APPENDIX E: GEOHYDROLOGY STUDY

GEOHYDROLOGICAL ASSESSMENT REPORT: JINDAL IRON ORE MINE

Melmoth, KwaZulu Natal

Prepared for: Jindal Iron Ore (Pty) Ltd

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- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the Specialist

Name of Company: SLR Consulting (Pty) Ltd

Date: 20 April 2023

EXECUTIVE SUMMARY

A geohydrological assessment was completed as part of the specialist investigation for the Environmental and Social Impact Assessment (ESIA) study underway for the Jindal Iron Ore Mine situated in Melmoth, KwaZulu Natal. The objective of the study was to characterise the current groundwater conditions in the study area, determine expected impacts on the groundwater resources and recommend mitigation measures should the mining project commence.

The catchment is inhabited by rural communities while commercial crop farming is widespread in the lower areas of the catchment along the Mhlatuze River. There are no other mining operations presently developed within the catchment area.

Considering hydrogeological conditions and utilisation, the assessment focuses on the proposed open pit, waste rock dump (WRD) and tailings storage facility (TSF). The TSF is included in this study (although in a very early phase) in order to look at the impacts on groundwater in a cumulative and consolidated way as is required for the Water Use Licence Application (WULA).

Hydrocensus

Four boreholes were surveyed during this hydrocensus. Most boreholes are used for a combination of domestic and agricultural irrigation. At each location the physical properties of the borehole were recorded, and details obtained. A further four surface water bodies were identified and appropriately sampled. The hydrocensus data is included in Appendix A. **Error! Reference source not found.** shows the locality map of the boreholes and surface water sites visited during the hydrocensus and indicates which of these boreholes are used for domestic, livestock and/ or prospecting purposes. With reference to **Error! Reference source not found.**, it is important to note that water level measurements were not obtainable due to access issues. The results of the hydrocensus are documented in Section 5.6.

Open pit area

The open pit has a proposed Life of Mine (LOM) of 25 years, however the model was done for a slightly extended period, i.e., 31 years, with a final pit elevation of 96 metres above mean sea level (mamsl) (± 300 m below the lowest elevation on the pit boundary), extending 4.45 km longitudinally (west to east) and 1 km at the widest area (north to south). This information was provided by AB Global in the Bankable Feasibility Study Report. The pit targets an outcrop comprising of amphibolite, gneiss and mica schist. The hydrogeological conditions are complex with varied water levels measured over short distances. The mean hydraulic head in the pit area is 450 mamsl while aquifer testing in the pit area had varied results ranging between 7 – 53 m^2/d (from 4 boreholes) and the borehole logs revealed that water strikes were not encountered above 180 m below surface. It was interpreted that the hydraulic conductivity increases with depth in the mine pit area. the following are summarised in terms of groundwater ingress, cone of depression, reduction in baseflow and post mining pit lake:

- **Groundwater ingress**; based on the conceptual model developed, ingress to the open pit is expected to be low (< 5 l/s) at elevation above 440 mamsl, with increasing depth ingress expected to gradually increase over time. Two scenarios were simulated to account for the uncertainty of hydraulic conductivity in the pit area. A range in peak inflows for the pit from 37 l/s to 80 l/s were applied to the model.
- **Cone of depression;** dewatering of the open pit will result in a cone of depression. The extent of drawdown, where drawdown exceeds 5 m relative to the steady state water level, is up to 2.5 km in a westerly direction, 1.6 km in a southerly direction, 1.2 km in a northerly direction and 1 km in an easterly direction. Groundwater users that fall within this area are expected to have a notable drawdown in water level in supply boreholes. The farm areas on which drawdown, exceeding 5 m, is expected to occur includes: Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871 and Maranqapawlu 15351.
- **Reduction in baseflow;** the dewatering of the aquifers around the pit area, results in a reduction of groundwater that would have ultimately discharged to the rivers in the catchment as baseflow. The assessment of reduction in baseflow indicated that a 9 % reduction in baseflow is expected over the operational period of the mine. Relative to stream flow, a 0.5 % reduction in stream flow is expected in the catchment at life of mine.
- **Post mining pit lake;** post mining a pit lake is expected to develop in the open pit. In the first 16 years following completion of mining, the recovery in water level is anticipated to be rapid (rise to ± 300 mamsl). Beyond 16 years to 160 years the pit level gradually rises by ± 74 m. The pit lake is expected to stabilise at this elevation between 160 and 300 years. The lowest elevation on the pit perimeter is 405 mamsl. Consequently, the pit lake is expected to remain below the edge of the pit and no decant/spillage will occur. Evaporation effects are expected to create a persistent sink. As consequence a pollution plume is not expected to develop from the pit area post mining. If a pit lake is allowed to form, it will be able to be used by the community as a reservoir with the associated benefits to agriculture etc of an additional water supply. If the pit is required to be backfilled this will not be relevant.

While this geohydrological assessment report considers the entire mine site, two features are of particular importance regarding groundwater, i.e., the Waste Rock Dump (WRD) and Tailings Storage Facility (TSF), due their respective significance in relation to the groundwater impact assessment.

Waste rock dump (WRD)

The WRD is located on the granites located north of the open pit. A large fault zone runs through the central portion of the WRD. The terrain proposed for the WRD undulates with hilltops exceeding 600 mamsl and valleys at 370 mamsl. Several small drainages flow in the valley areas proposed for the waste rock deposition.

A source term characterisation was completed for the various types of waste rock expected to be deposited on the facility. In all cases there are no potential contaminants of concern expected i.e., seepage quality is well within drinking water quality guidelines.

Seepage generated within the facility is expected to flow toward topographical low points and ultimately into the Nkwalinye River which is a tributary of the Mhaltuze. Seepage discharging into the river channel is not expected to negatively impact water quality and therefore it is not expected that downgradient water users would be impacted by water quality issues.

Tailings storage facility (TSF)

The TSF and the return water dam are located on the farms Bridgeford 12024 GU, Perseverance 15645, Umhlatuzi 11133 GU and Riversbend 15644. The surface area of the proposed TSF is 9 300 000 m^2 and the return water dam has a footprint of 710 000 m^2.

The TSF and return water dam are situated on shales of Pietermaritzburg formation. No aquifer testing has been completed in the formation, and it is generally expected that the formation has a low permeability. However, local fracturing and weathering may constitute preferential flow paths. The shales are underlain by Dwyka formation tillite which is expected to have a very low permeability at depth.

Groundwater levels in proximity of the TSF are shallow (2.6 metres below ground level (mbgl) to 5.9 mbgl). The footprint area is presently drained by a tributary which flows west to east. The general flow direction from the TSF is northerly toward the Mhlatuze River and its drainages.

The source term characterisation of the TSF found that only aluminium is a potential constituent of concern. No other macro or trace metal concentrations exceed drinking water quality. The TSF is proposed to be lined with either a high density polyethylene (HDPE) liner or a geosynthetic clay liner (GCL). Two scenarios in the model were considered, however, one where the TSF is unlined and a second where the TSF is lined with a GCL liner.

- Where unlined seepage from the facility is expected to reach the Mhlatuze river, in the context of river flows, the contribution from the TSF was small and would account for 3 % of flow rates in the river downgradient of the TSF. At this mixing ratio, it is unlikely that high aluminium concentrations would occur in the river system.
- Where the TSF is lined the seepage from the facility is not expected to migrate beyond the footprint of the TSF during life of the operation. Post operation, the facility will be rehabilitated so that precipitation runs off and surface water and does not infiltrate the waste material.

Recommendations

Following completion of the hydrogeological study the following data limitations and gaps need to be addressed before proceeding with the mining operation.

- Water level and water quality data:

 - Water level data in the pit area is outdated as water level measurements were last measured in 2014. Access issues from the local community were experienced in attempts to obtain more current data. Access needs to be arranged to revisit the boreholes in the pit area and collect current water level data. It was also observed that core holes had, in some case, deeper than expected water levels and re-examination of these water levels is required.
 - There is currently no hydrocensus information on adjacent farms to the mining areas. In particular, the current water users and characteristics of boreholes on the farms Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351. These areas may potentially become impacted by mine dewatering thus a hydrocensus to ascertain the current status is required to provide mitigation measures to water users in this area.
 - Currently, only once off water levels are available in the study area and many date to the Golder (2015) study. Therefore, monthly water level monitoring and quarterly quality monitoring should proceed to establish a sound baseline for potential future mining.
 - No water quality monitoring is currently available for the pit area (Pit and WRD). This information is necessary for baseline establishment.
- Drilling and aquifer characterisation:
 - Existing boreholes in the pit area occur within the pit footprint. Therefore, additional boreholes must be sited and drilled on the periphery of the pit to serve as long term monitoring boreholes.
 - Currently aquifer characterisation in the pit area is based on two pumping tests and two slug tests. Due to very limited data, there is significant uncertainty regarding hydraulic conductivity of the formations present within the pit. It is therefore recommended to undertake a drilling and aquifer testing program within the pit area.
 - Packer testing should be completed in existing boreholes within the pit area to characterise the hydraulic conductivity at various depths throughout the formations.
 - There are currently no water level or aquifer parameters for the granites north of the pit where the WRD facility is proposed. Therefore, borehole drilling and aquifer testing is required and recommended in this area to characterise the lithology and hydrogeology as well as serve as long term monitoring locations up and downgradient of the WRD facility.
 - The boreholes recently drilled at the TSF must be tested to confirm the hydraulic conductivity values assumed within the modelling.
- Water supply requirements for the project at different phases i.e., construction and operational are uncertain. Therefore, clarification on whether groundwater will be required for water supply needs to be addressed and associated impacts need to be reviewed.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
CDT	Constant Discharge Test
CMA	Catchment Management Area
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
ID	Inner diameter
K	Permeability
KZN	Kwa-Zulu Natal
LOM	Life of Mine
MAE	Mean annual evaporation
mamsl	Meters above mean sea level
MAP	Mean annual precipitation
Mbgl	Meters below ground level
MRA	Mining right application
mS/m	Microsiemens per meter
NEMA	National Environmental Management Act (No. 107 of 1998), as amended
NEM:AQA	National Environmental Management: Air Quality Act
NWA	National Water Act (No. 36 of 1998), as amended
RC	Reverse circulation
ROM	Run of mine
SAWQC	South African Water Quality Guidelines
SLR	SLR Consulting (South Africa) (Pty) Ltd
T	Transmissivity
TDS	Total dissolved solids
TSF	Tailings storage facility
WML	Waste management licence
WRD	Waste rock dump
WUL	Water Use Licence
WULA	Water Use Licence Application

Geohydrological Assessment Report: Jindal Iron Ore Mine

1. INTRODUCTION

1.1 PROJECT BACKGROUND

Jindal Mining Iron Ore (Pty) Ltd. (Jindal), the South African operating subsidiary of the multinational Indian conglomerate Jindal Steel and Power Limited (JSPL) holds two prospecting rights for two areas of land; the North Block and the South Block, 25 km southeast of Melmoth in the Kwa-Zulu Natal province (KZN), South Africa (Figure 1-1).

The North Block, PR 10644, is approximately 8,47 ha while the South Block, PR 10652, is 11,70 ha. Both prospecting rights have been renewed once with their expiry dates on the 17th of February 2022 and 24th of January 2022, respectively. It is anticipated that one Mining Right Application (MRA) will incorporate both blocks. Jindal appointed Wood to conduct a Bankable Feasibility Study (BFS) to determine the technical and financial feasibility of establishing an iron ore mining operation on site. Jindal now wishes to submit a MRA prior to the expiration of the prospecting rights.

1.2 LEGAL AUTHORISATIONS REQUIRED FOR THE PROPOSED PROJECT

Jindal's intent with their Mining Right Application (MRA) is to consolidate the Prospecting Rights for the North and South blocks into a single Mining Right. However, development of the mine and mining infrastructure would be undertaken in a phased approach with mining currently only proposed to be undertaken in the south-eastern section of the South Block, where the iron ore resource has been defined through previous prospecting. Infrastructure would be developed to support this mining operation. The MRA and EIA will consider the entire extent of the MRA area, but with a specific focus on Phase 1 of the Melmoth Iron Ore Project. The activities relating to mining and plant operations include the following:

- New Water pipelines for water supply
- New sewage, recycle water and process and potable water pipelines network servicing the mine, plant, laboratory, offices, workshop facilities.
- The construction and operation of a new substation (including transformer yard) and transmission lines with a capacity of up to 33 kV to provide electricity to infrastructure within the footprint of the mine, i.e., processing plant, offices, etc.
- Storage and handling of dangerous goods, i.e., diesel, oil, and other lubricants, etc.
- Construction of site infrastructure
- Construction of on-site haul and access roads.
- Construction and operation of a Sewage and Water Treatment Plant
- Excavation and processing of rock;
- Haulage to the run of mine (ROM) stockpile; and
- Backfilling / rehabilitation.
- Establishment of a Waste Rock Dump (WRD)
- Tailings storage facility (TSF);

The project requires an environmental authorisation under the National Environmental Management Act (NEMA) (Act 107 of 1998), a Waste Management Licence (WML) under the National Environmental Management: Waste Act (NEM:WA) (Act 59 of 2008), and a Water Use Licence (WUL) under the National Water Act (NWA) (Act 36 of 1998).

This report addresses the requirements for a groundwater specialist study in terms of NEMA and NWA, in terms of the mine. In terms of Section 21 of the NWA, the relevant water uses are as follows:

- Section 21 (a) – Taking water from a water resource
- Section 21 (c) - Impeding or diverting the flow of water in a watercourse,
- Section 21 (f) – Discharging waste or water containing waste into a water resource.
- Section 21 (g) – Disposing of waste in a manner which may detrimentally impact a water resource, and
- Section 21 (i) – Altering the bed, banks, course, or characteristics of a watercourse.
- Section 21 (j) – Removing, discharging or disposing of water found underground if it is necessary of the efficient continuation of an activity or for the safety of the people.

Table 1-1 provides a quick look-up for all relevant specialist report requirements.

Table 1-1: Specialist Report Requirements

Requirement from Appendix 6 of GN 326 EIA Regulation 2017	Section
(a) Details of - (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Before Executive Summary. CV attached.
(b) Declaration that the specialist is independent in a form as may be specified by the competent authority	Before Executive Summary.
(c) Indication of the scope of, and the purpose for which, the report was prepared	2
(cA)an indication of the quality and age of base data used for the specialist report	4
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	9
(d) Duration, Date and season of the site investigation and the relevance of the season to the outcome of the assessment	4
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	4
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of site plan identifying site alternatives;	1.2
(g) Identification of any areas to be avoided, including buffers	10

Requirement from Appendix 6 of GN 326 EIA Regulation 2017	Section
(h) Map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers	8
(I) Description of any assumptions made and any uncertainties or gaps in knowledge	1.4
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity including identified alternatives on the environment or activities;	8.8 and 9
(k) Mitigation measures for inclusion in the EMPr	9, 10 and 11
(I) Conditions for inclusion in the environmental authorisation	10 and 11
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	10
(n) Reasoned opinion - (i) as to whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and (ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	13
(o) Description of any consultation process that was undertaken during the course of preparing the specialist report	N/A
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	N/A
(q) Any other information requested by the competent authority	N/A

1.3 SPECIALIST DETAILS

Mihai Muresan is a Principal Hydrogeologist with more than 30 years of professional experience in mine dewatering, numerical modelling, geochemical modelling, project management and environmental consultancy. He possesses strong analytical and problem-solving skills with an excellent understanding of technical concepts related to the mining hydrogeology.

Preanna Naicker is a Hydrogeologist within SLR specializing in groundwater within SLR's Hydrology and Hydrogeology service in South Africa. Preanna has over 5 years of experience within Hydrogeology as well as on a project management level. Preanna has managed a wide range of major projects which include groundwater supply, exploration, groundwater monitoring as well as specialist studies which form part of Environmental Impact Assessment projects for major minerals developments throughout South Africa for many of the major commercial companies, as well as government.

1.4 ASSUMPTIONS AND LIMITATIONS

The following challenges were faced when executing the scope of work, thus limiting outcomes of the hydrogeological investigation. Further, the influence of these limitations are discussed in the relevant sections within the report and they also have influence on the recommendations made.

- Although there was a recommendation made for new boreholes only be drilled in the mining area; this was not completed due to accessibility issues.
- Recharge was estimated by the chloride mass balance for the shales. Due to limited water quality data, quantification of recharge based on measured data was not possible. Therefore the recharge was estimated and calibrated within the model.
- Only four aquifer tests have been completed in the study area. All four boreholes are located within the pit area. The transmissivities obtained varied between 7 m^2/d and 53 m^2/d. High variability is typical of fractured rock aquifers. The Golder (2015) study reported that the confidence of the test at MWGA03 is low due to artesian conditions within the borehole. The variability in results, however, reduces the certainty when applying a representative hydraulic conductivity in the pit area. To address the uncertainty, a range in hydraulic conductivity values for the pit area was included in the assessment to improve model outcomes.
- The current aquifer parameter data for the pit is very limited and the modelling presented here is suitable for ESIA level impact prediction and high-level estimation of ingress to the pit. The model is not suitable for developing a detailed dewatering strategy for the pit i.e., quantifying pore pressure difference in the pit wall and recommending suitable locations for dewatering boreholes.
- Records of water strikes in the pit boreholes indicated that there were very few water strikes obtained between surface and 180 mbgl. It has been assumed that the upper aquifer zones are less conductive than the deeper zones within the pit. The available aquifer testing does not however differentiate the two zones and hence the conductivity values for the upper and lower zone are required to be assumed.
- For the current study, three water levels were measured at the TSF boreholes that were recently drilled. TSF05-2, TSF05-03 and TSF05-01. No water level data was available for TSF05-01 and TSF05-05.
- Historical water levels collected by Golder (2015) were used to characterise the pit area. Access issues prevented an update of water levels in the pit area. The water levels have been plotted against elevation to determine if any deviations occur from the expected trend. The diamond drill holes STH-69, STH-57, STH-71, are considered outliers (i.e., not following the trend) – showing deeper water levels than expected. It is likely that these water levels are not in line with the regional water levels for the aquifer and were still recovering at the time of sampling. This should be validated by remeasurement of the water levels in the boreholes.
- There is no water level information in proximity of the WRD and consequently the water level conditions are inferred from water levels in the pit area.

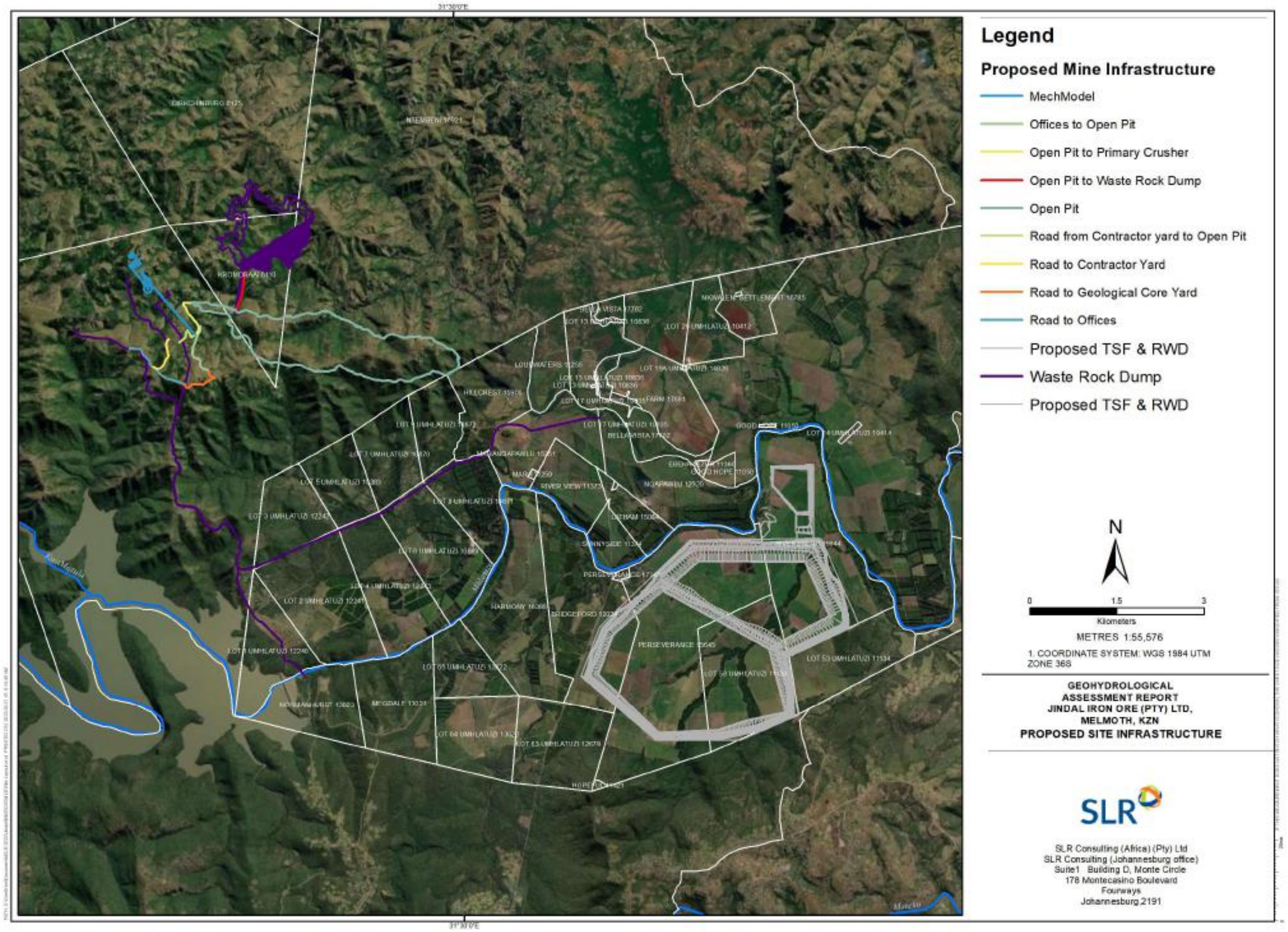


Figure 1-1: General site layout

2. SCOPE OF WORK

The following activities formed part of the work undertaken by SLR:

- Conduct site visit and desktop study to collate all existing geological, hydrogeological and mining information.
- Conduct a hydrocensus on a 5 km radius around the proposed mine; groundwater levels and water quality field parameters to be recorded; a water sample to be collected from each borehole and the samples submitted to an accredited laboratory.
- Drilling specification and locations for several groundwater boreholes in the Northern Block area and around the proposed TSF, to investigate the groundwater conditions, and for future monitoring of the TSF.
- Development of a hydrogeological conceptual model, to represent the hydrogeological units, groundwater flow directions and be the basis of the numerical groundwater model.
- Construction of a 3-dimensional numerical groundwater model to simulate the baseline conditions and how these will change during mining; the numerical model was to be run in transient mode and will also be used to simulate possible migration of a contaminant plume from the proposed source term facilities; due to the fact that there is a relatively short distance between the Northern and Southern Blocks, a single groundwater numerical model to include both Northern and Southern mining areas sufficed. Although the numerical simulation is focused on the Southern Block, the model caters for Northern Block simulation, at a later stage, if required.
- Interpretation of numerical model outcomes to inform the Impact Assessment of the mining activities on groundwater in terms of both quantity and quality.
- Document the findings in a format compatible for the NEMA and NWA requirements.

3. GEOGRAPHICAL SETTING

The topography, drainage and climate characteristics of the site are detailed below.

3.1 TOPOGRAPHY AND DRAINAGE

The site is located on the east coast of South Africa, within Kwa-Zulu Natal province, approximately 15 km southeast of the town of Melmoth. The terrain is mountainous with extensive hills characterising the area. This is seen by the valleys and mountains in the area having an elevation difference of approximately 650 mamsl (Golder, 2015).

The study site falls within the Mhlathuze River catchment (Quaternary Catchment W12D), within the Usuthu to Mhlathuze Catchment Management Area (CMA). The natural drainage systems flow in an eastern direction towards the Mhlathuze outlet, which flows into the Indian Ocean.

3.2 CLIMATE

This project site climate data was obtained from the Water Resources Study (WR2012) (WRC, 2021), which comprises the climatic and catchment information of each quaternary catchment in South Africa. The regional climate is classified as a sub-tropical climate with warm, humid summers and moderately cold and dry winters. The average summer mid-day temperature recorded in Melmoth is 26.5 ^{o}C, and winter mid-day temperature of 20.3 ^{o}C.

The site's Mean Annual Precipitation (MAP), and Mean Annual Evaporation (MAE), respectively, are to be 870 mm and 1 383 mm, respectively (Table 3-1). The evaporation in the area is relatively higher than the amount of rainfall this catchment receives. The monthly distribution of the rainfall and evaporation is presented in Figure 3-1.

Table 3-1: Quaternary Catchment Parameters

Quaternary Catchment	Evaporation	Rainfall	
	MAE WR2005 (mm)	Rainfall zone	MAP (mm)
W12B	1 400	W1B	932
W12C	1 400	W1C	848
W12D	1 350	W1C	848
Average	**1 383**	**-**	**870**

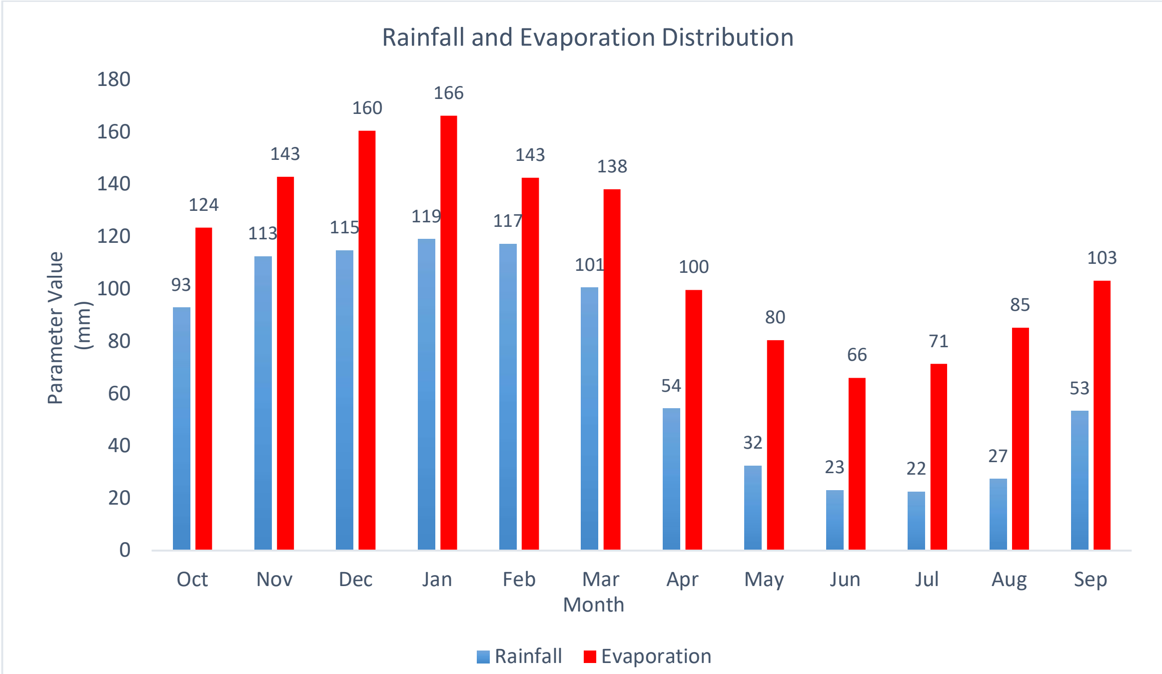


Figure 3-1: Rainfall and Evaporation Distribution Around the Project Site

4. METHODOLOGY

Detailed methodology adopted for each aspect of the scope of work is described in the sections below.

4.1 DESK STUDY

Information was sourced from work previously completed by Golder Associates Africa (Pty) Ltd in 2015 for the client, with the interim study carried out, and previous work undertaken by SLR that was reviewed to inform the compilation of this report includes:

- SLR (2022) Jindal Geochemical Risk Assessment for Waste Rock and Ore Rock.
- SLR (2021) Jindal Melmoth Iron Ore Project Specialist Scoping Report – Hydrogeology.
- SLR Consulting (2021) Jindal Melmoth Iron Ore Project Surface Water Scoping Report.
- Golder Associates Africa (Pty) Ltd. (2015) Interim hydrogeological study and modelling report.
- AB Global Mining. (2021). Pre-feasibility Study Update: Mining Study Report.

A review of existing information was undertaken to collate all pertinent data such as geological information, hydrogeological information, and proposed mining related information The information obtained from this desk study was also used to develop the conceptual hydrogeology for the site detailed within this report.

4.2 HYDROCENSUS

SLR undertook a hydrocensus for the proposed project in June 2022. The hydrocensus was undertaken within a 5 km radius of the proposed project area. The hydrocensus was only carried out in the southern part of the study area as access could not be obtained for the northern mining area. The purpose of the hydrocensus was:

- To identify boreholes within the vicinity of the proposed project area and to confirm the use of these boreholes;
- To obtain an understanding of the current water levels within and around the proposed project area; and
- To obtain an understanding of the baseline groundwater and surface water quality within and around the proposed project area.

4.3 GEOPHYSICAL SURVEY AND RESULTS

Geophysical surveys were not used to guide the siting of TSF monitoring boreholes. The location of boreholes was selected based on mapped geology and proposed site infrastructure.

4.4 DRILLING AND SITING OF BOREHOLES

The monitoring boreholes in the Pit areas were sited by Golder (2015) and were based on the mining plan at the time of investigation.

Drilling completed by Golder (2015) in the pit area and the recent drilling at the TSF completed by SLR, applied reverse circulation rotary air (RC) method while 1 m samples of the lithology were logged. The upper weathered zone was drilled using a 200 mm (8") drill diameter, after which, PVC casing was installed to prevent collapse and sample contamination. The remainder of each borehole was then drilled with a 146 mm (5¾") drill diameter and equipped with 90 mm ID PVC casing to the bottom. The casing was screened at water strike depths

4.5 AQUIFER TEST

A slug test was carried out by injecting or removing a known volume into a well followed by measuring the rate at which the water level declines/recovers. The test is to interpret hydraulic properties of the site. The injection produces an instantaneous head above the static water level that lowers over time back to static water level. Removal of volume produces negative head which recovers over time. The rate in which the water level declines/recovers in a borehole is directly correlated with hydraulic conductivity of the aquifer.

This test was suited for low to medium yielding boreholes as water is allowed to flow through connected pore spaces and available fracture networks. High yielding boreholes and boreholes with cavities or large open fractures do not allow for sufficient change in head in measurable duration and therefore slug tests provide less accurate data under these circumstances (Golder, 2015).

The minimum slug duration of 55 minutes was monitored using Solinst level loggers ® installed in the well.

Data analysis and interpretation was performed using HydroBench v.3.6.2. software developed by Golder Associates.

Pump-out tests were carried out by removing water from the aquifer at a known rate and measuring water level drawdown simultaneously. After the pumping phase is complete, recovery of water levels is measured for a time period equal to the pump time or until a general recovery trend judged suitable for analysis can be established.

The value of test pumping over slug testing comes from the longer duration of the tests. This combination tests a much larger volume of the aquifer around the borehole and integrates some of the anisotropy in fracturing, providing a better representation for groundwater resource analysis.

4.6 SAMPLING AND CHEMICAL ANALYSIS

Twelve groundwater samples from existing and drilled boreholes were submitted for chemical analyses, as documented in Golder (2015).

The physical water quality parameters considered include temperature, pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC). Temperature is critical factor for water quality, and significant in terms of the aquatic system. pH is a known standard measure of acidity and alkalinity, as it impacts many chemical reactions within living organisms, where a pH value of 7 represents a neutral condition. TDS and EC are both parameters used to evaluate and represent the salinity of water.

4.7 GROUNDWATER RECHARGE CALCULATIONS

The Chloride Mass Balance method (CMB) was used to estimate recharge in the TSF area. The mean annual rainfall was used as a guide to approximate the chloride in rainfall and the chloride dry deposition based on Bredenkamp (1995) using the chloride mass balance method recharge on the Karoo sediments in proximity of the TSF is 6.4 mm/a or 0.8 % of MAP (Figure 4-1 and Table 4-1).

The water chemistry results completed by Golder (2015) were not published in the report obtained and consequently a similar approximation for recharge in the pit areas was not possible.

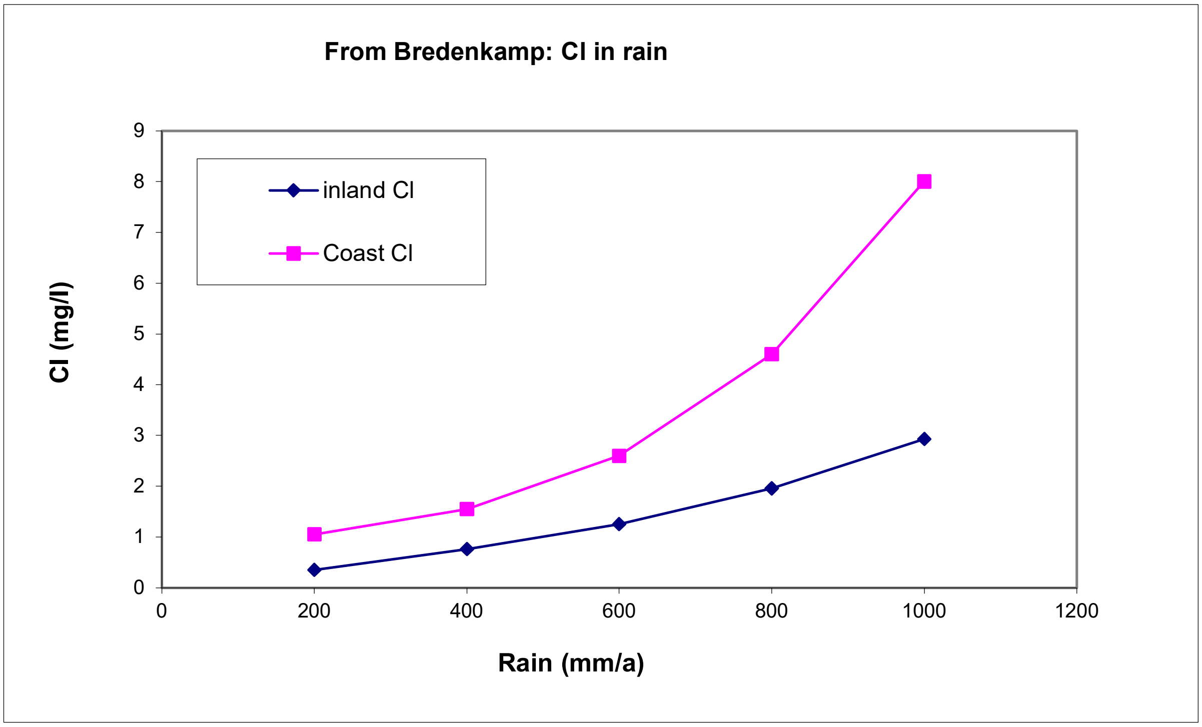


Figure 4-1: Approximation of chloride in rainfall (Bredenkamp, 1995)

Table 4-1: Estimated recharge based on the mass balance method

Parameter	Value	Comment
Average annual rainfall (mm)	730	Based on rainfall data for the site
Cl in rain (mg/l)	1.55	Based on the interpretation by Bredenkamp (above)
Dry deposition Cl (mg/l)	2.4025	Based on the interpretation by Bredenkamp (above)
Cl in Groundwater or Unsaturated zone (mg/l)	450	Based on average chloride in groundwater in TSF 05 Boreholes

Parameter	Value	Comment
Average annual recharge (mm)	6.4	Chloride mass balance
Percentage recharge	0.88	

4.8 GROUNDWATER MODELLING

A three-dimensional numerical model was developed in Feflow, a finite element software modelling package for simulating sub-surface flow and mass transport. The numerical model was developed based on the conceptualization of the site drawn on available site data and assumptions.

The scope of work for the proposed project includes the preparation of a numerical model that provides for the following:

- A model which simulates the impacts associated with drawdown as a consequence of lowering the water table to ensure dry mining conditions in the open cast pit;
- A mass transport simulation of the proposed WRD and TSF during the operational and closure phase.
- Post closure conditions of the pit.

4.9 GROUNDWATER AVAILABILITY ASSESSMENT

The assessment of groundwater availability for water supply for the current project is based upon an assessment of the available yields for groundwater abstraction determined from the aquifer testing (Section 4.5) and the determination of impacts from the numerical model due to long terms abstraction at the mine site (Section 7.7).

5. PREVAILING GROUNDWATER CONDITIONS

The following sections detail the hydrogeological environment which forms the basis for the conceptual understanding of the system.

5.1 GEOLOGY

5.1.1 Regional and local geology

The study site lies within the Ilangwe Greenstone Belt, which is separated from various granitoids to the north and south by major tectonic contacts (Mathe, 1997). The rocks of lIangwe Greenstone Belt form part of the Nondweni Group, which is divided into a lower Umhlathuze Subgroup (a suite of mafic-ultramafic metavolcanic suite) and upper Nkandla Subgroup, a meta-sedimentary suite. Both units host banded iron formation (BIF), which is the iron resource at Melmoth. The Mtonjaneni Iron Formation falls under the Swaziland Supergroup. This sequence is represented by Archean potassic granites and gneisses, surrounded by the Natal sediments, and these Archean granites and gneisses in this area appear to be highly faulted. The Mtonjaneni Iron Formation consists of magnetite grunerite-quartz schist. The Banded Iron Formation (BIF) outcrops on the surface that is visible in some areas of the concession area. Meta-dolerite dykes of Karoo age intrude the Mtonjaneni Iron Formation.

The younger Natal Group and Karoo sediments that are present in the south of the study area are juxtaposed against older basement granites by a regionally extensive thrust fault. The Natal Group which outcrops in the southwestern area of the study, is overlain by Dwyka formation tillite which in turn is overlain by Pietermaritzburg formation rock (Figure 5-1).

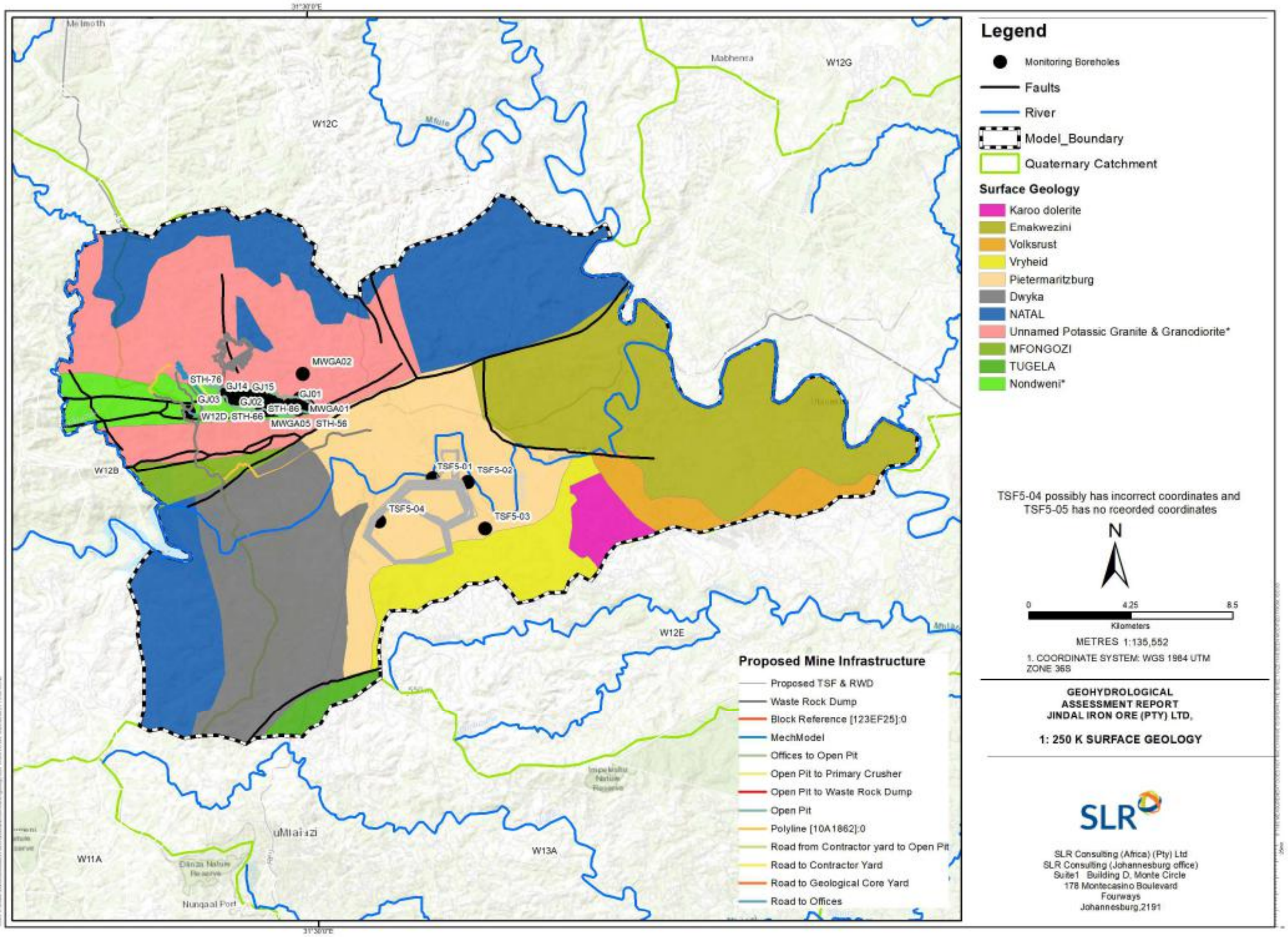


Figure 5-1: Geological map of the study site and surrounds

5.2 ACID GENERATION CAPACITY

The Acid base accounting for the waste rock and tailings material is provided in the SLR geochemistry reports - SLR (2021a) and SLR (2021b). The studies found that the all the waste rock lithologies are classified as Non-Potential Acid Generation (i.e., Non-PAG) materials. The study on the TSF material found that both the Jindal proxy tailings samples can clearly be classified as Non-PAG materials.

5.3 HYDROGEOLOGY

The hydrogeology of the catchment area with particular focus on the proposed mine site is outlined below in terms of the unsaturated zone, the saturated zone, and the aquifer parameters. The groundwater potential of the relevant aquifers has been included in Section 7.2.

5.3.1 Unsaturated Zone

In the general mining operations and pit areas, the terrain is mountainous and water levels are typically 40 - 50 mbgl. Characteristics of the unsaturated zone are not established. In proximity of the TSF which is in a low-lying area near to the Mhlatuze river groundwater is typically very shallow (< 5mbgl) and consequently the unsaturated zone is thin in this area.

5.3.2 Saturated Zone

In the mine area, the saturated zone is recharged through precipitation percolating through soil and exposed weathered rock. In the TSF area the aquifer comprises of weathered and fresh shale to between approximately 60 and 80 m. Dwyka underlays the shales. The shales formations in this area are expected to be low permeability aquifer zones. The shallow groundwater in proximity of the proposed TSF discharges to the Mhlatuze River and flow is thus in a northerly direction in relation to the footprint of the TSF.

5.3.3 Hydraulic Conductivity

The estimated hydraulic conductivity of the aquifer zones is described in Section 7.6.3

5.4 GROUNDWATER LEVELS

The groundwater levels were taken from the initial hydrocensus in the baseline study and the diamond core drilling. A total of 28 boreholes with groundwater levels were considered. The hydrocensus boreholes are shown in Figure 5-2**Error! Reference source not found.** with the proposed drilling of groundwater boreholes. The hydrocensus boreholes, together with the new TSF monitoring boreholes drilled will be used for aquifer characterisation and parameters.

The current the groundwater level averaged from available borehole data, most of which are located within the proposed pit footprint, is 56 mbgl. Groundwater levels ranges from artesian to 178.5 mbgl using the hydrocensus, diamond drilling and hydrogeological boreholes data. The hydrocensus groundwater levels give an average of 45 mbgl. The mean hydraulic head in the pit area is 450 mamsl. Several of the borehole water levels (STH-71, STH 57, STH 69 and STH 76) are deeper than expected and it is expected that these water levels are not reflective of steady state conditions (Figure 5-2).

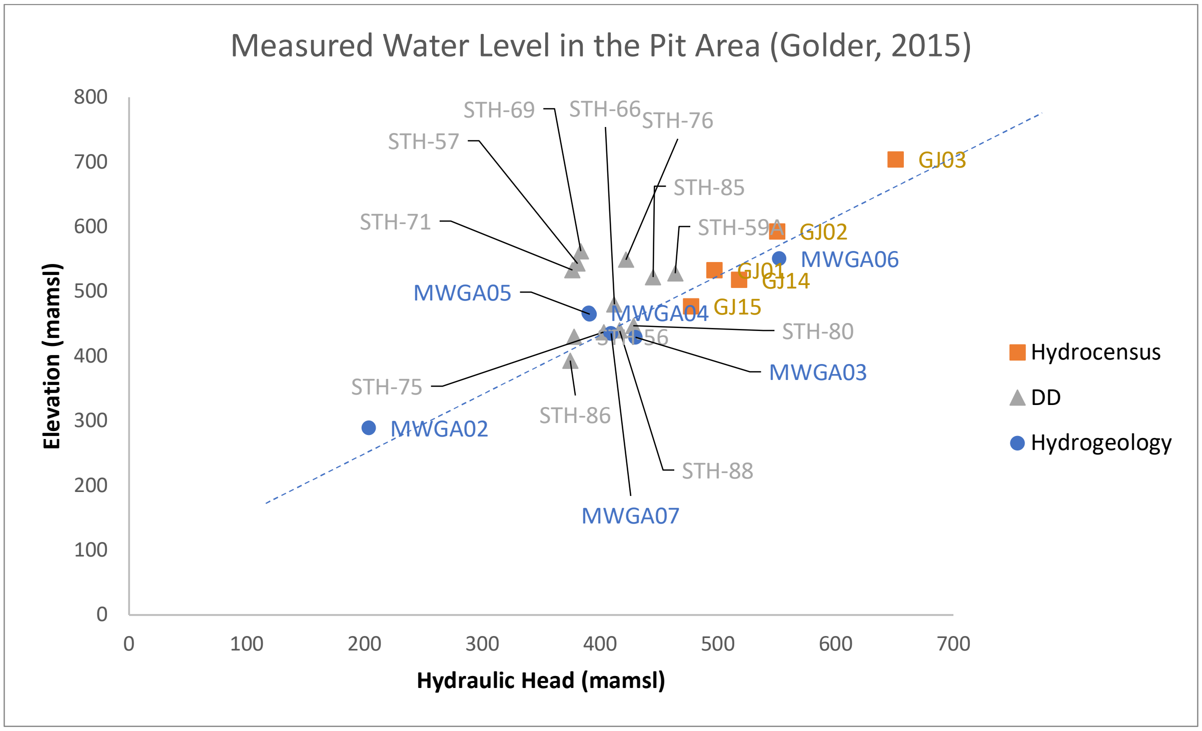


Figure 5-2: Water levels obtained from the Golder (2015) study in the pit area

5.5 GROUNDWATER POTENTIAL CONTAMINANTS

The geochemistry assessment completed by SLR (2022a) characterised the potential contaminants of concern (PCOC). The waste rock lithologies had no PCOCs while the TSF had elevated aluminium concentrations.

The analysis of material to be discarded in the WRD and TSF indicated the following:

- The waste rock lithologies and WRD modelled source terms predict no CoCs with the exception of mercury that exceeds both the SANS 241 ad IFC guidelines, however, mercury was reported below detection limits therefore this predicted value is based on a theoretical input concentration and should be disregarded.
- The modelled source terms for the TSF predict aluminium in the fresh tailings samples to be exceeding the drinking water quality of DWAF (1996) and SANS 241 (2015) guidelines while both tailings samples predicted an exceedance of SANS 241 and IFC mercury guidelines, however, mercury was reported below Synthetic Precipitation Leaching Procedure (SPLP) detection limits therefore this predicted value is based on a theoretical input concentration and can be disregarded. SPLP is a quick and inexpensive method to determine:

- The mobility/leachability of low volatility organic and inorganic analytes in liquids, soils, and wastes.
- The measure of desorption of contaminants from soil (rather than adsorption).
- The possibility of leaching metals into ground and surface waters.
- A site-specific impact to groundwater soil remediation standard.

- Sulphate was selected to trace potential migration of contaminants. The estimated seepage concentrations for sulphate in the TSF and WRD are summarised in Table 5-2. The sulphate concentrations are well below drinking water quality guidelines for the parameter.

5.6 GROUNDWATER QUALITY

The analyses performed on samples collected by Golder in 2015 were not presented in the Golder (2015) and not available for this study. No access was granted in the pit area and consequently no water chemistry data is available for the pit area. Samples collected at the TSF boreholes drilled in 2022 are outlined below and compared against SANS 241:2015 water quality guidelines for drinking water quality. This refence was selected as the rural water users in the area utilise groundwater for domestic supply.

Water quality in the TSF boreholes have several exceedances relative to the SANS 241:2015 drinking water quality guidelines. The exceedances are typical of water quality in crop farming areas.

- **TSF-GH-501**: Elevated Sodium, Chloride, Conductivity, TDS and ammonium.
- **TSF-GH-502:** Elevated Sodium, Chloride, Conductivity and TDS.
- **TSF-GH-503:** Elevated Sodium, Chloride, Conductivity and TDS.
- **TSF-GH-504:** Elevated Sodium, Chloride, Nitrite, Conductivity and TDS well above the guidelines, nitrate is also elevated in this borehole.
- **TSF-GH-503:** Elevated Sodium, Chloride, aluminium, and manganese.

The results were analysed for physical parameters, macro elements as well as a full scan of trace metals. Where relevant, the results are compared against the South African Water Quality Guidelines (SAWQG), Volume 1: Domestic Use (DWAF, 1996). It is noteworthy that the Golder (2015) report omits the lab data for the results and therefore these have not been included in this report's appendices.

The analytical results (Table 5-2) for the physical parameters show that all the sites tested are well within drinking water guidelines in terms of pH and salinity. The existing sites (GJ01-GJ16, STH/82) have very low salinities (10 to 40.1 mS/m) and neutral pH (average 7.4), with exception of GJ04 and GJ12 which have pH values below 7. Furthermore, the new sites (MWGA02, MWGA04, and MWGA07) have low salinity (24.1 to 58.8 mS/m) and neutral pH (7.5).

Table 5-1: Physical parameters of samples analysed

Site	pH	pH Temperature (°C)	Total Conductivity at 25 °C) (mS/m)	TDS (mg/l)
DWAF (1998) Domestic Use SAWQG	4 to 9	-	< 70	> 450
GJ01	7.31	25	22.2	162
GJ02	7.56	25	13.2	102
GJ03	7.85	25	13.9	110
GJ04	6.71	25	11	92
GJ07	7.62	25	14.8	150
GJ12	6.89	25	10	106
GJ13	7.54	25	28.1	204
GJ16	6.95	25	21	156
STH/82	8.24	25	40.1	314
MWGA02	7.39	25	24.1	220
MWGA04	7.78	25	57.8	402
MWGA07	7.41	25	58.8	414

Table 5-2: TSF Water Quality Data

Sample number.	Matrix.	Units (unless stated elsewhere)	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Mn	Mo
		SANS 241:2015	0.3	0.01	2.4	0.7			0.003		0.05	2	2		0.4	
TSF-GH-501	Water	mg/l [ppm]	0.14	<0.05	<0.5	0.14	<0.05	56.83	<0.05	<0.05	<0.05	0.08	0.06	5.63	0.23	<0.1
TSF-GH-502	Water	mg/l [ppm]	0.27	<0.05	<0.5	0.13	<0.05	17.06	<0.05	<0.05	<0.05	0.07	0.13	12.6	0.19	<0.1
TSF-GH-503	Water	mg/l [ppm]	0.06	<0.05	<0.5	0.19	<0.05	59.34	<0.05	<0.05	<0.05	<0.05	0.13	3.03	0.16	<0.1
TSF-GH-504	Water	mg/l [ppm]	0.06	<0.05	<0.5	<0.05	<0.05	38.36	<0.05	<0.05	<0.05	0.07	<0.05	2.9	0.06	<0.1
TSF-GH-505	Water	mg/l [ppm]	0.42	<0.05	<0.5	0.1	<0.05	73.05	<0.05	<0.05	<0.05	0.07	0.41	3.59	0.67	<0.1

Sample number.	Matrix.	Units (unless stated elsewhere)	Na	Ni	Pb	Sb	Se	Tl	V	Zn	Mg	Hg	Cl	SO4	NO3 as N	NO2 as N
		SANS 241:2015	200	0.07	0.01		0.04			5		0.006	300	500	11	0.9
TSF-GH-501	Water	mg/l [ppm]	283.2	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	0.07	41.32	<0.005	475.6	128.6	0.7	<0.13
TSF-GH-502	Water	mg/l [ppm]	594.4	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	0.05	22.35	<0.005	451.5	116	1.44	<0.13
TSF-GH-503	Water	mg/l [ppm]	653.2	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	0.1	43.18	<0.005	555.8	67.68	0.55	<0.13

TSF-GH-504	Water	mg/l [ppm]	345.4	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	0.11	43.93	<0.005	307.1	60.24	6.46	3.7
TSF-GH-505	Water	mg/l [ppm]	226.6	<0.05	<0.05	<0.05	<0.1	<0.1	<0.05	0.11	44.17	<0.005	303.5	98.78	0.7	<0.13
Sample number.	Matrix.	Units (unless stated elsewhere)	F	PO4 as P	pH	Conductivity (µs/cm)	TDS	NH4	CO3	HCO3						
		SANS 241:2015	1.5		≥5 to ≤9.7	1700	1200	1.5								
TSF-GH-501	Water	mg/l [ppm]	0.48	0.26	7.52	2465	1405	1.63	0	114.6						
TSF-GH-502	Water	mg/l [ppm]	1.44	<0.2	8.46	2697	1876	0.13	30.96	547.8						
TSF-GH-503	Water	mg/l [ppm]	0.58	0.25	7.62	2803	2086	0.42	0	1027						
TSF-GH-504	Water	mg/l [ppm]	0.63	<0.2	7.6	1781	1260	0.04	0	589.6						
TSF-GH-505	Water	mg/l [ppm]	0.33	<0.2	7	1602	1042	0.52	0	446.3						

6. BOREHOLE SITING DRILLING AND TEST PUMPING RESULTS

6.1 BOREHOLE SITING

Table 6-1 details the strategic location of each borehole sited by Golder in 2014. Five boreholes were sited by SLR to characterise the aquifers at the proposed TSF, coordinates of these boreholes are provided in Table 6-2. The boreholes are graphically represented in Figure 6-1.

Table 6-1: Details of boreholes sited by Golder in 2014 (Golder, 2015)

Borehole	East	South	Description
MWGA01	353007.67	6822266.03	North of Pit 1 / Up gradient of WRD
MWGA02	353118.79	6823280.14	Down gradient of WRD
MWGA03	353387.27	6821965.23	East of Pit 1
MWGA04	352881.80	6821797.00	Southwest of Pit 1
MWGA05	351395.58	6821726.32	South of Pit 2
MWGA06	350262.29	6822278.45	West of Pit 2 / Upgradient of Pit 1 and Pit 2
MWGA07	351467.79	6822472.12	Down gradient of Pit 2

Table 6-2: TSF monitoring boreholes drilled in 2022

Borehole	East	South	Description
TSF5-01	358549.45	6818911.48	North of TSF(down gradient) between TSF and Mhlatuze River
TSF5-02	360005.43	6818748.19	East of TSF (down gradient) between TSF and Mhlatuze River
TSF5-03	360726.62	6816815.96	Southeast of TSF on a tributary of the Mhlatuze
TSF5-04	356315.91	6817134.16	North-west area of the TSF
TSF5-05	356315.91	6817134.16	Redrill of TSF5-04

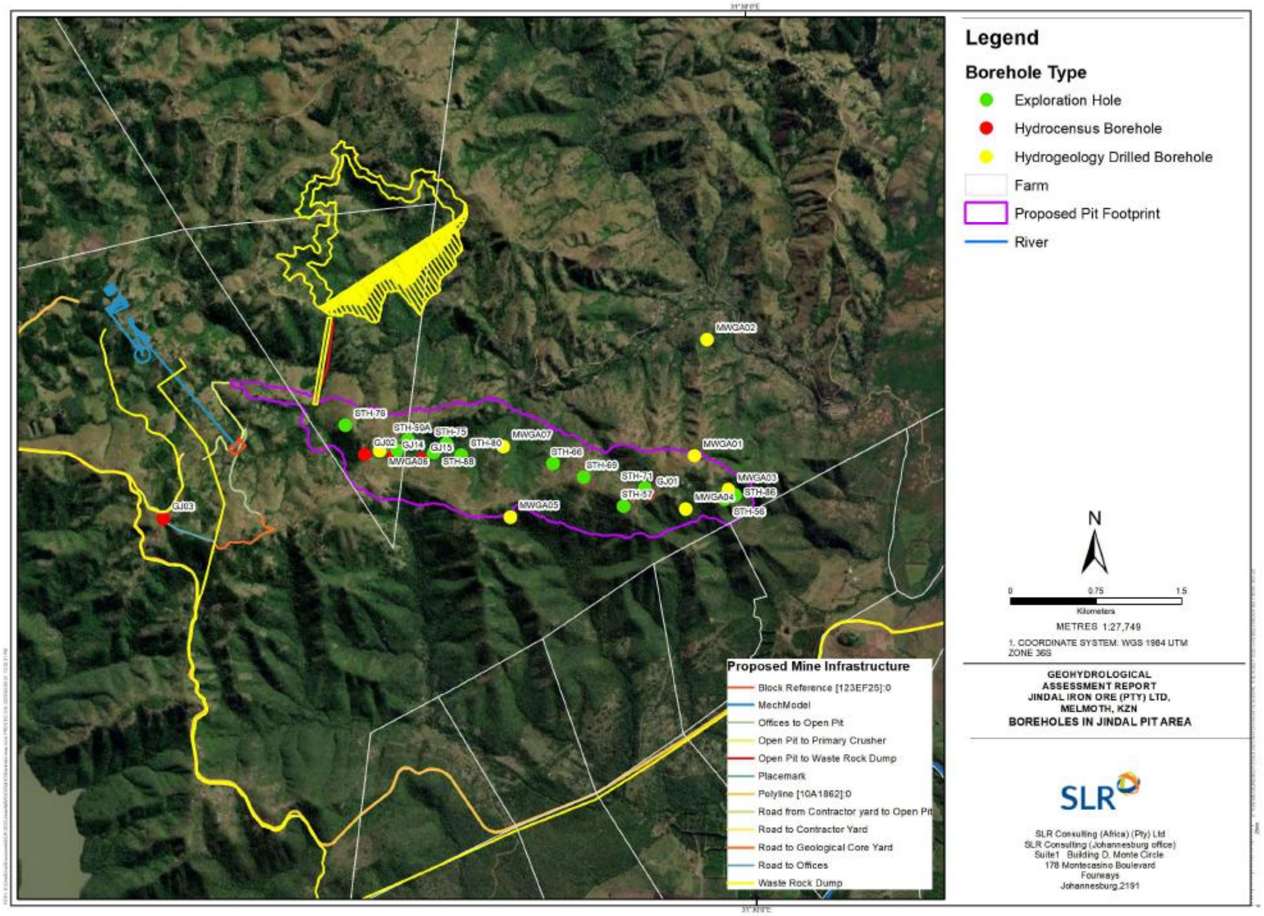


Figure 6-1: Boreholes located in the pit area

6.2 PIT AREA AND TSF DRILLING RESULTS

Seven of the ten boreholes were drilled by Major drilling in 2014 to aid the hydrogeological understanding of the site (Figure 6-1). The drilling was supervised by Jindal geologists, while Golder provided input on the logging and borehole construction aspects. From the drilling information shown in Table 6-3, it is clear all water strikes were intersected deeper than 94 mbgl with the deepest strike recorded at 234 mbgl at MWGA07 and an average water strike depth of 168 mbgl. The strikes intersect granite, meta dolerite, schist and meta sediments with the sediments having a higher yield potential than granite. Individual water strike yields vary from seepage <0.1 to 5.0 L/s resembling a fractured, anisotropic aquifer.

Table 6-3: Specifications of monitoring boreholes drilled in 2014 (Golder, 2015)

Borehole	Latitude (East)	Longitude (South)	Description	Depth (m)	Yield (L/s)	Weathered zone (m)	Water strike(s) (m)
MWGA01	353008	6822266	N of Pit 1 / Up gradient of WRD	300	0	34	Dry
MWGA02	3532150	6822337	Down gradient of WRD	127.4	0.5	126	94, 127
MWGA03	353387	6821965	E of Pit 1	217	3.6	22	182, 190, 216
MWGA04	352882	6821797	SW of Pit 1	340	0.6	23	241
MWGA05	351396	6821726	S of Pit 2	190	0.3	13	131, 188
MWGA06	350262	6822278	W of Pit 2 / Up gradient of Pit 1 and Pit 2	202	3.5	83	163, 200
MWGA07	350262	6822478	Down gradient of Pit 2	234	6.6	13	176, 198, 234

Table 6-4 shows the summary drilling details for each borehole (Golder, 2015). Water strikes were intersected in geological structures (dyke contact and quartz veins) and in fractures within individual lithologies. Boreholes MWGA03 and MWGA06 had to be sealed because of artesian water flow in line with DWS directive for the study area.

Table 6-4: Summary of borehole drilling results (Golder 2015)

Borehole	Drill depth (m)	Water strike(s) (m)	Airlift Yield (L/s)		Weathered Zone (m)	Lithology
			Cumulative	Individual		
MWGA01	300	Dry	-	-	34	Granite gneiss
MWGA02	127,4	94, 127	0.1	0.1	126	Meta dolerite
			0.5	0.4		Granite gneiss
MWGA03	217	182, 190, 216	1.5	1.5	22	Quartz Amphibole Magnetite Schist
			1.8	0.3		
			3.6	1.8		
MWGA04	340	241	0.6	0.6	23	Quartz veins
MWGA05	190	131, 188	<0.1	-	13	Granite gneiss
			0.3	0.3		
MWGA06	202	163, 200	0.8	0.8	83	Quartz Amphibole Magnetite Schist
			3.5	2.7		AQMcS
MWGA07	234	176, 198, 234	1.4	1.4	13	Quartz Amphibole Magnetite Schist
			1.6	0.2		
			6.6	5.0		

Five boreholes were drilled in proximity of the TSF (Table 6-5). All holes intersected shale of the Pietermaritzburg formation. The drilling depths varied between 51 m and 116 m. The weathered zone varies between 2 and 36 m. Blow yields were recorded in two holes, both had a yield of 0.4 l/s.

Static water levels were measured in four of the five drilled boreholes (Table 6-6). The static water levels vary between 2.61 – 5.86 mbgl. The pH varies between 7.23 and 9.28. The water is typically clear and odourless. TDS and EC are the same in all holes which is unlikely. It is possible that this indicates an instrument error.

Table 6-5: TSF Borehole drilling description

Borehole	Latitude (East)	Longitude (South)	Description	Depth (m)	Yield (L/s)	Weathered zone (m)	Water strike(s) (m)	Casing Type & Depth
TSF5-01	358549.45	6818911.48	North of TSF (down gradient) between TSF and Mhlatuze River	70	Not reported	2	43,56,69	Solid 0-11 mbgl Screen Interval 11 - 47 mbgl
TSF5-02	360005.43	6818748.19	East of TSF (down gradient) between TSF and Mhlatuze River	76	Not reported	36	11	Solid 0-3 mbgl Screen Interval 3 -12 mbgl
TSF5-03	360726.62	6816815.96	Southeast of TSF on a tributary of the Mhlatuze	116	0.40	12	42,85	Solid 0 -20 mbgl Screened 20-75mbgl
TSF5-04	356315.91	6817134.16	Northwest are of the TSF	51	Not reported. Noted to be high yielding.	8	26, 36, 40	Solid 0 -21 mbgl Screen interval 22-51 mbgl
TSF5-05			No Coordinate details	85	0.42	3	17,39	Solid 0 -12 mbgl Screen interval 12 -46 mbgl

Table 6-6: TSF Boreholes – Field measurements

Borehole	Latitude (East)	Longitude (South)	Geology	Static water level (mbgl)	pH	Temp	TDS (mg/l)	Comment
TSF5-01	358549.45	6818911.48	Shale	Not recorded	8.38	20.2^{0}C	994	Not recorded
TSF5-02	360005.43	6818748.19	Shale	5.86	9.28	21.7^{0}C	994	Brown with sediments
TSF5-03	360726.62	6816815.96	Shale	4.49	9.07	21.4^{0C}	994	Clear, odourless
TSF5-04	356315.91	6817134.16	Shale	4.69	8.17	21.12^{0}C	994	Clear, odourless
TSF5-05	356315.91	6817134.16	Shale	2.61	7.23	18.4^{0}C	994	Clear, odourless

6.3 AQUIFER TESTING

Aquifer testing was carried out by Golder (2015). Four boreholes were tested to determine aquifer parameters in the pit area. No further aquifer testing was completed in the pit area and no aquifer testing was completed at the TSF borehole area.

Slug tests and pump-out testing were conducted by Golder (2015) for estimates of aquifer parameters and included:

- Slug test - falling or recovering head tests conducted in two boreholes (MWGA02 and MWGA03), and
- Pump-out test - constant discharge tests (CDT) conducted in two boreholes (MWGA04 and MWGA07).

No aquifer tests were done in the following boreholes:

- MWGA01 – borehole was open but water level exceeds 150 m therefore, neither test pump nor data logger cable could reach for conducting a test. This well is considered dry.
- MWGA05 – borehole blocked at 45 m.
- MWGA06 – boreholes sealed due to artesian flow.

No aquifer testing has been completed in the TSF area. Shales were intersected in the TSF boreholes. Recorded blow yields were ± 0.4 l/s.

A falling head test was performed for MWGA03, and a recovering head test performed for MWGA02. The results of the falling head tests were used in assessing the transmissivity values for the well location and aquifer lithology (Golder, 2015).

A pump-out test was performed in MWGA04 and MWGA07. The results of the pump-out tests were used in assessing the transmissivity at the borehole locations and aquifer lithology. The duration of each test was determined by water level drawdown, water clarity and pH stability (Golder, 2015).

The minimum duration of pump-out testing at MWGA07 was 70 minutes while MWGA04 was subjected to testing of 195 minutes which included both the pumping and recovery phases (Golder, 2015). This test duration allows for defining preliminary aquifer parameter values (Transmissivity, Storativity etc). The pumping yield was measured volumetrically using a stopwatch and 20 L calibrated container. Water levels were recorded using Solinst Level Logger pressure transducer. The data reading interval was set at a 1 minute interval with manual water level verification taking place.

Hydraulic testing can provide appropriate estimates of hydraulic conductivities (K, often referred to as permeability and expressed as m^2/day) or transmissivity (T, the product of hydraulic conductivity and aquifer thickness, expressed as m^2/day). Transmissivity is more directly useful in groundwater resource studies and results are expressed as T and shown in Table 6-7. Cartesian plots of each test are shown from Figure 6-2 to Figure 6-5.

Table 6-7: Summary of hydraulic aquifer parameters (Golder, 2015)

Borehole	Test type	Test duration	T (m^2/day)	Formation	Comment
MWGA01	No test – dry			Granite gneiss	-
MWGA02	Slug (recovering head)	0h55min	16.4	Granite gneiss	-
MWGA03	Slug (falling head)	2h00min	37	Granite gneiss /Meta dolerite	T might be invalid due to artesian pressure
MWGA04	CDT (0.1 L/s)	3h15min	7.3	Quartz vein	-
MWGA05	No test – blocked		-	Granite gneiss	-
MWGA06	No test – sealed artesian		-	Quartz Amphibole Magnetite Schist	-
MWGA07	CDT (3.6 L/s)	1h10min	53	Quartz Amphibole Magnetite Schist	-

The T values vary between 7.3 – 53 m^2/d – these are typical of fracture aquifers that are anisotropic in nature. The yields pumped vs water level drawdown proves the airlift yields obtained during drilling correlate. The quantity of hydraulic testing hinders interpretation for each lithological unit therefore, further test pumping will be required prior to mining.

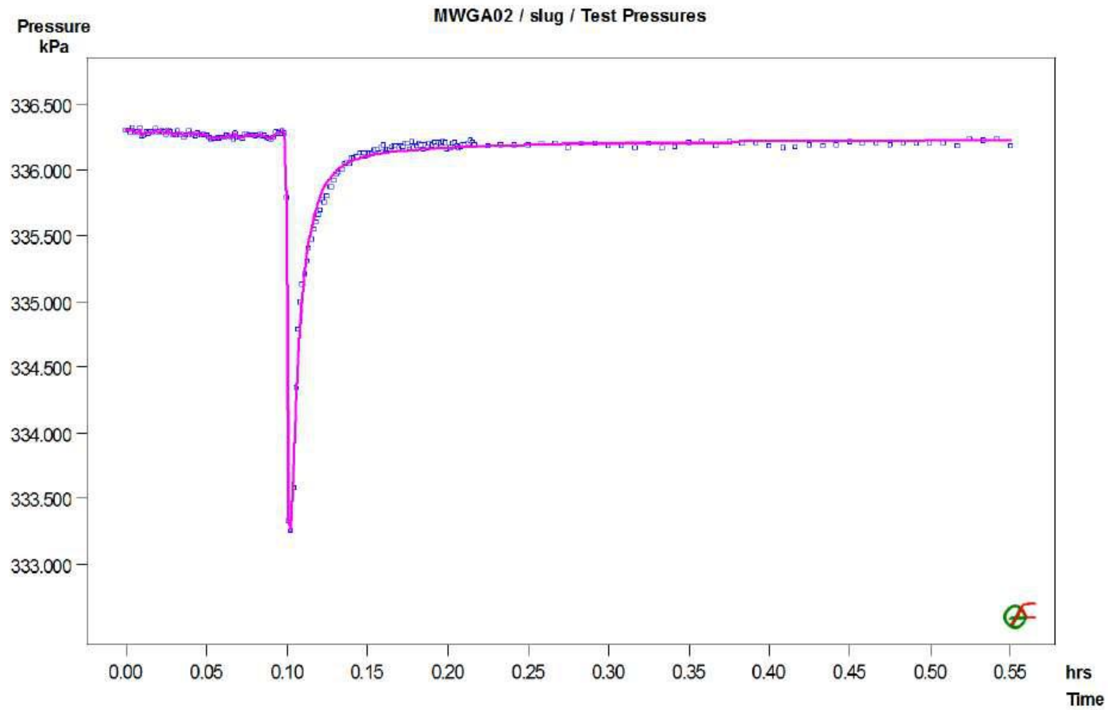


Figure 6-2: MWGA02 rising head test - Cartesian plot of pressure response (blue) and simulated (pink) (Golder, 2015)

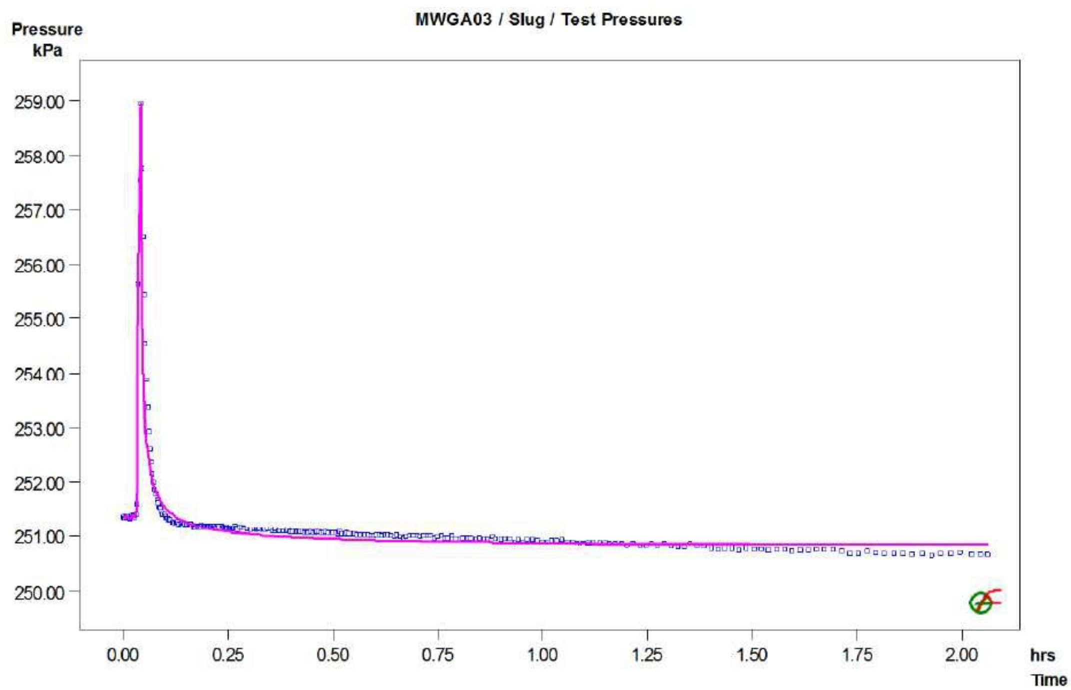


Figure 6-3: MWGA03 falling head test - Cartesian plot of pressure response (blue) and simulated (pink) (Golder, 2015)

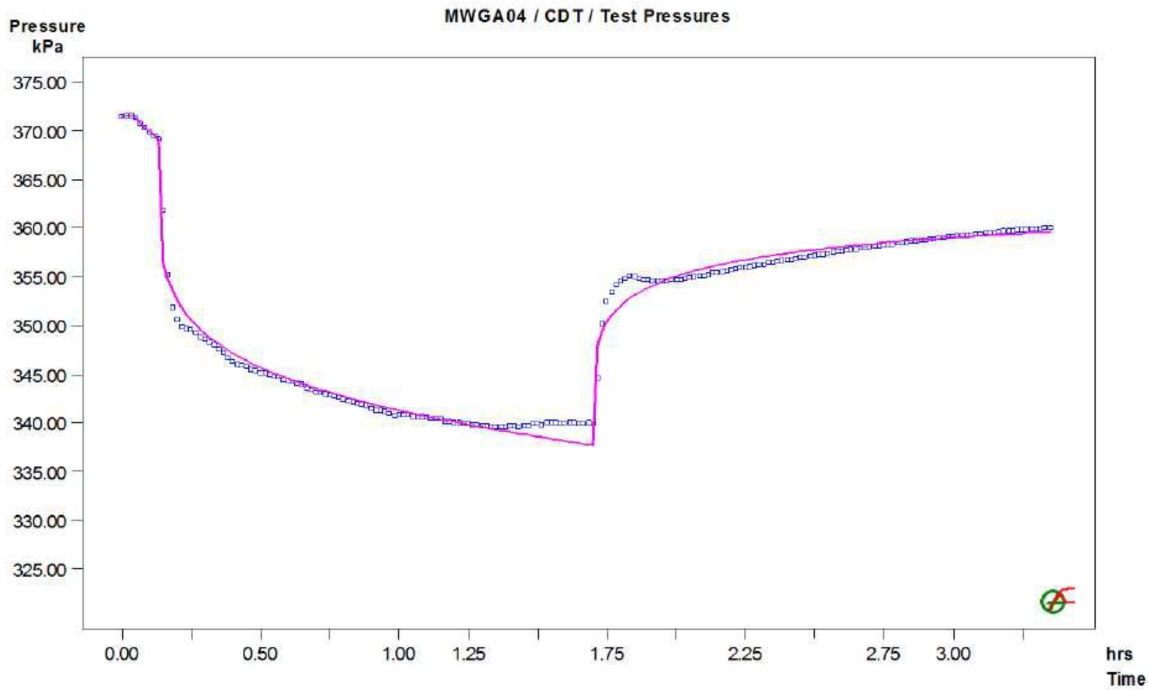


Figure 6-4: MWGA04 constant discharge and recovery test - Cartesian plot of pressure response (blue) and simulated (pink) (Golder, 2015)

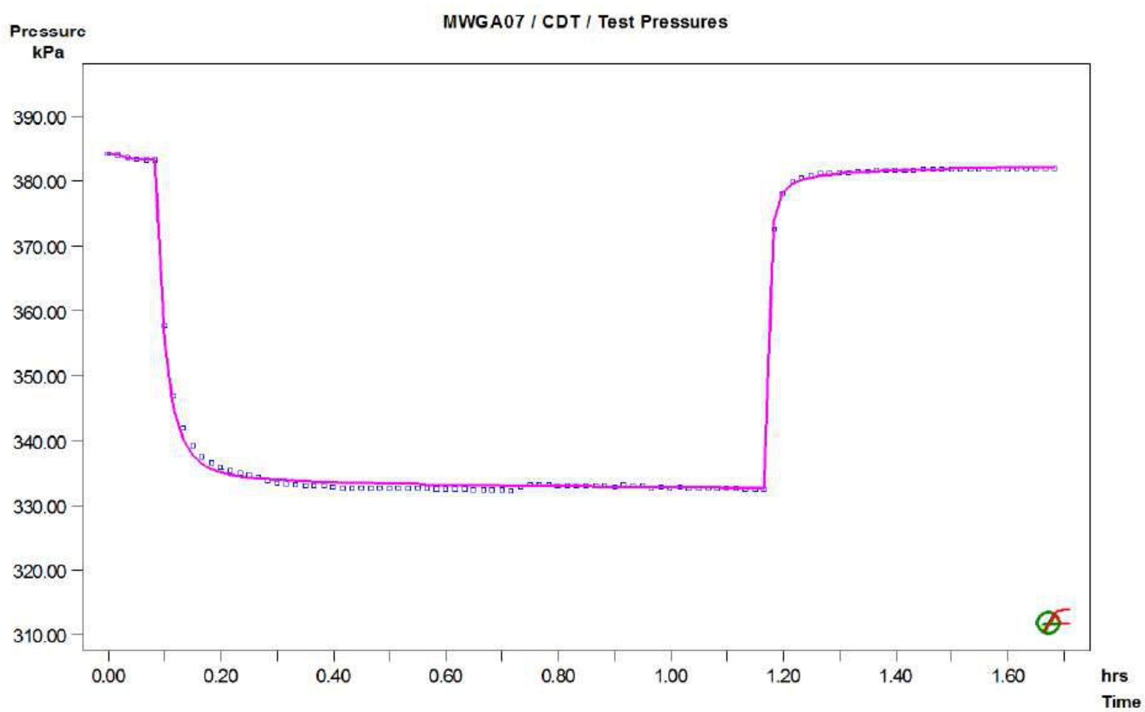


Figure 6-5: MWGA07 constant discharge and recovery test - Cartesian plot of pressure response (blue) and simulated (pink) (Golder, 2015)

7. AQUIFER CHARACTERISATION

The aquifer characterisation is determined based on the groundwater vulnerability, aquifer classification and aquifer protection classification.

7.1 GROUNDWATER VULNERABILITY

The Aquifer Vulnerability Map of South Africa (Matoti, *et al.* 1999) indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer (Figure 7-1). Based on the vulnerability map, the proposed project area is classified as having a low vulnerability.

7.2 AQUIFER CLASSIFICATION

According to the Aquifer Classification Map of South Africa (DWAF, 1999), the aquifers of the study area are characterized as minor aquifers (low yielding). Given the general aquifer profile (Lithology aquifer type), there are three major aquifer systems in the Pongola-Mtavuna Water Management Area (WMA):

- Intergranular and fractured aquifers with borehole yields between 0.5 and 2.0 l/s and water quality ranges < 70 mS/m and 70 - 300 mS/m.
- Fractured aquifers with boreholes yielding between 0.5 and 2.0 l/s and water quality ranges < 70 mS/m.
- Intergranular/alluvial (T-Qm coastal and inland deposits) with borehole yields between 0.5 and 2.0 L/s, but multi-layered aquifer systems may occur in the coastal belts (fresh, underlain by saline) (Figure 7-2).

7.3 AQUIFER PROTECTION CLASSIFICATION

Based on the vulnerability and aquifer classification, the aquifers contamination susceptibility is regarded as having low susceptibility.

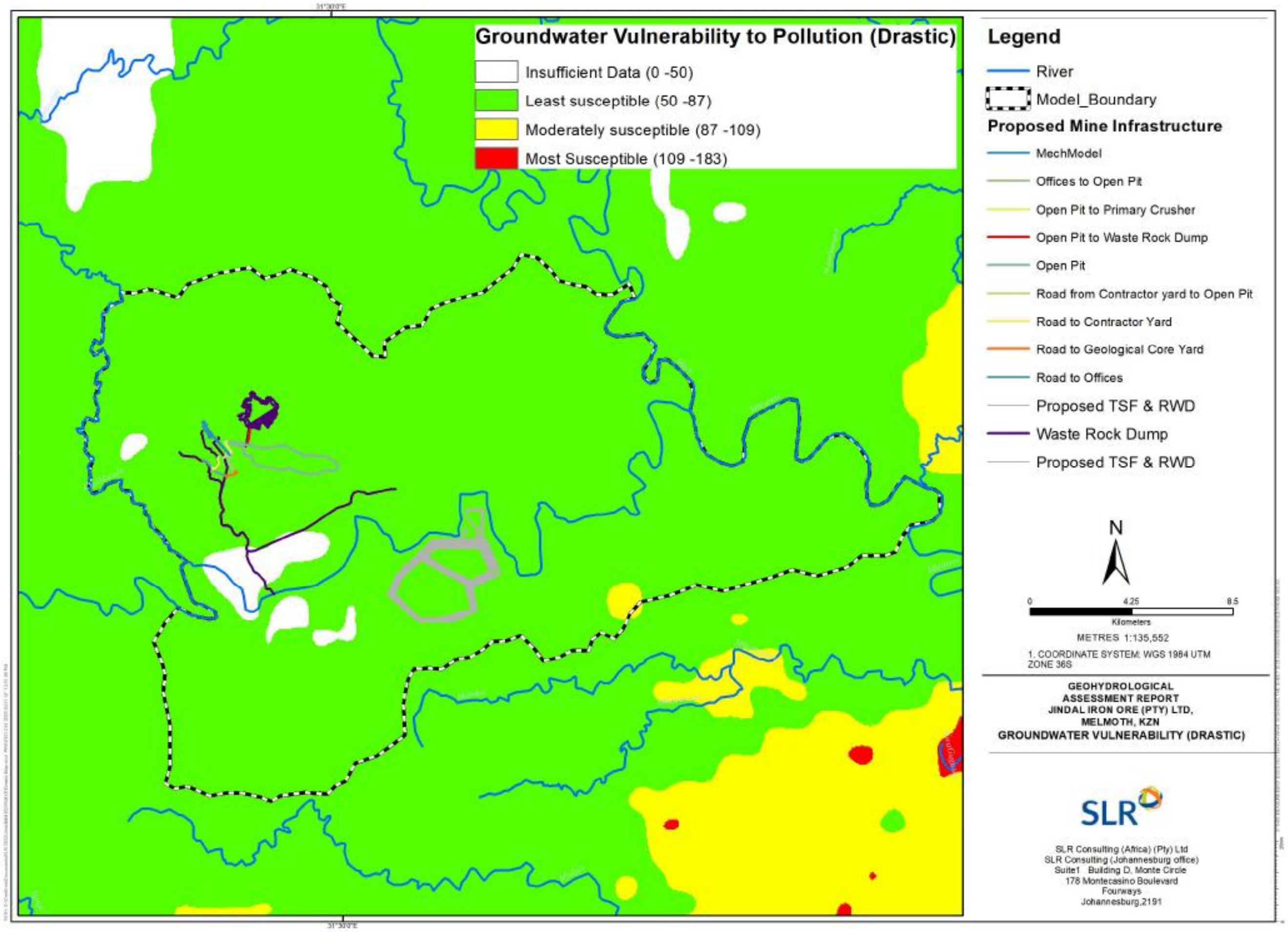


Figure 7-1: Aquifer vulnerability map of the study area

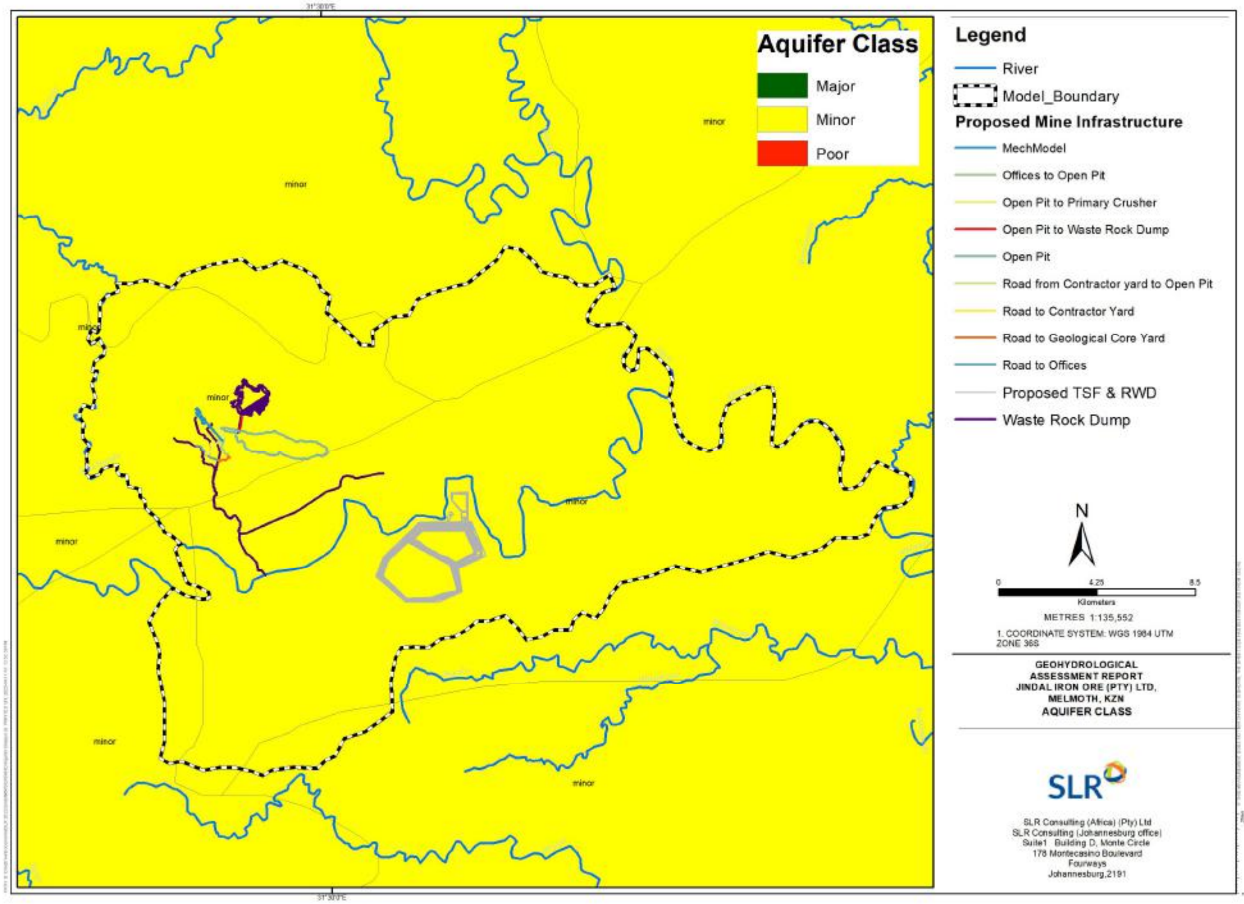


Figure 7-2: Aquifer classification map of the study area

8. GROUNDWATER MODELLING

The following section details the numerical groundwater flow model which was developed to evaluate the possible impacts associated with the proposed Jindal Iron Ore Project located on the farms:

- Ntembeni 16921 North Block, Portion 0
- Reserve No.11 15831North Block Portion 3 and 4
- Kromdraai 6110 South Block Remaining Extent.
- Black eyes 13385 Portion 1,2,3,4 and the Remaining Extent
- Wilderness 6107 Portion 3,4,5,6,7,8,12,13,14,15,16
- Goedgeloof 6106 Portion 1,2,3 and the Remaining Extent.
- Goedertrow 89 No. 7806-
- Reserve No.11 15831 Portion 0
- Vergelegen 6104 Portion 0.

The objectives of the modelling were to estimate:

- Groundwater inflows to the open pit during life of mine; and the expected cone of depression associated with mining and dewatering during the operational period of mining; and
- The migration and expected impact on receptors due to potential seepage of contaminants from the WRD, TSF and return water dam; and the expected impact on receptors post-mining.

8.1 SOFTWARE MODEL CHOICE

The numerical groundwater flow and mass transport model was setup in Feflow®, a finite element modelling package which is developed by DHI-WASY (Diersch, 2015). This code is an industry standard groundwater modelling tool widely used in mining and environmental applications. Feflow handles a broad variety of physical processes for subsurface flow, transport modelling and simulates groundwater level behaviour indirectly by means of a governing equation that represents the Darcy groundwater flow processes that occur in a groundwater system.

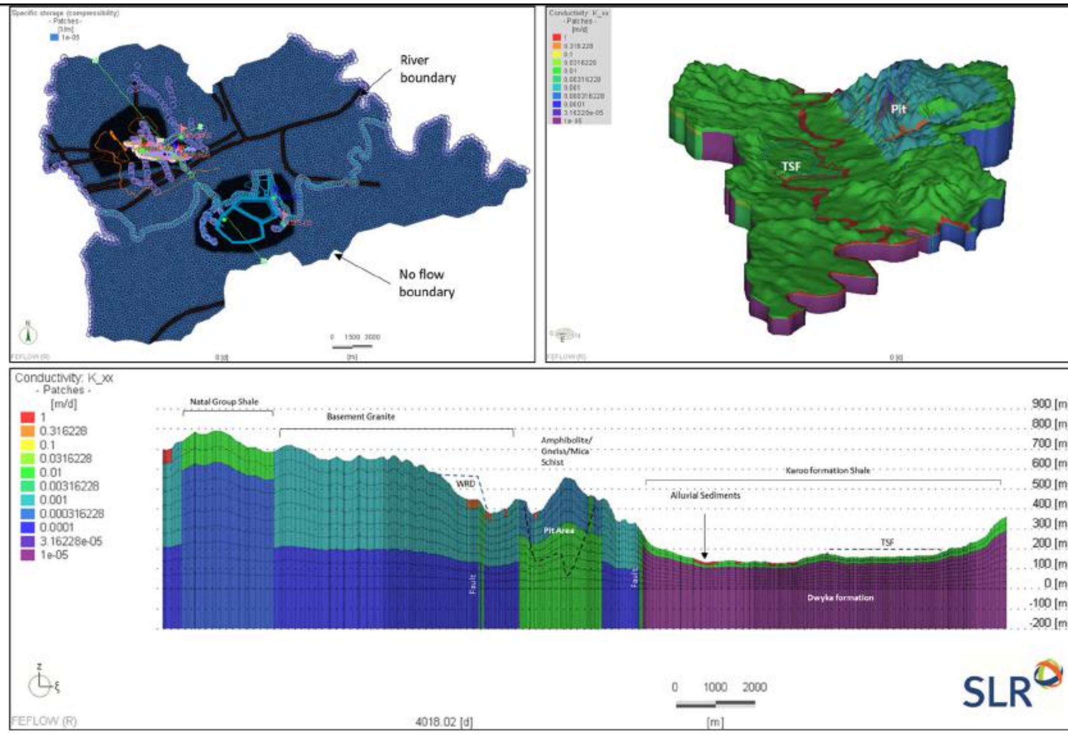
8.2 MODEL SET-UP AND BOUNDARIES

The numerical model extent was delineated based on geographic and hydrogeological features. The northern and southern boundary were aligned with the quaternary catchment boundaries which represent surface water divides and are expected to represent groundwater divides, these were assigned as 'no-flow boundaries". The western and eastern boundaries were delineated along rivers to which groundwater discharges. Internal boundaries considered within the model includes the Mhlatuze River. The river was simulated using Dirichlet boundaries equal in elevation the river channel. The rivers and associated drainages were assigned as gaining type rivers only (Figure 8-1). The pit was simulated with Dirichlet boundaries that mimic the expansion and deepening of the pit over time. The TSF and the WRD were simulated using fluid flux boundary conditions. The boundary conditions are discussed in later sections.

8.3 GROUNDWATER ELEVATION AND GRADIENT

In the proximity of the TSF, the measured hydraulic heads in proximity of the tailing's facility vary between 104 mamsl and 162 mamsl. The Ntshamanzi river currently drains the footprint of the proposed TSF from southwest to northeast. The drainage flows into the Mhlatuze River. The hydraulic gradients beneath the TSF are estimated to be 0.03 – 0.04 and a corresponding seepage velocity of 0.01 m/d assuming a porosity of 3 %.

The WRD and pit area, are in the hills north of the Mhlatuze River. There are no measured water levels in proximity of the WRD. However, based on interpolations from the pit area, a steep gradient beneath the WRD is anticipated (0.1). Topography beneath the WRD area undulates with elevations exceeding 600 m on the hill tops and elevations of 370 m in the valleys.



Jindal Iron Ore Project - Melmouth

Model Code	Feflow	Mesh	3D Finite Element Mesh (Triangular prisms)
Slices & Layers	12 & 11	Mesh Quality	0.1%>120^0 7%>90^0
Elements per slice	108777	Area & Volume	4.451E+08 m^2 & 2.248E+11 m^3

Figure 8-1: Jindal Iron Ore Model Setup

Groundwater is expected to discharge along the drainages developed in the valley areas. Seepage generated within the WRD will flow to the topographical low points and discharge along drainages including the Kwasengeni and the Memela Rivers.

The topography in the pit area comprises of hills and valleys with elevations varying between 615 mamsl and 320 mamsl. Measured water levels are highly variable within the pit area owing to the topography. Artesian conditions arising from hill side seeps occur in the northwestern valley areas of the pit (MWGA03 and MWGA06 in Figure 8-11). The mean water level within the pit area is 450 mamsl. The lowest elevation of the pit is 405 mamsl (eastern extent of the pit). Post-mining, should decant occur, seepage from the pit is anticipated to be in this area and runoff from areas around the open pit can possibly flow into a tributary of the Nkwalinye River which ultimately flows into the Mhlatuze River.

8.4 GEOMETRIC STRUCTURE OF THE MODEL

The conceptual model was mathematically represented by a mesh which encompasses a surface area of 445 km^2 and consist of 108 777 triangular elements. The mesh density was increased in areas of interest i.e., in the TSF area and the pit area and the Mhlatuze River was explicitly included in the mesh construction. The model thickness is variable due to the changes in surface topography of the model. To represent the hydrogeology with depth the base elevation of the model was set at -200 mamsl. Between surface and 0 mamsl the model was split into 11 layers. Thus, the model consists of 12 layers in total between surface and -200mamsl (Figure 8-1).

8.5 GROUNDWATER SOURCES AND SINKS

The only sources considered in the conceptual and numerical model are direct recharge from rainfall. The calibrated recharge assigned on the Karoo sediments and the Natal group shales was 6 mm/a and based on the chloride mass balance. Higher recharge of 25 mm/a was assigned to the outcropping granite and amphibolite in the mining area. No data was available to estimate the recharge on these units and was therefore estimated from model calibration.

The groundwater sinks considered in the conceptual and numerical models are the Mhlatuze River and its associated tributaries. The rivers are all assumed to behave as gaining type rivers only. Where groundwater elevations exceed the elevation of the river channel groundwater is simulated to discharge from the model domain.

8.6 CONCEPTUAL MODEL

The conceptual hydrogeological model is presented in Figure 8-5 and was developed in the preceding chapters of this report and is summarised below:

8.6.1 Model Boundaries

The boundaries are discussed in Section 8.2.

8.6.2 Sources and sinks

The sources and sinks are described in section 8.5.

8.6.3 Aquifer types and parameters

The hydrogeological zones present within the study area are outlined below and the assumed model parameters are summarised in Table 8-1 and shown spatially in the north south cross section in Figure 8-2. The following should be noted:

- **Karoo Sediments:** the southern and eastern extent of the model domain is underlain by Karoo shales. The sedimentary aquifers are expected to be low yielding minor aquifers. Dwyka formation tillite outcrops west of the TSF and occurs beneath the shales in the TSF area. At depth the Dwyka is anticipated to be a very low yielding aquifer.
- **Natal Group Shale:** which outcrop in the southwest of the domain and in the northeast are present beneath the Dwyka and are low permeability aquifers. No aquifer testing has been completed in proximity of the TSF and the parameters assumed in the model and summarised below in Table 8-1 are based on literature. A regional west to east striking thrust fault has resulted in the juxtaposition of basement granite and amphibolite, outcropping in the northwest of the domain, against the younger Karoo sediments present in the south.
- **Amphibolite/ Gneiss/Mica Schist (Pit Area):** boreholes drilled in the pit area intersected amphibolite, gneiss, and mica schist. Four aquifer tests were completed in this area and had varied hydraulic conductivity values ranging between 7 - 52 m^2/d. Analysis of the drilling logs and water strike details (Golder, 2015) indicated that water strikes were typically not encountered until depths of below 100m. The highest strikes were typically obtained between 180 and 200 m below surface. Water levels are typically much shallower than these strikes (30 -80 mbgl) and indicates confined conditions. Based on the observation of water strikes, the hydraulic conductivity in the pit area was assumed to have low conductivity values to a depth of approximately 200 mbgl and thereafter hydraulic conductivity increased.
- **Granite**: no borehole logs or aquifer testing is available for the granites north of the pit area and consequently literature parameters are assumed.
- **Regional faults**: regional fault structures crosscut the model domain. No aquifer testing was completed to characterise the fault structures. The faults are assumed to be conductive.
- **Alluvial sediments**: no aquifer testing is available in the river channel areas. The sediments are assumed to be highly conductive zones.
- The storativity of the aquifer is unknown and an assumed specific storage of 1e-05 m^{-1} has been applied within the model.

Table 8-1: Summary of hydraulic parameters assumed within the model (Kx = Ky = Kz)

Hydrogeological Zone	Layer	Thickness (m)	T (m2/d)	K(m/d)
Granite	Layer 1 - 7	280	0.28	1.00E-03
	Layer 8 -11	340	0.034	1.00E-04
Amphibolite	Layer 1 - 4	200	0.1	5.00E-04
	Layer 5 -11	500	5	1.00E-02
Karoo Sediments	Layer 1 - 2	35	0.35	0.01
	Layer 3 -11	320	0.0032	1.00E-05
Natal Group Shale	Layer 1 - 2	80	0.8	0.01
	Layer 3 -11	320	0.064	2.00E-04
Faults	Layer 1-11	500	5	0.014286
Alluvial Sediments	Layer 1	12	12	1

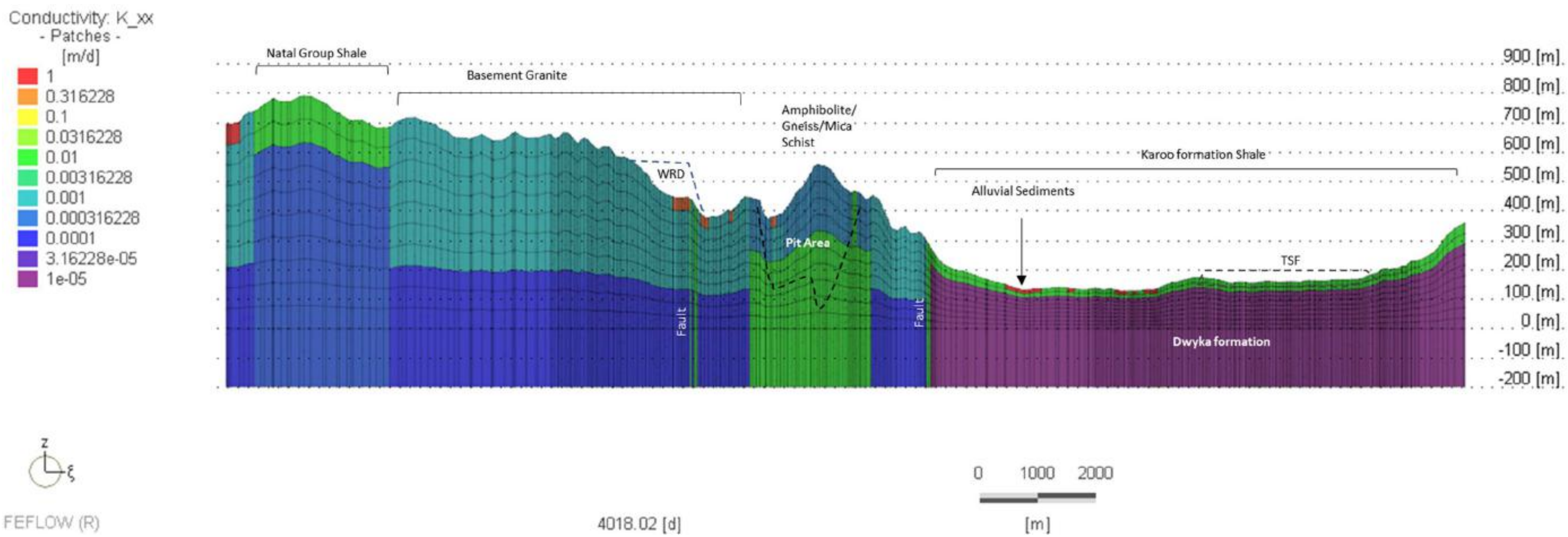


Figure 8-2: North – South (A- A') Cross Section of the hydraulic conductivity in the model domain

8.6.4 Mine pit development

An open pit mine is proposed to target the iron ore reserves at the site. The pit has west to east extent of 4.45 km and the north south width of the pit at the widest point is approximately 1 km. The current surface topography of the pit ranges from 615 mamsl to 320 mamsl and the average surface elevation is 500 mamsl. The deepest areas of the proposed pit are expected to reach 96 mamsl (*sc18reviseddesign (Final Pit) (strings).dxf*).

The modelling operation has been simulated for 31 years (2023 to 2053) although, the LOM is 25 years. The RoM ore and waste mined per year is indicated in Figure 8-3. The mine schedule and final pit shell (*sc18reviseddesign (Final Pit) (strings).dxf*)) was provided to SLR for the hydrogeological simulations of groundwater ingress to the pit. The provided schedule and the final pit shell was used to generate a mining sequence to be incorporated into the numerical model. The assumed mining elevation of the pit over time is shown in Figure 8-4.

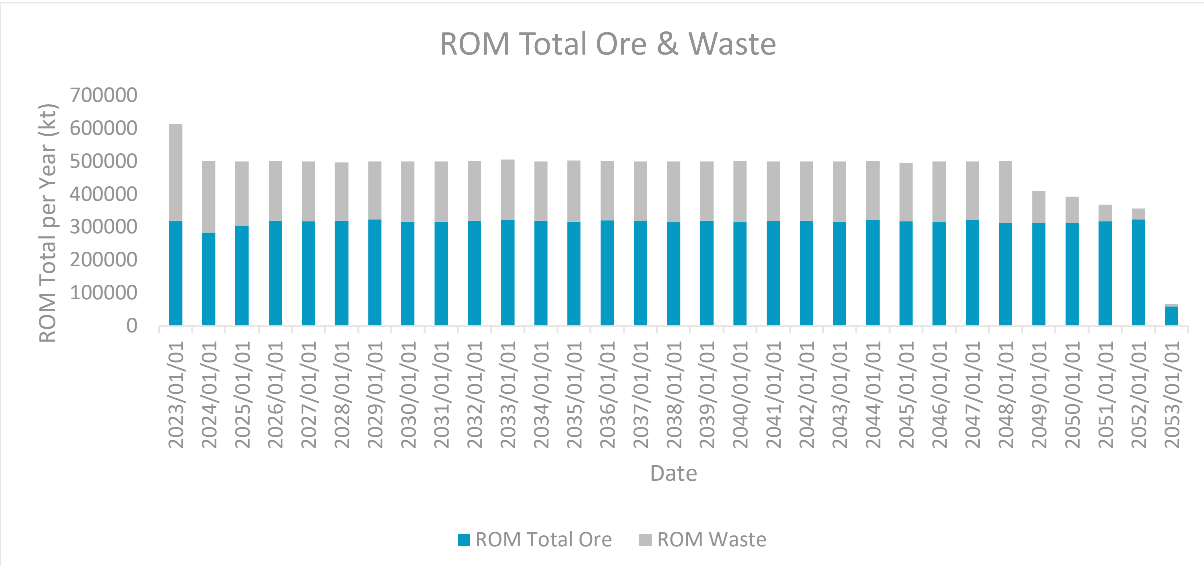


Figure 8-3: ROM Total Ore & Waste generated per year

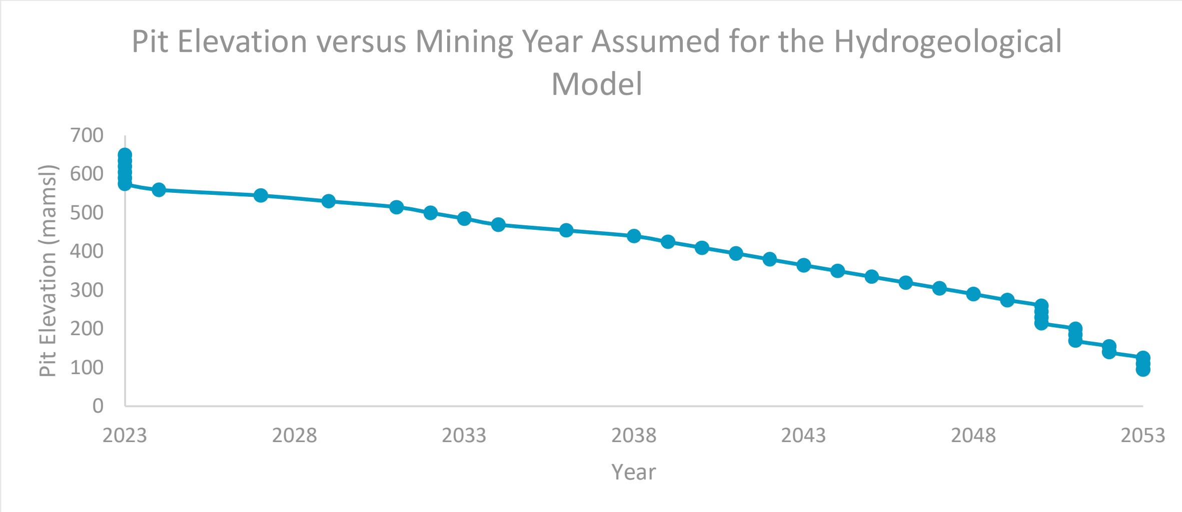


Figure 8-4: Pit elevation versus mining year assumed for the hydrogeological model

8.6.5 TSF & WRD

The TSF is proposed to be lined with a high density polyethylene (HDPE) liner or geosynthetic clay liner (GCL). Potential seepage is negligible (Table 8-2 and Table 8-3). The return water dam is proposed to be lined with concrete, HDPE or GCL and is similarly expected to have negligible seepage (Geotheta, 2023).

The waste rock dump is expected to be lined with a Class C liner. Potential seepage volumes around the dump are assumed to be comparable to recharge in the area.

Table 8-2: Seepage through TSF liner

Layer	K (m/s)	Hydraulic gradient	Area (m^2)	Q (l/d)
HDPE Liner	5.0×10^{-12}	1	9 3000 000	4 018
GCL	2.6×10^{-11}	1	9 3000 000	20 822

Table 8-3: Seepage through RWD liner

Layer	K (m/s)	Hydraulic gradient	Area (m^2)	Q (l/d)
Concrete	$1X10^{-12}$	1	710 000	61
HDPE Liner	5.0×10^{-12}	1	710 000	30
GCL	2.6×10^{-11}	1	710 000	1 555

The analysis of material to be discarded in the WRD and TSF indicated the following:

- The Waste Rock lithologies and WRD modelled source terms predict no CoCs with the exception of Mercury that exceeds both the SANS 241 ad IFC guidelines. Mercury was, however, reported to be below detection limits therefore this predicted value is based on a theoretical input concentration and should be disregarded.
- The modelled source terms for the TSF predict that Aluminium in the Fresh tailings samples is exceeding the DWAF and SANS 241 guidelines, while both tailings samples predicted an exceedance of SANS 241 and IFC Mercury guidelines, however Mercury was reported below SPLP detection limits therefore this predicted value is based on a theoretical input concentration and can be disregarded.
- Sulphate was selected to trace potential migration of contaminants. The estimated seepage concentrations for sulphate in the TSF and WRD are summarised in Table 8-4. The sulphate concentration is well below drinking water quality guidelines limit.

Table 8-4: Sulphate source terms

Source Term Area	SANS 241 / DWAF (mg/l)	Sulphate in Seepage (mg/l)
TSF	500	20
WRD	500	31

For the simulation of mass transport, additional parameters required include porosity and dispersivity. There is no field testing to provide guidance for these parameters and literature values are therefore assumed.

- Porosity: 3 %
- Longitudinal and transverse dispersivity: 5 m and 0.5 m

8.6.6 Model assumptions, limitations and data confidence

The following limitations were identified in conceptualisation and setup of the numerical model:

- Recharge was estimated by the chloride mass balance for the shales in the TSF area. However, no water quality data was available for the northern areas of the project in proximity of the pit and quantification of recharge based on measured data was not possible. Recharge was estimated and calibrated within the model.
- Only four aquifer tests have been completed in the study area. All four boreholes are located within the pit area. The transmissivities obtained varied between 7 m^2/d and 53 m^2/d. High variability is typical of fractured rock aquifers. The Golder (2015) study reported that the confidence of the test at MWGA03 is low due to artesian conditions within the borehole. The variability, however, reduces

the certainty when applying a representative hydraulic conductivity in the pit area. To address the uncertainty a range in hydraulic conductivity values for the pit area was included in the assessment.

- The current aquifer parameter data for the pit is very limited and the modelling presented here is suitable for ESIA level impact prediction and high-level estimation of ingress to the pit. The model is not suitable for developing a detailed dewatering strategy for the pit i.e., quantifying pore pressure difference in the pit wall and recommending suitable locations for dewatering boreholes.
- Records of water strikes in the pit boreholes indicated that there were very few water strikes obtained between surface and 180 mbgl. It has been assumed that the upper aquifer zones are less conductive than the deeper zones within the pit. The available aquifer testing does not, however, differentiate the two zones and hence the conductivity values for the upper and lower zone are required to be assumed.
- For the current study, three water levels were measured at the TSF boreholes that were recently drilled (TSF05-2, TSF05-03 and TSF05-01). No water level data was available for TSF05-01 and TSF05-05[1].
- Historical water levels collected by Golder (2015) were used to characterise the pit area. Access issues prevented an update of water levels in the pit area. The water levels have been plotted against elevation to determine if any deviations occur from the expected trend. STH-69, STH-57 and STH-71, which are diamond drill holes have deeper water levels than expected. It is likely that these water levels do not represent true water levels and the aquifer at the time of sampling was still recovering. This should be validated by remeasurement of the holes.
- There is no water level information in proximity of the WRDs and consequently the water level conditions are inferred from water levels in the pit area.

[1] The coordinates of TSF05-05 are not available.

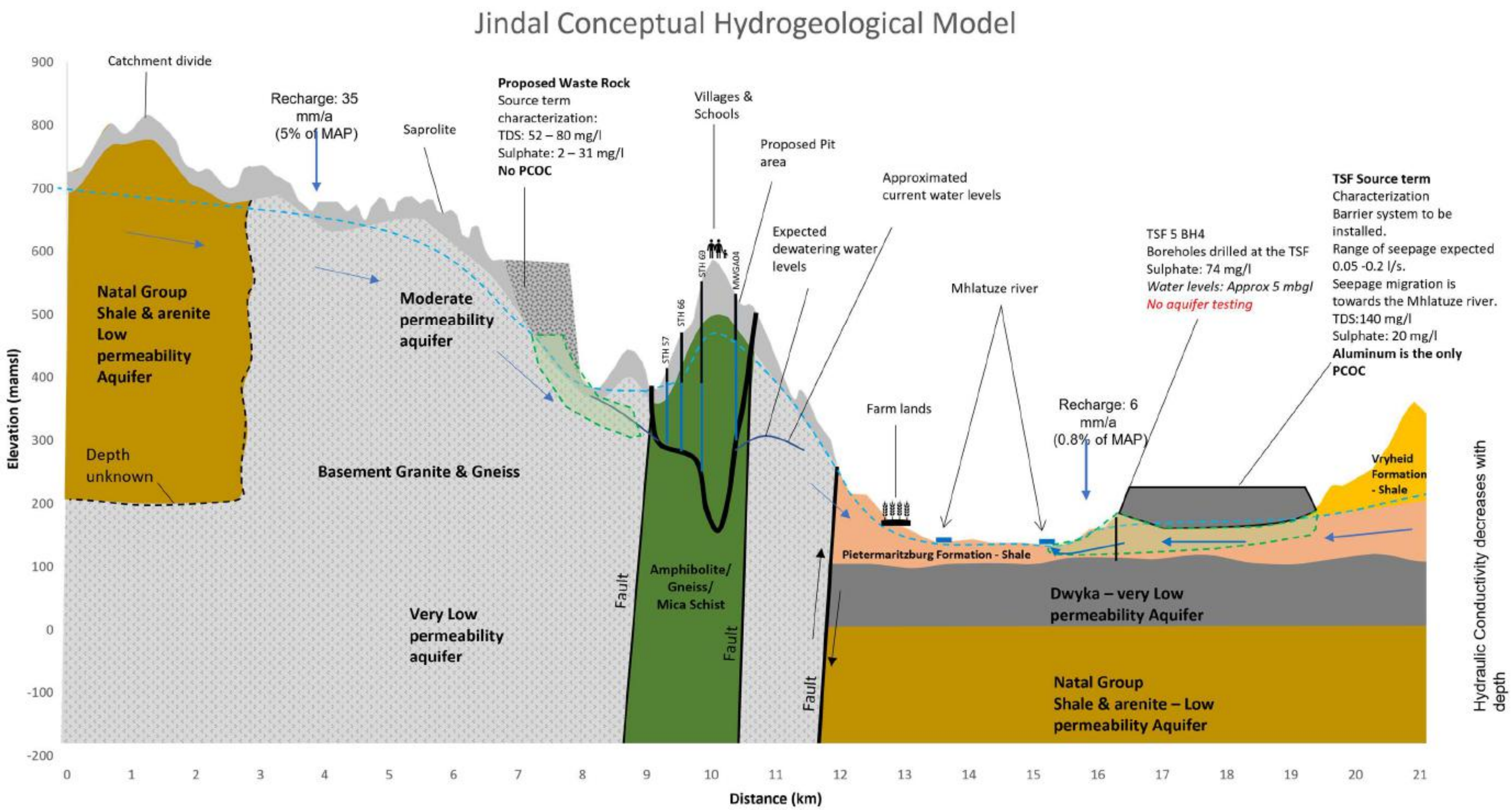


Figure 8-5: Jindal Conceptual Hydrogeological Model

8.7 NUMERICAL MODEL

A three-dimensional steady state groundwater flow model representing the study area was constructed to represent pre-mining groundwater flow conditions. These conditions serve as the initial conditions for the transient simulations of groundwater flow and mass transport associated with mine development.

The three-dimensional groundwater flow equation on which Feflow modelling is based is expressed below:

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ky\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(Kz\frac{\partial h}{\partial z}\right)\pm W=S\frac{\partial h}{\partial t}$$

Where:

- h: Hydraulic Head [L]
- Kx, Ky, Kz = Hydraulic conductivity [L/T]
- S = storage coefficient
- T = Time [T]
- W = Source and sinks [L/T]

The numerical model was calibrated in steady state against the water level data collected by Golder (2015) in the pit area and the three recent (2022) water level measurements at the TSF. The water level data in the pit is highly variable and it was observed that nearby boreholes often had widely varying water levels. To match conditions more closely within the pit, a detailed geological model for the pit area should be considered and supported with a larger dataset of aquifer parameters. Packer testing of boreholes would add significant value in this area to differentiate the conductivity in the upper and lower aquifer zones within the pit. Effort was made to fit the pit water levels to those observed and the general mean of water levels in the pit and those observed, was obtained (± 450 mamsl). Suitable fit between measured and computed water levels and consequently flow direction were obtained for the TSF area. Table 8-5 the quantified calibration considering measured and computed water levels. The calculated NRMSE (Normalised Root Mean Aquared Error) value of 7% shows that the calibration is reasonable, according to generally accepted guidelines for Numerical Models Calibration of less that 10%.

Table 8-5: Summary of model errors for the simulated and observed heads

Borehole	Observed Water Level (mamsl)	Simulated Water Level (mamsl)	Error (m)	Abs Error (m)
MWGA06	551.85	556.83	-4.98354	4.983541
GJ02	550.05	585.72	-35.6724	35.672399
GJ14	518.00	541.13	-23.1298	23.129752

Borehole	Observed Water Level (mamsl)	Simulated Water Level (mamsl)	Error (m)	Abs Error (m)
GJ01	497.08	439.17	57.91129	57.911289
GJ15	477.00	475.90	1.095047	1.095047
MWGA03	429.93	407.42	22.51472	22.514718
MWGA07	409.23	426.29	-17.059	17.059032
MWGA05	391.10	454.06	-62.9569	62.956887
MWGA04	390.32	421.53	-31.2129	31.212871
STH-56	378.00	409.93	-31.9301	31.930052
STH-86	374.60	401.10	-26.4976	26.497571
MWGA02	203.37	219.83	-16.4579	16.457936
TSF5-04	162.31	159.48	2.834272	2.834272
TSF5-03	124.51	126.06	-1.55119	1.551187
TSF5-02	104.14	111.71	-7.56878	7.568781
Error Type	Value			
Error (m)	-11.64			
Absolute Error (m)	22.89			
Root Mean Square Error (m) (RMSE)	29.42			
Normalized root mean square error (%) (NRMSE)	7%			

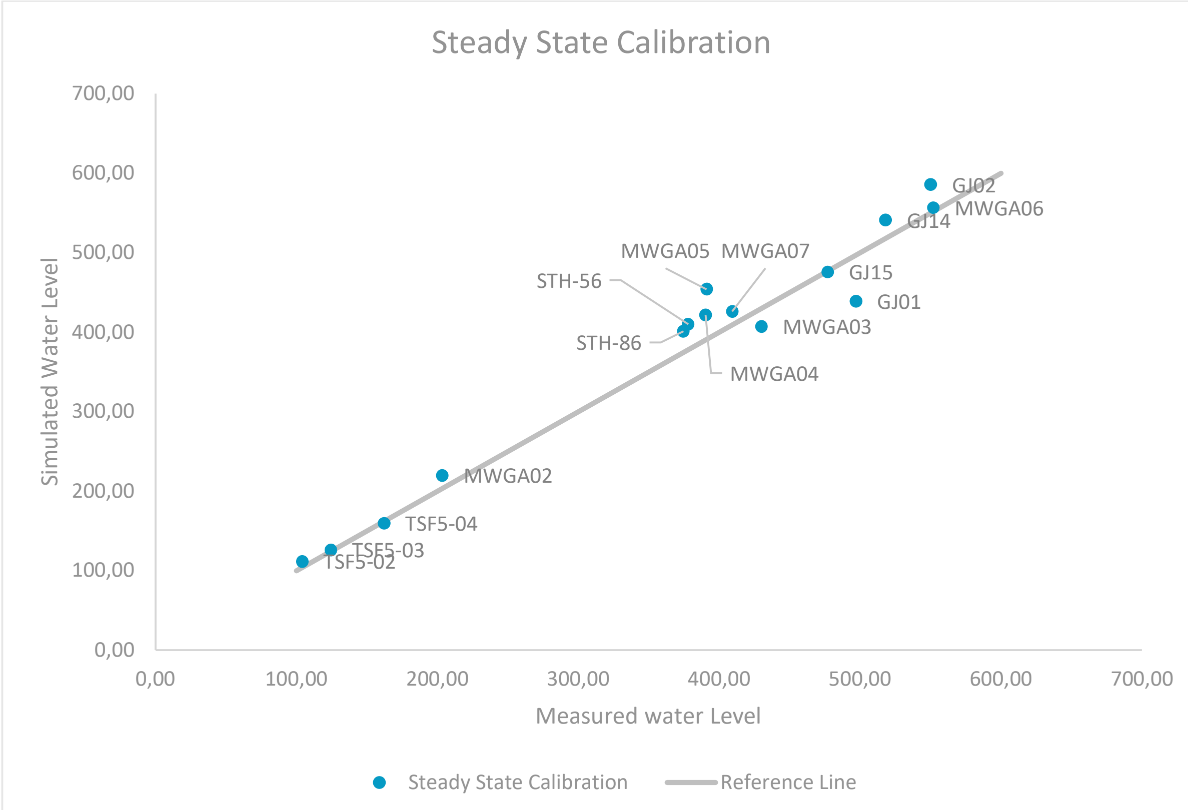


Figure 8-6: Steady state calibration simulated and observed hydraulic heads in meters above mean sea level

Due to the variability of transmissivity obtained from the pumping tests, a second scenario was modelled where conductivity in the pit area was increased to represent a median value of the aquifer tests. The input parameters are summarised in Table 8-6.

Table 8-6: Hydrogeological parameters of scenario 1 and scenario 2

			Scenario 1 (T Pit Area = 5m^2/d)		Scenario 1 (T Pit Area = 30m^2/d)	
Hydrogeological Zone	**Layer**	**Thickness (m)**	**T (m^2/d)**	**K (m/d)**	**T (m2/d)**	**K (m/d)**
Granite	Layer 1 - 7	280	0.280	1.00E-03	0.280	1.00E-03
	Layer 8 - 11	340	0.034	1.00E-04	0.034	1.00E-04

			Scenario 1 (T Pit Area = 5m²/d)		Scenario 1 (T Pit Area = 30m²/d)	
Amphibolite	Layer 1 - 4	200	0.100	5.00E-04	0.600	3.00E-03
	Layer 5 - 11	500	5.000	1.00E-02	30.000	6.00E-02
Karoo Sediments	Layer 1 - 2	35	0.350	0.01	0.350	0.01
	Layer 3 - 11	320	0.003	1.00E-05	0.003	1.00E-05
Natal Group Shale	Layer 1 - 2	80	0.800	0.01	0.800	0.01
	Layer 3 - 11	320	0.064	2.00E-04	0.064	2.00E-04
Faults	Layer 1- 11	500	7.143	0.014286	7.143	0.014286
Alluvial Sediments	Layer 1	12	12.000	1	12.000	1

The water balance pre-mining is summarised in Table 8-7. The pre-mining water levels are indicated in Figure 8-7.

Table 8-7: Steady State Water balance

Steady State Water Balance			
Parameter	Inflow	Outflow	Balance
Sources (Recharge) (m^3/d)	13 677	0	13 677
Sinks (Base flow, springs) (m^3/d)	0	-13.677	-13 677
Sinks (Mine Water Supply) (m^3/d)	0	0	0
Sinks (Mine Dewatering) (m^3/d)	0	0	0
Storage (m^3/d)	0	0	0
Balance (m^3/d)	13677	-13677	0

8.8 RESULTS OF THE MODEL

The calibrated steady state model was used to simulate the expected ingress into the pit and quantify the cone of depression. A mass transport simulation was performed to determine the expected impact of seepage from the WRD area and the TSF.

8.8.1 Pre-mining

Pre-mining activities may require some groundwater abstraction for dust suppression and construction activities. The required yields for this stage are expected to be small (50-100 m^3/d (±1 l/s)). The drawdown associated with abstraction for this purpose is expected to be localised and is unlikely to have long term impact on receptors. Prior to utilising a water supply borehole for construction purposes, aquifer testing and licencing should be completed.

8.8.2 Operational Phase

During the operational mining of the open pit, mining of the pit will result in ingress of groundwater to the pit and dewatering of the surrounding aquifers. The simulations of these processes are described in Section 8.8.2.1. The TSF and RWD are proposed to be lined and consequently the seepage from the facilities will be negligible. The characterised source terms indicate that even if seepage was to occur the seepage is of good quality and typically does not exceed drinking water quality guidelines apart from elevated aluminium. It should be noted that the modelled aluminium exceedance in the fresh tailings sample is theoretical due to input concentrations being modelled to equilibrium with the aluminosilicate mineral Phlogopite. Additionally, aluminium species solubility decreases in neutral to alkaline pH conditions reported for the tailing's leachate, and acid conditions are unlikely to occur over time due to the high neutralization potential of the materials.

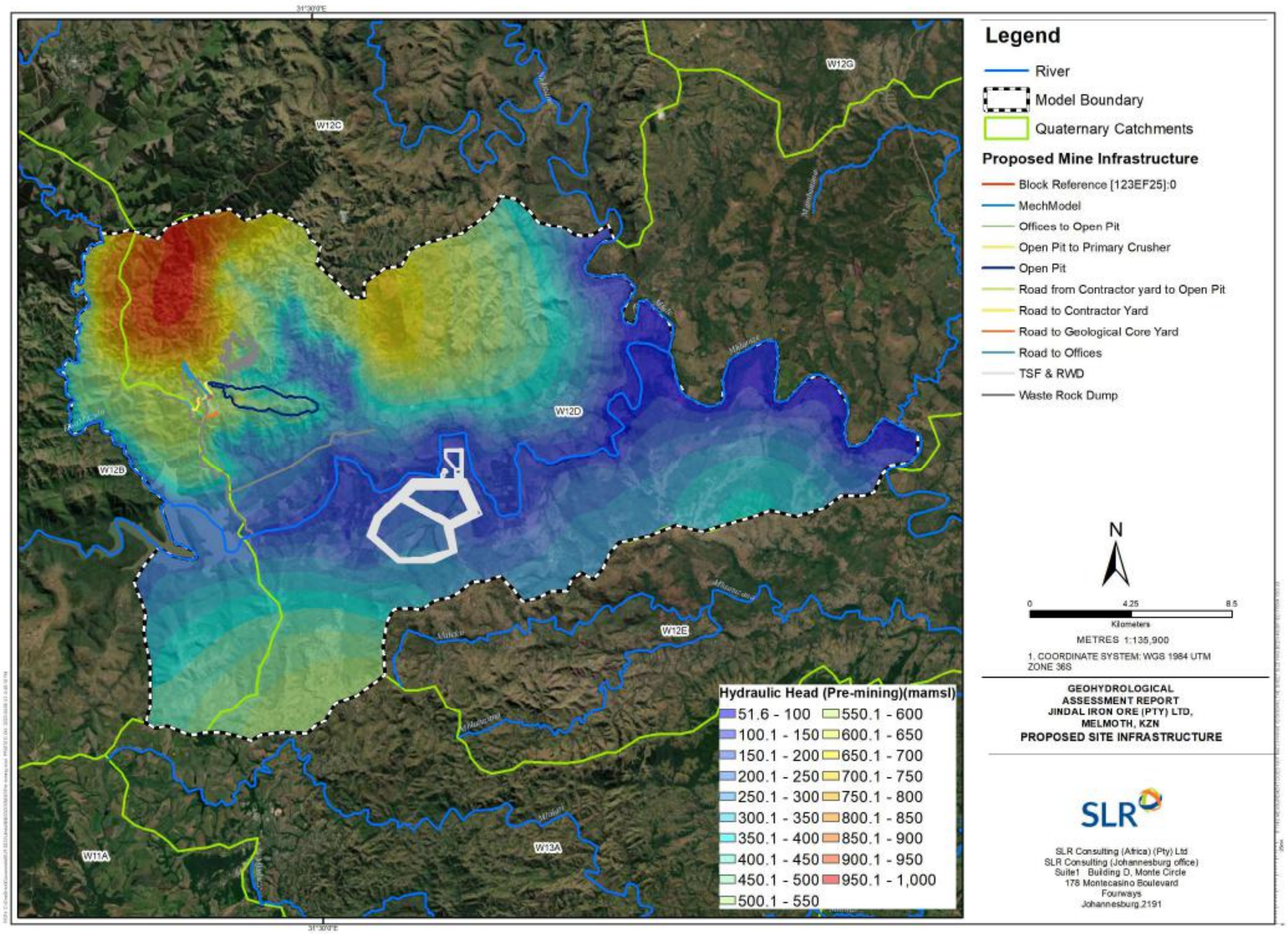


Figure 8-7: Hydraulic Head Pre-mining

8.8.2.1 Groundwater pit inflows and drawdown

During mining, the open pit will gradually expand and deepen during the 25-year life of mine. The conceptualisation of the aquifers in the pit area are that the upper zones (above 200 m) have a low hydraulic conductivity and higher conductivity values are encountered at depth. Due to the distribution of conductivity and the water levels within the pit, groundwater inflows into the pit are expected to be very low (< 5 l/s) initially. From approximately 440 mamsl to the pit bottom inflows gradually increase. The large range of potential inflows (i.e., peak inflows range between 37 l/s – 80 l/s) is indicative of the uncertainty associated with conductivity in the pit area.

The hydrology assessment (SLR, 2022b) outlines the expected surface water inflows to the pit. However, to contextualise the groundwater ingress, the hydrology has been considered. The mean annual rainfall for the area is 840 mm/and approximately 196 rainfall days are expected each year. Assuming only direct rainfall reports to the pit, mean rainfall contributions to the pit area in December (the wettest month of the year) is expected to exceed 120 l/s while in June (driest months of the year), mean rainfall on rainy days (avg. 8 rainy days in June) could contribute < 2 l/s (Figure 8-8). In the initial years of mining, surface water inflows are expected to significantly exceed groundwater inflows to the pit and water management will consequently be more intensive in the wet summer months. As the pit reaches deeper elevations (below 440 mamsl), groundwater ingress is expected to increase and water management will be required during both the wet and dry months of the year.

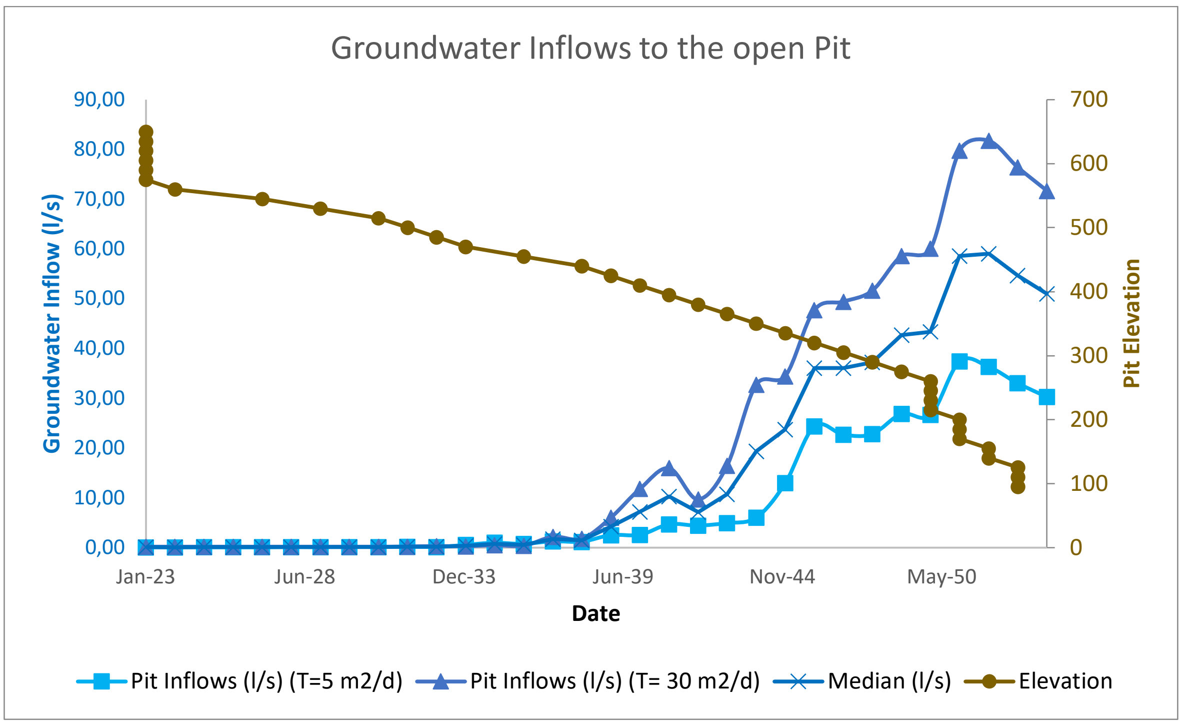


Figure 8-8: Estimated groundwater inflows versus pit elevation.

The cone of depression resulting from mining at life of mine is shown in

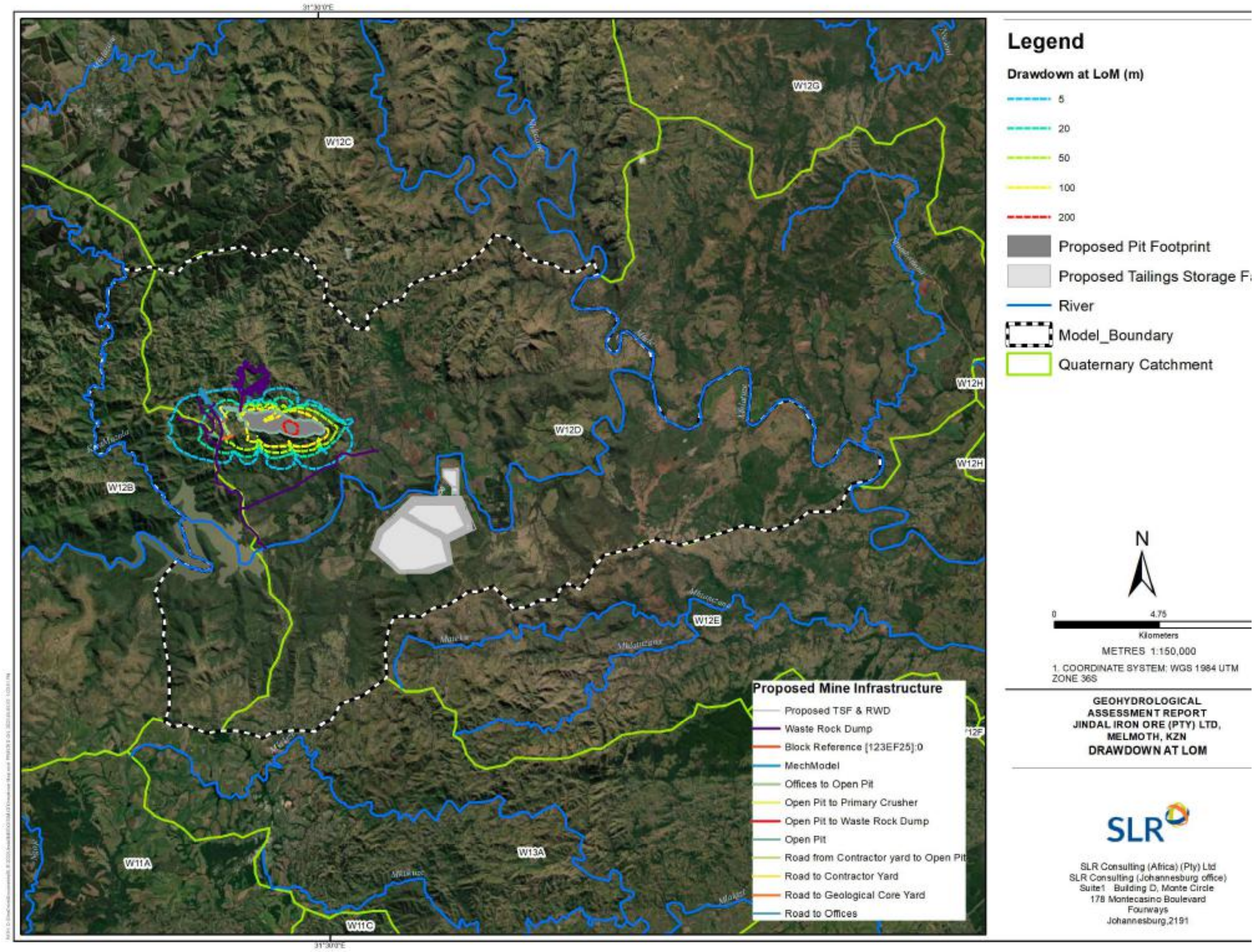


Figure 8-10 and Figure 8-11. The extent of drawdown, where drawdown exceeds 5 m relative to the steady state water level, is up to 2.5 km in a westerly direction, 1.6 km in a southerly direction, 1.2 km in a northerly direction and 1 km in an easterly direction. Groundwater users that fall within this area are expected to have a notable drawdown in water level in supply boreholes. The farm areas on which drawdown, exceeding 5 m, is expected to occur includes: Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters

11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351. This is graphically shown in

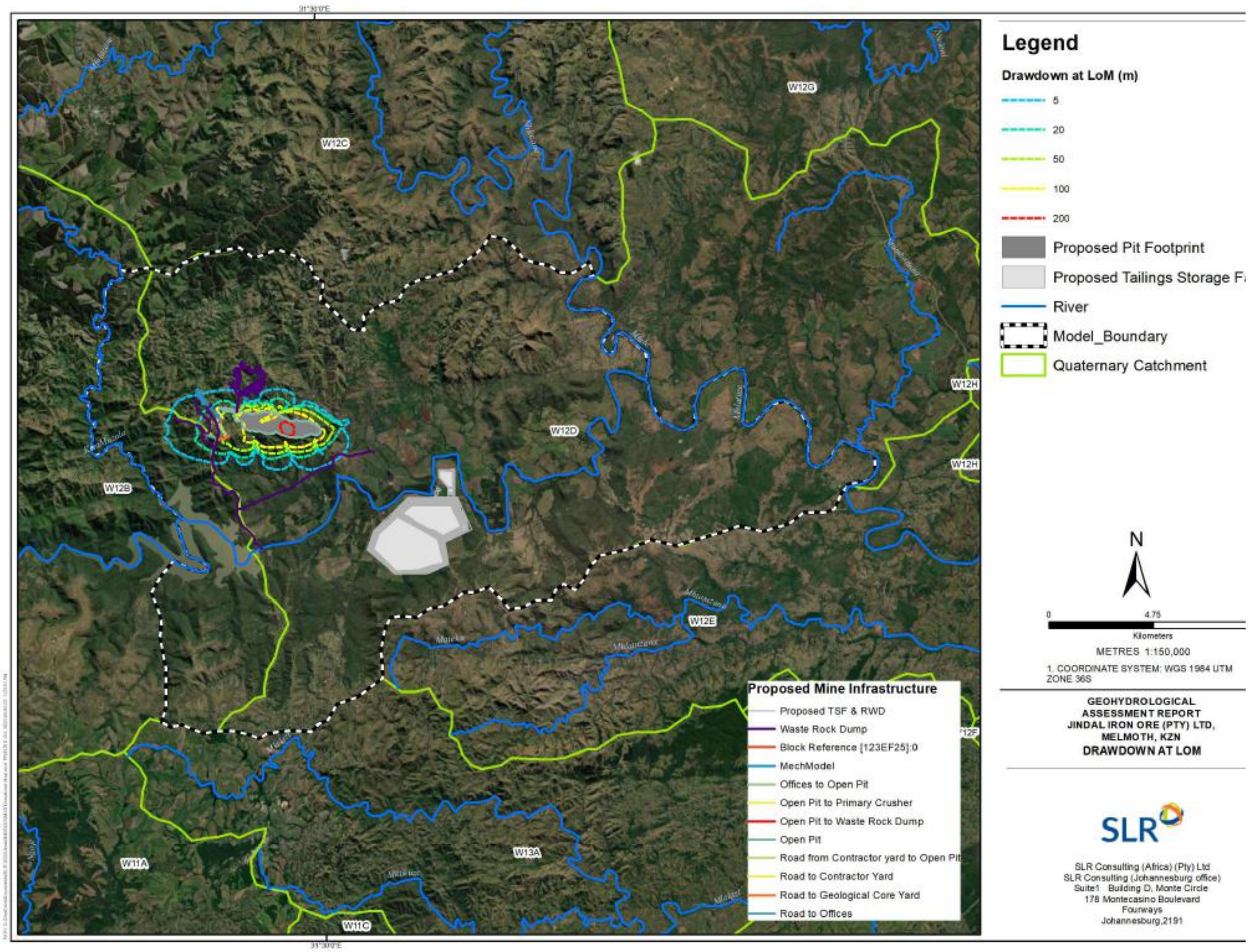


Figure 8-10 and Figure 8-11.

Groundwater abstracted from the pit for dewatering may be used in the plant if required or alternatively will be discharged into a nearby tributary. The implementation of silt traps and water quality testing protocols are required prior to discharge to ensure there are no adverse ecological effects.

8.8.2.2 Baseflow reduction

River flow comprises of surface water flow and groundwater contributions. The modelled groundwater contribution to the river flows in the catchment is estimated to be 6 % of river flow. The development of the cone of depression and dewatering of aquifer zones adjacent to the pit result in a lowering of water level and a reduction in the amount of groundwater baseflow that discharges to the streams in the catchment. The reduction in baseflow over the operational period is a 9 % reduction. The river flow reduction because of mining is a 0.5 % (37 539 042 m^3) reduction in river flow over a 30-year period, an insignificant change as seen in Figure 8-9.

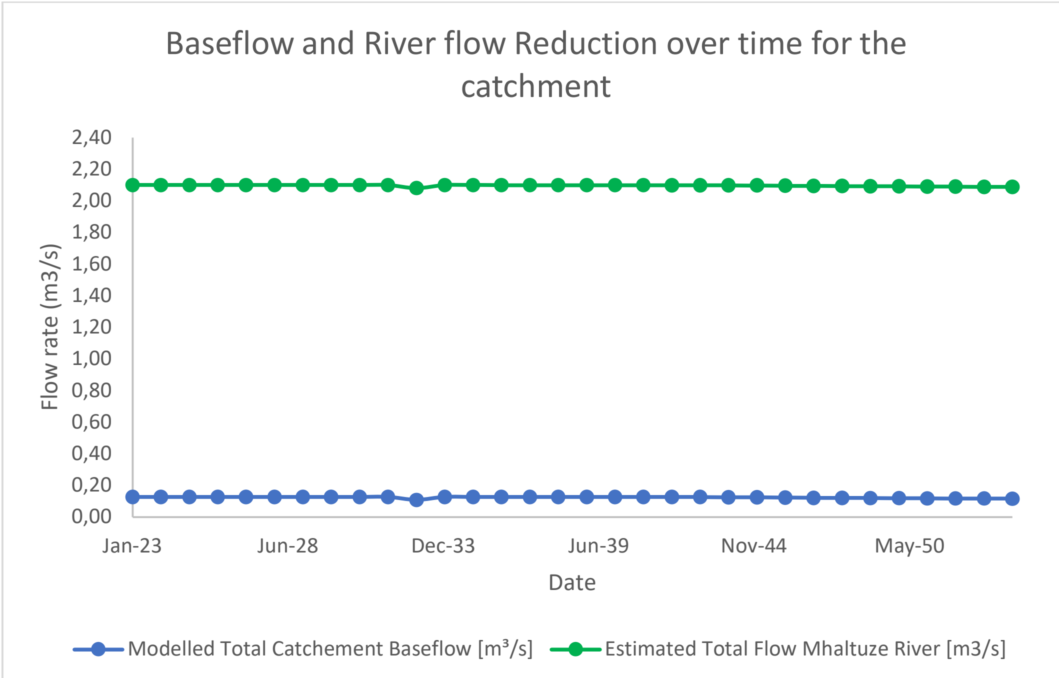


Figure 8-9: Baseflow and River flow Reduction over time for the catchment

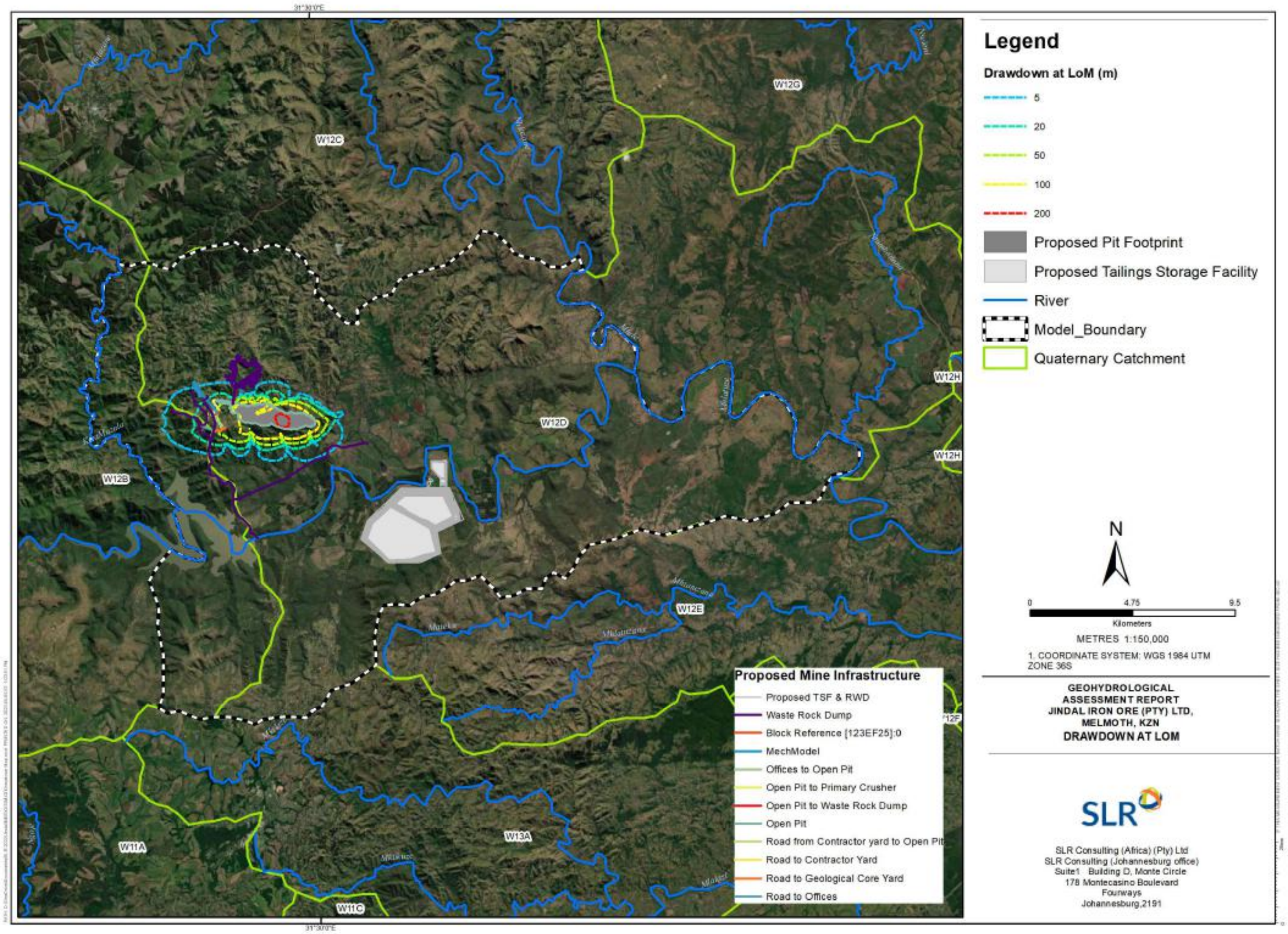


Figure 8-10: Drawdown exceeding 5 m at completion of mining

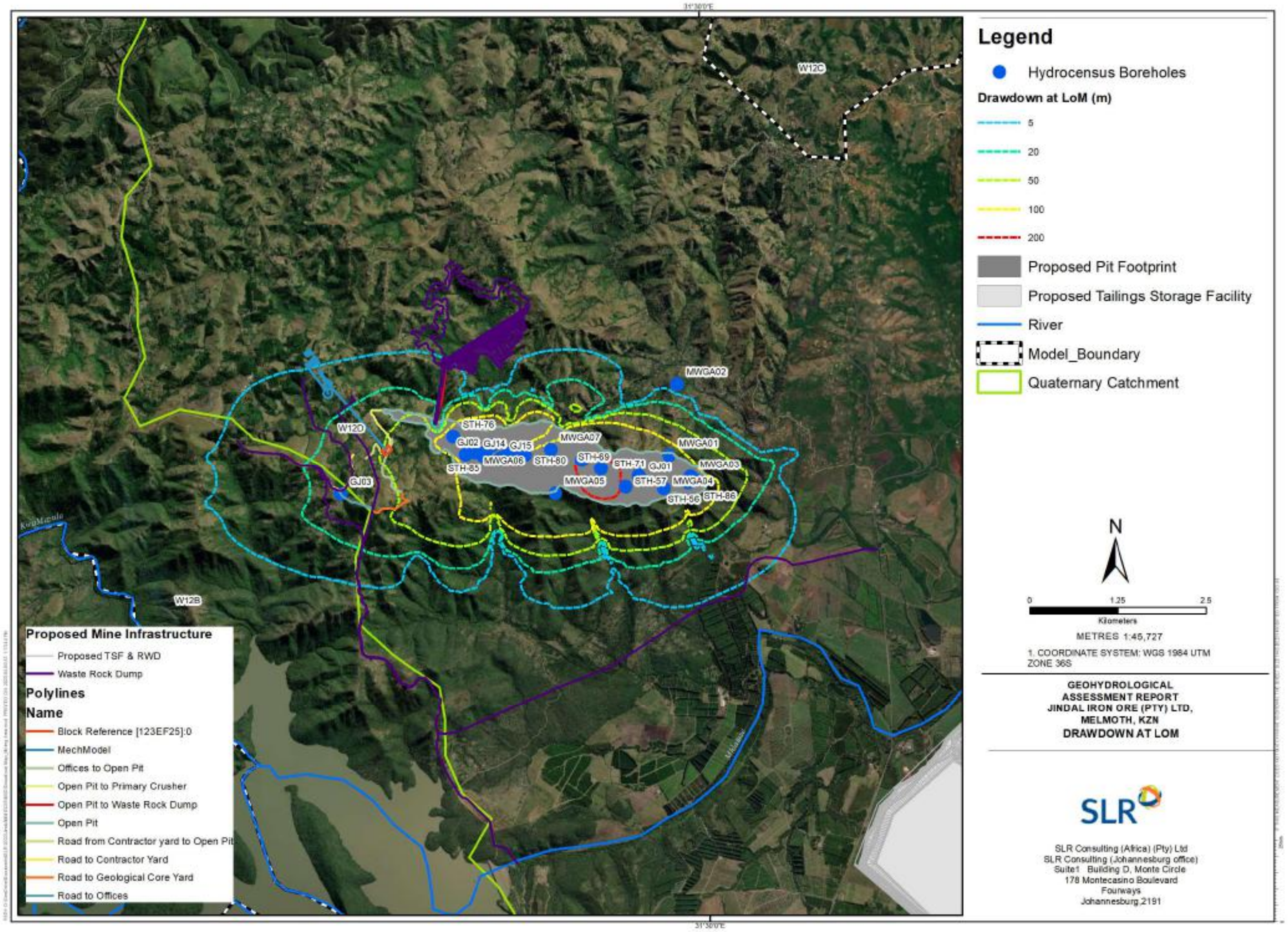


Figure 8-11: Drawdown exceeding 5 m at completion of mining – Mining Area

The operational groundwater balance at LoM is summarised in Table 8-8.

Table 8-8: Operational Groundwater Balance at LoM

Operational Groundwater Balance at LoM			
Parameter	Inflow	Outflow	Balance
Sources (Recharge) (m^3/d)	13 677.0	0.0	13 677.0
Sinks (Base flow, springs) (m^3/d)	0.0	-12 684.0	-12 684.0
Sinks (Mine Water Supply) (m^3/d)	0.0	0.0	0.0
Sinks (Mine Dewatering) (m^3/d)		-2 616.4	0.0
Storage (m^3/d)	1 629.6	-6.2	0.0
Balance (m^3/d)	15 306.6	-15 306.6	0.0

8.8.2.3 Mass transport

As outlined in the preceding sections the proposed TSF will be lined either by GCL or HDPE liner and consequently seepage is negligible. Aluminium is the only potential contaminant of concern at the TSF. Sulphate has been used as tracer to simulate migration of a contaminant plume from the TSF. Sulphate in the TSF seepage is expected to be 20 mg/l which is well below drinking water quality standards.

The resulting plumes for an unlined and lined scenario at completion of mining are shown in Figure 8-12 and Figure 8-13.

- If the tailings were unlined the seepage water would flow into the Mhlatuze River. The Mhlatuze river has been gauged at several points intermittently. The median flow rate for data collected downstream of the TSF is 2.1 m^3/s. In an unlined scenario the potential seepage rate to the Mhlatuze is 0.06 m^3/s. Thus, the TSF inflows to the river under these conditions would account for 3 % of the flow rate. Aluminium, the only potential contaminant of concern from the TSF is unlikely to be a water quality concern in the river downgradient of the site.
- Where the facility is lined, the seepage emanating from the TSF and RWD is not expected to reach the Mhlatuze river during the operational phase of the project. If seepage did, however, reach the river, the inflows would contribute 0.01 % of total flows occurring within the river downstream of the TSF. Considering the characterisation of the seepage from the TSF, no impact on receptors in the downgradient river environment are expected.

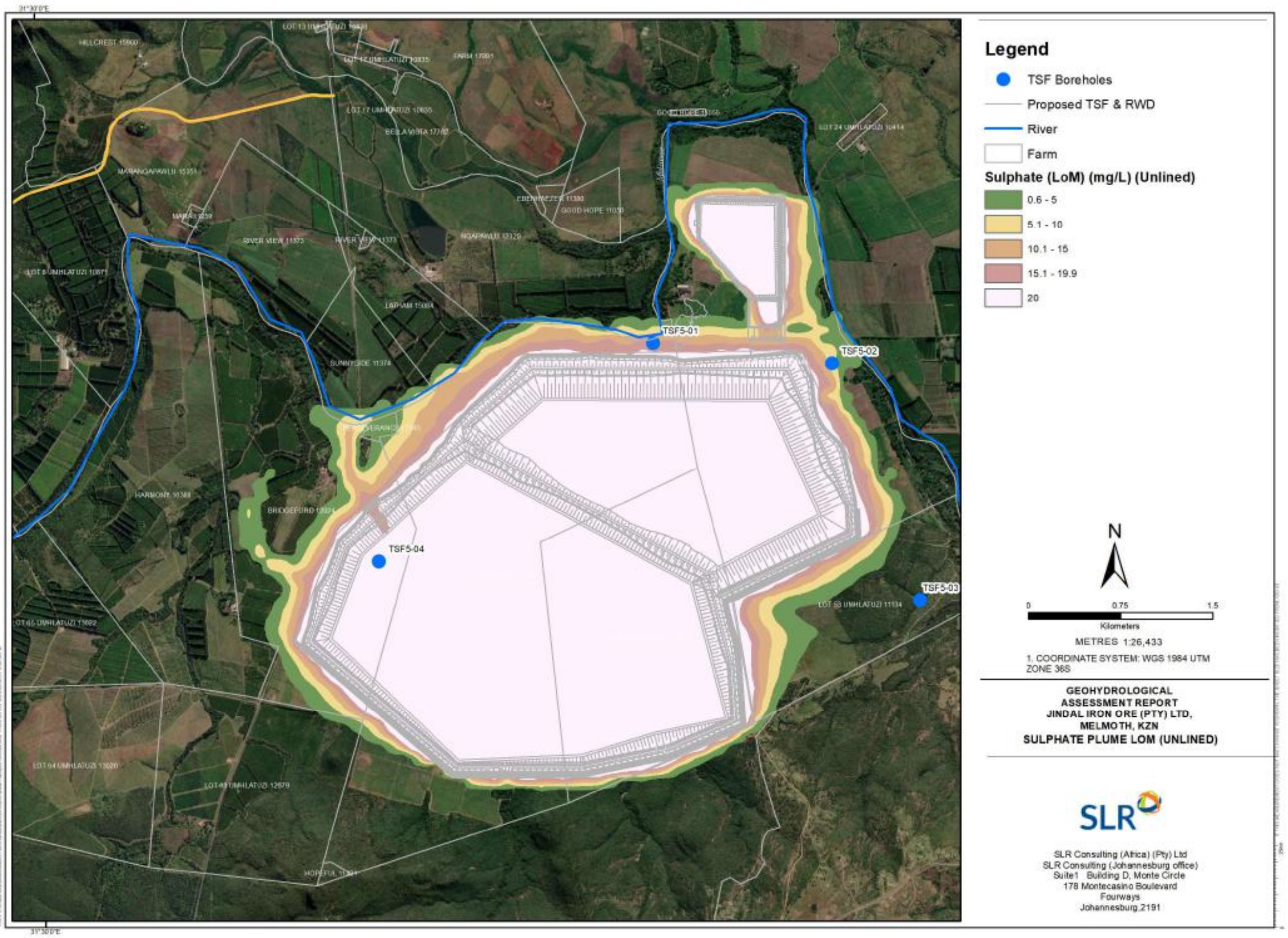


Figure 8-12: Sulphate plume at LOM at TSF (Unlined scenario)

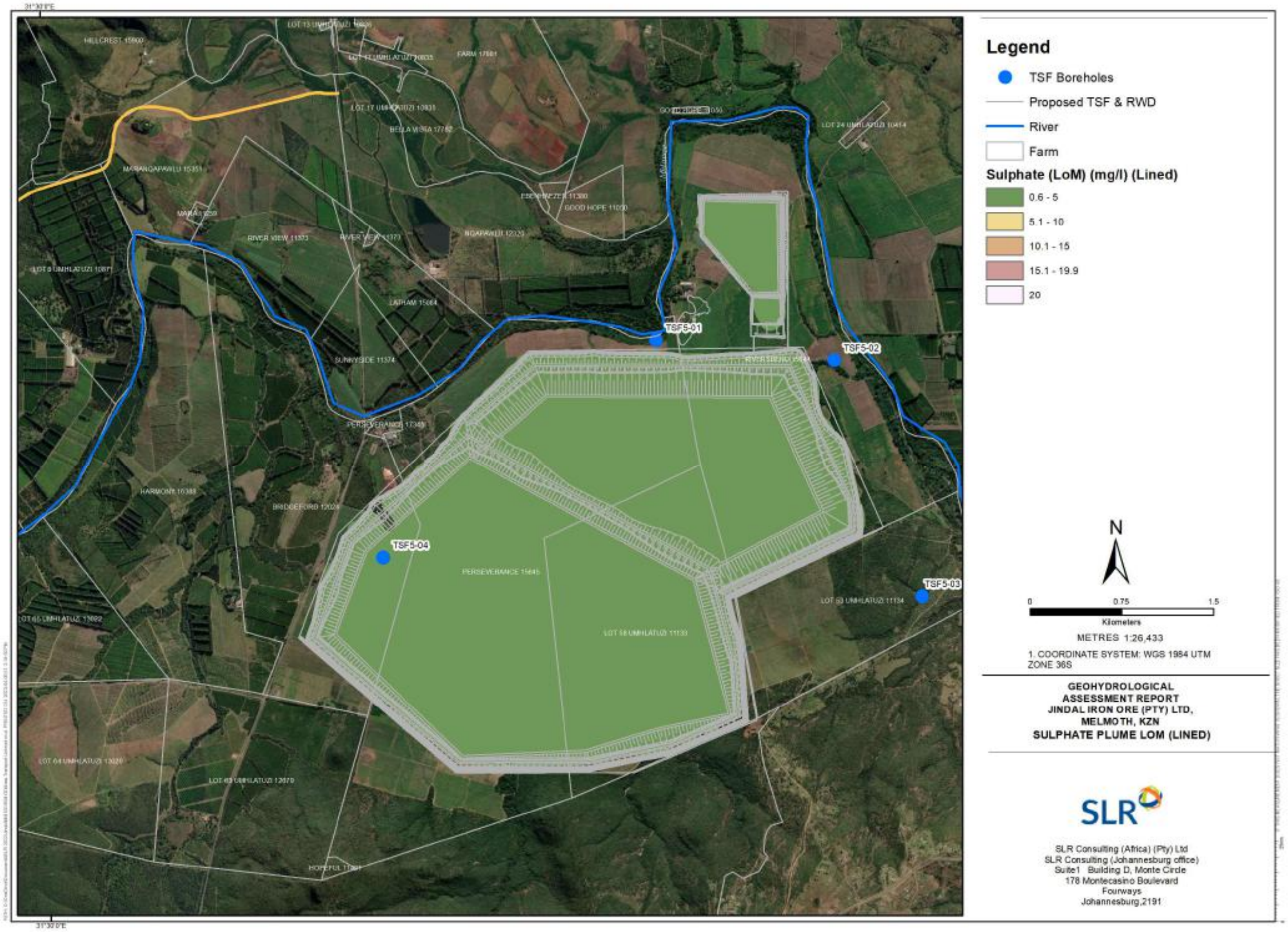


Figure 8-13: Sulphate plume at LOM at TSF (GCL - Lined scenario)

8.8.3 Post-mining

8.8.3.1 Post mining pit lake

Following cessation of mining the pit will fill due to ingress from the surrounding rebounding aquifers and direct rainfall onto the pit footprint area. Clean surface water will be directed away from the pit. The recovering water level within the pit is controlled by the inflows to the pit and the evaporation that acts on the surface water body (Table 8-9).

The lowest elevation on the pit wall is at 405 mamsl on the eastern extent of the pit. Should the pit decant or spill it would be expected to occur in this area (Figure 8-15).

A water balance of the pit lake was calculated based on modelled groundwater inflow rates, monthly mean rainfall and monthly mean evaporation. Based on this model the water level within the pit lake is expected to rapidly rise within the first year (± 100 m) following cessation of mining. The rapid rise occurs as the inflows (rainfall and groundwater) are initially substantially higher than the surface area of the lake for evaporation. The rise to 300 mamsl (i.e., ± 200 m rise in pit lake level) is expected to take a further 15 years. As the surface area of the lake increases so actual evaporation increases, and the rate of rise declines substantially.

Following 300 years the level in the pit lake is expected to be 374 mamsl and hence is below the decant elevation on the eastern edge of the pit. As such no overflow into the surrounding tributaries or rivers is anticipated as the pit remains a sink. No analysis has been completed on the quality of the pit lake over time.

Table 8-9: Average monthly rainfall and evaporation within the study area

Month	Monthly Rainfall (Melmoth Average Monthly Data) (www.weather-atlas.com)	Monthly Potential Evaporation (KZN Mean values - Agrohydrology atlas CSIR, 2001) *
January	83	192
February	77	163
March	71	127
April	53	127
May	46	108
June	22	93
July	27	103
August	27	133
September	35	153
October	74	170

Month	Monthly Rainfall (Melmoth Average Monthly Data) (www.weather-atlas.com)	Monthly Potential Evaporation (KZN Mean values - Agrohydrology atlas CSIR, 2001) *
November	94	173
December	98	197
Total	**707**	**1 739**

No adjustments were made for a conversion between pan and open water evaporation

Table 8-10: Estimated groundwater inflows at increasing pit lake elevations

Elevation (mamsl)	Groundwater inflows (l/s)
95	71.71
140	76.42
170	81.78
215	79.79
275	60.09
290	58.63
305	51.65
320	49.43
335	47.76
350	34.44
365	32.74
380	16.47
395	9.70
410	15.96

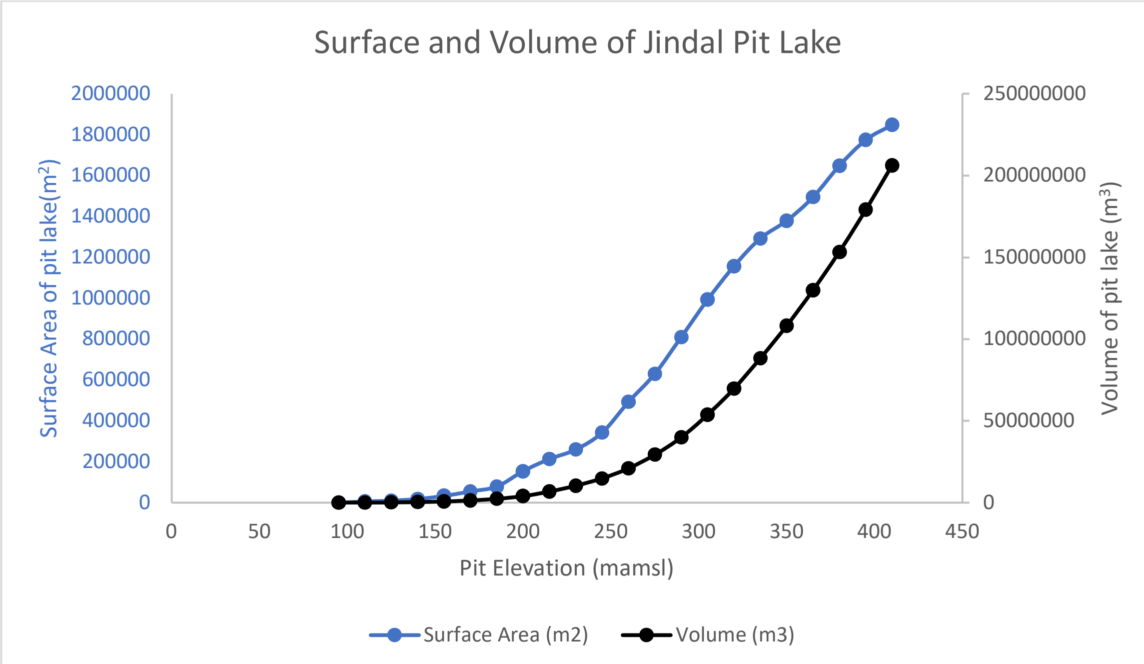


Figure 8-14: Surface area and pit lake volume relative to pit lake elevation

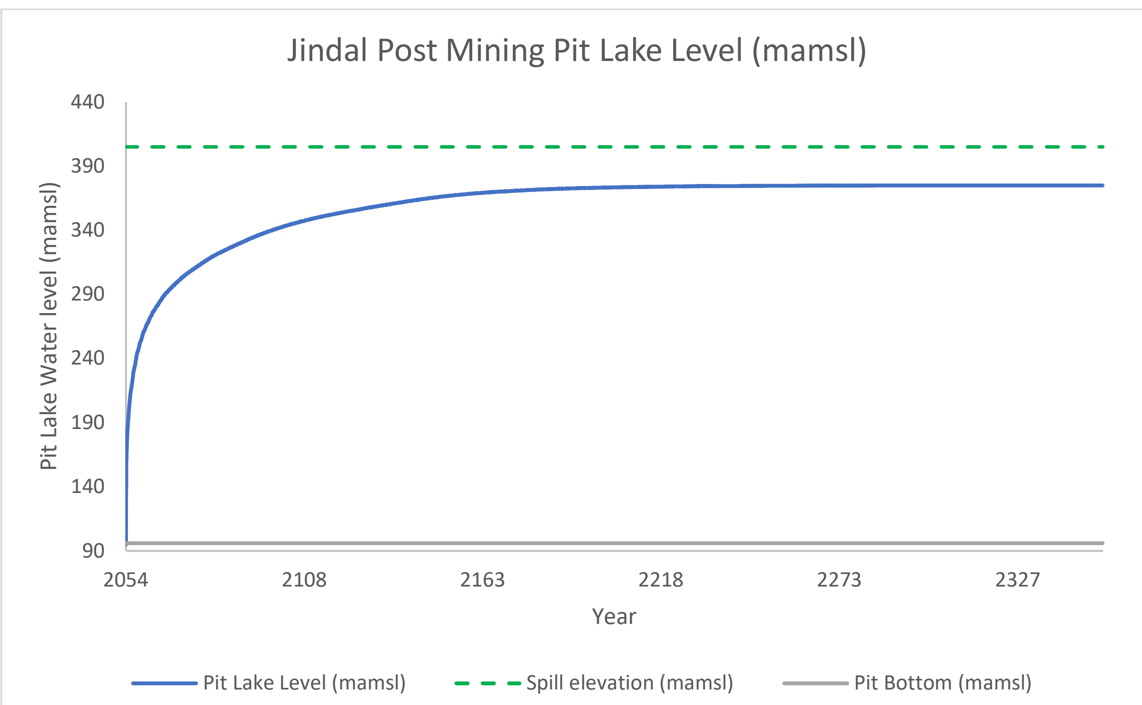


Figure 8-15: Post mining Jindal Pit Lake water level

8.8.3.2 Post mining mass transport

Following completion of mining the TSF and the WRD will be rehabilitated. Negligible seepage from the TSF is expected to occur following rehabilitation and there are no groundwater impacts (water level impacts or water quality impacts) anticipated post operations.

Rehabilitation of the WRD would reduce seepage from the facility. The source term characterisation of this facility indicated that there are no potential contaminants of concern and consequently any seepage which does arise post operations is not expected to impact upon nearby groundwater and surface water users.

9. GEOHYDROLOGICAL IMPACTS

Geohydrological impacts are possible at each phase of the mine's life cycle, i.e., construction, operation, decommissioning and post-mining phases. As such, potential impacts have been identified at each phase, in terms of groundwater quality and quantity and an impact assessment has been completed. The assessment methodology enables the assessment of geohydrological impacts including cumulative impacts and impact significance through the consideration of intensity, extent, duration, and the probability of the impact occurring. Consideration is also given to the degree to which impacts may cause irreplaceable loss of resources, be avoided, reversibility of impacts and the degree to which the impacts can be mitigated. The criteria on which the assessment is based, is presented in Appendix B.

It should be noted that the impacts "without mitigation", take into account the legal requirement of using a liner. According to the NEMWA GN R. 635 and 636 of 2013, all the WR lithologies are assessed to be **Type 3** waste that require incorporation into a waste facility that has a Class C liner or similar constructed barrier.

9.1 CONSTRUCTION PHASE

9.1.1 Impacts on groundwater quantity and quality

During the construction phase of the project a small amount of groundwater is expected to be required for construction purposes and dust suppression (Table 9-1). The required water supply is expected to be no more than 1 l/s for dust suppression. Abstraction for this purpose will result in a localised cone of depression at the pumping well.

From a groundwater quality perspective, during the construction phase potential water quality impacts could arise from the following sources:

- oil leakages from construction vehicles – localised impacts on aquifers in the study area;
- Fuel storage - leakages localised impacts on aquifers in the study area; and
- Sewage and effluent leakages at the on-site toilets localised impacts on aquifers in the study area.

Table 9-1: Impact assessment for the groundwater quantity in construction phase

Impact	Localized cone of depression at the abstraction borehole (dust suppression)		Impact of reduced groundwater quality due to construction phase activities	
Type of Impact	Direct		Direct	
Nature of Impact	Negative		Negative	
Phases	Construction		Construction	
Criteria	**Without Mitigation**	**With Mitigation**	**Without Mitigation**	**With Mitigation**
Intensity	Minor change (Low)	Negligible change (Very low)	Moderate change (Low)	Minor change (Low)
Duration	Short-term (1 to 5 years)	Short-term (1 to 5 years)	Short-term (1 to 5 years)	Very Short-term (< 1 year)
Extent	Whole site and nearby surroundings	Part of site/property	Beyond site	Part of site/property
Consequence	Low	Very low	Medium	Very low
Probability	Conceivable (Low)	Unlikely / improbable (Very low)	Possible / frequent (Medium)	Conceivable (Low)
Significance	**Very low**	Insignificant	**Low**	Insignificant
Additional Assessment Criteria				
Degree to which impact can be reversed	*Fully reversable. The volume to be abstracted for dust suppression is expected to be relatively low, i.e., not exceeding 1 L/s. This is considered to be within the supply of the local aquifer.*		*Partially reversable. Any leaks detected can be appropriately dealt with on site.*	
Degree to which impact may cause irreplaceable loss of resources	*None. The aquifer is likely to fully sustain the abstraction during this construction phase.*		*Low. Potential leaks can be quickly dealt with, it is unlikely that irreparable loss would occur.*	
Degree to which impact can be avoided	*High. With the implementation of a dedicated groundwater monitoring program as well as minimisation of water use on site as far as possible, no impact is expected.*		*High. With the implementation of a dedicated mitigation measures, no impact is expected.*	

Degree to which impact can be mitigated	*High. Groundwater monitoring measures will be able to provide early-warning signs should negative impacts start to occur.*		*High. Monitoring measures will be able to provide early-warning signs should negative impacts start to occur.*	
Cumulative Impact				
Extent to which a cumulative impact may arise	*Unlikely*		*Unlikely*	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**	**Without Mitigation**	**With Mitigation**
	Very low	Insignificant	**Very low**	Insignificant

9.1.2 Groundwater management

These are standard types of impacts during the construction and operational phase of most projects and are considered local and of low significance. Best practice should be followed to mitigate the potential for localised contamination associated with these activities. The following mitigation measures should be implemented:

- Good housekeeping, and adherence to good health and safety practices on site during construction.
- Establish good waste management practices on site, to include recycling, separation, and storage of hazardous waste at suitable lined/bunded areas.
- Supply chemical toilets, which should be regularly, maintained at sites where worker/ contractor numbers are high.
- Oil spill kits should be available on site in case of spills of hydrocarbon chemicals and the relevant training on the use of spill kits must be provided.

Prior to groundwater abstraction for water supply, supply boreholes should be aquifer tested and licenced to ensure that nearby water users are not impacted by drawdown due to pumping.

9.2 OPERATIONAL PHASE

9.2.1 Impacts on groundwater quantity

During the operational phase the mining of the open pit results in ingress of groundwater to the open pit and the consequent dewatering of adjacent aquifers (Table 9-2 and Figure 9-1). Where drawdown exceeds 5 m, water supply may be influenced. The extent of drawdown, where drawdown exceeds 5 m relative to the steady state water level, is up to 2.5 km in a westerly direction from the pit, 1.6 km in a southerly direction form the pit, 1.2 km in a northerly direction and 1 km in an easterly direction from the pit.

Groundwater users that fall within this area are expected to have a notable drawdown in water level in supply boreholes. The farm areas on which drawdown, exceeding 5 m, is expected to occur includes: Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351.From the hydrocensus results, it is known that groundwater is mainly used by the farms for irrigation and drinking water (post-treatment).

Further, the reduction in baseflow for the Mhlatuze River over the operational period is a 9 % reduction. The river flow reduction because of mining is a 0.5 % reduction in river flow.

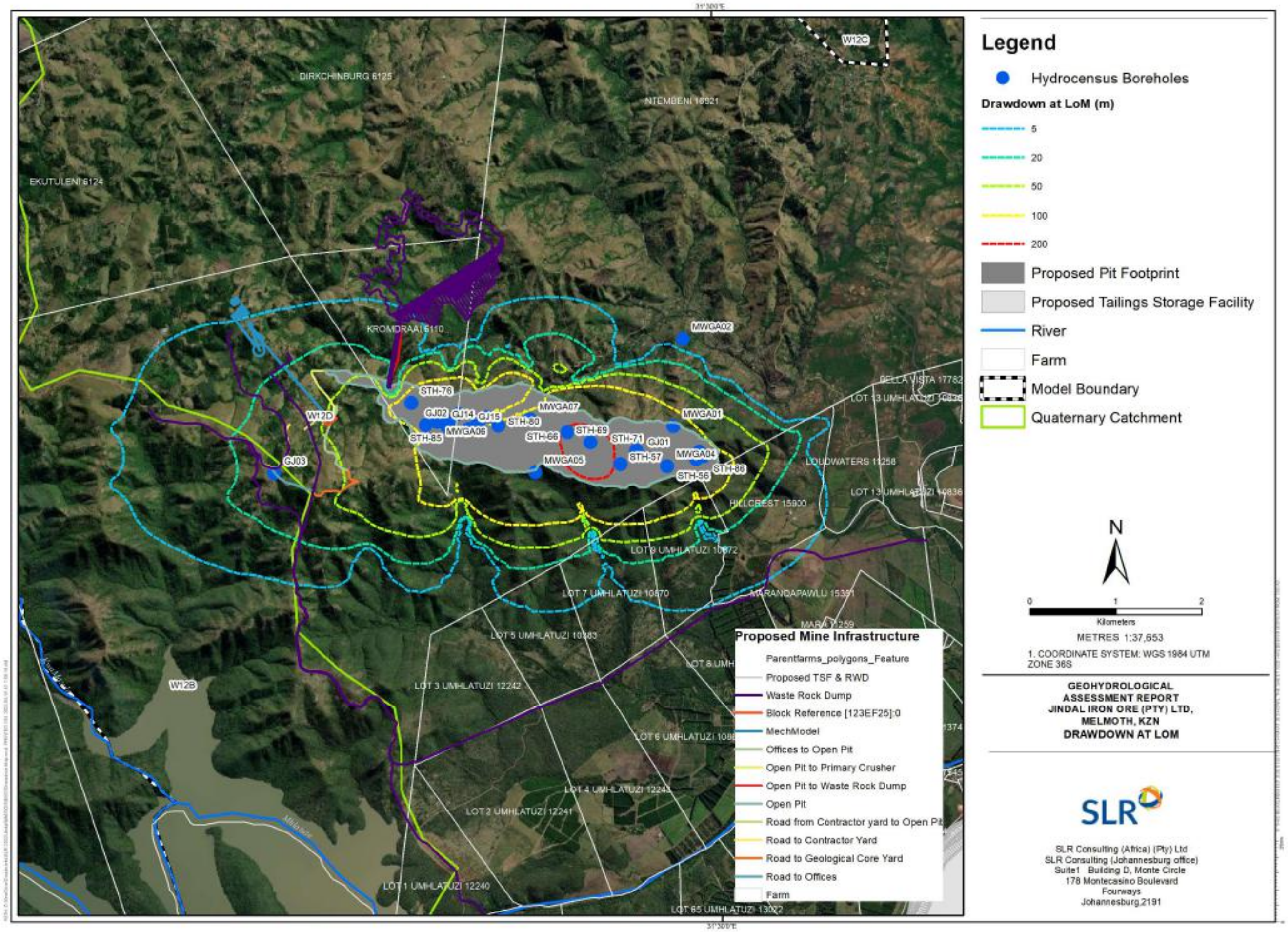


Figure 9-1: Downgradient farms in relation to drawdown zones

Table 9-2: Impact assessment of groundwater quantity for operational phase

Impact	Reduced groundwater quantity due to pit dewatering	
Type of Impact	Indirect	
Nature of Impact	Negative	
Phases	Operational	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Severe change (Very high)	Moderate change (Medium)
Duration	Very long term/ Permanent (> 20 years)	Very long term/ Permanent (> 20 years)
Extent	Local area, far beyond site	Local area, far beyond site
Consequence	Very high	High
Probability	Definite / Continuous (Very high)	Possible / frequent (Medium)
Significance	**Very high -**	**High -**
Degree to which impact can be reversed	*Partially reversable. Post-mining the pit would be rehabilitated to a degree and groundwater ingress would reduce, thereby lowering the dewatering impact.*	
Degree to which impact may cause irreplaceable loss of resources	*Medium. Lowering of the local water table could occur.*	
Degree to which impact can be avoided	*None. The pit is necessary in order to operate an open pit mine. However, with appropriate resource management measures, impacts can be reduced.*	
Degree to which impact can be mitigated	*Low. Some mitigation is possible but minimal in effect.*	

Extent to which a cumulative impact may arise	*Possible*	
Rating of cumulative impacts		
	Very high -	**High**

9.2.2 Impacts on groundwater quality

The source term characterisation of the WRD indicated that seepage emanating from the WRD does not have any potential contaminants of concern and concentrations of macro and micro elements are not expected to exceed drinking water quality guidelines. Further, the WRD is also currently proposed to be lined with a Class C liner, pending the outcome of humidity cell testing. As such no water quality issues are expected in proximity of the WRD because of seepage from the facility.

The source characterisation of the TSF found that only aluminium is expected to exceed drinking water quality guidelines. All other elements considered were within the guidelines for drinking water quality. The tailings facility is proposed to be lined by either a HDPE or GCL and consequently seepage from the facility is expected to be negligible (Table 9-3). The main receptor for seepage, should it occur, is the Mhlatuze River. Without a liner the contribution of seepage from the TSF to the total river flow is approximately 3 %. Where a liner is considered the contribution from the TSF to the river flow is less than 0.05 %. Under these conditions, it is unlikely that any receptors downgradient of the TSF would be impacted due to water quality issues.

Table 9-3: Reduced groundwater quality in operational phase

Impact	Seepage from TSF		Seepage from WRD	
Type of Impact	Direct		Direct	
Nature of Impact	Negative		Negative	
Phases	Operational		Operational	
Criteria	**Without Mitigation**	**With Mitigation**	**Without Mitigation**	**With Mitigation**
Intensity	Minor change (Low)	Negligible change (Very low)	Minor change (Low)	Negligible change (Very low)
Duration	Very long term/permanent (+20 years)	Very long term/permanent (+20 years)	Very long term/permanent (+20 years)	Very long term/permanent (+20 years)
Extent	Part of site/property	Part of site/property	Part of site/property	Part of site/property

Consequence	Very low	Very low	Very low	Very low
Probability	Unlikely / improbable (Very low)	Unlikely / improbable (Very low)	Unlikely / improbable (Very low)	Unlikely / improbable (Very low)
Significance	Insignificant	Insignificant	Insignificant	Insignificant
Additional Assessment Criteria				
Degree to which impact can be reversed	*Partially reversable. The liner reduces the contribution from the TSF to < 0.05 %.*		*Partially reversable. Pending the outcome of the humidity cell tests, the necessity of a liner will be determined. In the case where there is a need for a liner, the liner reduces seepage potential from the WRD. Recharge in the area of the WRD is comparable to natural recharge.*	
Degree to which impact may cause irreplaceable loss of resources	*None. No irreplaceable loss is expected. Minimal contribution from the TSF is likely to undergo mixing with groundwater and not cause any irreplaceable loss.*		*None. No irreplaceable loss is expected. Minimal contribution from the WRD is likely to undergo mixing with groundwater and not cause any irreplaceable loss.*	
Degree to which impact can be avoided	*High. The liner can reduce the contribution from the TSF to < 0.05 %.*		*High. The liner can reduce the contribution from the WRD significantly.*	
Degree to which impact can be mitigated	*High. Mitigation is possible and deemed effective.*		*High. Mitigation is possible and deemed effective.*	
Cumulative Impact				
Extent to which a cumulative impact may arise	*Unlikely. There are no notable sources in the vicinity.*		*Unlikely. There are no notable sources in the vicinity.*	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**	**Without Mitigation**	**With Mitigation**
	Very low	Insignificant	**Very low**	Insignificant

9.2.3 Groundwater management

The following mitigation measure should be put in place:

- The current boreholes are limited to the pit area and the TSF. An expanded hydrocensus on the farms Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu

15351 and accessible boreholes identified through this survey need to be incorporated into the groundwater monitoring program for the site.

- The boreholes on the above listed farms may potentially become impacted by mine dewatering. The depths of the boreholes and the required yields should be evaluated as part of the hydrocensus study. Alternative water supply sources may be required for water users identified to be affected by mine dewatering.
- Monitoring of boreholes at the TSF, near to the pit and on surrounding farms should be monitored monthly for a water level. Quarterly samples should be collected at these boreholes and sent for water quality analysis.
- Water quality sampling up and downgradient of the TSF should be completed per the surface water monitoring plan.
- The monitoring data should be collated quarterly and analysed in detail annually to validate the findings of the modelling.
- Once the mine is operational and the WR is reporting to the WRD, regular testing of the exposed WR material should be undertaken to document changes in its geochemical characterisation, most especially when operations transition into different stratigraphies. If the geochemistry is found to be evolving significantly, the groundwater model should be updated with the new source terms.
- To regularly document the performance of the WRD and its liner, an exceptive network of monitoring boreholes be put in place to monitor change in the groundwater chemistry in the vicinity of the facility.

9.3 DECOMMISSIONING PHASE

The impacts identified during the closure phase are applicable to the decommissioning phase of the project. See Section 9.4.

9.4 CLOSURE PHASE

9.4.1 Groundwater quantity

Post mining, a pit lake will develop at the Jindal Iron Ore Mine. The pit lake levels are expected to rapidly rise within the first 15 years (100 m) following cessation of mining (Table 9-4). Thereafter water levels will gradually increase to an estimated elevation of 375 mamsl (164 years post operations – 300 years post operations). The lowest elevation on the pit perimeter is 405 mamsl and consequently it is unlikely that the pit will decant. Instead, evaporation effects result in a persistent sink and the pit lake level would eventually reach an equilibrium at around 375 mamsl. A terminal pit lake will develop, and water levels will remain depressed around the pit area indefinitely.

In terms of the TSF, this will be lined and therefore negligible change in water level is expected.

Table 9-4: Groundwater quantity post-mining

Impact: Development of pit lake and water level fluctuations		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Closure	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Moderate change (Medium)	Minor change (Low)
Duration	Very long term/ Permanent (> 20 years)	Very long term/ Permanent (> 20 years)
Extent	Beyond the site	Part of site/property
Consequence	Medium	Low
Probability	Conceivable (Low)	Unlikely / improbable (Very low)
Significance	**Low -**	Insignificant -
Additional Assessment Criteria		
Degree to which impact can be reversed	*Partially reversable. It is unlikely that the pit will decant. Instead, evaporation effects result in a persistent sink.*	
Degree to which impact may cause irreplaceable loss of resources	*Low. The pit would have already been in a highly altered state, no significant additional loss would be expected.*	
Degree to which impact can be avoided	*Low. The pit lake levels are expected to rapidly rise within the first 15 years following cessation of mining and evaporation effects result in a persistent sink.*	
Degree to which impact can be mitigated	*Low. Mitigation is possible but to minimal effective.*	
Cumulative Impact		
Extent to which a cumulative impact may arise	*Possible*	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**
	Very low	Insignificant

9.4.2 Groundwater quality

9.4.2.1 Pit lake

The quality of the pit lake has not been assessed as part of this study and needs to be addressed as part of the closure study for the project. As discussed earlier, groundwater plume is not expected to occur due to sink conditions which develop within the pit post mining. Evaporation effects will impact the pit lake and lead to a persistent sink.

9.4.2.2 TSF

Prior to mining, the TSF is proposed to be lined with a high-density polyethylene (HDPE) liner or geosynthetic clay liner (GCL). Potential seepage is deemed negligible. Following completion of mining the TSF will be appropriately rehabilitated. Negligible seepage from the TSF is expected to occur following rehabilitation and there are no groundwater impacts (water level impacts or water quality impacts) anticipated post operations.

9.4.2.3 WRD

The waste rock dump is expected to be lined with a Class C liner, depending on humidity cell tests. Potential seepage volumes around the dump are assumed to be comparable to recharge in the area. Post-mining, the WRD will be rehabilitated. Rehabilitation of the WRD will reduce seepage from the facility. The source term characterisation of this facility indicated that there are no potential contaminants of concern and consequently any seepage which does arise post operations is not expected to impact upon nearby groundwater and surface water users.

9.4.3 Cumulative impacts

Cumulative impacts in terms of groundwater quantity within the catchment have been qualitatively assessed. There are no other mining operations within the catchment which could result in additional drawdown issues. Further expansion of the mine in the neighbouring concession areas could result in a larger drawdown and effects a wider number of farms becoming impacted. Should mining operations be expanded in the future these would need to be cumulatively assessed.

Commercial crop farming occurs in the lower areas of the catchment. Abstraction for water supply on these farms may result in additional water level drawdowns. The catchment is extensively used for crop farming. Groundwater and river water quality may be impacted by the application of fertilizers on the crop lands but deemed to be of low cumulative impact.

9.4.4 Groundwater management

Water quality impacts at the TSF and WRD are not expected post closure. In this respect there are no active mitigation measures apart from groundwater monitoring that are of relevance to the mine site.

Post mining monitoring should be carried out for a period of 5 years in order to validate the findings of the modelling (see Section 10.1).

The pit lake is not expected to decant, and a plume associated with the pit lake is not expected to occur post closure. Monitoring of the pit lake in terms of water level and water quality should be carried out five years post operations to validate the findings of this study.

The current information on water quality indicates pit lake water quality is unlikely to be an issue. This should however be studied to determine the long-term characteristics of the lake. Based on such a study, pit lake options can then be determined, and examples could include:

- Route surface water to the lake which could allow for flow through and spillage from the pit lake
- Use the pit lake for recreation activities or for local domestic and livestock water supply.

The depressed water levels could be mitigated by drilling deeper supply boreholes for water users located near to the pit.

10. GROUNDWATER MONITORING SYSTEM

10.1 GROUNDWATER MONITORING NETWORK

10.1.1 Source, plume, impact and background monitoring

The monitoring network has been designed to allow for evaluation at the potential source (i.e., near to the pit, below the WRD, near to the TSF), plume areas and background monitoring positions.

The existing network of boreholes is insufficient for the monitoring of the proposed operation. Additional monitoring boreholes required are outlined in Figure 10-1 and Table 10-1.

The existing boreholes within the pit area will ultimately be mined out. It will be valuable, however, to regularly monitor these boreholes prior to mining in order to better characterise the hydrogeology in the hills (Table 10-2). The TSF boreholes must be included into the monitoring network. The coordinates of TSF5-05 must be sourced and the coordinates of TSF5-04 must be validated. One additional borehole is proposed in this area based on the mass transport modelling in order to monitor the RWD.

Table 10-1: Additional boreholes required for characterisation and monitoring in the pit area

Borehole Name	East	South	Description	Type
Proposed BH 1	349694	6822771	Pit perimeter – Characterisation & Monitoring	Source/Pathway
Proposed BH 2	351248.4	6822768	Pit perimeter – Characterisation & Monitoring	Source/Pathway
Proposed BH 3	353432.4	6822103	Pit perimeter – Characterisation & Monitoring	Source/Pathway
Proposed BH 4	349972.5	6822007	Pit perimeter – Characterisation & Monitoring	Source/Pathway
Proposed BH 5	352729.3	6821570	Pit perimeter – Characterisation & Monitoring	Source/Pathway

Borehole Name	East	South	Description	Type
Proposed BH 6	351128.8	6821719	Pit perimeter – Characterisation & Monitoring	Source/Pathway
Proposed BH 7	349353.6	6823674	Down gradient WRD	Source/Pathway
Proposed BH 8	350492.6	6823311	Down gradient WRD	Source/Pathway
Proposed BH 9	349444.3	6824340	Upgradient of WRD	Background

Table 10-2: Existing boreholes in the pit area

Borehole	X	Y	Description	Type
GJ01	352600	6821934	Community Borehole - In Pit Area	Source
GJ02	350123	6822277	Community Borehole - In Pit Area	Source
GJ03	348358	6821714	Community Borehole - In Pit Area	Source
GJ07	335681	6824806	Community Borehole - In Pit Area	Source
GJ11	337321	6824016	Community Borehole - In Pit Area	Source
GJ13	338028	6824029	Community Borehole - In Pit Area	Source
GJ14	350371	6822260	Community Borehole - In Pit Area	Source
GJ15	350622	6822232	Community Borehole - In Pit Area	Source
STH-56	353271	6821880	DD - In Pit Area	Source
STH-57	352387	6821819	DD - In Pit Area	Source
STH-59A	350499	6822407	DD - In Pit Area	Source
STH-66	351770	6822196	DD - In Pit Area	Source
STH-69	352039	6822074	DD - In Pit Area	Source
STH-71	352576	6821979	DD - In Pit Area	Source
STH-75	350837	6822372	DD - In Pit Area	Source

Borehole	X	Y	Description	Type
STH-76	349952	6822534	DD - In Pit Area	Source
STH-80	350967	6822272	DD - In Pit Area	Source
STH-85	350407	6822316	DD - In Pit Area	Source
STH-86	353364	6821917	DD - In Pit Area	Source
STH-88	350725	6822290	DD - In Pit Area	Source
MWGA02	353119	6823280	Golder (2015) Drilled Characterisation hole	Background
MWGA03	353305	6821966	Golder (2015) Drilled Characterisation hole	Source
MWGA04	352932	6821798	Golder (2015) Drilled Characterisation hole	Source
MWGA05	351396	6821726	Golder (2015) Drilled Characterisation hole	Source
MWGA06	350251	6822312	Golder (2015) Drilled Characterisation hole	Source
MWGA07	351335	6822348	Golder (2015) Drilled Characterisation hole	Source
MWGA01	353008	6822266	Golder (2015) Drilled Characterisation hole	Source

10.1.2 Monitoring frequency

Boreholes identified to be part of the monitoring network should be monitored monthly for a water level. Quarterly sampling of these boreholes (Table 10-1) must be undertaken, and the samples must be submitted to a SANAS accredited laboratory.

Surface water samples must be collected monthly and analysed monthly at a SANAs accredited laboratory as per the approved Environmental Management Programme.

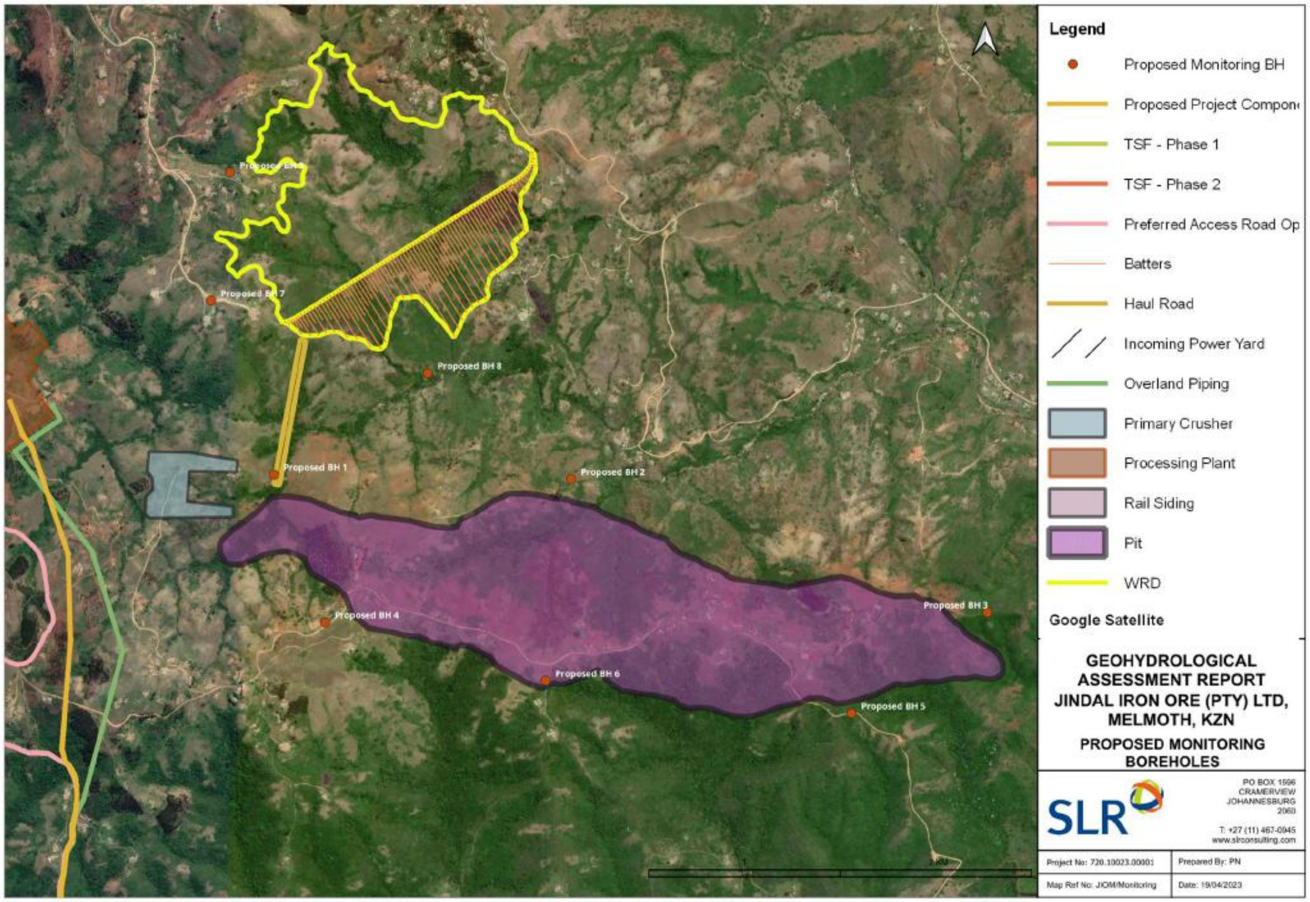


Figure 10-1: Proposed Boreholes

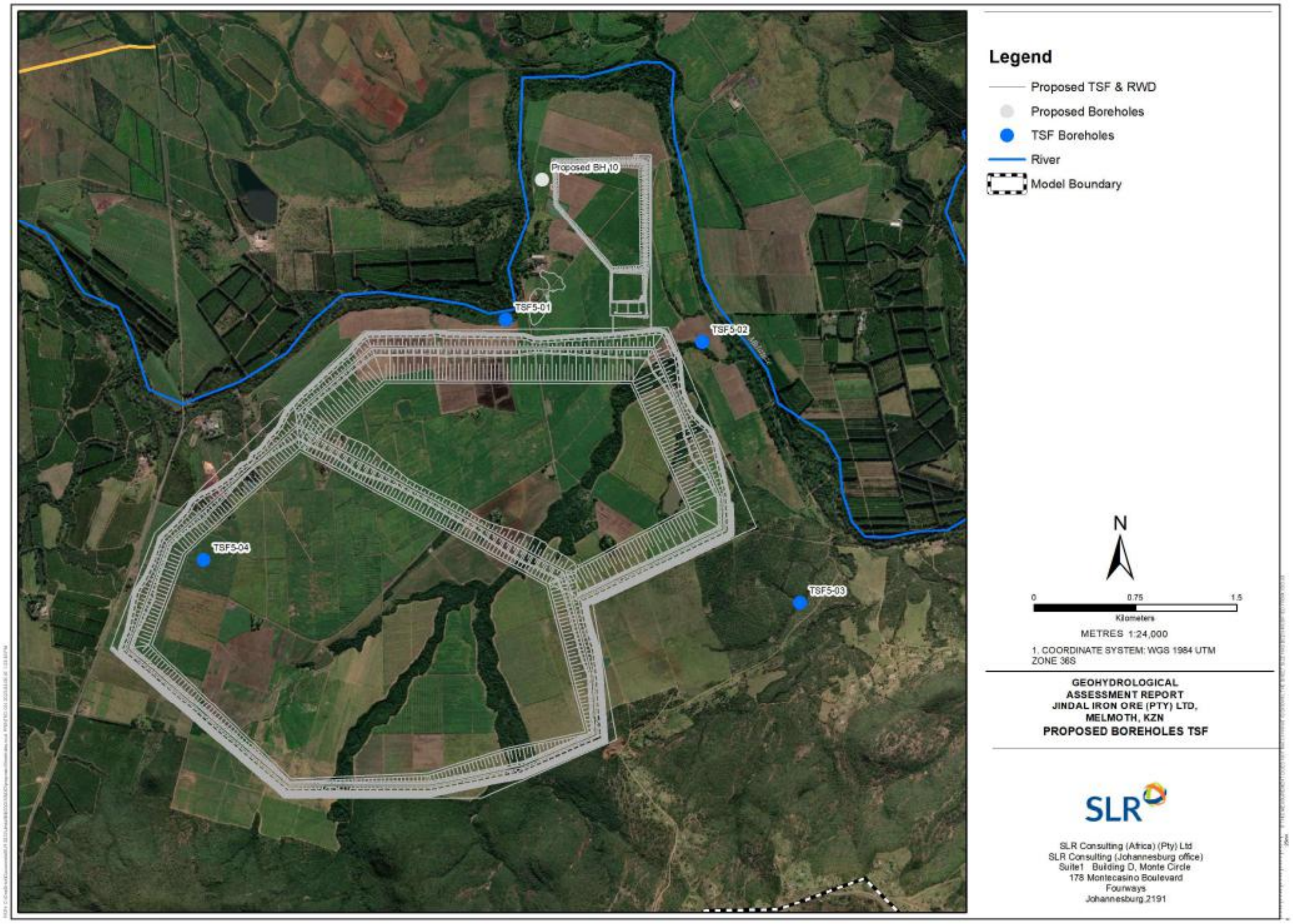


Table 10-3: Existing and proposed boreholes at the TSF

10.2 MONITORING PARAMETERS

The parameters for water quality monitoring are listed in Table 10-4.

Table 10-4: List of elements required for analysis as part the monitoring protocol

Elements			
Al	Mn	K	HCO_3
As	Mo	Na	pH
B	Ni	Mg	Conductivity (µs/cm)
Ba	Pb	Cl	TDS
Be	Sb	SO_4	
Ca	Se	NO_3 as N	
Cd	Tl	NO_2 as N	
Co	V	NH_4	
Cr	Zn	F	
Cu	Hg	PO_4 as P	
Fe	Si	CO_3	

10.3 MONITORING BOREHOLES

The monitoring boreholes are provided in Section 10.1.1.

11. GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAMME

The following section outlines the groundwater management programme for the site for the proposed Jindal Iron Ore mine.

11.1 CURRENT GROUNDWATER CONDITIONS

Groundwater in proximity of the TSF is shallow and water quality results indicate that the groundwater is impacted by agricultural practices in the area. The water has elevated concentration of chloride and sodium, elevated TDS and in some cases elevated nitrite (Section 5.6). Nitrates are below the water quality guidelines but are elevated in the study area.

In the pit area water levels are deeper owing to the mountainous terrain. The mean hydraulic head is 450 mamsl. Water quality data in the mine pit area is limited, with a few samples taken by Golder (2015) showing slightly elevated manganese concentrations at MWGA04 and MWGA07.

11.2 PREDICTED IMPACTS OF MINING

Mining will create a cone of depression around the mining pit which will result in drawdown in water levels on farms adjacent to the mining area. Where drawdown exceeds 5m, water users may observe a decline in yield in water supply boreholes. These farms include: Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351 (Figure 9-1).

The WRD, situated upgradient of the mine will release seepage into the drainage at the foot of the WRD, the Nkwalinye River, which is a tributary of the Mhlatuze River. The water quality is not, however, expected to be impacted.

The TSF and WRD are proposed to be lined. Any seepage emanating from the facility would discharge to the Mhlatuze river. It is not expected that water quality in the aquifers adjacent to the TSF nor the river would become impacted during the mining or post mining phases.

11.3 MITIGATION MEASURES

11.3.1 Lowering of the groundwater levels during mining

As outlined above a cone of depression is expected to develop around the open pit as mining progresses and water levels on adjacent farms are expected to become impacted over time. The current hydro census has not included the land parcels. A detailed hydrocensus of farms neighbouring the pit area is required in order to understand the number, state and yields of boreholes utilised by the communities surrounding the mine. Based on this survey, mitigation measures must be put in place to ensure the water supply of surrounding water users are not affected. Measures which can be introduced include:

- Drilling deeper boreholes to replace existing shallower boreholes.
- Relocating water supply boreholes beyond the zone of impact.

11.3.2 Rise of groundwater levels post mining operation

The modelling within this study has demonstrated that a pit lake is likely to develop within the Jindal Melmoth Iron Ore Mine pit post mining. Based on mean monthly rainfall and mean monthly evaporation, the pit lake level is expected to stabilise below the lowest edge of the open pit over time. Consequently decant/spillage is not expected to occur post operations.

Due to the persistent sink conditions which will develop, a pollution plume associated with the pit is not expected to occur. Therefore, the following mitigation measures are recommended:

- Water level monitoring is continued post-mining operation and reviewed until it is stable long term.
- Additionally, water quality sampling should take place concurrently to ensure that a pollution plume does not occur.
- Upon closure, access to the open pit should be restricted.

11.3.3 Spread of groundwater pollution post-mining

The source term characterisation showed that there are no potential contaminants of concern associated with the WRD. The WRD must be rehabilitated in accordance with the approved mine rehabilitation plan where long-term monitoring is required. Rehabilitation of the WRD post mining will reduce seepage through the facility. Consequently, a contaminated plume in the groundwater downgradient of the wate rock dump is not expected to occur.

The tailings facility is proposed to be lined and the source term characterisation indicated that excepting aluminium there are no potential contaminants of concern. With the liner in place, it is highly unlikely that the adjacent aquifers and Mhlatuze river will be impacted seepage.

12. POST CLOSURE MANAGEMENT PLAN

From a groundwater perspective, the following closure management activities are required:

12.1 REMEDIATION OF PHYSICAL ACTIVITY

The open pit is expected to form a pit lake sink i.e., no through flow is anticipated to occur. The post closure pit lake chemistry has not yet been determined and further studies are required to quantify the pit lake chemistry that could be anticipated post operations.

12.2 REMEDIATION OF STORAGE FACILITIES

The WRD and TSF will be rehabilitated at closure of the operation. Further studies are required to determine the appropriate capping design and simulate the potential seepage through the facilities after rehabilitation.

No contamination plume, exceeding drinking water quality guidelines, is expected to occur and therefore no remediation of aquifers surrounding the waste facilities is required.

Ongoing monitoring should be undertaken to ensure that groundwater quality is maintained, and measures be put in place should any potential contamination concerns arise.

12.3 REMEDIATION OF ENVIRONMENTAL IMPACTS

No action from a groundwater perspective is required.

12.4 REMEDIATION OF WATER RESOURCES IMPACTS

No contamination plume, exceeding drinking water quality guidelines, is expected to occur and therefore no remediation of aquifers surrounding the waste facilities is required.

12.5 BACKFILLING OF THE PITS

A pit lake is expected to develop post operation. Evaporation controls the level of pit lake and results in a persistent sink post operation. As consequence no pollution plume will develop and impact nearby water bodies or water users. Backfilling of the pit will result in a change of volume within the pit and could result in a situation of post mining seepage and decant. The pit lake condition, without backfilling is favoured.

13. CONCLUSION

A geohydrological assessment was completed as part of the specialist investigation for the ESIA study underway for the Jindal Iron Ore Mine. The objective of the study was to characterise the current groundwater conditions in the study area and determine the expected impacts on the groundwater resources should the mining project commence.

The catchment is inhabited by rural dwellers and commercial crop farming is widespread in the lower areas of the catchment along the Mhlatuze River. There are no other mining operations currently developed within the catchment area.

From a hydrogeological standpoint, the focus areas of this assessment are the proposed open pit, the WRD and the TSF.

13.1 OPEN PIT AREA

The open pit has a proposed life of mine of 31 years. The final pit elevation is 96 mamsl (± 300 m below the lowest elevation on the pit boundary). The proposed pit extends 4.45 km in west to east direction and at the widest area is 1 km wide (North to south).

The pit targets an outcrop comprising of amphibolite, gneiss and mica schist. The hydrogeology is complex with varied water levels measured in close proximity to one another. The mean hydraulic head in the pit area is 450 mamsl.

Aquifer testing in the pit area had varied results ranging between 7 – 53 m^2/d (n= 4) and the borehole logs revealed that water strikes were not encountered above 180 m below surface. It was interpreted that the conductivity increases with depth in the mine pit area.

Groundwater ingress based on the conceptual model developed, ingress to the open pit is expected to be low (< 5 l/s) at elevation above 440 mamsl. With increasing depth ingress is expected to gradually increase over time. Two scenarios were simulated to account for the uncertainty of hydraulic conductivity in the pit area. The range in peak inflows for the pit are 37 l/s to 80 l/s.

Cone of depression; dewatering of the open pit will result in a cone of depression. The extent of drawdown, where drawdown exceeds 5 m relative to the steady state water level, is up to 2.5 km in a westerly direction, 1.6 km in a southerly, 1.2 km in a northerly direction and 1 km in an easterly direction. Groundwater users that fall within this area are expected to have a notable drawdown in water level in supply boreholes. The farm areas on which drawdown, exceeding 5m, is expected to occur includes: Ntembeni 16921, Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351.

Reduction in baseflow; the dewatering of the aquifers around the pit area, results in a reduction of groundwater that would have ultimately discharged to the rivers in the catchment as baseflow. The assessment of reduction in baseflow indicated that a 9 % reduction in baseflow is expected over the operational period of the mine. Relative to stream flow, a 0.5 % reduction in stream flow is expected in the catchment at life of mine.

Post mining pit lake; post mining a pit lake is expected to develop in the open pit.in the first 16 years following completion of mining, the recovery in water level is anticipated to be rapid (rise to ± 300 mamsl). Beyond 16 years to 160 years the pit level gradually rises by ±74 m. The pit lake is expected to stabilise at this elevation between 160 and 300 years. The lowest elevation on the pit perimeter is 405 mamsl. Consequently, the pit lake is expected to remain below the edge of the pit and no decant/spillage will occur. Evaporation effects are expected to create a persistent sink. As a consequence, a pollution plume is not expected to develop from the pit area post mining.

13.2 WRD

The WRD is located on the granites located north of the open pit. A large fault zone runs through the central portion of the dump. The terrain proposed for dump undulates with hilltops exceeding 600 mamsl and valley at 370 mamsl. Several small drainages flow in the valley areas proposed for waste rock deposition.

A source term characterisation was completed for the various waste rock streams expected to be deposited on the facility. In all cases there are no potential contaminants of concern expected i.e., seepage quality is well within drinking water quality guidelines.

Seepage generated within the facility is expected to flow toward topographical low points and ultimately into the Nkwalinye River which is a tributary of the Mhaltzue. Seepage discharging into the river channel is not expected to negatively impact water quality and therefore it is not expected that downgradient water users will be impacted by water quality issues.

13.3 TSF

The tailings storage facility and the return water dam are located on the farms Bridgeford 12024 GU, Perseverance 15645, Umhlatuzi 11133 GU and Riversbend 15644. The surface area of the proposed TSF is 9 300 000 m^2 and the return water dam has a footprint of 710 000 m^2.

The TSF and return water dam is situated on shales of Pietermaritzburg formation. No aquifer testing has been completed in the formation but is expected that the formation has a low permeability. The shales are underlain by Dwyka formation tillite which is expected to have a very low permeability at depth.

Groundwater levels in proximity of the TSF are shallow (2.6 mbgl to 5.9 mbgl). The footprint area is presently drained by a tributary which flows west to east. The general flow direction from the TSF is northerly toward the Mhlatuze River and its drainages.

The source term characterisation of the TSF found that only aluminium is a potential constituent of concern. No other macro or trace metal concentrations exceed drinking water quality.

The TSF is proposed to be lined with either an HDPE liner or a GCL. Two scenarios were considered however, one where the TSF is unlined and a second where the TSF is lined with a GCL liner.

- Where unlined seepage from the facility is expected to reach the Mhlatuze river. In the context of river flows however the contribution from the TSF is small and would account for 3 % of flow rates in the river downgradient of the TSF. At this mixing ratio it is unlikely that high aluminium concentrations would occur in the river system.
- Where the TSF is lined the seepage from the facility is not expected to migrate beyond the footprint of the TSF during life of the operation.

14. RECOMMENDATIONS

Following completion of the hydrogeological study the following data and understanding of gaps needs to be addressed before proceeding with the mining operation.

14.1 WATER LEVEL DATA & WATER QUALITY DATA

- Water level data in the pit area is outdated as access was not possible during the assessment process and water level measurements were last taken in 2014. Access needs to be arranged to revisit the boreholes in the pit area and collect current water quality and water level data. The core holes had, in some case, deeper than expected water levels and re-examination of these water levels are required. The water quality of the pit lake has not been considered and must be investigated.
- There is currently no hydrocensus information on farms adjacent to the mining areas. In particular, the current water users and the characteristics of boreholes on the farms Kromdraai 6110, Lot No 5 1038, Lot No 5 10383 GU, Lot 7 Umhlatuzi 10870, Lot 9 Umhlatuzi 10872, Hillcrest 15900, Loudwaters 11258, Lot 8 Umhlatuzi 10871, Maranqapawlu 15351 need to be understood. These areas may potentially become impacted by mine dewatering and a census of the current state is required to be able to understand potential impacts and provide mitigation measures for water users in this area.
- Only ‘once off’ water levels are available in the study area and many date to the Golder (2015) study. Monthly water level monitoring and quarterly quality monitoring should proceed immediately to establish a sound baseline for potential future mining.
- No water quality monitoring is currently available for the pit area (Pit and WRD). This information is necessary for baseline establishment and should be commenced as soon as possible.

14.2 DRILLING AND AQUIFER CHARACTERISATION

- The existing boreholes in the pit area occur within the pit footprint. Additional boreholes must be sited on the periphery of the pit to serve as long term monitoring boreholes.
- Currently aquifer characterisation in the pit area is based on two pumping tests and two slug tests. Due to very limited data, there is significant uncertainty regarding hydraulic conductivity of the formations present within the pit. It is therefore recommended to undertake an aquifer testing program within the pit area. Suitable boreholes must be drilled, and aquifer testing must be completed.
- Packer testing should be completed in existing boreholes within the pit area to characterise the hydraulic conductivity at various depths throughout the formations.
- There are currently no water level or aquifer parameters for the granites north of the pit where the WRD facility is proposed. Borehole drilling and aquifer testing is required in this area to characterise the lithology and hydrogeology and serve as long term monitoring locations up and downgradient of the WRD facility.
- The boreholes recently drilled at the TSF must be tested to confirm the hydraulic conductivity values assumed within the modelling.
- Following drilling and testing the model should be re-simulated. This is particularly important if additional drilling data alters the current conceptual understanding.
- The water level data should be evaluated against the model predictions annually and if significant variation is observed, the model should be re-calibrated. Once operational the model should be re-looked at on a 3-year basis.

14.3 WATER SUPPLY

- Currently no water supply is expected to be from groundwater. However, should there be a need for groundwater supply, pertaining to requirements for the project at different phases i.e., construction and operational, this will need to be appropriately addressed and the associated impacts will need to be reviewed.

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APPENDIX A: HYDROCENSUS DATA

ID	Latitude	Longitude	Property Owner	Property Name	Contact Details	Email	Use	Sample collected	pH	EC (mS/m)	T (°C)	Comment
BH1	-28.722944°	31.540556°	DAVID FOWLER	FOWLER FARMS TRUST	0769842416	admin@dundulu.co.za	Domestic and irrigation	From tap	7,61	109	22,7	-
BH2	-28.726354°	31.525991°	Mr S Ngayawa	NKWALENI CLINIC	0792321425	-	Domestic and irrigation	From tap	7,93	142	20,2	-
BH3	-28.724966°	31.524955°	Mrs Norris	Nkwaleni stores	0784690895	-	Not in use due to pump issues	Bailer	7,51	142	22,6	The pump on the borehole is not working at was removed
BH4	-28.796779°	31.477229°	MR AM MTHEMBU	NCAMANENI C.P. SCHOOL	0723968549	Mthembumthembu1@gmail.com	Domestic and irrigation	From tap	8,98	142	28,1	Borehole was installed on 22 Feb 2022
DW1	-28.760680°	31.563970°	ANGUS McDONALD	RIVERBEND FARM	0738735578	-	Irrigation	Bailer	9,1	142	22,5	Water is pumped from a river into a dam and used for irrigation
DW2	-28.761827°	31.563970°	ANGUS McDONALD	RIVERBEND FARM	0738735578	-	Domestic	From tap	9,1	142	22,5	Water is pumped from a river to a dam and then

ID	Latitude	Longitude	Property Owner	Property Name	Contact Details	Email	Use	Sample collected	pH	EC (mS/m)	T (°C)	Comment
												flocculated for drinking water
DW3	-28.725806°	31.526056°	MRS NORRIS	NKWALENI STORES	0784690895	-	Domestic and irrigation	Bailer	8,11	73	24,3	Water is pumped from a river into a dam and then pump into the household dam where a chlorine bomb is used before water is used for drinking
DW4	-28.742205°	31.500154°	Mr DAVID NAIDOO	CHENNELS FARM HOLDING	0813281435	-	Irrigation	Bailer	8,7	282	22	Water is pumped from a river into a dam and then used for irrigation the same water is flocculated and used for drinking

APPENDIX B: CRITERIA FOR GROUNDWATER IMPACT ASSESSMENT

METHODOLOGY USED IN DETERMINING THE SIGNIFICANCE OF IMPACTS

Part A provides the definition for determining impact consequence (combining intensity, extent, and duration) and impact significance (the overall rating of the impact). Impact consequence and significance are determined from Part B and C. The interpretation of the impact significance is given in Part D. This methodology is utilised to assess both the incremental and cumulative project related impacts.

PART A: DEFINITIONS AND CRITERIA		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of intensity, extent, and duration**
Criteria for ranking of the INTENSITY of environmental impacts	**VH**	Severe change, disturbance, or degradation. Associated with severe consequences. May result in severe illness, injury, or death. Targets, limits, and thresholds of concern continually exceeded. Habitats or ecosystems of high importance for maintaining the persistence of species or habitats that meet critical habitat thresholds. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance, or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits, and thresholds of concern regularly exceeded. Habitats or ecosystems which are important for meeting national/provincial conservation targets. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance, or discomfort. Associated with real but not substantial consequences. Targets, limits, and thresholds of concern may occasionally be exceeded. Habitats or ecosystems with important functional value in maintaining biotic integrity. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance, or nuisance. Associated with minor consequences or deterioration. Targets, limits, and thresholds of concern rarely exceeded. Habitats and ecosystems which are degraded and modified. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance, or nuisance. Associated with very minor consequences or deterioration. Targets, limits, and thresholds of concern never exceeded. Species or habitats with negligible importance. No interventions or clean-up actions required. No complaints anticipated.

	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.
Criteria for ranking the DURATION of impacts	**Very Short term**	Very short, always less than a year or may be intermittent (less than 1 year). Quickly reversible.
	Short term	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	Medium term	Medium-term, 5 to 10 years.
	Long term	Long term, between 10 and 20 years. Likely to cease at the end of the operational life of the activity or because of natural processes or by human intervention.
	Very long term/ permanent	Very long, permanent, +20 years. Irreversible. Beyond closure or where recovery is not possible either by natural processes or by human intervention.
Criteria for ranking the EXTENT of impacts	**Site**	A part of the site/property. Impact is limited to the immediate footprint of the activity and within a confined area.
	Whole site	Whole site. Impact is confined to within the project area and its nearby surroundings.
	Beyond site	Beyond the site boundary, affecting immediate neighbours.
	Local	Local area, extending far beyond site boundary.

	Regional/ national	Regional/National. Impact may extend beyond district or regional boundaries with national implications.

PART B: DETERMINING CONSEQUENCE – APPLIES TO POSITIVE OR ADVERSE IMPACTS						
		EXTENT				
		Site	Whole site	Beyond the site, affecting neighbours	Local area, extending far beyond site	Regional/ National
INTENSITY = VL						
DURATION	Very long term /permanent	Low	Low	Medium	Medium	Medium
	Long term	Very Low	Low	Low	Medium	Medium
	Medium term	Very Low	Low	Low	Low	Medium
	Short term	Very low	Very Low	Low	Low	Low
	Very short term	Very low	Very Low	Very Low	Very Low	Low
INTENSITY = L						
DURATION	Very long term /permanent	Low	Medium	Medium	High	High
	Long term	Low	Medium	Medium	Medium	High
	Medium term	Low	Low	Medium	Medium	Medium
	Short term	Very low	Low	Low	Medium	Medium
	Very short term	Very low	Very low	Low	Low	Low
INTENSITY = M						
DURATION	Very long term /permanent	Medium	Medium	High	High	Very High
	Long term	Low	Medium	Medium	High	High
	Medium term	Low	Medium	Medium	Medium	High

	Short term	Low	Low	Medium	Medium	Medium
	Very short term	Very low	Low	Low	Low	Medium
INTENSITY = H						
DURATION	Very long term /permanent	Medium	High	High	Very High	Very High
	Long term	Medium	Medium	High	High	Very High
	Medium term	Low	Medium	Medium	High	High
	Short term	Low	Medium	Medium	Medium	High
	Very short term	Very low	Low	Low	Medium	Medium
INTENSITY = VH						
DURATION	Very long term /permanent	Medium	High	Very High	Very High	Very High
	Long term	Medium	High	High	Very High	Very High
	Medium term	Medium	Medium	High	High	Very High
	Short term	Low	Medium	Medium	High	High
	Very short term	Low	Low	Medium	Medium	Medium

PART C: DETERMINING SIGNIFICANCE - APPLIES TO POSITIVE OR ADVERSE IMPACTS							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	VH	Very Low	Low	Medium	High	Very High
	Probable	H	Very Low	Low	Medium	High	Very High
	Possible/ frequent	M	Very Low	Very Low	Low	Medium	High
	Conceivable	L	Insignificant	Very Low	Low	Medium	High
	Unlikely/ improbable	VL	Insignificant	Insignificant	Very Low	Low	Medium
			VL	L	M	H	VH

	CONSEQUENCE

PART D: INTERPRETATION OF SIGNIFICANCE		
Significance		**Decision guideline**
Very High	**Very High +**	Represents a key factor in decision-making. Adverse impact would be considered a potential fatal flaw unless mitigated to lower significance.
High	**High +**	These beneficial or adverse impacts are considered to be very important considerations and must have an influence on the decision. In the case of adverse impacts, substantial mitigation will be required.
Medium	**Medium +**	These beneficial or adverse impacts may be important but are not likely to be key decision-making factors. In the case of adverse impacts, mitigation will be required.
Low	**Low +**	These beneficial or adverse impacts are unlikely to have a real influence on the decision. In the case of adverse impacts, limited mitigation is likely to be required.
Very Low	**Very Low +**	These beneficial or adverse impacts will not have an influence on the decision. In the case of adverse impacts, mitigation is not required.
Insignificant		Inconsequential, not requiring any consideration.

ADDITIONAL ASSESSMENT CRITERIA

Additional criteria that are taken into consideration in the impact assessment process to further describe the impact and support the interpretation of significance in the impact assessment process include:

- the degree to which impacts may cause irreplaceable loss of resources;
- the degree to which impacts can be avoided;
- the degree to which impacts can be reversed;
- the degree to which the impacts can be mitigated; and
- the extent to which cumulative impacts may arise from interaction or combination from other planned activities or projects is tabulated below.

ADDITIONAL ASSESSMENT CRITERIA		
Criteria for DEGREE TO WHICH AN IMPACT CAN BE REVERSED	**IRREVERSIBLE**	Where the impact cannot be reversed and is permanent.
	PARTIALLY REVERSIBLE	Where the impact can be partially reversed and is temporary.
	FULLY REVERSIBLE	Where the impact can be completely reversed.

Criteria for DEGREE OF IRREPLACEABLE RESOURCE LOSS	**NONE**	Will not cause irreplaceable loss.
	LOW	Where the activity results in a marginal effect on an irreplaceable resource.
	MEDIUM	Where an impact results in a moderate loss, fragmentation or damage to an irreplaceable receptor or resource.
	HIGH	Where the activity results in an extensive or high proportion of loss, fragmentation or damage to an irreplaceable receptor or resource.
Criteria for DEGREE TO WHICH IMPACT CAN BE AVOIDED	**NONE**	Impact cannot be avoided and consideration should be given to compensation and offsets.
	LOW	Impact cannot be avoided but can be mitigated to acceptable levels through rehabilitation and restoration.
	MEDIUM	Impact cannot be avoided, but the significance can be reduced through mitigation measures.
	HIGH	Impact can be avoided through the implementation of preventative mitigation measures.
Criteria for the DEGREE TO WHICH IMPACT CAN BE MITIGATED	**NONE**	No mitigation is possible or mitigation even if applied would not change the impact.
	LOW	Some mitigation is possible but will have marginal effect in reducing the impact significance rating.
	MEDIUM	Mitigation is feasible and will may reduce the impact significance rating.
	HIGH	Mitigation can be easily applied or is considered standard operating practice for the activity and will reduce the impact significance rating.
Criteria for POTENTIAL FOR CUMULATIVE IMPACTS	**UNLIKELY**	Low likelihood of cumulative impacts arising.
	POSSIBLE	Cumulative impacts with other activities or projects may arise.
	LIKELY	Cumulative impacts with other activities or projects either through interaction or in combination can be expected.

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