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ENVIROGISTICS (PTY) LTD

DWARSRIVIER CHROME MINE (PTY) LTD

NEW KHULU TAILINGS STORAGE FACILITY AND OTHER CAPITAL PROJECTS ENVIRONMENTAL IMPACT ASSESSMENT

GEOHYDROLOGICAL SPECIALIST STUDY

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PROJECT DETAILS

PROJECT:	Dwarsrivier Chrome Mine (Pty) Ltd New Khulu Tailings Storage Facility (TSF) and other Capital Projects Environmental Impact Assessment and Integrated Water and Waste Management Plan
Report Title:	Geohydrological Specialist Study
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24 January 2022

Specialist details and declaration of independence

The project was completed by Irene Lea Environmental and Hydrogeology (iLEH). Irene has 30 years' experience in the field of hydrogeology. She has a M.Sc. in Geohydrology and is a registered Professional Natural Scientist. Her focus includes numerical groundwater flow and contaminant transport modelling, water treatment, integrated water management strategies, rehabilitation and closure projects, environmental management systems and risk assessments.

I, Irene Melville Lea, declare that -

General declaration:

- I act as the independent Hydrogeological practitioner for 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 hydrogeological impact assessments, 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;
- I will ensure that information containing all relevant facts in respect of the application is distributed or made available to interested and affected parties and the public and that participation by interested and affected parties is facilitated in such a manner that all interested and affected parties will be provided with a reasonable opportunity to participate and to provide comments on documents that are produced to support the application;
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not;
- All the particulars furnished by me in this form are true and correct;
- I will perform all other obligations as expected from a hydrogeological practitioner in terms of the Act and the constitutions of my affiliated professional bodies; and
- I realise that a false declaration is an offence in terms of regulation 71 of the Regulations and is punishable in terms of section 24F of the NEMA.

Disclosure of vested interest:

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Regulations.

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EXECUTIVE SUMMARY

The geohydrological study presented in this report addresses the anticipated impacts associated with the construction of a new tailings storage facility (TSF), referred to as the Khulu TSF. The work forms part of the environmental impact assessment (EIA) phase for the project and will also be used to complete the integrated water and waste management plan (IWWMP) for the project. Other capital projects considered as part of the EIA include a diesel and emulsion batching area, an extension to the main parking area, widening of an access road between the Offices/Plant and South Shaft and the construction of an access crossing between the Plant and North Mine. These capital projects do not pose a risk to groundwater. The report therefor focusses on the impact of the proposed Khulu TSF and its associated infrastructure. The design for the facility was prepared by Jones and Wagener (JAW) and was incorporated into the geohydrological impact assessment. In brief, the TSF design includes a Class C liner, above and below drainage, toe drains, a silt trap and stormwater management measures. The pollution control dam (PCD) to be constructed as part of the design will also feature a Class C liner, below liner drains, a spill way and a feed to the lower return water dam (LRWD) situated at the plant to accommodate the transfer of excess water when needed.

Aquifer conceptualisation

Three aquifers are typically present in the region. These include an alluvial aquifer associated with the floodplains of the Groot and Klein Dwars Rivers; a shallow weathered aquifer present in the upper 15m of the geological succession; and a deeper fractured rock aquifer in the pyroxenites, anorthosites and norites.

The geohydrological specialist study completed for the EIA includes the results of a fieldwork programme geared at obtaining sufficient information with which to characterise the aquifers present. The fieldwork includes a hydrocensus to identify and quantify existing groundwater use near the Khulu TSF footprint. The only private borehole is located 230m northeast of the TSF.

A geophysical survey was completed to confirm the locations of perceived faults and dykes that are present near the TSF. A total of seven new monitoring boreholes were drilled on the geophysical targets, including three sets of shallow and deep monitoring boreholes to target the aquifers present and one shallow borehole adjacent to an existing old deep monitoring borehole identified during the hydrocensus. Aquifer tests were completed in the deep monitoring boreholes, while observations were made in the shallow boreholes. The drilling programme and aquifer tests were used to obtain information to characterise the aquifers present.

Based on the information evaluated, a north-south trending fault, associated with a replacement pegmatoid body mapped in the underground mine plan, is identified as a preferential flow path to groundwater and therefore also for potential contamination associated with the Khulu TSF. This fault intersects the eastern edge of the TSF. A second southwest-northeast trending fault was also identified and characterised. This fault transects the Khulu TSF footprint and also exhibits enhanced aquifer conditions, which are variable along its strike. A borehole situated down gradient of the Khulu TSF on this fault line was dry at the time of drilling. Groundwater seepage was recorded afterwards in the borehole. This structure may therefore also be considered as a preferential flow path to groundwater, but with less significance compared to the north-south trending fault. A dyke situated east of the Khulu TSF could act as a preferential flow path to groundwater, south of the TSF footprint. In the vicinity of the Khulu TSF, the significance of the preferential flow along the dyke contact is considered less prominent as it does not intersect the footprint area.

An analysis of aquifer transmissivities calculated from field data is summarised in the table below. The information suggests that the N-S striking fault is the most prominent preferential flow path to groundwater.

Aquifer	Transmissivity range (m^2/d)	Average Transmissivity (m^2/d)
Alluvial	2.87 - 9.21	5,14
Shallow weathered	Dry - 5,46	0,16
Fractured rock: matrix	0.04 - 0.07	0,06
Fractured rock: SW-NE fault	Dry - 96	13,78
Fractured rock: N-S fault	6 - 328	77,08
Fractured rock: Dyke	0.25 - 17.5	2,36

Evaluation of monitoring data obtained during aquifer tests suggest that there is limited vertical movement between the shallow weathered and deeper fractured aquifers at the Khulu TSF footprint. Further south in the plant area, high transmissivities were recorded for the N-S striking fault in shallow and deep boreholes. It is thought that contamination from surface enters the fractured rock aquifer in this area.

Groundwater flow patterns confirm preferential flow along the N-S striking fault and to a lesser extent along the SW-NW striking fault and the dyke. Groundwater levels measured in shallow boreholes indicate that groundwater follows the topography in the weathered aquifer and discharges towards rivers and streams. Groundwater flow in the underlying fractured rock aquifer is only partially governed by the topography. Preferential flow along geological structures and the impact of mine dewatering also affects the fractured rock aquifer.

The average rate of recharge to the aquifers was calculated from groundwater level and rainfall data as around 4% of the mean annual precipitation. This is within the expected range for the aquifers present.

Existing groundwater abstraction by DCM to supply the operational with potable and process water was taken into consideration during simulations.

An assessment of process water quality and rock leach tests completed indicates that the risk of acid mine drainage associated with the operations is low. An analysis of the mine's monitoring database confirms that nitrate is the indicator element for the project. The impact assessment presented in this report is therefore completed at the hand of nitrate concentrations in groundwater.

The latest available groundwater quality sampling data shows that the nitrate concentration in the existing dirty water dams linked to the plant and the Northern TSF are comparable and exceed 1000 mg/l. Water quality in the LRWD, which is used to supply the plant and will impact on seepage quality in tailings deposited on the Khulu TSF has a nitrate concentration exceeding 1500 mg/l.

Groundwater quality data further indicates that the fractured rock already exhibits elevated nitrate concentrations at the Khulu TSF footprint. This contamination is thought to originate in the plant area and migrate preferentially along the faults and dykes in a northerly direction. Groundwater quality in the shallow weathered aquifer is not impacted at the TSF footprint. An analysis of the rate of contaminant migration in the alluvial aquifer and along the dyke structure confirms similar aquifer permeabilities/transmissivities to those calculated with aquifer testing data.

The available dataset was used to conceptualise the aquifers present at the Khulu TSF and generate input for the numerical groundwater flow and contaminant transport model updated and re-calibrated to complete the impact assessment. The source term used to simulate the impact of the project on nitrate concentrations in groundwater was generated from existing monitoring and leach test data.

JAW calculated the potential rate of leakage through the TSF and PCD liners. This information was incorporated in the groundwater model to complete the impact prediction simulations.

Model calibration and sensitivity analysis

Model calibration was undertaken with field-measured groundwater levels from the latest monitoring dataset. Both steady state and transient calibration was completed. Calibration results complied with the pre-set calibration criteria set.

The results indicate that the model is most sensitive to changes in the permeabilities of the regional geological structures that act as preferential flow paths, including the N-S dyke, the SW-NE fault, the rock matrix and the N-S fault. The level of confidence in the outcome of simulations can be improved if additional monitoring data is obtained to characterise aquifer characteristics. This can be done through ongoing water level monitoring in the existing boreholes as well as monitoring on-site rainfall rates.

Modelling further indicates that the contaminant transport model is sensitive to changes in the porosity of the rocks and the geological structures. The porosities used to complete the impact assessment were kept low in order to avoid under-estimating impacts. Adjustments to the porosities were undertaken to match monitoring data. It is however recommended that more work is undertaken to improve the understanding of aquifer porosities to be included in future simulations.

Geohydrological impact assessment

The designs and operational life of the Khulu TSF was integrated into the model to complete the geohydrological impact assessment for the project. The estimated impact at the end of the operational phase of the TSF and mine was calculated. An assessment of the no-project option is also included in the report. Three long-term liner scenarios were tested, namely:

- **Scenario 1:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere is managed and limited to a minimum, resulting in a life of liner of 280 years. During this time, it is assumed that seepage will be collected above and below the TSF and PCD liner and that this water will be transferred to the PCD. No seepage is therefore expected to infiltrate to the underlying aquifers. This is considered the best case scenario.
- **Scenario 2:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers according to the rates presented provided by JAW.
- **Scenario 3:** Poor liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers at the maximum rate. This is considered the worst case scenario.

During simulations, the specifications and findings of the latest overall annual rehabilitation plan for the operations were incorporated. The requirements of the 2018 Groundwater Remediation Strategy were not considered in this report. This strategy will be updated and finalised based on the outcome of fieldwork completed in 2021. Groundwater management scenarios will be assessed as part of a separate study during 2022 after which the implementation of the Groundwater Remediation Strategy will be finalised. It is acknowledged that groundwater management measures implemented as part of the remediation strategy will also benefit impacts associated with the Khulu TSF.

The simulated plumes presented in this report are delineated by the 30 mg/l nitrate concentration contour. This is equivalent to the long-term average nitrate concentration for the receiving water quality in the Groot Dwars River. Activities upstream of DCM already impacts on nitrate concentrations, which affect surface water and to some extent groundwater quality in the DCM mining area. The South African Drinking Water nitrate standard of 11 mg/l is also indicated on simulated plumes as reference.

Simulated nitrate concentrations are compared for all scenarios tested in the table below.

Scenario	Description	NO_3 in groundwater: Khulu TSF footprint (mg/l)	NO_3 in groundwater: Farm House BH	NO_3 in groundwater: Klein Dwars River	NO_3 in groundwater: Groot Dwars River
End operational Phase	No liner failure, evaluating other DCM mining and mineral processing activities	Weathered aquifer: <11 Fractured aquifer: > 400	<200	<11	<11
No project	Khulu TSF and PCD not built 300 years after mine closure	Weathered aquifer: <11 Fractured aquifer: <160	<100	<11	<11
1	Good liner installation, limited exposure to atmosphere 300 years after mine closure	Weathered aquifer: >600 Fractured aquifer: >180	<100	<11	<11
2	Good liner installation, exposure to atmosphere 300 years after mine closure	Weathered aquifer: >800 Fractured aquifer: >240	<170	<11	<11
3	Poor liner installation, exposure to atmosphere 300 years after mine closure	Weathered aquifer: >1500 Fractured aquifer: >1200	>750	30 - 200	30 - 150

The outcome of the assessment is summarised below:

Impacts on groundwater quality at the end of the operational phase:

- Nitrate contamination in the weathered aquifer will be contained to the plant and opencast mining areas. Based on the current characterisation of the alluvial and shallow weathered aquifers, it is unlikely that nitrate concentrations in the weathered aquifer would exceed 11 mg/l in the vicinity of the Groot Dwars River down gradient of the Khulu TSF.
- No impact on groundwater quality is expected in the vicinity of the Klein Dwars River west and northwest of the Khulu TSF and PCD at the end of the operational phase.
- Based on the conceptualisation of preferential groundwater flow in the fractured rock aquifer, the nitrate plume is expected to migrate in a northerly direction along the N-S striking fault. This contamination originates from the plant, historical TSF, dirty water dams, open cast and underground mining areas and not from the Khulu TSF and PCD.

Long-term impacts on groundwater quality if the project is not implemented:

- The simulations indicate that the nitrate plume will recede in the long-term in the weathered aquifer if all sources of contamination are removed at mine closure as part of the rehabilitation programme.
- At the Khulu TSF foot, nitrate concentrations are not expected to significantly exceed 11 mg/l in the long-term for this scenario.
- The impact on the Groot and Klein Dwars River is expected to reduce significantly in the long-term for this scenario. Nitrate concentrations in groundwater reaching these rivers in the weathered and alluvial aquifers are not expected to exceed 11 mg/l.
- The plume in the fractured aquifer is expected to continue to migrate along the preferential flow paths and to a lesser extent in unfractured rock matrix in the long-term. Nitrate concentrations are however expected to reduce inside the affected area as a result of plume dilution from recharge of fresh rain water and groundwater

throughflow. Over the footprint area of the Khulu TSF, nitrate concentrations are expected to reduce to below 160 mg/l on average.

Long-term impacts on groundwater quality associated with Scenario 1:

- Seepage through the TSF and PCD liners are expected to increase nitrate concentrations in the weathered aquifer underneath the Khulu TSF and PCD footprint areas. Nitrate concentrations may increase to above 600 mg/l over the footprint areas in the weathered and alluvial aquifers in the long-term.
- The nitrate plume is expected to migrate in a north-westerly direction towards the Klein Dwars River in the weathered and alluvial aquifers. At 300 years after mine closure, simulations suggest that it is unlikely that groundwater with nitrate concentrations exceeding 11 mg/l would reach the Klein Dwars River from the Khulu TSF and PCD to any significant extent.
- The effect of liner failure at the Khulu TSF and PCD on the fractured rock aquifer is not expected to add significantly to the pollution load associated with other DCM mining and mineral processing activities.
- Nitrate concentrations may increase to above 180 mg/l in the fractured rock aquifer as a result of infiltration over the Khulu TSF and PCD footprint areas. This is an estimated 20 mg/l increase in concentration compared to the no project option discussed above.
- The nitrate plumes originating from the Khulu TSF and PCD are expected to migrate in a northerly direction along the preferential flow paths identified. Contamination along these geological structures are however expected to be dominated by DCM mining and mineral processing activities and not significantly as a result of seepage from the Khulu TSF and PCD.
- The nitrate plume is expected to migrate more than 900m north outside the DCM mineral rights boundary along the N-S striking in the long-term for this scenario.

Long-term impacts on groundwater quality associated with Scenario 2:

- The extent of the impact on groundwater quality for this scenario is similar to that reported for Scenario 1. The extent of the plume is driven by aquifer parameters like permeability and porosity and to a lesser extent by the concentration gradient for Scenarios 1 and 2. This is due to the fact that the rate of seepage from the Khulu TSF liner for good installation is reported to be comparatively low, which means the concentration gradient from the source to the aquifer is low.
- Nitrate concentrations inside the delineated plumes are however expected to increase for this scenario compared to Scenario 1, as the seepage will take place for a longer period of time. The liner failure occurs after 69 years for this scenario, compared to after 280 years for Scenario 1.
- In the weathered and alluvial aquifers, nitrate concentrations may increase to above 800 mg/l in the long-term for this scenario. This is an increase of 200 mg/l compared to Scenario 1.
- The contamination is expected to migrate in a north-westerly direction towards the Klein Dwars River in the long-term. Nitrate concentrations are however not expected to significantly exceed 11 mg/l in groundwater reaching the Klein Dwars River in this time.
- The nitrate plume in the fractured rock aquifer will migrate preferentially along the N-S striking fault and the other preferential flow paths identified. As reported for Scenario 1, the nitrate plume may migrate more than 900m north along the N-S striking fault outside the DCM mineral rights boundary in the long-term.

- Nitrate concentrations in the fractured rock aquifer immediately underneath the Khulu TSF and PCD may increase to above 240 mg/l for this scenario. This is an increase of 60 mg/l in nitrate concentration compared to Scenario 1.
- Nitrate concentrations in at the Farm House borehole may decrease to around 170 mg/l in the long-term compared to the 200 mg/l expected at the end of the operational phase. This is however an increase of around 70 mg/l compared to the results of Scenario 1.
- Plume movement in unfractured rock matrix is expected to be low. Nitrate concentrations in the fractured rock aquifer immediately down gradient of the Khulu TSF and PCD are not likely to exceed 11 mg/l near the Klein Dwars River in the long-term.

Long-term impacts on groundwater quality associated with Scenario 3:

- Liner failure and maximum seepage rates to the underlying aquifers for this scenario is expected to result in a significant negative impact on groundwater quality. With the increased seepage rate, the concentration gradient at the Khulu TSF and PCD footprint will increase significantly, resulting in an accelerated spread of contamination in the long-term. The plume is also expected to migrate radially away from the Khulu TSF footprint area due to the high infiltration rates. A mound in groundwater levels is expected around the footprint in this case. It is noted that the rate of infiltration is significantly high and is most probably not a reality.
- The extent of the impact on the weathered and alluvial aquifers is expected to significantly increase for this scenario. Over the footprint area, nitrate concentrations may increase to 1500 mg/l in the long-term.
- The plume is expected to migrate in a north-westerly and westerly direction towards the Klein Dwars River. Nitrate concentrations in groundwater reaching the Klein Dwars River are expected to increase to above 30 mg/l over a length of 250m along the river. In places, nitrate concentrations in groundwater reaching the Klein Dwars River in the weathered and alluvial aquifers could exceed 200 mg/l for this scenario. This is expected to result in a noticeable impact on surface quality in the long-term.
- The plume is also likely to reach the Groot Dwars River southwest of the Khulu TSF due to the anticipated radial flow from the footprint area. Groundwater reaching the Groot Dwars River may have nitrate concentrations exceeding 30 mg/l over a stretch of around 200m along the river. In places, nitrate concentrations in groundwater may increase to above 150 mg/l at the river. This is also expected to result in a noticeable impact on surface water quality in the long-term.
- The high seepage rates from the Khulu TSF and PCD are also expected to result in significant vertical flow to the underlying fractured rock aquifer. This is different to the outcome of Scenarios 1 and 2, where the concentration gradient under lower seepage rates did not result in significant impacts on the fractured rock aquifer.
- Once the nitrate concentrations reach the fractured rock aquifer, preferential flow is expected along the N-S and the SW-NE striking fault lines.
- Over the Khulu TSF and PCD footprint areas, nitrate concentrations may increase to above 1200 mg/l in the fractured rock aquifer for this scenario, which is a significant increase from the impacts associated with Scenarios 1 and 2.
- Along the N-S striking fault, nitrate concentrations may exceed 700 mg/l in the long-term. This plume is also expected to migrate more than 1300m north and outside the DCM mineral rights area, as indicated.
- Nitrate concentrations in the SW-NE striking fault may increase to above 1000 mg/l in the long-term. In addition, a nitrate plume is expected to migrate along this structure in a southwesterly direction towards the Groot Dwars River. In the long-term, nitrate

concentrations may increase to around 450 mg/l in the fault line at the intersection with the Groot Dwars River.

- The groundwater mound that will develop underneath the Khulu TSF and PCD footprint areas is also expected to drive migration of the nitrate plume in the unfractured rock matrix towards the Klein Dwars River west of the site. On the long-term, this could result in an increase in nitrate concentrations in the fractured rock aquifer at the river of more than 30 mg/l, possibly as high as 50 mg/l.

An evaluation of the simulated nitrate concentration fluctuation with time indicate the following:

- The residual long-term impact on groundwater associated with other DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term, especially in the fractured rock aquifer. Even if the Khulu TSF and PCD is not constructed, nitrate concentrations are expected to be elevated above the average receiving surface water concentration of 30 mg/l in this aquifer.
- With the implementation of rehabilitation measures at mine closure aimed at source reduction, the long-term nitrate concentrations in the fractured rock aquifer is expected to reduce by between 100 and 200 mg/l in the long-term for no project option and Scenarios 1 and 2.
- Similar trends are observed for the weathered aquifer, but at lower concentrations compared to the fractured rock aquifer. This is as a result of preferential groundwater flow associated with the regional faults and dykes targeted in the fractured rock aquifer as part of this study.
- Liner failure for Scenario 1 will only impact on groundwater quality 280 years after liner installation, as discussed above. The increased nitrate concentrations in monitoring boreholes around the Khulu TSF footprint as a result of increased seepage rate after liner failure is expected manifest over a period of 40 – 60 years, after which concentrations are expected to plateau at 300 – 400 mg/l in the weathered aquifer.
- Liner failure for Scenario 2 will impact on groundwater quality 69 years after installation. At this point, nitrate concentrations are expected to increase to 300 – 400 mg/l over a period of 40 – 80 years and start to plateau at concentrations of between 300 – 400 mg/l.
- The significant impact of liner failure under Scenario 3 is evident from the graphs. It is shown that nitrate concentrations will increase significantly in both the shallow weathered and deeper fractured rock aquifers over a period of 10 – 20 years. In the weathered aquifer, nitrate concentrations may increase to above 1200 mg/l during this period. After the initial rapid increase in concentration, nitrate is expected to plateau at between 800 and 1300 mg/l in the weathered aquifer over a period of 100 years or longer.

Summary of impacts on groundwater quality and the receiving water body

As discussed above, even without construction of the Khulu TSF and PCD, the existing DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term. DCM is in the process of developing and implementing a Groundwater Remediation Strategy that will be designed to reduce nitrate concentrations in groundwater. This strategy will be developed as part of a separate study.

Liner failure under good installation conditions is expected to result in an increase in nitrate concentrations of between 20 and 80 mg/l in the long-term. The outcome of Scenario 1 resulted in the least significant impacts on groundwater and the receiving water quality.

If the liners are poorly installed and managed, negative impacts are expected on the receiving water bodies (the Klein and Groot Dwars Rivers) as well as on groundwater quality. Groundwater baseflow to the rivers at the concentrations reported will most likely result in an increase in nitrate concentrations in the rivers. The increased nitrate concentrations in groundwater will result in an unacceptable long-term impact.

Based on the outcome of the assessment, the preferred option in terms of liner design for the Khulu TSF and PCD is Scenario 1. For this scenario, good liner installation will be implemented and the liner will not be exposed to the atmosphere excessively. If this is achieved, the life of the liner is estimated to be 280 years. Simulations indicate that even if the liner fails, long-term impacts on the receiving water bodies are not expected to be significant.

Groundwater management and monitoring programme

The results of the impact assessment presented above were used to develop a groundwater management and monitoring programme for the Khulu TSF and PCD. The main objective of the management programmes is to reduce adverse impacts on the receiving water bodies and to prevent further deterioration of groundwater quality at the operations. In order to achieve this, overarching general groundwater management measures are proposed, mostly linked to good house-keeping measures.

Specific groundwater management measures to address impacts on groundwater quality are provided. These include:

- Finalise the implementation plan for the Groundwater Remediation Strategy for the operations, based on the outcome of fieldwork completed during 2021. The most effective groundwater management strategies must be developed and implemented as part of a groundwater impact assessment study to be completed during 2022. Due to the fact that groundwater quality at the Khulu TSF is affected by preferential flow along regional faults and dykes, it is accepted that the Groundwater Remediation Strategy will also improve groundwater quality at the TSF and PCD in the long-term.
- The outcome of the groundwater impact assessment presented in this report indicates that the Scenario 1 liner design is the preferred option to ensure that long-term impacts on groundwater quality are limited. This entails good installation of the liner and limited exposure of the HDPE to the atmosphere. Under these measures, the liner is expected to have a life of 280 years. Once the liner fails, the rate of seepage to the underlying aquifers is minimised with good liner installation.
- The liner design must include the above and below liner capture of seepage. Any seepage collected must be diverted to the PCD for containment.
- The water level in the PCD must be diligently monitored to avoid spills and/or seepage. If excess water collects in the PCD, this water must be pumped to the LRWD for reuse in the mine water balance.
- DCM must monitor the volumes of water transferred to and from the Khulu TSF and PCD as part of its flow meter monitoring network. Instruments installed to measure flow must be maintained and calibrated to ensure that accurate measurements are made. The data collected from the flow meters must be used to confirm that the assumptions on which this impact assessment are based, remain valid. If significant deviations in terms of water flow volumes are recorded, the impact assessment presented in this report must be re-evaluated, especially in terms of the volume of seepage available for infiltration from the TSF and PCD.
- All newly drilled monitoring boreholes must be surveyed to confirm accurate positions and elevations. The coordinates presented in this report were recorded with a hand-held GPS.
- Groundwater monitoring must be maintained in all boreholes dedicated to the Khulu TSF. Both groundwater quality and groundwater levels must be monitored in the boreholes according to the strategy below. The information from the monitoring programme must be kept in a spreadsheet. Trends must be analysed to ensure that any exceedances are immediately detected.
- In the event of deterioration in groundwater quality, an inspection must be held to identify the source of contamination. Any non-compliances must be rectified immediately to avoid prolonged negative impacts on groundwater.

- If any of the monitoring boreholes are destroyed during construction and/or operation of the TSF, these must be placed as a matter of urgency. Of specific concern is the location of boreholes DRM11S and D, which is located on the edge of the Khulu TSF design. These boreholes target the SW-NE trending fault and must be redrilled on this structure if destroyed to ensure efficient monitoring of groundwater in this position.
- Additional monitoring boreholes, as detailed below, must be drilled prior to the commencement of construction of the Khulu TSF and PCD to ensure that a baseline can be generated.

Based on the outcome of this assessment, three additional groundwater monitoring boreholes are recommended. These include a shallow and deep monitoring borehole northwest of the PCD. These boreholes must target the fault line indicated in this area, which is perceived to be a preferential flow path to groundwater. The third borehole is a shallow borehole on the north-western corner of the TSF located in the delineated plume of the weathered aquifer. No geological structures are thought to be present in this area.

Specific monitoring requirements and trigger response criteria were set for the project. These include monitoring of groundwater levels and quality at the Khulu TSF and PCD, the volumes of water pumped to and from the Khulu TSF and PCD and rainfall. A monitoring trigger-response criteria is set for each monitoring parameter, which must be reviewed on an annual basis and updated as necessary based on monitoring results. If significant exceedances are recorded, appropriate and timeous action must be taken to address these and to limit adverse impacts on groundwater.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS USED

BH	Borehole
BPG	Best Practice Guideline
CDT	Constant discharge test
DCM	Dwarsrivier Chrome Mine
DTM	Digital Terrain Model
DWS	Department of Water and Sanitation
DWAF	Former Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
EM	Electromagnetic
EMP	Environmental Management Plan
ESR	Environmental Scoping Report
FC	Flow Characteristic
IAP	Interested and Affected Party
HDPE	High-density polyethylene
iLEH	Irene Lea Environmental and Hydrogeology
IRUP	Iron rich ultramafic pegmatoid
JAW	Jones and Wagener Engineering and Environmental Consultants
K	Hydraulic conductivity (unit: m/d)
LCT	Leachable concentration threshold
LOM	Life of mine
LOW	Limit of weathering
LRWD	Lower Return Water Dam
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
MAE	Mean Annual Evaporation
mbgl	Metres below ground level
NA	Not applicable
PCD	Pollution Control Dam
ROM	Run of Mine
RWD	Return water dam
S	Storage coefficient (-)
S_y	Specific yield (-)
SANS	South African National Standards
SCS	Steelpoort Chromitite Seam
SDT	Step drawdown test
SWL	Static Water Level
T	Transmissivity (unit: m^2/d)
TSF	Tailings Storage Facility
URWD	Upper Return Water Dam
WTP	Water Treatment Plant
WUL	Water Use License

1 INTRODUCTION

1.1 Geographical setting

Dwarsrivier Chrome Mine (DCM) is situated approximately 25km southwest of the town of Steelpoort along the R577 road to Mashishing in Limpopo Province. The mine is located on the south-western boundary of the Eastern Bushveld Igneous Complex on the farms Dwarsrivier 372 KT and De Grooteboom 373 KT. DCM falls within the boundaries of the Fetakgomo-Greater Tubatse Local Municipality.

DCM is surrounded by operational chrome and platinum mining mines situated on adjacent farms. These include Tweefontein and Thorncliffe mines.

Within the project area, the topographical elevation of the river valley varies from 930 mamsl in the south to 890 mamsl in the north. The topography dips regionally towards the Groot and Klein Dwars Rivers, as indicated on Figure 1. These rivers drain in a northerly direction towards the Steelpoort River. In the floodplains of these rivers, the topographical gradient is flat, with average gradients of 1:70 (0.014). The flatter topographical landscape is associated with alluvial material deposited in the floodplains of the rivers.

Along the edges of the Dwars River valley, steep mountainous landscapes formed by hard rock formations of the Bushveld Igneous Complex occur with gradients of 1:4 (0.24) and steeper. In the mountains to the west, the topography steepens significantly to elevations of above 1300 mamsl on the Dwarsrivier mountain.

1.2 Mining activities

DCM has been mining chromite ore from the Steelpoort Chromitite Seam (SCS) seam since 1999. Between 1999 and 2005, ore was mined using opencast methods. The six pits have subsequently been mined out and backfilled with the exception of the South and North Pit portals from which access is gained to the underground workings.

Underground mine development commenced from the South Pit portal decline during 2003 and from the North Pit portal decline at in 2011. The current mine plan extends the life of the operations to 2052 through underground mining activities.

Ore is processed on site at a processing plant. Infrastructure includes various buildings, an ore conveyor, Run of Mine (ROM) stockpiles, a jaw crusher, ore bins, fines and product stockpiles as well as a salvage and scrap metal storage area. In this area, the main source of dirty water is the plant process water.

The plant produces mining waste (tailings and discard), which is stored on site. Tailings material was backfilled into portions of both North and South Pits during the opencast mining period. The extent of pit backfill is indicated on Figure 1. The majority of the tailings material was backfilled into North Pit while the construction of the Northern Tailings Storage Facility (TSF) was completed by 2012. A return water dam (RWD) was constructed in the north-western part of North Pit during this period. The RWD was excavated into backfilled tailings and lined with HDPE.

Tailings are currently deposited at the Northern TSF, which was commissioned in 2012. The life of the Northern TSF is estimated to be around three to five years as it was shortened due to increased ore production and consequently tailings deposition at the operations (Envirogistics, 2021b).

DCM also operated a historical TSF. An application was recently made to reprocess this tailings material in the processing plant.

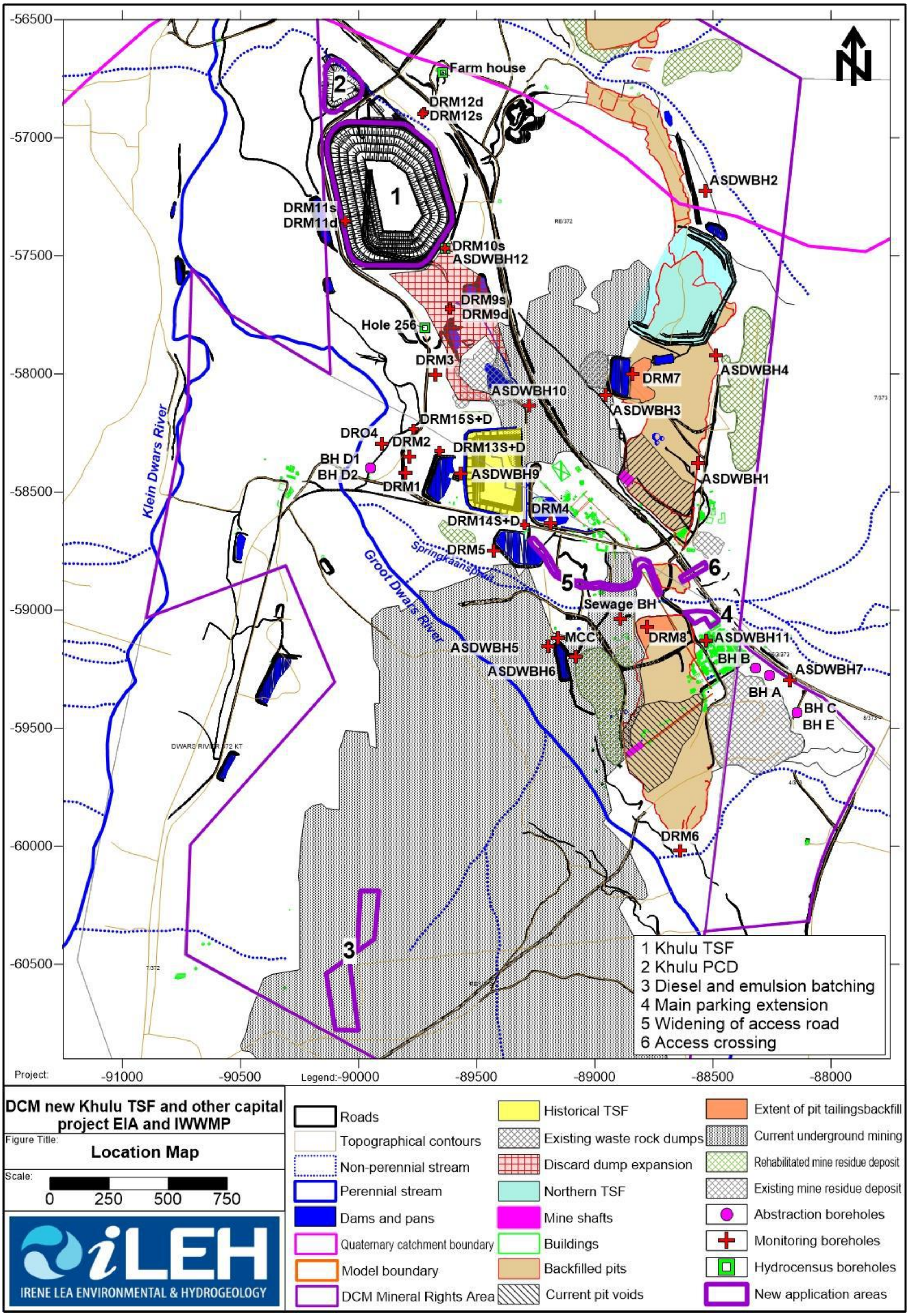


Figure 1 Location map

A number of waste rock dumps are situated around the operations. Some of these dumps have been rehabilitated. The operational waste rock dumps are situated east of South Pit, west of North Pit and north of the historical TSF. DCM plans to extend the Discard Dump in a northerly direction.

1.3 Project description

This report will be submitted as part of an Environmental Impact Assessment (EIA) and an Integrated Water and Waste Management Plan (IWWMP) application for the following (Envirogistics, 2021b):

- The construction of a new TSF, referred to as the Khulu TSF
- Diesel and Emulsion Batching
- Extension of the main parking area
- Widening of the access road between South Shaft / Main offices and the Plant.
- Construction of an access crossing between the Plant and North Mine.

The Environmental Assessment Practitioner (EAP) appointed to complete the application is Envirogistics (Pty) Ltd. The following project details are summarised from the Environmental Scoping Report (ESR) compiled by Envirogistics (2021b).

1.3.1 Khulu TSF

As discussed earlier, it is anticipated that the Northern TSF will reach its capacity within the next three to five years. The estimated life of the operations is 25 years (JAW, 2021c). Additional tailings storage capacity is therefore required. Initially seven potential sites were identified for the new TSF. These were reduced to four potential sites, based on a site selection process. A geohydrological baseline assessment was completed for the four sites (iLEH 2021). Each site was evaluated against the following criteria:

- The current status of aquifer(s) present in the vicinity of the delineated footprints provided.
- The proximity of potential preferential flow paths to groundwater like faults and dykes.
- Existing groundwater use near each footprint.
- The extent of historical, current and planned future undermining.
- The presence of rivers and streams, which may result in shallow groundwater conditions.
- Data availability

The following criteria were identified as potential fatal flaws from a geohydrological perspective:

- The presence of a shallow groundwater table that may rise into the base layer of the liner of the TSF during the wet season.
- The TSF situated near existing groundwater users and therefore potentially impacting on existing use.
- The TSF not lined with a suitable barrier system, including HDPE layer(s).

Based on the outcome of the assessment, Site D was identified as the preferred alternative from a geohydrological perspective for the Khulu TSF. No fatal flaw conditions were identified, based on the available dataset.

Subsequent to the site selection process, further geotechnical and engineering studies were undertaken which identified potential concerns for Site D. These include the proximity to a non-perennial tributary of the Dwarsrivier. Initially, Site B was considered fatally flawed as it coincided with a planned ESKOM substation. This substation will however no longer be constructed, which reintroduced Site B for consideration. Following the outcome of a further site selection process (JAW, 2021a), Site B was identified as the preferred position of the Khulu TSF. Sites C and D are considered as the preferred alternatives.

Jones and Wagener Engineering and Environmental Consultants (JAW) were appointed to draw up the designs for the Khulu TSF (JAW, 2021f). DCM plans to decommission the current North TSF once its reaches its maximum capacity and replaced it with the proposed Khulu TSF. The Khulu TSF will be developed by depositing tailings dewatered by means of a filter press plant. Tailings will be pumped as a slurry from the Plant to the filter press facility (FPF) where the tailings will be dewatered. The FPF will be located on the footprint of the old TSF. The dewatered tailings will be transported by trucks to, placed and compacted on the Khulu TSF. The designs include the following components (see Figure 2):

- The Khulu TSF with a footprint area of 22,5ha and a maximum height of 42m. Details regarding the TSF design are presented in Table 1.
- A pollution control dam (PCD), the designs of which include a spillway; Class C liner and associated drainage; and associated infrastructure including a pump station platform and access road.
- A pumping system to convey water stored in the PCD to the existing LRWD.
- Infrastructure for the management of dirty stormwater runoff, including a dirty water canal around the TSF footprint; a silt trap for settling and reducing silt that will report to the PCD and a culvert required to convey dirty water across the Richmond road from the silt trap to the PCD.
- A clean water diversion canal and berm to diver clean stormwater runoff around the Khulu TSF and PCD.
- A service road around the TSF.
- A haul road to transport tailings from the filter press facility (FPF) to the Khulu TSF.

The tailings is classified as a Type 3 waste (nettZero, 2018). Based on this outcome, the TSF and associated pollution control dam (PCD) have been designed with Class C barrier systems. Due to spatial constraints, the PCD will be located across the Richmond Road (see Figure 2). The PCD will be developed over previously undermined ground (Tweefontein Mine).

Volumetric modelling of the PCD, the spillway, the class C liner and associated drainage was used to calculate the volume of water that will be pumped from the PCD to the Lower Return Water Dam (LRWD) (JAW, 2021g). The operation of the pumps at the PCD will be automated to start and stop as required.

Water from the Khulu TSF PCD will be accommodated within the existing mine-wide water balance (iLEH, 2022).

Based on TSF design information made available to complete the geohydrological study, (JAW, 2021a – g; and Envirogistics 2021 a and b), the design parameters for the Khulu TSF applicable to this assessment are summarised in Table 1.

The topography is fairly flat over the Khulu TSF and PCD footprint areas, dipping gradually in a north-westerly direction towards the Klein Dwars River. According to the 1:50 000 topographical map (2430CC Kennedy's Vale), a non-perennial drainage line runs along the north-eastern boundary of the Khulu PCD and TSF site, as indicated on Figures 1 and 2. This area was assessed during a site visit and it was noted to be highly disturbed by what appeared to be old stockpiles and borrow pits, possibly from previous road construction in the area. As a result, water is likely to pond in this area and it is therefore highly unlikely that this area functions as a drainage line. Furthermore, the Freshwater Ecological Assessment did not identify this area as a potential watercourse.

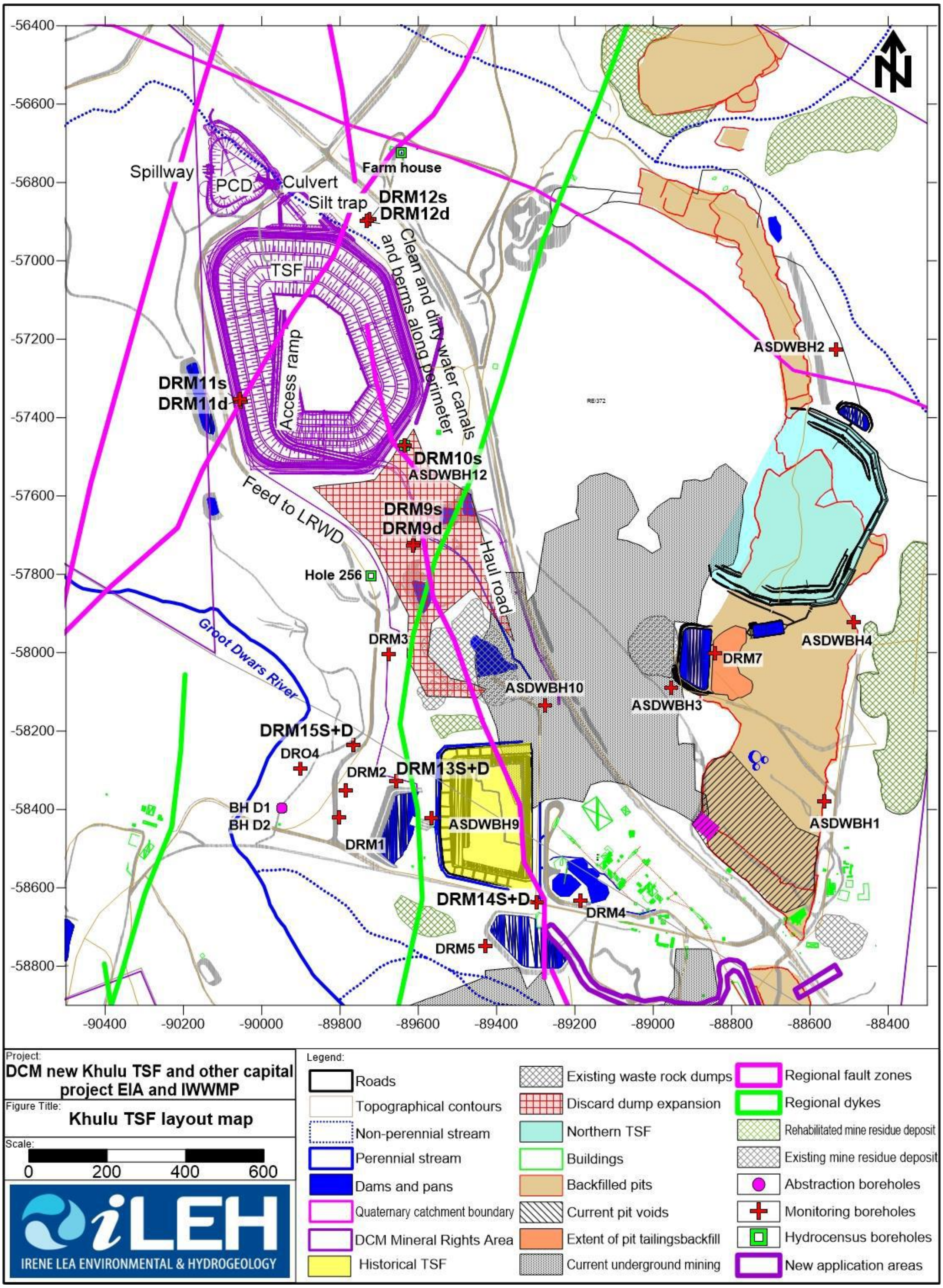


Figure 2 Khulu TSF layout

Table 1 Khulu TSF design parameters

Criteria	Khulu TSF
Footprint area (ha)	22,5
Final height (m)	42
Tailings deposition technology	Dry filter cake
Estimated life of the facility (years)	21
Modelled storage capacity (million m^3)	4.4
Construction	5m wide benches at every 10m height
Liner type	**Class C (Type 3 waste):** 2 x 150mm thick clay layers compacted to 98% Proctor Density at OMC 1.5mm thick HDPE geomembrane 150mm thick sandy protection layer (tailings) Above and below liner drainage and toe drains Possible seepage rate through liner: 24 – 2685 litres/ha/day Life of geomembrane: 69 years if exposed; 280 years if covered
Pollution Control Dam (PCD) design	Max volume: 24 000m^3 to a maximum of 49 900m^3 Maximum excavation depth: 8.6m Maximum dam depth: 6m **Class C liner:** 1.5mm HDPE geomembrane 2 x 150mm compacted clay layers Below liner drainage spaced 30m apart Possible seepage rate through liner: 467 litre/ha/day Life of geomembrane: 69 years

1.3.2 Diesel and Emulsion Batching

Based on the current and planned future extent of mining at South Shaft, additional off-loading and bulk storage of emulsion and diesel closer to the immediate work areas, is required (Envirogistics, 2021). The locations of these facilities are indicated on Figure 1.

These facilities will be self-containing and operated according strict protocols. As such, they are not expected to impact on groundwater within the mining area. The diesel and emulsion batching areas will therefore not be specifically addressed in this report.

1.3.3 Main parking extension

The mine requires the expansion of the existing parking area at the Main Offices (Envirogistics, 2021). The affected area is indicated on Figure 1. The parking area will be paved and will not involve any activity that may impact on groundwater. The diesel and emulsion batching areas will therefore not be specifically addressed in this report.

1.3.4 Widening of access road between South Shaft/Main Offices and Plant

This project will entail the widening of an existing access road between the Main Office Buildings and the Plant (Envirogistics, 2021). The location of this road is indicated on Figure 1. Since this is an existing road and the activities planned as part of the project do not pose a risk to groundwater, this activity will not be specifically addressed in this report.

1.3.5 Access crossing between the Plant and North Mine

A road will be constructed underneath the regional road bridge to optimise the logistical management between the South and North Mines and to reduce the number of vehicles on the regional road (Envirogistics, 2021). This crossing is indicated on Figure 1. The activities planned as part of this project do not pose a risk to groundwater and this activity will therefore not be specifically addressed in this report.

1.4 Mine water management

The project is situated in the Steelpoort sub-area (B41G quaternary catchment) of the Olifants River Water Management Area. The mining area is drained by the Groot Dwars River, which flows into the Klein Dwars River northwest of the main mining activities, as indicated on Figure 1. From there the river drains north into the Steelpoort River, a tributary of the Olifants River. DCM operates under three approved water use licenses (24053346, 04/B41G/G/792 and 04/B41G/CI/2240).

1.4.1 Potable water supply

DCM maintains a water monitoring and metering system at the operations. The information gathered as part of this system is recorded in a number of spreadsheets, which used for operational water management. The information presented in this section covers the period January 2017 to August 2021. Potable water is currently supplied from groundwater abstracted from three boreholes on the property, namely BH D1, D2 and E. Six groundwater supply boreholes are however in place at the operations. Boreholes A, B and C are not currently in use. The locations of these boreholes are indicated on Figure 1. Boreholes A, B and E are situated near the Main Office complex and were drilled into a fractured rock aquifer. Groundwater from BH E is pumped to the Main Office Tank from where it is distributed for use. Boreholes D1 and D2 are drilled into the alluvial aquifer associated with the Groot Dwars River. Groundwater is pumped from these boreholes to the Plant and Main Office tanks for potable use at the operations. Borehole C is drilled into the fractured rock aquifer situated on the northern side of the R557 and was used to supply North Mine up until April 2017. No groundwater is currently abstracted from this borehole.

The groundwater abstraction patterns for 2017 to 2021 are presented in Figure 3. Between 2017 and 2018, the total volume of groundwater abstracted was between 12 000 and 14 000 m^3/month. A decline in groundwater use is recorded over 2019 and 2020 to the impact of COVID-19 on mining activities. During this period, groundwater abstraction reduced to between 8 000 and 10 000m^3/month. Between August 2020 and August 2021 the total volume of groundwater abstracted amounted to 112 325 m^3/a, which is equivalent to 9 360 m^3/month.

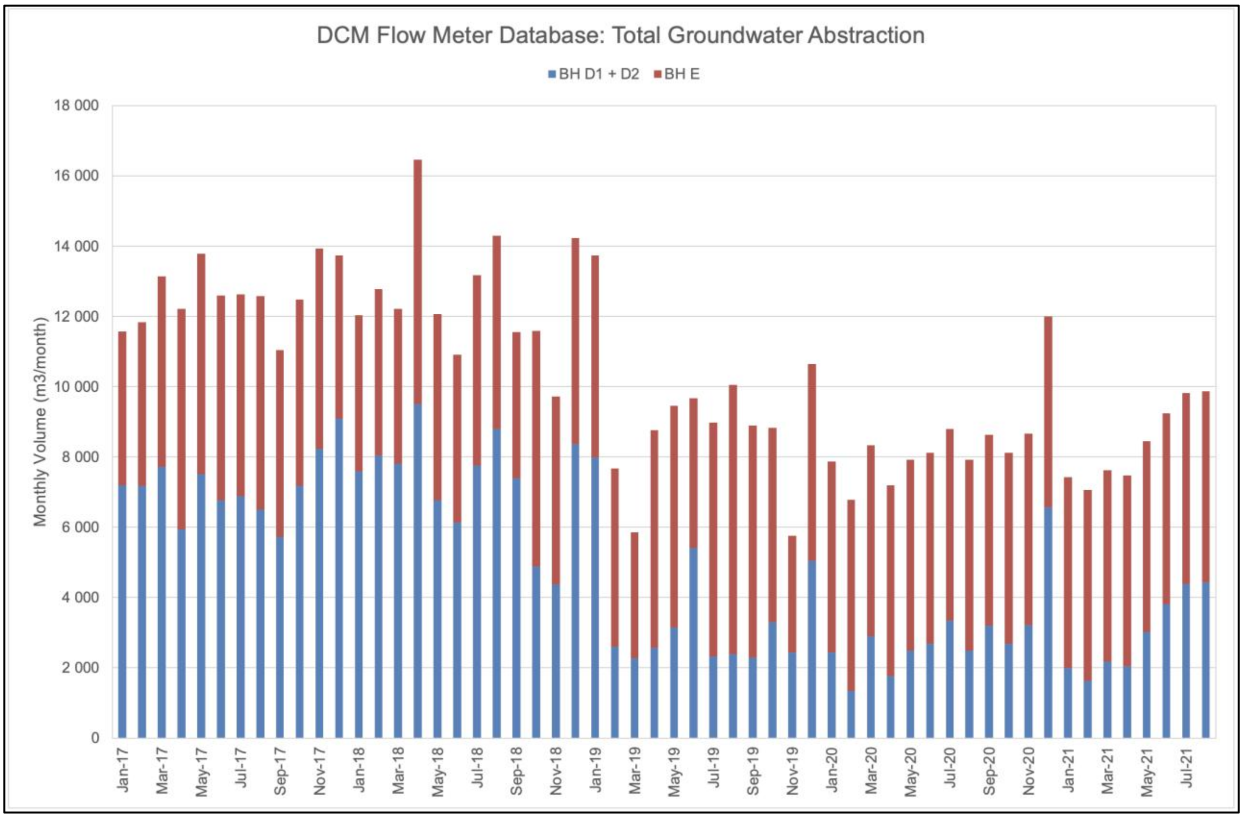


Figure 3 Measured groundwater abstraction volumes

1.4.2 Process water circuit

Several dams are used on site to contain and transfer dirty water around the operations. These include two pollution control dams, the Upper Return Water Dam (URWD) and Lower Return Water Dam (LRWD) situated adjacent to the historical TSF, as indicated on Figure 1. Both dams are lined with HDPE. Water in the dams originates from the underground workings as well as from the WUL authorised groundwater and river water abstraction and is continually pumped in a closed loop for use at the operations.

Extraneous water is pumped from the underground workings to the Clarifier. From here, water is transferred to Dam 26 via an HDPE lined open channel. Approximately half of the extraneous water is pumped back underground for reuse.

1.5 Mine dewatering volumes

DCM monitors the volume of water that is pumped from underground as part of their operational water balance. Both the North and South Mine underground workings are currently dewatered. This water originates from groundwater seepage into the underground workings where water-bearing geological structures are intersected during mining. The exact locations of all such water-bearing features are not all known, but DCM has mapped regional faults and dykes within its mining area. The locations of these structures are presented later in this report in the discussion of the regional geology.

The underground dewatering volumes for 2017 to 2021 are presented in Figure 4. A significant decline in dewatering volumes are recorded for the period 2019 – 2020, especially at South Mine due to the impact of COVID-19 on mining activities.

Between August 2020 and August 2021, a total of 33 609m^3/a was dewatered from South Mine and 129 539 m^3/a from North Mine.

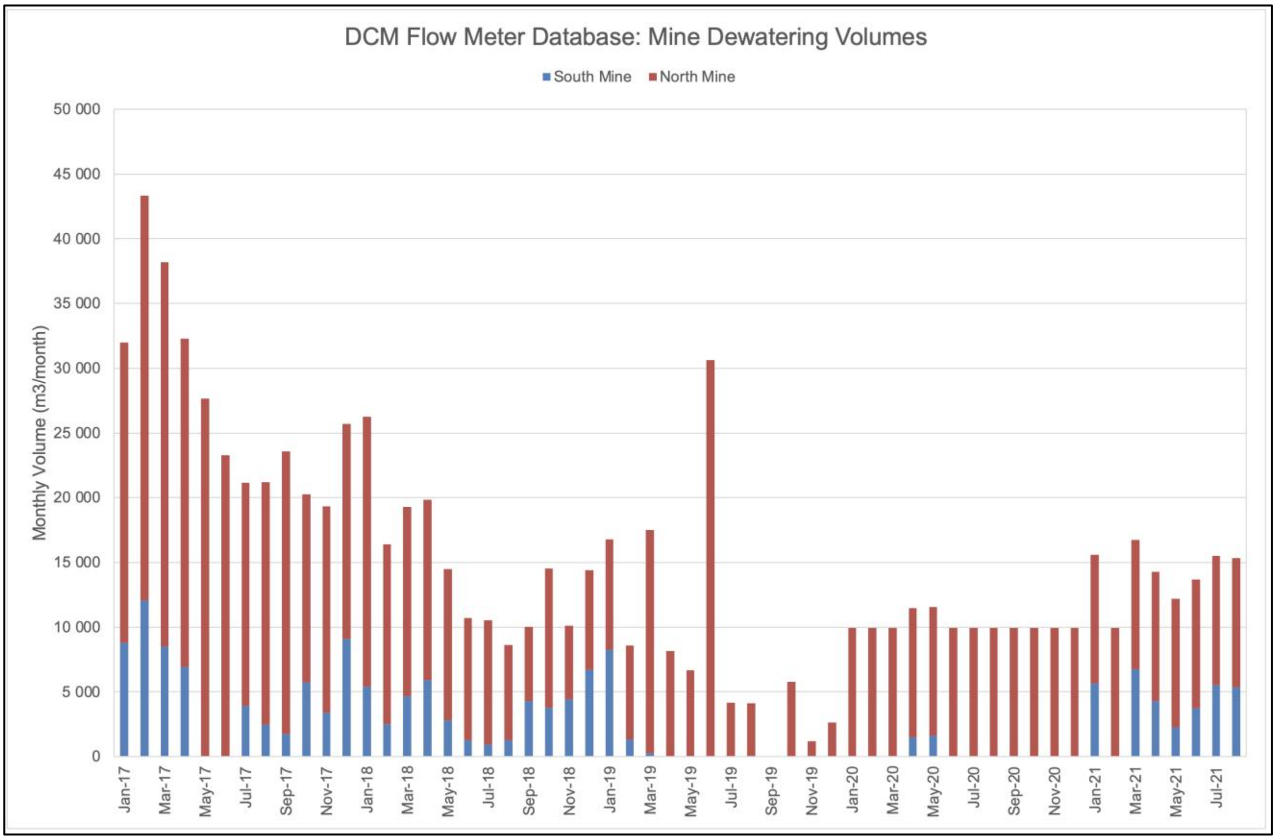


Figure 4 Recent DCM dewatering volumes

1.6 Climate

LEO (2010) reports that the mean annual precipitation (MAP) for the Martenshoop, the closest reliable rainfall station, is 683mm/a. This average is calculated from rainfall records dating from 1909 to 2000. No specific MAP value is reported in JAW (2021g), but is stated that the Martenshoop dataset was also used.

The mean annual evaporation (MAE) rate for the rainfall station is reported to be 1500mm/a, according to the WR2005 report. The project falls in Zone 4A of this report. This is similar to what is presented in JAW (2021g).

On-site rainfall measurements received from DCM for the period August 2015 to October 2020 are presented in Table 2 and Figure 5. The mean annual precipitation for the on-site rainfall measurements since 2015 is 578mm/a, which is 15% lower than the Martenshoop data. It is noted that the annual rainfall volume has reduced by 177mm/a on average since the 2015/2016 hydrological year.

Table 2 On-site rainfall measurements

Year	Total rainfall (mm)
2015/2016	719
2016/2017	516
2017/2018	544
2018/2019	529
2019/2020	580
2020/2021	Incomplete

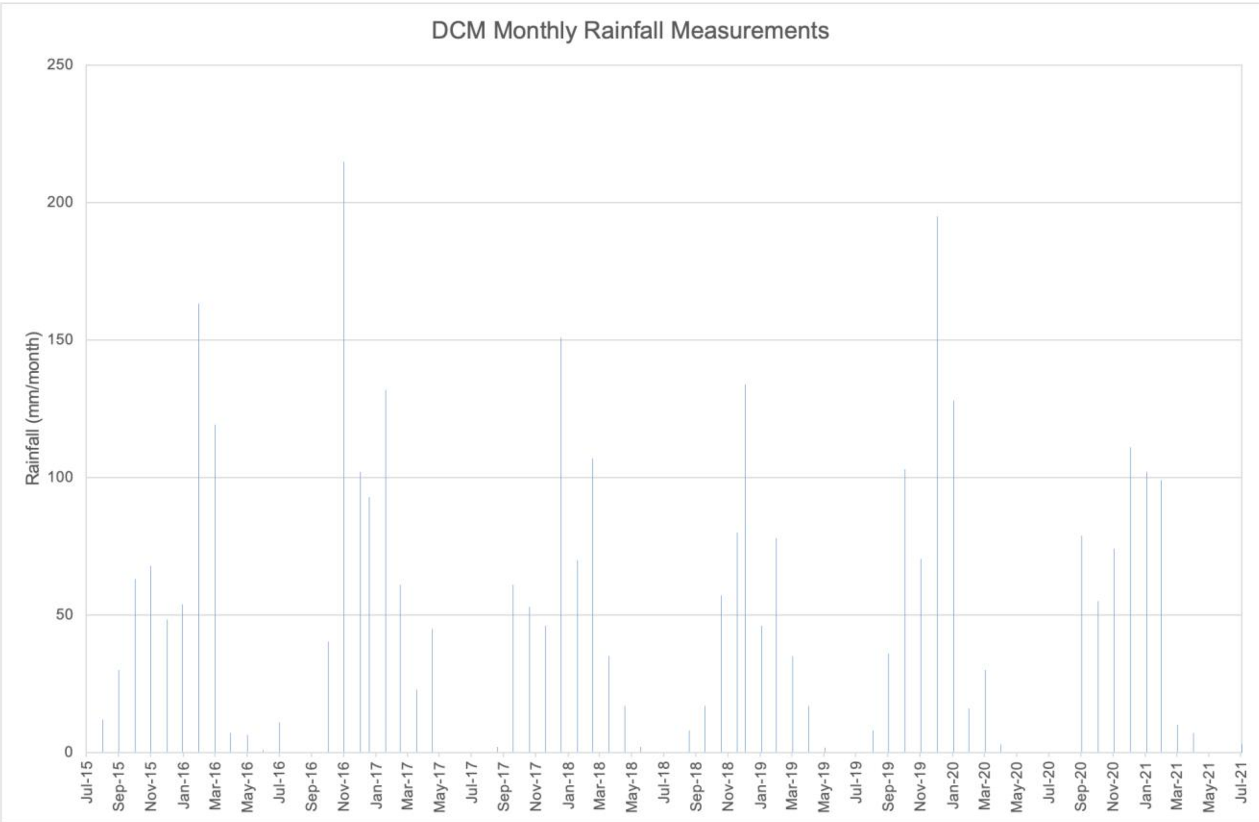


Figure 5 Monthly rainfall record (August 2015 to August 2021)

1.7 Reserve

The then Department of Water Affairs (DWA) published a reserve for the Dwars River in quaternary catchment B41H in 2010 (Ref. 26/8/3/3/310, 550/7). The reserve was prepared for the Richmond Dam, which is situated upstream of DCM. The study entailed an intermediate surface water and a rapid groundwater (quantity) reserve determination. The outcome of the assessment indicates that the present ecological state of the Dwarsrivier is rates B/C. The ecological importance and sensitivity was rates as high and the recommended ecological category was rated as B/C.

The groundwater reserve, defined as the amount of groundwater that is required to contribute to the surface water requirements of a water resource in order to achieve the recommended ecological category (baseflow contribution), was calculated as part of this study. The catchment wide of rate recharge of rain water to the aquifers present in the Dwarsriiver catchment is estimated to be 3% of MAP. Thirty eight percent of this recharge volume was determined as the required contribution to baseflow necessary to achieve the recommended ecological category of B/C. Groundwater is therefore thought to contribute significantly to surface water requirements in the catchment. The groundwater component of baseflow over the 442km^2 area of the catchment, was calculated to be 4,67 million m^3/a.

Surface water quality specifications (quality ecospecs) for the intermediate reserve for the Dwars River, as published in the reserve determination, is presented in Table 3.

Table 3 Dwars River Reserve Water Quality Specifications

Parameter	Ecological Requirements	Basic Human Needs Requirement	Reserve requirement: water quality
$MgSO_4$ (mg/l)	<16	N/A	<16
Na_2SO_4 (mg/l)	<20	N/A	<20
$MgCl_2$ (mg/l)	<15	N/A	<15
$CaCl_2$ (mg/l)	<21	N/A	<21
NaCl (mg/l)	<45	N/A	<45
$CaSO_4$ (mg/l)	<351	N/A	<351
Na (mg/l)	N/A	<200	<200
Mg (mg/l)	N/A	<100	<100
Cl (mg/l)	N/A	<200	<200
Ca (mg/l)	N/A	<80	<80
SO_4 (mg/l)	N/A	<400	<400
PO_4 (mg/l)	<0,02	N/A	<0,02
T Nitrogen (mg/l)	<4	N/A	<4
pH	6,5 – 8,8	5 – 9,5	6,5 – 8,8
Dissolved Oxygen (mg/l)	>7	N/A	>7
Electrical Conductivity (mS/m)	<55	0 - 70	<55

1.8 Date and season of the investigation

Fieldwork completed as over the footprint area of Site B was undertaken during May and June 2021, which represents dry season conditions. The fieldwork results are discussed below.

In addition to the fieldwork data, the DCM monitoring database was incorporated into the study, which includes data from both wet and dry seasons.

1.9 Alternatives considered

Alternatives considered for the proposed projects include (Envirogistics, 2021b):

- Location of the Khulu TSF (also see discussion above). Based on the site selection studies completed, Site B is identified as the most feasible location for the TSF.
- Tailings deposition technology (also see discussion above). An evaluation of the available tailings deposition options indicated that dry deposition is the preferred option. This will be achieved by submitting wet tailings through a filter press and trucking filter cakes to the TSF for deposition.
- No go alternatives if the projects are not approved. Without the construction of the Khulu TSF, DCM will not be able to continue with mining and mineral processing, as the Northern TSF will reach its capacity in three to five years. This will result in loss of the beneficiation of chrome, optimal mining, income to the local municipality, loss of employment and loss of opportunities developed as part of the Social and Labour Plan.

The other projects are required for the safe and logistically efficient operation of the mine.

2 SCOPE OF WORK

The scope of work for the geohydrological specialist study entails the following:

- Compile a geohydrological Scoping Report that includes an alternative assessment.
- Compile a geohydrological specialist study for inclusion in the EIA phase of the project that also complies with the requirements of an IWWMP for the project.
- The geohydrological study was expanded to include fieldwork over the Site B footprint. This included:
  - A hydrocensus of private and existing groundwater use surrounding Site B.
  - A ground geophysical survey using electromagnetic, magnetic and resistivity methods to be completed around and over the Site B footprint to identify geological structures that could act as preferential flow paths to groundwater. These structures will be targets for groundwater monitoring borehole drilling.
  - Drilling of three sets of shallow and deep monitoring boreholes on the geophysical targets. These boreholes must target the shallow weathered and the deeper fractured rock aquifers.
  - Complete aquifer tests on the new monitoring boreholes in order to characterise the aquifers present.
  - Take groundwater samples from the new monitoring boreholes for chemical analysis.
  - Take a composite tailings sample for leach tests in order to characterise the source term for the project.
- Update the existing conceptual aquifer model with the results of the fieldwork in order to reflect conditions underneath the Site B footprint.
- Undertake calibration of the existing numerical groundwater flow and contaminant transport model using the fieldwork results and the DCM monitoring data, as applicable.
- Complete a geohydrological impact assessment with the existing numerical groundwater flow and contaminant transport model that will meet the requirements of the EIA Regulations as well as that for the compilation of an IWWMP.
- Use the impact assessment results to compile a groundwater management plan as well as a monitoring programme for the Khulu TSF.

3 METHODOLOGY

3.1 Report format

The report was compiled according to the requirements of DWS BPG G4 (2008) as well as Regulation 267 of the National Water Act (1998) (NWA).

This report evaluates the impact of the capital projects discussed in Section 1.3.

The focus of the study is however the potential impacts of the Khulu TSF on groundwater. The fieldwork programme undertaken for the project focusses on the Site B footprint, as it was identified as the preferred alternative during the site selection process. No fieldwork was under taken at the two alternative footprint areas nor at the other capital project locations.

Where applicable, the DCM monitoring database was integrated into the conceptualisation of the aquifers present. This is discussed in more detail below.

3.2 Desk study

The geohydrological impact assessment was initiated with a desktop study on information contained in existing monitoring programmes, specialist reports and documentation made available by DCM and Envirogistics. The list of documents assessed is presented in the References at the end of this report. This includes information on the design of the Khulu TSF (JAW, 2021a-g). All information that was used during the assessment is summarised in the report and detailed information is appended, as required.

3.3 Hydrocensus

A hydrocensus was conducted at the proposed Khulu TSF Site B footprint during May 2021. During the hydrocensus existing boreholes were assessed to gain information on groundwater use, quality and depth to groundwater level in the region.

During the hydrocensus 11 boreholes were surveyed, including DCM monitoring boreholes located near the project area. Eight of the boreholes assessed are used for groundwater monitoring by DCM. Two of the boreholes are fitted with submersible pumps and supplies water to the old Farm House (Farm House BH) and to the Plant and Clinic (D1 and D2). One open exploration borehole (number 256) could be accessed. It was noted that a number of exploration boreholes are present over the footprint of Site B. Data from these were made available by DCM, the results of which are discussed in the geological section below. The locations of the boreholes are shown on Figure 1.

Groundwater level measurements could be taken in 10 boreholes. No access could be gained to the old Farm Borehole as it is fenced in. Three groundwater samples were collected during the hydrocensus for chemical analysis. During the hydrocensus the following information was collected for each site:

- Borehole position (X, Y, Z-coordinates);
- Information relating to equipment installed;
- Groundwater level, where accessible; and
- Current use.

The results of the 2021 hydrocensus is presented in Table 4. All coordinates were taken with a hand-held Garmin GPS (Global Positioning System) and are presented in WGS84 format.

Groundwater levels were measured using a dip meter from the collar elevation to the groundwater table in the borehole. Groundwater levels are presented in meters below ground level (mbgl) as well as in meters above mean sea level (mamsl) in Table 4.

Table 4 2021 Hydrocensus information

Site ID	Lat (WGS84)	Long (WGS84)	Elevation (mamsl)	Water level depth (mbgl)	Collar height (m)	Groundwater level (mamsl)	BH depth (m)	Casing diameter	Sampled	Pump type	Use	Notes
DRM 1	-24.928562°	30.110969°	921	4,81	0,45	916,56	29	165mm outer steel 125mm inner PVC	no	none	monitoring	BH is downstream from return water dams
DRM 2	-24.927795°	30.111128°	921	4,64	0,60	917,40	30	170mm outer steel 130mm inner PVC	no	none	monitoring	BH is downstream from return water dams. Bees sometimes move into borehole
DRM 3	-24.924703°	30.112253°	927	4,16	0,09	922,66	30	160mm outer steel 130mm inner PVC	no	none	monitoring	BH near Discard Dump gate
DRM 4	-24.930384°	30.117042°	941	10,46	0,23	930,84	30	165mm outer steel 125mm inner PVC	no	none	monitoring	BH at Plant, next to storm water drainage line
DRO 4	-24.927310°	30.109998°	920	2,59	0,41	918,17	30	170mm outer steel 125mm inner PVC	no	none	monitoring	BH near Groot Dwars River and Clinic & Plant BHs
ASDW BH09	-24.928439°	30.113313°	926	4,69	0,61	921,92	39	170mm outer steel 135mm inner PVC	no	none	monitoring	BH upstream from return water dams and downstream from old dump
ASDW BH10	-24.925895°	30.116208°	935	4,30	0,20	930,90	35	155mm outer steel 145mm inner PVC	no	none	monitoring	BH near and upstream from Discard Dump
ASDW BH12	-24.919931°	30.112606°	930	12,27	0,72	918,45	45	170mm outer steel 125mm inner PVC	yes	none	monitoring	Old borehole found near sub-station
D1 + D2 (Plant, Clinic BHs)	-24.928086°	30.109543°	918	3,14	0,28	915,14	---	165mm outer steel 125mm inner PVC	yes	Submersible	supplies Plant and Clinic	3 BHs close to each other. BH closest to river is used.
Farm House	-24.911753°	30.114796°	926	---	---	---	---	---	yes	Submersible	house water supply	Borehole inside very secure palisade fence with no access. Took sample from tap.
hole 256	-24.923398°	30.112350°	927	2,97	1,07	925,10	10	70mm steel	no	none	none	Old exploration borehole with cap near discard dump gate

The depth to groundwater level varied between a maximum of 12.27 mbgl (borehole ASDW BH12), and a near surface depth of 2.59 mbgl for borehole DRO4. Borehole DRO4 is situated near the Groot Dwars River. A comparison of groundwater levels in mamsl indicates that the highest groundwater elevations were measured in boreholes DRM4 and ASDWBH10, both situated near the Plant. The lowest groundwater level elevations were recorded in the boreholes near the Groot Dwars River (DRM1, DRM2, D1 and D2 and DRO4).

3.4 Additional fieldwork undertaken as part of this report

The fieldwork programme was undertaken by Groundwater Abstract. The information presented below was taken from the fieldwork report prepared upon completion of the work (Groundwater Abstract, 2021). The fieldwork data is presented in Appendices A – C.

3.4.1 Geophysical survey

A ground geophysical investigation was conducted by Groundwater Abstract (2021) to identify linear geological structures and assess the presence of an alluvial aquifer underlying the proposed Khulu TSF Site B footprint. It is thought that these geological structures could act as preferential groundwater flow paths to groundwater. The geophysical survey was interpreted with the available remote sensing images and geological maps (Gap Geophysics, 2018). Three linear north-south and northeast-southwest geological structures identified from airborne surveys were the key targets.

The geophysical survey was conducted from 11 to 13 May 2021 and included Magnetometer, Electromagnetic (EM) and 2D electrical resistivity surveying. The following techniques were applied:

- Magnetic survey with Geotron G5 Magnetometer system with a station separation of 5m.
- EM survey with an EM34-3 instrument. A 20 m coil separation was used.
- 2D Resistivity survey with 5 m electrode spacing.

The survey included 6 survey lines and the line and station coordinates were marked in the field using a handheld Garmin GPS. The geophysical lines were surveyed as follows and presented in Appendix 1. The locations and extent of the geophysical survey was influenced by the presence of structures that affect the readings, including electrical fences, pipelines, overhead electrical power lines and existing structures:

- Line 1: Magnetics and 2D Resistivity. Assessment of two linear geological structures between the Discard Dump and the Khulu TSF Site B footprint.
- Line 2: Magnetics and 2D Resistivity. Assessment of two linear geological structures, as well as possible alluvial deposit below Khulu TSF Site B footprint.
- Line 3: Magnetics and EM34. Assessment of linear geological structure for an upstream monitoring borehole.
- Line 4: Magnetics and EM34. Assessment of linear geological structures for a downstream (northern) monitoring borehole.
- Line 5: Magnetics and 2D Resistivity. Assessment of two linear geological structures, as well as possible alluvial deposit depth below Khulu TSF Site B footprint.
- Line 6: Magnetics and EM34. Assessment of linear geological structures for a downstream (western) monitoring borehole.

The results indicate (please refer to Appendix 1 for graphic presentation):

- Line 1: An overhead power line resulted in a loss of approximately 40 m of Magnetics survey data (stations 180 to 220). The Magnetics survey was successful in mapping the dolerite dyke, to the west. A deep conductive zone was mapped east of the dyke (around station 200), that could relate to the north-south fault.

- Line 2: The Resistivity data indicates that the depth of weathering is approximately 10 m deep. Below this is a very resistive (hard, solid) rock formations. The Magnetic data indicates a large negative anomaly at the start of the line (mapped fault/dyke) and another anomaly near station 400 (north-south fault/dyke). This area (station 400) has a much deeper conductive zone associated with this linear geological feature.
- Line 3: The Magnetic and EM data indicate that borehole ASDW BH12 is located on the north-south linear structure, on the side of a Magnetic anomaly. The EM data indicates a possible dip toward the west.
- Line 4: Overhead power lines had an impact on the survey extent, but it was possible to identify a suitable drill position from the Magnetic data. The second northeast-southwest trending structure was possible near stations 160 to 180, but data recording was influenced by the nearby power lines.
- Line 5: The Resistivity data indicates a uniform layered earth across Line 5. The linear geological structure at station 200 does not appear to be associated with a weathered zone along its strike. The weathered zone across the length of the line is approximately 12 to 15 m deep, with a slight increase in depth east of the northeast-southwest structure. The large Magnetic anomaly at station 200 is the same structure identified at the start of Line 2.
- Line 6: The northeast-southwest orientated geological structure was identified at the start of the line. The EM data indicates a small weathered signature to the east of the structure.

The northeast-southwest orientation structure, across the footprint of the Khulu TSF Site B footprint could be an older remnant dyke, identified by the large negative Magnetic anomalies. The dyke dips north-west.

Based on the interpretation of the geophysical data, 3 potential drilling targets were identified and are presented in Table 5. These targets were set out for the DCM appointed drilling team.

Table 5 Recommended groundwater monitoring borehole drilling targets

Site number	Latitude (WGS84)	Longitude (WGS84)	Notes
1-230	-24.922150°	30.112871°	Borehole set – DRM09
4-105	-24.919049°	30.108547°	Borehole set – DRM11
6-50	-24.914709°	30.111744°	Borehole set – DRM12

3.4.2 Drilling of monitoring boreholes

Based on the geophysical survey results, three new monitoring borehole drilling positions were identified the Khulu TSF Site B footprint. The percussion drilling programme was carried out from 17 to 26 May 2021 by Ubuntu Rock Drilling. Two monitoring boreholes were drilled at each of the three targets. One borehole (with abbreviation “D” at the end of its name) was drilled to a depth of 80 m below surface to target the deeper fractured aquifer. The second borehole (with abbreviation “S” at the end of its name) was drilled to the base of the weathered zone (8 to 12 m deep), with the aim of monitoring the shallow weathered aquifer in the area. In addition to these three sets of boreholes, a shallow monitoring borehole (DRM10S) was drilled adjacent to an existing deep monitoring borehole (ASDWBH12), which was identified during the hydrocensus. This facilitated obtaining information on both aquifers at four of positions around the Site B TSF footprint.

Data collected during drilling include the recording of geological formations at 1 metre intervals, water strike depths, the cumulative final blow yield and final rest water level. A summary of the results is presented in Table 6.

Table 6 Summary of new monitoring borehole drilling results

		Borehole ID	DRM9s	DRM9d	DRM10s	DRM11s	DRM11d	DRM12s	DRM12d
Borehole Location	WGS84	Latitude	-24.922133°	-24.922177°	-24.919872°	-24.918849°	-24.918790°	-24.914657°	-24.914707°
		Longitude	30.112895°	30.112873°	30.112683°	30.108539°	30.108518°	30.111836°	30.111769°
		Elevation	932 mamsl	932 mamsl	930 mamsl	923 mamsl	923 mamsl	918 mamsl	918 mamsl
Borehole Data	Borehole Depth (m)		12	80	12	12	80	8	80
	Blow Yield (L/h)		Dry	5 760	Dry	Dry	Dry	Dry	8 600
	Water Strike depth (m)		None	19 m	None	None	None	None	14 to 20m
	Main Strike Geology		---	Fractured pyroxenite	---	---	---	---	Fractured pyroxenite
	Borehole Geology		Weathered dolerite	Anorthosite, Norite, Pyroxenite sequence	Pyroxenite, with dolerite at end	Dolerite, with norite last 5 m	Anorthosite, Norite, Pyroxenite sequence, with dolerite 12-24m	Norite	Pyroxenite and norite, with dolerite last 12m
	Static Water Level (m bgl)		10.70	10.09	Dry	Dry	68.25	5.46	5.40
	Depth of Weathering		5m	6 m	6 m	7 m	10 m	2 m	6 m
	Steel Casing Depths (m)		0-12m perforated	Solid 0-14m and 32-56m Perforated 14-32m and 56-80m	0-12m perforated	0-12m perforated	Solid 0-16m Perforated 16-64m	0-8m perforated	Solid 0-14m and 20-26m Perforated 14-20m

The deep boreholes were fitted with 152mm steel casing across the weathered and unstable formations in the borehole. The shallow boreholes were fitted with 177 mm perforated steel casing across the full length of the borehole.

The geological profiles intercepted by the percussion drilling programme are presented in Appendix 2. No borehole log is available for ASDWBH12.

The new DCM monitoring boreholes produced blow yields between zero l/hr (dry) and 8 600 l/hr as seen in Table 6. The 4 shallow boreholes were all dry at the time of drilling. Seepage did however collect in some of the shallow boreholes which could be measured and sampled afterwards. Two of the deep boreholes produced blow yields of 5 700 and 8 600 l/hr.

The information presented in Table 6 indicate that the main water strikes are associated with the upper sections of the fractured aquifer at a depth of approximately 20 mbgl. Water strikes are also associated with the linear geological structures crossing the Site TSF footprint and which were specifically targeted with the geophysical investigation completed. The weathered zone and geological contacts yielded no groundwater during drilling.

The fractured aquifers in the area can be classified as semi-confined aquifers based on an assessment of the rest groundwater level depths compared to the depths of the water strikes. All rest water levels were at a shallower depth compared to the water strike depths.

The depth of highly weathered material (limit of weathering or LOW) varies between 2 and 12 mbgl, but on average around 5 to 6 metres below surface. The groundwater level below surface varied between 5 m and 11 m bgl.

The northeast-southwest striking geological structure that intersects the Site 3 TSF footprint is likely to be an older remnant dyke. The shallow and deeper boreholes positioned on this geological feature yielded no water and after several days the water level in the deeper borehole was still at 68 m below surface. The dyke dips to the northwest, based on the drill data for boreholes DRM11s and DRM11d. The high yielding boreholes (DRM9d, DRM12d and ASDW BH12) are all associated with the north-south geological feature.

The water strikes are related to fractured zones in the pyroxenite. The contact between the Bushveld Complex formations and the dolerite dykes yielded no water.

One to two meters of clay was observed in DRM10s and at the DRM12 cluster. Loose sand or rounded small pebbles / boulders, characteristic of alluvium, were not seen in any of the boreholes.

3.4.3 Aquifer test results

Following completion of the drilling programme, an aquifer test programme was initiated to determine the characteristics of the aquifers present. This includes defining:

- Borehole drawdown and recovery characteristics.
- Aquifer hydraulic parameters:
    - Transmissivity (T) defined as the product of the average hydraulic conductivity (K) and the saturated aquifer thickness. It is a measure of the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the aquifer. The unit of measurement is m^2/day.
- Characterisation of aquifer flow boundaries such as low permeable, no-flow or recharge boundaries. No-flow or low permeable boundaries refer to a lower transmissive structure (e.g. fracture with a lower conductance or low permeable dyke) or aquifer boundary (limit of aquifer or no-flow boundary) that results in an increase in groundwater drawdown during borehole abstraction. Recharge boundaries relate often to leakage from surface water bodies.

AquaSub was subcontracted to carry out the aquifer testing during July 2021. Sufficient groundwater was intersected in boreholes DRM9d, DRM12d and ASDWBH12 to complete aquifer tests.

Prior to the aquifer test, static groundwater levels were measured in the pumping and observation boreholes to enable drawdown calculations during test pumping. Pumped water was released via a discharge pipe at least 100 m from the test borehole, to avoid rapid recharge from the discharged water. During the test, the abstraction rate is continuously monitored by means of electronic flow meters and calibrated by manually measuring the time it takes to fill a container of known volume, with a stopwatch and drum.

The in order to design optimal constant discharge pumping test, the following was undertaken during the aquifer testing programme:

- A step drawdown test (SDT) is performed. During the SDT the borehole is pumped at a constant discharge rate for 60 minutes where after the step is repeated at a progressively higher discharge rate. During the SDT the drawdown over time is recorded in pumping and observation boreholes. The advantage of this test is that the pumping rate for any specific drawdown can easily be determined from the relationship between laminar and turbulent flow. After the SDT is stopped, residual drawdown is measured until approximately 90% recovery of the water level has been reached. The discharge rate for the constant discharge test is calculated from the interpretation of the time drawdown data generated during the SDT.
- The constant discharge test (CDT) follows the SDT. During a CDT a borehole is pumped for a predetermined time at a constant rate. During the CDT test the drawdown over time is recorded in the pumping and observation borehole. Discharge measurements are taken at predetermined time intervals to ensure that the constant discharge rate is maintained throughout the test period. Any changes in discharge rate are recorded. Twelve-hour CDT were undertaken on the DCM boreholes to ensure that the aquifer is stressed sufficiently to identify boundary effects that may impact the aquifers present in aid of conceptualisation of these.
- The recovery test follows directly after pump shut down, at the end of the SDT and CDT. The residual drawdown over time (water level recovery) is measured in pumping and observation boreholes until approximately 90% recovery is reached. Aquifer parameters and sustainable borehole yields can be derived from the time drawdown data of the CDT and recovery tests by application of a variety of analytical methods.

The following software was used for test pumping data analysis:

- The Flow Characteristic Method or FC Method. The FC method uses the first and second order derivatives interpreted from time drawdown data (during test pumping), available drawdown, boundary conditions and recharge to derive aquifer parameters and sustainable borehole yields. The method is suited for characterising fractured rock aquifers.

A summary of the test programme is given in Table 7 and the drawdown data is presented in Appendix 3.

All boreholes tested indicate a fast recovery, with 90% recovery often within 90 minutes. The recovery of the groundwater table after abstraction is a good indicator of the aquifer yield potential.

The good borehole yields, small water level drawdown and fast recovery observed during the aquifer testing indicate high transmissivity (T) aquifers. The highest T-value (190 m^2/d) was observed at borehole ASDW BH12 that is located on the north-south linear structure. The fractured aquifer intercepted by borehole DRM12d has a T-value of 95 m^2/d and for DRM9d it is 6 m^2/d. The thickness of the water-yielding zones differ and is possibly the reason for the difference in T-values obtained for the three boreholes. The thickness of the water-yielding zones are as follows:

- DRM9d – water strike and fractured rock 19m to 21 m below surface.
- DRM12d – water strikes and fractured rock between 11m and 24 m below surface.

- ASDW BH12 – water strikes and fractured rock between 15m and 32 m below surface.

The following is concluded from the aquifer test data:

- There seems to be a connection between the shallow and the deep boreholes during the aquifer testing. The shallow boreholes (where they had water before the testing) were quickly pumped dry during the step tests and did not recover for the duration of the aquifer testing. It has been assumed that the shallow weathered zone carries little water and does not contribute significantly to borehole level recovery once the pump is switched off.
- The north-south lineament is a preferred groundwater flow path, with high T-values compared to the matrix of the Bushveld Complex formations.
- The base of the weathered zone and the geological contact zones yield no water.

Table 7 Aquifer test programme summary

	Borehole ID	DRM 9d	DRM 12d	ASDW BH12
Aquifer Test Data	Available Drawdown (m)	67.63	68.20	31.60
	Step 1 (L/s) / Drawdown (m)	0,5 / 0.76	0.5 / 0.11	0.5 / 0.04
	Step 2 (L/s) / Drawdown (m)	1 / 2.97	1.5 / 0.49	1.5 / 0.19
	Step 3 (L/s) / Drawdown (m)	2 / 7.09	4 / 1,59	4 / 0.54
	Step 4 (L/s) / Drawdown (m)	5 / 67.63	6.5 / 2.88	6.3 / 0.99
	Step Recovery - % vs time	90% (7 min)	90% (15 min)	75% (8 min)
	Constant Discharge (L/s)	3.0	6.0	6.0
	Duration (min)	720	720	720
	Max Drawdown (m)	47.63	3.07	1.50
	Constant Recovery - % vs time	90% (50 min)	90% (70 min)	82% (12 min)
	Obs Bhs	BH 12m deep - water level 11.04 m. BH emptied at start of Step 2 and never recovered	BH 8m deep - water level 7.15 m. Level dropped by 25cm at end of Step test and remained there. Did not recover	BH 12m deep - dry
	FC Method			
	T - m^2/day	6	95	189
	Borehole yield	1.6 L/s	12.0 L/s	19.5 L/s

Groundwater samples were taken from monitoring boreholes that yielded water during the aquifer testing. These results are discussed below.

3.5 Groundwater recharge calculations

The rate of recharge of rainwater to the underlying alluvial and fractured rock aquifers was calculated with the Saturated Volume Fluctuation (SVF) method developed by Bredenkamp et al (1995). The calculations are based on the hydrographs for the all monitoring boreholes presented in Appendix 1. These include monitoring boreholes DRM7 and 8 drilled into the pit tailings backfill areas, as described in DWE (2018). Details regarding these boreholes are presented later in this report.

In order to complete the SVF calculations, groundwater level fluctuations from latest DCM monitoring databased was evaluated. The calculations are based on the principle that groundwater level rise and fall is the result of the rate of recharge as well as the storage coefficient of the aquifers. The rate of recharge is interdependent on the storage coefficient of the aquifer and in the absence of field measured values, assumptions were made. Four storage coefficient values were assumed to complete the calculations, as indicated in Table 8. The locations of the boreholes listed are indicated on Figure 1.

The rainfall volumes used during calculations are based on on-site rainfall measurements.

The recharge calculations are presented as a percentage of the MAP for the project area in Table 8. It is shown that the rate varies between 1 and 6% of MAP, with an average recharge rate of 4,3% of MAP. This is lower than the 5% of MAP rate reported in iLEH (2015). The lower rate of recharge, as recorded from groundwater level fluctuations, is most probably attributed to the lower rainfall intensity over the last three to four years.

The rate of recharge calculated from groundwater level fluctuations in boreholes DRM7 and DRM8 are comparable to those in the other monitoring boreholes, albeit slightly higher on DRM8 compared to the average recharge rate calculated for the other data points.

Table 8 Estimated recharge rates calculated from monitoring data

Borehole ID Monitoring position	Average recharge rate (% of MAP)			
	S = 1E-3	S = 1E-4	S = 1E-5	S = 1E-6
ASDWBH1 North Pit	5,3	5,0	5,0	4,9
ASDWBH2 Northern TSF	No good data			
ASDWBH3 North Pit	6,1	5,5	5,4	5,4
ASDWBH4 North Pit	5,3	5,0	5,0	4,9
ASDWBH5 Dam 26	No good data			
ASDWBH6 Dam 26	6,2	5,9	5,9	5,8
ASDWBH7/8 WRD	5,2	5,0	5,0	4,9
ASDWBH9 Historical TSF	2,9	2,7	2,7	2,7
ASDWBH10 Discard dump	No good data			
ASDWBH11 South Pit	5,9	5,9	5,8	5,8
DRM1 LRWD	5,2	5,0	5,0	4,9
DRM2 LRWD	No good data			
DRM3 Quarry	5,7	5,4	5,4	5,4
DRM4 Plant	1,5	1,4	1,4	1,3
DRM5 URWD	5,8	5,4	5,4	5,4
DRM6 South Pit	5,5	5,4	5,4	5,4
DRO4 Alluvial aquifer	2,6	2,3	2,3	2,2
MCC BH MCC	6,1	5,9	5,9	5,8
SW BH Sewage Plant	5,0	4,6	4,5	4,5
DRM7 North Pit backfill	3,3	2,8	2,7	2,7
DRM8 South Pit backfill	5,7	5,4	5,4	5,4

The rate of recharge depends on several factors, including rainfall intensity and surface runoff, soil conditions, local geology, the depth to groundwater and the extent to which an area has been disturbed. The following groundwater recharge trends can be summarised from the calculations presented in Table 8:

- Boreholes drilled into the fractured rock aquifer generally yield a recharge rate of 5% of MAP. Surprisingly, the rate of recharge calculated from the only monitoring borehole thought to be drilled into the alluvial aquifer (DRO4) is below 3% of MAP.
- Recharge rates calculated in boreholes around the TSF suggest lower than average conditions. No good data is available for the Northern TSF, however the average rate of recharge at the historical TSF is estimated to be below 3% of MAP.
- The rate of recharge calculated from the borehole drilled in the plant area is low, around 1,4% of MAP. This is lower than all other rates calculated with the latest dataset. Considering that borehole DRM4 contains significantly elevated nitrate concentrations, it is surprising that the rate of recharge is so low. Previous assessments of the recharge rate from borehole DRM4 yielded a value of 2,3% of MAP (iLEH, 2020), which is also low in the context of the information presented here. This trend must be evaluated in more detail as part of the effort to resolve groundwater contamination associated with the plant area.
- In the area around North Pit, the rate of recharge is estimated to be above 5% of MAP. The rate of recharge calculated for the tailings backfill area is however estimated to be below 3% of MAP. This could be a attributed to the physical character of the tailings in the pit. Analysis of on-going groundwater level monitoring data from this area should be used to establish the recharge characteristics in this area.
- Similar recharge rates are calculated for the area around South Pit. However the calculated rate of recharge in the tailings backfill area in South Pit was 5,5% of MAP, which is higher compared to that calculated for North Pit. As indicated above, these recharge rates should be confirmed through analysis of on-going monitoring data.
- Recharge rates from boreholes associated with the LRWD and URWD are above 5% of MAP.
- The rate of recharge at Dam 26 is slightly higher at 6% of MAP.

3.6 Groundwater modelling

A detailed description of the methodology used to complete the groundwater modelling for the project is presented in Section 9 of this report.

3.7 Groundwater availability assessment

Groundwater is abstracted from both the alluvial aquifer associated with the Groot and Klein Dwars Rivers as well as from the fractured rock aquifer associated with pyroxenite, anorthosite and norite host rock for use at the mine. Groundwater is currently abstracted from boreholes D1 and D2 and E. Boreholes D1 and D2 are operated as a cluster.

The annual volume of groundwater used at the operations is presented in Table 9 and in Figure 6. It is shown that groundwater abstracted from boreholes D1 and D2 comprised around 50% of the total volume between 2015 and 2017. During 2018 and 2019, when abstraction from borehole C stopped, the volume of groundwater abstracted from boreholes D1 and D2 increased to around 70% of the total volume abstracted. During 2020, more groundwater was abstracted from Borehole E, as shown. There is a decline in groundwater use between 2019 and 2020, which is attributed to the impact of COVID-19 on the operations. The dataset for 2021 is incomplete.

Monitoring boreholes DRM1, DRM2 and DRO4 are situated closest to abstraction boreholes D1 and D2. Groundwater level fluctuations in these boreholes indicate a 1,2 – 2,0 m decline in groundwater levels over the 2018 - 2021 monitoring period. These fluctuations are however within seasonal variations and are not thought to indicate over-abstraction. Based on available evidence, it is concluded that the alluvial aquifer can sustain the volumes of groundwater that are currently abstracted from boreholes D1 and D2. Groundwater level trends in boreholes DRM1 and 2 should however be closely monitored to establish long-term trends, which will provide a better indication on the sustainable use of groundwater from boreholes D1 and D2.

Monitoring borehole ASDWBH7/8 is situated near borehole E. Groundwater level fluctuations in this borehole indicates a slight rise in the groundwater table over the period 2018 – 2021 within seasonal fluctuations. This suggests that borehole E is also not over-abstracted and can maintain abstraction rates reported.

No groundwater is currently abstracted from borehole C.

Table 9 Recent groundwater abstraction volumes

	2015	2016	2017	2018	2019	2020	2021 *
Borehole E	71 433	69 708	65 632	63 631	60 061	70 842	43 504
Borehole C	14 919	21 657	8 180	-	-	-	-
Borehole D1 and D2	106 919	101 850	89 114	170 943	117 817	35 118	23 474

* Incomplete dataset

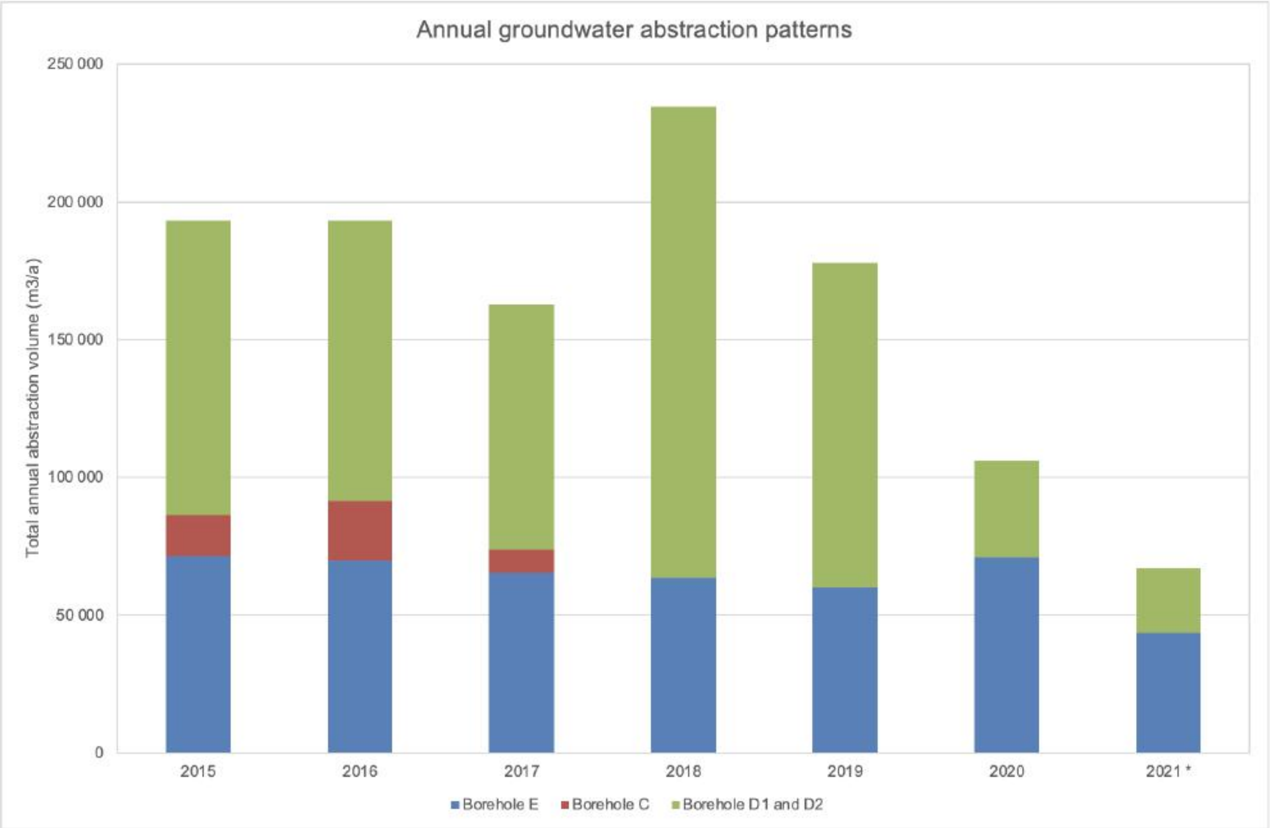


Figure 6 Total annual groundwater abstraction patterns

4 PREVAILING GROUNDWATER CONDITIONS

4.1 Geology

4.1.1 Regional Geology

Dwarsrivier mine is situated in the Eastern Limb of the Bushveld Igneous Complex and the chrome deposits form part of the Critical Zone. The Dwarsrivier ore body represents an open-ended structural synform with a north-south orientated axis that plunges gently to the south (iLEH, 2015). The Steelpoort Chromite Seam (SCS) seam is mined. The geology overlying the chromite comprises norite, pyroxenite and anorthosite, as indicated on Figure 7. Along the eastern, western and southern boundaries of the sub-catchment in which the project is situated, Critical and Marginal Zone anorthosites, pyroxenites and norites outcrop. These have a general northerly strike and a dip of 7 – 10° west (Gap Geophysics, 2018). The igneous rocks form steep sloping mountain land and hills. From east to west, the DCM mineral rights area hosts Lower (LG) and Middle Group (MG) chromitite seams and higher up the stratigraphic sequence, the UG2 and Merensky Reefs. The LG6 (or Steelpoort) seam is the economic ore body mined by DCM. Differential weathering rates of the igneous rocks give rise to the topography:

- The peaks of the Dwarsriver mountain appear to be marked by outcropping dykes and replacement pegmatoids, both of which area weathering resistant.
- The slopes, their directions and the breaks in their curvature are controlled by the presence or lack of faults and shear zones. Where discrete fault zones exist, weathering channels are apparent.

Large-scale alluvial aquifers occur in the floodplains of the Groot and Klein Dwars Rivers in the central part of the project area. These aquifers are exploited for groundwater supply to the mining operations.

4.1.2 Local Geology

The mining operations are situated approximately 10km southeast of the Steelpoort lineament that affects the general area of Kennedy's Vale. Splays from this regionally dominant feature include the Dwarsrivier Fault, which defines the flow of the Klein Dwars River. This fault resulted in increased joint densities and associated alteration and therefore increased weathering rates.

Numerous fault zones are known and intersected in the DCM underground workings, as indicated on Figure 7. The positions of these faults were confirmed through a study completed by Gap Geophysics (2018) as well as information provided by DCM. It is thought that these major regional fault lines are associated with enhanced aquifer conditions and would therefore act as preferential flow paths to groundwater. It is know that faults intersected in the underground workings in South Mine yield groundwater that is captured for reuse in the mine water balance. This water is pumped from underground to a dedicated tank on surface for redistribution.

A number of NNE striking dolerite dykes are present in the area, as indicated on Figure 7. These dykes are associated with the Dwarsrivier Fault and are of late-Bushveld age. The strike orientation of these dykes are the result of the regional stress tensional system. For this reason, significant faults are aligned along or in close proximity to individual dykes. It is estimated that regionally approximately 10% of dykes infill faults. Cross-cut WNW trending dykes also seem to correlate with faulting (Gap Geophysics, 2018). Based on the close relationship between faults and dykes, it is likely that the dykes would also be associated with enhanced aquifer conditions and hence act as preferential flow paths to groundwater.

For the purpose of this study, it was assumed that the geological structures mapped within the DCM mineral rights area by Gap Geophysics (2018) extends outside the mining area along the defined strike. The extension of the structures are indicated as dashed lines in Figure 7.

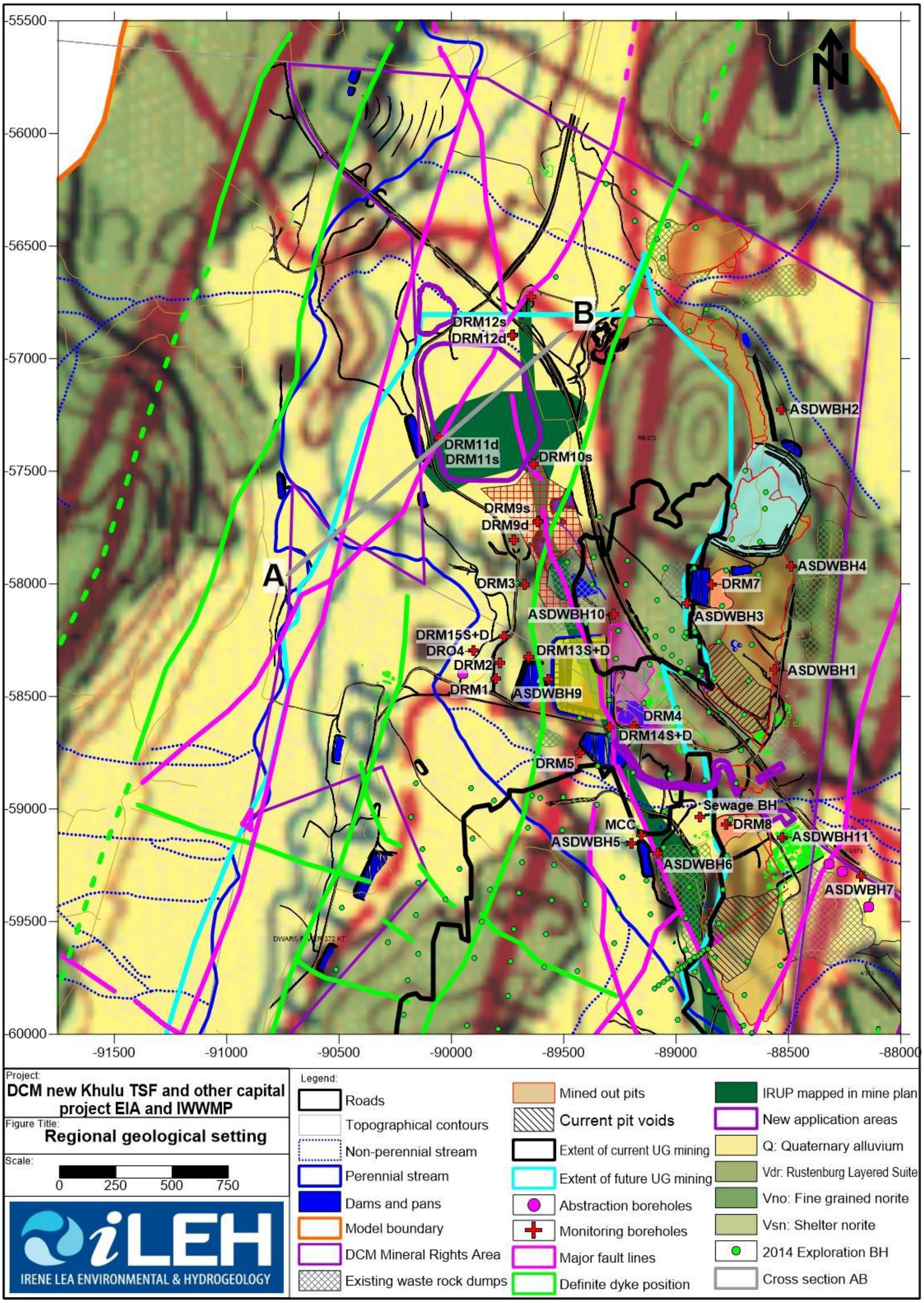


Figure 7 Geological setting

4.1.3 Geological conditions at the proposed Khulu TSF

The geological information presented in Figure 7 indicates that the TSF footprint is located on alluvial material associated with the valley of the Klein Dwars River. The alluvial material is underlain by norite, pyroxenite and anorthosite, which does not outcrop over the footprint of the Khulu TSF. The nature of the alluvial material can be seen from the groundwater monitoring borehole logs presented in Appendix B. The alluvial material consists of black, light brown to reddish brown weathered material with calcrete in places. The weathered material is clay-rich in places and sandy in patches.

A regional fault line transects the footprint of the Khulu TSF. Details regarding this fault are discussed below.

JAW (2021f) completed a geotechnical investigation over the footprint of the Khulu TSF in order to characterise the in-situ soil conditions. The results indicate that the soil profile on the western side of the fault zone comprises 1m thick black clayey hillwash underlain by fine sandy residual norite to a depth of 6m. Highly weathered norite was encountered below 6m under the residual norite layer. On the eastern side of the fault, the soil profile also consists of a 1m thick black clayey hillwash. The fault is associated with a 2 – 3m thick brown clay, which is underlain by residual norite sand. The thickness of the clay layer reduces away from the fault.

The footprint of the PCD is highly eroded in places and overlain by sandy hillwash to the thickness of 0.9m.

No seepage or water table was encountered in any of the test pits.

A summary of the permeability test results completed as part of the geotechnical investigation is presented in Table 10. The permeabilities are indicated in m/d, which is the unit that will be used in this report. It is shown that the permeability of the tailings material vary between 0.1 and 1.4m/d. Soil with a clayey characteristic has an average permeability of 1.06E-4m/d. Soil with a sandy nature has an average permeability of 0,04m/d, which is two orders of magnitude higher.

Table 10 Summary of soil and tailings permeabilities (after JAW, 2021f)

Sample No	Depth (m)	Description	Permeability (m/d)
TY01/1	NA	Tailings underflow	1.400
MT01/1	NA	Mixed tailings	0.113
TP04/1	2.7	Sand	0.028
TP06/1	2.4	Brown clay	9.50E-06
TP09/1	2.6	Brown clay	5.88E-04
TP12/1	3.5	Brown clay	5.73E-06
TP13/1	0.3	Black clay	3.57E-05
TP13/3	1.8	Sand	0.049
TP14/3	2.5	Brown clay	6.91E-05
TP34/1	0.5	Black clay	7.37E-06
TP34/2	1.8	Brown clay	2.32E-05

As mentioned above, a regional southwest-northeast trending fault line transects the Khulu TSF footprint area. The position of this fault is indicated on Figure 7.

Analysis of DCM exploration borehole data suggests that the majority of fractures and faults are found in the upper 60m of the geological succession, as indicated in Figure 8. Fracturing occurs to depths 140m and then again between 170 and 200m. The exploration borehole data unfortunately do not indicate whether the fractures and faults are water-bearing

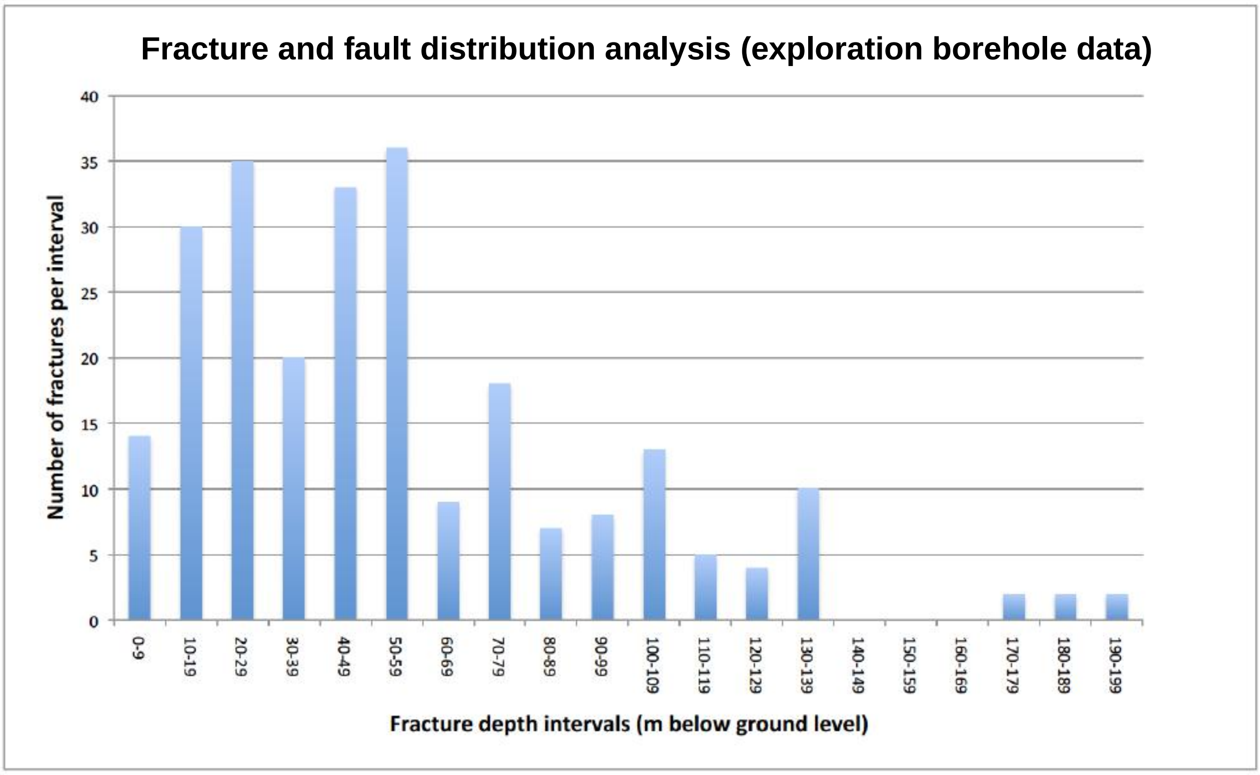


Figure 8 **Fracture and fault distribution analysis**

Monitoring boreholes DRM11S and D and DRM12S and D targets the southwest-northeast trending fault zone. The Farm House borehole included in the hydrocensus is also situated on this fault zone.

A second north-south striking fault line transects the eastern section of the Khulu TSF footprint area, if regional mapped faults are extrapolated. Monitoring boreholes DRM9S and D, DRM10S (and ASDWBH12) and DRM12S and D targets this fault line. It is noted that monitoring borehole DRM14S and D drilled recently by DCM for a separate drilling and pump testing project targets the north-south trending fault in the vicinity of the plant (nettZero, 2021). The logs for these boreholes are presented in Appendix B.

The iron rich ultramafic pegmatoid replacement (IRUP) bodies and marker horizons identified within the mining area are stratigraphic of nature. The Khulu TSF footprint area is partially underlain by an IRUP, which is associated with the N-S striking fault present in the mining area. The position of the IRUP is indicated on Figure 7. The replacement body is aligned with the N-S striking fault mapped along the eastern side of the Khulu TSF. It was logged in borehole DRM11D at a depth of 70m. It is noted that ASDWBH12, an existing monitoring borehole identified during the hydrocensus is also located along the N-S striking fault at the position where the pipe balloons (see Figure 7). This borehole yields groundwater at an estimated rate of 19 l/s and has a transmissivity of 189m^2/d, suggesting that the IRUP in combination with the N-S striking fault forms a strong aquifer.

A summary of the aquifer characteristics for the boreholes that target the fault zones is presented in Table 11. It is shown that water strikes associated with the fault zones occur between 15 and 32m below surface. This corresponds to the exploration borehole data presented in Figure 8. Borehole yield and transmissivities along the fault zones are variable, as is expected. DRM11S and D, situated down gradient of the Khulu TSF was dry at the time of drilling. Groundwater levels recovered in the deep borehole to around 14m, which is comparable to regional trends. This information could indicate that the rock matrix (unfractured pyroxenite) is tight and is not expected to transmit significant volumes of groundwater. It is further likely that the southwest-northeast trending fault is not associated with a strong aquifer, based on data from DRM11D.

Further north, aquifer conditions measured in DRM12D could indicate that the fault zone can transmit groundwater. It is however acknowledged that DRM12D is located at the intersection between two fault zones and that the data from the borehole is characteristic of the north-south trending fault. The information suggests that the north-south trending fault forms a stronger aquifer with higher borehole yields in DRM9D, DRM12D and ASDWBH12. The transmissivity of this structure varies between 6 and 189m^2/d.

Information from borehole DRM14D indicates water strikes between 13 and 43m in the north-south striking fault zone. Aquifer conditions in this borehole are well developed with a high transmissivity of 328m^2/d with a moderate borehole yield (nettZero, 2021).

Based on the information evaluated, it is concluded that the north-south trending fault is a strong aquifer with high permeabilities. It is therefore identified as a preferential flow path to groundwater and therefore also for potential contamination associated with the Khulu TSF.

The southwest-northeast trending fault also exhibits enhanced aquifer conditions, which are variable along its strike. It is significant that borehole DRM11D situated down gradient of the Khulu TSF on this fault was dry at the time of drilling. This structure may therefore also be considered as a preferential flow path to groundwater, but with less significance compared to the north-south trending fault.

Table 11 Aquifer conditions associated with the fault zones present

Borehole ID	Water strike depth (m)	Main strike geology	Borehole yield (l/s)	Static water level (m)	Transmissivity (m^2/d)
DRM9D	19	Fractured pyroxenite	1.6	10.09	6
DRM11D	None	None	Dry	68.3 recovering to 13.78	-
DRM12D	14 - 20	Fractured pyroxenite	12.0	5.40	95
ASDWBH12	15 - 32	-	19.5	12.27	189
DRM14D	13 - 43	Fractured norite and anorthosite	6.0	9.84	328
DRM3	-	-	0.1	4.22	0.3
ASDWBH9	2 – 4	-	0.3	3.83	17.5

In addition to the fault zones, sub-parallel southwest-northeast trending dykes are present in the vicinity of the Khulu TSF footprint area, as indicated on Figure 7. Boreholes DRM3, DRM13S and D and ASDWBH9 likely target this dyke. Borehole DRM9S and D was also used to target the dyke. Aquifer tests were completed on DRM3, DRM13D and ASDWBH9 by nettZero (2021). Aquifer characteristics for these boreholes are presented in Table 11. It is shown that the transmissivity for the dyke is lower compared to the fault zones discussed above, varying between 0.3 and 17.5m^2/d. Borehole yields are also lower ranging between 0.1 and 1.6 l/s.

Based on the information assessed, it is concluded that the contact zone of the dyke situated east of the Khulu TSF could act as a preferential flow path to groundwater, especially around ASDWBH9. In the vicinity of the Khulu TSF, the significance of the preferential flow along the dyke contact is considered less.

4.2 Acid generation capacity

An Acid Base Accounting study was not completed as part of this assessment.

Leach tests were however completed with distilled water as part of a waste classification study completed on mine residue deposits, including tailings material produced (iLEH, 2018).

A fresh tailing sample was submitted during 2021 for leach tests in order to confirm the source term for the Khulu TSF impact assessment. The 2021 leach tests included both distilled water and acid rain methods.

The pH of the distilled water leach tests completed is neutral (above 7) as indicated in Table 11. Due to the nature of the Acid Rain test, an acidic pH is reported for this analysis. This is however not reflective of a risk of acid mine drainage from the tailings material.

The leach tests presented in Table 11 are compared to leachable concentration thresholds (LCT) according to the Waste Classification and Management Regulations (R635) of the National Environmental Management: Waste Act (Act 59 of 2008) in the table. The results of the leach tests are discussed in more detail below when the source term for the project is defined.

The DCM monitoring programme furthermore confirm that both groundwater have neutral to alkaline pH conditions, as indicated in Figure 9.

The pH of dirty water associated with the existing Northern TSF (N RWD and N PCD in Figure 9) has a neutral to alkaline nature, which confirms that the metallurgical process in the plant does not increase the risk of acidification of the tailings material on the Khulu TSF. The risk of acidification of the tailings material is therefore considered to be low.

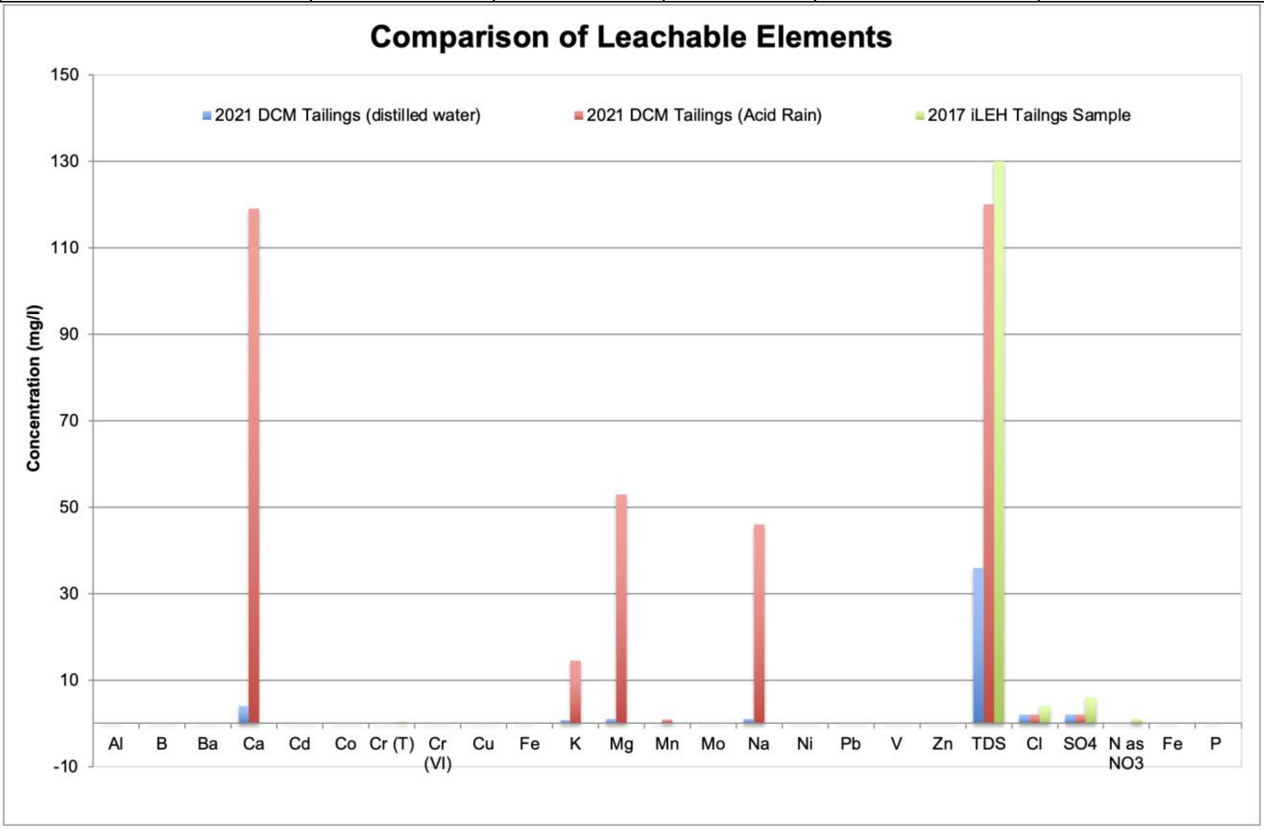
Similarly, pH conditions in the two pollution control dams, the LRWD and URWD, also has a neutral to alkaline nature. These dams are used to receive and transfer the bulk of the dirty water within the mine water balance and are therefore a good indication of mine water quality.

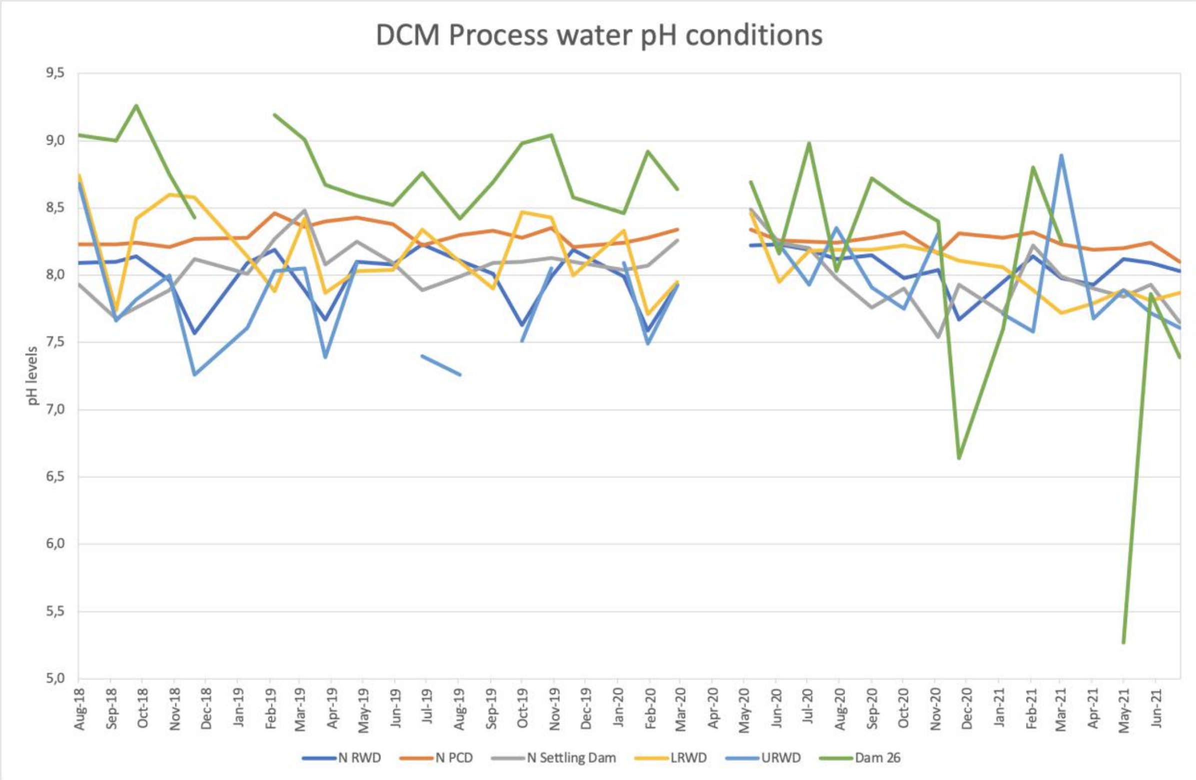
It is noted from Figure 9 that the pH of Dam 26 has steadily changed from alkaline in 2018 to slightly acidic to neutral at present. This could be attributed to the impact of the Water Treatment Plant (WTP) operated at Dam 26. All water from the dam is treated at the WTP after which it is returned to Dam 26 for reuse in the mine water balance. An assessment of the impact of Dam 26 falls outside the scope of this study, but it is recommended that the potential long-term impact of acidification of the mine water circuit as a result of introducing water from Dam 26 is investigated in more detail.

Information presented in EScience (2010c) confirms the fact that the mine is unlikely to acidify, including the tailings material generated. Acid-base accounting undertaken as part of this study indicates that the tailings and waste rock is relatively inert and has low levels of potential acid generation. Sulphides are present, but in extremely minor quantities and in highly competent and impermeable rock. Sulphate concentrations in in groundwater is therefore also expected to remain low. The neutralising potential exceeds the acid generating potential in all cases. In the long-term, neutral pH conditions are therefore expected. Under these conditions, low dissolved metal concentrations are expected.

Table 11 Tailings leach test results

Elements	2021 DCM Tailings (distilled water)	2021 DCM Tailings (Acid Rain)	2018 iLEH Tailings Sample	LCT0 (mg/l)	LCT1 (mg/l)	LCT2 (mg/)l	LCT3 (mg/l)
Al, Aluminium	<0,025	0,149					
B, Boron	<0,025	0,084	<0.025	0,5	25	50	200
Ba, Barium	<0,025	0,054	0,04	0,7	35	70	280
Ca, Calcium	4	119					
Cd, Cadmium	<0,001	<0,001	<0.003	0,003	0,15	0,3	1,2
Co, Cobalt	<0,025	<0,025	<0.025	0,5	25	50	200
Cr (Tota)l, Chromium Total	0,027	<0,025	0,39	0,1	5	10	40
Cr(VI), Chromium (VI)	<0,01	<0,01	<0.010	0,05	2,5	5	20
Cu, Copper	<0,01	<0,01	0,047	2	100	200	800
Fe, Iron	0,124	0,161					
K, Potassium	0,8	14,5					
Mg, Magnesium	1	53					
Mn, Manganese	<0,025	0,92	0,235	0,5	25	50	200
Mo, Molybdenum	<0,025	<0,025	<0.025	0,07	3,5	7	28
Na, Sodium	<1	46					
Ni, Nickel	<0,025	<0,025	0,114	0,07	3,5	7	28
Pb, Lead	<0,001	<0,001	0,012	0,01	0,5	1	4
V, Vanadium	<0,025	<0,025	<0.025	0,2	10	20	80
Zn, Zinc	<0,025	<0,025	<0.025	5	250	500	2000
Total Dissolved Solids	36	120	130	1000	12500	25000	100000
Chloride as Cl	<2	<2	4	300	15000	30000	120000
Sulphate as SO_4	<2	<2	6	250	12500	25000	100000
Nitrate as N	<0,1	0,2	1	11	550	1100	4400
Fluoride as F	0,11	<0,05	0,3	1,5	75	150	600
Ortho-Phosphate, P	<0,1	<0,1					
pH	7,7	5,1	7,3	Not specified			





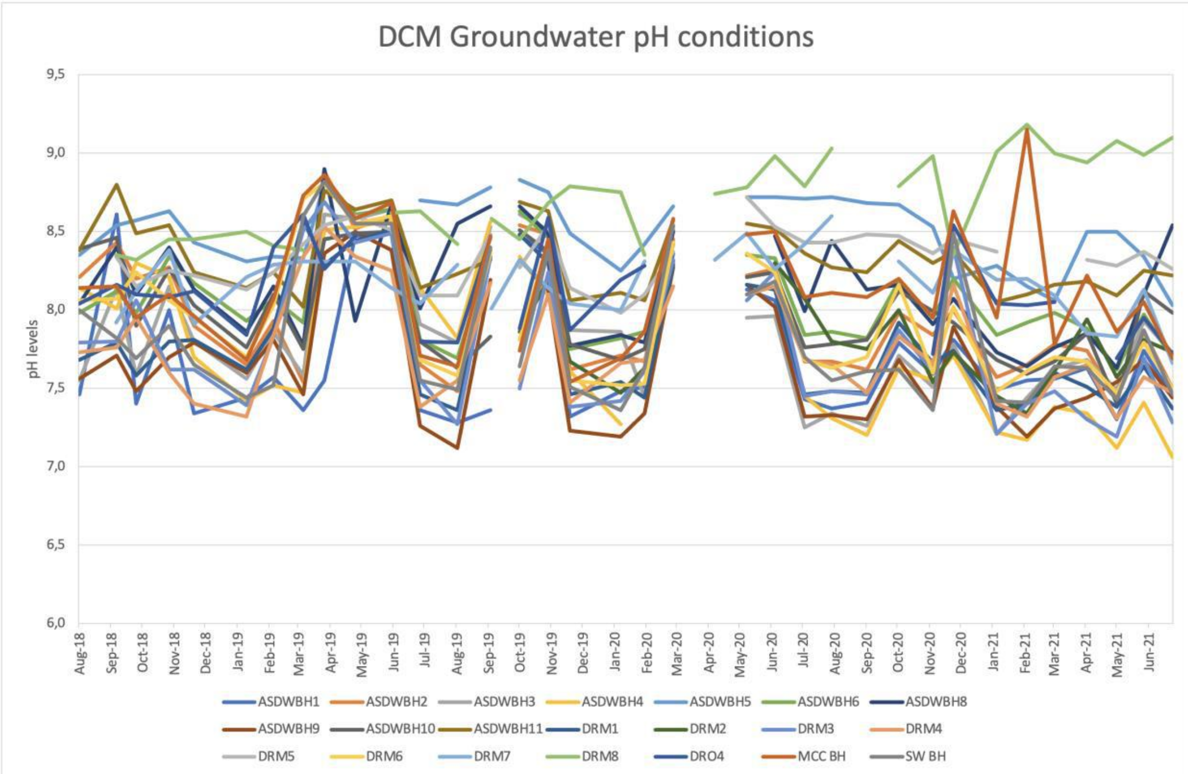


Figure 9 **DCM process water and groundwater pH conditions**

4.3 Hydrogeology

4.3.1 Monitoring boreholes

Up to 2021, DCM monitored 19 boreholes. During 2021, additional monitoring boreholes were drilled to quantify the aquifers associated with the Khulu TSF, which is discussed in this report. In addition, six monitoring boreholes were drilled as part of a separate project (nettZero, 2021), pertinent details of which are presented in this report. The locations of all monitoring boreholes are indicated on Figure 2.

Borehole details are presented in Table 7.

Groundwater monitoring is undertaken on a monthly basis according to the DCM monitoring protocol (Aquatico, 2018). Both groundwater level and quality monitoring is undertaken. The July 2021 dataset is the most complete monitoring set that is comparable to the Khulu TSF hydrocensus data and the nettZero (2021) study in terms of monitoring time lines. For this reason, the July 2021 water level measurement dataset will be used in this report.

Information pertaining to aquifer transmissivities date from a study completed in 2009 and 2010 (iLEH, 2010).

4.3.2 Unsaturated zone

Information regarding the soils present was sourced from EScience (2010c). The results of a soil study completed on a 200 – 300m grid at the time indicates that the indicates the predominant soil include Glenrosa and Mispah Forms with small pockets of Hutton soil forms. On lower slopes associated with the streams, the soil forms include Hutton, Clovely, Augrabies and Katspruit. Valsrivier soils were found exposed in erosion gullies.

The Glenrosa and Mispah soil forms are generally present to depths of 0,3 – 0,6m and showed no signs of wetness. The Clovely and Hutton forms have a marked increase in clay content with depth and extend to depths of more than 0,6m and in places as deep as 1,5m. The Katspruit and Valsrivier form soils associated with the streams indicate signs of prolonged saturation.

The alluvial material associated with the rivers and streams is unconsolidated sand, possibly with lenses of clay, slit or calcrete.

Additional information regarding soil conditions underlying the Khulu TSF is discussed in Section 4.1.3 above. This information was sourced from JAW (2021f)

Table 12 Summary of groundwater monitoring borehole information

BH ID	X-Coordinate (LO 31)	Y-Coordinate (LO31 FN 2700000)	Elevation (mamsl)	BH Depth (m)	Purpose	Depth to water strike (mbgl)	SWL Jul '21(m)*	SWL Jul '21 (mamsl)*	Transmissivity (m^2/d)
ASDW BH1	-88 562	-58 379	967	60	Monitoring: North Pit	31	24.96	942,04	0,69
ASDW BH2	-88 533	-57 227	963	41	Monitoring: Northern TSF, possibly on a fault	19, 21	16.38	946,62	59,24
ASDW BH3	-88 953	-58 089	937	30	Monitoring: North Pit	19, 24	10.14	926,86	2,31
ASDW BH4	-88 487	-57 923	974	40	Monitoring: North Pit	21, 26	22.40	951,60	2,7
ASDW BH5	-89 198	-59 152	936	50	Monitoring: Dam 26, associated with fault	26	12.49	923,51	0,9
ASDW BH6	-89 080	-59 198	939	20	Monitoring: Dam 26, associated with fault	12	13.14	925,86	33,82
ASDW BH8/7	-88 176	-59 299	968	30	Monitoring: WRD, associated with fault	16, 19	11.50	956,50	196,6
ASDW BH9	-89 567	-58 423	926	40	Monitoring: Historical TSF, associated with dyke	2, 4	4.73	921,27	17.5**
ASDW BH10	-89 277	-58 134	935	35	Monitoring: Discard Dump	21, 23	3.40	931,60	0.07**
ASDW BH11	-88 529	-59 129	958		Monitoring: South Pit	21, 22, 25	17.92	940,08	13,62
DRM1	-89 802	-58 421	916	29	Monitoring: LRWD	0,3	4.93	911,07	9.21**
DRM2	-89 785	-58 351	911	29	Monitoring: LRWD	0,2	4.75	906,25	2.87**
DRM3	-89 675	-58 004	920	30	Monitoring: Discard dump (old quarry), associated with dyke	0,6	3.35	916,65	0,25**
DRM4	-89 187	-58 632	941	30	Monitoring: Plant		10.52	930,48	0.04**
DRM5	-89 429	-58 749	935		Monitoring: URWD		4.21	930,79	
DRM6	-88 638	-60 019	940		Monitoring: Up gradient South Pit		8.96	931,04	
DRM7	-88 842	-59 002	959	30	Monitoring: North Pit backfill		26.63	932,37	
DRM8	-88 778	-59 070	948	39	Monitoring: South Pit backfill		26.61	921,39	
DRO4	-89 901	-58 296	941		Monitoring: Alluvial aquifer		2.66	938,34	
MCC BH	-89 156	-59 118	937		Monitoring: Main Contractors' Camp		9.36	927,64	
SW BH	-88 893	-59 036	943		Monitoring Sewage Plant and South Pit tailings backfill area		15.5	927,50	27,59
DRM9S	-89 612	-57 721	932	12	Monitoring: Khulu TSF down gradient on dyke	None	13.15	918,85	
DRM9D	-89 614	-57 726	932	80	Monitoring: Khulu TSF down gradient on dyke	19	10.50	921,50	6
DRM10S	-89 635	-57 471	930	12	Monitoring: Khulu TSF down gradient on fault line	None	13.08	916,92	
ASDWBH12	-89 635	-57 471	930	45	Monitoring: Khulu TSF down gradient on fault line (old BH)	None	12.27	917,73	189
DRM11S	-90 054	-57 360	923	12	Monitoring: Khulu TSF down gradient on fault line	None	12.66	910,34	
DRM11D	-90 057	-57 354	923	80	Monitoring: Khulu TSF down gradient on fault line	None	13.78	909,22	
DRM12S	-89 724	-56 894	918	8	Monitoring: Khulu TSF upgradient on fault line	None	6.02	911,98	
DRM12D	-89 731	-56 899	918	80	Monitoring: Khulu TSF upgradient on fault line	14 - 20	5.90	912,10	95
DRM13S	-89 657	-58 327	921	15	Monitoring: LRWD and old TSF, associated with dyke	None	6.80**	914,20	0.46
DRM13D	-89 657	-58 327	921	80	Monitoring: LRWD and old TSF, associated with dyke	13,19,23,29,43	6.16**	914,84	1.18
DRM14S	-89 298	-58 638	935	15	Monitoring: Plant, associated with fault	14	10.00**	925,00	273.7
DRM14D	-89 298	-58 638	935	53	Monitoring: Plant, associated with fault	13,17,18,31	9.84**	925,16	327.6
DRM15S	-89 767	-58 236	916	12	Monitoring: LRWD, Plant and Groot Dwars River	6	5.52**	910,48	5.46
DRM15D	-89 767	-58 236	916	80	Monitoring: LRWD, Plant and Groot Dwars River	6	4.40**	911,60	0.07

* DCM monitoring data

* nettZero (2021) data, dated August – September '21

4.3.3 Saturated zone

There are three main aquifers found in the area (iLEH, 2020). These include:

- An alluvial aquifer present in the floodplains of the Groot- and Klein Dwars Rivers. In this aquifer, the lithology varies from large boulders to fine silty material. Monitoring boreholes drilled into this aquifer suggests that it is 15m thick on average in the vicinity of the Khulu TSF. This thickness was correlated with the depth of weathering.
- A shallow weathered aquifer present in the upper 15m of the geological succession.
- A fractured rock aquifer consisting of fractured pyroxenites, anorthosites and norites. The depth to weathering in this aquifer varies from 0 – 32m, but is on average 15m below surface in the vicinity of the Khulu TSF. Pockets of deeper weathering are associated with faulting and/or jointing. The intersection of fractures in exploration boreholes suggests that the majority of fractures occur within the upper 60m of the geological succession. Deeper fracturing is however found to a depth of 200m. Information from monitoring boreholes suggests that water-bearing fractures typically occur to a depth of 40m. The localised fractured aquifers in the rocks are thought to be restricted to contact zones between intrusions and the host rock as well as with joints, faults and fractures. Groundwater in the fractured aquifer system is drained from storage in the overlying weathered aquifer as well as through recharge of rainwater and from watercourses. Two regional fault lines are present in the project area, as discussed earlier. Based on field data, it is concluded that both fault lines will act as preferential flow paths to groundwater. The north-south striking fault specifically has significantly enhanced aquifer conditions. In addition, a regional north-south striking dyke is located east of the Khulu TSF. The contact zone of this dyke is also thought to be a preferential flow path to groundwater. This dyke does however not transect the Khulu TSF footprint. The unfractured rock matrix is tight and unlikely to transmit groundwater flow to any significant extent. Groundwater flow is expected mainly along the faults, fractures and dyke contact zones present.

4.3.4 Aquifer transmissivity

Aquifer transmissivity information that is currently available is presented in Table 7. This information was sourced from iLEH (2020), nettZero (2021) and the fieldwork completed as part of the Khulu TSF geohydrological study. The available information for the aquifers identified from the geological setting of the project is summarised in Table 13. The table indicates the range of transmissivities for the aquifers as well as an average value calculated from the available dataset. The calculation of average transmissivities considered the heterogeneity of th aquifers present. The following is concluded from the average transmissivities for each aquifer:

- The N-S striking fault zone has the highest average transmissivity and will be considered a preferential flow path to groundwater.
- The alluvial aquifer also has a comparatively high transmissivity and is therefore also considered a preferential flow path. The information gained from recent aquifer test data could be used to obtain a better understanding of the nature of the alluvial aquifer. The transmissivity of this aquifer is lower than previously thought. This is supported by the borehole logs, which does not indicate unconsolidated material, but clay-rich to sandy deposits.
- The dolerite dyke contact zone has a moderately low average transmissivity. It is likely to act as a preferential flow path to groundwater, but to a lesser extent compared to the N-S striking fault.
- The aquifer associated with the SW-NE trending fault is also not as well developed as the N-S striking fault. Boreholes DRM11S and D, situated down gradient of the Khulu TSF were dry at the time of drilling. Seepage did however subsequently collect in DRM11D, suggesting low groundwater seepage conditions in this position. The transmissivity of DRM12D, situated along this fault up gradient of the Khulu TSF, is however significantly higher. This suggests that the fault could act as a preferential flow path to groundwater.

- The transmissivities of the shallow weathered aquifer are generally low with dry aquifer conditions at the time of drilling. In places this aquifer could have transmissivities above 5 m^2/d, as shown.
- The fractured rock matrix has a very low transmissivity. Groundwater flow is not expected to take place at any significant extent in unfractured rock.

Table 13 Aquifer transmissivity analysis: Khulu TSF footprint area

Aquifer	Boreholes with data	Transmissivity range (m^2/d)	Average Transmissivity (m^2/d)
Alluvial	DRM1, DRM2	2.87 - 9.21	5,14
Shallow weathered	DRM9S, DRM10S, DRM11S, DRM12S, DRM13S, DRM15S	Dry - 5,46	0,16
Fractured rock: matrix	DRM15D, ASDWBH10, DRM4	0.04 - 0.07	0,06
Fractured rock: SW-NE fault	DRM11D, DRM12D, Farm Borehole	Dry - 96	13,78
Fractured rock: N-S fault	DRM9D, ASDWBH12, DRM12D, DRM14D	6 - 328	77,08
Fractured rock: Dyke	DRM9D, DRM13D, DRM3(?), ASDWBH9	0.25 - 17.5	2,36

4.4 Interaction between shallow and deep aquifers

Monitoring in shallow boreholes was undertaken during aquifer tests completed during 2021 in order to gain information on how the shallow weathered aquifer interacts with the deeper underlying fractured rock aquifer.

Results from the aquifer tests completed as part of this study suggests that there is limited interaction between the shallow and deep aquifers during constant discharge aquifer tests on the deep monitoring boreholes at each location (see Table 7). It is noted that borehole DRM10 and 11S were dry at the time of the tests. The information suggests that the shallow weathered aquifer does not carry water and does not significantly contribute to the rate of recovery in the deep monitoring boreholes.

NettZero (2021) installed an automatic level recorder in borehole DRM9 to determine if there is a hydraulic connection when boreholes DRM13 – 15 were pumped. Although groundwater level fluctuations were observed in borehole DRM9, it was concluded form the study that the observed fluctuations are rather due to daily atmospheric changes than impacts associated with the constant discharge tests in boreholes DRM13 – 15. Limited drawdown was also observed in boreholes close to each of the pump tested boreholes.

Based on this information, it is concluded that there is limited vertical movement between the shallow weathered and the deeper fractured rock aquifer. The exception is at DRM14S and D, where high transmissivities were recorded in both shallow and deep boreholes by nettZero (2021). This borehole is located on the IRUP body mapped in the underground workings as well as on the N-S striking fault. The information suggests that vertical infiltration of contamination in this are is likely, which is furthermore supported by monitoring data in boreholes along this fault line.

4.5 Groundwater levels

The July 2021 groundwater level monitoring dataset, presented in Table 7, were used to generate groundwater flow contours for the project area. These contours are presented in Figures 10 and 11 for measurements in the shallow and deep boreholes respectively. The contours indicate that regional groundwater flow in both aquifers is in a north-westerly to westerly direction towards the Klein Dwars River and its tributaries. The average flow gradient over the Khulu TSF footprint area in the shallow aquifer is 0.017 (1:58) and 0.02 (1:50) in the deeper fractured aquifer. Flow patterns aver very similar in th two aquifers.

The average depth to groundwater in the shallow monitoring boreholes in the area is 10m. This is close to the average depth in deep monitoring boreholes which is 12m. Borehole logs suggest there is no geological barrier between the two aquifers. The limit of the weathered aquifer is defined by the depth of weathering and for this reason is hydraulically connected to the fractured aquifer.

There is a slight cone of depression around boreholes DRM1 and 2 in both aquifers. This is probably attributed to the impact of groundwater abstraction from boreholes D1 and D2, which is situated in this area near the Groot Dwars River (see Figure 2).

In contrast, a mound in groundwater levels has developed around the URWD. This is indicative of shallow groundwater conditions in this area and could reflect seepage from the dam. A detailed assessment of the URWD falls outside the scope of this report. It is however important to investigate groundwater flow at the URWD in order to develop measures to minimise contamination associated with the DCM operations.

Groundwater level measurements along the N-S fault, the SW-NE fault and the dyke were used to trace preferential flow along these structures (Figure 10). This information indicates that there is a well-developed preferential flow path along the N-S striking fault. In this structure, flow is from the plant area in a northerly direction and not westerly as regional flow patterns suggest. Less pronounced preferential flow takes place along the SW-NE striking fault and the N-S striking dyke, as shown.

A comparison between topographical elevation and groundwater elevation in the shallow and deep monitoring boreholes is included in Figures 10 and 11. A strong correlation between these two parameters suggest that groundwater flow takes place mainly under the force of gravity from high-lying areas towards the rivers and streams. In the shallow boreholes, a 92% correlation exists. In the deeper boreholes, the correlation is 83%. This suggest that other factors could control groundwater flow, including pressure along the fault lines and dyke contact zones as well as the impact of mine dewatering.

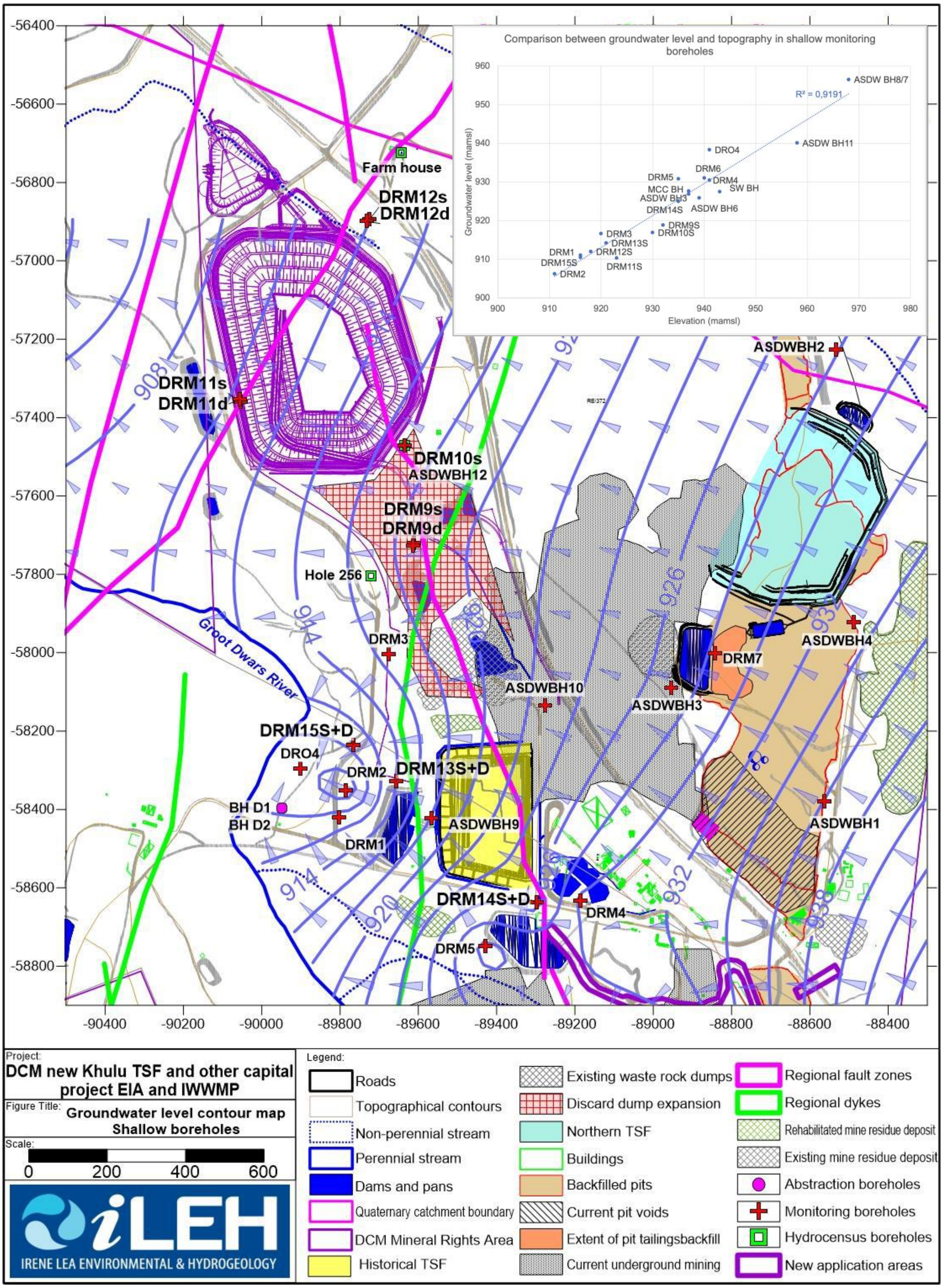


Figure 10 Groundwater flow contours in shallow boreholes

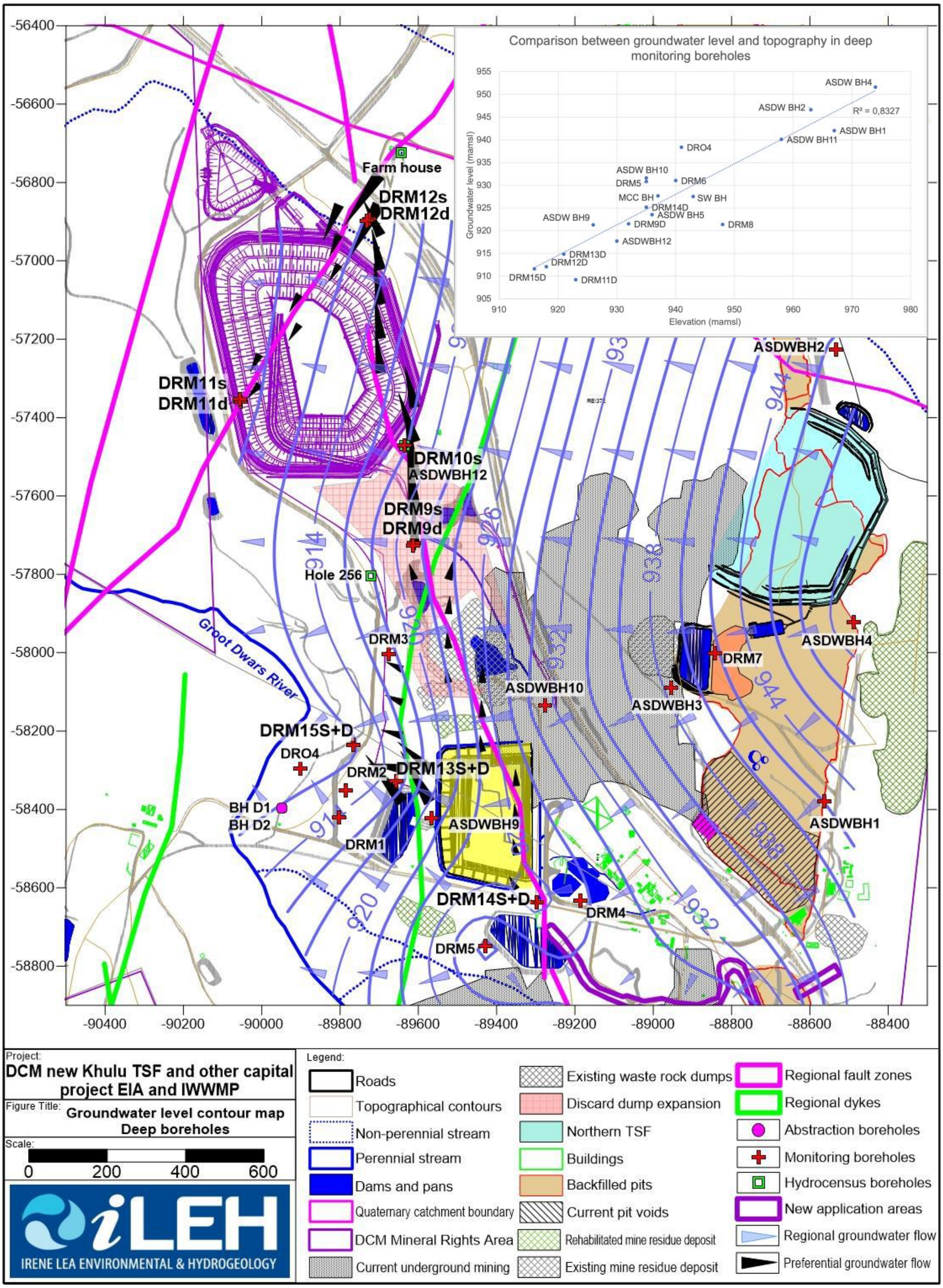


Figure 11 Groundwater flow contours in deep boreholes

4.7 Groundwater potential contaminants

The water quality in the LRWD was used to identify the potential groundwater contaminants associated with mining area as it is thought to be representative of the overall DCM dirty water circuit. Water from the Upper Return Water Dam (URWD) as well as feed from the Northern TSF and its return water dam is currently discharged to the LRWD for re-use.

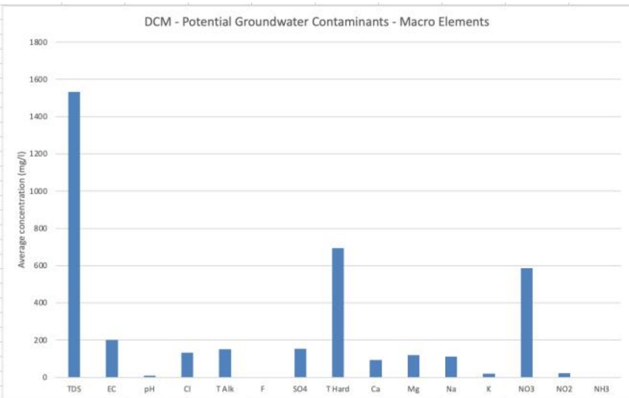
In future, water from the LRWD will be entrained in the tailings slurry that will be pumped to the FPF prior to the discharge of filter cakes on the Khulu TSF.

As such, the long-term average concentrations for macro and trace elements provide an indication of the indicator elements for the 8ining operations as a whole, but also for the Khulu TSF. These are presented graphically in Figure 12.

The information presented inf Figure 12 indicates that the water has elevated total dissolved solids (TDS), total hardness (T Hard) and nitrate (NO_3). Nitrates are of specific concern, as the average concentration in the LRWD (600 mg/l) is significantly higher than the water use license (WUL) condition of 6 mg/l. The average 2021 nitrate concentration for the LRWD is 1167mg/l, which indicates that nitrate concentrations are increasing in this dam. This increasing trend is discussed later in this report.

In terms of trace metals, the average concentrations are all below 0,07 mg/l. It is noted that aluminium (Al) and total chromium (T Cr) have the highest average concentrations of the metals included in the monitoring database.

Nitrate was previously identified as the indicator element for the operations (Future Flow, 2015 and iLEH, 2017). The averaged macro and trace element qualities assessed confirm this finding and NO_3 will therefore be used to complete the impact assessment presented in this report.



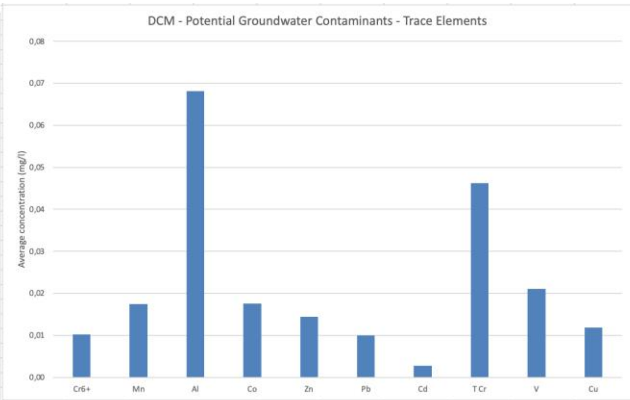


Figure 12 Average macro and trace element concentrations for the LRWD

4.8 Groundwater Quality

4.8.1 Khulu TSF pre-construction groundwater quality

Groundwater samples were taken from the six boreholes at the Khulu TSF footprint as part of this study. These include three hydrocensus borehole samples (Farm House, ASDWBH12 and Boreholes D1+D2) as well as groundwater monitoring boreholes that contained groundwater at the time of the aquifer testing.

Samples were taken using single valve, decontaminated bailers or from pump discharge lines, or water supply taps in the case of boreholes which were equipped and in use. Sterilized 1 litre (L) sample bottles were used and filled to the top. Samples were stored in a cooler box during the site surveys.

The samples were submitted to Waterlab, a SANAS accredited laboratory for analysis. The water samples were analysed for basic inorganic parameters and the results were compared against the SANS 241:2015 Drinking Water Standards. The results are presented in Table 14. The laboratory certificates are attached in Appendix D.

Three of the boreholes sampled had elevated electrical conductivity levels (and total dissolved solid (TDS) concentrations). These elements provide an indication of total salt content. The groundwater from all boreholes is considered very hard.

Significantly elevated nitrate concentrations were recorded in all but one of the boreholes. This is indicative of the impact of the DCM mining activities on water quality. It is noted that the receiving water quality in the Groot Dwars River upstream of DCM also exhibits elevated nitrate concentrations, which suggest that surrounding mining activities also impacts on groundwater and surface water quality in this area.

Borehole D1+D2, situated at the Clinic and used to supply drinking water to the mine, had low nitrate concentrations and this water is suitable for domestic use. This borehole did however have an elevated manganese concentration, which could be indicative of old pipes. Borehole DRM9D showed elevated chloride concentrations, significantly higher than ambient trends. It is not known what the source of the elevated chloride in this borehole is. All other metal concentrations were low with trace elements mostly below the laboratory detection limits. This is expected with neutral to alkaline pH conditions reported for the groundwater samples taken.

The following conclusions were drawn in terms of the groundwater quality:

- Nitrate: At the concentrations reported methaemoglobinaemia may occur in infants. No effects on adults are expected.
- Manganese: Manganese tends to precipitate out of solution to form a black hydrated oxide which is responsible for staining. At the concentration reported, no health effects are expected.
- Chloride: at the concentration reported, the water is expected to have a distinct salty taste, but no health effects are expected. The water may also result in a noticeable increase in corrosion in domestic appliances.
- Total Hardness: The groundwater from all boreholes are considered very hard. These concentrations of calcium and magnesium could lead to scaling on heat exchange surfaces. For this reason, descaling of the water is recommended.

Table 14 Groundwater quality (July 2021)

All concentrations in mg/L unless noted otherwise	SANS241:2015 Drinking Water Standard Limits		D1+D2 (Clinic BH)	Farm House	ASDW BH12	ASDW BH12	DRM 9D	DRM 12D
	Aesthetic effects	Chronic health effects						
pH	≥5 to ≤9.7		8.0	7.9	7.6	7.4	7.4	7.6
Electrical Conductivity (mS/m)	Aesthetic ≤170		61.1	114	184	196	251	122
TDS	Aesthetic ≤1200		348	694	1158	1394	2116	790
Total Alkalinity			304	440	252	304	308	400
Bicarbonate	Not specified		371	536	307	371	375	488
P Alkalinity			<5	<5	<5	<5	<5	<5
Total Hardness	150–200 mg/l, moderately hard; 200–300 mg/l, hard; >300 mg/l, very hard		311	613	885	938	1225	601
Aluminium	Operational ≤ 0,30		<0.1	0.113	0.118	0.108	0.128	<0.1
Calcium			46	62	150	161	154	52
Copper		Chronic health ≤2	<0.01	0.032	<0.01	0.016	0.019	0.014
Total Iron	Aesthetic ≤0,3	Chronic health ≤2	<0.025	<0.025	<0.025	<0.025	0.026	<0.025
Magnesium			48	112	124	130	204	115
Manganese	Aesthetic ≤0,1	Chronic health ≤0,4	0.304	<0.025	<0.025	<0.025	<0.025	<0.025
Potassium			0.8	1.1	0.8	0.5	0.6	1.5
Sodium	Aesthetic ≤200		14	13	27	26	26	27
Chloride	Aesthetic ≤300		11	14	178	200	313	31
Fluoride		Chronic health ≤1,5	<0.2	<0.2	<0.2	0.2	0.2	0.2
Free & Saline Ammonia	Aesthetic ≤1,5		<0.1	0.1	<0.1	0.3	0.7	0.5
Nitrate		Acute health ≤11	3.3	46	89	82	106	49
Nitrite		Acute health ≤0,9	<0.05	<0.05	0.07	<0.05	<0.05	<0.05
Ortho Phosphate as P			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Nitrogen as N			3.9	46	89	82	107	50
Kjeldahl Nitrogen			0.6	<0.5	<0.5	<0.5	1.1	1.1
Sulphate	Aesthetic ≤250	Acute health ≤500	27	45	124	135	185	64
Cadmium		Chronic health ≤0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead		Chronic health ≤0.01	<0.001	0.001	<0.001	0.002	0.001	0.001
Total Chrome		Chronic health ≤0,05	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Hexavalent Chromium			<0.01	<0.01	<0.01	0.012	<0.01	<0.01
Barium		Chronic health ≤0.7	0.039	0.058	0.045	0.049	0.063	0.069
Boron		Chronic health ≤2.4	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Nickel		Chronic health ≤0.07	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Molybdenum			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cobalt			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Silver			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Vanadium			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Zinc	Aesthetic ≤5		<0.025	0.091	<0.025	<0.025	<0.025	<0.025

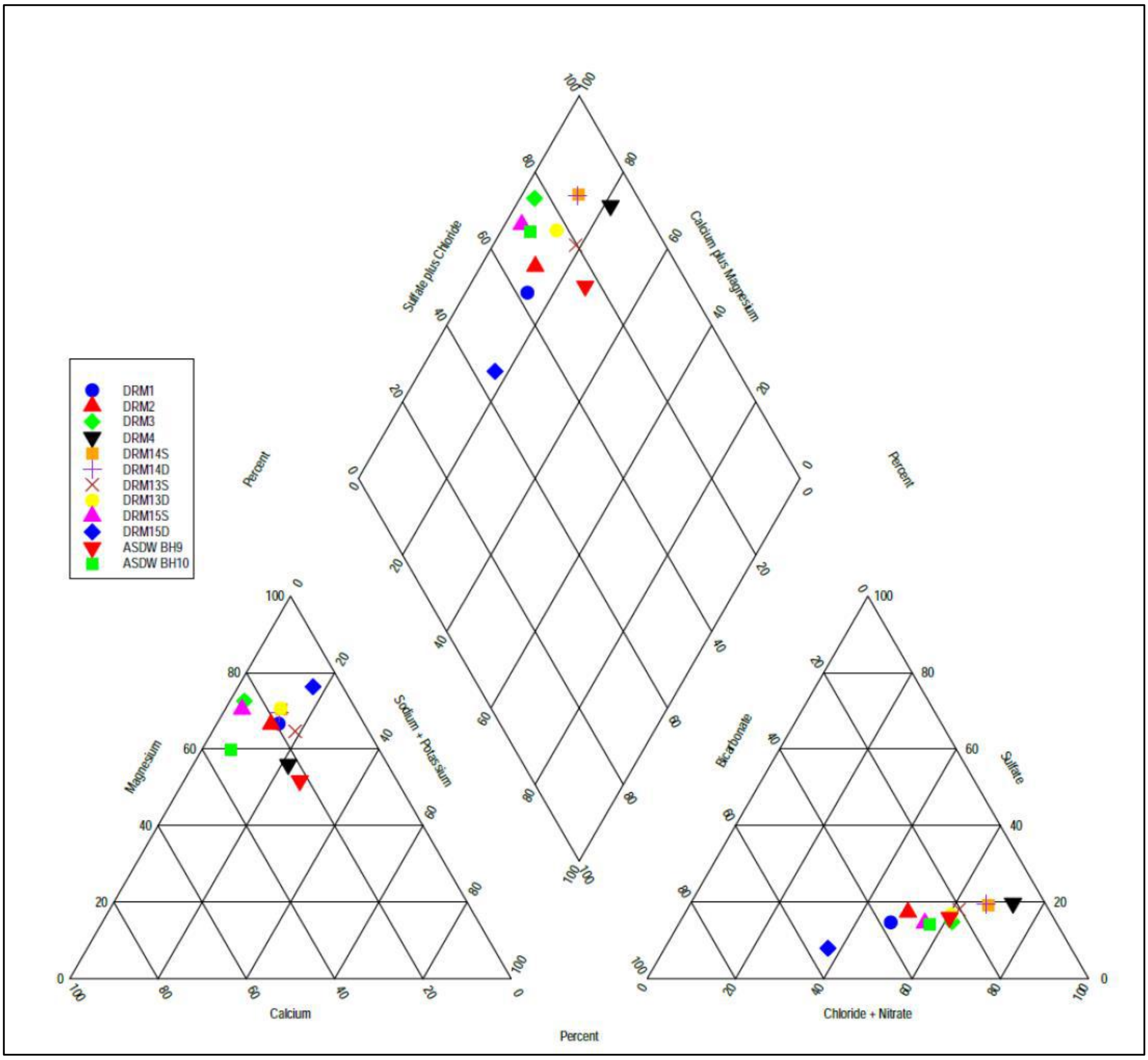


Figure 13 Piper Diagram

Groundwater samples taken from the 12 additional boreholes drilled around the plant area (nettZero, 2021) show similar trends to that discussed above. All the groundwater samples exceeded EC levels, as well as TDS, Ca, Mg, Cl, NO_3 and N. Sulphate concentrations were furthermore exceeded in some of these boreholes. Elevated fluoride, sodium and manganese were also reported. The groundwater samples indicated a clear impact from the DCM mining activities.

The general water quality is shown in the Piper Diagram in Figure 13. The diagram indicates that the groundwater is mainly Mg-HCO_3-NO_3-N dominant.

4.8.2 Nitrate concentration trends

An overview of nitrate concentrations in groundwater is presented in this section. Nitrate is an indicator element for the operations and a sound understanding of the impacts of mining and mineral processing activities on groundwater quality is therefore important to conceptualise the project. The data on which this assessment is based, is presented in Appendix E.

Nitrate concentrations for the latest available sampling period are presented for the groundwater around the Khulu TSF footprint as well as for process water that may affect tailings deposition in future. These include the LRWD and URWD, from which water is supplied to the plant for mineral processing. Also indicated is tailings return water quality from the Northern TSF, which is currently operational. The Northern TSF water qualities provide an indication of the expected water qualities for the Khulu TSF. It is shown that the nitrate concentration in the URWD, the LRWD and the N RWD is comparable. Also included is the last available concentration for seepage from the Old TSF, which dates from 2017.

The information presented in Table 15 was used to generate a nitrate diagnostic map to show the spatial distribution of nitrate concentrations for the project. This map is shown in Figure 14.

Table 15 Nitrate concentrations at monitoring points around the Khulu TSF

Sample position	Latest NO_3 concentration (mg/l)
URWD	1508
LRWD	1497
Northern TSF RWD (N RWD)	1191
Northern TSF PCD (N PCD)	811
Old TSF seepage	730
DRM4	299
DRM14D	259
DRM14S	259
Clarifier 1	223
DRM13S	164
DRM13D	161
ASDW BH9	152
ASDW BH10	130
DRM9D	118
DRM1	112
DRM2	100
DRM3	96
DRM15S	88
DRM10D (ASDWBH12)	79
Dam 26	70
DRM12D	49
Farm House	46
DRM9S	31
DRM11D	23
DRM15D	20
DRM12S	4
Borehole D1+D2	3

The following is concluded from the information presented:

- Groundwater in the fractured rock aquifer already exhibits elevated nitrate concentrations at the Khulu TSF footprint. Nitrate concentrations in this aquifer vary between 20 and 100 mg/l, which exceeds the WUL condition of 6 mg/l.
- Only one water sample is available from the shallow weathered aquifer, DRM12S. Nitrate concentrations in this borehole are below 6 mg/l and complies with the WUL conditions.
- This information suggests that the existing groundwater contamination is moving preferentially in the fractured rock aquifer along the identified preferential flow paths. These include the two fault zones and the dyke.

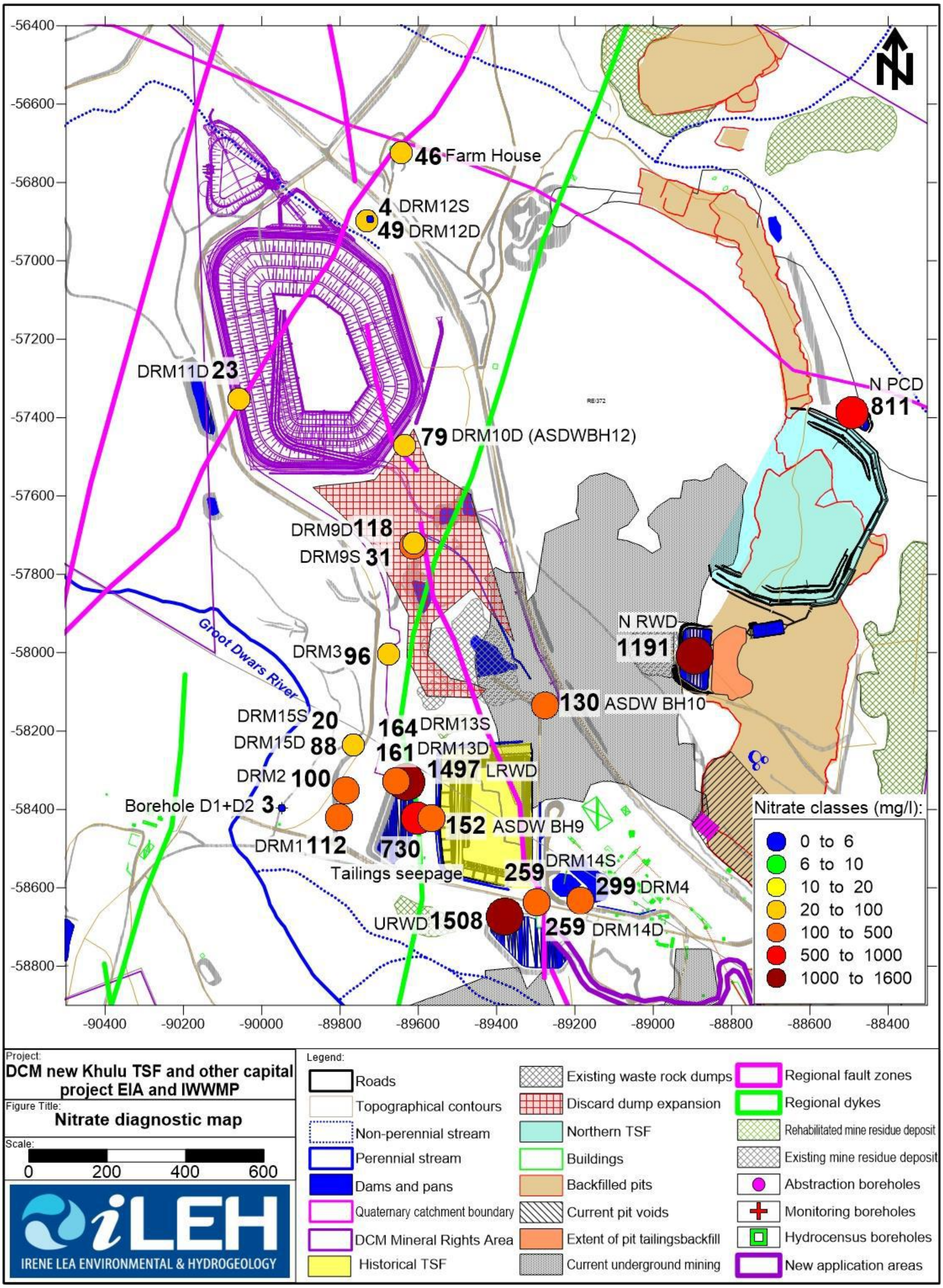


Figure 14 Diagnostic map: Latest nitrate concentrations

- A nitrate concentration time series graph for the LRWD, Northern RWD and Old TSF seepage is presented in Figure 15. The information indicates a steady increase in nitrate from around 200 – 400 mg/l in 2009 to above 1200 mg/l at present. This suggests concentration of nitrates in the dirty water circuit, which is operated in a closed loop. Evaporation and chemical reactions in the open dams could also contribute to the increased nitrate salt load.
- The source of the elevated nitrate concentrations is the plant as well as the URWD and the LRWD. Nitrate concentrations in the two dams are currently around 1500 mg/l. In the plant, nitrate concentrations vary between 250 and 300 mg/l. In the past, nitrate concentrations measured in DRM4, the borehole located in the plant area were significantly elevated. This is demonstrated in Figure 16.
- The elevated nitrates in the new deep monitoring boreholes at the Khulu TSF decreases along the N-S fault line in a northerly direction. Borehole DRM14S, situated on this fault in the plant area has a nitrate concentration of 259 mg/l. DRM9D, approximately 900m north of the source area has a nitrate concentration of 118 mg/l. This decreases to 79 mg/l in ASDWBH12 (DRM10D) another 300m along the fault and to 49 mg/l in DRM12D situated another 550m along the fault line. This suggests that a plume is migrating along the N-S fault line from the plant area to the Khulu TSF and possibly beyond.
- Similarly, contamination is moving preferentially along the dyke contact zone. The dyke transects the base of the LRWD. Borehole DRM13D, drilled immediately north of the LRWD on the dyke has a nitrate concentration of 161 mg/l. Nitrate concentrations decrease to 96 mg/l at DRM3, situated 300m north of the source area along the dyke. Borehole DRM9D is located at the intersection between the fault line and the dyke and could therefore provide an indication of plume migration along both structures. Nitrate concentrations in DRM9D is 118 mg/l a further 250m north along the dyke. It is however more likely that nitrate concentrations at DRM9D reflects plume movement along the N-S striking fault line.
- Nitrate concentrations have steadily increased in borehole DRM3 since 2007, as indicated in Figure 16. This probably demonstrates the point at which contamination from the source areas reach this borehole along the dyke contact zone. Mining commenced in 1999. If it is assumed that the LRWD was constructed by the end of 1999, the information in DRM3 suggests that pollution along the dyke contact zone moves at a rate of approximately 35m/a. By using the flow gradient along the dyke and an assumed porosity for the dyke contact zone of 0,035 (based on S-value calculations presented in nettZero (2021)), the permeability of the contact zone is calculated as 0.34m/d using Darcy's Law and the migration time along the structure. This translates to a transmissivity of 7,9m^2/d over the saturated thickness of DRM3. This falls within the range of transmissivities reported for the dyke in Table 13 and is slightly higher compared to the average T-value calculated from the aquifer test data.
- Long-term nitrate concentrations in boreholes ASDWBH9 and 10 are presented in Figure 17. The information indicates a steady increase in nitrate concentrations in ASDWBH9 up to May 2018 when the monitoring contractor was changed at the mine. ASDWBH9 is located along the N-S striking dyke and monitors contamination originating from the Old TSF as well as from the LRWD. Monitoring in this borehole commenced in 2009 and can therefore not be used to accurately calculate plume migration rates. Nitrate concentrations in ASDWBH10 has remained constant over the monitoring period. This borehole is not located on any of the preferential flow paths identified. It does however contain elevated nitrate concentrations that probably originate from the old opencast pits, tailings backfill to North Pit and possibly from the N RWD.
- It is interesting that elevated nitrate concentrations are also recorded in the SW-NE-striking fault in boreholes DRM11D and the Farm House borehole. This could be attributed to two scenarios. The first is that contamination moving along the N-S striking fault line intersects the SW-NE striking fault at DRM12D. This could result in contamination moving along the SW-NE striking fault under the influence of pressure in the fractured rock aquifer along the fault lines. Groundwater flow is regionally in a westerly direction towards the Groot Dwars River. This probably also plays a role in plume migration along the SW-NE striking fault.

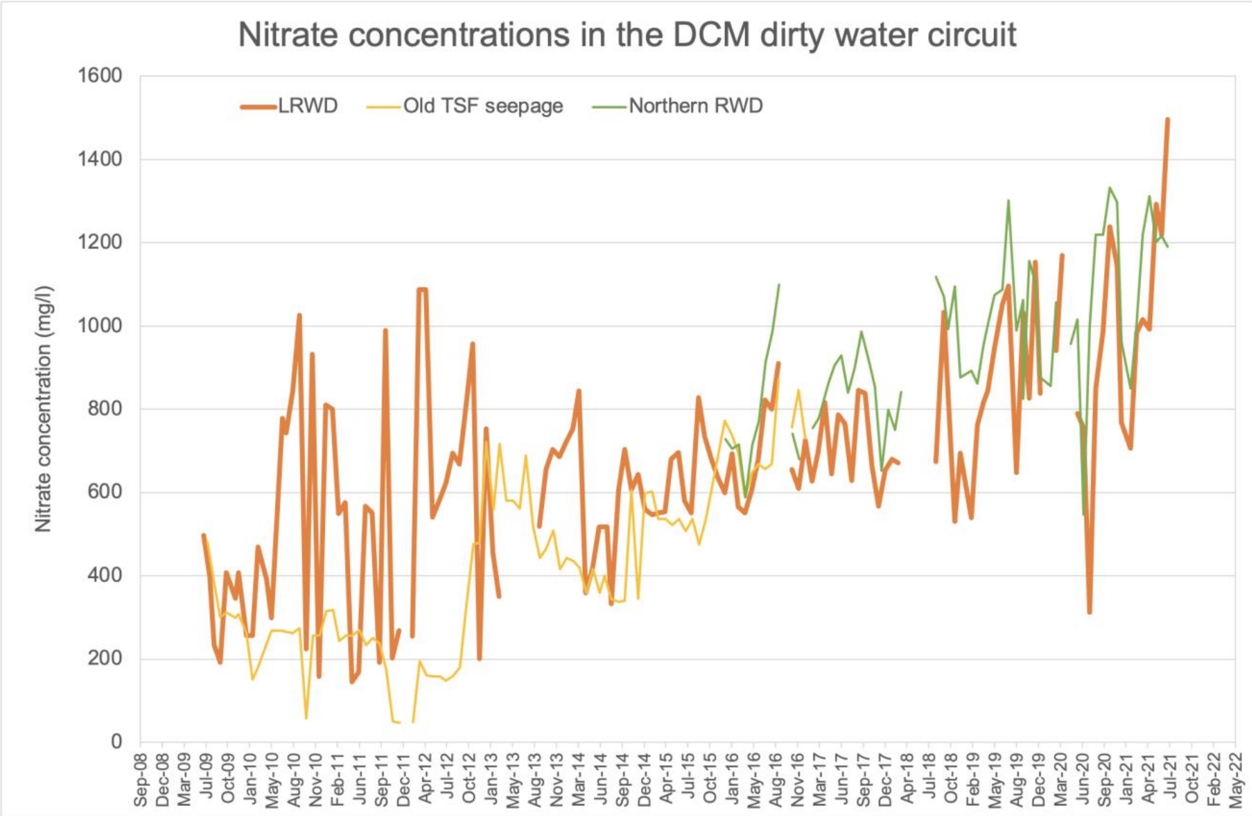


Figure 15 Nitrate concentration trends in the LRWD, the Northern RWD and Old TSF

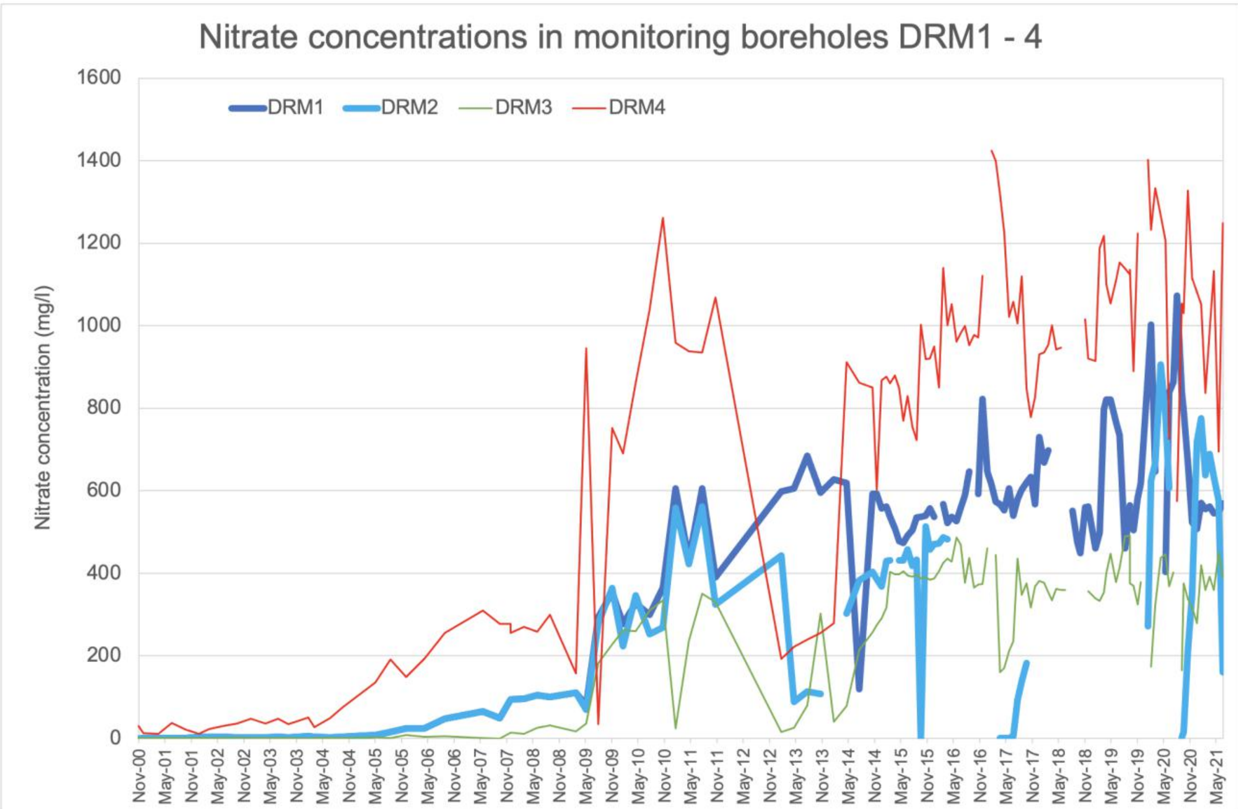


Figure 16 Nitrate concentration in boreholes DRM1 - 4

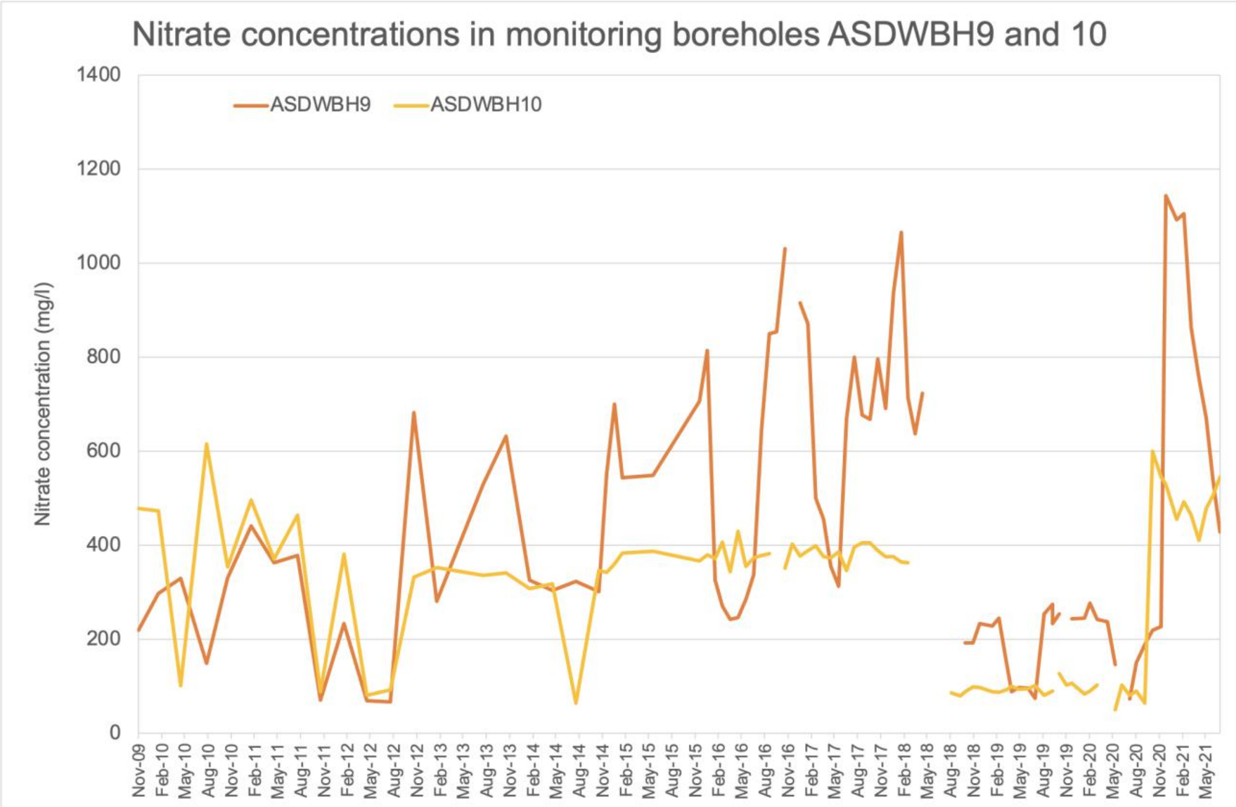


Figure 17 Nitrate concentrations in boreholes ASDWBH9 and 10

- The nitrate timeseries for DRM1 and 2 can be used to calculate the estimated permeability of the alluvium using Darcy's Law. Monitoring information suggests that nitrate concentrations start to increase significantly by May 2005 in these boreholes (see Figure 16). Depending on the source of the contamination in DRM1 and DRM2 and an assumed porosity of 6%, the calculated permeability of the alluvium is equivalent to a transmissivity of between 0.99 and 2.27m^2/d. This is lower than the transmissivities calculated from aquifer testing data presented in Table 13. It could be that aquifer conditions in and the boreholes are enhanced compared to the flow paths through the alluvium from the sources of contamination used to complete this calculation.

NettZero (2018) reports that supernatant compounds associated with blasting and materials handling that cling to the solid matter (ore, waste rock, tailings, etc) accounts for the high nitrate concentrations in the DCM water circuit. Leach tests proven that nitrogen does not form part of the mineralogy or minerals internal structures. The explosives (ammonium nitrate) that is present on the surface of materials handled on the mine are readily available for dissolution with rain and pore water and is therefore considered the most likely source of nitrate contamination on the mine. NettZero further reports that the possibility further exists that nitrates will remain supernatant in the mine water circuit for the foreseeable future and will therefore continue to leach out into surface and groundwater.

With the presence of ammonium nitrate in the mine water circuit, the possibility of oxidation of ammonia to nitrite and nitrate should also be considered. This typically happens in the presence of ammonia and/or nitrite oxidising bacteria, which could occur naturally or be introduced through the re-use of treated sewage effluent in the mine water circuit.

5 AQUIFER CHARACTERISATION AND VULNERABILITY

Based on aquifer classification methodology and regions published in the Aquifer Classification Map Series of South Africa (DWS, 2012), the fractured rock aquifers present at the DCM operations are minor aquifers with moderately yields and variable quality. The aquifers fall in a moderately vulnerable category, which means they are vulnerable to some pollutants when these are continuously discharged or leached. Overall, the aquifers presented are ranked with a medium susceptibility to the impacts of pollutants. Based on the information above, as well as the methodology described by Parsons (1995), the aquifer protection classification is rated as medium.

It is however noted that the alluvial aquifer will be an aquifer with significance and should therefore be protected.

6 CONCEPTUAL MODEL

A cross section was generated from exploration borehole as well as groundwater monitoring borehole data to contextualise the aquifers present. The location of the cross section is indicated on Figure 7 and the section in Figure 18. The available exploration borehole information indicates that the depth of weathering varies across the mining area from 1 to 68m below surface. The average depth of weathering is however around 15m. No underground mining is currently taking place underneath the Khulu TSF. Mining is however planned in this area in future from 2030 onwards as indicated on the mine plan in Appendix F. The Khulu TSF footprint area however underlain by an area of iron rich ultramafic pegmatoid replacement (IRUP). The estimated extent of this replacement body is indicated on Figure 18 and on the mine plant in Appendix F. It is unclear whether or not the replacement body extends to surface. The northern section of the Khulu TSF is not underlain by IRUP and will be mined, as shown in Appendix F. Very little information is currently available to characterise the IRUP transmissivity. Along the fault lines, enhanced aquifer conditions have developed, as indicated from field data.

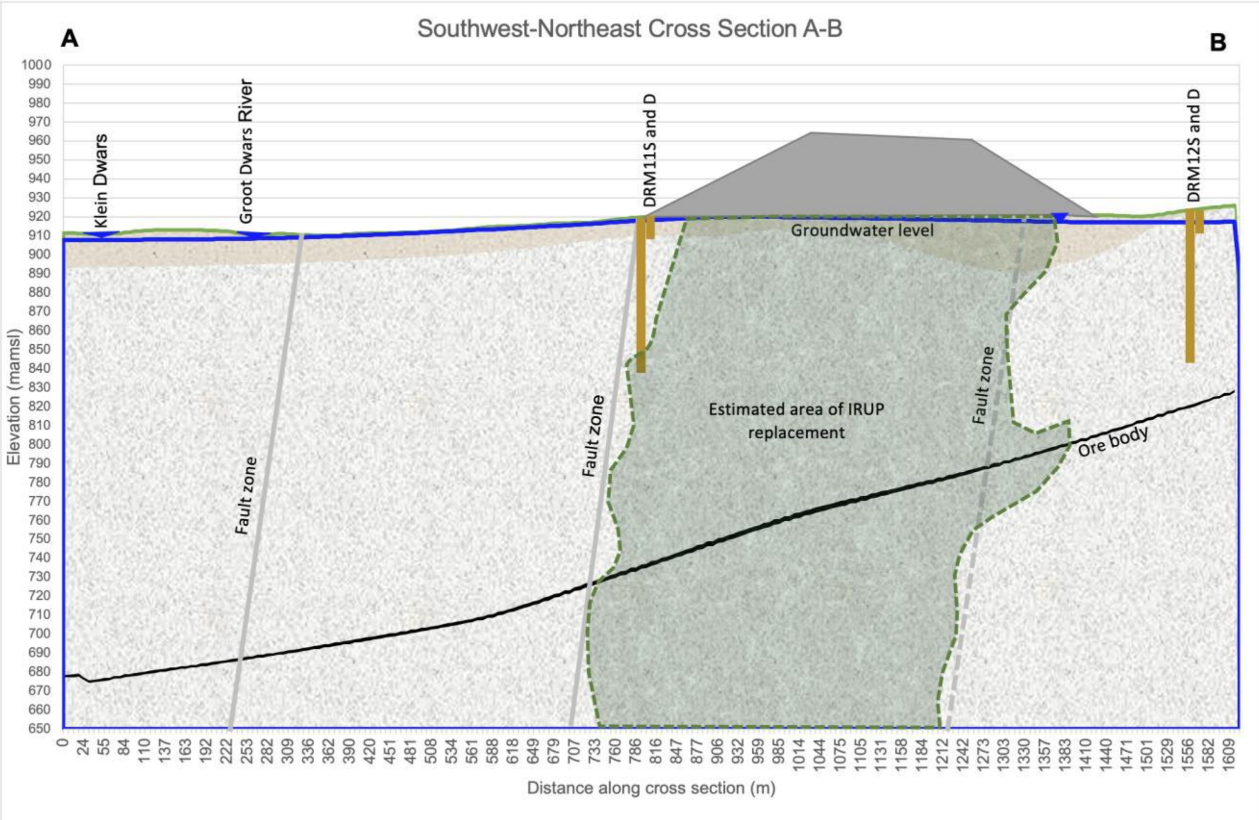


Figure 18 Cross section through the project area

The ore body dips regionally in a westerly direction towards the Klein Dwars River. At the north-western boundary of the Khulu TSF, the depth the ore body is approximately 100m. The depth of the ore body increases to the west where it is located approximately 200m below surface.

The regional fault lines are typically sub-vertical, as indicated on Figure 18.

Based on the information discussed above, the conceptual model consists of three aquifers:

- The upper unconfined alluvial aquifer with a thickness of 15m. The alluvial aquifer is simulated in the upper layer of the numerical model for the project. This aquifer is replenished through the recharge of rainwater.
- The weathered aquifer, which is present in the upper 15m of the geological succession. The alluvial and weathered aquifers are hydraulically connected, as there is no information available that suggests the presence of an impermeable barrier between the two aquifers. The vertical extent of this aquifer is defined by the limit of weathering.
- The lower semi-confined fractured rock aquifer formed by fractures and faults in the pyroxenites and anorthosites. The fractured rock aquifer is also hydraulically connected to the alluvial and weathered aquifers and will be recharged with rainwater from the two upper aquifers. The vertical movement of groundwater between the two aquifers is however expected to be at least and order of magnitude lower compared to horizontal flow rates.
- Outcrops of pyroxenite, anorthosite and norite are extensions of the lower fractured rock aquifer that penetrate through the weathered and alluvial aquifers. These areas were included as discrete zones in the model.
- The model base is assumed to be the floor of the SCS seam, which will be incorporated into the model, based on exploration borehole data.
- The fault lines and dykes are included as discrete zones. These structures act as preferential flow paths to groundwater and have higher transmissivities compared to the surrounding rock matrix

The numerical model constructed for the project was calibrated during the previous model updates (iLEH, 2010, 2015, 2017 and 2020). The 2020 calibrated parameters will be used as the starting point for model calibration undertaken as part of this assessment. Where additional information is available, especially for the fault lines and dyke, average field measured data will be used, specifically the transmissivity values presented in Table 13. Information reported by nettZero (2021) was also incorporate, where required. Some of the parameters were assumed, based on calibration from previous model updates.

The conceptual aquifer parameters are presented in Table 16. Transmissivities were converted to hydraulic conductivity for input to the model.

The parameters presented in Table 16 will be systematically adjusted during model calibration in order to obtain an optimal match between measured and simulated groundwater levels. This process is discussed below.

Table 16 Conceptual aquifer parameters

Aquifer Unit	Aquifer parameter	Value
Unconfined alluvial aquifer	Hydraulic conductivity (K)	0.15 - 0.34 m/d
	Vertical hydraulic conductivity (K_v)	0.03 m/d
	Porosity	6%
	Specific yield (S_y)	0.06
	Rate of recharge	14% of MAP
Weathered aquifer	Hydraulic conductivity (K)	0.011m/d
	Vertical hydraulic conductivity (K_v)	0.001 m/d
	Porosity	3%
	Specific storage (S)	1.62E-2
	Rate of recharge	4% of MAP
Semi-confined fractured rock aquifer: Unfractured matrix	Hydraulic conductivity (K)	0.0012 m/d
	Vertical hydraulic conductivity (K_v)	0.00001 m/d
	Porosity	1%
	Specific storage (S)	1.16E-3
	Rate of recharge	-
N-S Striking fault	Hydraulic conductivity (K)	1.54
	Specific storage (S)	1E-3
SW-NE Striking fault	Hydraulic conductivity (K)	0.28 m/d
	Specific storage (S)	1E-3
Dykes	Hydraulic conductivity (K)	0.34 m/d
	Specific storage (S)	1E-3

7 GROUNDWATER SOURCES AND SINKS

7.1 Source term

The information presented in this report was used to update the sources to groundwater contamination present within the mining area. This includes monitoring data and leach test data sourced from several reports as well as fieldwork data obtained as part of this study.

The updated source term that will be used during simulations is presented in Table 17 and Figure 19. The information presented below includes all activities in the DCM mining area. Groundwater modelling will be undertaken across the mining sub-catchment, but focus is placed on impacts associated with the Khulu TSF.

Table 17 Conceptual source term

Source area	Conceptual nitrate concentration (mg/l)	Flow path to groundwater	Comments
Khulu TSF seepage	1500	Infiltration through liner	Assumed to be similar to LRWD
Khulu PCD water	1500	Infiltration through liner	Assumed to be similar to LRWD
URWD	1500	Infiltration from source with liner	2021 monitoring data
LRWD	1500	Infiltration from source with liner	2021 monitoring data
Plant area	1500	Infiltration from surface: 5% of MAP	2020 model calibration
North Pit tailings backfill	1500	Source located in aquifer: seepage	2020 model calibration
Northern RWD	1500	Infiltration from source with liner	2021 monitoring data
Northern TSF	1500	Infiltration from source with liner	2021 monitoring data
Northern PCD	900	Infiltration from source with liner	2021 monitoring data
Historical TSF	900	Infiltration from surface: 10% of MAP	2020 model calibration
Northern WRD	400	Infiltration from surface: 6% of MAP	2020 model calibration
Underground	180	Source located in aquifer: seepage	2020 model calibration
Dam 26	180	Infiltration from source with liner	2021 monitoring data
Pit backfill areas	90	Source located in aquifer: seepage	2020 model calibration
South Pit tailings backfill	90	Source located in aquifer: seepage	2020 model calibration
WRD and Discard	20	Infiltration from surface: 10% of MAP	Leach tests (NettZero, 2018)

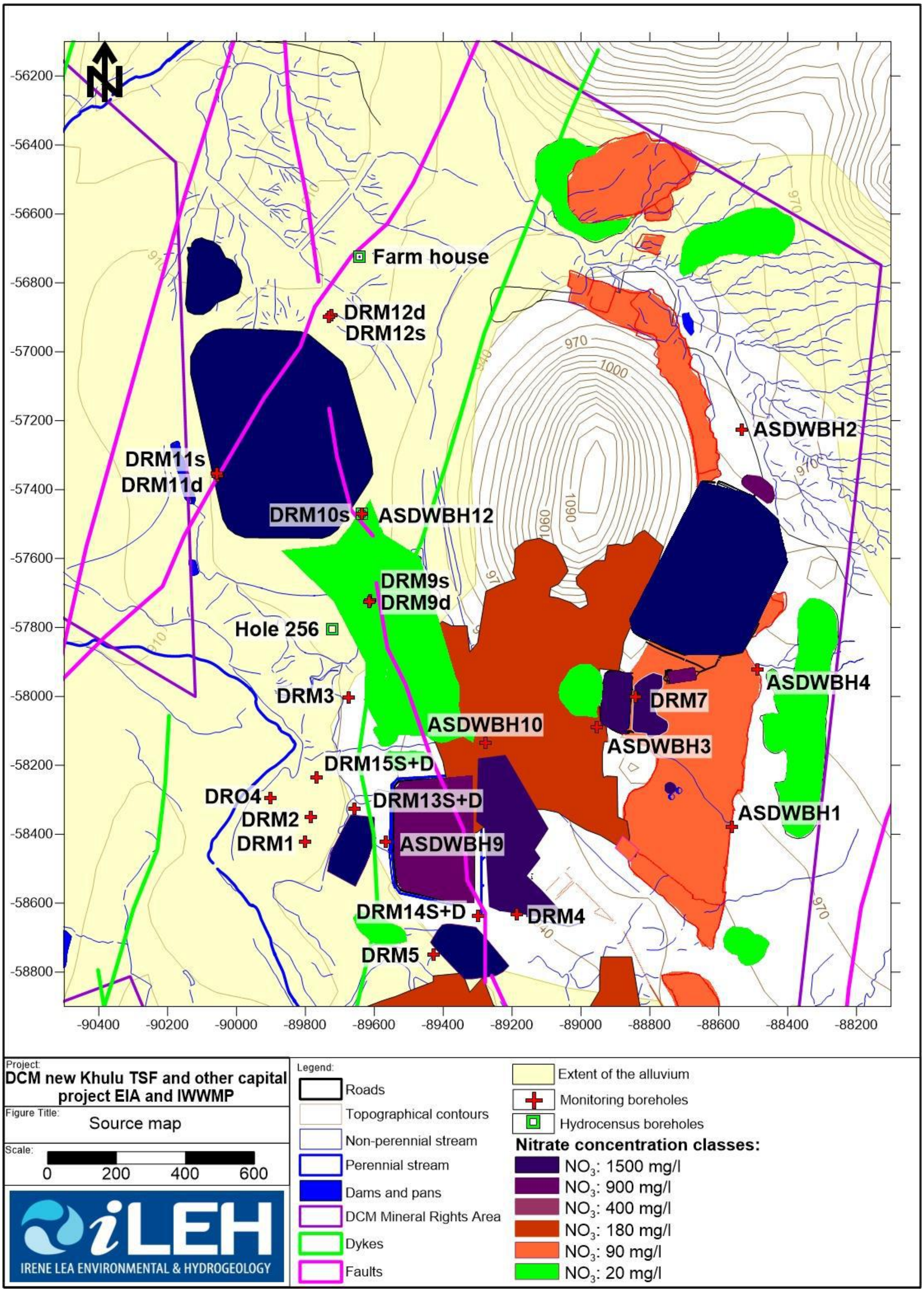


Figure 19 **Source map indicating pathways and sensitive receptors**

7.2 Potential leakage through liners

The potential seepage rate through the liner system was calculated by JAW (2021f). The seepage rate was estimated based on the method developed by Rowe (2012). Parameters used for the calculation of the expected leakage rate is presented in Table 18. A description of the liner designs is presented in Table 1.

Table 18 Parameters assumed for leakage rate calculations (JAW, 2021f)

Parameter	Assumed value	Unit
Hydraulic conductivity of clay layer	1E-09	m/s
Hydraulic conductivity of attenuation later	1E-04	m/s
Wrinkle width	0.1	m
Length of connected wrinkle	20	m
Wrinkles per hectare	3	

Based on a good liner installation, the estimated seepage through the liner to be installed underneath the Khulu TSF is 2.4E-2m^3/d per ha. If proper quality control is not implemented and the liner system is constructed poorly, this seepage rate may increase to 2.7 m^3/d per ha. The Khulu TSF design includes a below liner drainage system designed to collect seepage through the liner and the relieve possible pressure build up under the liner. The below liner drainage system is designed to remove the seepage volumes calculated.

Similar calculations were made for the Khulu TSF PCD. The results indicate that the seepage rate through the PCD liner is around 4.7E-1 m^3/d per ha. The below liner drainage system is however designed to remove 23 times more seepage than the estimated volume. With good installation, no seepage should escape the liner system and therefore no seepage is expected to reach the underlying aquifers.

JAW (2021f) estimate that the life of the Khulu TSF liner is 69 years, which could be extended to 280 years if the HDPE liner is covered with tailings and not exposed to excessive ambient temperatures. The life of the Khulu TSF PCD is also estimated to be 69 years.

The leakage rates for the Khulu TSF are summarised in Table 19.

Table 19 Estimated leakage rates through liners

Lined facility	Measured area (ha)	Seepage through liner (m^3/d per ha)	Seepage as % of MAP	Seepage as recharge rate (m/d)
Khulu TSF (good installation)	22,5	2.4E-2	4%	7.48E-5
Khulu TSF (poor installation)	22,5	2.7	395%	7.39E-3
Khulu TSF PCD	2,5	4.7E-1	69%	1.29E-4

8 PATHWAYS AND RECEPTORS

Based on the available dataset, the following aquifer pathways are identified for the project (also refer to Figure 19):

- Preferential flow along the alluvial aquifer, due slightly elevated permeability. This aquifer is associated with the floodplains of the rivers and streams. The Khulu TSF and PCD footprint areas are located on the alluvium. It is however noted that the designs for the facilities take the interception of seepage above and below the liners into consideration.
- Vertical flow through the soil horizon from surface sources of contamination to the underlying aquifers. The rate at which the vertical flow can take place is governed by the vertical permeability of the soils and the weathered aquifer, which was assumed to be 1/10th of the horizontal permeabilities.
- Lateral flow through the weathered and alluvial aquifers to the receiving water bodies, which are the rivers and streams down gradient of the mining area. At the Khulu TSF and PCD, the receiving water body is the Groot Dwars River.
- Vertical flow from the weathered and alluvial aquifers to the underlying fractured rock aquifer. There is no geological evidence that these two aquifers are separated by an impermeable layer. For this reason, it is assumed that the two aquifers are interconnected.
- Once the possible contamination reaches the fractured rock aquifer, the preferential flow paths include the N-S and SW-NE striking faults and the contact zone with the N-S striking dyke. The locations of dykes and faults were inferred from Gap Geophysics (2018) and are discussed above. Aquifer testing data from monitoring boreholes that intersect these structures confirm enhanced aquifer conditions.
- Groundwater will also flow through the rock matrix, but at much lower rates compared to the preferential pathways listed above. Flow in the rock matrix is considered insignificant in the context of this study.

The following receptors were identified:

- Watercourses associated with the rivers and streams, including the Groot and Klein Dwars Rivers.
- The Farm House borehole identified during the hydrocensus is located up gradient of the Khulu TSF and as such will not be affected by any impacts from the operation and management of tailings deposition in this area. No other private boreholes are located between the Khulu TSF and the Groot Dwars River.

9 KEY ASSUMPTIONS AND LITERATURE-BASED DATA INPUTS

The numerical modelling is based on the following assumptions:

- Aquifer parameters were inferred from studies completed at DCM. Aquifer parameters used to construct the numerical model are summarised in Table 16. It is further assumed that the vertical permeability is 1/10th that of the horizontal permeability.
- The source characterisation used for the project was inferred from the existing dataset. The values that will be assigned during simulations are presented in Table 17.
- The potential liner seepage rates for the Khulu TSF and PCD were calculated by JAW (2021f). The designs of the facilities include above and below liner drains, which means that all seepage should be captured and removed before it can impact on aquifers. Scenario modelling will be undertaken as part of this study to estimate the impact of tailings seepage on aquifers should the design measures fail.
- The potential rate at which leachate could leak through liners installed at the Northern TSF and

associated dams as well as the URWD and LRWD was calculated based on published information, as discussed in iLEH (2020).

- Only advective transport of contaminants was simulated. Assumptions made regarding advection, are discussed below. While it is acknowledged that attenuation will take place in the soils, there is currently insufficient information available to quantify the extent to which this takes place. As such, simulations are based on the precautionary principle and take the worst-case scenario into consideration.
- The extent of the numerical model is based on natural groundwater barriers, as discussed below. These include water divides as well as rivers and streams.

10 GROUNDWATER MODELLING

10.1 Software used

The numerical modelling was undertaken according to accepted industry principles and standards, including the Department of Water and Sanitation's Best Practice Guideline for Impact Prediction (DWAF, 2008).

The numerical model for the project was constructed using MODFLOW and MT3DMS. MODFLOW is a modular three-dimensional groundwater flow model and MT3DMS a modular three dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3DMS use 3D finite difference discretization and flow codes to solve the governing equations. MODFLOW and MT3DMS is a widely used simulation code, which is well documented. MODFLOW is used to simulate groundwater flow rate and direction. MT3DMS is superimposed on the MODFLOW simulation results and is used to predict the rate and direction of contaminant movement in the aquifers.

10.2 Model set-up, boundaries and geometric structure

The model area was refined into block cells of 10 x 10m around the areas of interest (Figure 20). The finer grid allowed more detailed simulations around the areas of interest. Towards the model boundaries and away from the area of interest, the model grid size increases to 250m.

The point where the Klein Dwars River exits the model in the north was simulated as a constant head boundary. The rest of the model boundaries were included as no-flow boundaries.

Perennial rivers and streams inside the model boundary were simulated with MODFLOW's River Package.

All units used during simulations were presented in metres (length) and days (time).

10.3 Model data integration including groundwater elevation and gradient

The conceptual model discussed above was used to construct the numerical model for the project area. The initial aquifer parameters used are presented in Table 16. These were gradually adjusted during calibration, as discussed below.

The topographical surface was interpolated from the Digital Terrain Model (DTM) (i.e. the surface topography) and incorporated into the model to ensure that the elevations of the package used to simulate the streams reflect the site conditions.

The geology included in the model was inferred from the data presented in Figure 7. Aquifer parameters for the fractured aquifer and the matrix were determined during the model calibration process.

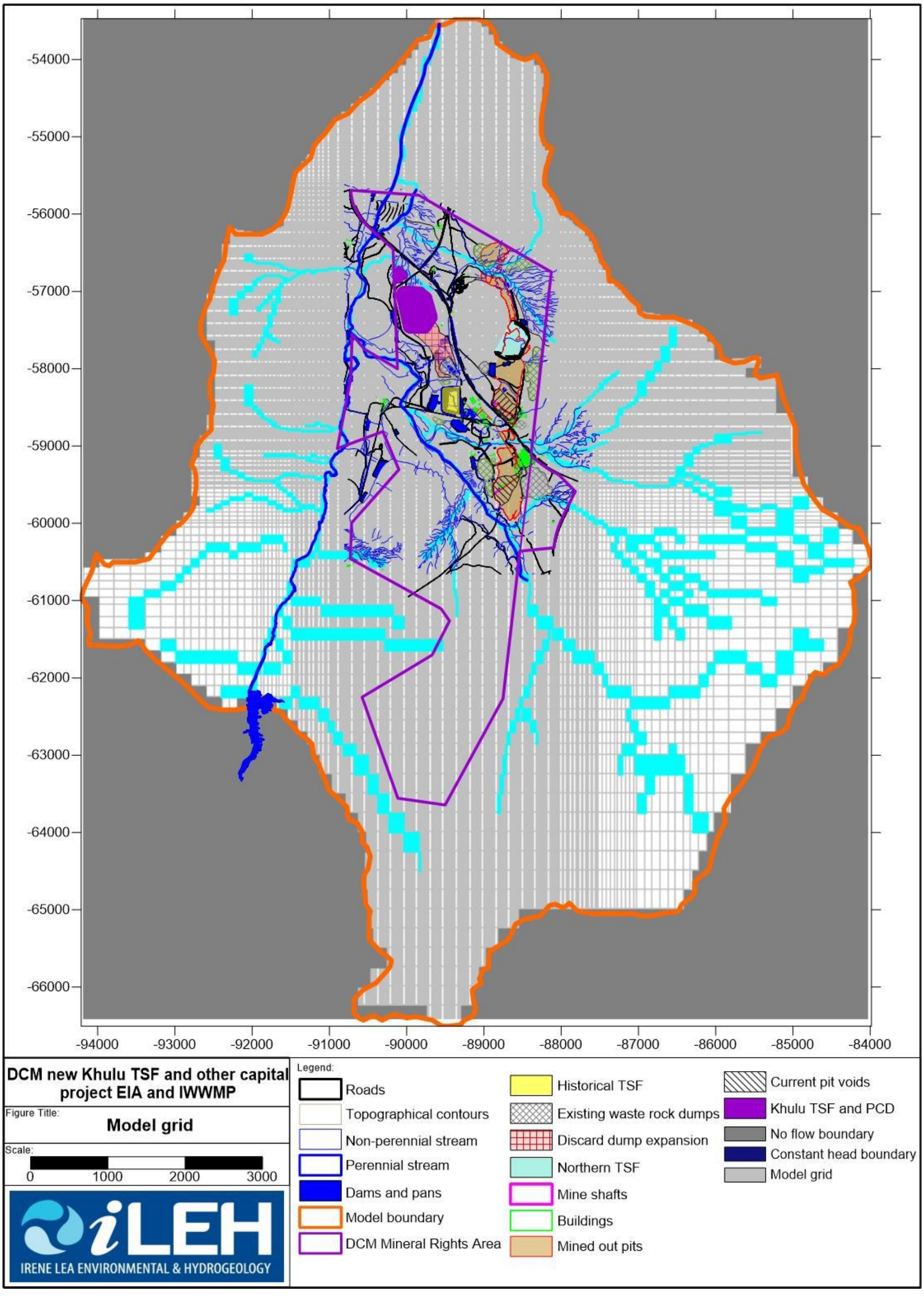


Figure 20 Model grid

10.4 Numerical model

10.4.1 Calibration results

Calibration of a numerical model refers to the demonstration that the model is capable of reproducing field-measured data, which are the calibration values. Calibration is achieved when a set of parameters, boundary conditions, source terms and stresses are found that produce simulated heads and concentrations that match field measured data within the calibration criteria set for the project. This is an important step in the modelling project, which ensures that model results are reliable. The calibration criteria set for the project to remove the historical TSF are presented in Table 20.

Table 20 Flow model calibration criteria

Requirement	Acceptability criteria	Compliance
Model convergence	Maximum change in head of 0,001m	Complied with (see discussion below)
Water balance	Difference between inflow and outflow <1%	Complied with (see discussion below)
Root Mean Square Error	<5m for targets	Complied with (see discussion below)
Calibration error	80% of targets with <5m error between simulated and measured head	Complied with (see discussion below)

Model calibration was undertaken with field-measured groundwater levels from the latest monitoring dataset. Both steady state and transient calibration was completed. The results of the calibration process are presented in Table 20 and Figure 21. It is shown that 85% of the residuals are within the 5m error set as a calibration criterion. The Root Mean Square Error of the residuals is 3,5 which complies with the calibration criteria.

Table 20 Calibration results

Borehole ID	Simulated head (mamsl)	Measured head (mamsl)	Residual (m)
DRM1	916,02	911,07	4,95
DRM2	911,20	906,25	4,95
DRM3	920,56	916,65	3,91
DRM4	931,40	930,48	0,92
DRM5	927,77	930,79	-3,02
DRM6	935,46	931,04	4,42
ASDW1	945,39	942,04	3,35
ASDW2	947,22	946,62	0,60
ASDW3	924,78	926,86	-2,08
ASDW4	951,33	955,60	-4,27
ASDW5	925,27	923,51	1,76
ASDW6	927,93	925,86	2,07
ASDW7	*954,21*	956,50	-2,29
ASDW9	922,64	921,27	1,37
ASDW10	923,37	931,60	-8,23
ASDW11	945,70	940,08	5,62
DRM7	936,98	932,37	4,61
DRM8	929,46	921,39	8,07
DRM9D	920,37	921,50	-1,13
DRM9S	920,32	918,85	1,47
ASDWBH12	917,93	917,73	0,20
DRM10S	918,89	916,92	1,97
DRM11D	914,12	909,22	4,90
DRM11S	915,19	910,34	4,85
DRM12D	912,60	912,10	0,50
DRM12S	914,80	911,98	2,82
DRM13D	922,43	914,84	7,59
DRM13S	918,84	914,20	4,64
DRM14D	930,01	925,16	4,85
DRM14S	926,55	925,00	1,55
DRM15D	911,47	911,60	-0,13
DRM15S	913,17	910,48	2,69

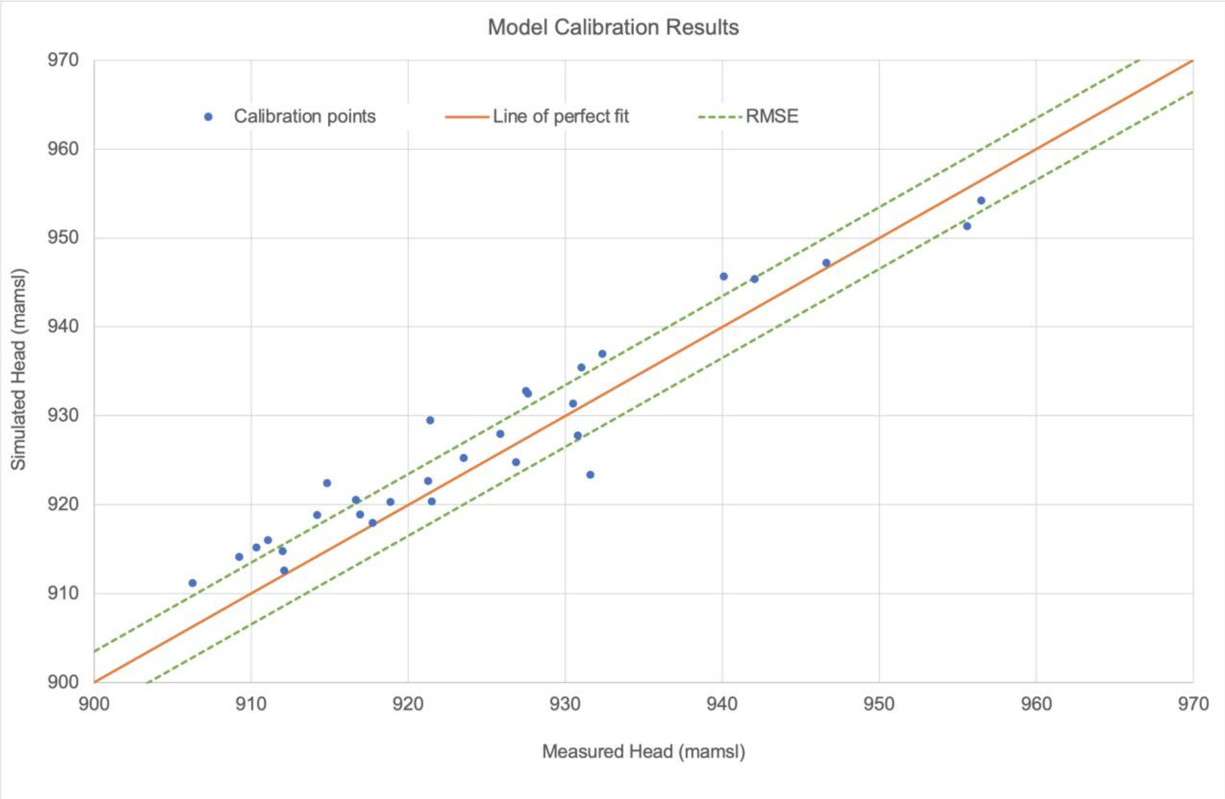


Figure 21 Model calibration results

The model was also calibrated to match the vertical reaction between the shallow weathered and deeper fractured rock aquifers

The model convergence of 0,001m was achieved during calibration. The water balance error obtained at the end of calibration was 0,004, as presented in Table 21.

Table 21 Model water balance output

Flow term	Inflow (m^3/d)	Outflow (m^3/d)	Balance (m^3/d)
Storage	2.08E+03	6.21E+03	-4.13E+03
Constant head	0,00E+00	7.97E+01	-7.97E+01
Wells	0,00E+00	6.62E+02	-6.62E+02
Drains	0,00E+00	6.61E+02	-6.61E +03
Recharge	1.08E+04	0,00E+00	1.08E+04
River leakage	2.44E+02	5.56E+03	-5.32E+033
SUM	2,05E+04	2,05E+04	-1,40E+00
Discrepancy	0,004		

10.4.2 Model sensitivity

A sensitivity analysis was completed on the DCM model in order to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses and boundary conditions. The level of heterogeneity of the aquifer material can never be accurately measured with field data. The uncertainty of the impact of heterogeneity on simulations is therefore assessed as part of the sensitivity analysis.

The results of a sensitivity analysis can be used to identify data gaps and to plan for additional fieldwork, including monitoring requirements, once the modelling has been completed.

The comparative sensitivity for the parameters included during calibration is presented in Figure 22. The comparative sensitivity provides an indication of how sensitive the model is to changes in each parameter compared to the other parameters tested. A low value indicates a low sensitivity and a high value a high sensitivity.

The results indicate that the model is most sensitive to changes in the permeabilities of the regional geological structures that act as preferential flow paths, including the N-S dyke, the SW-NE fault, the rock matrix and the N-S fault.. The level of confidence in the outcome of simulations can be improved if additional monitoring data is obtained to characterise aquifer characteristics. This can be done through ongoing water level monitoring in the existing boreholes as well as monitoring on-site rainfall rates.

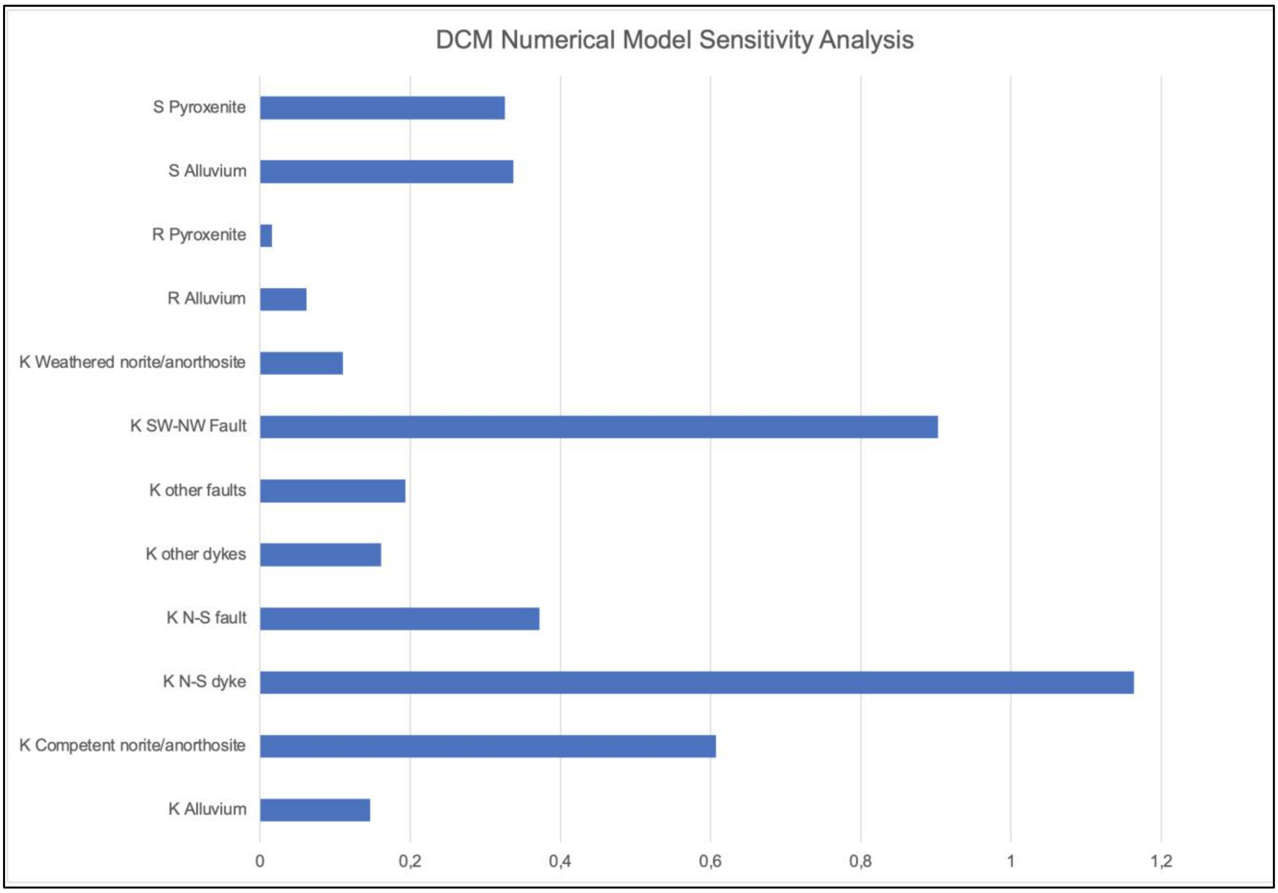


Figure 22 Comparative sensitivity

Modelling further indicates that the contaminant transport model is sensitive to changes in the porosity of the rocks and the geological structures. The porosities used to complete the impact assessment were kept low in order to avoid under-estimating impacts. Adjustments to the porosities were undertaken to match monitoring data. It is however recommended that more work is undertaken to improve the understanding of aquifer porosities to be included in future simulations.

10.4.3 Assessment uncertainties

The accuracy of the modelling project depends on the quality of the input data, the available information, time available to complete the calibration process and to test the outcome of scenario modelling. Even with an unchanging environment, impacts are difficult to predict with absolute certainty. Predictions were calculated with the calibrated flow model, which is a simplified version of reality. The model represents a tool that can be used to assess the impact of the DCM operations on groundwater quality using nitrate as an indicator element and to identify data gaps. The calibration process is discussed above and is thought to be acceptable within the limitations of the study.

The model should be updated and verified with additional monitoring information, as it becomes available. Uncertainties are approached conservatively, based on the precautionary principle, in order to ensure that the predictions and impact assessment in this report addresses the maximum potential impact of the proposed development. The uncertainties in the model include:

- Assumption and estimation uncertainties: These include uncertainties regarding the aquifer parameters.
- Mathematical modelling uncertainties: It is not possible with the available information to quantify the heterogeneity present in the aquifers simulated. For this reason, there are inherent uncertainties in the model. The level of confidence in the model can be improved with the incorporation of additional monitoring data. Of specific importance is aquifer test data to calculate the specific yield and storage coefficient for the aquifers.

10.5 Results of the model

The results of the modelling are discussed below.

11 GEOHYDROLOGICAL IMPACT ASSESSMENT

11.1 Mine Plan Used

The latest mine plan, dated 30 June 2020, was used to complete the geohydrological impact assessment presented in this report. A copy of this map is included in Appendix F as reference. This mine plan focusses only on underground mining from North and South Mine. Access to the underground workings is gained from declines in North and South Pit voids, as indicated on Figure 1.

The simulation stress periods used, which incorporates the mine plan and the Khulu TSF operational life, is presented in Table 22.

For the purpose of the simulations it was assumed that mine closure will be reached in 2046.

Table 22 Simulation stress periods

Period	Timing	Duration	Description
1	1999 - 2003	4 yrs	Opencast mining period. Old TSF, URWD, LRWD and Dam 26 are operational.
2	2003 - 2005	2 yrs	Underground mining from South Mine. Opencast mining continues. Old TSF, URWD, LRWD and Dam 26 are operational.
3	2006 - 2010	4 yrs	Underground mining from South Mine. Opencast mining ceases and pits are partially backfilled. Old TSF, URWD, LRWD and Dam 26 are operational. Dams are lined.
4	2010 - 2012	2 yrs	Underground mining from South and North Mine. Opencast mining ceases and pits are partially backfilled. Tailings backfill to North and South Pits while Northern TSF is constructed Old TSF, URWD, LRWD and Dam 26 are operational. Dams are lined.
5	2012 - 2024	8 yrs	New TSF operational and is lined. URWD, LRWD and Dam 26 are operational. Dams are lined. Underground mining at North and South Mine
6 - 36	2025 - 2046	21 yrs	Future underground mining according to mine schedule in Appendix F. Northern TSF is decommissioned. Khulu TSF constructed and operational Old TSF is removed between 2021 and 2023. URWD, LRWD and Dam 26 are operational. Dams are lined..
37 - 42	2047 - 2157	100 yrs	Long-term scenario post closure in 10 year increments.

11.2 Khulu TSF liner design

The liner design for the Khulu TSF and PCD was completed by JAW (2021f). Details pertaining to the groundwater study are discussed in Section 1.3.1 above. Potential leakage through the liner was estimated by JAW, as presented in Table 19.

Water balance calculations made available by JAW (2021g) indicate that the average annual volume of seepage that will be collected above and below the liner is 18 268m^3/a. This translates to an average daily rate of 2,2 m^3/d per ha of the TSF footprint area.

The liner design caters for collecting seepage in dedicated drains above and below the TSF and PCD liners. Provision is made to capture all seepage in these drains and to transfer the seepage to the PCD. Thus, while the liners are functional, no significant seepage to the aquifers is anticipated.

JAW (2021f) indicates that the life of the Khulu TSF liner is between 69 and 280 years, depending on the extent to which the liner will be exposed to the atmosphere.

If the maximum volume of seepage available for infiltration (2.2m^3/d per ha) is compared to the calculated potential seepage rates through the liner in Table 19, it is shown that the calculated seepage rates through the liner (2.4E-2 – 2.7 m^3/d per ha) are less than the maximum volume of seepage available for infiltration in all cases except for the poorly installed liner installation scenario. If this is the case, it can be concluded that the volumes reported in Table 19 will seep into the underlying aquifers if the liner fails. If the liner is poorly installed, the maximum available seepage volume can potentially infiltrate (2.2m^3/d per ha).

Based on the above, three scenarios will be evaluated to test the impact of liner failure on the aquifers:

- **Scenario 1:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere is managed and limited to a minimum, resulting in a life of liner of 280 years. During this time, it is assumed that seepage will be collected above and below the TSF and PCD liner and that this water will be transferred to the PCD. No seepage is therefore expected to infiltrate to the underlying aquifers. This is considered the best case scenario.
- **Scenario 2:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers according to the rates presented in Table 19.
- **Scenario 3:** Poor liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers at the maximum rate. This is considered the worst case scenario.

In addition to the three scenarios listed above, a no project option was also evaluated. During this simulation, it was assumed that the Khulu TSF and PCD will not be constructed.

11.3 Rehabilitation measures considered during simulations

In order to integrate the impact of other activities that may impact on groundwater quality during simulations, the 2020 Annual Rehabilitation Plan (DWE, 2020b) was used to assess rehabilitation measures that will be considered as part of simulations.

Both North and South Pits have been partially backfilled, mainly with waste rock. A portion of the pit void at each pit was however used for tailings backfill prior to the construction of the Northern TSF. A section of each pit is also open to facilitate access to the North and South Mine underground workings via portal declines in pit highwalls. The extent of these areas are indicated on Figure 1.

An assessment of the status of rehabilitation on site indicated that the majority of surface mining activities have ceased and the impacted areas were rehabilitated. No concurrent rehabilitation is currently taking place. The main surface activity is tailings deposition on the Northern TSF and discard disposal on the discard dump north of the plant area. No rehabilitation is currently undertaken in these areas. DCM is committed to monitor the effectiveness of the measures implemented on areas already rehabilitated. Monitoring of these areas will be carried out to ensure rehabilitation is successful and does not contribute to water contamination. This includes biodiversity, erosion, surface and groundwater, subsidence and dust monitoring.

DCM has evaluated the impact of reprocessing the historical TSF. This impact was assessed with the numerical groundwater model in 2020 (iLEH, 2020). The following key findings were reported for this planned activity:

- The impact of tailings reclamation is expected to be most significant on the shallow weathered pyroxenite and alluvial aquifers. The impact on the deeper fractured rock aquifer is less pronounced. Groundwater quality in the fractured rock aquifer will most likely be affected by underground mining rather than tailings reclamation.
- This project is not expected to have an impact on groundwater levels and/or quantity, as no groundwater will be abstracted for use during tailings reclamation.
- If the tailings reclamation project is completed successfully, nitrate concentrations in the footprint area of the TSF are expected to reduce by 20% by the end of the life of the DCM operations and by 40% in the long-term, post mine closure.
- The nitrate salt load on the Groot Dwarsrivier is furthermore expected to reduce by 40% as a result of the removal of the TSF.
- Nitrate concentrations in the two abstraction boreholes are furthermore expected to reduce by around 5% as a result of the removal of the TSF.
- If tailings reclamation is not implemented and the TSF is rehabilitated in situ, it is likely that negative impacts on groundwater with a high significance would prevail, especially in the long-term.

The study further recommended that all rehabilitation of the reclaimed historical TSF footprint area must be completed during the decommissioning phase. In terms of groundwater, the rehabilitation must focus on containing dirty water and leachate, preventing the ingress of clean runoff and rainfall to the rehabilitated footprint and avoid ponding over rehabilitated areas. In order to minimise negative long-term impacts associated with the project, it is important to complete tailings reclamation to soil level over the entire footprint. All tailings must be removed during the project. Soil testing and remediation must form part of the rehabilitation phase. Groundwater monitoring must continue post closure to measure the effectiveness of the rehabilitation measures.

Mine-wide, DCM is committed to complete rehabilitation to a level that will ensure restoration of the physical, chemical and biological quality of land and water regimes disturbed by mining (DWE, 2020). This is geared at creating self-sustaining natural ecosystems or alternate land use based on an agreed set of objectives. The short-term rehabilitation objectives include monitoring and maintenance of areas already rehabilitated.

The DCM Rehabilitation and Closure Plan (DWE, 2020c) makes provision for the following activities:

- DCM should undertake concurrent rehabilitation during its operational phase when and where possible.
- Further trials should be conducted during the operational phase to determine other rehabilitation options that could be considered, for example potential alternate grow media and vegetation types.
- Implementation of the groundwater remediation strategy developed by DWE (2019). More details regarding this strategy are provided below. It's main focus is the implementation of

scavenger boreholes to abstract contaminated groundwater and thus reduce impacts on the receiving environment.

- Implementation of water treatment measures. It is estimated that water treatment will be required for a period of 17 years post closure to accommodate the abstraction of contaminated groundwater from the scavenger boreholes.
- Continuation of the monitoring programme implemented at the operations.
- Monitoring and maintenance of rehabilitated areas to be undertaken on an annual basis at least 5 years post mine closure.

11.4 Integration of the Groundwater Remediation Strategy

DWE (2019) developed a Groundwater Remediation Strategy for DCM. The groundwater remediation strategy focusses on implementing measures to reduce nitrate concentration in both the shallow and deeper aquifers through effective source removal. The following scenarios were tested with a numerical groundwater model as part of the study:

- Natural attenuation with source removal: no active remediation was considered as part of this scenario, however DWE avoided the release of further nitrate to the aquifer from sources during simulations. Results indicate that the nitrate plume will eventually enter the surface streams at levels exceeding the DCM WUL conditions. It is therefore concluded that additional intervention will be required as natural attenuation is not effective in reducing nitrate contamination in groundwater to within acceptable levels.
- Insertion of an interception trench: a 5m deep trench was inserted along the Springkaan Spruit and the Groot Dwars River down gradient of the plant area during simulations to test the impact of this option. During simulations it was assumed that water captured in the trench will be removed and treated at the water treatment plant. Results indicate that this option will only be effective in reducing contamination in the shallow aquifers, not in the deeper fractured rock aquifer. The effectiveness of the trench is also linked to the depth to which it can be installed.
- Abstraction of contaminated groundwater from scavenger boreholes: the simulations undertaken involved optimising the abstraction regime in order to minimise operational costs, while maximising plume remediation. Groundwater abstraction from boreholes ASDWBH9, DRM1, DRM3, DRM4, DRM5 and one proposed new borehole was recommended as part of the study. The contaminated groundwater abstracted from the proposed scavenger boreholes is to be treated either at the existing DCM water treatment plant at an estimated cost of R3,1 million or through a wetland at an estimated cost of R8,8 million. Several uses were identified for this water.

It is the intention of the mine to implement the preferred recommendation of this study as soon as possible. This entails the abstraction of contaminated groundwater using scavenger boreholes and treating this water in the water treatment plant operated on site.

DCM has completed fieldwork to obtain measured data with which to finalise this project design (nettZero, 2021). Impact assessments associated with the scavenger borehole project will be addressed in a separate study, as it will focus on reducing nitrate concentrations around the plant area.

11.5 Plume delineation

The modelling results are presented as estimated nitrate concentrations in the weathered as well as the fractured rock aquifers for each scenario tested. In order to define the nitrate concentration that will be used to delineate the plumes, an assessment of the effects of nitrate on human health as well as nitrate concentrations in the receiving surface water in the Groot Dwars River was undertaken.

The effects of nitrate on human health, as described by DWAF (1997) is presented in Table 23. The ranges are slightly different to that prescribed by SANS241:2015, but the information provides an indication of the expected effects with increasing concentrations of nitrate.

Table 23 Effects of nitrate on human health

Aluminium range (mg/l)	Effects
0 – 6	No adverse health effects
6 - 10	Rare instances of methemoglobinemia in infants, no effects in adults. Concentrations in this range is generally well tolerated. The SANS241:2015 standard is 11 mg/l.
10 - 20	Methemoglobinemia may occur in infants. No effects in adults
>20	Methemoglobinemia occurs in infants. Occurrence of mucous membrane irritation in adults

The 11mg/l nitrate concentration contour will also be indicated as reference on the delineated plumes discussed below. This is the SANS241:2015 standard for nitrate for domestic use.

DCM monitoring information indicates that the receiving water quality in the Groot Dwars River already exhibits elevated nitrate concentrations, as shown in Figure 23. Since monitoring commenced in 2009, nitrate concentrations increased from below 6 mg/l on average to above 50 mg/l at present. The average long-term nitrate concentration for this upstream sampling position is 30 mg/l, which exceeds the highest concentration to assess human health presented in Table 23.

It is likely that upstream impacts also affect groundwater quality in the DCM mining area. In order to consider this impact, not associated with the DCM operations, the 30mg/l nitrate concentration contour line will be used to delineate the plumes associated with the operations.

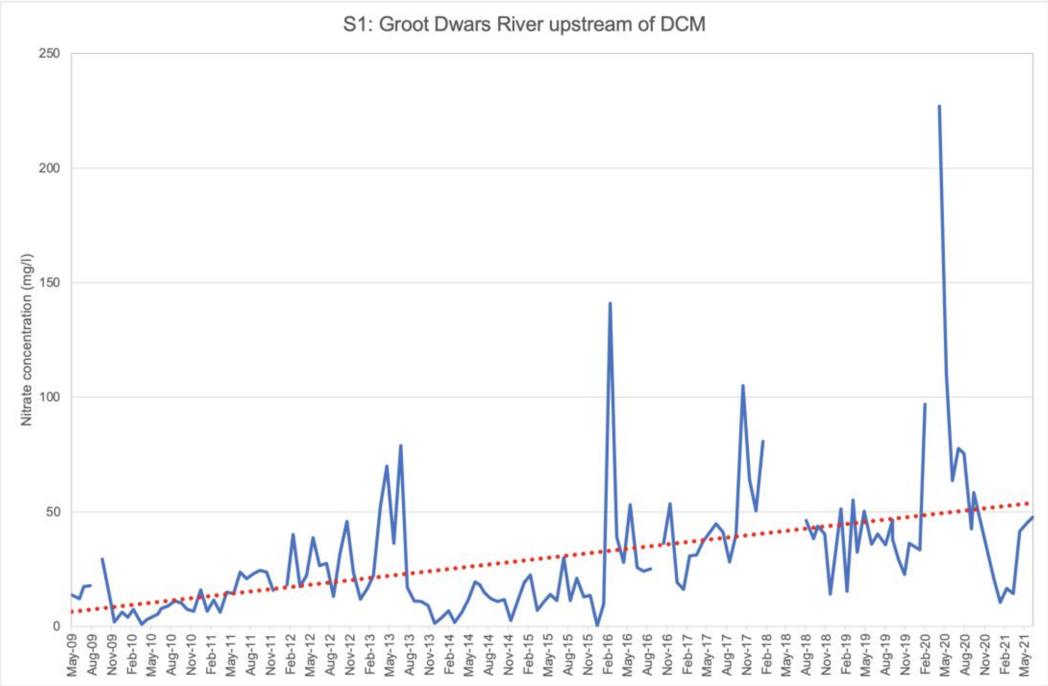


Figure 23 Nitrate concentrations in the receiving water quality

The shape of the plume is defined by aquifer conditions as described above. The alluvium associated with the watercourses is assumed to be a preferential flow path due to a higher anticipated permeabilities compared to for example fresh rock matrix. Flow in this aquifer will be controlled by the elevation of water in the Klein Dwars River and its tributaries. This elevation was inferred from the DTM generated for the project area.

In the fractured rock aquifer the N-S and SW-NE striking faults and the N-S striking dyke are preferential flow paths and were included in the model according to the discussion above. Available information suggests that these regional geological structures do not extend to surface and will therefore not impact on groundwater flow in the weathered aquifer. The exception of this is in the plant area, where elevated transmissivities were calculated for both the shallow weathered and deeper fractured rock aquifer for DRM14S and D. This borehole is situated on the IRUP structure and the N-S striking fault. Infiltration of contaminated water in this area is expected to flow in a northerly direction along the N-S striking fault.

Flow in unfractured rock matrix is expected to be very slow due to low permeabilities/transmissivities.

The following general observations are made, based on the outcome of simulations:

- The shape of the plumes are delineated by the presence of preferential flow paths as well as the permeabilities of the rock formations in the weathered and fractured rock aquifers. The effect of this difference in permeability is that potential contamination will move further in the fractured rock aquifer with time. However, dilution from throughflow of clean groundwater is also expected to play a more significant role compared to that in the weathered aquifer.
- In the weathered aquifer, the flow is largely controlled by the position and the interpolated water level elevation in the Klein Dwars River, as discussed above.
- The simulated extent of the nitrate plume is presented separately for the weathered and fractured rock aquifers in the discussion below.
- At the sources of groundwater contamination on surface, the most significant impact of the project is on the shallow weathered aquifer, including weathered pyroxenite and alluvium. Due to the perceived low rate at which groundwater moves vertically from the weathered to the fractured rock aquifer, the impact on the underlying fractured rock aquifer is less pronounced.
- Long-term simulations were run for a period of 300 years after mine closure in order to assess the long-term impact of liner failure on groundwater quality. If the liners are well installed and not exposed to the atmosphere for excessive periods of time, the life of the liner is expected to be 280 years (JAW, 2021f).

11.6 Results of the geohydrological impact assessment

11.6.1 Anticipated impacts at the end of the operational phase

The model was used to assess the impact on groundwater quality at the end of the operational phase. This was assumed to coincide with the end of life of the Khulu TSF, which is indicated as 21 years in JAW (2021f).

During the operational phase, it is assumed that the liner at the TSF and the PCD will remain in tact and that seepage from the tailings material will be collected above and below the drains to installed. As such, no significant seepage from the Khulu TSF to the underlying aquifers is expected.

Impacts associated with other sources of contamination to groundwater, including the plant, the historical TSF (before it is reworked), the dirty water dams, pit backfill areas and the underground workings are assumed to continue to impact over the life of the operations. It is noted that DCM is in the process of developing a groundwater remediation strategy to reduce nitrate concentrations in groundwater in the plant area. This project will be evaluated in a separate study.

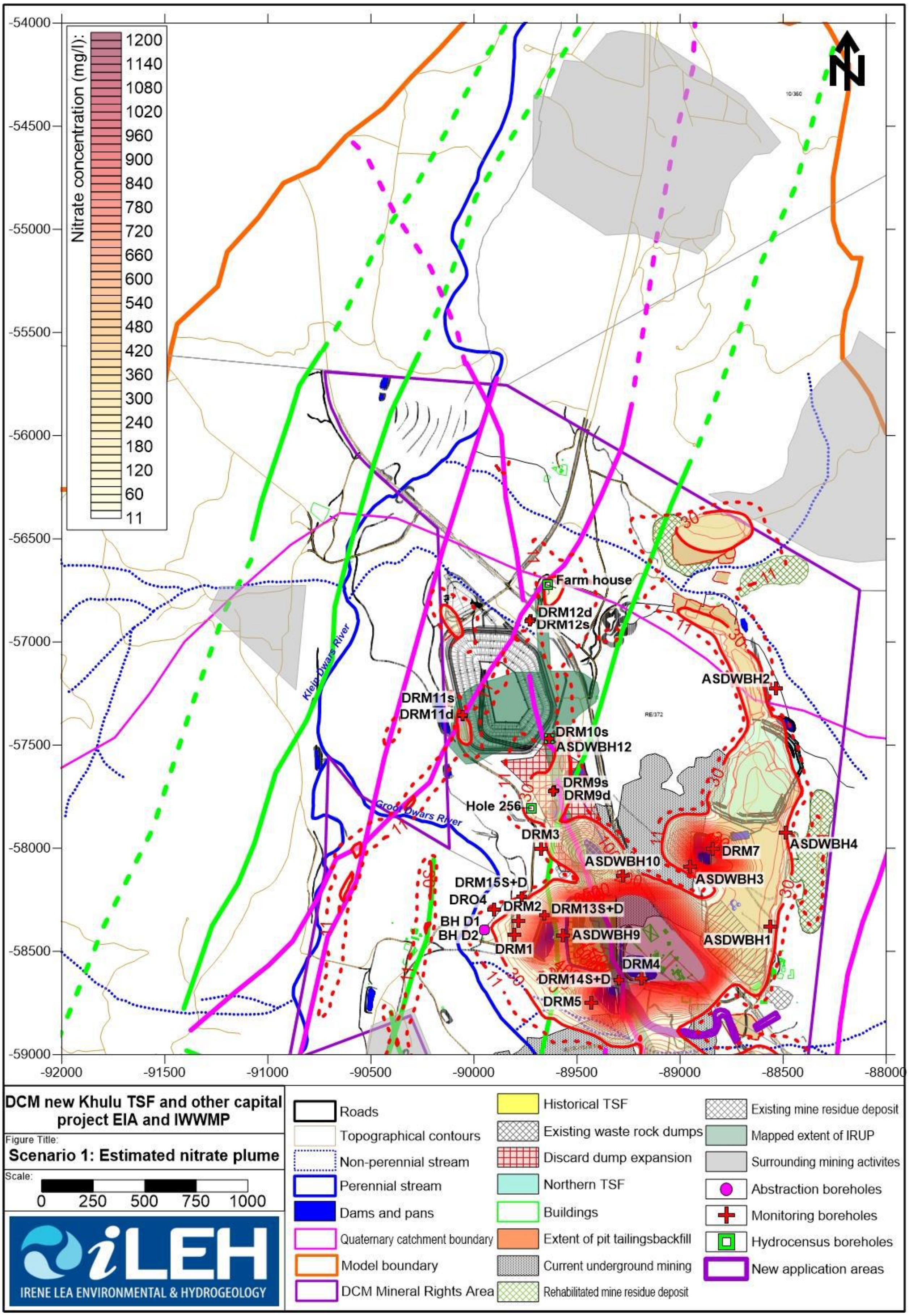


Figure 24 Simulated NO_3 plume at the end of the operational phase in the weathered aquifer

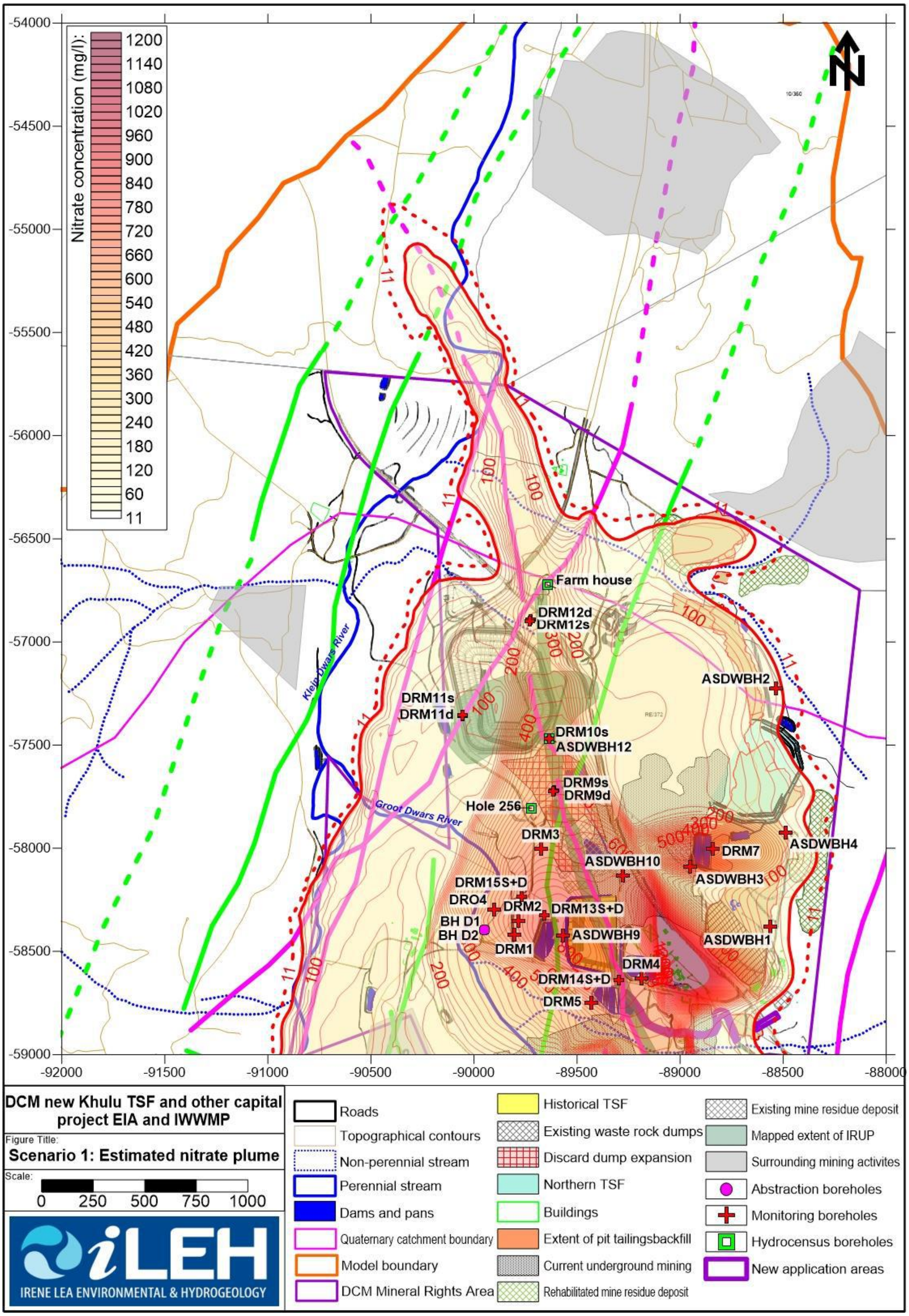


Figure 25 Simulated NO_3 plume at the end of the operational phase in the fractured aquifer

The results of the simulations to estimate the impact at the end of the operational phase, as presented in Figures 24 and 25, indicate the following:

- Nitrate contamination in the weathered aquifer will be contained to the plant and opencast mining areas, as indicated in Figure 24. Based on the current characterisation of the alluvial aquifer, it is unlikely that nitrate concentrations in the weathered aquifer would exceed 11 mg/l in the vicinity of the Groot Dwars River.
- No significant impact is expected on the shallow weathered and alluvial aquifers during the operational phase. Nitrate concentrations in these aquifers at the Khulu TSF footprint are expected to remain below 11 mg/l in general.
- No impact on groundwater quality is expected in the vicinity of the Klein Dwars River west and northwest of the Khulu TSF and PCD at the end of the operational phase.
- Based on the conceptualisation of preferential groundwater flow in the fractured rock aquifer, the nitrate plume is expected to migrate in a northerly direction along the N-S striking fault. This contamination originates from the plant, historical TSF, dirty water dams, open cast and underground mining areas and not from the Khulu TSF and PCD.
- At the Khulu TSF footprint, nitrate concentrations may increase to above 400 mg/l along the fault line. It is likely that the plume may migrate more than 500m north of the DCM mineral rights boundary by the end of the operational phase. The extent to which contamination may migrate from existing mining and mineral processing activities will depend on the manner in which the sources to groundwater are managed as well as the permeability and porosity of the preferential flow path.
- As noted above, DCM is in the process of developing a groundwater remediation strategy to address existing nitrate contamination. This strategy will be addressed in a separate study, but it will be designed to reduce the impact on the fractured rock aquifer in the long-term.
- Nitrate concentrations in the Farm House borehole may increase to around 200mg/l by the end of the operational phase. At present, the nitrate concentration in this borehole is 46 mg/l.

11.6.2 Long-term impacts

11.6.2.1 No project option

A modelling scenario was run to estimate the long-term impact on groundwater quality if the Khulu TSF project does not go ahead. The estimated extent of the nitrate plumes 300 years after mine closure in the weathered and fractured rock aquifers are presented in Figures 26 and 27. The following is concluded from the simulations presented:

- The simulations indicate that the nitrate plume will recede in the long-term in the weathered aquifer. Nitrate concentrations are expected to reduce to below 60 mg/l in the plant area if all sources of contamination are removed at mine closure as part of the rehabilitation programme.
- At the Khulu TSF, nitrate concentrations are not expected to significantly exceed 11 mg/l in the long-term for this scenario.
- The impact on the Groot and Klein Dwars River is expected to reduce significantly in the long-term for this scenario. Nitrate concentrations in groundwater reaching these rivers in the weathered and alluvial aquifers are not expected to exceed 11 mg/l.
- Long-term impacts associated with leakage through the Northern TSF and the associated dirty water dams liners are however expected to impact on groundwater quality in the long-term. A detailed discussion of this impact falls outside the scope of this report.
- The plume in the fractured aquifer is expected to continue to migrate along the preferential flow paths and to a lesser extent in unfractured rock matrix in the long-term. Nitrate concentrations are however expected to reduce inside the affected area as a result of plume dilution from recharge of fresh rain water and groundwater throughflow. Over the footprint area of the Khulu TSF, nitrate concentrations are expected to reduce to below 160 mg/l on average.

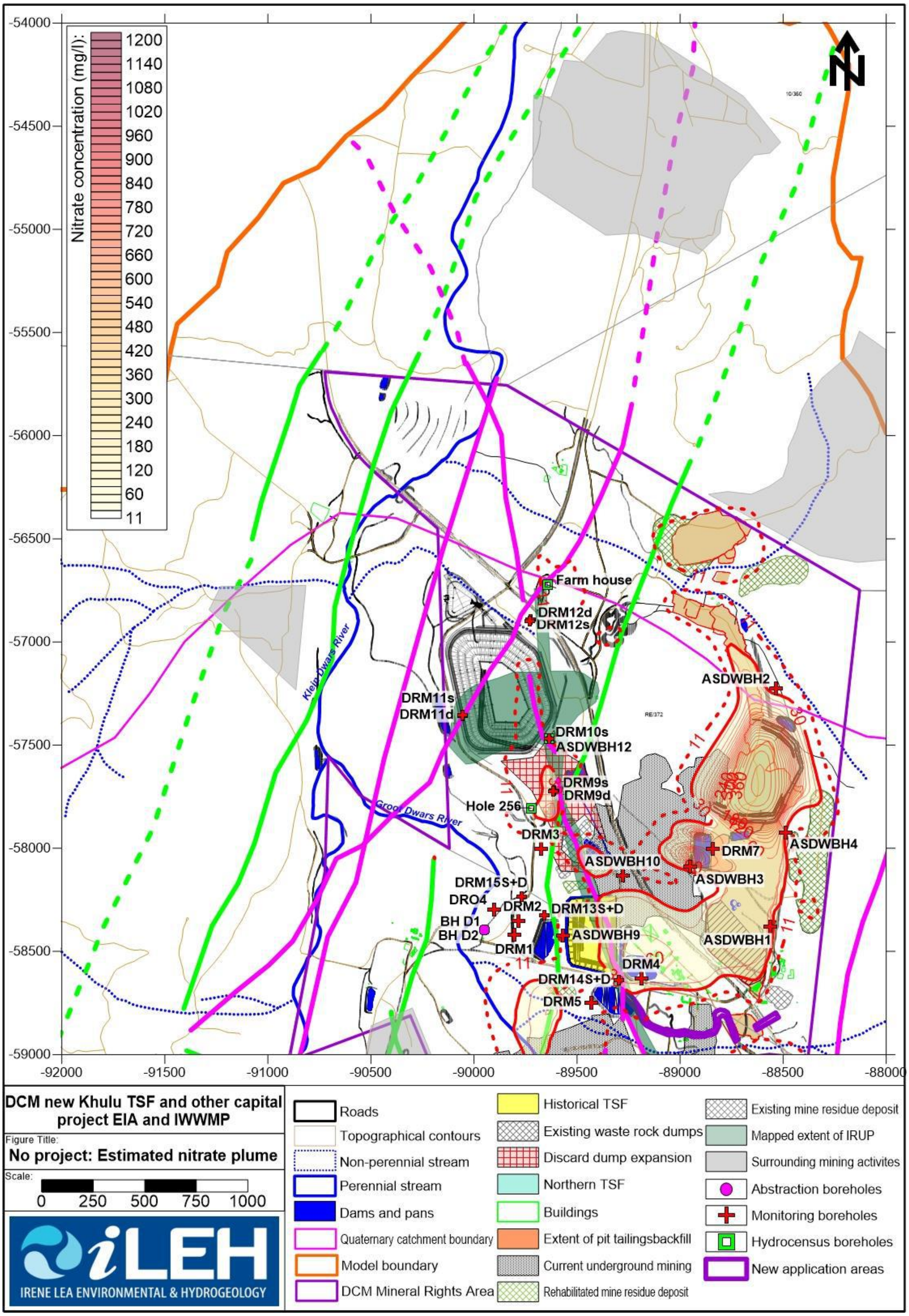


Figure 26 **No project: Simulated NO_3 plume 300 years after mine closure - weathered aquifer**

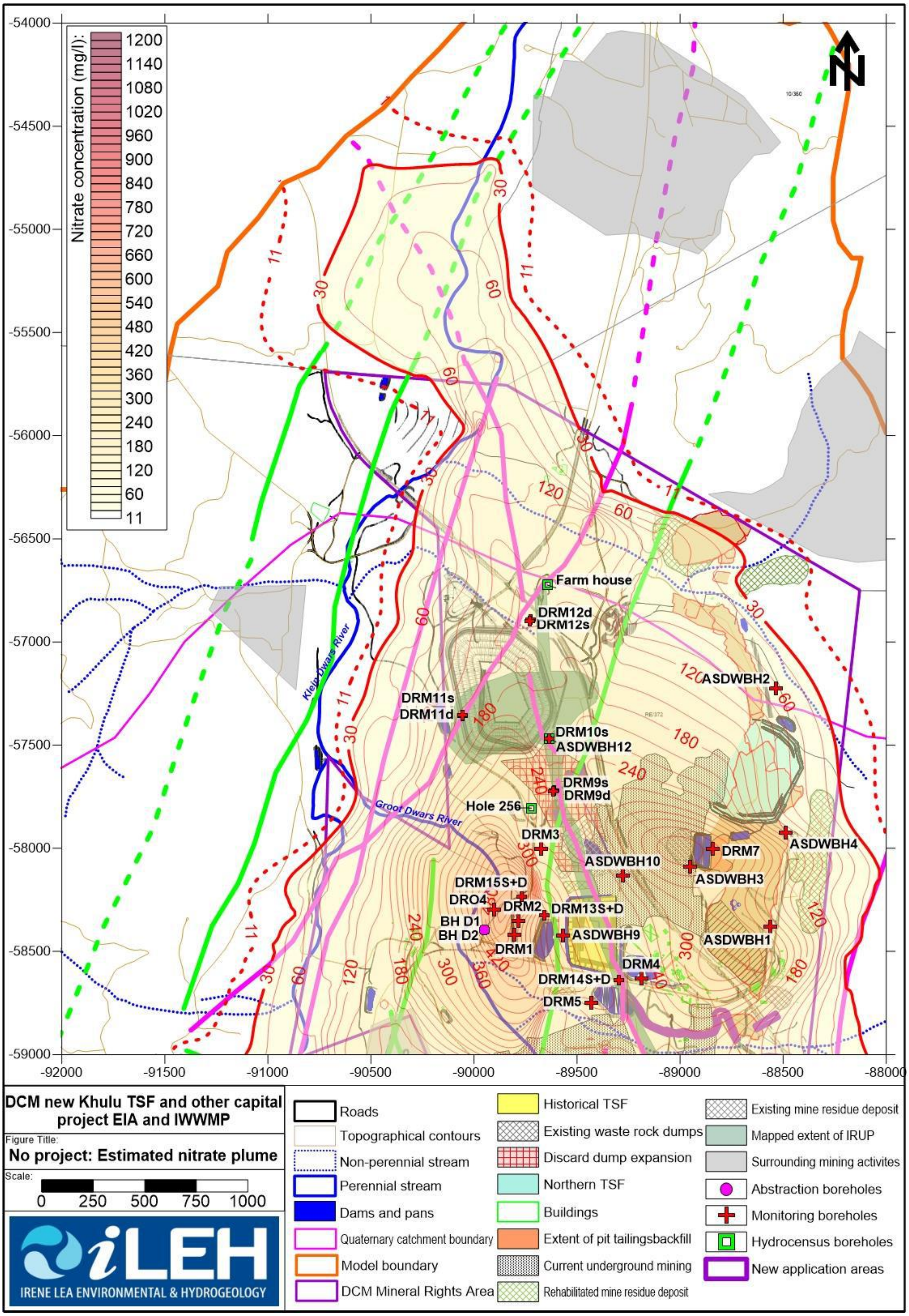


Figure 27 No project: Simulated NO_3 plume 300 years after mine closure - fractured aquifer

11.6.2.2 Scenario 1: Good liner installation and limited exposure to the atmosphere

The long-term impacts on groundwater associated with the Khulu TSF and PCD for Scenario 1 are presented in Figures 28 and 29.

This scenario assumes that the TSF and PCD liners will fail after 280 years. In this event, seepage from the TSF and PCD may reach the underlying aquifers at a rate of 2.4E-2 m^3/d per ha, as indicated in Table 19 (JAW, 2021f).

The following is concluded from the results of the simulations:

- Seepage through the TSF and PCD liners are expected to increase nitrate concentrations in the weathered aquifer underneath the footprint areas. Nitrate concentrations may increase to above 600 mg/l over the footprint areas in the weathered and alluvial aquifers in the long-term.
- The nitrate plume is expected to migrate in a north-westerly direction towards the Klein Dwars River in the weathered and alluvial aquifers. At 300 years after mine closure, simulations suggest that it is unlikely that groundwater with nitrate concentrations exceeding 11 mg/l would reach the Klein Dwars River from the Khulu TSF and PCD to any significant extent.
- The effect of liner failure at the Khulu TSF and PCD on the fractured rock aquifer is not expected to add significantly to the pollution load associated with other DCM mining and mineral processing activities.
- Nitrate concentrations may increase to above 180 mg/l in the fractured rock aquifer as a result of infiltration over the Khulu TSF and PCD footprint areas. This is an estimated 20 mg/l increase in concentration compared to the no project option discussed above.
- The nitrate plumes originating from the Khulu TSF and PCD are expected to migrate in a northerly direction along the preferential flow paths identified. Contamination along these geological structures are however expected to be dominated by DCM mining and mineral processing activities and not significantly as a result of seepage from the Khulu TSF and PCD.
- In the long-term, nitrate concentrations in the Farm House borehole could reduce to below 100 mg/l from the anticipated 200 mg/l at the end of the operational phase. This borehole is located along a preferential groundwater flow path, which means that long-term plume migration will result in elevated nitrate in this borehole under the rehabilitation measures implemented.
- The nitrate plume is expected to migrate more than 900m north outside the DCM mineral rights boundary along the N-S striking in the long-term for this scenario.
- Additional measures to reduce nitrate concentrations associated with the plant and historical TSF areas will be investigated and developed as part of the DCM Groundwater Remediation Strategy, which will be undertaken in a separate study. These measures will be focussed around the preferential flow paths identified and will be geared at reducing long-term contamination.

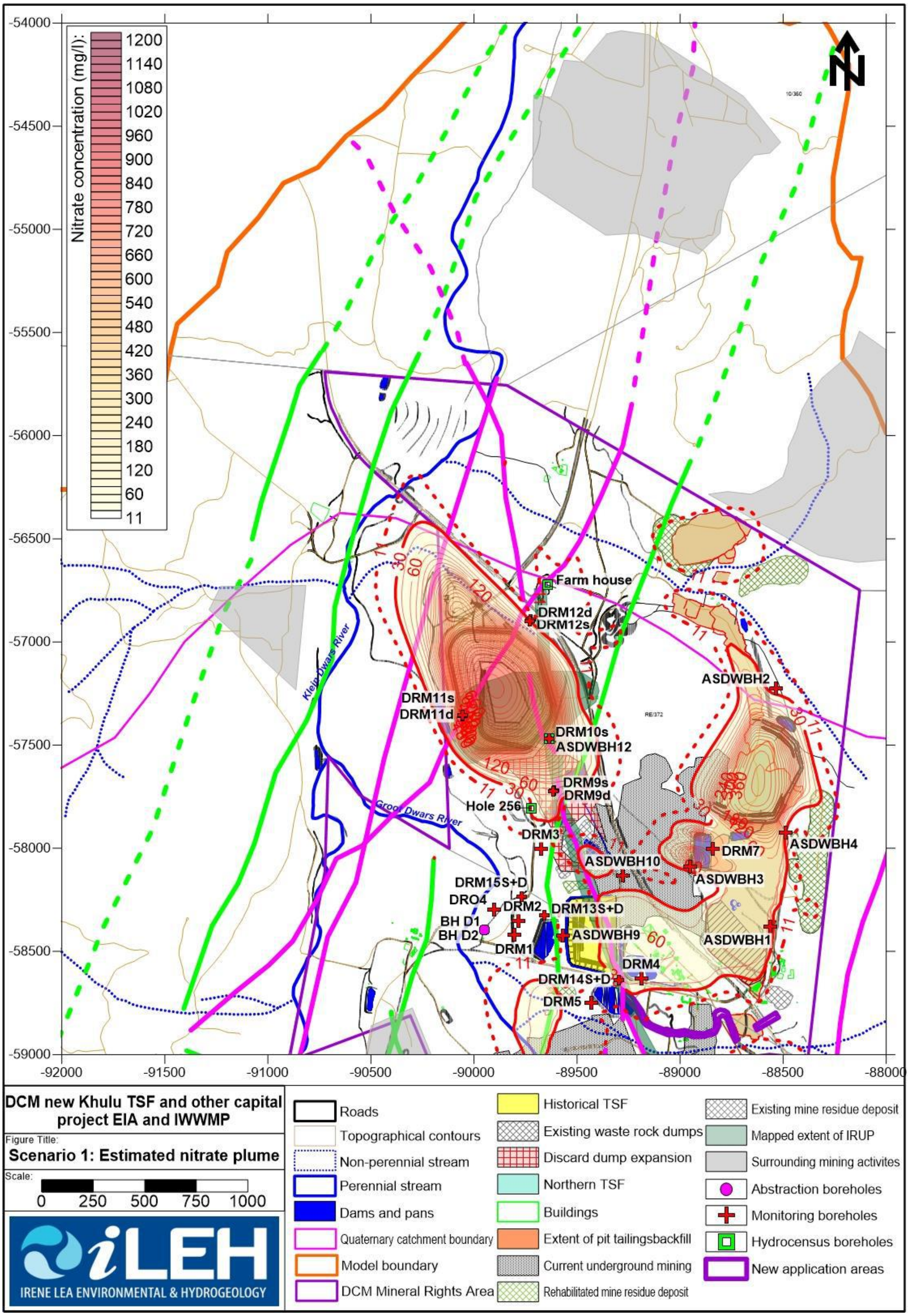


Figure 28 Scenario 1: Simulated NO_3 plume 300 years after mine closure - weathered aquifer

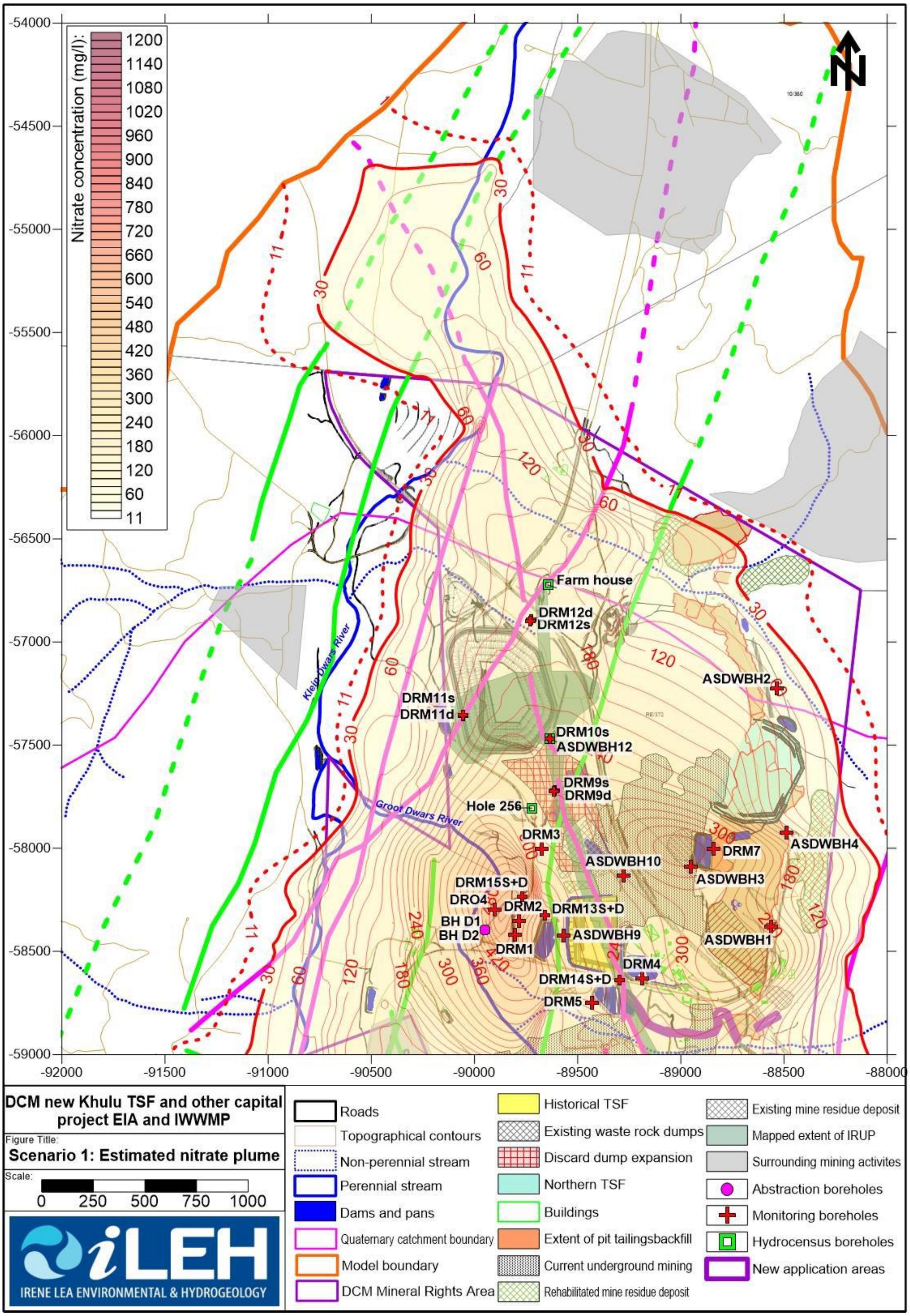


Figure 29 Scenario 1: Simulated NO_3 plume 300 years after mine closure - weathered aquifer

11.6.2.3 Scenario 2: Good liner installation with exposure to atmosphere

Scenario 2 evaluates the long-term impact if exposure to the atmosphere results in a reduced liner life of 69 years. At this time, it is assumed that the liner would leak at a rate of 2.4E-2 m^3/d per ha if the liner installation is good (JAW, 2021f).

The results of the long-term simulations are presented in Figures 30 and 31. These figures indicate the anticipated extent of the nitrate plumes 300 years after mine closure in order to ensure comparison with the output of other scenarios tested.

The following is concluded from the simulations presented:

- The extent of the impact on groundwater quality for this scenario is similar to that reported for Scenario 1. The extent of the plume is driven by aquifer parameters like permeability and porosity and to a lesser extent by the concentration gradient for Scenarios 1 and 2. This is due to the fact that the rate of seepage from the Khulu TSF liner for good installation is reported to be comparatively low, which means the concentration gradient from the source to the aquifer is low.
- Nitrate concentrations inside the delineated plumes are however expected to increase for this scenario compared to Scenario 1, as the seepage will take place for a longer period of time. The liner failure occurs after 69 years for this scenario, compared to after 280 years for Scenario 1.
- In the weathered and alluvial aquifers, nitrate concentrations may increase to above 800 mg/l in the long-term for this scenario. This is an increase of 200 mg/l compared to Scenario 1.
- The contamination is expected to migrate in a north-westerly direction towards the Klein Dwars River in the long-term. Nitrate concentrations are however not expected to significantly exceed 11 mg/l in groundwater reaching the Klein Dwars River in this time.
- The nitrate plume in the fractured rock aquifer will migrate preferentially along the N-S striking fault and the other preferential flow paths identified. As reported for Scenario 1, the nitrate plume may migrate more than 900m north along the N-S striking fault outside the DCM mineral rights boundary in the long-term.
- Nitrate concentrations in the fractured rock aquifer immediately underneath the Khulu TSF and PCD may increase to above 240 mg/l for this scenario. This is an increase of 60 mg/l in nitrate concentration compared to Scenario 1.
- Nitrate concentrations in at the Farm House borehole may decrease to around 170 mg/l in the long-term compared to the 200 mg/l expected at the end of the operational phase. This is however an increase of around 70 mg/l compared to the results of Scenario 1.
- Plume movement in unfractured rock matrix is expected to below. Nitrate concentrations in the fractured rock aquifer immediately down gradient of the Khulu TSF and PCD are not likely to exceed 11 mg/l near the Klein Dwars River in the long-term.

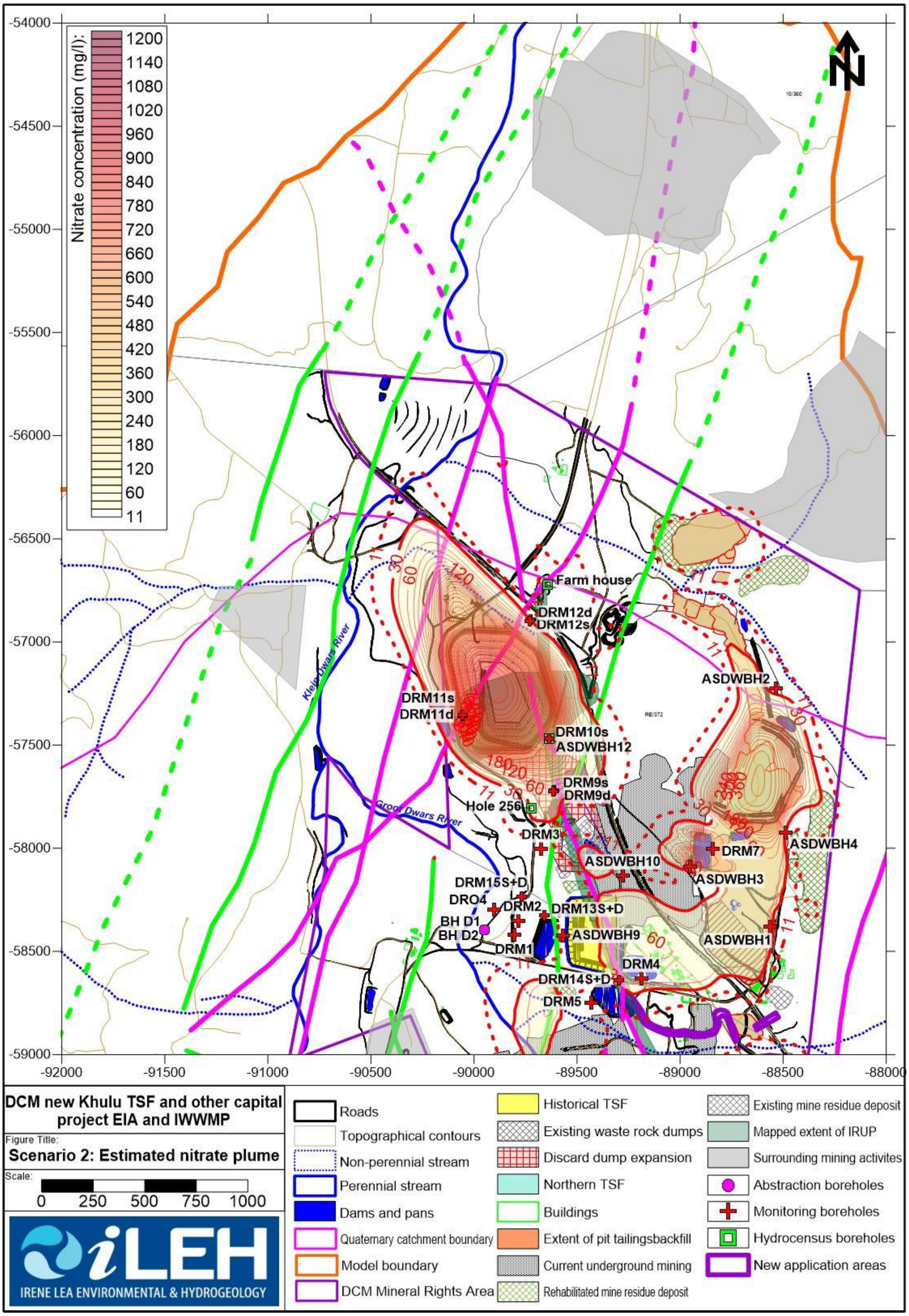


Figure 30 Scenario 2: Simulated NO_3 plume 300 years after mine closure - weathered aquifer

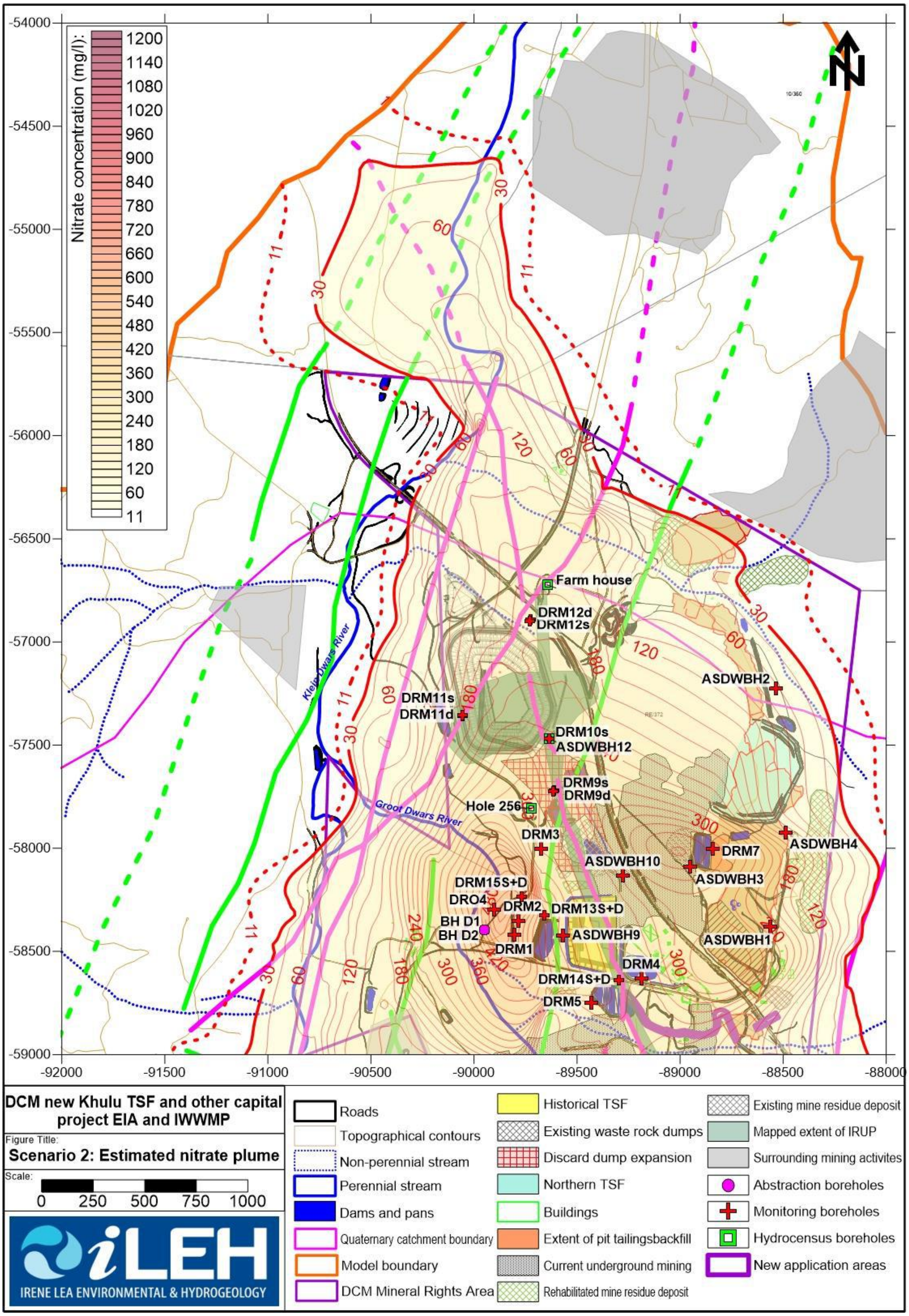


Figure 31 Scenario 2: Simulated NO_3 plume 300 years after mine closure - fractured aquifer

11.6.2.4 Scenario 3: Poor liner installation

This scenario tests the effect if the Khulu TSF and PCD liners are poorly installed and exposed to the atmosphere. Under these conditions, the life of the liner is 69 years. At this stage, the maximum volume of seepage could infiltrate to the underlying aquifers at a reported rate of 2.2 m^3/d per ha. This is the maximum volume of seepage calculated by JAW (2021f and g).

The results of the simulations for Scenario 3 are presented in Figures 32 and 33.

The following is concluded from the simulation results:

- Liner failure and maximum seepage rates to the underlying aquifers for this scenario is expected to result in a significant negative impact on groundwater quality. With the increased seepage rate, the concentration gradient at the Khulu TSF and PCD footprint will increase significantly, resulting in an accelerated spread of contamination in the long-term. The plume is also expected to migrate radially away from the Khulu TSF footprint area due to the high infiltration rates. A mound in groundwater levels is expected around the footprint in this case. It is noted that the rate of infiltration is significantly high an is most probably not a reality.
- The extent of the impact on the weathered and alluvial aquifers is expected to significantly increase for this scenario. Over the footprint area, nitrate concentrations may increase to 1500 mg/l in the long-term.
- The plume is expected to migrate in a north-westerly and westerly direction towards the Klein Dwars River. Nitrate concentrations in groundwater reaching the Klein Dwars River are expected to increase to above 30 mg/l over a length of 250m along the river. In places, nitrate concentrations in groundwater reaching the Klein Dwars River in the weathered and alluvial aquifers could exceed 200 mg/l for this scenario. This is expected to result in a noticeable impact on surface quality in the long-term.
- The plume is also likely to reach the Groot Dwars River southwest of the Khulu TSF due to the anticipated radial flow from the footprint area. Groundwater reaching the Groot Dwars River may have nitrate concentrations exceeding 30 mg/l over a stretch of around 200m along the river. In places, nitrate concentrations in groundwater may increase to above 150 mg/l at the river. This is also expected to result in a noticeable impact on surface water quality in the long-term.
- The high seepage rates from the Khulu TSF and PCD are also expected to result in significant vertical flow to the underlying fractured rock aquifer. This is different to the outcome of Scenarios 1 and 2, where the concentration gradient under lower seepage rates did not result in significant impacts on the fractured rock aquifer.
- Once the nitrate concentrations reach the fractured rock aquifer, preferential flow is expected along the N-S and the SW-NE striking fault lines.
- Over the Khulu TSF and PCD footprint areas, nitrate concentrations may increase to above 1200 mg/l in the fractured rock aquifer for this scenario, which is a significant increase from the impacts associated with Scenarios 1 and 2.
- Along the N-S striking fault, nitrate concentrations may exceed 700 mg/l in the long-term. This plume is also expected to migrate more than 1300m north and outside the DCM mineral rights area, as indicated.
- Nitrate concentrations in the SW-NE striking fault may increase to above 1000 mg/l in the long-term. In addition, a nitrate plume is expected to migrate along this structure in a southwesterly direction towards the Groot Dwars River. In the long-term, nitrate concentrations may increase to around 450 mg/l in the fault line at the intersection with the Groot Dwars River.
- The groundwater mound that will develop underneath the Khulu TSF and PCD footprint areas is also expected to drive migration of the nitrate plume in the unfractured rock matrix towards the Klein Dwars River west of the site. On the long-term, this could result in an increase in nitrate concentrations in the fractured rock aquifer at the river of more than 30 mg/l, possibly as high as 50 mg/l.

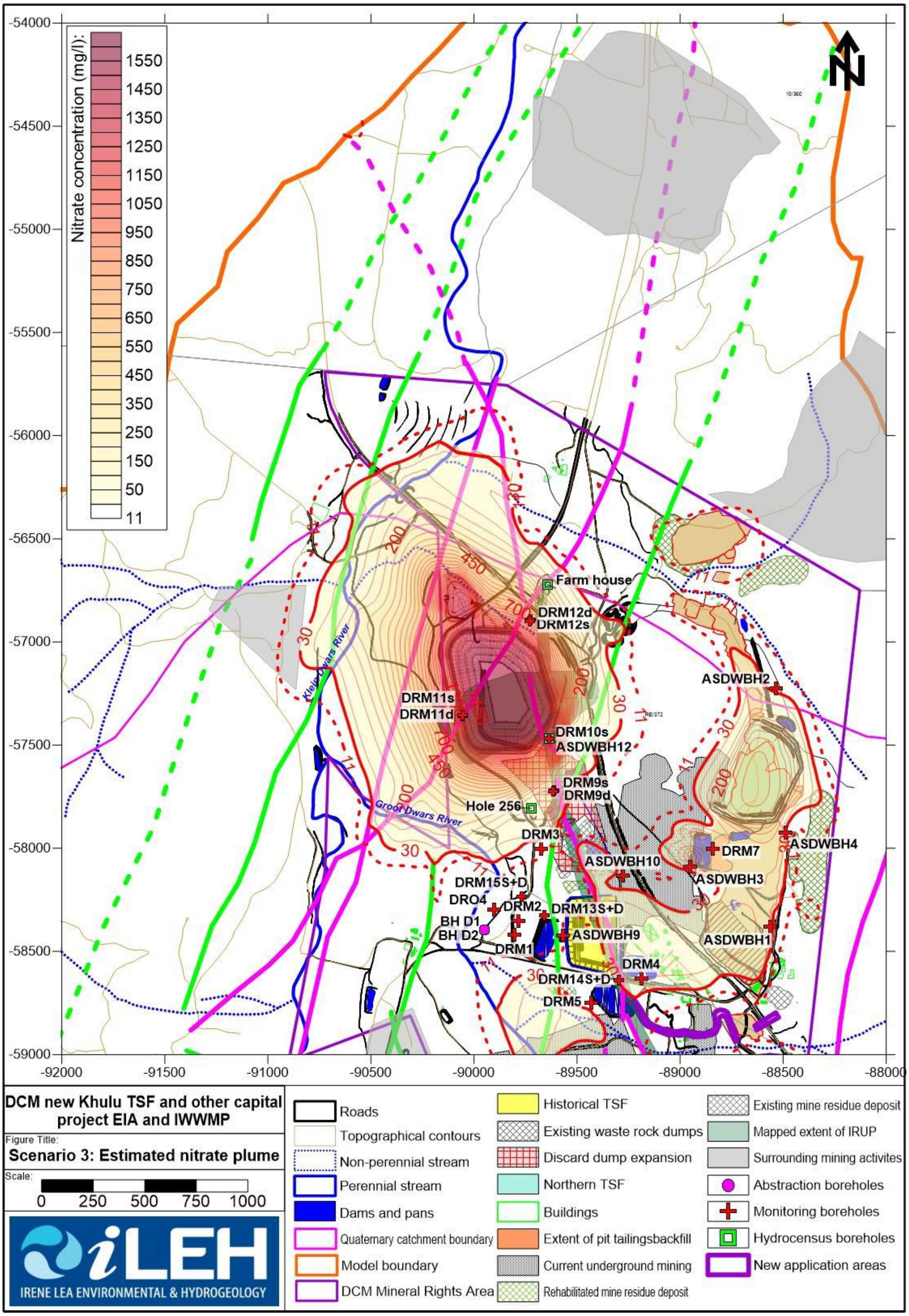


Figure 32 Scenario 3: Simulated NO_3 plume 300 years after mine closure - weathered aquifer

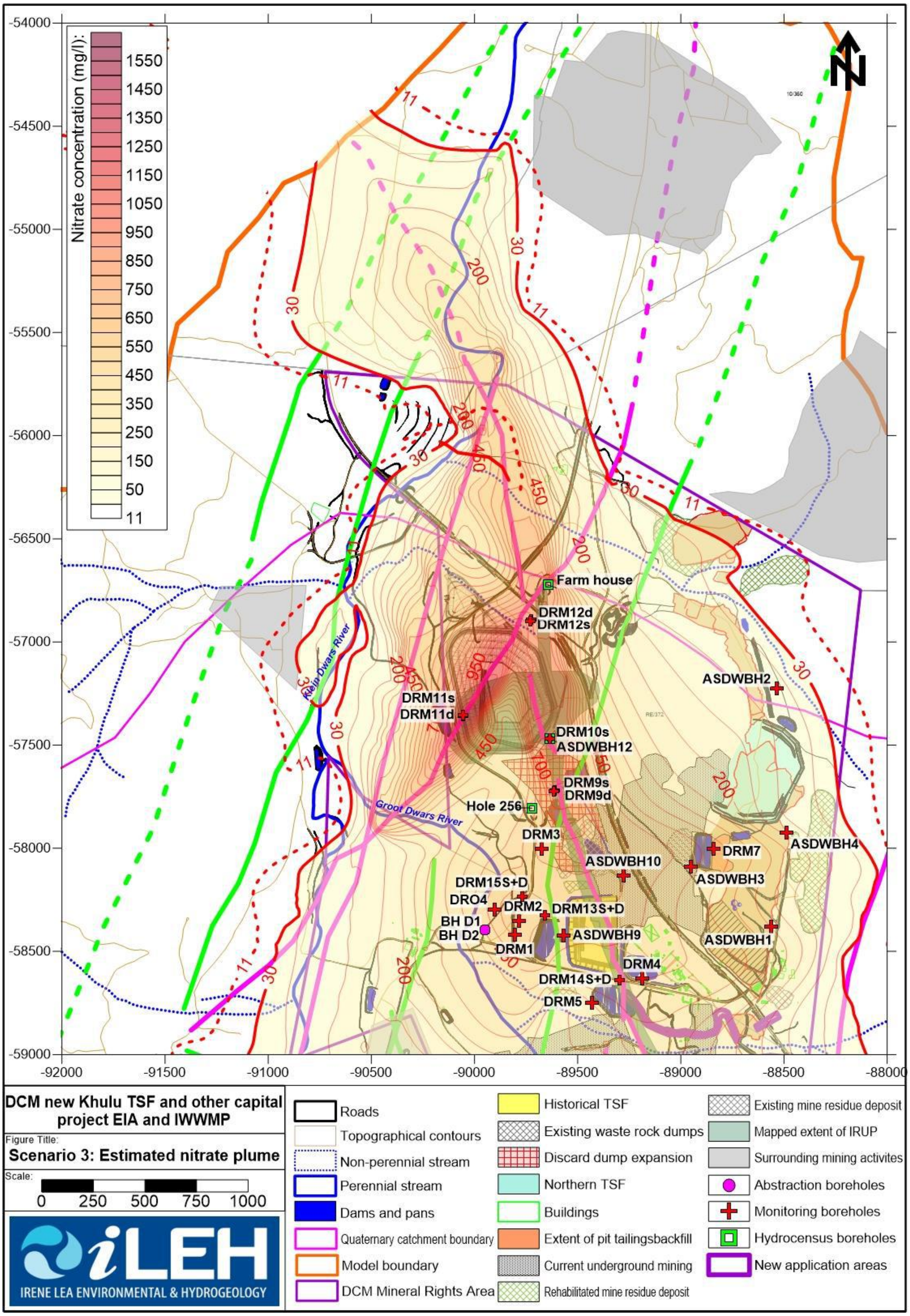


Figure 33 Scenario 3: Simulated NO_3 plume 300 years after mine closure - fractured aquifer

11.6.3 Simulated nitrate concentration time-series evaluation

The simulated nitrate concentration time series for the three clusters of monitoring boreholes closest to the Khulu TSF footprint area are presented in Figures 34 to 36. These graphs indicate the simulated nitrate concentrations with time for the no project option in comparison with the outcome of simulations for Scenarios 1 to 3.

The information presented confirms the following outcome:

- The residual long-term impact on groundwater associated with other DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term, especially in the fractured rock aquifer. Even if the Khulu TSF and PCD is not constructed, nitrate concentrations are expected to be elevated above the average receiving surface water concentration of 30 mg/l in this aquifer.
- With the implementation of rehabilitation measures at mine closure aimed at source reduction, the long-term nitrate concentrations in the fractured rock aquifer is expected to reduce by between 100 and 200 mg/l in the long-term for no project option and Scenarios 1 and 2.
- Similar trends are observed for the weathered aquifer, but at lower concentrations compared to the fractured rock aquifer. This is as a result of preferential groundwater flow associated with the regional faults and dykes targeted in the fractured rock aquifer as part of this study.
- Liner failure for Scenario 1 will only impact on groundwater quality 280 years after liner installation, as discussed above. The increased nitrate concentrations in monitoring boreholes around the Khulu TSF footprint as a result of increased seepage rate after liner failure is expected manifest over a period of 40 – 60 years, after which concentrations are expected to plateau at 300 – 400 mg/l in the weathered aquifer.
- Liner failure for Scenario 2 will impact on groundwater quality 69 years after installation. At this point, nitrate concentrations are expected to increase to 300 – 400 mg/l over a period of 40 – 80 years and start to plateau at concentrations of between 300 – 400 mg/l.
- The significant impact of liner failure under Scenario 3 is evident from the graphs. It is shown that nitrate concentrations will increase significantly in both the shallow weathered and deeper fractured rock aquifers over a period of 10 – 20 years. In the weathered aquifer, nitrate concentrations may increase to above 1200 mg/l during this period. After the initial rapid increase in concentration, nitrate is expected to plateau at between 800 and 1300 mg/l in the weathered aquifer over a period of 100 years or longer.

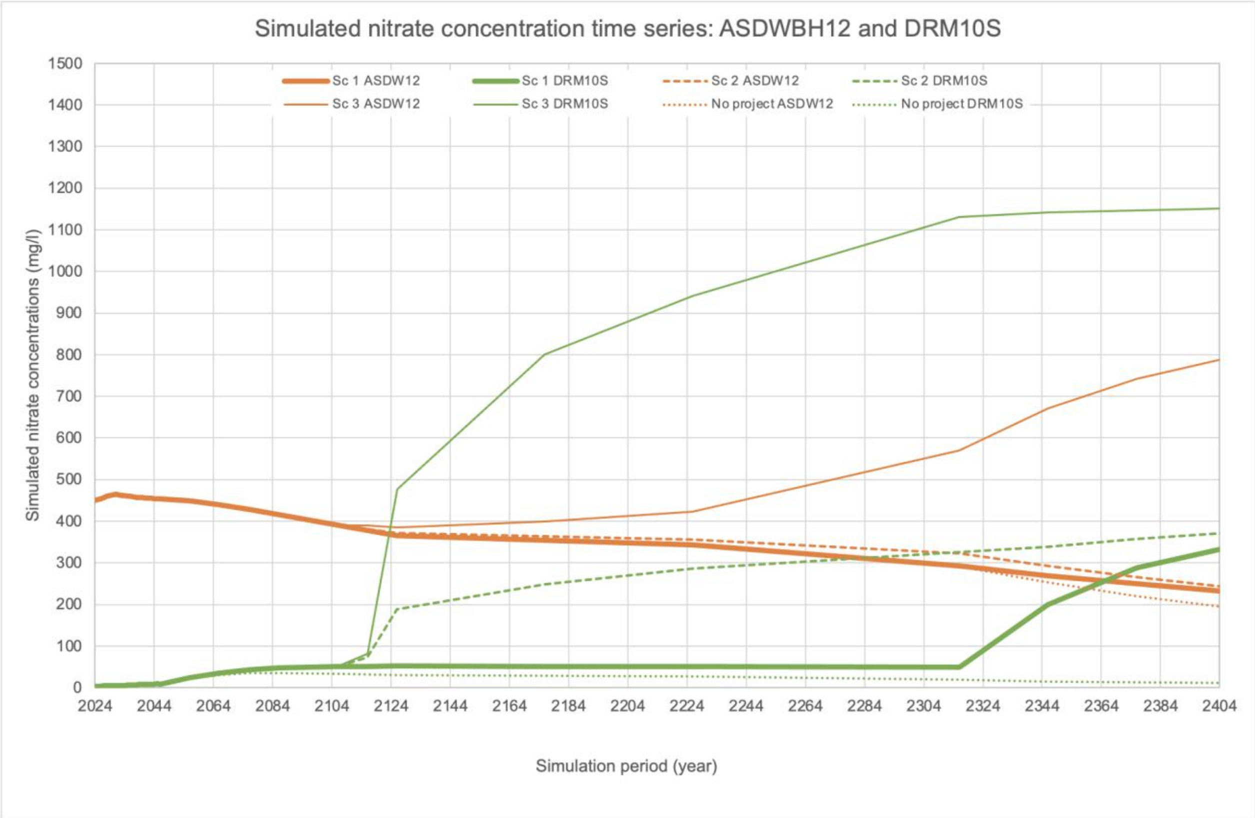


Figure 34 Simulated nitrate concentration time series: ASDWBH12 and DRM10S

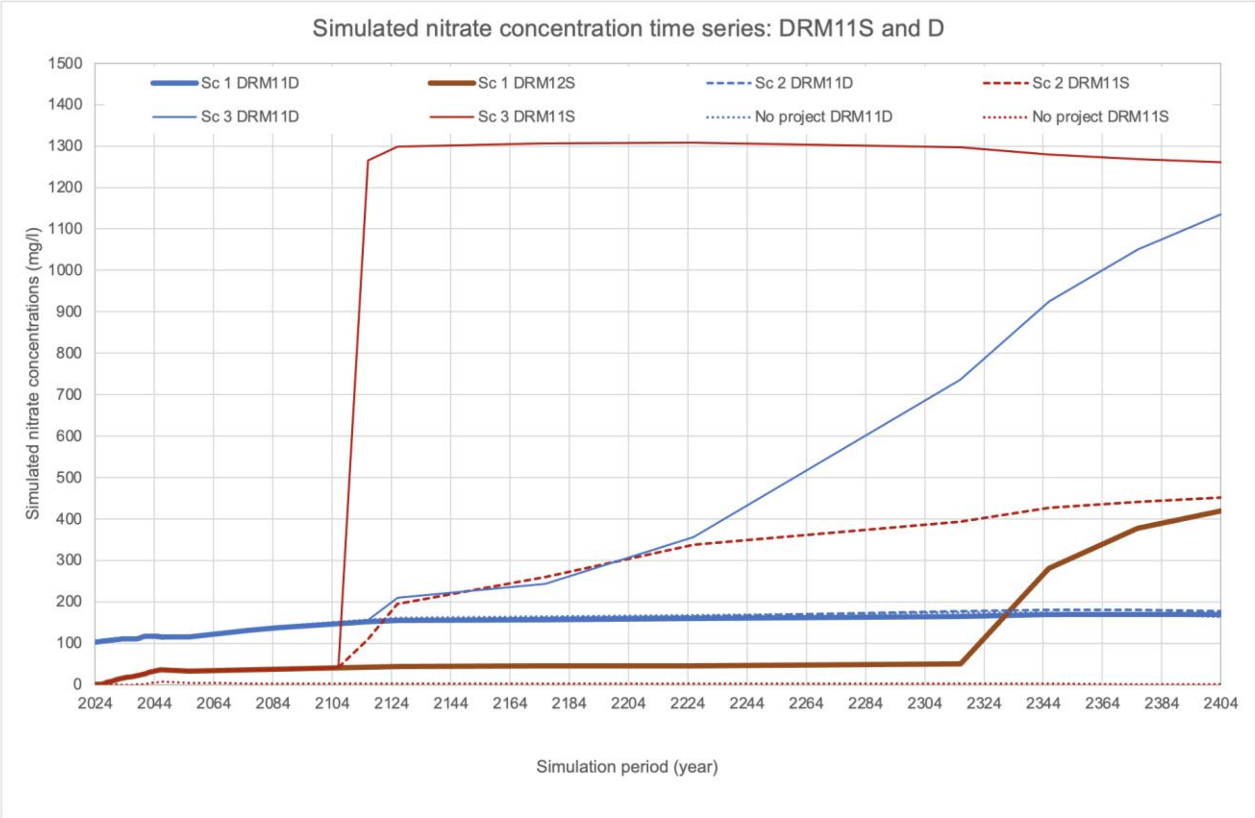


Figure 35 Simulated nitrate concentration time series: DRM11S and D

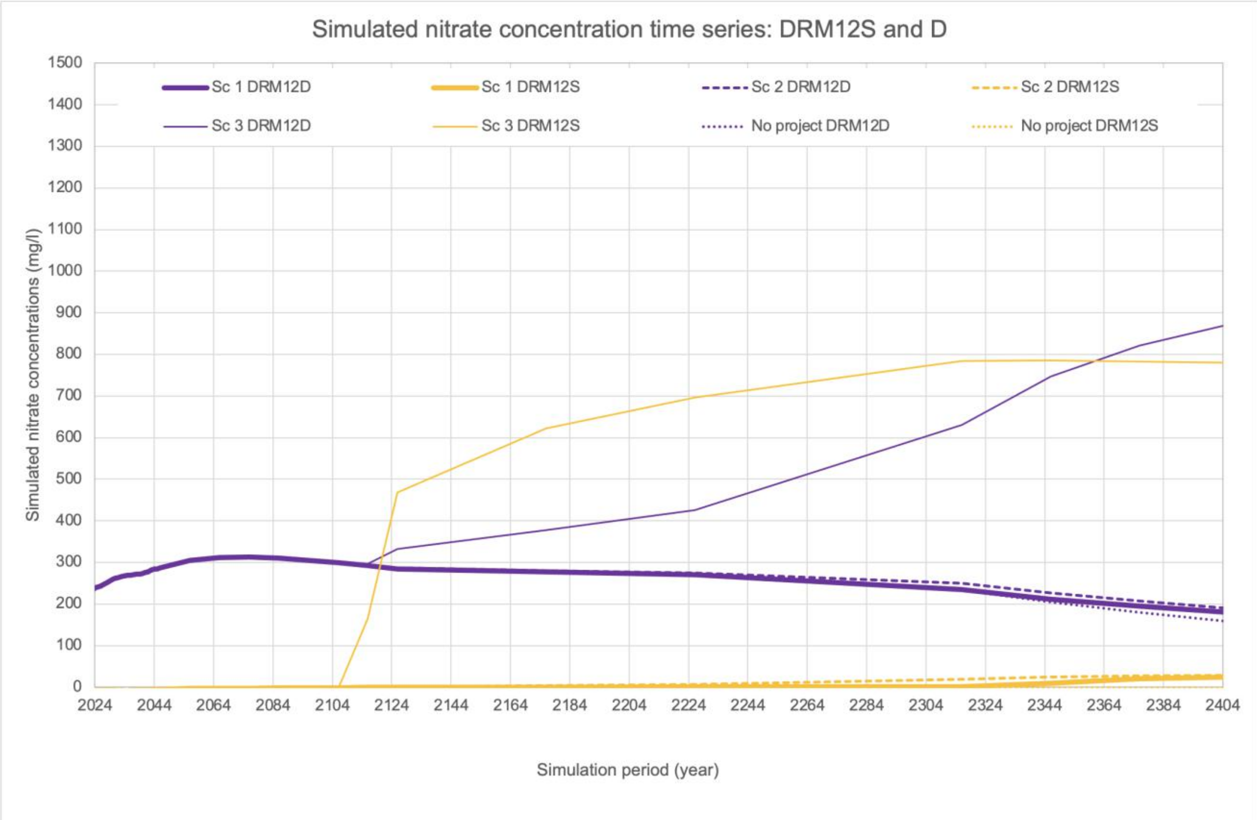


Figure 36 Simulated nitrate concentration time series: DRM12 S and D

11.6.4 Summarised impact on groundwater quality and the receiving water body

The results of the impact prediction simulations discussed above are summarised in Table 24 in terms of each impact on groundwater quality and the receiving water body.

As discussed above, even without construction of the Khulu TSF and PCD, the existing DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term. DCM is in the process of developing and implementing a Groundwater Remediation Strategy that will be designed to reduce nitrate concentrations in groundwater. This strategy will be developed as part of a separate study.

Liner failure under good installation conditions is expected to result in an increase in nitrate concentrations of between 20 and 80 mg/l in the long-term. The outcome of Scenario 1 resulted in the least significant impacts on groundwater and the receiving water quality.

If the liners are poorly installed and managed, negative impacts are expected on the receiving water bodies (the Klein and Groot Dwars Rivers) as well as on groundwater quality. Groundwater baseflow to the rivers at the concentrations listed in Table 24 will most likely result in an increase in nitrate concentrations in the rivers. The increased nitrate concentrations in groundwater will result in an unacceptable long-term impact.

Table 24 Summary of groundwater impact prediction simulations

Scenario	Description	NO_3 in groundwater: Khulu TSF footprint (mg/l)	NO_3 in groundwater: Farm House BH	NO_3 in groundwater: Klein Dwars River	NO_3 in groundwater: Groot Dwars River
End operational Phase	No liner failure, evaluating other DCM mining and mineral processing activities	Weathered aquifer: <11 Fractured aquifer: > 400	<200	<11	<11
No project	Khulu TSF and PCD not built 300 years after mine closure	Weathered aquifer: <11 Fractured aquifer: <160	<100	<11	<11
1	Good liner installation, limited exposure to atmosphere 300 years after mine closure	Weathered aquifer: >600 Fractured aquifer: >180	<100	<11	<11
2	Good liner installation, exposure to atmosphere 300 years after mine closure	Weathered aquifer: >800 Fractured aquifer: >240	<170	<11	<11
3	Poor liner installation, exposure to atmosphere 300 years after mine closure	Weathered aquifer: >1500 Fractured aquifer: >1200	>750	30 - 200	30 - 150

Based on the outcome of the assessment, the preferred option in terms of liner design for the Khulu TSF and PCD is Scenario 1. For this scenario, good liner installation will be implemented and the liner will not be exposed to the atmosphere excessively. If this is achieved, the life of the liner is estimated to be 280 years. Simulations indicate that even if the liner fails, long-term impacts on the receiving water bodies are not expected to be significant.

11.6.5 Risk of decant

No risk of decant was identified for the Khulu TSF and PCD. Seepage will be collected and managed with above and below liner drains until liner failure. The impact of liner failure is an increased rate of infiltration to the underlying aquifers, as discussed above.

12 GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAMME

12.1 Groundwater objectives and targets

The following general objectives and targets are proposed for groundwater management at the operations:

- Implement a Groundwater Remediation Strategy with the objective that no further deterioration in groundwater quality occurs at the operations. It is acknowledged that this objective cannot be achieved immediately, as residual impacts on groundwater quality are expected to remain up to mine closure in some areas.
- Implement management plans aimed at reducing adverse impacts on the receiving water bodies.
- Track and record the progress of implementation of all groundwater management measures. This process must be geared at optimising the measures earmarked for implementation from the Groundwater Remediation Strategy.
- Implement sufficient monitoring procedures to measure the effectiveness of groundwater management measures within the delineated zones of influence.
- Analyse the information obtained from all monitoring programmes against compliance targets to establish trends as well as the objectives of the Groundwater Remediation Strategy.
- Should the trends indicate adverse impacts on groundwater levels and/or quality, implement suitable measures within the shortest possible time to remediate and/or eliminate such adverse impacts identified.

12.2 Over-arching groundwater management measures

Several broad over-arching groundwater management measures should be implemented by DCM to minimise impacts on groundwater the proposed Khulu TSF project. Most of these form part of good house-keeping measures, as detailed in Table 25.

Table 25 General groundwater management measures

Operational Phase
Develop and implement a sound surface runoff management plan for the project. This plan must focus on containing all dirty water that could be generated during the project and preventing clean runoff from entering the footprint area. These measures are considered in the TSF designs developed by JAW (2021a-g).
Ensure that sufficient capacity is available to all contain dirty water within mining area. This management measure must consider the containment of additional dirty water that will be discharged from the Khulu TSF PCD to the LRWD. The water balance calculations completed as part of the Khulu TSF WULA suggests that the LRWD can accommodate the PCD discharge through use in the DCM plant. If the capacity of the dirty water containment measures are compromised, these structures must managed to free up capacity.
Complete regular inspections of all dirty water management systems, including toe drains, cutoff trenches and berms, pollution control dams and stormwater diversion structures, specifically noting incidences of overflow and leakage. If the latter is identified, measures must be taken to rectify non-compliances immediately.
Maintain sound house-keeping measures to prevent spills and leaks. If spills and/or leaks occur, they must be addressed and remediated as a matter of urgency.
Maintain the groundwater monitoring programme in existing and proposed additional monitoring boreholes. Some amendments to the current monitoring programme is proposed. These are detailed below.
Measure and record rainfall daily on site
Decommissioning and Closure Phase
Complete all rehabilitation to a satisfactory level, focussing specifically on maintaining dirty water and runoff in designated areas. Effective rehabilitation of these areas must aim to reduce the rate of recharge of rainwater as far as possible. No ponding must be allowed over rehabilitated areas. All rehabilitated surfaces must be free draining.
Plan for and budget to continue with the groundwater monitoring period for a minimum of two years after mine closure. The continued need for groundwater monitoring will depend on the outcome of the final mine closure groundwater impact assessment.

12.3 Mitigation measures to address impacts on groundwater quality

The following specific measures are recommended to minimise and/or eliminate the impacts on groundwater quality and the spread of groundwater pollution associated with the Khulu TSF:

- Finalise the implementation plan for the Groundwater Remediation Strategy for the operations, based on the outcome of fieldwork completed during 2021. The most effective groundwater management strategies must be developed and implemented as part of a groundwater impact assessment study to be completed during 2022. Due to the fact that groundwater quality at the Khulu TSF is affected by preferential flow along regional faults and dykes, it is accepted that the Groundwater Remediation Strategy will also improve groundwater quality at the TSF and PCD in the long-term.
- The outcome of the groundwater impact assessment presented in this report indicates that the Scenario 1 liner design is the preferred option to ensure that long-term impacts on groundwater quality are limited. This entails good installation of the liner and limited exposure of the HDPE to the atmosphere. Under these measures, the liner is expected to have a life of 280 years. Once the liner fails, the rate of seepage to the underlying aquifers is minimised with good liner installation.
- The liner design must include the above and below liner capture of seepage. Any seepage collected must be diverted to the PCD for containment.
- The water level in the PCD must be diligently monitored to avoid spills and/or seepage. If excess water collects in the PCD, this water must be pumped to the LRWD for reuse in the mine water balance.
- DCM must monitor the volumes of water transferred to and from the Khulu TSF and PCD as part of its flow meter monitoring network. Instruments installed to measure flow must be maintained and calibrated to ensure that accurate measurements are made. The data collected from the flow meters must be used to confirm that the assumptions on which this impact assessment are based, remain valid. If significant deviations in terms of water flow volumes are recorded, the impact assessment presented in this report must be re-evaluated, especially in terms of the volume of seepage available for infiltration from the TSF and PCD.
- All newly drilled monitoring boreholes must be surveyed to confirm accurate positions and elevations. The coordinates presented in this report were recorded with a hand-held GPS.
- Groundwater monitoring must be maintained in all boreholes dedicated to the Khulu TSF. Both groundwater quality and groundwater levels must be monitored in the boreholes according to the strategy below. The information from the monitoring programme must be kept in a spreadsheet. Trends must be analysed to ensure that any exceedances are immediately detected.
- In the event of deterioration in groundwater quality, an inspection must be held to identify the source of contamination. Any non-compliances must be rectified immediately to avoid prolonged negative impacts on groundwater.
- If any of the monitoring boreholes are destroyed during construction and/or operation of the TSF, these must be placed as a matter of urgency. Of specific concern is the location of boreholes DRM11S and D, which is located on the edge of the Khulu TSF design. These boreholes target the SW-NE trending fault and must be redrilled on this structure if destroyed to ensure efficient monitoring of groundwater in this position.
- Additional monitoring boreholes, as detailed below, must be drilled prior to the commencement of construction of the Khulu TSF and PCD to ensure that a baseline can be generated.

13 GROUNDWATER MONITORING PROGRAMME

13.1 Monitoring locations

DCM has implemented a comprehensive groundwater monitoring programme at the operations. It is recommended that this monitoring programme is continued as prescribed by the WUL conditions and is currently done.

In addition to the existing monitoring programme, DCM must continue with monitoring of the newly drilled monitoring boreholes, as presented in Table 6. It is noted that these boreholes are already included in the routine DCM monitoring programme.

It is recommended that three additional monitoring boreholes are drilled to augment the new monitoring boreholes at the Khulu TSF and PCD, as indicated on Figure 37. These include a set of shallow and deep monitoring boreholes down gradient of the PCD. These boreholes must target the fault line indicated in this area. The locations of these boreholes must be determined through surface geophysics to pinpoint the position of the fault line. In addition, it is recommended that a shallow monitoring borehole is drilled on the north-western corner of the Khulu TSF in the path of the plume in the shallow weathered aquifer. The position of this borehole is not dependent on a geological structure and can be drilled at a convenient location in this area.

Table 26 Proposed Khulu TSF additional monitoring boreholes

Monitoring ID	X Coordinate (LO31)	Y Coordinate (LO31 FN 2700000)	Depth (m)	Purpose
Proposed additional monitoring boreholes				
DRM16S and D	-90175*	-56640*	Shallow: 15m Deep: 80m	Target the fault line down gradient of the PCD, which is perceived to be a preferential flow path to groundwater
DRM17S	90144	-56972	15m	Drilled down gradient of the Khulu TSF in the delineated plume in the weathered aquifer.

* The coordinates of this set of boreholes must be confirmed with geophysics. .

13.2 Monitoring requirements

The parameters to be included during monitoring as well as the proposed frequency of monitoring are presented in Table 27. It is recommended that groundwater levels are monitored in all the new and proposed additional Khulu TSF and PCD monitoring boreholes on a monthly basis. This information is important to improve the understanding of water level fluctuations in the area and groundwater level rise and fall in response to rainfall. This information will be used to improve the conceptual understanding of the aquifers and the interaction between shallow and deep aquifers.

It is recommended that all new and additional Khulu TSF and PCD groundwater monitoring positions are sampled on a quarterly basis. In order to keep continuity with the baseline information presented in this report, it is recommended that the elements listed in Table 14 are included in the water quality analyses.

Rainfall must be recorded daily at the operations. This information must be analysed with the results of the groundwater level monitoring in order to improve aquifer conceptualisation.

Table 27 Monitoring requirements in all proposed monitoring positions

Monitoring parameter	Element for analysis	Monitoring frequency	Monitoring trigger-response criteria
Depth to groundwater level in Khulu TSF boreholes	Groundwater level	Monthly	Variations by more than 3m for 2 consecutive months should be investigated.
Volume of water pumped to and from the Khulu TSF and PCD	Volume of water abstracted	Daily	This must be an on-going mine water management measure to confirm the assumptions made in this report.
Water quality analysis in all boreholes, including the additional boreholes	All elements included in Table 14	Quarterly	Variations in concentrations by more than 15% for major cations and anions and more than 7% for metal concentrations for more than 2 consecutive months should be investigated. Any result that exceed specified water quality objectives must be investigated when it occurs.
Rainfall	Rain depth (mm)	Daily on site	None

The monitoring trigger-response criteria listed in Table 27 must be reviewed on an annual basis and updated, based on the outcome of the monitoring programme results. All monitoring information must be entered into a spreadsheet for record keeping and analysis. Copies of the certificates of analyses must be kept on file for inspection. If significant exceedances are recorded during the monitoring programme as presented in Table 27, the following actions should be taken:

- Log the exceedances in the incident reporting system within 24-hours of it occurring.
- Undertake an investigation to identify causes of the exceedances.
- Implement the necessary remedial actions according to the outcome of the investigation and consultation with the affected parties.

The results of the monitoring programme must be reported on a quarterly and annual basis for the purpose of internal DCM water management. Annual reports must also be submitted to the authorities for review.

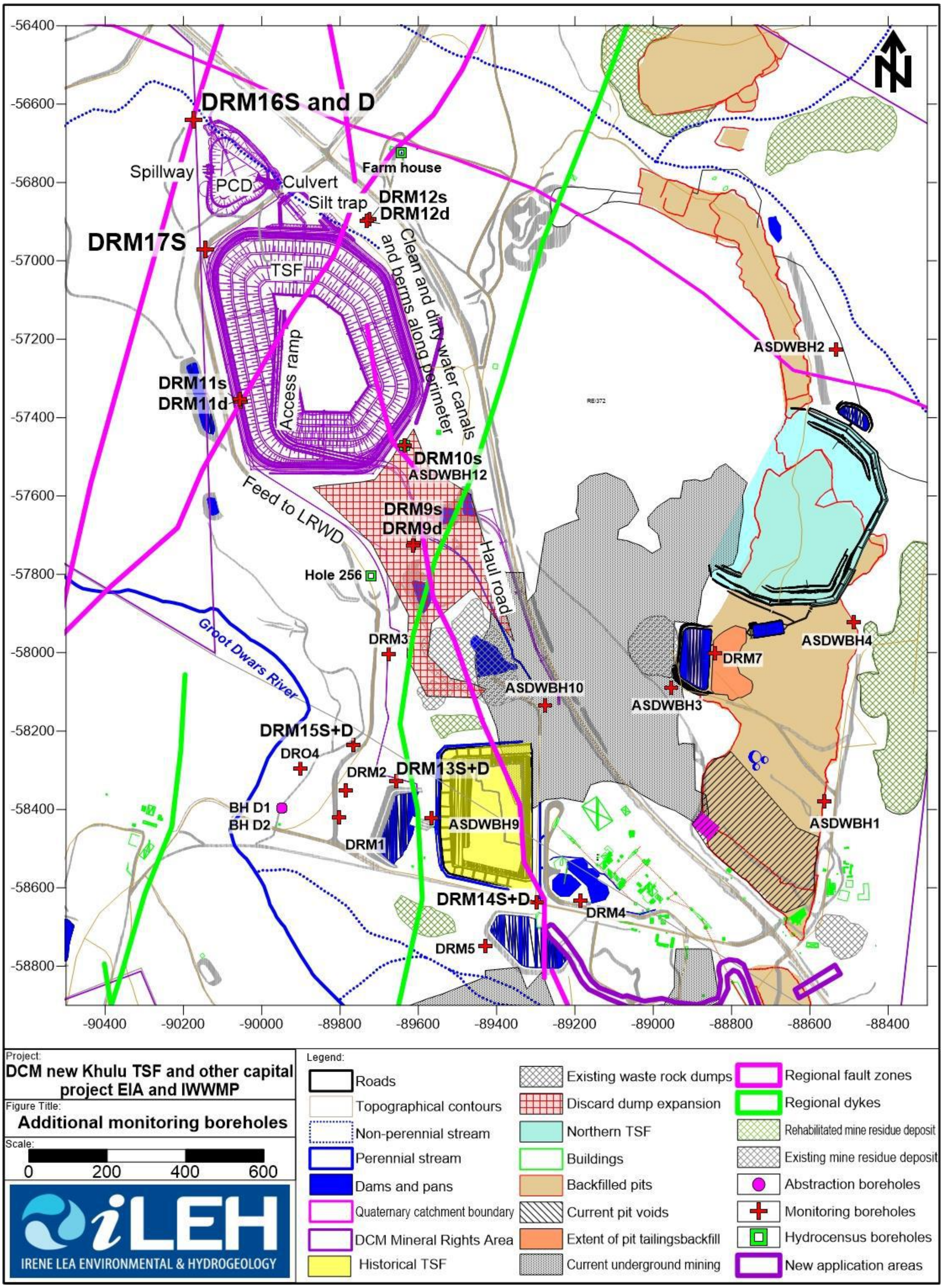


Figure 37 Proposed additional monitoring borehole locations

14 SUMMARY OF GROUNDWATER MANAGEMENT AND MONITORING PLAN

An overall groundwater management and monitoring plan is presented in Table 28, based on the phases of the project and the discussion above.

Table 28 Summary of groundwater management measures proposed

Planning Phase	Construction Phase	Operational Phase	Rehabilitation and Closure	Long-term
• Survey newly drilled monitoring boreholes. • Drill three additional monitoring boreholes, two down gradient of the PCD and one on the north-western corner of the TSF. • Implement the monitoring programme dedicated to the Khulu TSF in boreholes. • Finalise the Groundwater Remediation Strategy for the DCM operations. The objective of the strategy must be to avoid further deterioration of groundwater quality. The study must be based on the field data obtained from newly drilled monitoring boreholes during 2021. • The TSF design should consider the locations of all monitoring boreholes to avoid borehole destruction. • Develop a conceptual rehabilitation plan that takes the outcome of the geohydrological study into consideration. This plan should consider the implementation of concurrent rehabilitation during the operational phase to reduce long-term impacts.	• Maintain groundwater and rainfall monitoring programme. • Monitoring boreholes destroyed during construction must be replaced and target the specific preferential flow path intersected. • Analyse monitoring results to improve understanding of the conceptual model.	• Maintain groundwater and rainfall monitoring programme. • Analyse monitoring results to improve understanding of the conceptual model, risk of groundwater contamination and monitoring response action triggers. • Implement the necessary measures if the monitoring response action triggers are exceeded. • Monitor and measure all water pumped to and from the Khulu TSF and PCD in order to confirm the volumes used in this impact assessment. • Capture seepage from the Khulu TSF and reuse it in the mine water balance. • Monitor the risk of overflow and/or spill at the PCD and the LRWD to avoid adverse impacts on groundwater quality. • Update the numerical groundwater flow and contaminant transport modelling as additional monitoring information becomes available, but at least every five years. The final closure numerical groundwater modelling must be undertaken five years before closure of the facility.	• Maintain groundwater and rainfall monitoring programme. • Analyse monitoring results to improve understanding of the conceptual model and risk groundwater contamination. • Implement an effective rehabilitation strategy geared at reducing the volume of seepage from the Khulu TSF to the underlying aquifers.	• Maintain groundwater and rainfall monitoring programme for the agreed-upon post-closure monitoring period. • Analyse monitoring results to improve understanding of the conceptual model and risk of groundwater contamination. • Keep dirty water containment facilities, including the cutoff trench and berm, the liner drainage system and the PCD intact to manage seepage volumes post closure.

15 POST CLOSURE MANAGEMENT

A detailed rehabilitation plan has not yet been prepared for the proposed Khulu TSF and PCD. As such, a detailed post-closure groundwater management plan cannot be presented at this stage. A number of post-closure groundwater management measures are discussed earlier in this report and summarised below in order to comply with the requirements of Regulation 267 of the NWA.

Also refer to the information presented in Table 28.

15.1 Remediation of physical activity

Based on the outcome of this assessment it is recommended that dirty water management structures, such as the cutoff trench and berm, the above and below liner drains and the PCD are not demolished at closure. These structures must be left in place to capture, divert and contain seepage from the Khulu TSF to an appropriate dirty water dam like the LRWD.

15.2 Remediation of storage facilities

It is anticipated that the Khulu TSF will be shaped and rehabilitated in situ at closure. During the construction of the facility, topsoil will be stripped and stockpiled on site for rehabilitation.

15.3 Remediation of environmental impacts

Details regarding remediation of environmental impacts considered in this study are discussed above. It is noted that a more detailed rehabilitation plan must be developed for the facility. It is recommended that the information presented in this report is revised against the detailed rehabilitation plan during the planning phase of the project in order to confirm long-term impacts.

15.4 Remediation of water resources impacts

As for the environmental impacts, the most significant impact on water resources is associated with liner failure post closure and seepage from the Khulu TSF to the underlying aquifers. This is discussed in more detail above.

15.5 Backfilling of pits

This is not applicable to the project.

16 CONCLUSIONS AND RECOMMENDATIONS

16.1 Conclusions

Based on the outcome of this assessment, the following conclusions are presented:

16.1.1 Aquifer conceptualisation

Three aquifers are typically present in the region. These include an alluvial aquifer associated with the floodplains of the Groot and Klein Dwars Rivers; a shallow weathered aquifer present in the upper 15m of the geological succession; and a deeper fractured rock aquifer in the pyroxenites, anorthosites and norites.

The geohydrological specialist study completed for the EIA includes the results of a fieldwork programme geared at obtaining sufficient information with which to characterise the aquifers present. The fieldwork includes a hydrocensus to identify and quantify existing groundwater use near the Khulu TSF footprint. The only private borehole is located 230m northeast of the TSF.

A geophysical survey was completed to confirm the locations of perceived faults and dykes that are present near the TSF. A total of seven new monitoring boreholes were drilled on the geophysical targets, including three sets of shallow and deep monitoring boreholes to target the aquifers present and one shallow borehole adjacent to an existing old deep monitoring borehole identified during the hydrocensus. Aquifer tests were completed in the deep monitoring boreholes, while observations were made in the shallow boreholes. The drilling programme and aquifer tests were used to obtain information to characterise the aquifers present.

Based on the information evaluated, a north-south trending fault, associated with a replacement pegmatoid body mapped in the underground mine plan, is identified as a preferential flow path to groundwater and therefore also for potential contamination associated with the Khulu TSF. This fault intersects the eastern edge of the TSF. A second southwest-northeast trending fault was also identified and characterised. This fault transects the Khulu TSF footprint and also exhibits enhanced aquifer conditions, which are variable along its strike. A borehole situated down gradient of the Khulu TSF on this fault line was dry at the time of drilling. Groundwater seepage was recorded afterwards in the borehole. This structure may therefore also be considered as a preferential flow path to groundwater, but with less significance compared to the north-south trending fault. A dyke situated east of the Khulu TSF could act as a preferential flow path to groundwater, south of the TSF footprint. In the vicinity of the Khulu TSF, the significance of the preferential flow along the dyke contact is considered less prominent as it does not intersect the footprint area.

An analysis of aquifer transmissivities calculated from field data is summarised in the Table 13. The information suggests that the N-S striking fault is the most prominent preferential flow path to groundwater.

Evaluation of monitoring data obtained during aquifer tests suggest that there is limited vertical movement between the shallow weathered and deeper fractured aquifers at the Khulu TSF footprint. Further south in the plant area, high transmissivities were recorded for the N-S striking fault in shallow and deep boreholes. It is thought that contamination from surface enters the fractured rock aquifer in this area.

Groundwater flow patterns confirm preferential flow along the N-S striking fault and to a lesser extent along the SW-NW striking fault and the dyke. Groundwater levels measured in shallow boreholes indicate that groundwater follows the topography in the weathered aquifer and discharges towards rivers and streams. Groundwater flow in the underlying fractured rock aquifer is only partially governed by the topography. Preferential flow along geological structures and the impact of mine dewatering also affects the fractured rock aquifer.

The average rate of recharge to the aquifers was calculated from groundwater level and rainfall data as around 4% of the mean annual precipitation. This is within the expected range for the aquifers present.

Existing groundwater abstraction by DCM to supply the operational with potable and process water was taken into consideration during simulations.

An assessment of process water quality and rock leach tests completed indicates that the risk of acid mine drainage associated with the operations is low. An analysis of the mine's monitoring database confirms that nitrate is the indicator element for the project. The impact assessment presented in this report is therefore completed at the hand of nitrate concentrations in groundwater.

The latest available groundwater quality sampling data shows that the nitrate concentration in the existing dirty water dams linked to the plant and the Northern TSF are comparable and exceed 1000 mg/l. Water quality in the LRWD, which is used to supply the plant and will impact on seepage quality in tailings deposited on the Khulu TSF has a nitrate concentration exceeding 1500 mg/l.

Groundwater quality data further indicates that the fractured rock already exhibits elevated nitrate concentrations at the Khulu TSF footprint. This contamination is thought to originate in the plant area and migrate preferentially along the faults and dykes in a northerly direction. Groundwater quality in the shallow weathered aquifer is not impacted at the TSF footprint. An analysis of the rate of contaminant migration in the alluvial aquifer and along the dyke structure confirms similar aquifer permeabilities/transmissivities to those calculated with aquifer testing data.

The available dataset was used to conceptualise the aquifers present at the Khulu TSF and generate input for the numerical groundwater flow and contaminant transport model updated and re-calibrated to complete the impact assessment. The source term used to simulate the impact of the project on nitrate concentrations in groundwater was generated from existing monitoring and leach test data.

JAW calculated the potential rate of leakage through the TSF and PCD liners. This information was incorporated in the groundwater model to complete the impact prediction simulations.

16.1.2 Model calibration and sensitivity analysis

Model calibration was undertaken with field-measured groundwater levels from the latest monitoring dataset. Both steady state and transient calibration was completed. Calibration results complied with the pre-set calibration criteria set.

The results indicate that the model is most sensitive to changes in the permeabilities of the regional geological structures that act as preferential flow paths, including the N-S dyke, the SW-NE fault, the rock matrix and the N-S fault. The level of confidence in the outcome of simulations can be improved if additional monitoring data is obtained to characterise aquifer characteristics. This can be done through ongoing water level monitoring in the existing boreholes as well as monitoring on-site rainfall rates.

Modelling further indicates that the contaminant transport model is sensitive to changes in the porosity of the rocks and the geological structures. The porosities used to complete the impact assessment were kept low in order to avoid under-estimating impacts. Adjustments to the porosities were undertaken to match monitoring data. It is however recommended that more work is undertaken to improve the understanding of aquifer porosities to be included in future simulations.

16.1.3 Geohydrological impact assessment

The designs and operational life of the Khulu TSF was integrated into the model to complete the geohydrological impact assessment for the project. The estimated impact at the end of the operational phase of the TSF and mine was calculated. An assessment of the no-project option is also included in the report. Three long-term liner scenarios were tested, namely:

- **Scenario 1:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere is managed and limited to a minimum, resulting in a life of liner of 280 years. During this time, it is assumed that seepage will be collected above and below the TSF and PCD liner and that this water will be transferred to the PCD. No seepage is therefore expected to infiltrate to the underlying aquifers. This is considered the best case scenario.
- **Scenario 2:** Good liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers according to the rates presented provided by JAW.
- **Scenario 3:** Poor liner installation for the Khulu TSF and PCD. Exposure to the atmosphere cannot be managed, resulting in a life of liner of 69 years. After 69 years, the liner starts seeping into the aquifers at the maximum rate. This is considered the worst case scenario.

During simulations, the specifications and findings of the latest overall annual rehabilitation plan for the operations were incorporated. The requirements of the 2018 Groundwater Remediation Strategy were not considered in this report. This strategy will be updated and finalised based on the outcome of fieldwork completed in 2021. Groundwater management scenarios will be assessed as part of a separate study during 2022 after which the implementation of the Groundwater Remediation Strategy will be finalised. It is acknowledged that groundwater management measures implemented as part of the remediation strategy will also benefit impacts associated with the Khulu TSF.

The simulated plumes presented in this report are delineated by the 30 mg/l nitrate concentration contour. This is equivalent to the long-term average nitrate concentration for the receiving water quality in the Groot Dwars River. Activities upstream of DCM already impacts on nitrate concentrations, which affect surface water and to some extent groundwater quality in the DCM mining area. The South African Drinking Water nitrate standard of 11 mg/l is also indicated on simulated plumes as reference.

Simulated nitrate concentrations are compared for all scenarios tested in Table 24. The outcome of the assessment is summarised below:

16.1.4 Impacts on groundwater quality at the end of the operational phase:

- Nitrate contamination in the weathered aquifer will be contained to the plant and opencast mining areas. Based on the current characterisation of the alluvial and shallow weathered aquifers, it is unlikely that nitrate concentrations in the weathered aquifer would exceed 11 mg/l in the vicinity of the Groot Dwars River down gradient of the Khulu TSF.
- No impact on groundwater quality is expected in the vicinity of the Klein Dwars River west and northwest of the Khulu TSF and PCD at the end of the operational phase.
- Based on the conceptualisation of preferential groundwater flow in the fractured rock aquifer, the nitrate plume is expected to migrate in a northerly direction along the N-S striking fault. This contamination originates from the plant, historical TSF, dirty water dams, open cast and underground mining areas and not from the Khulu TSF and PCD.

16.1.5 Long-term impacts on groundwater quality if the project is not implemented:

- The simulations indicate that the nitrate plume will recede in the long-term in the weathered aquifer if all sources of contamination are removed at mine closure as part of the rehabilitation programme.

- At the Khulu TSF foot, nitrate concentrations are not expected to significantly exceed 11 mg/l in the long-term for this scenario.
- The impact on the Groot and Klein Dwars River is expected to reduce significantly in the long-term for this scenario. Nitrate concentrations in groundwater reaching these rivers in the weathered and alluvial aquifers are not expected to exceed 11 mg/l.
- The plume in the fractured aquifer is expected to continue to migrate along the preferential flow paths and to a lesser extent in unfractured rock matrix in the long-term. Nitrate concentrations are however expected to reduce inside the affected area as a result of plume dilution from recharge of fresh rain water and groundwater throughflow. Over the footprint area of the Khulu TSF, nitrate concentrations are expected to reduce to below 160 mg/l on average.

16.1.6 Long-term impacts on groundwater quality associated with Scenario 1:

- Seepage through the TSF and PCD liners are expected to increase nitrate concentrations in the weathered aquifer underneath the Khulu TSF and PCD footprint areas. Nitrate concentrations may increase to above 600 mg/l over the footprint areas in the weathered and alluvial aquifers in the long-term.
- The nitrate plume is expected to migrate in a north-westerly direction towards the Klein Dwars River in the weathered and alluvial aquifers. At 300 years after mine closure, simulations suggest that it is unlikely that groundwater with nitrate concentrations exceeding 11 mg/l would reach the Klein Dwars River from the Khulu TSF and PCD to any significant extent.
- The effect of liner failure at the Khulu TSF and PCD on the fractured rock aquifer is not expected to add significantly to the pollution load associated with other DCM mining and mineral processing activities.
- Nitrate concentrations may increase to above 180 mg/l in the fractured rock aquifer as a result of infiltration over the Khulu TSF and PCD footprint areas. This is an estimated 20 mg/l increase in concentration compared to the no project option discussed above.
- The nitrate plumes originating from the Khulu TSF and PCD are expected to migrate in a northerly direction along the preferential flow paths identified. Contamination along these geological structures are however expected to be dominated by DCM mining and mineral processing activities and not significantly as a result of seepage from the Khulu TSF and PCD.
- The nitrate plume is expected to migrate more than 900m north outside the DCM mineral rights boundary along the N-S striking in the long-term for this scenario.

16.1.7 Long-term impacts on groundwater quality associated with Scenario 2:

- The extent of the impact on groundwater quality for this scenario is similar to that reported for Scenario 1. The extent of the plume is driven by aquifer parameters like permeability and porosity and to a lesser extent by the concentration gradient for Scenarios 1 and 2. This is due to the fact that the rate of seepage from the Khulu TSF liner for good installation is reported to be comparatively low, which means the concentration gradient from the source to the aquifer is low.
- Nitrate concentrations inside the delineated plumes are however expected to increase for this scenario compared to Scenario 1, as the seepage will take place for a longer period of time. The liner failure occurs after 69 years for this scenario, compared to after 280 years for Scenario 1.
- In the weathered and alluvial aquifers, nitrate concentrations may increase to above 800 mg/l in the long-term for this scenario. This is an increase of 200 mg/l compared to Scenario 1.
- The contamination is expected to migrate in a north-westerly direction towards the Klein Dwars River in the long-term. Nitrate concentrations are however not expected to significantly exceed 11 mg/l in groundwater reaching the Klein Dwars River in this time.
- The nitrate plume in the fractured rock aquifer will migrate preferentially along the N-S striking fault and the other preferential flow paths identified. As reported for Scenario 1, the nitrate plume may migrate more than 900m north along the N-S striking fault outside the DCM mineral rights boundary in the long-term.

- Nitrate concentrations in the fractured rock aquifer immediately underneath the Khulu TSF and PCD may increase to above 240 mg/l for this scenario. This is an increase of 60 mg/l in nitrate concentration compared to Scenario 1.
- Nitrate concentrations in at the Farm House borehole may decrease to around 170 mg/l in the long-term compared to the 200 mg/l expected at the end of the operational phase. This is however an increase of around 70 mg/l compared to the results of Scenario 1.
- Plume movement in unfractured rock matrix is expected to be low. Nitrate concentrations in the fractured rock aquifer immediately down gradient of the Khulu TSF and PCD are not likely to exceed 11 mg/l near the Klein Dwars River in the long-term.

16.1.8 Long-term impacts on groundwater quality associated with Scenario 3:

- Liner failure and maximum seepage rates to the underlying aquifers for this scenario is expected to result in a significant negative impact on groundwater quality. With the increased seepage rate, the concentration gradient at the Khulu TSF and PCD footprint will increase significantly, resulting in an accelerated spread of contamination in the long-term. The plume is also expected to migrate radially away from the Khulu TSF footprint area due to the high infiltration rates. A mound in groundwater levels is expected around the footprint in this case. It is noted that the rate of infiltration is significantly high and is most probably not a reality.
- The extent of the impact on the weathered and alluvial aquifers is expected to significantly increase for this scenario. Over the footprint area, nitrate concentrations may increase to 1500 mg/l in the long-term.
- The plume is expected to migrate in a north-westerly and westerly direction towards the Klein Dwars River. Nitrate concentrations in groundwater reaching the Klein Dwars River are expected to increase to above 30 mg/l over a length of 250m along the river. In places, nitrate concentrations in groundwater reaching the Klein Dwars River in the weathered and alluvial aquifers could exceed 200 mg/l for this scenario. This is expected to result in a noticeable impact on surface quality in the long-term.
- The plume is also likely to reach the Groot Dwars River southwest of the Khulu TSF due to the anticipated radial flow from the footprint area. Groundwater reaching the Groot Dwars River may have nitrate concentrations exceeding 30 mg/l over a stretch of around 200m along the river. In places, nitrate concentrations in groundwater may increase to above 150 mg/l at the river. This is also expected to result in a noticeable impact on surface water quality in the long-term.
- The high seepage rates from the Khulu TSF and PCD are also expected to result in significant vertical flow to the underlying fractured rock aquifer. This is different to the outcome of Scenarios 1 and 2, where the concentration gradient under lower seepage rates did not result in significant impacts on the fractured rock aquifer.
- Once the nitrate concentrations reach the fractured rock aquifer, preferential flow is expected along the N-S and the SW-NE striking fault lines.
- Over the Khulu TSF and PCD footprint areas, nitrate concentrations may increase to above 1200 mg/l in the fractured rock aquifer for this scenario, which is a significant increase from the impacts associated with Scenarios 1 and 2.
- Along the N-S striking fault, nitrate concentrations may exceed 700 mg/l in the long-term. This plume is also expected to migrate more than 1300m north and outside the DCM mineral rights area, as indicated.
- Nitrate concentrations in the SW-NE striking fault may increase to above 1000 mg/l in the long-term. In addition, a nitrate plume is expected to migrate along this structure in a southwesterly direction towards the Groot Dwars River. In the long-term, nitrate concentrations may increase to around 450 mg/l in the fault line at the intersection with the Groot Dwars River.
- The groundwater mound that will develop underneath the Khulu TSF and PCD footprint areas is also expected to drive migration of the nitrate plume in the unfractured rock matrix towards the Klein Dwars River west of the site. On the long-term, this could result in an increase in nitrate

concentrations in the fractured rock aquifer at the river of more than 30 mg/l, possibly as high as 50 mg/l.

An evaluation of the simulated nitrate concentration fluctuation with time indicate the following:

- The residual long-term impact on groundwater associated with other DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term, especially in the fractured rock aquifer. Even if the Khulu TSF and PCD is not constructed, nitrate concentrations are expected to be elevated above the average receiving surface water concentration of 30 mg/l in this aquifer.
- With the implementation of rehabilitation measures at mine closure aimed at source reduction, the long-term nitrate concentrations in the fractured rock aquifer is expected to reduce by between 100 and 200 mg/l in the long-term for no project option and Scenarios 1 and 2.
- Similar trends are observed for the weathered aquifer, but at lower concentrations compared to the fractured rock aquifer. This is as a result of preferential groundwater flow associated with the regional faults and dykes targeted in the fractured rock aquifer as part of this study.
- Liner failure for Scenario 1 will only impact on groundwater quality 280 years after liner installation, as discussed above. The increased nitrate concentrations in monitoring boreholes around the Khulu TSF footprint as a result of increased seepage rate after liner failure is expected manifest over a period of 40 – 60 years, after which concentrations are expected to plateau at 300 – 400 mg/l in the weathered aquifer.
- Liner failure for Scenario 2 will impact on groundwater quality 69 years after installation. At this point, nitrate concentrations are expected to increase to 300 – 400 mg/l over a period of 40 – 80 years and start to plateau at concentrations of between 300 – 400 mg/l.
- The significant impact of liner failure under Scenario 3 is evident from the graphs. It is shown that nitrate concentrations will increase significantly in both the shallow weathered and deeper fractured rock aquifers over a period of 10 – 20 years. In the weathered aquifer, nitrate concentrations may increase to above 1200 mg/l during this period. After the initial rapid increase in concentration, nitrate is expected to plateau at between 800 and 1300 mg/l in the weathered aquifer over a period of 100 years or longer.

16.1.9 Summary of impacts on groundwater quality and the receiving water body

As discussed above, even without construction of the Khulu TSF and PCD, the existing DCM mining and mineral processing activities will continue to impact on groundwater quality in the long-term. DCM is in the process of developing and implementing a Groundwater Remediation Strategy that will be designed to reduce nitrate concentrations in groundwater. This strategy will be developed as part of a separate study.

Liner failure under good installation conditions is expected to result in an increase in nitrate concentrations of between 20 and 80 mg/l in the long-term. The outcome of Scenario 1 resulted in the least significant impacts on groundwater and the receiving water quality.

If the liners are poorly installed and managed, negative impacts are expected on the receiving water bodies (the Klein and Groot Dwars Rivers) as well as on groundwater quality. Groundwater baseflow to the rivers at the concentrations reported will most likely result in an increase in nitrate concentrations in the rivers. The increased nitrate concentrations in groundwater will result in an unacceptable long-term impact.

Based on the outcome of the assessment, the preferred option in terms of liner design for the Khulu TSF and PCD is Scenario 1. For this scenario, good liner installation will be implemented and the liner will not be exposed to the atmosphere excessively. If this is achieved, the life of the liner is estimated to be 280 years. Simulations indicate that even if the liner fails, long-term impacts on the receiving water bodies are not expected to be significant.

16.2 Recommendations

The following recommendations are made:

16.2.1 Groundwater management and monitoring programme

The results of the impact assessment presented above were used to develop a groundwater management and monitoring programme for the Khulu TSF and PCD. The main objective of the management programmes is to reduce adverse impacts on the receiving water bodies and to prevent further deterioration of groundwater quality at the operations. In order to achieve this, overarching general groundwater management measures are proposed, mostly linked to good house-keeping measures.

Specific groundwater management measures to address impacts on groundwater quality are provided. These include:

- Finalise the implementation plan for the Groundwater Remediation Strategy for the operations, based on the outcome of fieldwork completed during 2021. The most effective groundwater management strategies must be developed and implemented as part of a groundwater impact assessment study to be completed during 2022. Due to the fact that groundwater quality at the Khulu TSF is affected by preferential flow along regional faults and dykes, it is accepted that the Groundwater Remediation Strategy will also improve groundwater quality at the TSF and PCD in the long-term.
- The outcome of the groundwater impact assessment presented in this report indicates that the Scenario 1 liner design is the preferred option to ensure that long-term impacts on groundwater quality are limited. This entails good installation of the liner and limited exposure of the HDPE to the atmosphere. Under these measures, the liner is expected to have a life of 280 years. Once the liner fails, the rate of seepage to the underlying aquifers is minimised with good liner installation.
- The liner design must include the above and below liner capture of seepage. Any seepage collected must be diverted to the PCD for containment.
- The water level in the PCD must be diligently monitored to avoid spills and/or seepage. If excess water collects in the PCD, this water must be pumped to the LRWD for reuse in the mine water balance.
- DCM must monitor the volumes of water transferred to and from the Khulu TSF and PCD as part of its flow meter monitoring network. Instruments installed to measure flow must be maintained and calibrated to ensure that accurate measurements are made. The data collected from the flow meters must be used to confirm that the assumptions on which this impact assessment are based, remain valid. If significant deviations in terms of water flow volumes are recorded, the impact assessment presented in this report must be re-evaluated, especially in terms of the volume of seepage available for infiltration from the TSF and PCD.
- All newly drilled monitoring boreholes must be surveyed to confirm accurate positions and elevations. The coordinates presented in this report were recorded with a hand-held GPS.
- Groundwater monitoring must be maintained in all boreholes dedicated to the Khulu TSF. Both groundwater quality and groundwater levels must be monitored in the boreholes according to the strategy below. The information from the monitoring programme must be kept in a spreadsheet. Trends must be analysed to ensure that any exceedances are immediately detected.
- In the event of deterioration in groundwater quality, an inspection must be held to identify the source of contamination. Any non-compliances must be rectified immediately to avoid prolonged negative impacts on groundwater.
- If any of the monitoring boreholes are destroyed during construction and/or operation of the TSF, these must be placed as a matter of urgency. Of specific concern is the location of boreholes DRM11S and D, which is located on the edge of the Khulu TSF design. These boreholes target

the SW-NE trending fault and must be redrilled on this structure if destroyed to ensure efficient monitoring of groundwater in this position.

- Additional monitoring boreholes, as detailed below, must be drilled prior to the commencement of construction of the Khulu TSF and PCD to ensure that a baseline can be generated.

Based on the outcome of this assessment, three additional groundwater monitoring boreholes are recommended. These include a shallow and deep monitoring borehole northwest of the PCD. These boreholes must target the fault line indicated in this area, which is perceived to be a preferential flow path to groundwater. The third borehole is a shallow borehole on the north-western corner of the TSF located in the delineated plume of the weathered aquifer. No geological structures are thought to be present in this area.

Specific monitoring requirements and trigger response criteria were set for the project. These include monitoring of groundwater levels and quality at the Khulu TSF and PCD, the volumes of water pumped to and from the Khulu TSF and PCD and rainfall. A monitoring trigger-response criteria is set for each monitoring parameter, which must be reviewed on an annual basis and updated as necessary based on monitoring results. If significant exceedances are recorded, appropriate and timeous action must be taken to address these and to limit adverse impacts on groundwater.

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b: I031-02_CAL-007_rA_SiteB_PCD_Options.xls, dated 3 May 2021

c: I031-02_PPT-002_rA_Dry_TSF_Concept.pdf, dated 14 June 2021

d: I031-02_FLD-2100524_rA_TP.pdf, dated 24 June 2021

e: I0341-00_Testpit_Locations_rev2.pdf, dated 29 July 2021

f: Technical Note – Dwarsrivier Chrome Mine Khulu Dry Tailings Storage Facility – Design Note, File ref. I031-00-21-TN080_r0_DCM_Khulu_Dry_TSF_Preliminary_Design, dated 30 November 2021

g: Water balance spreadsheet for the Khulu TSF PCD entitled I031-02_CAL-007_rD_PCD_Water_Balance.xlsm

MSC, 2018. Environmental Impact Assessment and Environmental Management Programme Report for the Proposed Extension of the Two Rivers Platinum Mining Right Area, Steelpoort, Limpopo Province, Ref MSC/57/18/TRP, dated 9 November 2018

nettZero, 2018. Waste Classification and Characterisation Phase 4 Report, ref. DWR/18/01/01, dated December 2018.

nettZero, 2021 Drilling and pump testing project, Project No DCM/21/01, dated 12 October 2021.

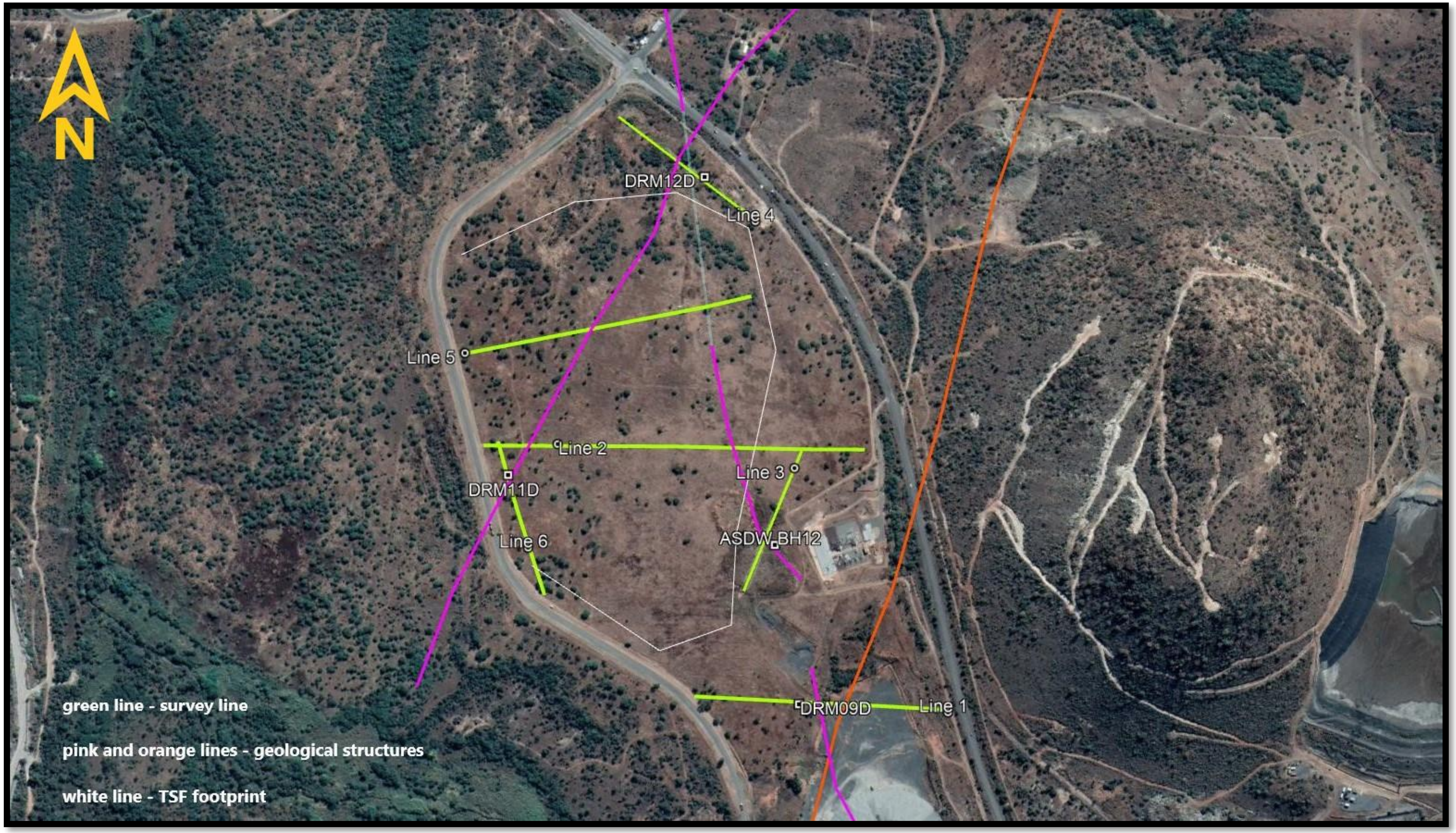
Nortje, R. 2017. Estimating leakage rates through barrier systems, presented to the Institute of Waste Management of Southern Africa by Jones & Wagener Engineering and Environmental Consultants.

Parsons, 1995. A South African Aquifer System Management Classification, prepared for the Water Research Commission and the Department of Water Affairs and Forestry, WRC Report KV88/95, dated December 1995.

Rowe, K R. 2012. Short- and long-term leakage through composite liners. The 7th Arthur Casagrande Lecture, Canadian Geotechnical Journal 49: 141 – 169, dated 20 January 2012.

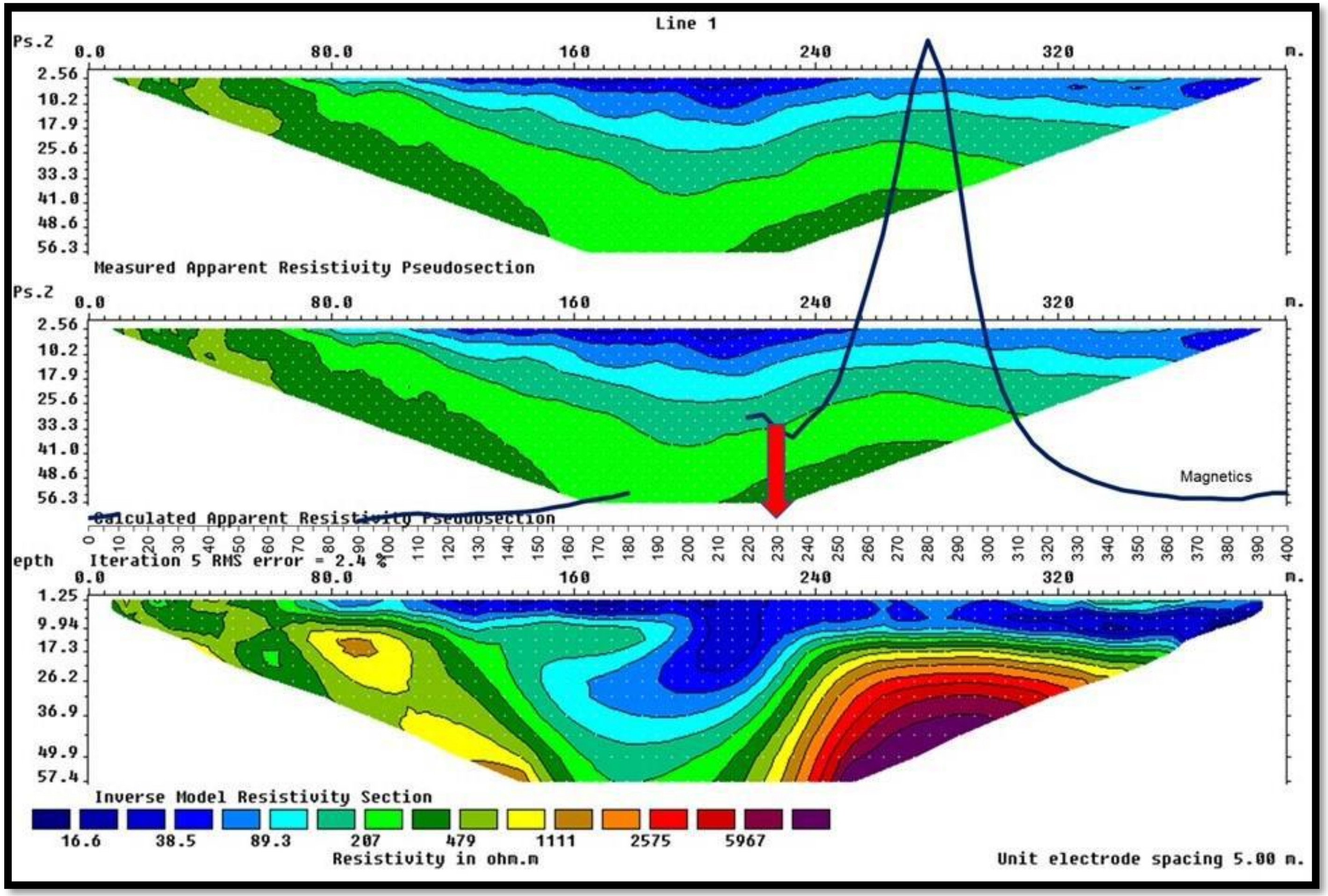
SANS 241-1:2015, 2015. South African National Standard – Drinking water – Part 1: Microbiological, physical, aesthetic and chemical determinants, ISBN 978-0-626-29841-8.

APPENDIX A GEOPHYSICAL SURVEY DATA

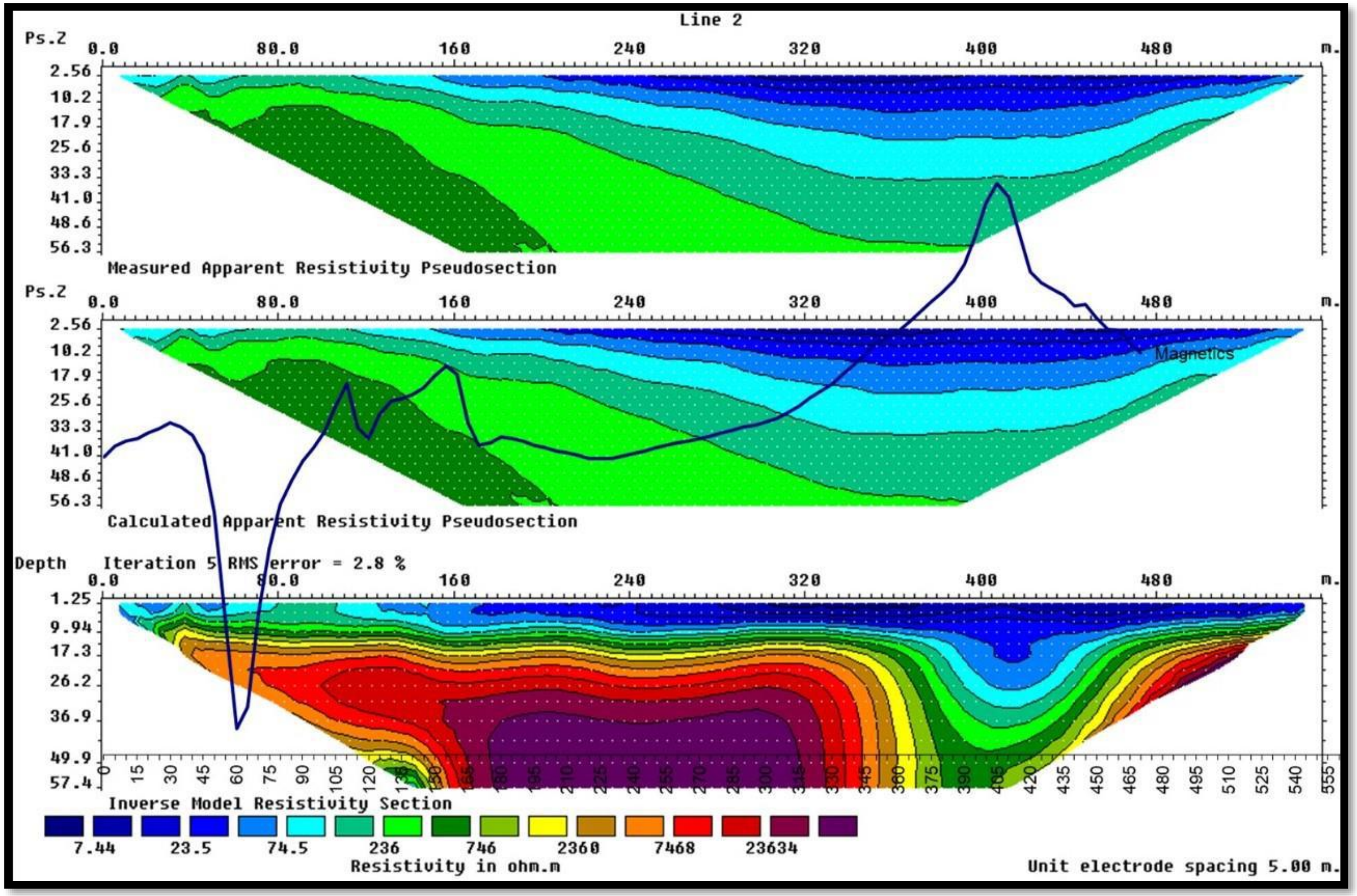


Geophysical survey layout

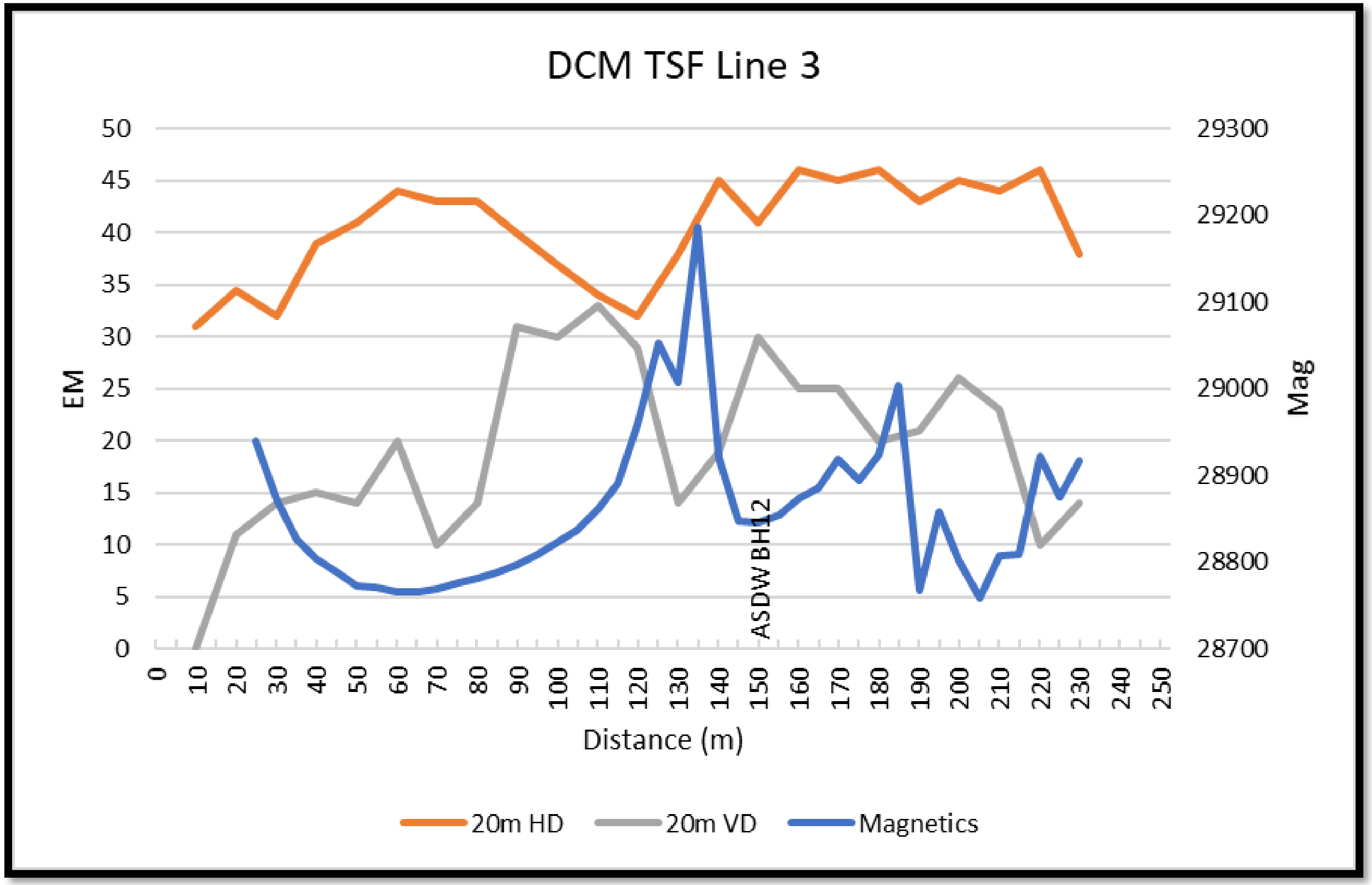
Line 1


Line 1
Ps.Z
0.0
80.0
160
240
320
m.
2.56
10.2
17.9
25.6
33.3
41.0
48.6
56.3
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Magnetics
Iteration 5 RMS error = 2.4 %
Depth
1.25
9.94
17.3
26.2
36.9
49.9
57.4
Inverse Model Resistivity Section
16.6
38.5
89.3
207
479
1111
2575
5967
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

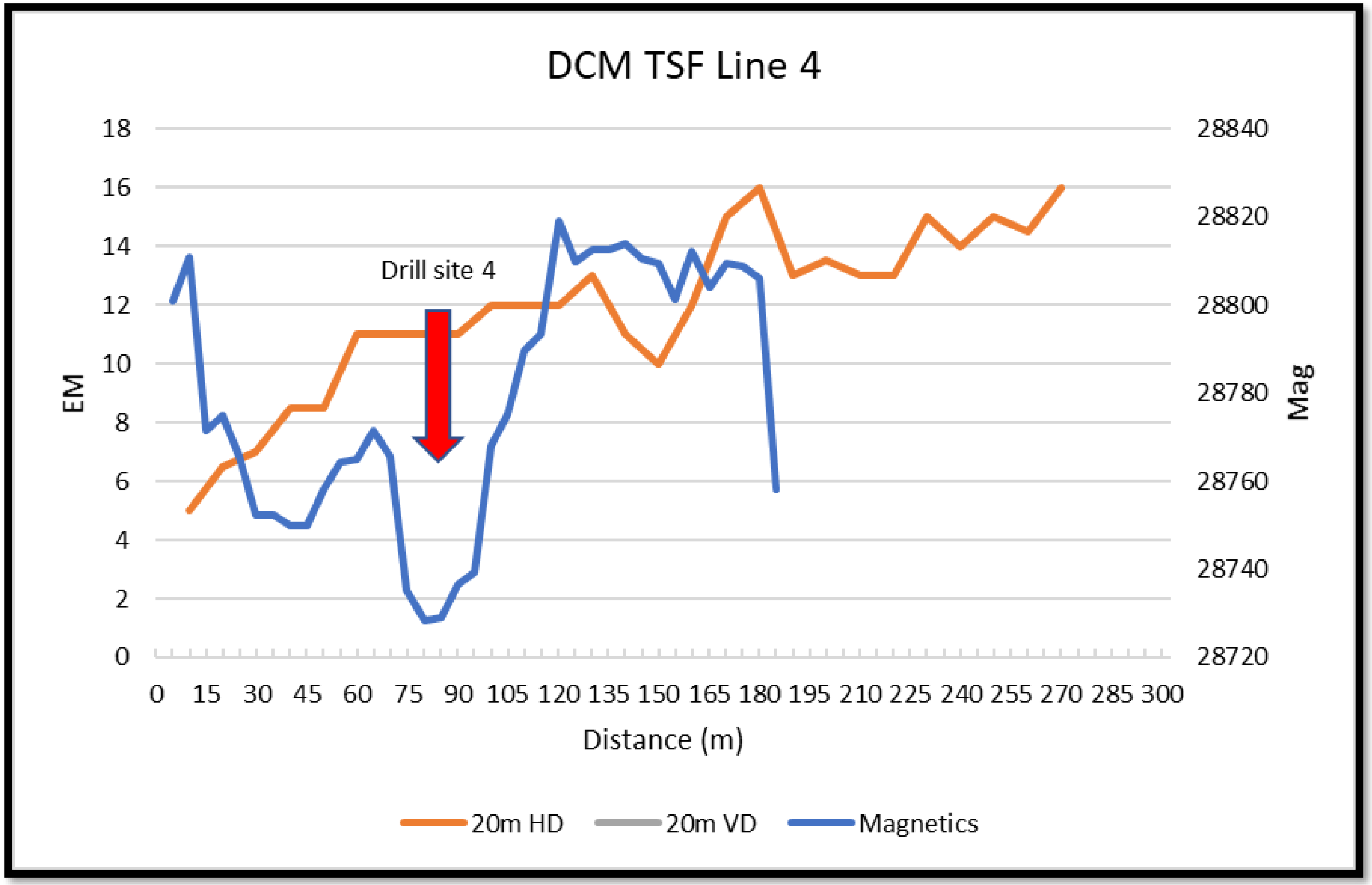
Line 2


Line 2
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Iteration 5 RMS error = 2.8 %
Magnetics
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

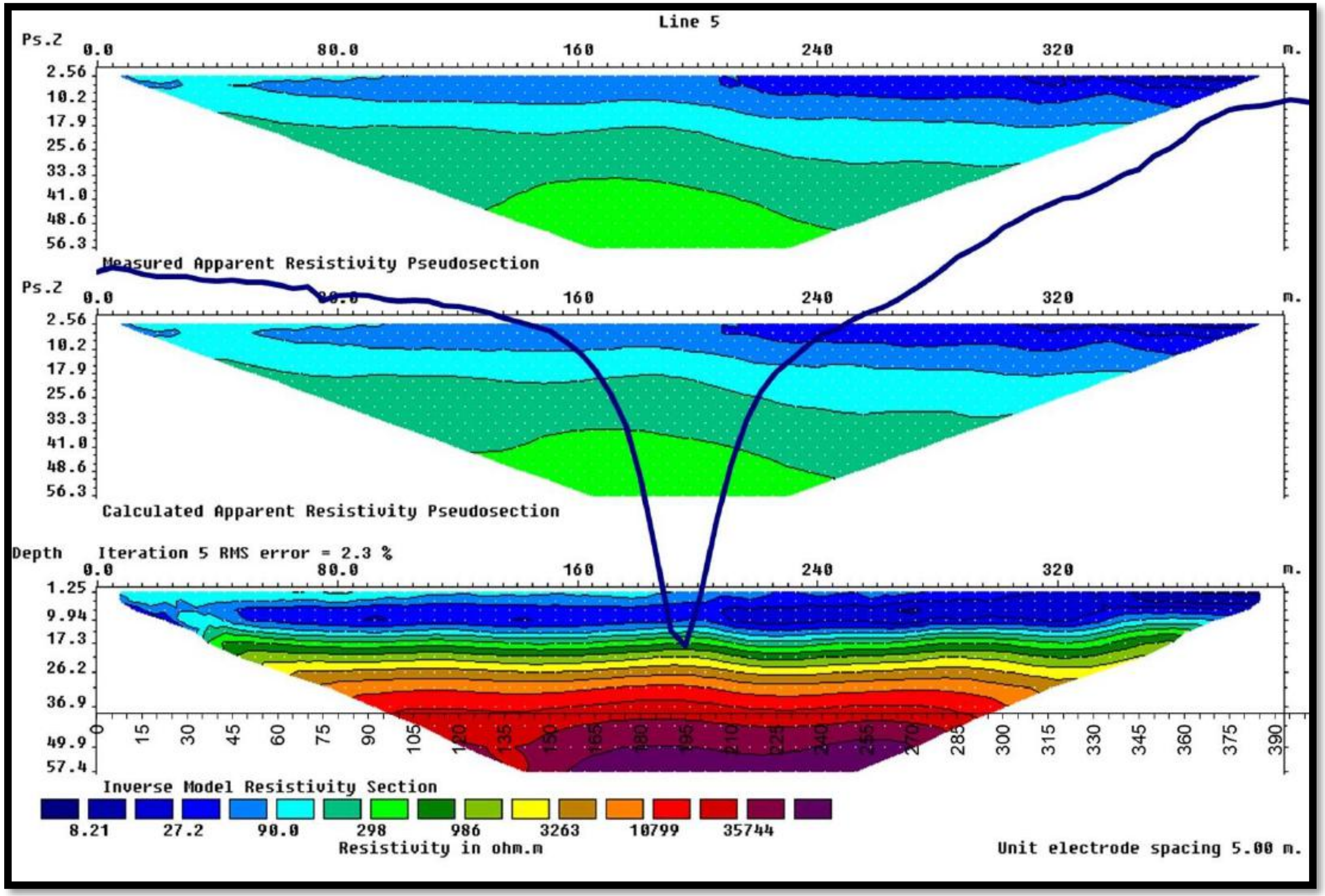
Line 3


DCM TSF Line 3
EM
50
45
40
35
30
25
20
15
10
5
0
Mag
29300
29200
29100
29000
28900
28800
28700
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
Distance (m)
ASDW BH12
20m HD
20m VD
Magnetics

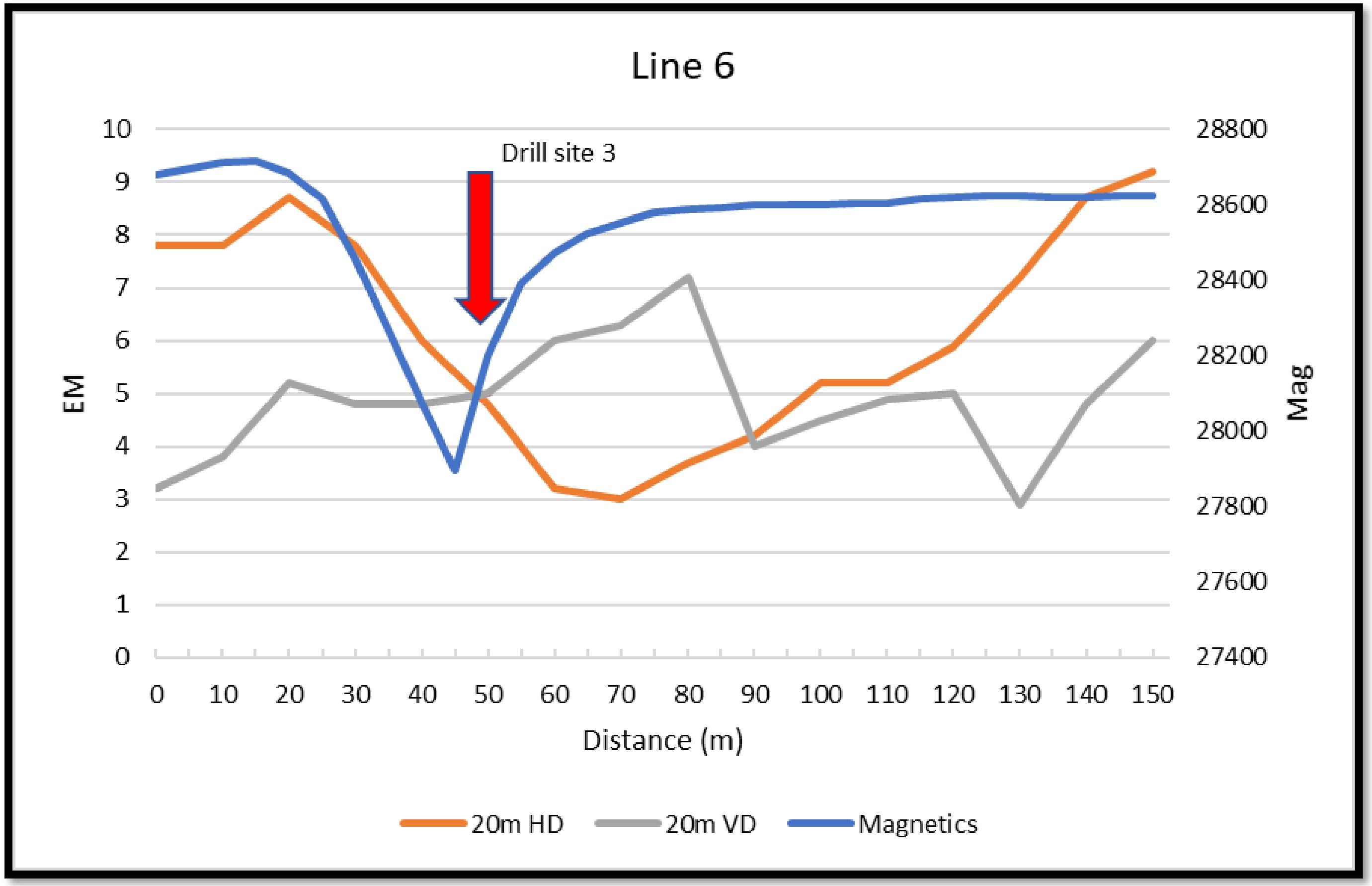
Line 4


DCM TSF Line 4
EM
Mag
18
16
14
12
10
8
6
4
2
0
28840
28820
28800
28780
28760
28740
28720
Drill site 4
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300
Distance (m)
20m HD
20m VD
Magnetics

Line 5

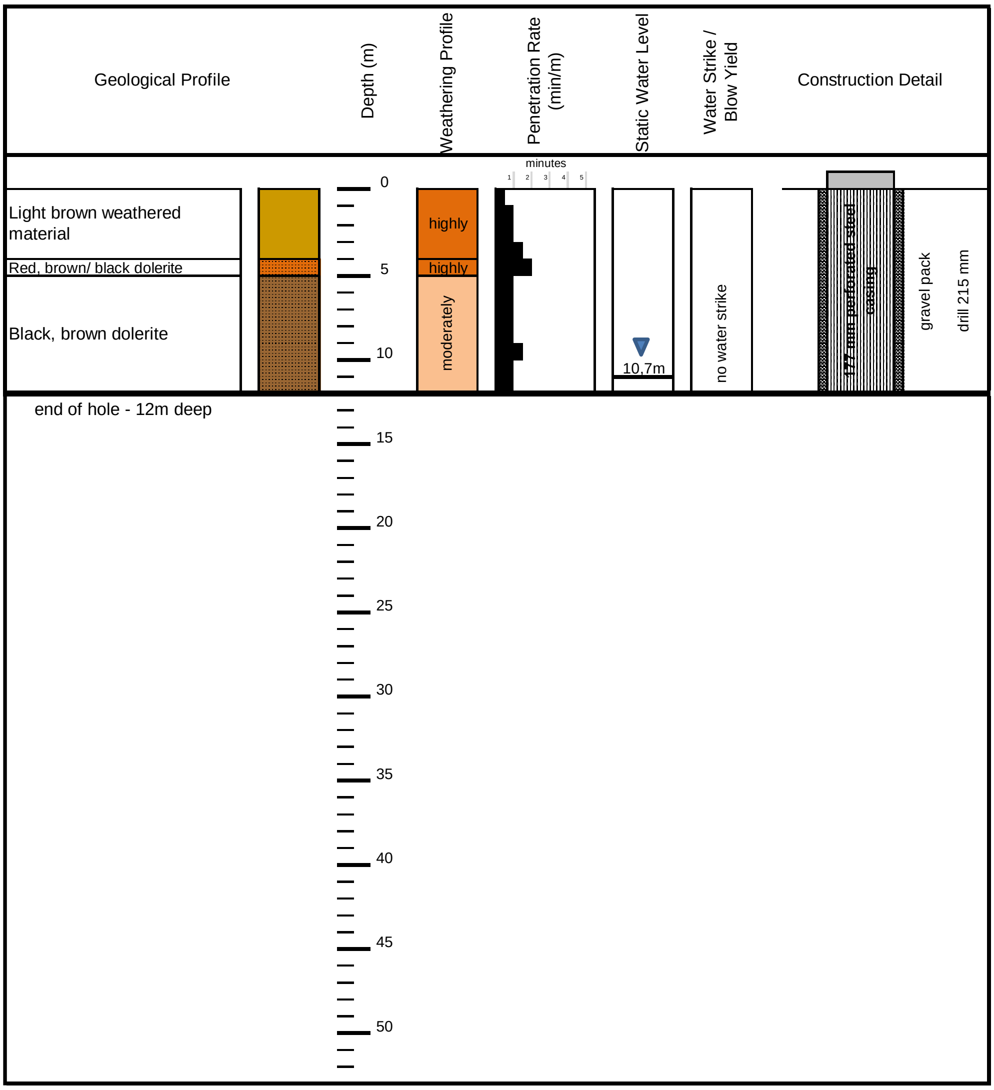

Line 5
Ps.Z
0.0
80.0
160
240
320
m.
2.56
10.2
17.9
25.6
33.3
41.0
48.6
56.3
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Depth
Iteration 5 RMS error = 2.3 %
1.25
9.94
17.3
26.2
36.9
49.9
57.4
Inverse Model Resistivity Section
8.21
27.2
90.0
298
986
3263
10799
35744
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

Line 6


Line 6
Drill site 3
EM
Mag
10
9
8
7
6
5
4
3
2
1
0
28800
28600
28400
28200
28000
27800
27600
27400
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Distance (m)
20m HD
20m VD
Magnetics

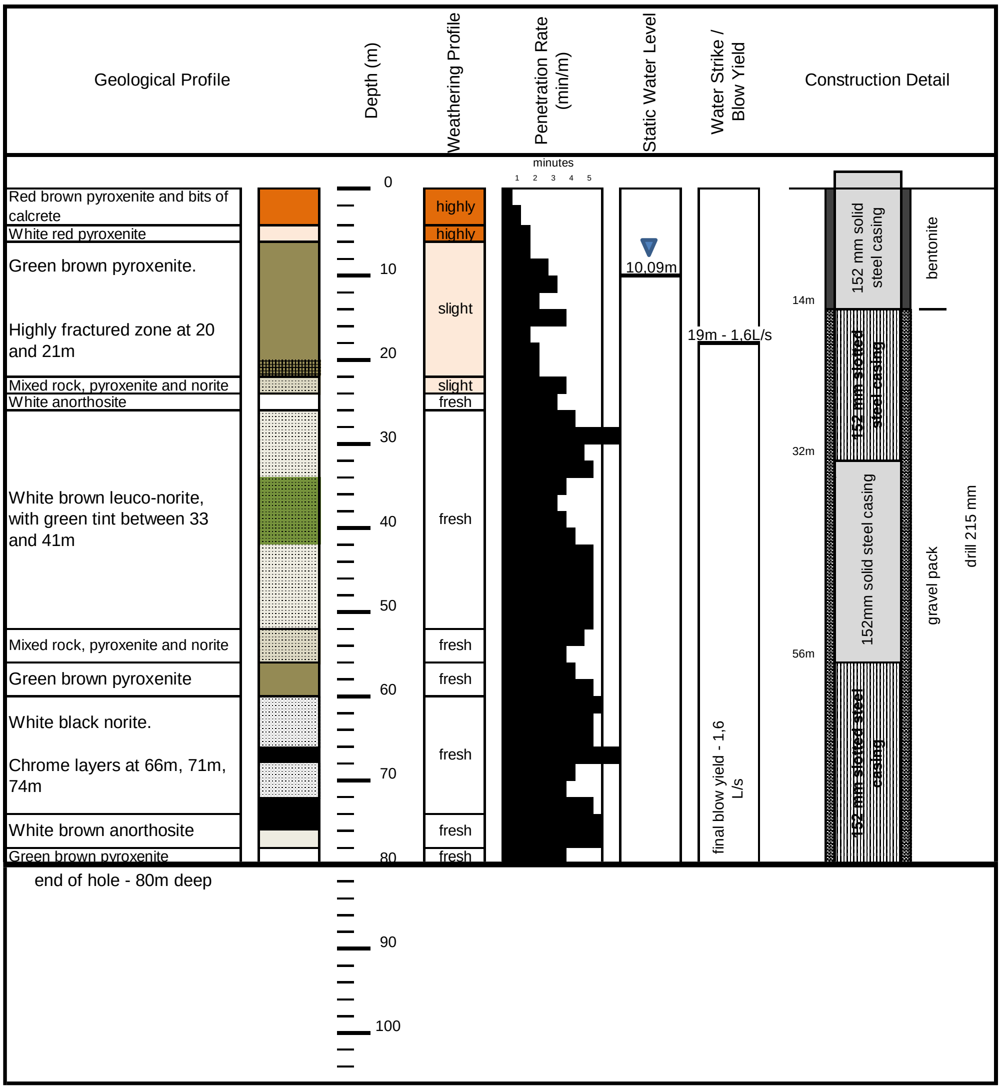
APPENDIX B GROUNDWATER MONITORING BOREHOLE LOGS

Groundwater Abstract (Pty) Ltd	Percussion Drilling Borehole Log		Borehole No. DRM 09 S	
	Client:	Dwarsrivier Chrome Mine		
Lucas Smith	PROJECT:	Khulu TSF	COORDINATES	
			Latitude	24°55'19.68"S
0825778439	LOCATION:	Steelpoort area	Longitude	30°06'46.42"E
	DRILLER:	Ubuntu Rock Drilling	Elevation	920 mamsl
Lucas@wells.africa	DRILL DATE:	19/05/2021	COORD SYSTEM	
	LOGGED BY	Lucas Smith		WGS84



Casing Height:	26 cm	pH:	sample not taken
		EC (ms/m):	
Concrete Height:	13 cm	TDS (mg/L):	
		TDS (ppm):	
Development Time:	none	Salinity (ppm):	
		Temp °C:	

Groundwater Abstract (Pty) Ltd	Percussion Drilling Borehole Log	Borehole No. DRM 09 D
Lucas Smith	**Client:** Dwarsrivier Chrome Mine	COORDINATES
0825778439	PROJECT: Khulu TSF	Latitude 24°55'19.84"S
Lucas@wells.africa	LOCATION: Steelpoort area	Longitude 30°06'46.34"E
	DRILLER: Ubuntu Rock Drilling	Elevation 920 mamsl
	DRILL DATE: 17/05/2021	COORD SYSTEM
	LOGGED BY Lucas Smith	WGS84



Casing Height:	44 cm	Temp C:	
		EC ms/m:	
Concrete Height:	15 cm	Salinity ppm:	no sample taken
		pH:	
Development Time:	30 minutes	DO:	
		EH mv:	

Groundwater Abstract (Pty) Ltd

Lucas Smith

0825778439

Lucas@wells.africa

Percussion Drilling Borehole Log

Borehole No. DRM 10 S

Client:	**Dwarsrivier Chrome Mine**	COORDINATES	
PROJECT:	Khulu TSF	Latitude	24°55'11.54"S
LOCATION:	Steelpoort area	Longitude	30°06'45.66"E
DRILLER:	Ubuntu Rock Drilling	Elevation	932 mamsl
DRILL DATE:	26/05/2021	COORD SYSTEM	
LOGGED BY	Lucas Smith		WGS84

Geological Profile	Depth (m)	Weathering Profile	Penetration Rate (min/m)	Static Water Level	Water Strike / Blow Yield	Construction Detail
Black, grey clay	0	highly	minutes 1 2 3 4 5	dry	no water strike	177 mm perforated steel casing; gravel pack; drill 215 mm
Red, brown material/ soil		highly				
White, grey pyroxenite, calcite	5	highly				
Green, white pyroxenite. Calcite veins.	10	slight				
Black, brown dolerite		moderate				
end of hole - 12m deep	15, 20, 25, 30, 35, 40, 45, 50					

Casing Height:	23 cm	pH:	sample not taken
Concrete Height:	13 cm	EC (ms/m):	
Development Time:	none	TDS (mg/L):	
		TDS (ppm):	
		Salinity (ppm):	
		Temp °C:	

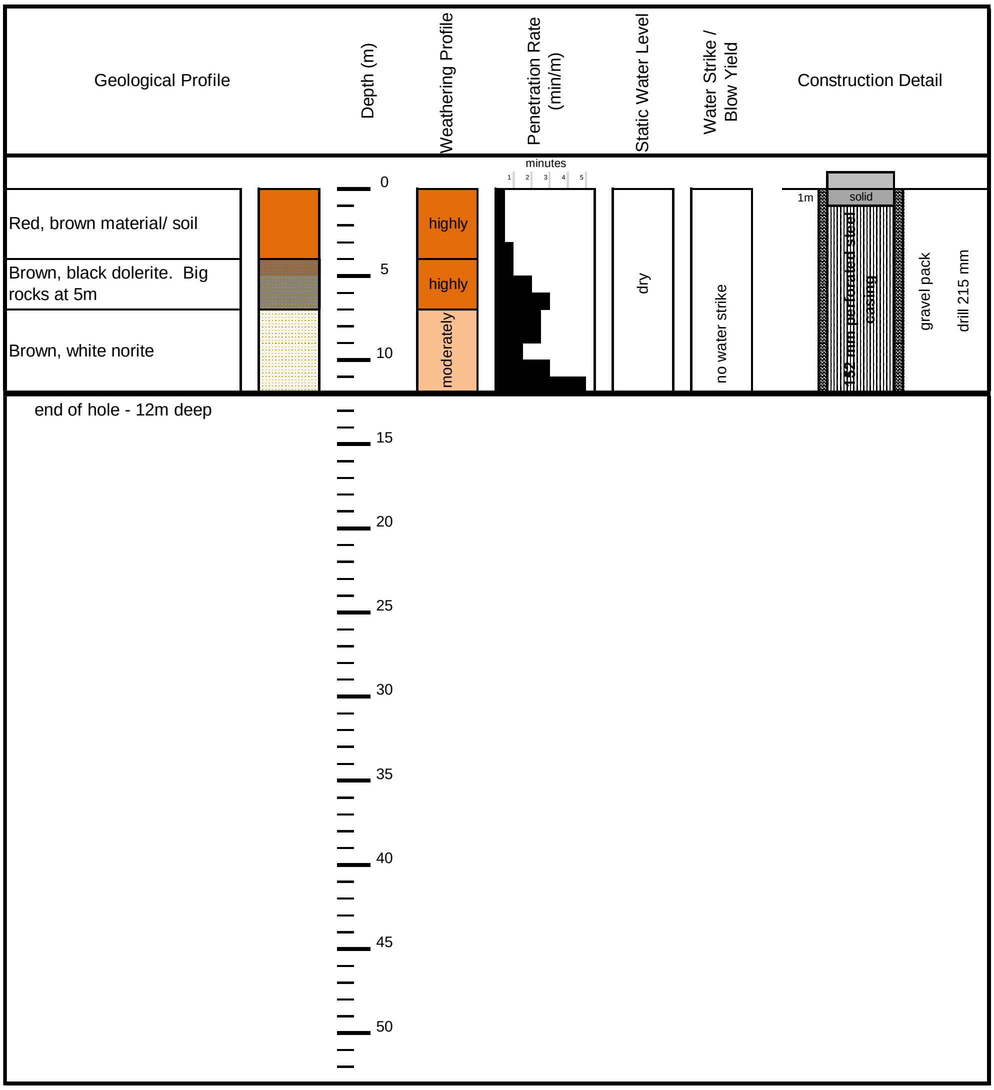
Groundwater Abstract (Pty) Ltd

Lucas Smith

0825778439

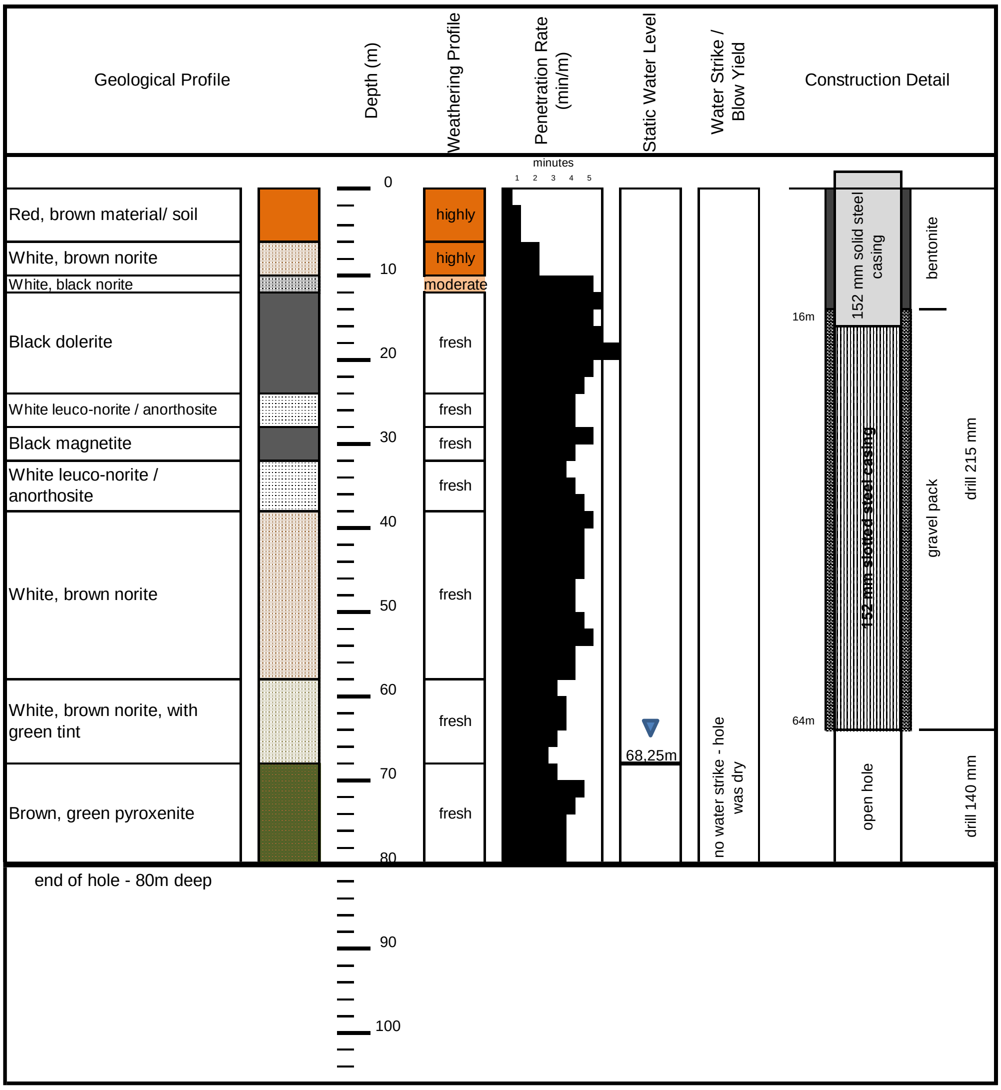
Lucas@wells.africa

Percussion Drilling Borehole Log		Borehole No. DRM 11 S
Client:	**Dwarsrivier Chrome Mine**	COORDINATES
PROJECT:	Khulu TSF	Latitude 24°55'07.86"S
LOCATION:	Steelpoort area	Longitude 30°06'30.74"E
DRILLER:	Ubuntu Rock Drilling	Elevation 917 mamsl
DRILL DATE:	20/05/2021	COORD SYSTEM
LOGGED BY	Lucas Smith	WGS84



Casing Height:	38 cm	pH:	
		EC (ms/m):	
Concrete Height:	16 cm	TDS (mg/L):	sample not taken
		TDS (ppm):	
Development Time:	none	Salinity (ppm):	
		Temp °C:	

Groundwater Abstract (Pty) Ltd	Percussion Drilling Borehole Log		Borehole No. DRM 11 D	
	Client:	Dwarsrivier Chrome Mine		
Lucas Smith	PROJECT:	Khulu TSF	COORDINATES	
			Latitude	24°55'07.64"S
0825778439	LOCATION:	Steelpoort area	Longitude	30°06'30.66"E
	DRILLER:	Ubuntu Rock Drilling	Elevation	917 mamsl
Lucas@wells.africa	DRILL DATE:	25/05/2021	COORD SYSTEM	
	LOGGED BY	Lucas Smith		WGS84



Casing Height:	47 cm	Temp C:	
		EC ms/m:	
Concrete Height:	11 cm	Salinity ppm:	no sample taken
		pH:	
Development Time:	30 minutes	DO:	
		EH mv:	

Groundwater Abstract (Pty) Ltd

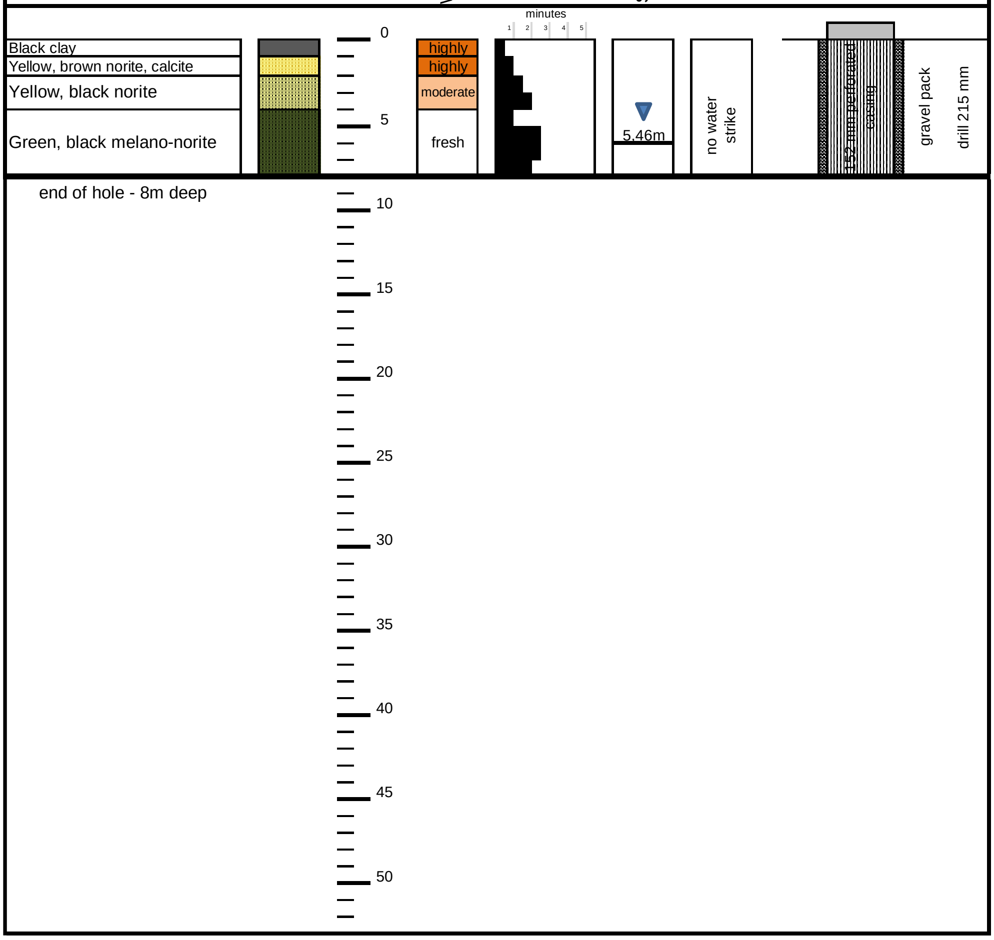
Lucas Smith

0825778439

Lucas@wells.africa

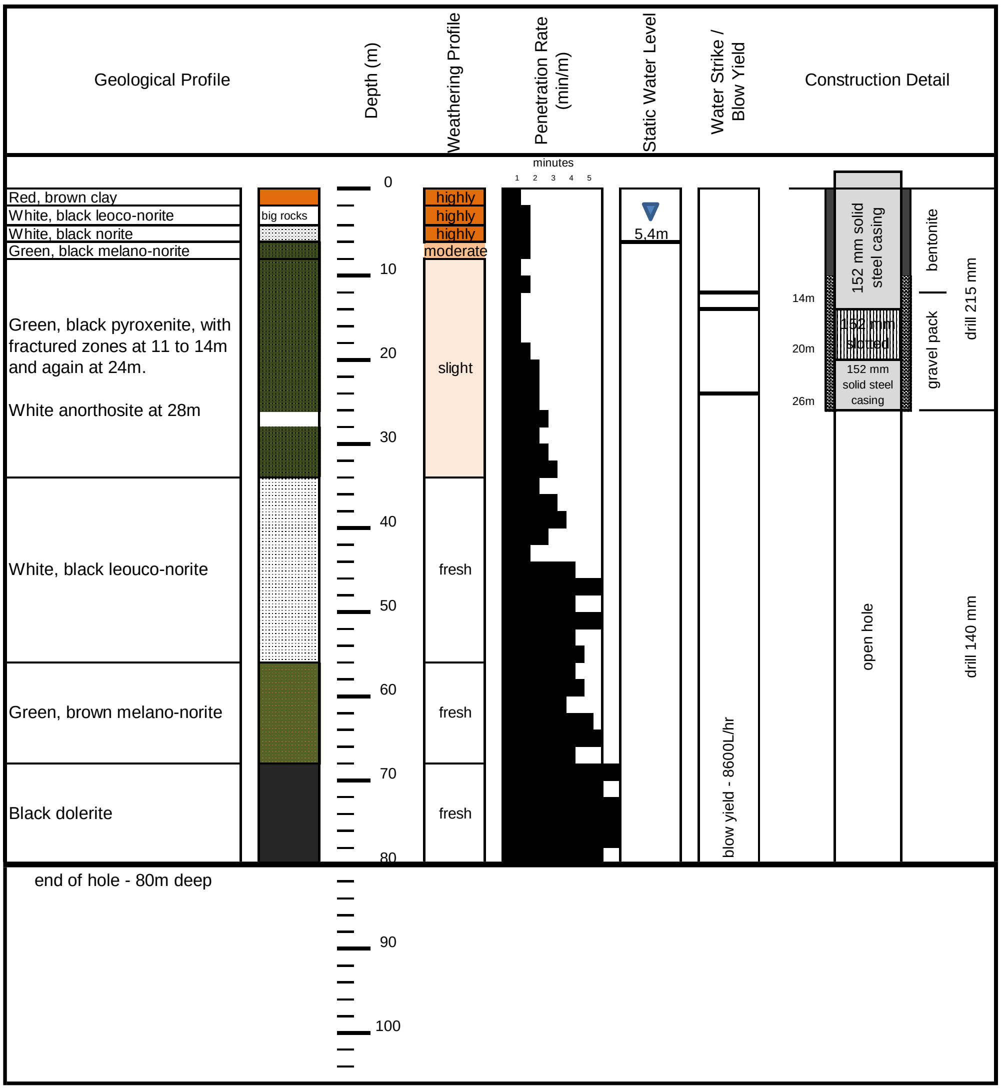
Percussion Drilling Borehole Log		Borehole No. DRM 12 S
Client:	**Dwarsrivier Chrome Mine**	COORDINATES
PROJECT:	Khulu TSF	Latitude 24°54'52.77"S
LOCATION:	Steelpoort area	Longitude 30°06'42.61"E
DRILLER:	Ubuntu Rock Drilling	Elevation 908 mamsl
DRILL DATE:	21/05/2021	COORD SYSTEM
LOGGED BY	Lucas Smith	WGS84

Geological Profile	Depth (m)	Weathering Profile	Penetration Rate (min/m)	Static Water Level	Water Strike / Blow Yield	Construction Detail



Casing Height:	40 cm	pH:	
		EC (ms/m):	
Concrete Height:	22 cm	TDS (mg/L):	sample not taken
		TDS (ppm):	
Development Time:	none	Salinity (ppm):	
		Temp °C:	

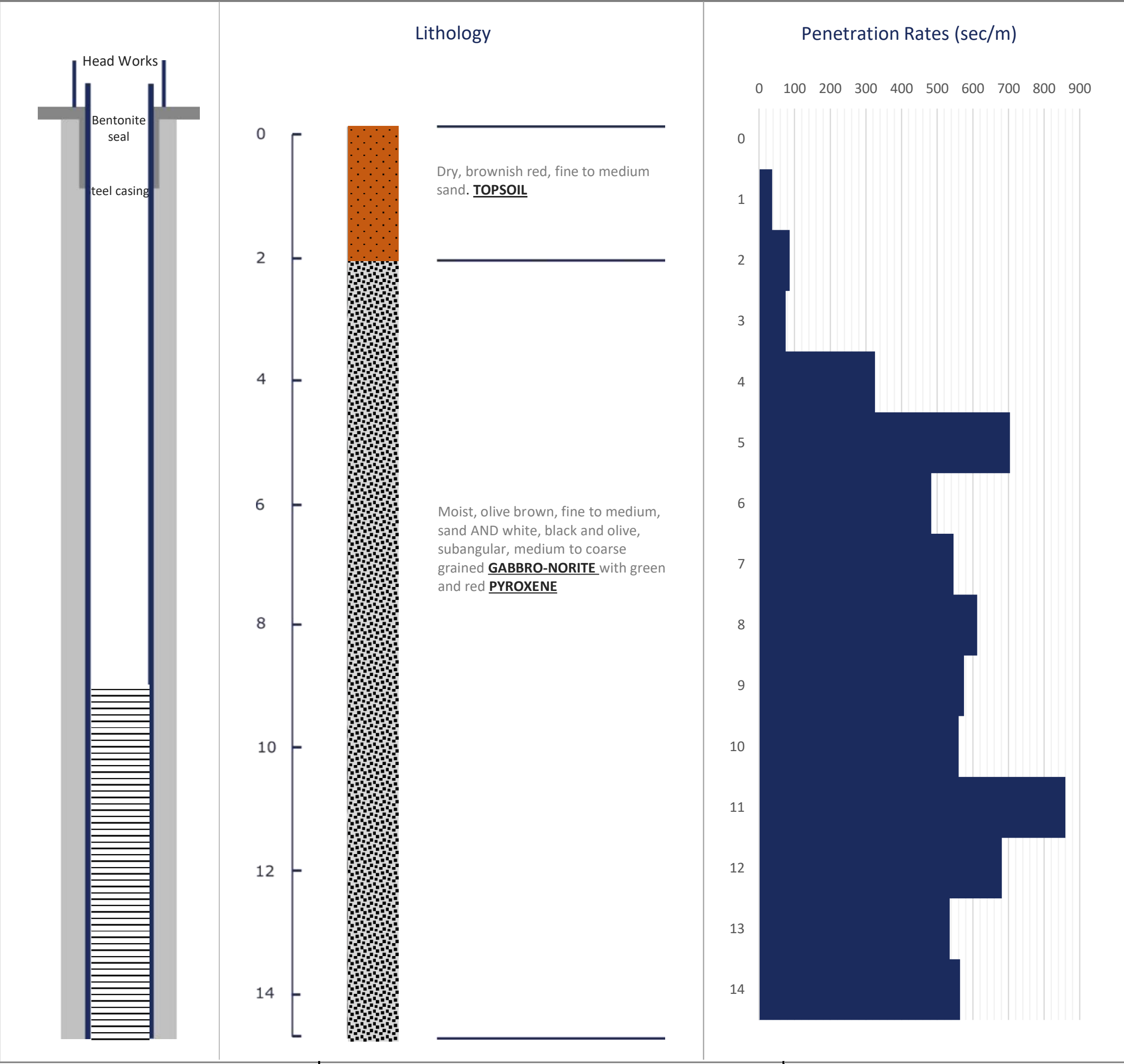
Groundwater Abstract (Pty) Ltd	Percussion Drilling Borehole Log		Borehole No. DRM 12 D	
	Client:	Dwarsrivier Chrome Mine		
Lucas Smith	PROJECT:	Khulu TSF	COORDINATES	
0825778439			Latitude	24°54'52.95"S
	LOCATION:	Steelpoort area	Longitude	30°06'42.37"E
	DRILLER:	Ubuntu Rock Drilling	Elevation	914 mamsl
Lucas@wells.africa	DRILL DATE:	20/05/2021	COORD SYSTEM	
	LOGGED BY	Lucas Smith		WGS84



Casing Height:	33 cm	Temp C:	
		EC ms/m:	
Concrete Height:	19 cm	Salinity ppm:	no sample taken
		pH:	
Development Time:	30 minutes	DO:	
		EH mv:	

Borehole construction and lithology report for DRM 13S

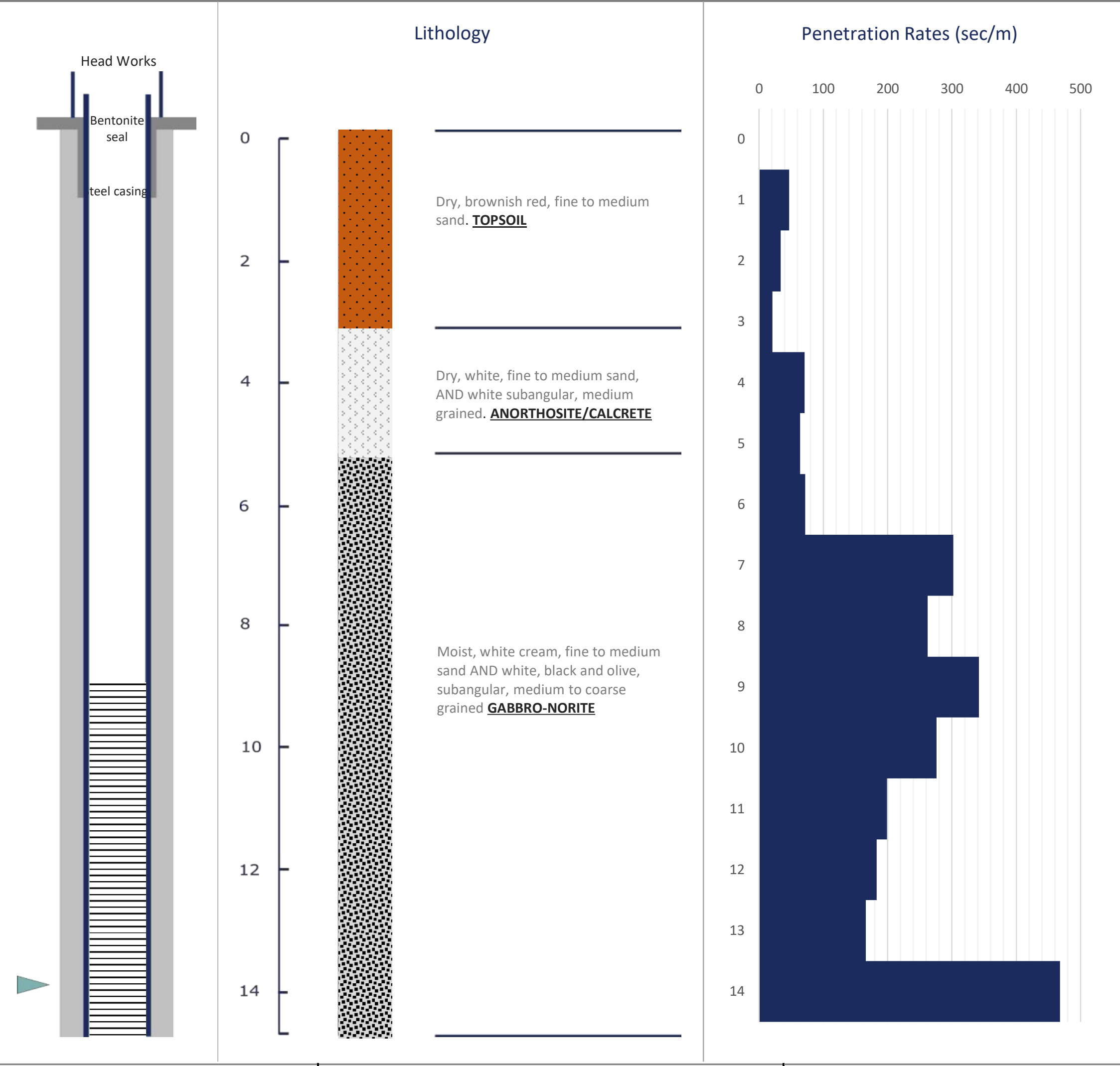
Site Name:	Dwarsrivier	**Number:**	DRM13S	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.9276	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11241			**Depth:**	15
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	



Water details:		**Casing detail:**				**Companies:**
Blow yield (l/s)	None	**Casing and Screen detail:**				nettZero
		Size:	**Type:**	**Top (m):**	**Bot (m):**	
		Casing	Steel	0	15	
		Plain/Solid	Steel	0	9	
Water strike (mbgl)	None	Screen	Steel	9	15	

Borehole construction and lithology report for DRM 14S

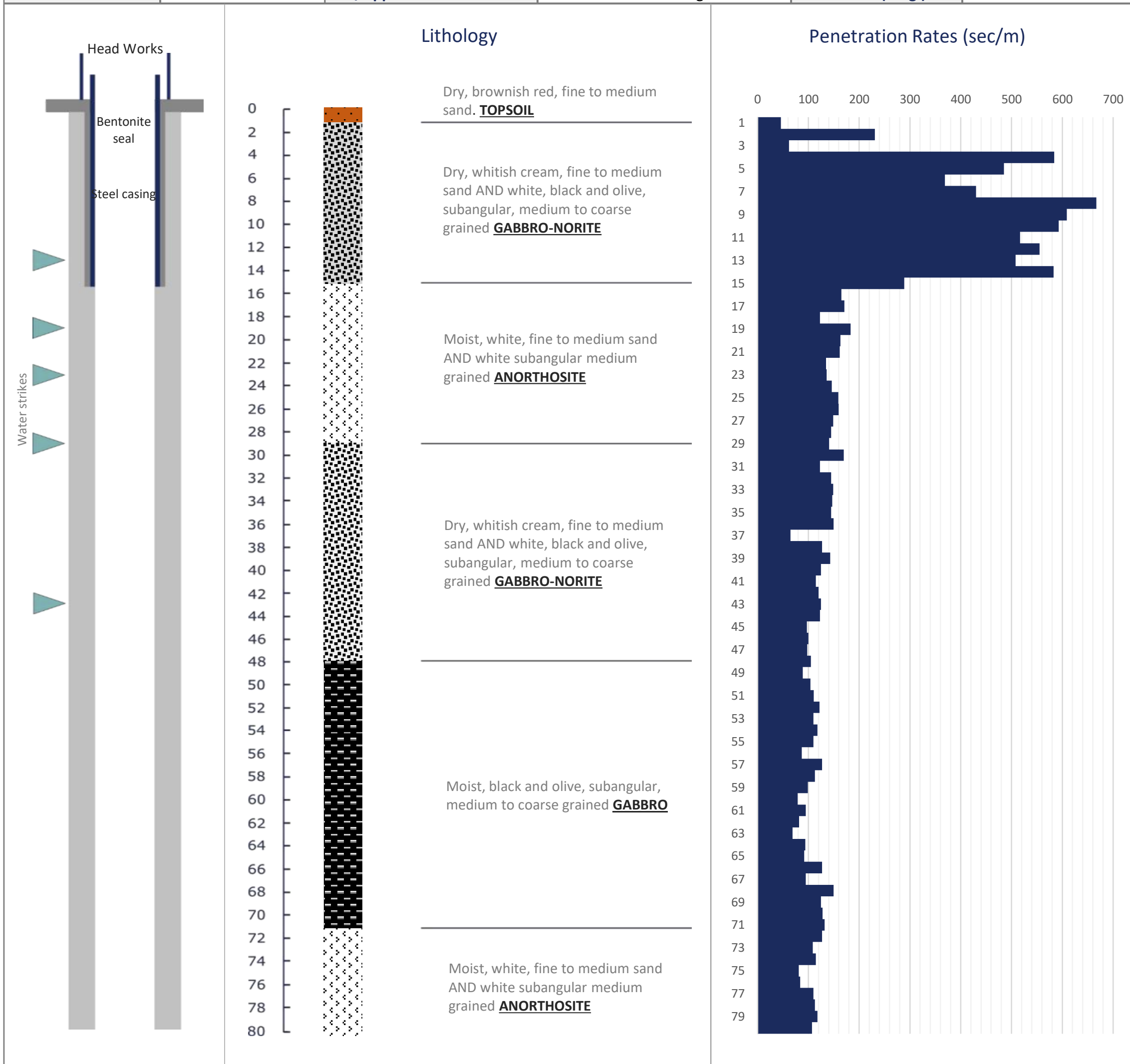
Site Name:	Dwarsrivier	**Number:**	DRM14S	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.93043	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11594			**Depth:**	15
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	



Water details:		**Casing detail:**				**Companies:**
Blow yield (l/s)	5 l/s	**Casing and Screen detail:**				
		Size:	**Type:**	**Top (m):**	**Bot (m):**	
		Casing	Steel	0	15	
		Plain/Solid	Steel	0	9	
Water strike (mbgl)	14	Screen	Steel	9	15	

Borehole construction and lithology report for DRM 13D

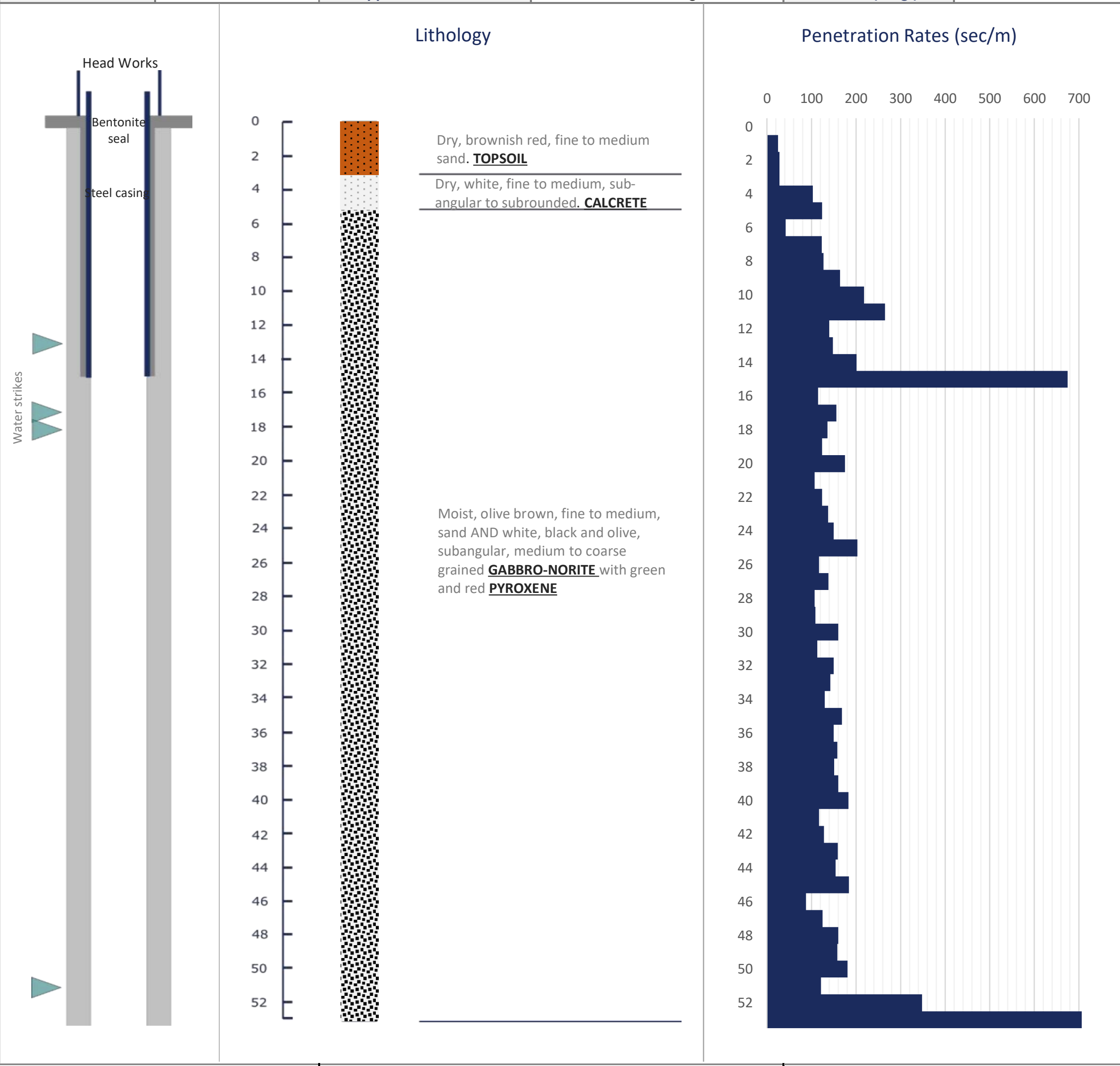
Site Name:	Dwarsrivier	**Number:**	DRM13D	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.9276	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11241			**Depth:**	80
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	



Water details:		**Casing detail:**				**Company details:**
Blow yield (l/s)	< 1 l/s	**Casing and Screen detail:**				
		Size:	**Type:**	**Top (m):**	**Bot (m):**	
		Casing	Steel	0	15	
		Plain/Solid	Steel	0	15	
Water strike (mbgl)	13, 19, 23, 29, 43	Screen	Steel			

Borehole construction and lithology report for DRM 14D

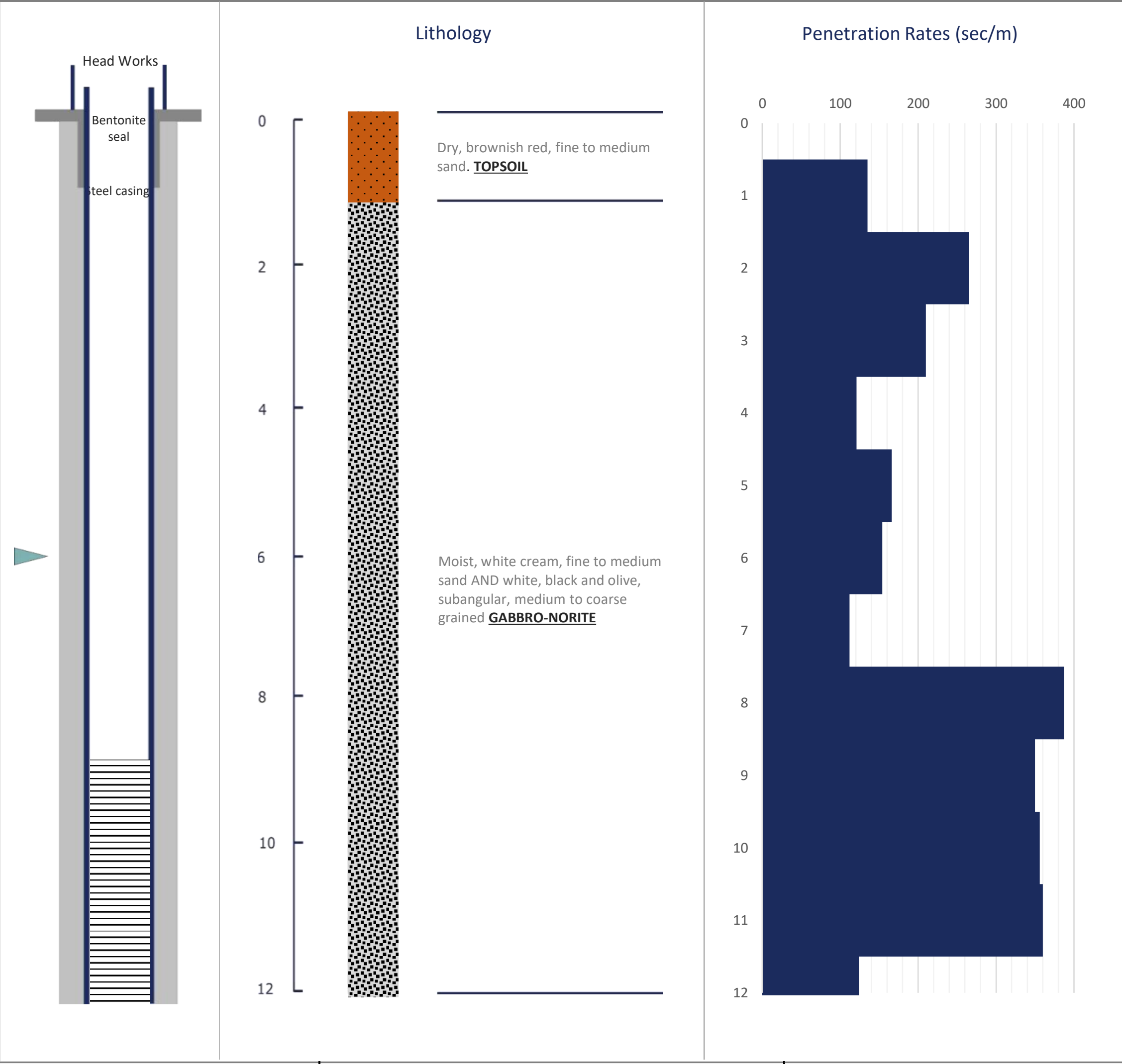
Site Name:	Dwarsrivier	**Number:**	DRM14D	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.93043	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11594			**Depth:**	53
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	



Water details:		**Casing detail:**				**Companies:**
Blow yield (l/s)	5 l/s	**Casing and Screen detail:**				nettZero
		Size:	**Type:**	**Top (m):**	**Bot (m):**	Δh
		Casing	Steel	0	15	
		Plain/Solid	Steel	0	15	
Water strike (mbgl)	13, 17, 18, 31	Screen	Steel			

Borehole construction and lithology report for DRM 15S

Site Name:	Dwarsrivier	**Number:**	DRM15S	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.92677	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11133			**Depth:**	12
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	

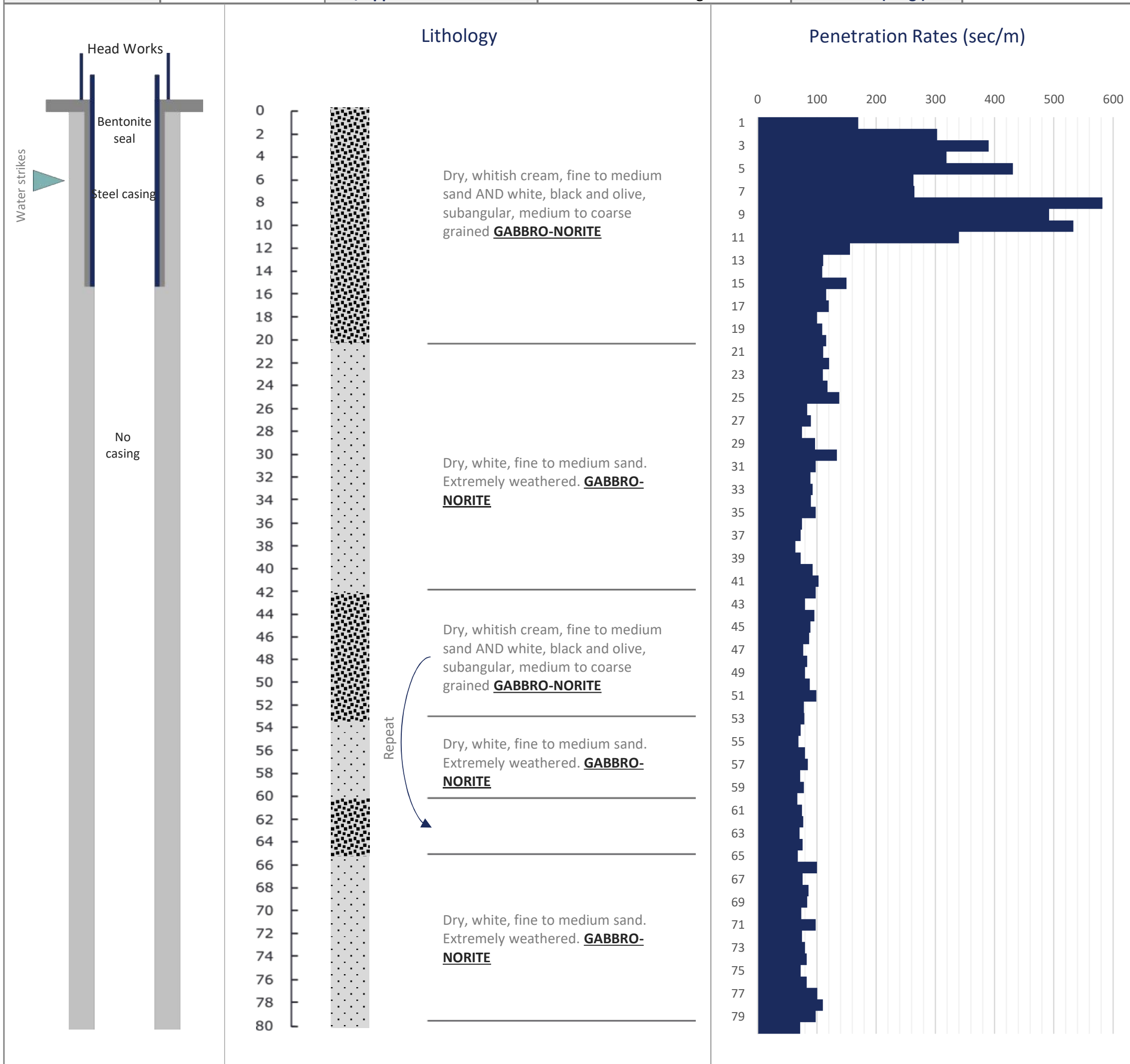


Water details:		**Casing detail:**			
Blow yield (l/s)	< 1 l/s	**Casing and Screen detail:**			
		Size:	**Type:**	**Top (m):**	**Bot (m):**
		Casing	Steel	0	12
		Plain/Solid	Steel	0	9
Water strike (mbgl)	6	Screen	Steel	9	12

Companies:

Borehole construction and lithology report for DRM 15D

Site Name:	Dwarsrivier	**Number:**	DRM15D	**Drain. Regn:**	B41G
Site Type:	Mine	**Region Description:**	Bushveld Complex	**Province:**	Limpopo
Lat (˚)	-24.92677	**Client:**	Dwarsrivier Chrome Mine	**Drilled Diam:**	203mm, 177mm
Long (˚)	30.11133			**Depth:**	80
Coor. Meth.:	GPS	**Coord. System:**	WGS 84	**Casing outer (mm):**	165
Altitude:	-	**Use/Application:**	Monitoring	**Water level (mbgl):**	

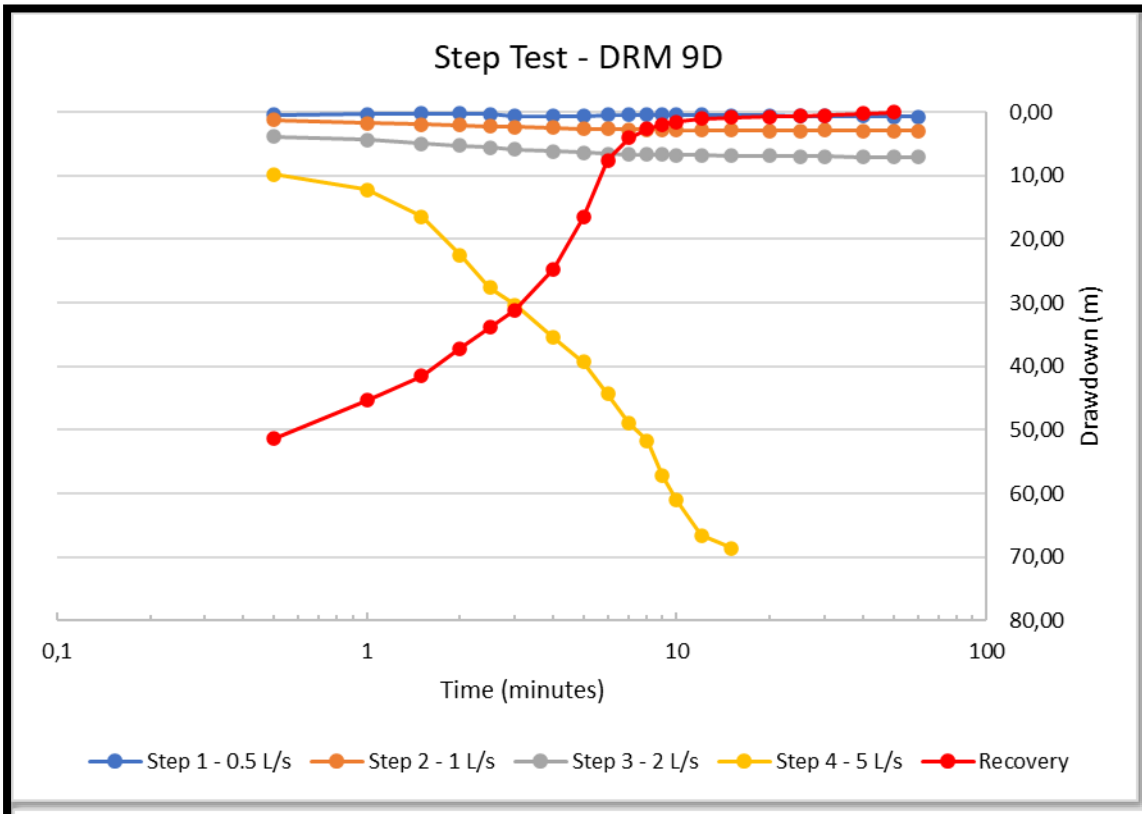


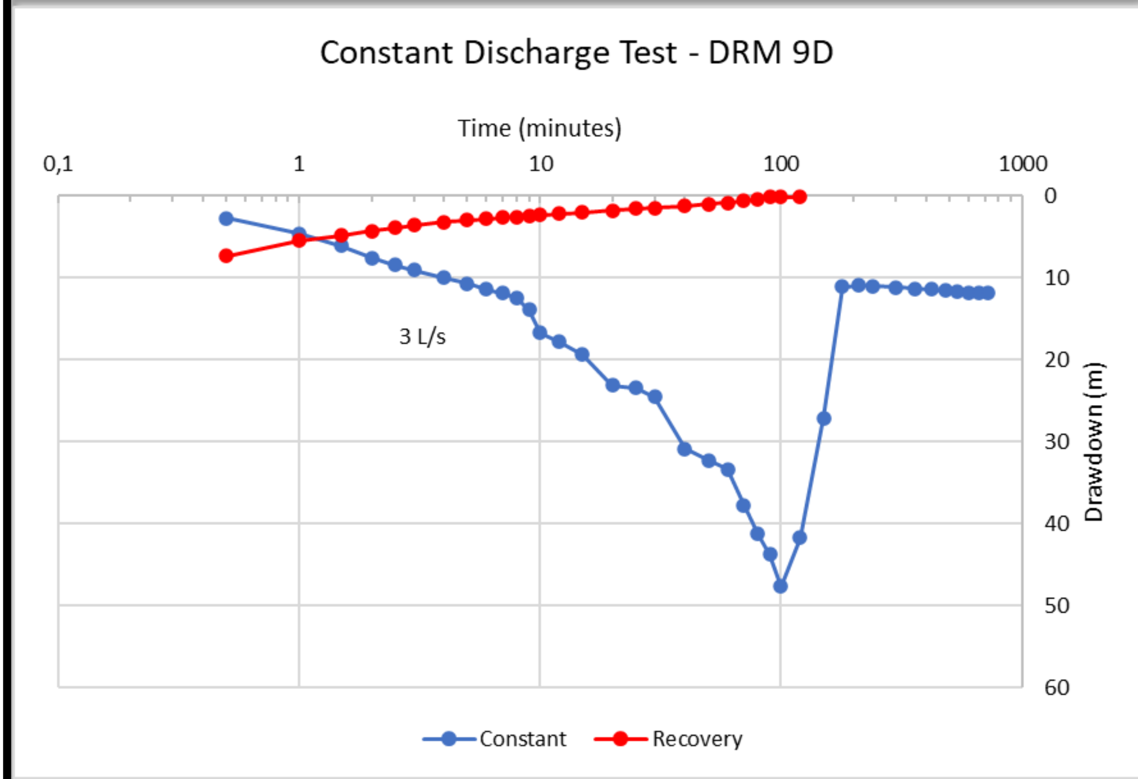
Water details:		**Casing detail:**			
Blow yield (l/s)	< 1 l/s	**Casing and Screen detail:**			
		Size:	**Type:**	**Top (m):**	**Bot (m):**
		Casing	Steel	0	15
		Plain/Solid	Steel	0	15
Water strike (mbgl)	6	Screen	Steel		

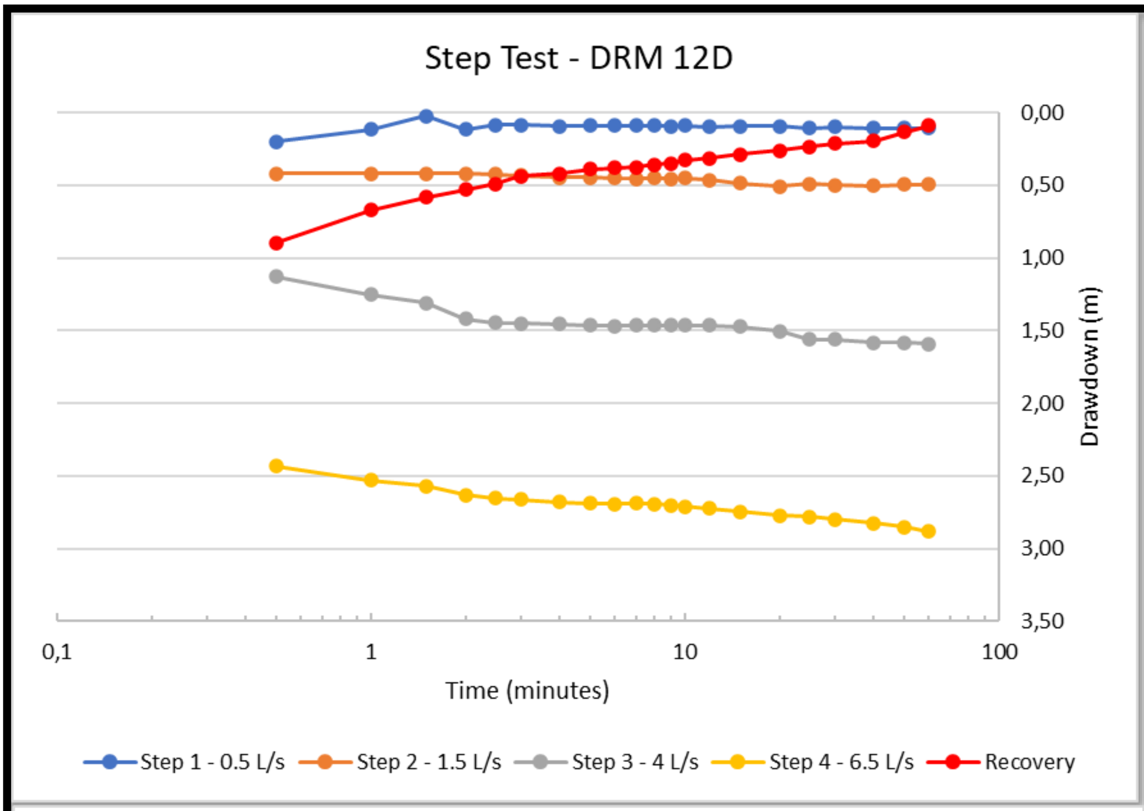
Company details:

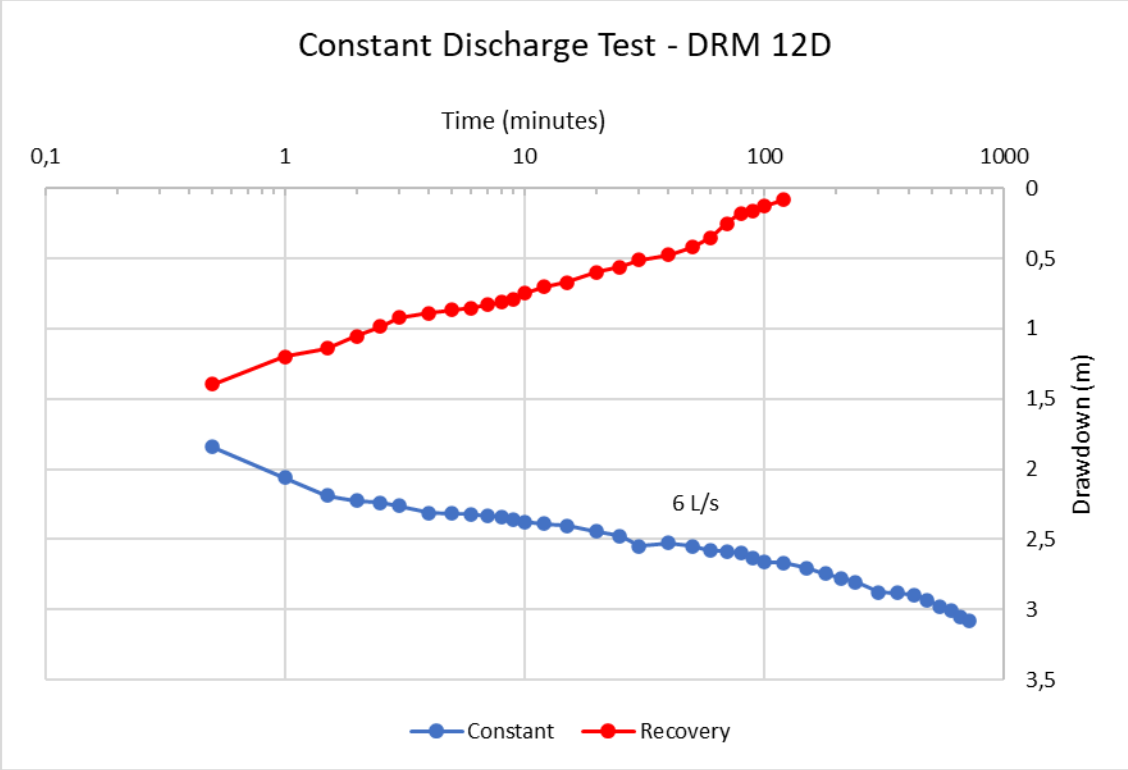
nettZero

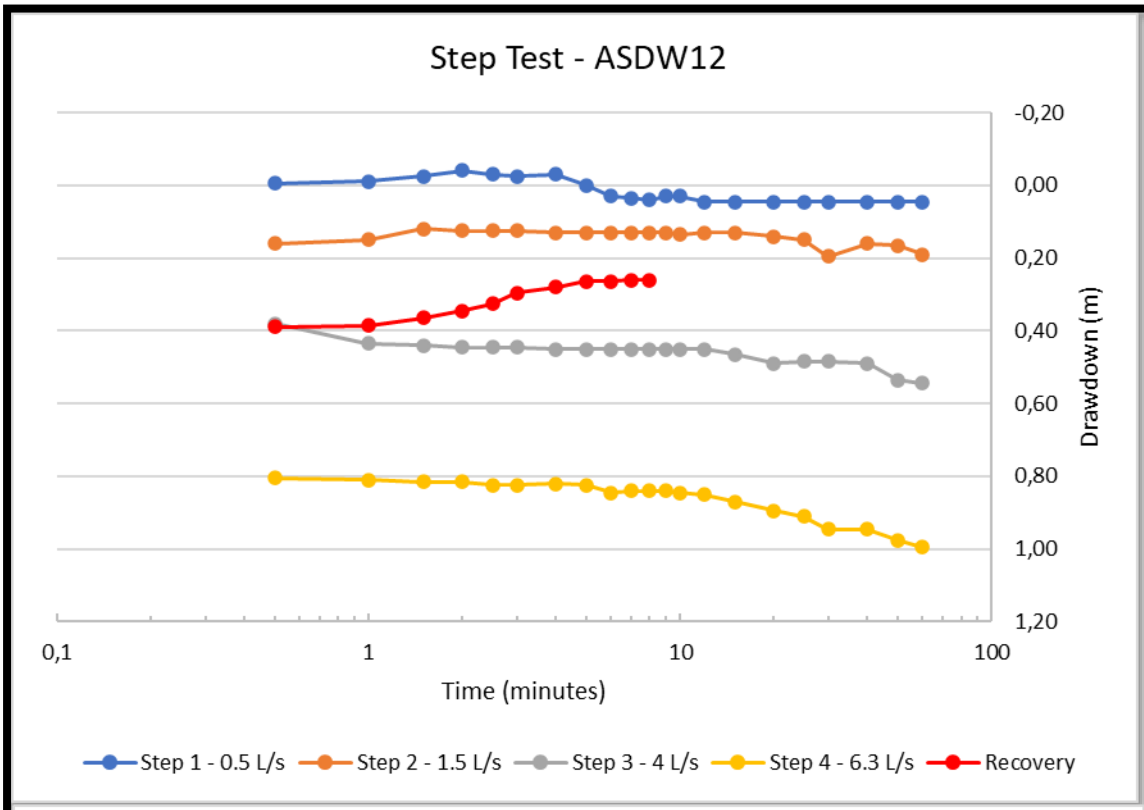
APPENDIX C AQUIFER TEST RESULTS

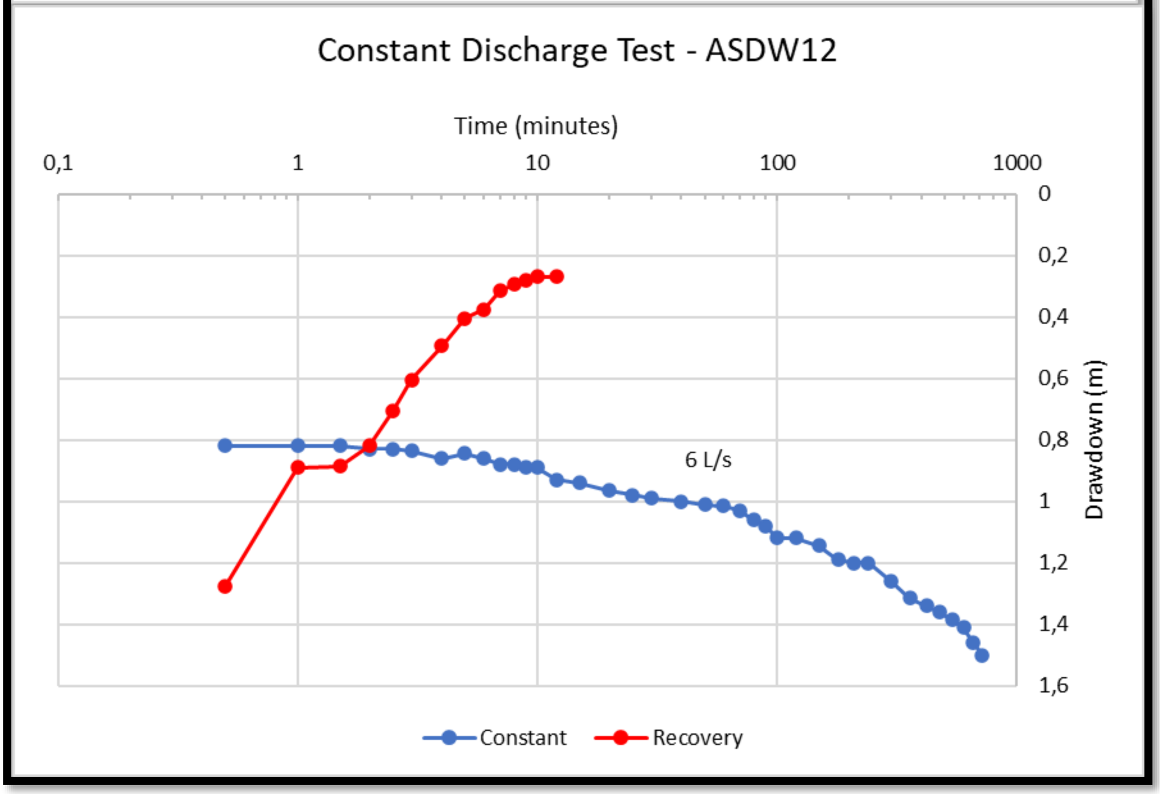





Step Test - DRM 12D
0,00
0,50
1,00
1,50
2,00
2,50
3,00
3,50
Drawdown (m)
0,1
1
10
100
Time (minutes)
Step 1 - 0.5 L/s
Step 2 - 1.5 L/s
Step 3 - 4 L/s
Step 4 - 6.5 L/s
Recovery


Constant Discharge Test - DRM 12D
Time (minutes)
0,1
1
10
100
1000
0
0,5
1
1,5
2
2,5
3
3,5
Drawdown (m)
6 L/s
Constant
Recovery


Step Test - ASDW12
-0,20
0,00
0,20
0,40
0,60
0,80
1,00
1,20
Drawdown (m)
0,1
1
10
100
Time (minutes)
Step 1 - 0.5 L/s
Step 2 - 1.5 L/s
Step 3 - 4 L/s
Step 4 - 6.3 L/s
Recovery


Constant Discharge Test - ASDW12
Time (minutes)
0,1
1
10
100
1000
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
Drawdown (m)
6 L/s
Constant
Recovery

APPENDIX D LABORATORY CERTIFICATES OF ANALYSES

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-05-26 **Date completed:** 2021-06-09
Project number: 1000 **Report number:** 100731 **Order number:**

Client name: Irene Lea Environmental and Hydrogeology cc **Contact person:** Ms. I. Lea
Address: P.O Box 343, Dunnotter, 1590 **e-mail:** irene@ileh.co.za
Telephone: 011 363 2926 **Facsimile:** **Mobile:**

Analyses in mg/ℓ (Unless specified otherwise)		Method Identification	Sample Identification		
			D1	Farm House	ASDWBH12
Sample Number			129012	129013	129014
Date/Time Sampled			N/A	N/A	N/A
pH - Value @ 25 ºC	A	WLAB065	8.0	7.9	7.6
Electrical Conductivity in mS/m @ 25°C	A	WLAB002	61.1	114	184
Total Dissolved Solids @ 180°C	A	WLAB003	348	694	1158
Total Alkalinity as $CaCO_3$	A	WLAB007	304	440	252
P-Alkalinity as $CaCO_3$	A	WLAB023	<5	<5	<5
Bicarbonate as HCO_3	A	WLAB023	371	536	307
Total Hardness as $CaCO_3$	A	WLAB051	311	613	885
Chloride as Cl	A	WLAB046	11	14	178
Sulphate as SO_4	A	WLAB046	27	45	124
Fluoride as F	N	WLAB046	<0.2	<0.2	<0.2
Nitrate as N	A	WLAB046	3.3	46	89
Nitrite as N	A	WLAB046	<0.05	<0.05	0.07
Ortho Phosphate as P	A	WLAB046	<0.1	<0.1	<0.1
Total Nitrogen as N	N	WLAB026	3.9	46	89
Kjeldahl Nitrogen	N	WLAB025	0.6	<0.5	<0.5
Free and Saline Ammonia as N	A	WLAB046	<0.1	0.1	<0.1
Sodium as Na	A	WLAB015	14	13	27
Potassium as K	A	WLAB015	0.8	1.1	0.8
Calcium as Ca	A	WLAB015	46	62	150
Magnesium as Mg	A	WLAB015	48	112	124
Aluminium as Al (Dissolved)	A	WLAB015	<0.100	0.113	0.118
Barium as Ba (Dissolved)	A	WLAB015	0.039	0.058	0.045
Boron as B (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Cadmium as Cd (Dissolved)	A	WLAB050	<0.001	<0.001	<0.001
Total Chromium as Cr (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Hexavalent Chromium as Cr	A	WLAB032	<0.010	<0.010	<0.010
Cobalt as Co (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Copper as Cu (Dissolved)	A	WLAB015	<0.010	0.032	<0.010

E. Nkabinde - Chemical Technical Signatory

A = Accredited N = Not Accredited S = Subcontracted

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Sample condition acceptable unless specified on the report.

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WATERLAB (Pty) Ltd

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e-mail: admin@waterlab.co.za

sanas Testing Laboratory
T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-05-26 **Date completed:** 2021-06-09
Project number: 1000 **Report number:** 100731 **Order number:**

Client name: Irene Lea Environmental and Hydrogeology cc **Contact person:** Ms. I. Lea
Address: P.O Box 343, Dunnotter, 1590 **e-mail:** irene@ileh.co.za
Telephone: 011 363 2926 **Facsimile:** **Mobile:**

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	Sample Identification		
			D1	Farm House	ASDWBH12
Sample Number			129012	129013	129014
Date/Time Sampled			N/A	N/A	N/A
Iron as Fe (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Lead as Pb (Dissolved)	A	WLAB050	<0.001	0.001	<0.001
Manganese as Mn (Dissolved)	A	WLAB015	0.304	<0.025	<0.025
Molybdenum as Mo (Dissolved)	N	WLAB015	<0.025	<0.025	<0.025
Nickel as Ni (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Silver as Ag (Dissolved)	N	WLAB015	<0.025	<0.025	<0.025
Vanadium as V (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Zinc as Zn (Dissolved)	A	WLAB015	<0.025	0.091	<0.025
% Balancing	N	---	97.8	98.1	99.7

E. Nkabinde - Chemical Technical Signatory

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T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-07-12 **Date completed:** 2021-07-29
Project number: 1000 **Report number:** 102001 **Order number:**

Client name: Irene Lea Environmental and Hydrogeology cc **Contact person:** Ms. I. Lea
Address: P.O Box 343, Dunnotter, 1590 **e-mail:** irene@ileh.co.za
Telephone: 011 363 2926 **Facsimile:** **Mobile:**

Analyses in mg/ℓ (Unless specified otherwise)		Method Identification	Sample Identification: Ground Water		
			DRM9D	DRM12D	ASDW12
Sample Number			133361	133362	133363
Date/Time Sampled			N/A	N/A	N/A
pH - Value @ 25 ºC	A	WLAB065	7.4	7.6	7.4
Electrical Conductivity in mS/m @ 25°C	A	WLAB002	251	122	196
Total Dissolved Solids @ 180°C	A	WLAB003	2116	790	1394
Total Alkalinity as $CaCO_3$	A	WLAB007	308	400	304
P-Alkalinity as $CaCO_3$	A	WLAB023	<5	<5	<5
Bicarbonate as HCO_3	A	WLAB023	375	488	371
Total Hardness as $CaCO_3$	A	WLAB051	1225	601	938
Chloride as Cl	A	WLAB046	313	31	200
Sulphate as SO_4	A	WLAB046	185	64	135
Fluoride as F	N	WLAB014	0.2	0.2	0.2
Nitrate as N	A	WLAB046	106	49	82
Nitrite as N	A	WLAB046	<0.05	<0.05	<0.05
Ortho Phosphate as P	A	WLAB046	<0.1	<0.1	<0.1
Total Nitrogen as N	N	WLAB026	107	50	82
Kjeldahl Nitrogen	N	WLAB025	1.1	1.1	<0.5
Free and Saline Ammonia as N	A	WLAB046	0.7	0.5	0.3
Sodium as Na	A	WLAB015	26	27	26
Potassium as K	A	WLAB015	0.6	1.5	0.5
Calcium as Ca	A	WLAB015	154	52	161
Magnesium as Mg	A	WLAB015	204	115	130
Aluminium as Al (Dissolved)	A	WLAB015	0.128	<0.100	0.108
Barium as Ba (Dissolved)	A	WLAB015	0.063	0.069	0.049
Boron as B (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Cadmium as Cd (Dissolved)	A	WLAB050	<0.001	<0.001	<0.001
Total Chromium as Cr (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Hexavalent Chromium as Cr	A	WLAB032	<0.010	<0.010	0.012
Cobalt as Co (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Copper as Cu (Dissolved)	A	WLAB015	0.019	0.014	0.016

A. van de Wetering - Chemical Technical Signatory

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WATERLAB (Pty) Ltd
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T0391

CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2021-07-12
Project number: 1000
Report number: 102001
Date completed: 2021-07-29
Order number:

Client name: Irene Lea Environmental and Hydrogeology cc
Contact person: Ms. I. Lea
Address: P.O Box 343, Dunnotter, 1590
e-mail: irene@ileh.co.za
Telephone: 011 363 2926
Facsimile:
Mobile:

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	Sample Identification: Ground Water		
			DRM9D	DRM12D	ASDW12
Sample Number			133361	133362	133363
Date/Time Sampled			N/A	N/A	N/A
Iron as Fe (Dissolved)	A	WLAB015	0.026	<0.025	<0.025
Lead as Pb (Dissolved)	A	WLAB050	0.001	0.001	0.002
Manganese as Mn (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Molybdenum as Mo (Dissolved)	N	WLAB015	<0.025	<0.025	<0.025
Nickel as Ni (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Silver as Ag (Dissolved)	N	WLAB015	<0.025	<0.025	<0.025
Vanadium as V (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
Zinc as Zn (Dissolved)	A	WLAB015	<0.025	<0.025	<0.025
% Balancing	N	---	98.5	98.5	98.7

A. van de Wetering - Chemical Technical Signatory

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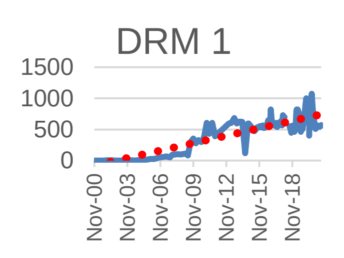
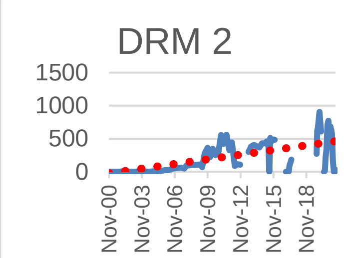
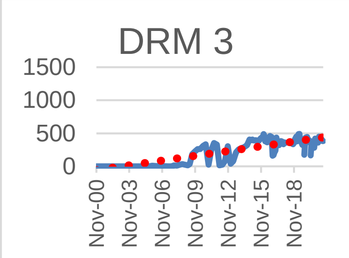
APPENDIX E LONG-TERM NITRATE MONITORING DATA

Groundwater database – boreholes in the vicinity of the Khulu TSF



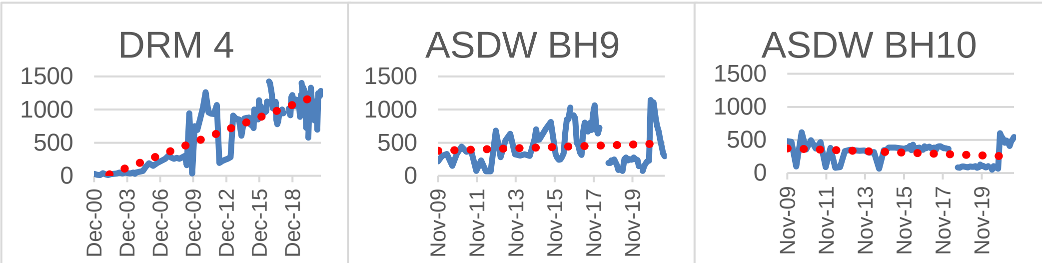




Monitors: LRWD Depth: Unknown		Monitors: LRWD (bees) Depth: Unknown		Monitors: Quarry Depth: Unknown	
DRM1		**DRM2**		**DRM3**	
Nov-00	0	Nov-00	0	Nov-00	0,7
Dec-00	0,94	Dec-00	0,94	Dec-00	1,11
Apr-01	1,2	Apr-01	1,2	Apr-01	0,54
Jul-01	0,9	Jul-01	0,9	Jul-01	0,56
Oct-01	1,3	Oct-01	1,3	Oct-01	0,55
Jan-02	3	Jan-02	3	Jan-02	0,41
Mar-02	3,8	Mar-02	3,8	Mar-02	0,44
Jun-02	3	Jun-02	3	Jun-02	0,47
Sep-02	2,5	Sep-02	2,5	Sep-02	1,5
Jan-03	2,7	Jan-03	2,7	Jan-03	0,72
Apr-03	2	Apr-03	2	Apr-03	0,36
Jul-03	4,2	Jul-03	4,2	Jul-03	0,1
Sep-03	2,76	Sep-03	2,76	Aug-03	1,08
Feb-04	5,5	Feb-04	5,5	Feb-04	0
Mar-04	3,6	Mar-04	3,6	Mar-04	0,54
Jul-04	1,4	Jul-04	1,4	Jul-04	0,41
Oct-04	3,24	Oct-04	3,24	Oct-04	0,72
May-05	8,5	May-05	8,5	May-05	1,8
Aug-05	15,6	Aug-05	15,6	Aug-05	1,04
Dec-05	24,2	Dec-05	24,2	Dec-05	8,25
Apr-06	23,6	Apr-06	23,6	Apr-06	3,61
Sep-06	48,2	Sep-06	48,2	Sep-06	5,7
Jun-07	64,7	Jun-07	64,7	Jun-07	0,19
Sep-07	49,4	Sep-07	49,4	Sep-07	0
Dec-07	94,8	Dec-07	94,8	Dec-07	14,1
Dec-07	94,8	Dec-07	94,8	Dec-07	14,1
Mar-08	95,3	Mar-08	95,3	Mar-08	11
Jun-08	105	Jun-08	105	Jun-08	25,9
Sep-08	100	Sep-08	100	Sep-08	31,7
Mar-09	111	Mar-09	111	Mar-09	16,2
May-09	80	May-09	69,5	May-09	36,3
Aug-09	294	Aug-09	279	Aug-09	183
Nov-09	354	Nov-09	364	Nov-09	228
Feb-10	277	Feb-10	224	Feb-10	261
May-10	328	May-10	346	May-10	260
Aug-10	300	Aug-10	253	Aug-10	310
Nov-10	365	Nov-10	269	Nov-10	335
Feb-11	606	Feb-11	558	Feb-11	24,8
May-11	432	May-11	423	May-11	237

Aug-11	606	Aug-11	562	Aug-11	351
Nov-11	390	Nov-11	325	Nov-11	330
Feb-13	598	Feb-12	443	Feb-12	15,7
May-13	606	May-12	88	May-12	25,3
Aug-13	685	Aug-12	114	Aug-12	79,1
Nov-13	595	Nov-12	108	Nov-12	303
Feb-14	627	Feb-13		Feb-13	40
May-14	619	Aug-13	302	May-13	78,5
Aug-14	120	Nov-13	383	Aug-13	214
Nov-14	593	Feb-14	404	Nov-13	257
Dec-14	593	May-14	386	Feb-14	275
Jan-15	557	Aug-14	368	May-14	290
Feb-15	562	Nov-14	430	Aug-14	317
Mar-15	536	Dec-14	431	Nov-14	404
Apr-15	509	Jan-15		Dec-14	398
May-15	478	Feb-15	431	Jan-15	397
Jun-15	474	Mar-15	431	Feb-15	405
Jul-15	491	Apr-15	458	Mar-15	394
Aug-15	505	May-15	418	Apr-15	391
Sep-15	535	Jun-15	432	May-15	398
Oct-15	536	Jul-15	0,04	Jun-15	387
Nov-15	540	Aug-15	513	Jul-15	390
Dec-15	557	Sep-15	458	Aug-15	384
Jan-16	536	Oct-15	471	Sep-15	387
Feb-16		Nov-15	473	Oct-15	405
Mar-16	567	Dec-15	487	Nov-15	425
Apr-16	522	Jan-16	482	Dec-15	436
May-16	536	Feb-16		Jan-16	428
Jun-16	527	Mar-16		Feb-16	487
Jul-16	558	Apr-16		Mar-16	469
Aug-16	589	May-16		Apr-16	377
Sep-16	646	Jun-16		May-16	437
Oct-16		Jul-16		Jun-16	365
Nov-16	593	Aug-16		Jul-16	372
Dec-16	823	Sep-16		Aug-16	374
Jan-17	646	Oct-16		Sep-16	460
Feb-17	614	Nov-16		Oct-16	
Mar-17	573	Dec-16		Nov-16	444
Apr-17	567	Jan-17	0,1	Dec-16	161
May-17	553	Feb-17	0,84	Jan-17	171
Jun-17	606	Mar-17	0,1	Feb-17	212
Jul-17	540	Apr-17	5,09	Mar-17	235
Aug-17	579	May-17	93	Apr-17	435
Sep-17	602	Jun-17	138	May-17	348
Oct-17	620	Jul-17	182	Jun-17	375
Nov-17	633	Aug-17		Jul-17	317
Dec-17	567	Sep-17		Aug-17	369
Jan-18	730	Oct-17		Sep-17	381
Feb-18	668	Nov-17		Oct-17	377
Mar-18	698	Dec-17		Nov-17	353
Apr-18		Jan-18		Dec-17	334
May-18		Feb-18		Jan-18	363
Jun-18		Mar-18		Feb-18	359
Jul-18		Apr-18		Mar-18	359
Aug-18	551	May-18		Apr-18	

Sep-18	475	Jun-18		May-18	
Oct-18	449	Jul-18		Jun-18	
Nov-18	560	Aug-18		Jul-18	
Dec-18	561	Sep-18		Aug-18	356
Jan-19	461	Oct-18		Sep-18	339
Feb-19	499	Nov-18		Oct-18	333
Mar-19	797	Dec-18		Nov-18	353
Apr-19	821	Jan-19		Dec-18	400
May-19	821	Feb-19		Jan-19	448
Jun-19	767	Mar-19		Feb-19	378
Jul-19	734	Apr-19		Mar-19	414
Aug-19	460	May-19		Apr-19	490
Sep-19	565	Jun-19		May-19	491
Sep-19		Jul-19	503	Jun-19	375
Oct-19	505	Aug-19		Jul-19	370
Nov-19	583	Sep-19	763	Aug-19	325
Dec-19	618	Sep-19		Sep-19	379
Jan-20	882	Oct-19	272	Sep-19	
Feb-20	1002	Nov-19	624	Oct-19	173
Mar-20	647	Dec-19	667	Nov-19	323
Apr-20		Jan-20	906	Dec-19	437
May-20	403	Feb-20	783	Jan-20	446
Jun-20	839	Mar-20	607	Feb-20	369
Jul-20	863	Apr-20		Mar-20	402
Aug-20	1073	May-20		Apr-20	
Sep-20	838	Jun-20	2,03	May-20	164
Oct-20	795	Jul-20	15,5	Jun-20	376
Nov-20	669	Aug-20	213	Jul-20	337
Dec-20	523	Sep-20	349	Aug-20	318
Jan-21	508	Oct-20	718	Sep-20	279
Feb-21	571	Nov-20	776	Oct-20	420
Mar-21	556	Dec-20	638	Nov-20	359
Apr-21	561	Jan-21	689	Dec-20	392
May-21	546	Feb-21	634	Jan-21	360
Jun-21	549	Mar-21	576	Feb-21	450
Jul-21	569	Apr-21	160	Mar-21	390
		May-21	0.859	Apr-21	398
		Jun-21	1,89	May-21	411
		Jul-21	30,3	Jun-21	381
				Jul-21	382

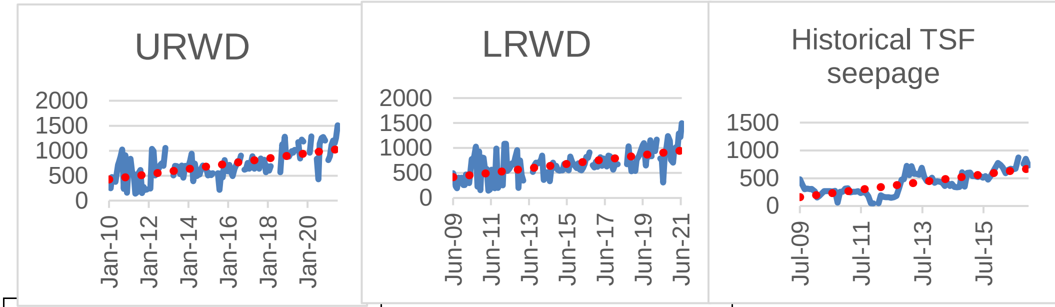


Monitors: Plant Depth: Unknown		Monitors: Historical TSF Depth: 40m		Monitors: Discard Dump Depth: 35m	
DRM4		**ASDW BH9**		**ASDW BH10**	
Dec-00	29,6	Nov-09	219	Nov-09	479
Apr-01	12,7	Feb-10	298	Feb-10	474
Jul-01	10,7	May-10	330	May-10	101
Oct-01	36,7	Aug-10	149	Aug-10	616
Jan-02	20,8	Nov-10	331	Nov-10	354
Mar-02	10,7	Feb-11	441	Feb-11	496
Jun-02	23	May-11	363	May-11	371
Sep-02	30	Aug-11	378	Aug-11	465
Jan-03	36,1	Nov-11	70,8	Nov-11	88,8
Apr-03	47	Feb-12	233	Feb-12	381
Jul-03	36	May-12	69,8	May-12	80,8
Sep-03	48,2	Aug-12	67,5	Aug-12	92,1
Mar-04	34,4	Nov-12	682	Nov-12	332
Jul-04	50,4	Feb-13	281	Feb-13	353
Sep-04	27,1	May-13	530	Aug-13	336
Oct-04	49,6	Aug-13	633	Nov-13	341
May-05	74,7	Nov-13	326	Feb-14	308
Aug-05	136	Feb-14	304	May-14	318
Dec-05	191	May-14	323	Aug-14	63,9
Apr-06	148	Aug-14	301	Nov-14	347
Sep-06	193	Nov-14	553	Dec-14	342
Jun-07	256	Dec-14	700	Jan-15	360
Sep-07	310	Jan-15	544	Feb-15	384
Dec-07	278	Feb-15	549	Jun-15	387
Dec-07	278	Jun-15	707	Dec-15	367
Mar-08	256	Sep-15	814	Jan-16	380
Jun-08	270	Dec-15	326	Feb-16	372
Sep-08	259	Jan-16	271	Mar-16	407
Mar-09	299	Feb-16	243	Apr-16	344
May-09	158	Mar-16	246	May-16	430
Aug-09	945	Apr-16	285	Jun-16	355
Nov-09	34	May-16	338	Jul-16	374
Feb-10	752	Jun-16	646	Aug-16	378
May-10	691	Jul-16	850	Sep-16	383
Aug-10	862	Aug-16	854	Oct-16	
Nov-10	1039	Sep-16	1031	Nov-16	352
Feb-11	1262	Oct-16		Dec-16	403
May-11	959	Nov-16	916	Jan-17	377
Aug-11	938	Dec-16	871	Feb-17	389
Nov-11	935	Jan-17	500	Mar-17	399
Feb-12	1069	Feb-17	456	Apr-17	376
May-12	193	Mar-17	355	May-17	374

Aug-12	222	Apr-17	313	Jun-17	386
Nov-12	240	May-17	668	Jul-17	347
Feb-13	256	Jun-17	801	Aug-17	396
May-13	279	Jul-17	677	Sep-17	406
Aug-13	911	Aug-17	668	Oct-17	405
Nov-13	862	Sep-17	797	Nov-17	389
Feb-14	850	Oct-17	691	Dec-17	376
May-14	603	Nov-17	938	Jan-18	376
Aug-14	867	Dec-17	1066	Feb-18	365
Nov-14	876	Jan-18	715	Mar-18	363
Dec-14	861	Feb-18	637	Apr-18	
Jan-15	880	Mar-18	724	May-18	
Feb-15	849	Apr-18		Jun-18	
Mar-15	769	May-18		Jul-18	
Apr-15	830	Jun-18		Aug-18	86,5
May-15	755	Jul-18		Sep-18	79,7
Jun-15	722	Aug-18	193	Oct-18	88,1
Jul-15	1002	Sep-18	192	Nov-18	99,3
Aug-15	919	Oct-18	233	Dec-18	97,9
Sep-15	921	Nov-18	229	Jan-19	89,1
Oct-15	950	Dec-18	245	Feb-19	87
Nov-15	850	Jan-19	154	Mar-19	92,7
Dec-15	1140	Feb-19	88,4	Apr-19	100
Jan-16	1001	Mar-19	98	May-19	94,3
Feb-16	1053	Apr-19	96,5	Jun-19	94,9
Mar-16	962	May-19	75,2	Jul-19	102
Apr-16	982	Jun-19	254	Aug-19	80,8
May-16	999	Jul-19	275	Sep-19	90,6
Jun-16	952	Aug-19	233	Sep-19	
Jul-16	977	Sep-19	254	Oct-19	127
Aug-16	972	Sep-19		Nov-19	103
Sep-16	1121	Oct-19	244	Dec-19	107
Oct-16		Nov-19	245	Jan-20	83,7
Nov-16	1424	Dec-19	277	Feb-20	89,4
Dec-16	1400	Jan-20	242	Mar-20	103
Jan-17	1319	Feb-20	238	Apr-20	
Feb-17	1227	Mar-20	146	May-20	50,4
Mar-17	1022	Apr-20		Jun-20	103
Apr-17	1058	May-20	72,8	Jul-20	81,2
May-17	1005	Jun-20	150	Aug-20	89,7
Jun-17	1119	Jul-20	189	Sep-20	63,7
Jul-17	847	Aug-20	220	Oct-20	600
Aug-17	779	Sep-20	227	Nov-20	545
Sep-17	826	Oct-20	1144	Dec-20	530
Oct-17	931	Nov-20	1093	Jan-21	455
Nov-17	935	Dec-20	1106	Feb-21	493
Dec-17	954	Jan-21	863	Mar-21	464
Jan-18	1001	Feb-21	755	Apr-21	411
Feb-18	942	Mar-21	671	May-21	479
Mar-18	947	Apr-21	542	Jun-21	506
Apr-18		May-21	429	Jul-21	545
May-18		Jun-21	335		
Jun-18		Jul-21	296		
Jul-18					
Aug-18	1016				

Sep-18	921				
Oct-18	914				
Nov-18	1189				
Dec-18	1218				
Jan-19	1101				
Feb-19	1054				
Mar-19	1109				
Apr-19	1153				
May-19	1139				
Jun-19	1124				
Jul-19	1136				
Aug-19	889				
Sep-19	1224				
Sep-19					
Oct-19	1402				
Nov-19	1232				
Dec-19	1334				
Jan-20	1267				
Feb-20	1206				
Mar-20	725				
Apr-20					
May-20	575				
Jun-20	1054				
Jul-20	1031				
Aug-20	1328				
Sep-20	1115				
Oct-20	1082				
Nov-20	1053				
Dec-20	837				
Jan-21	986				
Feb-21	1133				
Mar-21	695				
Apr-21	1249				
May-21	1220				
Jun-21	1202				
Jul-21	1281				

Process water database – dirty water quality associated with the Khulu TSF

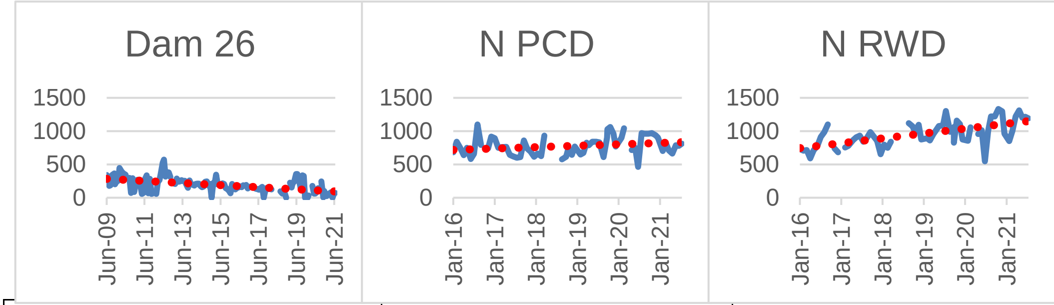


URWD (S7)		LRWD (S6)		Tailings seepage (S9)	
Mar-09	150	Jun-09	497	Jul-09	482
Apr-09	80,3	Jul-09	397	Aug-09	383
May-09	509	Aug-09	235	Sep-09	301
Jun-09	507	Sep-09	192	Oct-09	312
Jul-09	371	Oct-09	407	Nov-09	299
Aug-09	257	Nov-09	346	Dec-09	308
Sep-09	256	Dec-09	407	Jan-10	263
Oct-09	392	Jan-10	257	Feb-10	151
Nov-09	367	Feb-10	256	Mar-10	181
Dec-09	402	Mar-10	469	May-10	268
Jan-10	282	Apr-10	392	Jun-10	269
Feb-10	250	May-10	299	Jul-10	265
Mar-10	474	Jun-10	779	Aug-10	263
Apr-10	433	Jul-10	744	Sep-10	275
May-10	377	Aug-10	844	Oct-10	58
Jun-10	713	Sep-10	1026	Nov-10	256
Jul-10	776	Oct-10	225	Dec-10	256
Aug-10	880	Nov-10	932	Jan-11	315
Sep-10	1023	Dec-10	158	Feb-11	318
Oct-10	233	Jan-11	810	Mar-11	244
Nov-10	910	Feb-11	801	Apr-11	256
Dec-10	158	Mar-11	550	May-11	256
Jan-11	810	Apr-11	576	Jun-11	270
Feb-11	837	May-11	146	Jul-11	233
Mar-11	566	Jun-11	169	Aug-11	251
Apr-11	527	Jul-11	567	Sep-11	237
May-11	140	Aug-11	552	Oct-11	176
Jun-11	167	Sep-11	192	Nov-11	49,9
Jul-11	549	Oct-11	989	Dec-11	46,6
Aug-11	616	Nov-11	203	Jan-12	
Sep-11	155	Dec-11	268	Feb-12	48
Oct-11	272	Jan-12		Mar-12	195

Nov-11	216	Feb-12	255	Apr-12	162
Dec-11	223	Mar-12	1088	May-12	158
Jan-12		Apr-12	1088	Jun-12	159
Feb-12	240	May-12	541	Jul-12	148
Mar-12	1039	Jun-12	580	Aug-12	160
Apr-12	992	Jul-12	623	Sep-12	180
May-12	506	Aug-12	695	Oct-12	321
Jun-12	629	Sep-12	668	Nov-12	477
Jul-12	640	Oct-12	809	Dec-12	479
Aug-12	715	Nov-12	957	Jan-13	722
Sep-12	749	Dec-12	201	Feb-13	558
Oct-12	695	Jan-13	754	Mar-13	717
Nov-12	1055	Feb-13	455	Apr-13	580
Dec-12		Mar-13	351	May-13	580
Jan-13		Apr-13		Jun-13	562
Feb-13		May-13		Jul-13	689
Mar-13		Jun-13		Aug-13	518
Apr-13	507	Jul-13		Sep-13	443
May-13	696	Aug-13		Oct-13	465
Jun-13	692	Sep-13	519	Nov-13	509
Jul-13	615	Oct-13	655	Dec-13	416
Aug-13	530	Nov-13	704	Jan-14	443
Sep-13	703	Dec-13	686	Feb-14	435
Oct-13	457	Jan-14	721	Mar-14	420
Nov-13	696	Feb-14	753	Apr-14	360
Dec-13	667	Mar-14	845	May-14	416
Jan-14	687	Apr-14	360	Jun-14	359
Feb-14	792	May-14	416	Jul-14	401
Mar-14	942	Jun-14	517	Aug-14	344
Apr-14	388	Jul-14	517	Sep-14	337
May-14	739	Aug-14	333	Oct-14	340
Jun-14	494	Sep-14	607	Nov-14	607
Jul-14	518	Oct-14	704	Dec-14	345
Aug-14	523	Nov-14	607	Jan-15	598
Sep-14	644	Dec-14	644	Feb-15	602
Oct-14	704	Jan-15	560	Mar-15	536
Nov-14	641	Feb-15	547	Apr-15	536
Dec-14	635	Mar-15	552	May-15	522
Jan-15	506	Apr-15	554	Jun-15	536
Feb-15	548	May-15	680	Jul-15	508
Mar-15	509	Jun-15	697	Aug-15	536

Apr-15	548	Jul-15	580	Sep-15	475
May-15		Aug-15	552	Oct-15	536
Jun-15		Sep-15	829	Jan-16	772
Jul-15	548	Oct-15	735	Feb-16	738
Aug-15	214	Nov-15	676	Mar-16	696
Sep-15	548	Dec-15	635	Apr-16	588
Oct-15	463	Jan-16	600	May-16	646
Nov-15	811	Feb-16	693	Jun-16	669
Dec-15	597	Mar-16	566	Jul-16	657
Jan-16	589	Apr-16	551	Aug-16	669
Feb-16	718	May-16	605	Sep-16	873
Mar-16	574	Jun-16	682	Oct-16	
Apr-16	490	Jul-16	823	Nov-16	756
May-16	636	Aug-16	801	Dec-16	846
Jun-16	712	Sep-16	911	Jan-17	730
Jul-16	792	Oct-16		Feb-17	
Aug-16	781	Nov-16	655	Mar-17	
Sep-16	904	Dec-16	610	Apr-17	
Oct-16		Jan-17	726	May-17	
Nov-16	618	Feb-17	627	Jun-17	
Dec-16	634	Mar-17	698	Jul-17	
Jan-17	753	Apr-17	816	Aug-17	
Feb-17	638	May-17	645	Sep-17	
Mar-17	747	Jun-17	788	Oct-17	
Apr-17	886	Jul-17	766	Nov-17	
May-17	640	Aug-17	629	Dec-17	
Jun-17	784	Sep-17	846	Jan-18	
Jul-17	788	Oct-17	838	Feb-18	
Aug-17	639	Nov-17	666	Mar-18	
Sep-17	846	Dec-17	568	Apr-18	
Oct-17	760	Jan-18	654	May-18	
Nov-17	818	Feb-18	680	Jun-18	
Dec-17	569	Mar-18	672	Jul-18	
Jan-18	689	Apr-18		Aug-18	
Feb-18	599	May-18		Sep-18	
Mar-18	687	Jun-18		Oct-18	
Apr-18		Jul-18		Nov-18	
May-18		Aug-18	675	Dec-18	
Jun-18		Sep-18	1034	Jan-19	
Jul-18		Oct-18	835	Feb-19	
Aug-18	570	Nov-18	531	Mar-19	

Sep-18	1123	Dec-18	695	Apr-19	
Oct-18	1015	Jan-19	539	May-19	
Nov-18	1280	Feb-19	762	Jun-19	
Dec-18	877	Mar-19	817	Jul-19	
Jan-19	883	Apr-19	845	Aug-19	
Feb-19	936	May-19	947	Sep-19	
Mar-19	989	Jun-19	1053	Sep-19	
Apr-19	959	Jul-19	1096	Oct-19	
May-19	1017	Aug-19	648	Nov-19	
Jun-19		Sep-19	1027	Dec-19	
Jul-19	1172	Sep-19	1032	Jan-20	
Aug-19	843	Oct-19	827	Feb-20	
Sep-19		Nov-19	1153	Mar-20	
Sep-19	1224	Dec-19	838	Apr-20	
Oct-19	1182	Jan-20		May-20	
Nov-19		Feb-20	941	Jun-20	
Dec-19	627	Mar-20	1170	Jul-20	
Jan-20		Apr-20		Aug-20	
Feb-20	961	May-20	790	Sep-20	
Mar-20	1283	Jun-20	755		
Apr-20		Jul-20	313		
May-20		Aug-20	850		
Jun-20	837	Sep-20	988		
Jul-20	430	Oct-20	1239		
Aug-20	1136	Nov-20	1145		
Sep-20	1251	Dec-20	768		
Oct-20	1271	Jan-21	707		
Nov-20	1202	Feb-21	984		
Dec-20		Mar-21	1016		
Jan-21	810	Apr-21	992		
Feb-21	891	May-21	1293		
Mar-21	1111	Jun-21	1219		
Apr-21	1200	Jul-21	1497		
May-21	1152				
Jun-21	1252				
Jul-21	1508				



Dam 26 (S10)		**N PCD (S12)**		**N RWD (S11)**	
Jun-09	340	Jan-16	683,00	Jan-16	729,00
Jul-09	245	Feb-16	840,00	Feb-16	705,00
Aug-09	178	Mar-16	750,00	Mar-16	716,00
Sep-09	186	Apr-16	640,00	Apr-16	589,00
Oct-09	342	May-16	750,00	May-16	714,00
Nov-09	367	Jun-16	581,00	Jun-16	773,00
Dec-09	203	Jul-16	657,00	Jul-16	915,00
Jan-10	254	Aug-16	1100,00	Aug-16	987,00
Feb-10	254	Sep-16	792,00	Sep-16	1100,00
Mar-10	447	Oct-16		Oct-16	
Apr-10	398	Nov-16	742,00	Nov-16	742,00
May-10	370	Dec-16	920,00	Dec-16	680,00
Jun-10	344	Jan-17	895,00	Jan-17	
Jul-10	296	Feb-17	749,00	Feb-17	755,00
Aug-10	295	Mar-17	758,00	Mar-17	778,00
Sep-10	296	Apr-17	766,00	Apr-17	863,00
Oct-10	71	May-17	642	May-17	906
Nov-10	291	Jun-17	620	Jun-17	930
Dec-10	88	Jul-17	599	Jul-17	840
Jan-11	219	Aug-17	609	Aug-17	900
Feb-11	269	Sep-17	859	Sep-17	987
Mar-11	226	Oct-17	742	Oct-17	924
Apr-11	197	Nov-17	690	Nov-17	854
May-11	56	Dec-17	616	Dec-17	653
Jun-11	73,6	Jan-18	662	Jan-18	799
Jul-11	283	Feb-18	625	Feb-18	750
Aug-11	336	Mar-18	931	Mar-18	841
Sep-11	66	Apr-18		Apr-18	
Oct-11	283	May-18		May-18	
Nov-11	58	Jun-18		Jun-18	
Dec-11	68	Jul-18		Jul-18	
Jan-12		Aug-18	578	Aug-18	1119
Feb-12	59,7	Sep-18	615	Sep-18	1072

Mar-12	241	Oct-18	739	Oct-18	992
Apr-12	264	Nov-18	646	Nov-18	1095
May-12	360	Dec-18	770	Dec-18	876
Jun-12	523	Jan-19	649	Jan-19	893
Jul-12	572	Feb-19	672	Feb-19	862
Aug-12	315	Mar-19	825	Mar-19	955
Sep-12	385	Apr-19	786	Apr-19	1003
Oct-12	381	May-19	841	May-19	1075
Nov-12	313	Jun-19	843	Jun-19	1088
Dec-12		Jul-19	832	Jul-19	1302
Jan-13	217	Aug-19	610	Aug-19	989
Feb-13	205	Sep-19	903	Sep-19	1063
Mar-13	287	Sep-19	1026	Sep-19	826
Apr-13	242	Oct-19	1063	Oct-19	1157
May-13	246	Nov-19	962	Nov-19	1104
Jun-13	263	Dec-19	768	Dec-19	876
Jul-13	252	Jan-20	899	Jan-20	856
Aug-13	253	Feb-20	1041	Feb-20	1057
Sep-13	197	Mar-20		Mar-20	
Oct-13	147	Apr-20	715	Apr-20	958
Nov-13	258	May-20	751	May-20	1016
Dec-13	212	Jun-20	463	Jun-20	547
Jan-14	195	Jul-20	970	Jul-20	999
Feb-14	181	Aug-20	959	Aug-20	1220
Mar-14	206	Sep-20	959	Sep-20	1220
Apr-14	210	Oct-20	970	Oct-20	1332
May-14	213	Nov-20	936	Nov-20	1298
Jun-14	178	Dec-20	901	Dec-20	963
Jul-14	158	Jan-21	702	Jan-21	850
Aug-14	166	Feb-21	815	Feb-21	1005
Sep-14	240	Mar-21	709	Mar-21	1220
Oct-14	244	Apr-21	663	Apr-21	1312
Nov-14	182	May-21	788	May-21	1202
Dec-14	208	Jun-21	777	Jun-21	1216
Jan-15	0,44	Jul-21	811	Jul-21	1191
Feb-15	223				
Mar-15	202				
Apr-15	348				
May-15	201				
Jun-15	186				
Jul-15	185				

Aug-15	214				
Sep-15	206				
Oct-15	144				
Nov-15	131				
Dec-15	105				
Jan-16	66,7				
Feb-16	205				
Mar-16	139				
Apr-16	124				
May-16	150				
Jun-16	154				
Jul-16	171				
Aug-16	157				
Sep-16	186				
Oct-16					
Nov-16	193				
Dec-16	140				
Jan-17	164				
Feb-17	169				
Mar-17	171				
Apr-17	153				
May-17	135				
Jun-17	129				
Jul-17	122				
Aug-17	145				
Sep-17	162				
Oct-17	0,71				
Nov-17	116				
Dec-17	148				
Jan-18	129				
Feb-18	138				
Mar-18	123				
Apr-18					
May-18					
Jun-18					
Jul-18					
Aug-18	96,3				
Sep-18	60				
Oct-18	112				
Nov-18	64				
Dec-18	2,03				

Jan-19					
Feb-19	228				
Mar-19	152				
Apr-19	214				
May-19	242				
Jun-19	355				
Jul-19	356				
Aug-19	246				
Sep-19	126				
Sep-19	194				
Oct-19	335				
Nov-19	327				
Dec-19	2,03				
Jan-20	2,03				
Feb-20	32,5				
Mar-20					
Apr-20	179				
May-20	62,5				
Jun-20	64,5				
Jul-20	86,1				
Aug-20	145				
Sep-20					
Oct-20	244				
Nov-20	6,43				
Dec-20	99,4				
Jan-21	24,7				
Feb-21	41,9				
Mar-21	60,1				
Apr-21	81,9				
May-21	2,03				
Jun-21	56,5				
Jul-21	69,6				

APPENDIX F MINE PLAN USED