- Groundwater management plans
- Groundwater monitoring programmes
- Soil classification and contamination assessments
- Project management, including financials and technical aspects;
- Management of junior staff
- Proposal writing
- Groundwater numerical modelling:
  - Mine dewatering
  - Construction dewatering
  - Groundwater contaminant and heat transport
  - Aquifer thermal energy storage (ATES) studies
- Risk assessments
- Hydrogeological fieldwork
- Surface water modelling

5 Project Experience

Some of the Projects Include:

- Kibali Gold – Groundwater dewatering study for the Megi pit.
- Kibali Gold – Groundwater dewatering and in-pit deposition study for the Pamao pit.
- Pan African Resources – Prism Project Due Dilligence – High Level Liability Assessment
- Kibali Gold – Groundwater investigations for the ESIA and dewatering studies for the Kalimva Ikamva pit extension
- Pilanesburg Platinum Mine – Groundwater Impacts for a Water Liability assessment
- Dagsoom Coal Mine – Groundwater Impact Assessment as part of an EIA for the Twyfelaar coal mine, Ermelo
- Mbuyelo Coal Mines – Groundwater Impact Assessment as part of an EIA for the Weltevreden coal mine, Belfast
- Musina SEZ - Soil Impact Assessment
- Harmony - Soil contamination assessment for the Paballong site

- Hydrogeological and hydrological input and groundwater modelling for a proposed TSF complex at the Mutoshi mine, Kolwezi, DRC to be designed and built.
- Feasibility Study Comide mine, Kolzwezi: Water section and complex numerical model for a multi open-pit copper cobalt mine operation in the DRC;
- Hydrogeological numerical model for the Moatize mine, Tete: complex numerical model for a multi-opencast coal mine in Mozambique;
- Impact assessment and numerical model for a Manganese mine near Hotazel, Northern Cape;
- Impact assessments and numerical modelling for numerous coal mines for Exxaro;
- Hydrogeological investigation Letseng Mine, Lesotho: Update of an existing numerical model using time series data of groundwater levels and hydrochemistry data.
- Hydrogeological investigation Styldrift mine: numerical modelling of potential groundwater inflows into a proposed expansion of an existing platinum mine near Pilanesberg.
- SAAone: the widening of a highway, including construction of Europe's largest aquaduct, between Amsterdam and Almere (A1 and A6). Hydrogeological consultant for all geohydrological aspects of this project, including construction dewatering, groundwater monitoring and WULAs.
- ATES system for a proposed data centre of the Royal Dutch Weather Institute (KNMI). Geohydrological modelling, impact assessment and permit application
- Regional groundwater monitoring network in the surroundings of Kampen, The Netherlands. Proposal request, design and quality control during installation.
- Groundwater monitoring network of the municipality of Langedijk, The Netherlands. Installation of piezometers and measuring equipment, data analysis and data management.
- Proposed quarry sites for Roadstone Provinces Ltd. and Cemex Ireland: site investigations and compilation of the EIS chapters soils, geology and hydrogeology.
- Soil and groundwater site investigations for Guinness Brewery, Dublin and Schwarz Pharma Ltd., Shannon: site inverstigations, installation of piezometers, sampling, data analysis and reporting.
- Production wells for Bulmers Ltd.: yield testing of new wells.
- Group Water Schemes for Galway County Council: supervision of drilling for new wells, yield testing of new and existing wells, catchment delineation and vulnerability assessments for the new production wells.
- Drinking water supply for Tory Island: locating, design, construction supervision and yield testing of a Ranney-type well.

6 Professional Affiliations

WISA membership no. 29935

7 Professional Registration

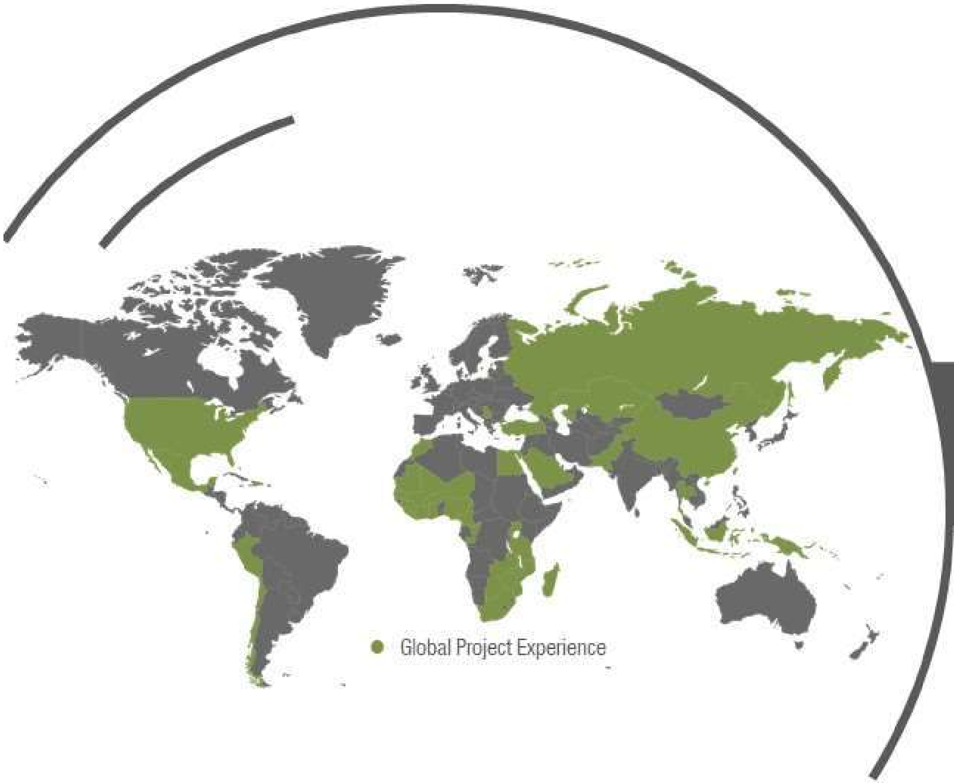
Registered Professional Natural Scientist (Pr.Sci.Nat.) with the South African Council for Natural Scientific Professions – Registration Number: 115656

8 Publications

Asten, P.J.A. van; Zelfde, J.A. van 't; Zee, S.E.A.T.M. van der; Hammecker, C.. The effect of irrigated rice cropping on the alkalinity of two alkaline rice soils in the Sahel. Geoderma 119(3-4):233-247, April 2004.

Zelfde, J.A. van 't; Bredenkamp, B.J.; Levay, E.; Marais, A.W.C.. Estimation Of Groundwater Inflow And Pore Pressure Distribution For A Coal Mine Using A Numerical Flow Model With Accurate Grid Refinement – GWD 2017 Conference, Cape Town - Conference paper

Appendix B: Waste Classsification And Geochemical Assessment



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Dorstfontein East Expansion Project- Geochemical and Waste Assessment

Geochemistry Assessment and Waste Assessment Report

Prepared for:
Exxaro Coal Central (Pty) Ltd

Project Number:
EXX6358

April 2021

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Name	Responsibility	Signature	Date
Kgaugelo Thobejane	Reporting	KThobejane	April 2021
Andre van Coller	Review		April 2021

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been requested by Exxaro Coal Central (Pty) Ltd. to conduct a geochemical and waste assessment for the Dorstfontein East Expansion Project. The aim is to determine if the materials have acid-producing potential, leachate capability and at what rate will acid generate if there is any.

The aim of the project is to update the geochemical assessment and the waste classification of the discard material with the purpose of the possible expansion of the co-disposal facility or backfilling of the opencast. The study will be compared to the previous geochemical assessment and waste classification. The geochemical assessment and waste classification will aid as an input into the numerical groundwater model for the proposed Dorstfontein expansion project. The objectives of this study were as follows:

- To assess the mineralogical composition of the discard samples;
- Determining the acid mine drainage potential that may occur over time; and
- Leachable metals that may occur from discard material into the surrounding environment over time.

A total of six discard samples were made available for testing with five samples weighing at least 1 kg and the sixth sample weighing 6 kg. The five samples were sent for static testing analyses, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Sulphur Speciation (SS%), Acid-Base Accounting (ABA), Net Acid Generation (NAG) and paste-pH analyses. The 6kg sample was sent for sub-aerial column leach testing.

The mineralogy for all the samples detected kaolinite as a dominant mineral (ranging between 46 and 71 wt. %). This is a common clay mineral formed through the breakdown of minerals like alkali-feldspar. Lizardite was also detected in trace amounts of 0.4 wt. % and this form part of the Kaolin-Serpentine group. There was also illite detected which part of a group of non-expanding clay minerals and commonly found in soils, clay-rich sedimentary rocks, and low-grade metamorphic rocks. No acid-forming minerals were detected but acid neutralising minerals like dolomite (excluding Discard 4) were detected ranging between 1 and 9 wt. %, and aragonite (calcite polymorph) only in Discard 4 and 5 at 2.1 and 2.4 wt. % respectively.

Paste-pH of all samples are neutral, Discard 1, Discard 3 and Discard 5 Sulphide-Sulphur (S^{2-}-S%) results show that they are above 0.3% at 0.32, 0.56 and 0.64% respectively. The above recommended 0.3% normally indicates acid-generation potential if the sulphide sulphur is above 0.3% (Soregaroli & Lawrence, 1998). Net Neutralising Potential (NNP) is positive indicating that there are more neutralizing minerals than acid-forming ones. The overall results indicate that Discard 1, Discard 2, Discard 3 and Discard 5 samples are Non-Acid Forming (NAF). Discard 4 demonstrates the uncertainty of whether it has the acid-forming potential or not. This is due to acid-neutralising minerals being equivalent to the acid-forming minerals and once acid neutralising minerals are depleted acid generation potential increases and the extent of this increase leads to the unclear conclusion form the available static results for this sample.

Conclusions

Geochemistry

- The most dominant mineral detected by XRD is clay mineral kaolinite the followed by quartz mineral. Other clay minerals detected included lizardite and illite in trace amounts;
- Minor minerals detected include titanium oxide anatase, spinel and magnetite;
- No acid-forming minerals were detected but acid-neutralising minerals such as dolomite and a calcite polymorph aragonite were detected. XRF indicated that P_2O_5 and Al_2O_3 are above the AUC and the TiO_2 is elevated 3 to 5 times above the AUC; and
- The mineralogy of the current study samples in comparison to the GCS report 2016, the discard materials all indicate kaolinite as dominant followed by quartz.

Acid Generation Potential

- All paste-pH of the samples are circumneutral with positive NNP. Two out of the five samples are above the 0.3% mark of S^{2-}-S% ranging between 0.32% to 0.64%. The overall results indicate that Discard 1, Discard 2, Discard 3 and Discard 5 samples have NAF potential. Discard 4 demonstrates the uncertainty of whether it is acid forming potential or not; and
- Three discard samples were analysed in the GCS report 2016 and it indicated all samples S^{2-}-S are above the 0.3% threshold with low NP. All samples were Potentially Acid Forming (PAF) while other being just short term. However, for this study all samples are NAF.

Column Leach Test

- No acidification was observed.
- Sulphate and metals such as Ca, Mg, Mn, and Ni leached at elevated levels from the column, especially Ni leaching slightly above the chronic health risk of SANS drinking water standards;
- It is however expected that the column will become acidic as soon as the available carbonates become depleted; and
- In the column leach test results from GCS report 2016, no parameters were significantly elevated while in this study sulphate was elevated for the first 24 days while electrical conductivity was elevated for the first 4 days. For this study Ca, Mg, Mn, and Ni were metals above the SANS water standards while in the GCS report all-metal parameters were below the recommended limits. This may be due to different sampling periods. In the GCS report, samples were taken at different times and then a

composite was made. For this study, the discard sample was taken directly from the dump and no composite was made.

Recommendations

- Oxygen should be cut off during in-pit deposition to ensure that the tailings are deposited below a constant water level. This is to ensure that to avoid any potential of AMD as the analyses are more small scale and there could be the possibility of more acid-forming minerals present;
- The monitoring of boreholes and surface water upstream and downstream of the area should be implemented to track the progress of the groundwater. If there are no monitoring boreholes present, then a drilling programme will be required; and
- Due to the low concentration of alkaline, adding lime to discard may lead to a reduction of AMD formation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATION

Abbreviation	Description
ABA	Acid-Base Accounting
Alk	Alkalinity
AMD	Acid Mine Drainage
AP	Acid Potential
ARL	Acceptable Risk Level
AUC	Average Upper Crust
DW	Distilled Water
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
LC	Leachable Concentration
LCT	Leachable Concentrations Threshold
mg/kg	milligram per kilogram
mg/L	milligram per litre
NAF	Non-Acid Forming
NAG	Nett Acid Generation
NAPP	Net Acid Production Potential
NNP	Nett Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
PAF	Potential Acid Forming
NEM: WA	National Environmental Management: Waste Amendment Act 26 of 2014
S^{2-}-S%	Sulphide-Sulphur Percentage
SANS	South African National Standard
SO_4^{2-}-S %	Sulphate-Sulphur Percentage
TCT	Total Concentrations Threshold
TDS	Total Dissolved Solids
TS%	Total Sulphur Percentage
XRD	X-Ray Diffraction
XRF	X-Ray Florescence

1 Introduction

Digby Wells Environmental (hereinafter Digby Wells) has been requested by Exxaro Coal Central (Pty) Ltd. to conduct a geochemical and waste assessment for the Dorstfontein East Expansion Project. The purpose of this report is to provide an understanding of the geochemical risk associated with the acid-generating potential and leachate potential of the discard materials from the Expansion Project.

This report presents the Dorstfontein geochemical characterisation results of discard material as a basis for the Acid Rock Drainage/Metal Leaching risk potential for the proposed expansion. A comparison from the available data to the new data from this study will be conducted and be an input into the geochemical assessment.

1.1 Terms of Reference

The terms of reference (ToR) of this report is to undertake a geochemical assessment to evaluate acid-base generation potential and/or neutralisation potential of the waste rock materials from the proposed Dorstfontein Coal Mine East Expansion Project in order to:

- Characterise and classify the acid-generating and non-acid generating waste rock material;
- Assess ARD and ML potential of the various geological strata that will be disturbed by the planned mining operations; and
- Understand the potential impact the various geological strata will have to the surrounding areas.

1.2 Deliverables

The following deliverables will be provided as part of the report:

- Laboratory Certificates;
- Geochemical assessment for the mineralogy, acid-base generation and/or neutralisation potential of the waste materials (tailings material and waste rock);
- Kinetic Column Test analyses; and
- Reporting and recommendations.

2 Methodology

The section below describes the methodology used to accomplish the study objectives.

2.1 Legislative Guidelines

On 2 June 2014, the National Environmental Management: Waste Amendment Act (NEM: WA), 2014 (Act No. 26 of 2014) was published, which for the first time included “residue deposits” and “residue stockpiles” under the environmental waste legislation (previously mining residue was covered under the MPRDA). Mine wastes are listed under Schedule 3, under the category "Hazardous Waste", therefore the understanding is that mine wastes are considered to be hazardous unless the applicant can prove that the waste is non-hazardous.

As residue deposits and residue stockpiles are considered to be waste, they are regulated by the following regulations, both promulgated on 23 August 2013 under NEM:WA:

- Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R635 of 23 August 2013); and
- National Norms and Standards for Disposal of Waste to Landfill (GN R636 of 23 August 2013).

According to these regulations, waste that is generated must be classified in accordance with SANS 10234 within 180 days of generation. Waste that has already been generated, but not previously classified must be classified within 18 months of the date of commencement of the regulations. The norms and standards specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Environmental Affairs (DEA) has further published the Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits (GN R632 of 24 July 2015, as amended) and in terms of waste classification, these regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (i.e. toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

2.2 Description of Waste Rock Material Sampling

A total of five (5) samples were collected by the clients for the possible expansion of the co-disposal facility or backfilling of the opencasts. Digby Wells consultant collected the samples and were later delivered to Aquatico Laboratory (Pty) Ltd which is a South African National Accreditation System (SANAS) accredited laboratory.

The following testing will be performed on all samples (5 samples):

- Acid-base accounting (ABA);
- Net-acid generation (NAG); and
- Paste pH.

The following testing to be performed on 3 selected samples:

- X-ray diffraction (XRD);
- X-ray fluorescence (XRF);

- S speciation (SS%).

The following humidity cell testing will be carried out:

- Kinetic leach testing of one (1) sample including leach water analyses (10 weeks)

2.3 Geochemical and Waste Assessment Techniques

The section below describes the geochemistry assessment and waste classification assessment methodology/techniques.

2.3.1 Geochemical Testing

2.3.1.1 X-Ray Diffraction and X-Ray Fluorescence

XRD allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material that allows the specialist to determine whether any reactive solids will lead to environmental risks through the study of the various minerals. XRF is an X-ray method used to determine the elemental composition of a material that allows for the evaluation of a material's chemical compound distribution, as well as the various trace element concentrations.

The following pertains to the XRD method used:

- The samples were prepared for XRD analysis using a back-loading preparation method. They were analysed with a PANalytical Empyrean diffractometer with X'Celerator detector and fixed receiving slits with Cu-Kα radiation. The mineral phases were identified using X'Pert Highscore plus software; and
- The weight percentages of the minerals were determined using the Rietveld method (Autoquan Program).

The following pertains to the XRF method and the Loss-On-Ignition (LOI) used:

- Samples were analysed using pressed powder pellets;
- Analyses were performed using the fusion technique with a Rigaku Supermini 200 with SC and F-PC detectors and fixed receiving slits with Zr of Al filtered Pd-K radiation. The elements were identified using ZSX software; and
- LOI was then determined by placing samples in weighed crucibles which is then weighed. Weight loss is measured after heating at 750ºC overnight to remove water, organic matter, and carbonates. After heating, the firebrick holding crucibles is allowed to cool completely in the oven or furnace before weighing.

Exclusions and Limitations

- The mineral names in this report may not reflect the specific mineral identified, but rather the mineral group
- Trace minerals at concentrations below ± 1% are often not detected using XRD testing on whole-rock samples as the error might become larger than the analyses reported;

- Due to preferred orientation and crystallite size effects as well as small sample amounts, results may not be as accurate as shown.
- Amorphous phases, if present, were not considered during quantification

2.3.1.2 Acid-Base Accounting and Net Acid Generation

ABA is a first-order classification procedure whereby the acid-neutralising potential and acid-generating potential of rock samples are determined, and the difference Net Neutralising Potential (NNP) is calculated. This procedure includes NAG tests that evaluate the Net Acid Generation and neutralising potential of the material to evaluate the potential of the material to counter acid production. The NNP, and/or the ratio of neutralising potential to acid-generation potential, is compared with a predetermined value, or set of values, to divide samples into categories that either require or do not require further determinative acid potential generation test work. A description of the different ABA components is given below:

- AP (Acid Potential) is determined by multiplying %S with a factor of 31.25. The unit of AP is kg CaCO3/t rock and indicates the theoretical amount of calcite that could be neutralized by the acid produced; and
- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulphuric acid (the sample and acid are heated to insure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg CaCO3/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage.

The Acid-Mine-Drainage (AMD) potential for classification of the material the ABA results could be screened in terms of Net Neutralising Potential (NNP), Sulphur Speciation (SS, in %) and Neutralising Potential, Acid Producing Potential (NP:AP) ratio is as follows:

- Acid drainage from rocks can theoretically occur when the NNP < 0 kg $CaCO_3$/t while neutral drainage occurs when NNP > 0 kg $CaCO_3$/t. Carbonate and sulphide mineral reactions are complex. Research has indicated that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t is referred to as an area of uncertainty to establish if there is a net acid generation or neutralisation potential of rock. Material with an NNP above this range is normally considered not to be a problem in terms of AMD. To classify the materials the NP:AP ratio is used in addition to the NNP. The classification of the materials is shown in Table 2-1.
- Soregaroli and Lawrence (1998) further state that samples with less than 0.3% sulphide-sulphur are regarded as having insufficient oxidisable sulphides to sustain long-term acid generation. Anything above the 0.3% mark indicates a potential of AMD formation including other supporting factors demonstrated in Table 2-1 (based on Price, 1997 and Soregaroly and Lawrence, 1998). For the Sulphur-Speciation the following parameters were analysed: Total-Sulphur (Total-S), Sulphate-Sulphur (SO_4^{2-}-S) and Sulphide-Sulphur (S^{2-}-S). This is driven by the mineralogy of the materials that

are acid buffering/neutralising and other minerals like sulphides that are the main drivers of acid production and AMD under aerobic conditions.

- The NAG test is a static test that is used to determine the formation of ARD by reacting a sample with hydrogen peroxide, which accelerates the oxidation of sulphide minerals in the sample. During the test, acid generation and acid neutralization reactions can occur simultaneously, end-result representing a direct measurement of the net amount of acid generated by the sample and the pH. The test does not estimate the neutralisation potential hence it needs to be performed with the ABA test (Smart, et al., 2002).

Table 2-1: Criteria for interpreting ABA results updated from Price (1997) and Soregaroly and Lawrence (1998)

Potential for AMD	Criterion	S^{2-}-S%	Comments
Rock Type I: Likely	NPR<1	>0.3	Potentially acid-generating unless sulphide minerals are non-reactive
Rock Type II: Possible	1<NPR<2	0.2-0.3	Possibly acid-generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides
Rock Type III: Low	2<NPR<4	0.1-0.2	Not potentially acid-generating unless significant preferential exposure of sulphide
Rock Type IV: None	NPR>4	<0.1	Non-acid generating

Table 2-2: A classification system based on Paste-pH and NAG-pH edited from Miller et al. (1997)

Acid Forming Potential	Test Criteria	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. PAF High Risk	Paste-pH < 4.0 NAG-pH < 4	>10	Negative
Rock Type Ib. PAF Medium Risk	Paste-pH 4.0 – 6 NAG-pH < 4	≤10	-
PAF – Lag to ARD	Paste-pH >6.0 NAG-pH < 4		
Uncertain, possibly Sediment Type Ib	NAG-pH < 4	>10	Positive
Uncertain	NAG-pH ≥4.5	0	Negative (reassess mineralogy)
Rock Type IV: NAF	Paste-pH >6 NAG-pH >4	0	Positive

2.3.2 Leachate Tests and Total Elemental Analysis

2.3.2.1 Waste Assessment Methodology

Leachate tests are done to simulate the heavy metal and anion leachate potential of soils, waste material and wastewater left in-situ under the expected conditions, with the solution type and pH determined based on guidelines or the expected conditions on-site. These tests will simulate and evaluate the potential of any heavy metal or ion contamination from the waste material that will be produced. The leachate tests are used to evaluate the leachability of material that will be mono- or co-disposed. In the case of this study, mono-disposal testing was conducted because samples will be disposed of in respective facilities such as WRD for waste rocks and TSF. The analyses are as follows:

Total Concentration values in mg/kg were determined by *aqua regia* digestion and analysis with ICP methods by Waterlab Laboratory in Gauteng Province. This was done to determine the complete chemical make-up of the material before being leached or altered.

Total Concentration Threshold limits are subdivided into three categories as indicated in Table 2-4 and are summarised 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 were derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

Leachable concentration was determined by following the Australian Standard Leaching Procedure for Wastes, Sediments and Contaminated Soils (AS 4439.3-1997), as specified in the NEMWA Regulations (2013). The procedure recommends the use of DI Water to detect the metals that are present on the surface exterior. The procedure can also be done under Synthetic Precipitation Leachate Procedure which consists of 2 types of pH 3.4 for co-disposal and 5 for mono-disposal with the latter performed for this study. Leachate of 1:4 solids per reagent water was advised for the NEM: WA guidelines but for this study, a 1:4 solid ratio was prepared and analysed by Waterlab Laboratory.

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 DWS, SANS, WHO or the United States Environmental Protection Agency (USEPA);
- 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 are derived by multiplying the LCT2 values by a factor of 4.

Waste is classified by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill as per Table 2-3.

Table 2-3: 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

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Table 2-4: 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**
Sulphate as SO4	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**

2.4 Kinetic Test

Kinetic tests are conducted over a certain period (typically months) and allow for on-going measurements of the kinetic properties of the samples. Information that can be obtained from kinetic tests include (Sondergaard, et al., 2018):

- Weathering rates of minerals and release rates of elements;
- Rates of acid generation and neutralisation;
- Time to onset of net acid conditions; and
- Depletion of soluble and oxidizable elements in the samples over time.

The kinetic tests are designed to simulate the deposition of materials under different conditions e.g. waste rock and ore deposition on land under well flushed aerated conditions and tailings deposition underwater in a tailings dam (Sondergaard, et al., 2018). The significance of static testing is to characterise the samples before and after in order to evaluate the changes in the solid phases (e.g. depletion of soluble minerals) during the test. The analysed parameters are demonstrated in Table 2-5.

Table 2-5: Analysed parameters in the HCT

Parameters			
Chloride as Cl	B, Boron	Fe, Iron	Ni, Nickel
Sulphate as SO_4	Ba, Barium	Ga, Gallium	Pb, Lead
Nitrate as N	Be, Beryllium	K, Potassium	Rb, Rubidium
F, Fluoride	Bi, Bismuth	Li, Lithium	Sr, Strontium
Electrical Conductivity (EC)	Ca, Calcium	Mg, Magnesium	Te, Tellurium
Total Alkalinity as $CaCO_3$	Cd, Cadmium	Mn, Manganese	Tl, Thallium
Orthophosphate as P	Co, Cobalt	Mo, Molybdenum	V, Vanadium
Ag, Silver	Cr, Chromium	Na, Sodium	Zn, Zinc
Al, Aluminium	Cu, Copper		

2.4.1 Humidity Cell Test

Humidity cell test is a simulation test that accelerates weathering and release of the weathering products (i.e. elements) under accelerated and well-flushed conditions (i.e. with minimum precipitation of secondary minerals). Normally recommended for testing of waste rock and ore deposition on land.

One kilogram of dry, crushed (<6.5 mm) rock samples is placed into a specially designed humidity cell apparatus that is closed in and has air and water pumped in and out. This is then subjected to weekly cycles that alternate between the circulation of dry air and moist air over the samples to simulate precipitation cycles (EnvironMail13, 2019).

Weekly humidity cell leachates are analysed for several diagnostic chemical parameters, typically including acidity, alkalinity, anions (chloride, fluoride, sulphate, nitrate, nitrite), dissolved metals, pH, and conductivity, with additional tests added as required based on the material or project requirements (EnvironMail13, 2019).

2.4.2 Column leach Tests

Column leach tests can either be a sub-aerial or sub-aqueous test (Sondergaard, et al., 2018).

A sub-aerial test is also placed in a column with similar sampling preparation as a humidity cell test. The column is flushed using water volumes and flushing intervals likely to be encountered in the field and temperatures resembling field conditions (Sondergaard, et al., 2018). Deionised water or similar water at the deposition site can be utilised for flushing. The objective is to simulate the net impact of both primary mineral weathering and potential secondary mineral precipitation/dissolution on the drainage water likely to be encountered in the field (Sondergaard, et al., 2018). The leach water is collected similarly to the humidity cell test.

Sub-aqueous column test is typically utilised for deposition underwater by assessing the release of elements from tailings when disposed of underwater. A sample of approximately 2 kg of e.g. tailings is placed in a long, thin Plexiglas test column that is enclosed in and has valves that put air and water in and out. Deionised water is typically utilised. The test can be conducted at room temperature or temperature close to the mean air temperature at the site (Sondergaard, et al., 2018). The test is conducted for several months and leach water is collected and replaced at short intervals (e.g. daily) at the beginning and long intervals (e.g. monthly) at the end.

For this study, the subaerial column leaching test was performed on discard material. A rapid test was performed for the first five days and thereafter the analyses were performed weekly

3 Review of existing information

In 2016 GCS (Pty) Ltd. was appointed by Exxaro and conducted a study named the "*Dorstfontein East Environmental Impact Assessment - Hydrogeological Investigation*". In this report, in-depth geochemical characterisation and modelling were done. The report indicated that in 2014/2015 geochemical sampling and modelling were conducted for the Dorstfontein Coal Mines East and West (DCMW and DCME) to determine the short- and long-term pollution potential of the opencast, underground and disposal facilities. A total of eight samples were taken from DCME in 2014 while in 2016 only seven (three discard, three waste rocks and one slurry samples) were collected. Various samples were collected from different discard and waste rock dumps. However, for this study, the main focus of comparison will be the discard materials ranging between a few weeks old to 3 months old. The reason for this focus was that in the previous study the fewer samples were analysed thus not providing an overview of discard material.

3.1.1 Mineralogy

One discard sample was analysed for the mineralogy analyses. The results were compared to the average upper crust (AUC) of Rudnick and Gao (2003).

The discard sample XRD and XRF results detected the following:

- Kaolinite was the predominant mineral greater than 40 wt. %, followed by quartz ranging between 15-40 wt.% and minor minerals included microcline and muscovite between 5-14 wt. %;
- Accessory and carbonate-rich minerals such as calcite and dolomite were also detected ranging between 2-5 wt. % and lastly traces of plagioclase (<2 wt.%) were detected; and
- XRF results only indicated an excessive sulphur content, more than 5 times above the AUC.

3.1.2 Acid Generation Potential

ABA test on three discard samples was conducted to determine the acid drainage generation potential. The Percent Sulphur (%S, referred to sulphide-sulphur in this study), the Acid Potential (AP), the Neutralization Potential (NP), and the Net Neutralization Potential (NNP) of the rock material was determined in this test.

The results were summarised as followed:

- The discard sample had a high %S of ranging between 0.9 and 1.74 % (which is more than 0.3% based on Soregaroli and Lawrence (1998);
- Discard 1 comprised of higher sulphide content and lower NNP compared to the other two discard samples. There is a high capacity for an acid-generation; and
- The paste-pH of all discard samples was circum-neutral.

3.1.3 Kinetic Column Leach Test

A composite discard sample was subjected to a kinetic test with a rock to water ratio of 2:1. 1kg of the sample was leached with 500 ml distilled water daily for 5 days, and thereafter weekly for the remainder of the test. The aim of the initial faster leaching rate is for the leaching of more soluble secondary minerals as per the American Society for Testing and Materials (ASTM) Standard method D5744 (Standard, 2012). The column was set up by mixing the 3 discard samples collected from the site at an equal ratio.

From the kinetic leaching test results the following observations could be made:

- The pH was near neutral during the first 115 days measured thus far with no clear evidence of acidification yet. The alkalinity stayed fairly constant after the second leach at between 40-45 mg/l;
- The EC and SO_4 were slightly elevated in the first 2 leaches because of the leaching of more soluble secondary minerals. After 16 weeks the SO_4 stayed at a more constant concentration of between 65 – 75 mg/l;
- Ammonia (NH_3) leached at marginally elevated levels during the 1st leach but below the SANS drinking water standard; and
- No metals leached at elevated levels from the column. Se leached at marginal levels only in the 2nd leach.

No acidification was observed, and no metals leached at elevated levels from the column. It is however expected that the column will become acidic as soon as the available carbonates become depleted

4 Laboratory Results and Interpretations

4.1 Discard Mineralogy and Chemical Composition

The XRD and XRF results are indicated in Table 4-1 and Table 4-2 and displayed in Figure 4-1.

XRD results for the discard samples indicated the following:

- Kaolinite is a dominant mineral ranging between 46 and 71 wt. %. These results are similar to the report conducted from the GCS report. This is a common clay mineral formed through the breakdown of minerals like alkali-feldspar. Lizardite was also detected in trace amounts of 0.4 wt. % and this form part of the Kaolin-Serpentine group. Illite was also detected in relatively low concentration or quantity. Generally, illite is part of a group of non-expanding clay minerals and is commonly found in soils, clay-rich sedimentary rocks, and low-grade metamorphic rocks.
- Quartz ranges between 18 and 40 wt. % similar to the samples analysed in the GCS report;
- Carbonate minerals identified were dolomite (excluding Discard 4) ranging between 1 and 9 wt. %, and aragonite (calcite polymorph) only in Discard 4 and 5 at 2.1 and 2.4 wt. % respectively.
- Muscovite was also detected in Discard 4 and Discard 5 at 12.1 and 1.9 wt. % respectively.
- Spinel group minerals were detected, this includes Spinel (in Discard 1 at 0.6 wt. %), magnetite (detected in discard 4 at 5.2 wt. %) and Franklinite as traces in Discard 5 at 0.5 wt. %.

- Titanium oxide anatase was detected in Discard 1 and Discard 3 at 1.6 and 1.4 wt. %, respectively.
- No acid-forming minerals were detected.

XRF results indicated the following:

- TiO_2 is elevated at least 3 to 5 times above the AUC while Al_2O_3 is slightly elevated.
- Discard 1 indicates that P_2O_5 is 3 to 5 times above the AUC while for the other samples it was slightly elevated.

Table 4-1: XRD Results demonstrated in wt. %

Sample ID	Kaolinite	Quartz	Dolomite	Calcite	Anatase	Spinel	Lizardite	Illite	Muscovite	Magnetite	Aragonite	Franklinite	Microcline	Plagioclase
GCS-Discard 1	43.5	27.8	4.59	2.66	-	-	-		5.73	-	-	-	13.8	1.95
Discard 1	68.6	20.9	7.9		1.6	0.6	0.4	-	-	-	-	-		
Discard 2	70.6	27.5	1.9		-	-	-	5.5	-	-	-	-		
Discard 3	46.3	39.8	7		1.4	-	-	-	-	-	-	-		
Discard 4	58.9	21.6	-		-	-	-	-	12.1	5.2	2.1	-		
Discard 5	68.5	18.2	8.5		-	-	-	-	1.9	-	2.4	0.5		

Table 4-2: X-ray fluorescence major oxides in wt. %

Sample ID	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	CaO	Na_2O	K_2O	P_2O_5	Cr_2O_3
GCS Discard 3	29.1	0.76	17.3	1.58	0.50	0.01	1.53	<0.2	0.30	0.04	
Discard 1	56.48	2.18	31.31	3.32	1.38	0.03	3.52	<0.01	0.61	0.52	0.03
Discard 2	60.33	2.50	31.68	1.57	0.74	0.01	1.72	<0.01	0.57	0.25	0.03
Discard 3	61.89	2.40	23.56	5.09	1.39	0.03	3.32	<0.01	0.59	0.38	0.03
Discard 4	60.94	2.38	32.60	1.19	0.57	0.02	0.69	<0.01	0.81	0.15	0.03
Discard 5	60.85	2.70	27.71	2.05	1.10	0.02	3.10	<0.01	0.43	0.21	0.04
AUC	66.6	0.64	14.4	11.2	2.48	0.1	3.59	3.27	2.8	0.15	

Sample ID	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	CaO	Na_2O	K_2O	P_2O_5	Cr_2O_3
AUC 3-5 times higher	-	1.92	46.2	33.6	7.44	0.3	10.8	9.81	8.4	0.45	

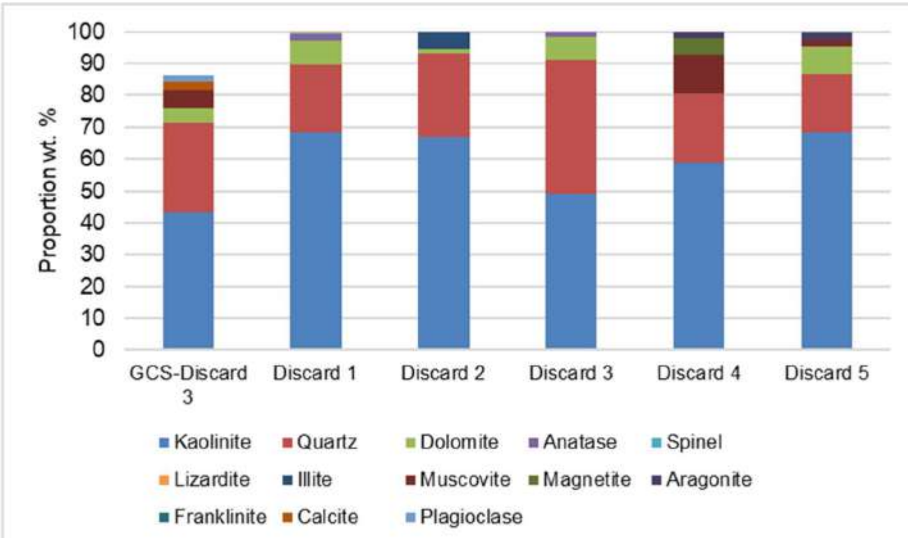

Figure 4-1: Mineralogical composition of discard material

4.2 Acid Generating Potential

To interpret the ABA results, five characteristics of the materials were assessed namely paste-pH, Neutralisation Potential (NP), Acid Generation Potential (AP) and Neutralisation Potential Ratio (NPR). For the Sulphur-Speciation the following parameters were analysed: Total-Sulphur (Total-S), Sulphate-Sulphur (SO_4^{2-}-S) and Sulphide-Sulphur (S^{2-}-S). This is driven by the mineralogy of the materials that are acid buffering/neutralising and other minerals like sulphides that are the main drivers of acid production and AMD under aerobic conditions. The results are summarised in Table 4-3 and Figure 4-2.

The results are summarised as follows:

- Paste-pH results are circumneutral.
- Discard 1, Discard 3 and Discard 5 S^{2-}-S% demonstrates that they are above 0.3% at 0.32, 0.56 and 0.64% respectively. The 0.3 % mark (Soregaroli & Lawrence, 1998) normally indicates acid-generation potential. However, looking at the absence of acid-forming minerals and the low concentration of the S^{2-}-S% it can be assumed the samples are NAF as long as the NP minerals do not deplete.
- Net Neutralising Potential (NNP) is the difference between Neutralising Potential (NP) and Acid Potential (AP). Positive NNP indicates that there are more NP minerals in the samples as indicated in the samples below.

- The overall results indicate that Discard 1, Discard 2 and Discard 3 samples have NAF potential. Discard 4 demonstrates the uncertainty of whether it has the acid-forming potential or not.

Table 4-3: ABA Test Results

Sample ID	Discard 1	Discard 2	Discard 3	Discard 4	Discard 5
Paste pH	7.88	8.06	7.96	8.29	8.07
S^{2-}-S%	0.32	0.23	0.56	0.17	0.64
SO_4^{2-}-S (%)	0.046	0.09	0.054	<0.01	0.065
Total %S	0.37	0.32	0.61	0.17	0.71
AP (kg/t)	10.00	7.19	17.50	5.16	20.10
NP $CaCO_3$ kg/t	25.50	20.00	42.80	9.50	41.20
NNP (kg $CaCO_3$/t)	15.50	12.80	25.30	4.34	21.10
NPR	2.55	2.78	2.45	1.84	2.05
Rock Type S^{2-}-S%	Rock Type II	Rock Type II	Rock Type I	Rock Type III	Rock Type I
Rock Type NPR	Rock Type III	Rock Type III	Rock Type III	Rock Type II	Rock Type III
Overall Classification	NAF	NAF	NAF	NAF	NAF

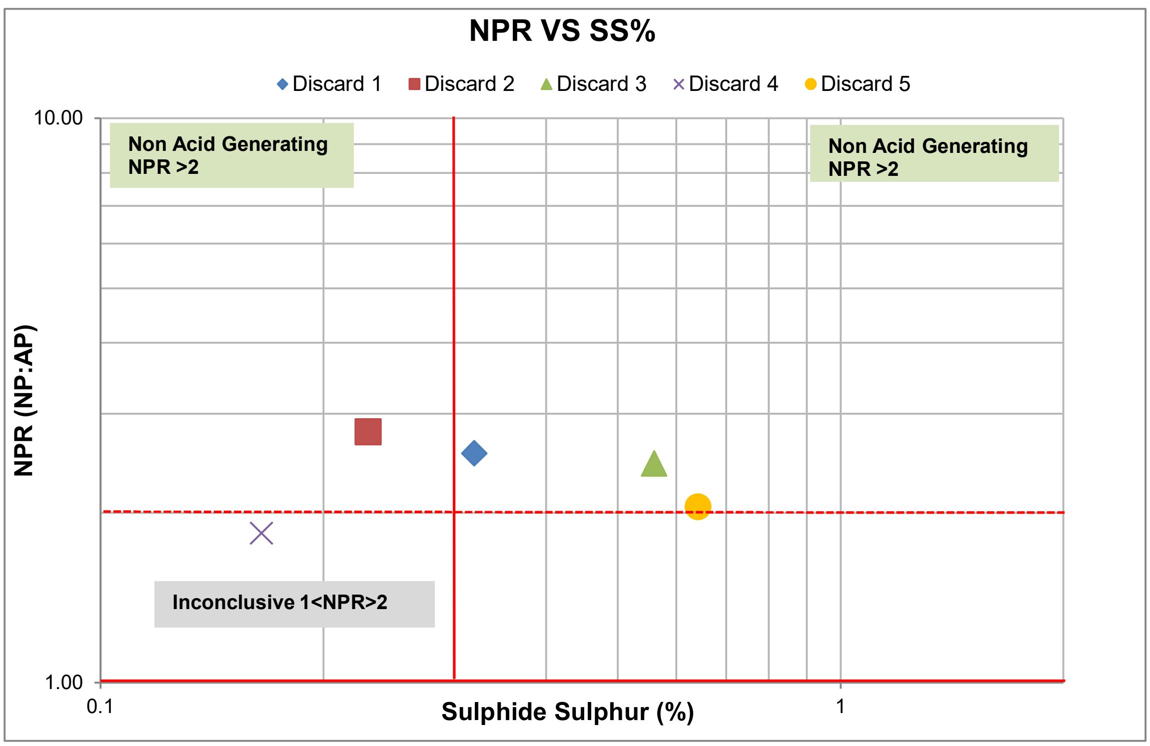

Figure 4-2: Classification of samples in terms of S^{2-}-S and NPR

4.3 Column Leach Test

The results are presented in Table 4-4 and Table 4-5. From the kinetic leaching test results the following observations could be made:

- During the 73 days of the column leach test, the pH was near neutral with no clear evidence of acidification. The alkalinity indicates an increase from 44.9 mg/L to 121 mg/L then decreases to 56.1 mg/L.
- For the first 5 leaches, EC was above the operational risk for the SANS drinking water standards ranging between 199 to 207 mg/L.
- The first 10 days, SO_4 ranges between 652-1949 mg/L. On these days the parameters were above the SANS drinking water quality of 500 mg/L affecting acute health. Then on day 17 until 24 the discard material was still above the aesthetic risk of 250 mg/L. This is demonstrated in Figure 4-3 with the red line indicating the SO_4 acute health SANS drinking water threshold limit. The highest concentration was observed on day 1 at 1949 mg/L while in the GCS report maximum concentration was at 198 mg/L on day 0.
- Ca, Mg and Mn were above the recommended aesthetic risk of 150 mg/L, 70 mg/L and 0.1 mg/L respectively for the first 4 days. Ca continued to day 5 while Mn of the 10^{th} and 45^{th} day the leach indicated to be above the operational risk. In the GCS report, Pb was the only metal that leached slightly above the SANS parameters after 143 days. While in this study parameters like Ca, Mg, Mn, and Ni were above the SANS drinking water quality at some point during the test.
- Ni was only detected to be above the SANS drinking water quality on day 2 of the test at 0.078 mg/L, which is slightly above the chronic health risk standard from the SANS drinking water standard of 0.07 mg/L. On the other days, the Ni concentration is below the SANS parameters.
- No acidification was observed for the duration of the test, the concentration of sulphate poses a threat on the acid-forming potential. It is expected that the column will become acidic as soon as the available carbonates become depleted.

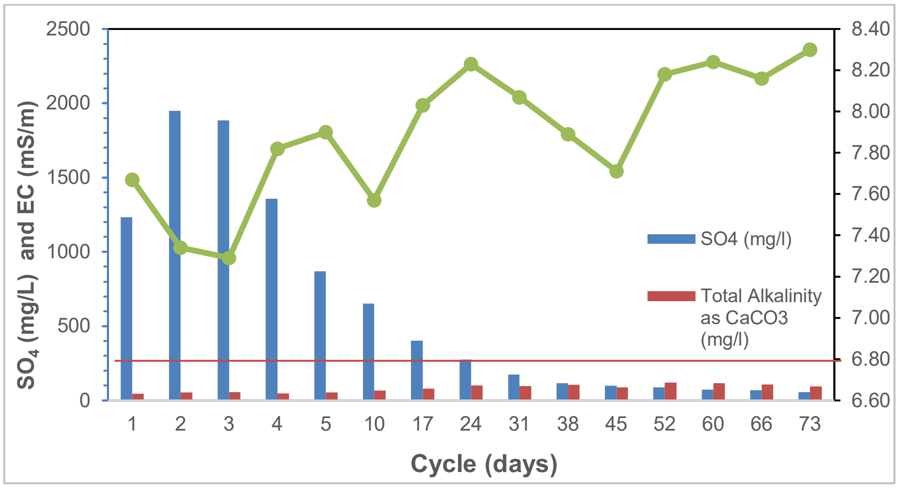

Figure 4-3: Changes measured pH, SO_4 and EC from day 1 to 73

Table 4-4: Analyses of weekly leach for the discard material

Leach	Days	pH	EC (mS/m)	SO_4 (mg/l)	Total Alkalinity (mg/l)	NH_4 as N (mg/l)	Nitrate as N(mg/l)	PO_4 as P(mg/l)	Cl (mg/l)	F (mg/l)
SANS 241: 2015										
Operational		<5; >9.7								
Aesthetic			>170	250			>11		>300	
Acute Health				>500						
Chronic Health										>1.5
0	1	7.67	199	1232	44.9	0.858	0.578	<0.005	16	0.953
1	2	7.34	295	1949	53.70	0.683	0.764	<0.005	22.0	1.310
2	3	7.29	271	1886	54.90	0.482	0.601	<0.005	7.1	1.300
3	4	7.82	207	1359	48.20	0.443	3.580	<0.005	4.3	1.320
4	5	7.90	155	870	53.30	0.421	0.404	<0.005	2.8	1.270
5	10	7.57	122	652	65.50	0.167	0.487	<0.005	2.2	1.220
6	17	8.03	83	401	79.00	0.032	<0.194	<0.005	1.3	1.120
7	24	8.230	64.50	274	99.60	0.03	<0.194	0.021	1.40	0.97
8	31	8.070	53.20	174	96.70	0.04	<0.194	<0.005	2.02	0.90
9	38	7.890	45.00	117	107.00	0.08	0.636	<0.005	0.77	0.88
10	45	7.710	39.20	98	88.00	0.06	0.566	<0.005	0.89	0.87
11	52	8.180	38.70	88	121.00	0.06	<0.194	<0.005	0.63	0.85
12	60	8.240	35.90	73	117.00	0.05	<0.194	<0.005	1.55	0.95
13	66	8.160	30.60	70	108.00	0.07	0.265	<0.005	0.58	0.73
14	73	8.03	30	56.1	94.1	0.14	3.3	<0.005	1.19	0.68

Table 4-5: ICP-OES results in mg/L for discard materials

Discard																SANS 241-1: 2015			
Leach	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Operational	Aesthetic	Acute	Chronic
Days	1	2	3	4	5	10	17	24	31	38	45	52	60	66	73				
Ag	0.001	0.002	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Al	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.3			
B	0.072	0.096	0.098	0.091	0.071	0.076	0.064	0.054	<0.013	<0.013	<0.013	0.033	0.051	0.050	0.043				2.4
Ba	0.163	0.050	0.034	0.039	0.042	0.044	0.047	0.070	0.062	0.067	0.090	0.095	0.086	0.099	0.102				0.7
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				
Bi	0.021	0.033	0.037	0.025	0.019	<0.004	<0.004	0.011	<0.004	<0.004	<0.004	<0.004	0.008	<0.004	<0.004				
Ca	273	410	400	340	220	186	124	101	72.6	59.1	51.2	51.9	46.8	46.7	40.00		150		
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002				0.003
Co	<0.003	0.008	0.009	0.009	0.012	<0.003	0.003	0.005	0.005	<0.003	<0.003	0.007	0.004	<0.003	<0.003				0.5
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003				0.05
Cu	0.06	0.045	0.030	0.01	0.02	0.03	0.02	0.019	0.016	0.011	0.011	0.009	0.008	0.009	0.005				2
Fe	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004		0.3		2
Ga	0.008	0.011	0.011	0.011	0.009	0.021	0.016	0.008	0.006	0.006	0.006	0.006	0.007	0.004	0.006				

Discard																SANS 241-1: 2015			
Leach	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Operational	Aesthetic	Acute	Chronic
Days	1	2	3	4	5	10	17	24	31	38	45	52	60	66	73				
K	12	16.30	14.40	11.40	8.37	6.00	4.99	4.60	3.49	3.47	2.88	2.84	2.40	2.31	2.33	50			
Li	0.024	0.031	0.032	0.025	0.019	0.012	0.011	0.010	0.013	0.011	0.010	0.01	0.011	0.009	0.01				
Mg	111	192	178	128	68.70	48	33	30.50	20.30	17.40	15.3	15.10	13.60	13.70	12.40		70		
Mn	0.190	0.128	0.157	0.126	0.088	0.113	0.087	0.077	0.057	0.044	0.177	0.041	0.042	0.050	0.061		0.1		0.4
Mo	0.092	0.215	0.213	0.143	0.150	0.157	0.160	0.142	0.117	0.128	0.09	0.095	0.091	0.084	0.10				
Na	94.2	143	108	63.30	30.8	16.20	11.8	10.1	7.47	6.31	5.50	4.32	3.58	3.02	2.74		200		
Ni	0.049	0.078	0.054	0.042	0.111	0.051	0.055	0.064	0.031	<0.002	0.018	0.030	0.03	0.022	<0.002				0.07
Pb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004				0.01
Rb	0.027	0.036	0.034	0.025	0.015	0.015	0.007	0.009	0.004	0.003	0.004	0.004	0.004	0.003	0.006				
Sr	4.2	6.85	6.78	5.87	4.40	4.4	3.90	3.45	2.86	2.600	2.49	2.54	2.34	2.41	2.30				
Te	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Tl	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037				
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				0.2
Zn	0.062	0.11	0.094	0.087	0.12	1.33	0.139	0.112	0.079	0.005	0.276	0.077	0.066	0.030	0.002		5		

5 Conclusions

Geochemistry

- The most dominant mineral detected by XRD is clay mineral kaolinite the followed by quartz mineral. Other clay minerals detected included lizardite and illite in trace amounts;
- Minor minerals detected include titanium oxide anatase, spinel and magnetite;
- No acid-forming minerals were detected but acid-neutralising minerals such as dolomite and a calcite polymorph aragonite were detected. XRF indicated that P_2O_5 and Al_2O_3 are above the AUC and the TiO_2 is elevated 3 to 5 times above the AUC; and
- The mineralogy of the current study samples in comparison to the GCS report 2016, the discard materials all indicate kaolinite as dominant followed by quartz.

Acid Generation Potential

- All paste-pH of the samples are circumneutral with positive NNP. Two out of the five samples are above the 0.3% mark of S^{2-}-S% ranging between 0.32% to 0.64%. The overall results indicate that Discard 1, Discard 2, Discard 3 and Discard 5 samples have NAF potential. Discard 4 demonstrates the uncertainty of whether it is acid-forming potential or not; and
- Three discard samples were analysed in the GCS report 2016 and it indicated all samples S^{2-}-S are above the 0.3% threshold with low NP. All samples were PAF while other being just short term. However, for this study all samples are NAF.

Column Leach Test

- No acidification was observed.
- Sulphate and metals such as Ca, Mg, Mn, and Ni leached at elevated levels from the column, especially Ni leaching slightly above the chronic health risk of SANS drinking water standards;
- It is however expected that the column will become acidic as soon as the available carbonates become depleted; and
- In the column leach test results from GCS report 2016, no parameters were significantly elevated while in this study sulphate was elevated for the first 24 days while electrical conductivity was elevated for the first 4 days. For this study Ca, Mg, Mn, and Ni were metals above the SANS water standards while in the GCS report all-metal parameters were below the recommended limits. This may be due to different sampling periods. In the GCS report, samples were taken at different times and then a composite was made. For this study, the discard sample was taken directly from the dump and no composite was made.

6 Recommendations

- Oxygen should be cut off during in-pit deposition to ensure that the tailings are deposited below a constant water level. This is to ensure oxygen is not available for any potential acid-producing reactions;
- The monitoring of boreholes and surface water upstream and downstream of the area must be done to track the progress of the groundwater contaminant plume. If there are no monitoring boreholes present, then a drilling borehole around the area is recommended; and
- Due to the low concentration of alkaline minerals, adding lime to the discard may lead to a reduction of acid production.

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DIGBY WELLS
ENVIRONMENTAL

Appendix A: Static Testing Laboratory Certificates

FINAL CERTIFICATE OF ANALYSIS
REVISON: 0

TO: Theo Meyer
CLIENT NAME: Aquatico Laboratories
CLIENT ADDRESS:

TEL:
MOBILE:
EMAIL:

FROM: UIS Analytical Services
XRF Laboratory
ADDRESS: 13 Esdoring Nook, Highveld Technopark, Centurion

TEL: +27 12 665 4291
FAX: +27 12 665 4294

REQUEST DATE:
DATE REQUIRED:

ANALYSED GRADE PERCENTAGES

CLIENT SAMPLE ID	UIS SAMPLE ID	Fe_2O_3	SiO_2	Al_2O_3	K_2O	P_2O_5	Mn_3O_4	CaO	MgO	TiO_2	Na_2O	V_2O_5	BaO	Cr_2O_3	SrO	ZrO_2	MnO	SO_3	Total (XRF)	ASH
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%		%	%
101670/Discard/1	711683	3.319	56.475	31.309	0.611	0.516	0.037	3.515	1.383	2.183	<0.010	0.016	0.101	0.030	0.187	0.070	0.026	1.117	100.868	51.710
101671/Discard/2	711684	1.570	60.325	31.682	0.566	0.246	0.016	1.724	0.742	2.502	<0.010	0.018	0.073	0.032	0.095	0.076	0.011	0.523	100.190	48.207
101672/Discard/3	711685	5.091	61.893	23.556	0.594	0.375	0.041	3.322	1.391	2.396	<0.010	0.013	0.084	0.029	0.122	0.074	0.030	1.760	100.741	47.961
101673/Discard/4	711686	1.189	60.941	32.603	0.808	0.150	0.020	0.693	0.566	2.381	<0.010	0.018	0.075	0.025	0.072	0.082	0.018	0.593	100.216	59.868
101674/Discard/5	711687	2.053	60.853	27.708	0.434	0.209	0.023	3.097	1.098	2.696	<0.010	0.018	0.074	0.035	0.105	0.099	0.021	1.997	100.498	55.267

NOTES:
*Report on Ash Basis
*The results relate specifically to the items as tested
*The report shall not be reproduced except in full, without the written approval of the laboratory

Identification of test method: X-ray fluorescence spectroscopy using the fusion technique
UIS method identification: UIS-XF-PTA-T002
Instrument model: ARL ADVANT'X SERIES
Asset number: UIS-AS 0885

Identification file: UIS 32009_Report
Authorisation date: 19-May-2020
Authorised by: NAME: V van Wyk
DESIGNATION: HOD

Page 1 of 1

aquatico
Laboratories (Pty). Ltd.

Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84723
Project: Digby Wells & Associates

Date of certificate: 24 April 2020
Date accepted: 27 March 2020
Date completed: 23 April 2020
Date received: 25 March 2020

				101660	101661	101662	101663	101664
Lab no:				101660	101661	101662	101663	101664
Date sampled:				25-Mar-20	25-Mar-20	25-Mar-20	25-Mar-20	25-Mar-20
Aquatico sampled:				No	No	No	No	No
Sample type:				Geochem	Geochem	Geochem	Geochem	Geochem
Locality description:				Discard 1	Discard 2	Discard 3	Discard 4	Discard 5
	Analyses	**Unit**	**Method**					
N	Geo - Milling 75um	-	Geochem	Yes	Yes	Yes	Yes	Yes
N	Paste pH (1:2)	pH	Geochem	7.88	8.06	7.96	8.29	8.07
N	Total Sulphur	%	Geochem	0.366	0.320	0.614	0.172	0.707
N	Sulphide Sulphur	%	Geochem	0.320	0.230	0.560	0.165	0.642
N	Sulphate Sulphur	%	Geochem	0.046	0.090	0.054	<0.010	0.065
N	Acid Potential based Total Sulphur	CaCO3 kg/t	Geochem	11.4	10.0	19.2	5.38	22.1
N	Acid Potential based Sulphide Sulphur	CaCO3 kg/t	Geochem	10.0	7.19	17.5	5.16	20.1
N	Neutralization Potential (NP)	CaCO3 kg/t	Geochem	25.5	20.0	42.8	9.50	41.2
N	Net Neutralization Potential (NNP)	CaCO3 kg/t	Geochem	15.5	12.8	25.3	4.34	21.1
N	NP / AP (TS)	-	Geochem	2.23	2.00	2.23	1.77	1.87
N	NP / AP (SS)	-	Geochem	2.55	2.78	2.45	1.84	2.05

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H. Holtzhausen
Technical Signatory

aquatico Scientific (Pty). Ltd.
leaders in environmental monitoring
address: 89 Regency drive, R21 Corporate Park, Centurion
postal: P.O. Box 905008, Garsfontein, 0042
web: www.aquatico.co.za
office: 012 450 3800 • fax: 012 450 3851

48 GROSVENOR ROAD
TURNBERRY OFFICE PARK
BRYANSTON

ATTENTION: DIGBY WELLS & ASSOCIATES

28 APRIL 2020

Digby Wells & Associates

(TEST REPORT 84724)

Qualitative and quantitative XRD results

5 Geochem samples were submitted to Aquatico Laboratories on **27 March 2020** for Rietveld analysis.

The samples were analysed with a PANalytical Empyrean diffractometer with X'Celerator detector and fixed slits with a Cu-Kα radiation.
The phases were identified by using X'Pert Highscore plus software.

Comments:

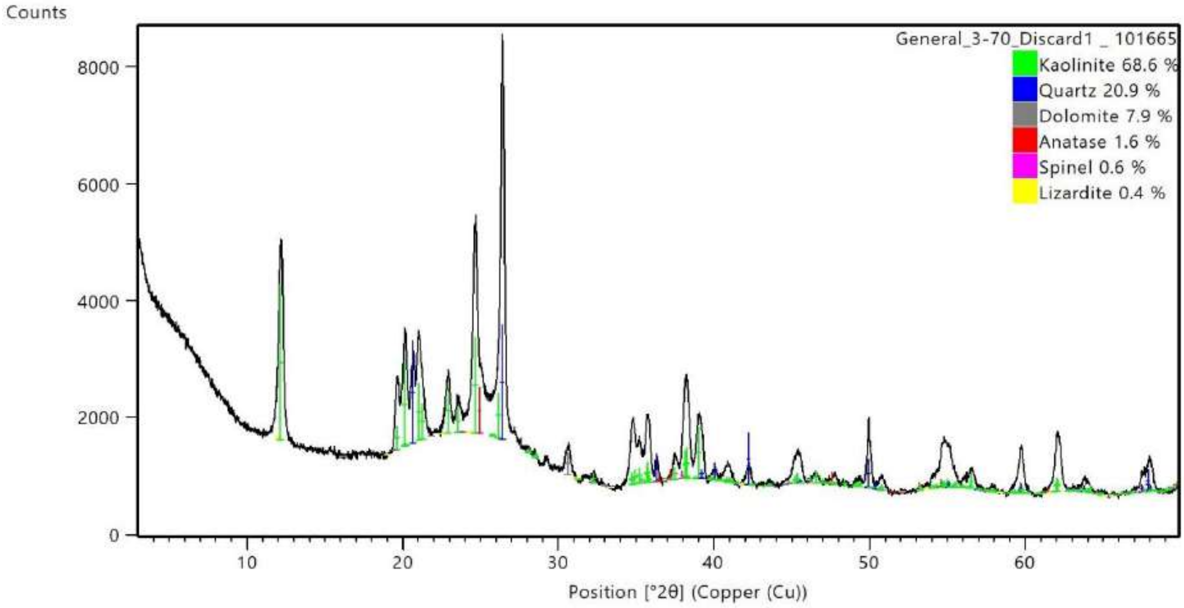
- If the results in this report do not correspond to results of other analytical techniques, please contact us for further review of the XRD results.
- The mineral names in this report may not reflect the specific mineral identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects as well as small sample amounts, results may not be as accurate as shown.
- Small amounts of additional phases may be present.
- **It may be advisable to confirm results using alternative analytical techniques.**
- Amorphous phases, if present, were not taken into account during quantification.

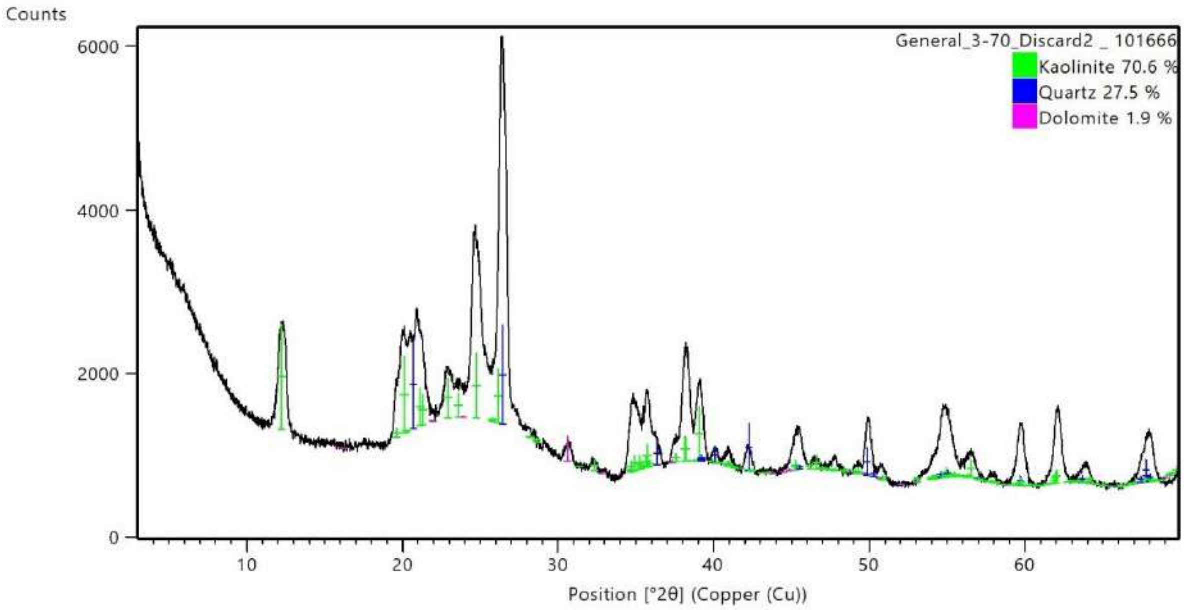
If you have any further queries please contact the laboratory.

Analyst
Paula Aucamp
BSc (Hons) Geology

Samples will be stored for 1 month after which it will be discarded

Results:


Counts
8000
6000
4000
2000
0
General_3-70_Discard1 _ 101665
Kaolinite 68.6 %
Quartz 20.9 %
Dolomite 7.9 %
Anatase 1.6 %
Spinel 0.6 %
Lizardite 0.4 %
10
20
30
40
50
60
Position [°2θ] (Copper (Cu))


Counts
6000
4000
2000
0
General_3-70_Discard2 _ 101666
Kaolinite 70.6 %
Quartz 27.5 %
Dolomite 1.9 %
10
20
30
40
50
60
Position [°2θ] (Copper (Cu))

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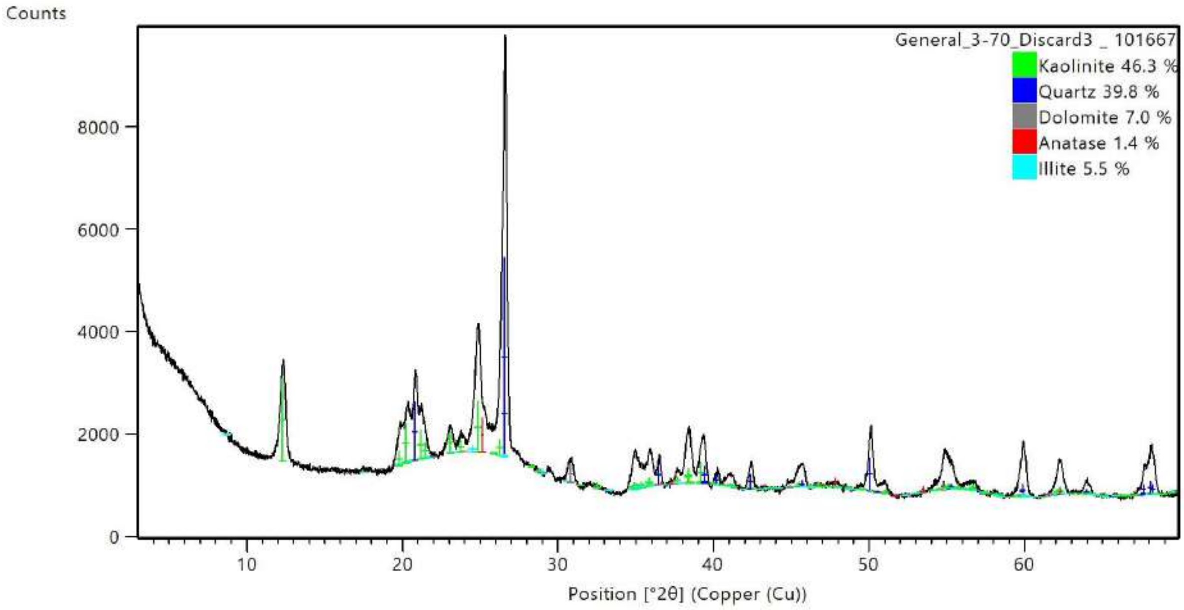
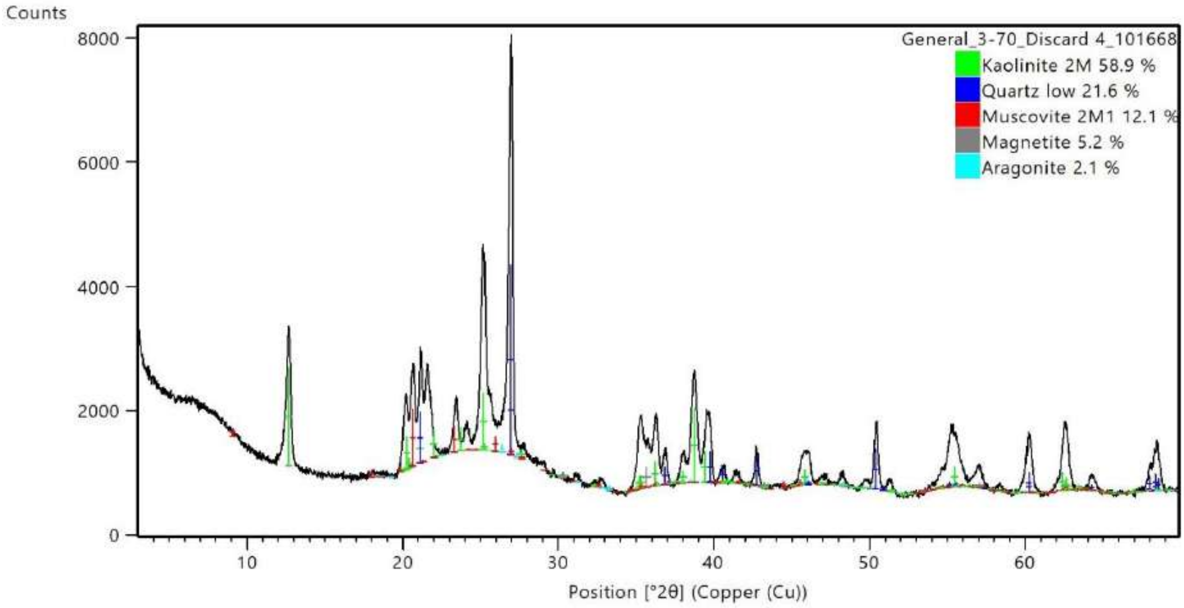
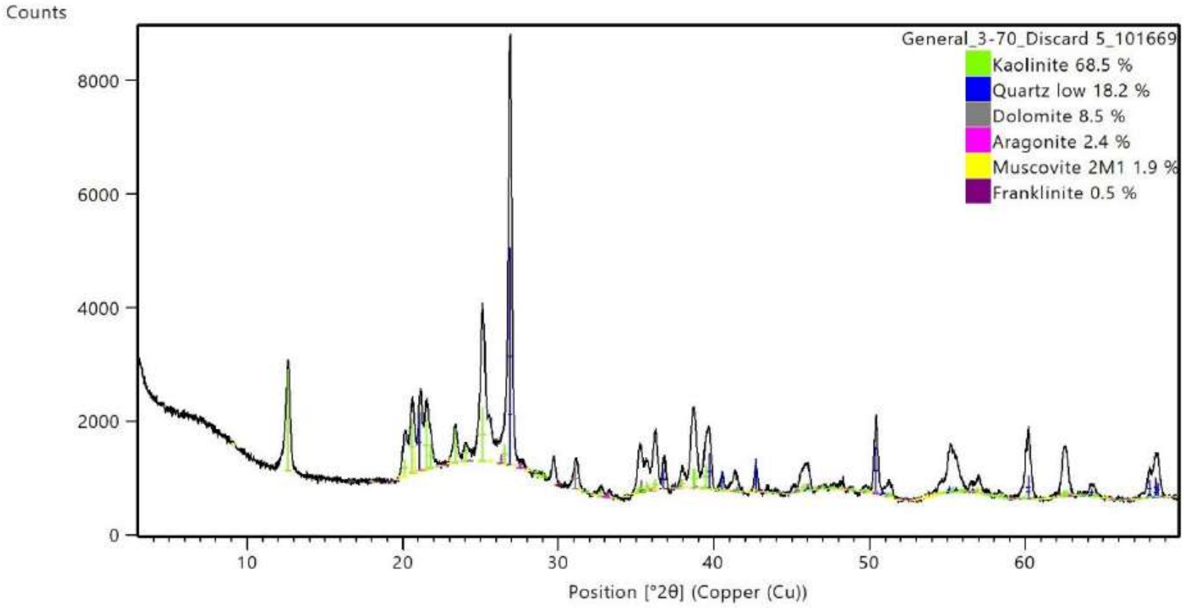
web: www.aquatico.co.za
office: 012 450 3800 • fax: 012 450 3851






Counts
General_3-70_Discard 5_101669
Kaolinite 68.5 %
Quartz low 18.2 %
Dolomite 8.5 %
Aragonite 2.4 %
Muscovite 2M1 1.9 %
Franklinite 0.5 %
8000
6000
4000
2000
0
10
20
30
40
50
60
Position [°2θ] (Copper (Cu))

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Mineral description:

Mineral	Chemical formula	Description
Anatase	TiO_2	Anatase is one of three titanium oxides; the other two are rutile and brookite. These minerals are usually found in veins in igneous and metamorphic rocks like granite pegmatites, gneiss and mica schist.
Aragonite	$CaCO_3$	Aragonite is a polymorph of the carbonate mineral calcite (i.e., the minerals have the same chemical formula but different crystal structures). Aragonite is stable under higher pressure conditions compared to calcite.
Dolomite	$CaMg(CO_3)_2$	Dolomite is a carbonate mineral composed of calcium magnesium carbonate. Dolomite can be found in sedimentary rocks, hydrothermal veins, replacement deposits and in marble.
Franklinite	$ZnFe_2O_4$	Franklinite is a zinc iron oxide which is part of the spinel group of minerals. Similar to magnetite, franklinite can contain both ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron with manganese commonly occurring together with zinc.
Illite	$KAl_5Si_7O_{20}(OH)_4$	Illite represents a group of non-expanding clay minerals that are slightly potassium deficient and more hydrated compared to true micas. Illite is commonly found in soils, clay-rich sedimentary rocks and low-grade metamorphic rocks.
Kaolinite	$Al_2Si_2O_5(OH)_4$	Kaolinite is a common clay mineral with a characteristic white colour. It is classified as a secondary mineral because it is formed through the breakdown of minerals like alkali-feldspar.
Lizardite	$Mg_3(Si_2O_5)(OH)_4$	Lizardite is part of the kaolinite-serpentine group of minerals (a group of hydrous magnesium iron phyllosilicates) typically formed during retrograde metamorphism.
Magnetite	Fe_3O_4	Magnetite is part of the spinel group of minerals. The mineral has a metallic black colour and is magnetic.
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Muscovite is a hydrated phyllosilicate mineral containing aluminium and potassium. It has a perfect basal cleavage yielding remarkably thin laminae (sheets) which are often highly elastic.
Quartz	SiO_2	Quartz is one of the most common minerals on Earth, and is present in many sedimentary, igneous and metamorphic rocks.
Spinel	XY_2O_4 X= Fe^{2+}, Mn^{2+}, Mg^{2+}, Co^{2+}, Zn^{2+}, Ni^{2+} Y= Fe^{3+}, Cr^{3+}, Al^{3+}, V^{3+}	Spinel is the name for a group of metal oxide minerals that can substitute various metals into the X and Y positions (see general formula). Magnetite and chromite are examples of some of the common spinel minerals.

References for mineral description:

1. Cairncross, B., (2004) Field Guide to Rocks and Minerals of South Africa. South Africa, Struik Nature.
2. Dutrow, B., & Klein, C., (2007) The Manual of Minerals Science. 23rd Edition, United States of America, Jay O'Callaghan

Appendix B: Column Leach Test Laboratory Certificates

Client:	Digby Wells & Associates	**Date of certificate:**	01 June 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	28 May 2020
Report no:	86749	**Date completed:**	01 June 2020
Project:	Digby Wells & Associates	**Date received:**	28 May 2020

Lab no:				11882
Date sampled:				28-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	8.24
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	35.9
N	Total alkalinity	mg CaCO3/l	ALM 01	117
N	Chloride (Cl)	mg/l	ALM 02	1.55
N	Sulphate (SO4)	mg/l	ALM 03	72.9
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.050
N	Nitrate (NO3) as N	mg/l	ALM 06	<0.194
N	Fluoride (F)	mg/l	ALM 08	0.954
N	Chemical oxygen demand (COD)	mg/l	ALM 10	45.5
N	Calcium (Ca)	mg/l	ALM 30	46.8
N	Magnesium (Mg)	mg/l	ALM 30	13.6
N	Sodium (Na)	mg/l	ALM 30	3.58
N	Potassium (K)	mg/l	ALM 30	2.40
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.042
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.004
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.008
N	Nickel (Ni)	mg/l	ALM 31	0.030
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.066
N	Boron (B)	mg/l	ALM 33	0.051
N	Barium (Ba)	mg/l	ALM 33	0.086
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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The results apply to the sample received.

H. Holtzhausen
Technical Signatory

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 86749
Project: Digby Wells & Associates

Date of certificate: 01 June 2020
Date accepted: 28 May 2020
Date completed: 01 June 2020
Date received: 28 May 2020

Lab no:				11882
Date sampled:				28-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.008
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.007
N	Lithium (Li)	mg/l	ALM 32	0.011
N	Molybdenum (Mo)	mg/l	ALM 33	0.091
N	Rubidium (Rb)	mg/l	ALM 32	0.004
N	Strontium (Sr)	mg/l	ALM 33	2.34
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84749
Project: Digby Wells & Associates

Date of certificate: 03 April 2020
Date accepted: 30 March 2020
Date completed: 03 April 2020
Date received: 30 March 2020

Lab no:				101764
Date sampled:				30-Mar-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses				
		Unit	**Method**	
N	pH @ 25°C	pH	ALM 20	7.67
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	199
N	Total alkalinity	mg CaCO3/l	ALM 01	44.9
N	Chloride (Cl)	mg/l	ALM 02	16.0
N	Sulphate (SO4)	mg/l	ALM 03	1232
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.858
N	Nitrate (NO3) as N	mg/l	ALM 06	0.578
N	Fluoride (F)	mg/l	ALM 08	0.953
N	Chemical oxygen demand (COD)	mg/l	ALM 10	64.6
N	Calcium (Ca)	mg/l	ALM 30	273
N	Magnesium (Mg)	mg/l	ALM 30	111
N	Sodium (Na)	mg/l	ALM 30	94.2
N	Potassium (K)	mg/l	ALM 30	12.0
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.190
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	<0.003
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.056
N	Nickel (Ni)	mg/l	ALM 31	0.049
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.062
N	Boron (B)	mg/l	ALM 33	0.072
N	Barium (Ba)	mg/l	ALM 33	0.163
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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H. Holtzhausen
Technical Signatory

Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84749
Project: Digby Wells & Associates

Date of certificate: 03 April 2020
Date accepted: 30 March 2020
Date completed: 03 April 2020
Date received: 30 March 2020

Lab no:				101764
Date sampled:				30-Mar-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.021
N	Silver (Ag)	mg/l	ALM 32	0.001
N	Gallium (Ga)	mg/l	ALM 32	0.008
N	Lithium (Li)	mg/l	ALM 32	0.024
N	Molybdenum (Mo)	mg/l	ALM 33	0.092
N	Rubidium (Rb)	mg/l	ALM 32	0.027
N	Strontium (Sr)	mg/l	ALM 33	4.20
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Client:	Digby Wells & Associates	**Date of certificate:**	03 April 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	31 March 2020
Report no:	84757	**Date completed:**	03 April 2020
Project:	Digby Wells & Associates	**Date received:**	31 March 2020

Lab no:				122
Date sampled:				31-Mar-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.34
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	295
N	Total alkalinity	mg CaCO3/l	ALM 01	53.7
N	Chloride (Cl)	mg/l	ALM 02	22.0
N	Sulphate (SO4)	mg/l	ALM 03	1949
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.683
N	Nitrate (NO3) as N	mg/l	ALM 06	0.764
N	Fluoride (F)	mg/l	ALM 08	1.31
N	Chemical oxygen demand (COD)	mg/l	ALM 10	143
N	Calcium (Ca)	mg/l	ALM 30	410
N	Magnesium (Mg)	mg/l	ALM 30	192
N	Sodium (Na)	mg/l	ALM 30	143
N	Potassium (K)	mg/l	ALM 30	16.3
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.128
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.008
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.045
N	Nickel (Ni)	mg/l	ALM 31	0.078
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.110
N	Boron (B)	mg/l	ALM 33	0.096
N	Barium (Ba)	mg/l	ALM 33	0.050
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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Client:	Digby Wells & Associates	**Date of certificate:**	03 April 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	31 March 2020
Report no:	84757	**Date completed:**	03 April 2020
Project:	Digby Wells & Associates	**Date received:**	31 March 2020

Lab no:				122
Date sampled:				31-Mar-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses		**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.033
N	Silver (Ag)	mg/l	ALM 32	0.002
N	Gallium (Ga)	mg/l	ALM 32	0.011
N	Lithium (Li)	mg/l	ALM 32	0.031
N	Molybdenum (Mo)	mg/l	ALM 33	0.215
N	Rubidium (Rb)	mg/l	ALM 32	0.036
N	Strontium (Sr)	mg/l	ALM 33	6.85
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84759
Project: Digby Wells & Associates

Date of certificate: 07 April 2020
Date accepted: 01 April 2020
Date completed: 07 April 2020
Date received: 01 April 2020

Lab no:				124
Date sampled:				01-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.29
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	271
N	Total alkalinity	mg CaCO3/l	ALM 01	54.9
N	Chloride (Cl)	mg/l	ALM 02	7.14
N	Sulphate (SO4)	mg/l	ALM 03	1886
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.482
N	Nitrate (NO3) as N	mg/l	ALM 06	0.601
N	Fluoride (F)	mg/l	ALM 08	1.30
N	Chemical oxygen demand (COD)	mg/l	ALM 10	7.99
N	Calcium (Ca)	mg/l	ALM 30	400
N	Magnesium (Mg)	mg/l	ALM 30	178
N	Sodium (Na)	mg/l	ALM 30	108
N	Potassium (K)	mg/l	ALM 30	14.4
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.157
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.009
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.030
N	Nickel (Ni)	mg/l	ALM 31	0.054
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.094
N	Boron (B)	mg/l	ALM 33	0.098
N	Barium (Ba)	mg/l	ALM 33	0.034
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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H. Holtzhausen
Technical Signatory

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Report no: 84759
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Date of certificate: 07 April 2020
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Date completed: 07 April 2020
Date received: 01 April 2020

Lab no:				124
Date sampled:				01-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.037
N	Silver (Ag)	mg/l	ALM 32	0.002
N	Gallium (Ga)	mg/l	ALM 32	0.011
N	Lithium (Li)	mg/l	ALM 32	0.032
N	Molybdenum (Mo)	mg/l	ALM 33	0.213
N	Rubidium (Rb)	mg/l	ALM 32	0.034
N	Strontium (Sr)	mg/l	ALM 33	6.78
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84775
Project: Digby Wells & Associates

Date of certificate: 07 April 2020
Date accepted: 02 April 2020
Date completed: 07 April 2020
Date received: 02 April 2020

Lab no:				194
Date sampled:				02-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.82
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	207
N	Total alkalinity	mg $CaCO_3$/l	ALM 01	48.2
N	Chloride (Cl)	mg/l	ALM 02	4.30
N	Sulphate (SO_4)	mg/l	ALM 03	1359
N	Orthophosphate (PO_4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH_4) as N	mg/l	ALM 05	0.443
N	Nitrate (NO_3) as N	mg/l	ALM 06	3.58
N	Fluoride (F)	mg/l	ALM 08	1.32
N	Chemical oxygen demand (COD)	mg/l	ALM 10	7.88
N	Calcium (Ca)	mg/l	ALM 30	340
N	Magnesium (Mg)	mg/l	ALM 30	128
N	Sodium (Na)	mg/l	ALM 30	63.3
N	Potassium (K)	mg/l	ALM 30	11.4
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.126
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.009
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.029
N	Nickel (Ni)	mg/l	ALM 31	0.042
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.087
N	Boron (B)	mg/l	ALM 33	0.091
N	Barium (Ba)	mg/l	ALM 33	0.039
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	02 April 2020
Report no:	84775	**Date completed:**	07 April 2020
Project:	Digby Wells & Associates	**Date received:**	02 April 2020

Lab no:				194
Date sampled:				02-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.025
N	Silver (Ag)	mg/l	ALM 32	0.002
N	Gallium (Ga)	mg/l	ALM 32	0.011
N	Lithium (Li)	mg/l	ALM 32	0.025
N	Molybdenum (Mo)	mg/l	ALM 33	0.143
N	Rubidium (Rb)	mg/l	ALM 32	0.025
N	Strontium (Sr)	mg/l	ALM 33	5.87
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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aquatico Laboratories (Pty). Ltd.

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84791
Project: Digby Wells & Associates

Date of certificate: 08 April 2020
Date accepted: 03 April 2020
Date completed: 08 April 2020
Date received: 03 April 2020

Lab no:				222
Date sampled:				03-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.90
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	155
N	Total alkalinity	mg CaCO3/l	ALM 01	53.3
N	Chloride (Cl)	mg/l	ALM 02	2.82
N	Sulphate (SO4)	mg/l	ALM 03	870
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.421
N	Nitrate (NO3) as N	mg/l	ALM 06	0.404
N	Fluoride (F)	mg/l	ALM 08	1.27
N	Chemical oxygen demand (COD)	mg/l	ALM 10	23.5
N	Calcium (Ca)	mg/l	ALM 30	220
N	Magnesium (Mg)	mg/l	ALM 30	68.7
N	Sodium (Na)	mg/l	ALM 30	30.8
N	Potassium (K)	mg/l	ALM 30	8.37
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.088
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.012
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.022
N	Nickel (Ni)	mg/l	ALM 31	0.111
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.123
N	Boron (B)	mg/l	ALM 33	0.071
N	Barium (Ba)	mg/l	ALM 33	0.042
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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Technical Signatory

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Report no: 84791
Project: Digby Wells & Associates

Date of certificate: 08 April 2020
Date accepted: 03 April 2020
Date completed: 08 April 2020
Date received: 03 April 2020

Lab no:				222
Date sampled:				03-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.019
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.009
N	Lithium (Li)	mg/l	ALM 32	0.019
N	Molybdenum (Mo)	mg/l	ALM 33	0.150
N	Rubidium (Rb)	mg/l	ALM 32	0.015
N	Strontium (Sr)	mg/l	ALM 33	4.40
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84857
Project: Digby Wells & Associates

Date of certificate: 20 April 2020
Date accepted: 08 April 2020
Date completed: 20 April 2020
Date received: 08 April 2020

Lab no:				458
Date sampled:				08-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.57
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	122
N	Total alkalinity	mg CaCO3/l	ALM 01	65.5
N	Chloride (Cl)	mg/l	ALM 02	2.20
N	Sulphate (SO4)	mg/l	ALM 03	652
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.167
N	Nitrate (NO3) as N	mg/l	ALM 06	0.487
N	Fluoride (F)	mg/l	ALM 08	1.22
N	Chemical oxygen demand (COD)	mg/l	ALM 10	54.0
N	Calcium (Ca)	mg/l	ALM 30	186
N	Magnesium (Mg)	mg/l	ALM 30	48.3
N	Sodium (Na)	mg/l	ALM 30	16.2
N	Potassium (K)	mg/l	ALM 30	5.72
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.113
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	<0.003
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.028
N	Nickel (Ni)	mg/l	ALM 31	0.051
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	1.33
N	Boron (B)	mg/l	ALM 33	0.076
N	Barium (Ba)	mg/l	ALM 33	0.044
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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aquatico Laboratories (Pty). Ltd.

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Project: Digby Wells & Associates

Date of certificate: 20 April 2020
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Date completed: 20 April 2020
Date received: 08 April 2020

Lab no:				458
Date sampled:				08-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.021
N	Lithium (Li)	mg/l	ALM 32	0.012
N	Molybdenum (Mo)	mg/l	ALM 33	0.157
N	Rubidium (Rb)	mg/l	ALM 32	0.015
N	Strontium (Sr)	mg/l	ALM 33	4.38
N	Tellurium (Te)	mg/l	ALM 32	0.003
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 84910
Project: Digby Wells & Associates

Date of certificate: 23 April 2020
Date accepted: 15 April 2020
Date completed: 23 April 2020
Date received: 15 April 2020

Lab no:				775
Date sampled:				15-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	8.03
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	82.5
N	Total alkalinity	mg CaCO3/l	ALM 01	79.0
N	Chloride (Cl)	mg/l	ALM 02	1.27
N	Sulphate (SO4)	mg/l	ALM 03	401
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.032
N	Nitrate (NO3) as N	mg/l	ALM 06	<0.194
N	Fluoride (F)	mg/l	ALM 08	1.12
N	Chemical oxygen demand (COD)	mg/l	ALM 10	51.2
N	Calcium (Ca)	mg/l	ALM 30	124
N	Magnesium (Mg)	mg/l	ALM 30	32.9
N	Sodium (Na)	mg/l	ALM 30	11.8
N	Potassium (K)	mg/l	ALM 30	4.99
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.087
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.003
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.020
N	Nickel (Ni)	mg/l	ALM 31	0.055
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.139
N	Boron (B)	mg/l	ALM 33	0.064
N	Barium (Ba)	mg/l	ALM 33	0.047
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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Client:	Digby Wells & Associates	**Date of certificate:**	23 April 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	15 April 2020
Report no:	84910	**Date completed:**	23 April 2020
Project:	Digby Wells & Associates	**Date received:**	15 April 2020

Lab no:				775
Date sampled:				15-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.016
N	Lithium (Li)	mg/l	ALM 32	0.011
N	Molybdenum (Mo)	mg/l	ALM 33	0.160
N	Rubidium (Rb)	mg/l	ALM 32	0.007
N	Strontium (Sr)	mg/l	ALM 33	3.90
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 85127
Project: Digby Wells & Associates

Date of certificate: 29 April 2020
Date accepted: 22 April 2020
Date completed: 28 April 2020
Date received: 22 April 2020

Lab no:				2162
Date sampled:				22-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	8.23
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	64.5
N	Total alkalinity	mg CaCO3/l	ALM 01	99.6
N	Chloride (Cl)	mg/l	ALM 02	1.40
N	Sulphate (SO4)	mg/l	ALM 03	274
N	Orthophosphate (PO4) as P	mg/l	ALM 04	0.021
N	Ammonium (NH4) as N	mg/l	ALM 05	0.031
N	Nitrate (NO3) as N	mg/l	ALM 06	<0.194
N	Fluoride (F)	mg/l	ALM 08	0.965
N	Chemical oxygen demand (COD)	mg/l	ALM 10	<5.10
N	Calcium (Ca)	mg/l	ALM 30	101
N	Magnesium (Mg)	mg/l	ALM 30	30.5
N	Sodium (Na)	mg/l	ALM 30	10.1
N	Potassium (K)	mg/l	ALM 30	4.60
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.077
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.005
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.019
N	Nickel (Ni)	mg/l	ALM 31	0.064
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.112
N	Boron (B)	mg/l	ALM 33	0.054
N	Barium (Ba)	mg/l	ALM 33	0.070
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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Client:	Digby Wells & Associates	**Date of certificate:**	29 April 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	22 April 2020
Report no:	85127	**Date completed:**	28 April 2020
Project:	Digby Wells & Associates	**Date received:**	22 April 2020

Lab no:				2162
Date sampled:				22-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses		**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	0.011
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.008
N	Lithium (Li)	mg/l	ALM 32	0.010
N	Molybdenum (Mo)	mg/l	ALM 33	0.142
N	Rubidium (Rb)	mg/l	ALM 32	0.009
N	Strontium (Sr)	mg/l	ALM 33	3.45
N	Tellurium (Te)	mg/l	ALM 32	0.008
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client:	Digby Wells & Associates	**Date of certificate:**	07 May 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	29 April 2020
Report no:	85408	**Date completed:**	07 May 2020
Project:	Digby Wells & Associates	**Date received:**	29 April 2020

Lab no:				3538
Date sampled:				29-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	8.07
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	53.2
N	Total alkalinity	mg CaCO3/l	ALM 01	96.7
N	Chloride (Cl)	mg/l	ALM 02	2.02
N	Sulphate (SO4)	mg/l	ALM 03	174
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.039
N	Nitrate (NO3) as N	mg/l	ALM 06	<0.194
N	Fluoride (F)	mg/l	ALM 08	0.901
N	Chemical oxygen demand (COD)	mg/l	ALM 10	78.1
N	Calcium (Ca)	mg/l	ALM 30	72.6
N	Magnesium (Mg)	mg/l	ALM 30	20.3
N	Sodium (Na)	mg/l	ALM 30	7.47
N	Potassium (K)	mg/l	ALM 30	3.49
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.057
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.005
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.016
N	Nickel (Ni)	mg/l	ALM 31	0.031
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.079
N	Boron (B)	mg/l	ALM 33	<0.013
N	Barium (Ba)	mg/l	ALM 33	0.062
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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H. Holtzhausen
Technical Signatory

Client:	Digby Wells & Associates	**Date of certificate:**	07 May 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	29 April 2020
Report no:	85408	**Date completed:**	07 May 2020
Project:	Digby Wells & Associates	**Date received:**	29 April 2020

Lab no:				3538
Date sampled:				29-Apr-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.006
N	Lithium (Li)	mg/l	ALM 32	0.013
N	Molybdenum (Mo)	mg/l	ALM 33	0.117
N	Rubidium (Rb)	mg/l	ALM 32	0.004
N	Strontium (Sr)	mg/l	ALM 33	2.86
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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aquatico
Laboratories (Pty). Ltd.

Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 85637
Project: Digby Wells & Associates

Date of certificate: 09 May 2020
Date accepted: 06 May 2020
Date completed: 09 May 2020
Date received: 06 May 2020

Lab no:				4857
Date sampled:				06-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	7.89
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	45.0
N	Total alkalinity	mg CaCO3/l	ALM 01	107
N	Chloride (Cl)	mg/l	ALM 02	0.766
N	Sulphate (SO4)	mg/l	ALM 03	117
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.078
N	Nitrate (NO3) as N	mg/l	ALM 06	0.636
N	Fluoride (F)	mg/l	ALM 08	0.879
N	Chemical oxygen demand (COD)	mg/l	ALM 10	45.0
N	Calcium (Ca)	mg/l	ALM 30	59.1
N	Magnesium (Mg)	mg/l	ALM 30	17.4
N	Sodium (Na)	mg/l	ALM 30	6.31
N	Potassium (K)	mg/l	ALM 30	3.47
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.044
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	<0.003
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.011
N	Nickel (Ni)	mg/l	ALM 31	<0.002
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.005
N	Boron (B)	mg/l	ALM 33	<0.013
N	Barium (Ba)	mg/l	ALM 33	0.067
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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H. Holtzhausen
Technical Signatory

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 85637
Project: Digby Wells & Associates

Date of certificate: 09 May 2020
Date accepted: 06 May 2020
Date completed: 09 May 2020
Date received: 06 May 2020

Lab no:				4857
Date sampled:				06-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses		**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.006
N	Lithium (Li)	mg/l	ALM 32	0.011
N	Molybdenum (Mo)	mg/l	ALM 33	0.128
N	Rubidium (Rb)	mg/l	ALM 32	0.003
N	Strontium (Sr)	mg/l	ALM 33	2.60
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Client:	Digby Wells & Associates	**Date of certificate:**	15 May 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	13 May 2020
Report no:	85951	**Date completed:**	15 May 2020
Project:	Digby Wells & Associates	**Date received:**	13 May 2020

Lab no:				6915
Date sampled:				13-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses				
		Unit	**Method**	
N	pH @ 25°C	pH	ALM 20	7.71
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	39.2
N	Total alkalinity	mg CaCO3/l	ALM 01	88.0
N	Chloride (Cl)	mg/l	ALM 02	0.892
N	Sulphate (SO4)	mg/l	ALM 03	97.8
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.059
N	Nitrate (NO3) as N	mg/l	ALM 06	0.566
N	Fluoride (F)	mg/l	ALM 08	0.866
N	Chemical oxygen demand (COD)	mg/l	ALM 10	40.8
N	Calcium (Ca)	mg/l	ALM 30	51.2
N	Magnesium (Mg)	mg/l	ALM 30	15.3
N	Sodium (Na)	mg/l	ALM 30	5.50
N	Potassium (K)	mg/l	ALM 30	2.88
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.177
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.003
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.011
N	Nickel (Ni)	mg/l	ALM 31	0.018
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.276
N	Boron (B)	mg/l	ALM 33	<0.013
N	Barium (Ba)	mg/l	ALM 33	0.090
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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M. Swanepoel
Technical Signatory

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 85951
Project: Digby Wells & Associates

Date of certificate: 15 May 2020
Date accepted: 13 May 2020
Date completed: 15 May 2020
Date received: 13 May 2020

Lab no:				6915
Date sampled:				13-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
Analyses		**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.006
N	Lithium (Li)	mg/l	ALM 32	0.010
N	Molybdenum (Mo)	mg/l	ALM 33	0.090
N	Rubidium (Rb)	mg/l	ALM 32	0.004
N	Strontium (Sr)	mg/l	ALM 33	2.49
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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Test Report

Client:	Digby Wells & Associates	**Date of certificate:**	25 May 2020
Address:	48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191	**Date accepted:**	20 May 2020
Report no:	86331	**Date completed:**	25 May 2020
Project:	Digby Wells & Associates	**Date received:**	20 May 2020

Lab no:				9035
Date sampled:				20-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	pH @ 25°C	pH	ALM 20	8.18
N	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	38.7
N	Total alkalinity	mg CaCO3/l	ALM 01	121
N	Chloride (Cl)	mg/l	ALM 02	0.634
N	Sulphate (SO4)	mg/l	ALM 03	88.3
N	Orthophosphate (PO4) as P	mg/l	ALM 04	<0.005
N	Ammonium (NH4) as N	mg/l	ALM 05	0.059
N	Nitrate (NO3) as N	mg/l	ALM 06	<0.194
N	Fluoride (F)	mg/l	ALM 08	0.849
N	Chemical oxygen demand (COD)	mg/l	ALM 10	<5.10
N	Calcium (Ca)	mg/l	ALM 30	51.9
N	Magnesium (Mg)	mg/l	ALM 30	15.1
N	Sodium (Na)	mg/l	ALM 30	4.32
N	Potassium (K)	mg/l	ALM 30	2.84
N	Aluminium (Al)	mg/l	ALM 31	<0.002
N	Iron (Fe)	mg/l	ALM 31	<0.004
N	Manganese (Mn)	mg/l	ALM 31	0.041
N	Cadmium (Cd)	mg/l	ALM 31	<0.002
N	Cobalt (Co)	mg/l	ALM 31	0.007
N	Chromium (Cr)	mg/l	ALM 31	<0.003
N	Copper (Cu)	mg/l	ALM 31	0.009
N	Nickel (Ni)	mg/l	ALM 31	0.030
N	Lead (Pb)	mg/l	ALM 31	<0.004
N	Zinc (Zn)	mg/l	ALM 31	0.077
N	Boron (B)	mg/l	ALM 33	0.033
N	Barium (Ba)	mg/l	ALM 33	0.095
N	Beryllium (Be)	mg/l	ALM 33	<0.005
N	Vanadium (V)	mg/l	ALM 33	<0.001

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H. Holtzhausen
Technical Signatory

Test Report

Client: Digby Wells & Associates
Address: 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
Report no: 86331
Project: Digby Wells & Associates

Date of certificate: 25 May 2020
Date accepted: 20 May 2020
Date completed: 25 May 2020
Date received: 20 May 2020

Lab no:				9035
Date sampled:				20-May-20
Aquatico sampled:				No
Sample type:				Geochem
Locality description:				Slurry
	Analyses	**Unit**	**Method**	
N	Bismuth (Bi)	mg/l	ALM 32	<0.004
N	Silver (Ag)	mg/l	ALM 32	<0.001
N	Gallium (Ga)	mg/l	ALM 32	0.006
N	Lithium (Li)	mg/l	ALM 32	0.011
N	Molybdenum (Mo)	mg/l	ALM 33	0.095
N	Rubidium (Rb)	mg/l	ALM 32	0.004
N	Strontium (Sr)	mg/l	ALM 33	2.54
N	Tellurium (Te)	mg/l	ALM 32	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037

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