Section 102 EMP Amendment for Lanxess Chrome Mine

Groundwater Assessment Report

Project Number:

LAN3111

Prepared for:

Lanxess Chrome Mine Pty (Ltd)

May 2015

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EXECUTIVE SUMMARY

Lanxess Mining (Pty) Ltd (Lanxess) has proposed to expand their existing underground chrome operations into neighbouring farm portions, as well as to establish an open pit operation within their existing mining rights area. Lanxess Chrome Mine is located 7 kilometres (km) east of Kroondal and 11 km south-east of Rustenburg and falls within the Bojanala Platinum District Municipality, North West Province, South Africa.

Mining at the Kroondal and Overstep segments are due to commence from 2017 till 2020. The southern portion of the Wonderkop segment will be mined in 2018 and 2019. The northern portion of the Wonderkop segment is due from 2020 till 2025. Mining at the Klipfontein segment will run from 2020 till 2027

Digby Wells Environmental (hereafter Digby Wells) has been commissioned by Lanxess to conduct a hydrogeological study for the amendment of the existing Environmental Management Programme (EMP) Report.

The objective of the hydrogeological study is to provide a reference point (current conditions) against which potential mining impacts on the groundwater system can be identified and measured in future. The scope of work includes:

- A description of the groundwater flow system and the main processes that influence system behaviour;
- An assessment of potential impacts (type, degree, extent) related to various project components (e.g. dewatering of the proposed opencast mine; potential reduction in local groundwater level and degradation of groundwater quality during and after mining); and
- An assessment of potential mitigation options related to groundwater use, abstraction or contamination.

This report details the groundwater impact assessment completed for the proposed underground expansion areas. Please refer to the Digby Wells Report “ Groundwater Report for the Proposed Opencast at Lanxess Chrome Mine” dated August 2014.

Baseline Hydrogeology

Lanxess Chrome Mine falls within the middle-veld climatic zone with hot summers and mild winters. Regional mean annual precipitation (MAP) varies between 558 mm and 730 mm. The surface elevation varies between 1180 m above mean sea level (mamsl) in the west and 1220 mamsl in the east. The main water courses in the study area are the Hex River and the Sterkstroom River.

The larger study area is underlain by norite and anorthosite of the mafic to ultramafic Bushveld Igneous Complex (BIC) which dip at an angle of 10^{o} to the north. Numerous faults, some of which contain intruded material, traverse the study area. A major dyke flanks the west of the project area, and is associated with a major fault in the area and constitutes the most noticeable topographic feature. This syenite dyke dips to the east and forms a no-flow groundwater boundary. The regional aquifer systems consist of weathered, fractured and fresh pyroxenite and norite, with a thin overburden/soil cover.

The predominant aquifer type in the Lanxess area is a shallow, weathered zone aquifer, which occurs in the weathered and weathering related fractured zones within the pyroxenite and norite. The weathering profile is unevenly distributed across the project area, with an average weathering depth of 20 m below ground level (mbgl).

Mining occurs within the deep fractured aquifer. Groundwater occurrence within this aquifer is restricted to geological contact zones and linear geological features. There exists higher yielding groundwater bearing fractures north of the east-west dyke that traverse the mine voids. However, the north-south dykes in the study area are very low yielding. The yield of boreholes drilled into the syenite dyke was less than 0.02 L/s to dry.

In general, blow yields in the study area vary between 0.02 and 5 L/s, with hydraulic conductivities between 0.45 and 6.7 m/d. The mean annual recharge (MAR) to the groundwater systems for the study area is estimated to be between 3% and 7% of the mean annual precipitation. The depth to groundwater within the project area ranges between 10 and 24 m, with an average of 16 mbgl.

Historical boreholes, with water levels less than 11 mbgl, plotted against surface elevation indicate that the regional shallow groundwater levels are less influenced by underground mining and correlate with topography.

In terms of groundwater quality, chromium levels in groundwater are below detection limits. The general groundwater quality is characterised by elevated and non-compliant magnesium levels. Specifically, the current impacts on groundwater quality around the proposed pit lies in the vicinity of the old underground workings at Makuku informal settlement.

Impact Assessment

Construction Phase

Minor seepage may be encountered during shaft construction. The groundwater inflows into the shafts may lead to localised dewatering. It is anticipated that the low permeability bedrock will naturally mitigate the progress of the cone of depression around the shafts. Therefore no significant groundwater cone of depression is expected around the shaft area. The impact is therefore negligible.

Operational Phase

Impact of Mine Dewatering

The groundwater model predicts the inflow to rise to a maximum of 540 m^3/d in 2025. This estimate is broadly comparable to anecdotal information from the historical mining activity at Lanxess which suggests that a dewatering rate of approximately 500 m^3/d was required to keep the underground workings dry.

The 5 m drawdown cone is not predicted to migrate more than 1 km from the proposed extension segments due to the low permeability associated with the deep fractured aquifer.

The impact of mine dewatering in the new segments will also be mitigated by the fact that existing mining has already led to depleted aquifer storage in proposed segments.

In the weathered aquifer, mining in the new segments is not expected to cause additional dewatering, no more than already impacted. Interestingly, the model predicts that the 1 m drawdown cone will be limited to the west of the catchment diving dyke. As groundwater is used on ad hoc basis, the impacts on groundwater quantity during the operational phase rated as minor.

Impact of Mine Water Contamination

There is a concern that mining underneath the slimes dam at Kroondal, Klipfontein and Wonderkop segments will induce seepage from these facilities to the underground mine. The groundwater model predicts that any seepage emanating from the overlying slimes dam will eventually join the underlying weathered zone and migrate towards the streams and not downward into the mine workings.

The current impact on groundwater quality lies in the vicinity of the old underground workings. Mining at the new segments is therefore predicted to increase the TDS levels of groundwater pumped from underground. Because this water will be pumped out as part of the dewatering, the impact of underground mining on groundwater quality will be minor.

Closure and Post Closure Impact Assessment

Impact of Mine Decant

After the operational phase, the underground mine will be left to flood. As the underground mine floods, impacted groundwater levels will recover towards pre-mining levels. If the hydraulic head in the mine void reaches equilibrium with the hydraulic head in the weathered aquifer, then the hydraulic head in the mine void fluctuate according to natural recharge patterns. If at this level, there exists an open shaft or an open borehole from the mine void to the surface, with the same collar elevation as the hydraulic head in the mine void, then decant would occur. The rate of decant would be equal to the rate of natural recharge to the underground panels.

At this stage, insufficient information exist for accurate prediction of decant, decant rates and time to decant. However, the probability of mine decant is not ruled out and therefore rated as minor.

Impact of Mine Water Contamination

The quality of groundwater in the post-closure environment will depend on background groundwater quality and the geochemical processes that occur in the mine void, above and below water level. The current water quality from the old underground workings indicates that cation exchange processes will be dominant in the post-closure environment. Contaminant migration away from the mine voids can only be induced by groundwater abstractions within the capture zone of the mine workings, and if decant occurs. The significance of mine water contamination in the post-closure environment is therefore rated as minor.

Groundwater Monitoring and Management Measures

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and effective measures can be taken at an early stage before serious damage to the environment occurs. Fourteen boreholes are proposed for the groundwater monitoring plan. The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume.
- The following groundwater management measures are proposed to mitigate the impacts assessed.

Mitigation and Management during Construction Phase

- Undertake groundwater intrusive investigation around the shaft to optimise the position of the shaft and associated infrastructure to avoid major water bearing features;
- Handle and store blasting material according to manufacturing requirements;
- Establish the depth to groundwater table prior to construction;
- Grout or pump out any significant inflow of groundwater during shaft construction to ensure a dry and safe working environment;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Monitor quality of mine water.

Mitigation of and Management of Mine Dewatering during Operation Phase

- Dewater very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Monitor groundwater abstractions to ensure that the aquifer from which water is abstracted is not over-exploited;
- Pump excess underground water to appropriate surface storage facility according to manage and minimise the water quality impacts. When required by the process plant, the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use marginal mine water or grey water before using pristine groundwater; and

- Monitor water influx, water stored, water removed; and water levels in the underground mine and groundwater levels in the perimeter of the underground mine.

Mitigation and Management of Mine Water Contamination during Operation Phase

- The mine water management measures recommended during construction phase should continue during the operational phase;
- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;
- Monthly or quarterly monitoring of groundwater qualities and water levels are recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to negligible.

Mitigation and Management of Mine Decant during Closure and Post-closure Phase

- Monitor water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Seal all boreholes that connects the mine void to surface;
- Monitor groundwater levels in boreholes in the surrounding aquifers to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

Mitigation and Management of Mine Water Contamination during Closure and Post-closure Phase

- No abstraction boreholes should be drilled in a 3 km radius from the underground workings in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and re-vegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

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1 Introduction

Lanxess Mining (Pty) Ltd (Lanxess) has proposed to expand their existing underground chrome operations into neighbouring farm portions, as well as to establish an open pit operation within their existing mining rights area. Lanxess Chrome Mine is located 7 kilometres (km) east of Kroondal and 11 km south-east of Rustenburg and falls within the Bojanala Platinum District Municipality, North West Province, South Africa (Figure 1).

The current mining rights of Lanxess covers various portions of the farms Kroondal 304 JQ, Rietfontein 338 JQ and Klipfontein 300 JQ. The proposal involves the authorisation of the proposed open pit mining operation on the farm of Rietfontein 338 JQ (owned by the mine) and the proposed underground mining operations on portions of the farms Kroondal 304 JQ, Klipfontein 300 JQ and Brakspruit 299 JQ.

1.1 Project Description and Objectives

The proposed project is obligated to comply with the requirements of the Minerals and Petroleum Resources Development Act (MPRDA), (no 28 of 2002), and the Environmental Impact Assessment Regulations (2014), promulgated in terms of Sections 24(5) and 44 of the National Environmental Management Act (NEMA) (1998), (GN R982 of 4 December 2014).

Lanxess currently has an Environmental Impact Assessment and Environmental Management Plan (EIA/EMP) in line with the MPRDA and would therefore need to amend the existing approved document to include the details of the proposed opencast mining operations, as well as the extension of the underground sections (Segment 1, 2, 3 and 4) as part of a section 102 amendment. An amendment to the existing Integrated Water Use License Application (IWULA) is also required to be submitted to the Department of Water and Sanitation (DWS).

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1.2 Information Sources

In order to develop a reliable conceptual hydrogeological understanding, it was necessary to characterise the geological and hydrogeological conditions in the project area by reviewing historical investigations and data. Information from the following documents was assessed:

- Digby Wells, 2006. Environmental Impact Assessment and Management Programme. Bayer Rustenburg, Chrome Mine;
- Digby Wells, June 2014. Lanxess Mining Groundwater Gap Analysis Report;
- Digby Wells, August 2014. Groundwater Report for the Proposed Opencast at Lanxess Chrome Mine;
- Geostratum, July 2009. Quantification of seepage from and classification of waste, Xstrata Alloys Wonderkop Operations;
- JMA Consulting, August 2009. Groundwater Specialist Study Report, Xstrata Alloys Wonderkop Operations; and
- Simultech AG, 2009. Influence of Groundwater Seepage on Pillar Stability at Bayer/Lanxess Chrome Mine, Rustenburg.

2 Site Description

2.1 Mining Activities

Mining at Lanxess Chrome Mine is currently done through underground mining methods. Proposed future mining activities will include the expansion into the neighbouring Glencore underground areas, as well the opening of a pit within the existing Lanxess mining right area.

2.1.1 Underground Mining

The underground mining method used will be the standard bord and pillar system. The pillar dimensions and bord widths are such that a safety factor of 1.6 is maintained. Primary extraction is carried out by using drill rigs to drill the faces and conventional explosives. Access to the underground chrome reserves is gained by means of surface declines that are developed from the reef outcrop. Run of Mine clearance is facilitated by a series of conveyor belts fed by underground Load Haul Dump loaders.

It is calculated that the production rate will be 30,000 to 40,000 tons per month with a total Life of Mine of 14 years.

2.1.2 Reprocessing of Tailings

Lanxess has applied in terms of Section 102 to obtain the rights to the PGM in the orebody they are mining. If this is granted they intend to re-mine all the tailings facilities to extract the chrome left in the tailings. The tailings generated as a result of the re-miming of the tailings facilities, containing the PGM's will be sold to potential buyers. The volume of the dump has been surveyed and shows a contained volume of 1,735 m^3 with an average content of chromite reporting to the tailings to be between 20 and 23% Cr_2O_3.

2.1.3 Mineral Deposit

Lanxess produces four products namely; lumpy ore, metallurgical grade chrome ore, foundry grade chrome ore and chemical grade chrome ore (Table 1):

- Lumpy (metallurgical) ore with typically 38 to 41% Cr_2O_3 and a specified size distribution is sold to the ferrochrome industry where it is processed together with coal in an electric furnace to form ferrochrome. Ferrochrome is the master alloy used in the production of a wide range of corrosion and heat resistant stainless steel.
- Metallurgical grade chrome ore with 44% chrome is sold to the local ferrochrome industry where it is processed together with coal in an electric furnace to form ferrochrome.
- Foundry grade chrome ore with a Cr_2O_3 content of typically 46.5% and a strictly specified grain size distribution is used for the manufacture of casting moulds in foundries. The same material is also used in the production of refractory materials.
- Chemical grade chrome ore with a typical Cr_2O_3 content of 46.0% is the raw material for the production of sodium dichromate processed by Lanxess in their other operations (chemical plants), which is the main constituent of all chrome chemicals. Chrome chemicals are used for example as leather tanning agents.

Table 1: Product

List of Product	Tons/year	% of total
Lumpy	324 kt	27%
Foundry sand	120 kt	10%
Chemical Grade	384 kt	32%
Metallurgical Concentrate	372 kt	31%
Total	1 200 kt	100

2.1.4 Processing

The Lanxess Chrome Mine processing plant treats LG6 ore to produce the four chrome products by means of Heavy Medium Separation (HMS) in the HMS Plant and Gravity Concentration in the Gravity and Pilot Plants. The HMS plant has a capacity of 3,600 tonnes per day and the gravity plant has a capacity of 1,800 tons per day. This processing plant will remain in operation and will not be impacted by the proposed activities.

All products are sold to external clients. Chemical grade is also sold to other Lanxess business sites for the production of chrome chemicals. A high level block flow diagram of the processing plant is shown in Figure 2.

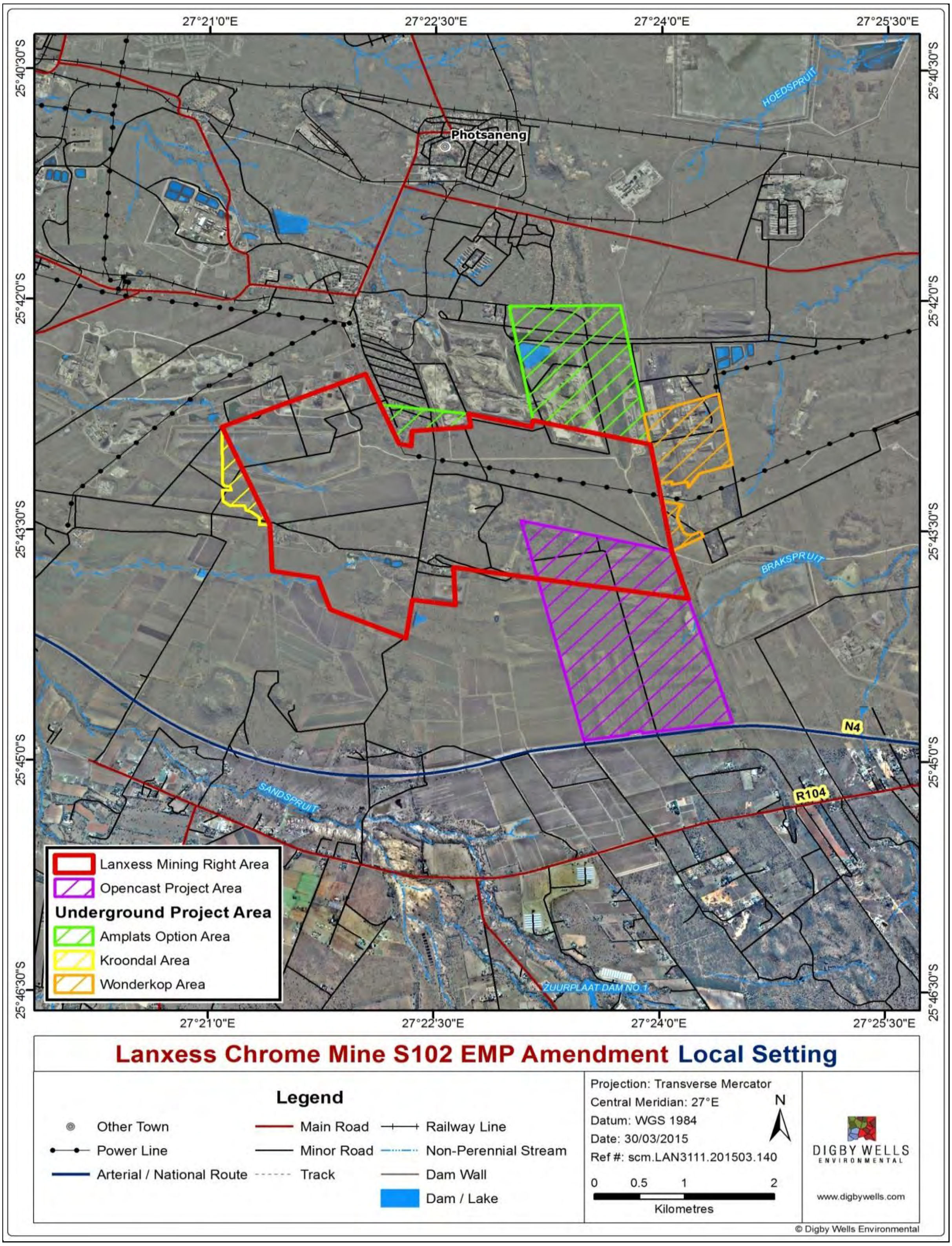

Figure 1: Local setting

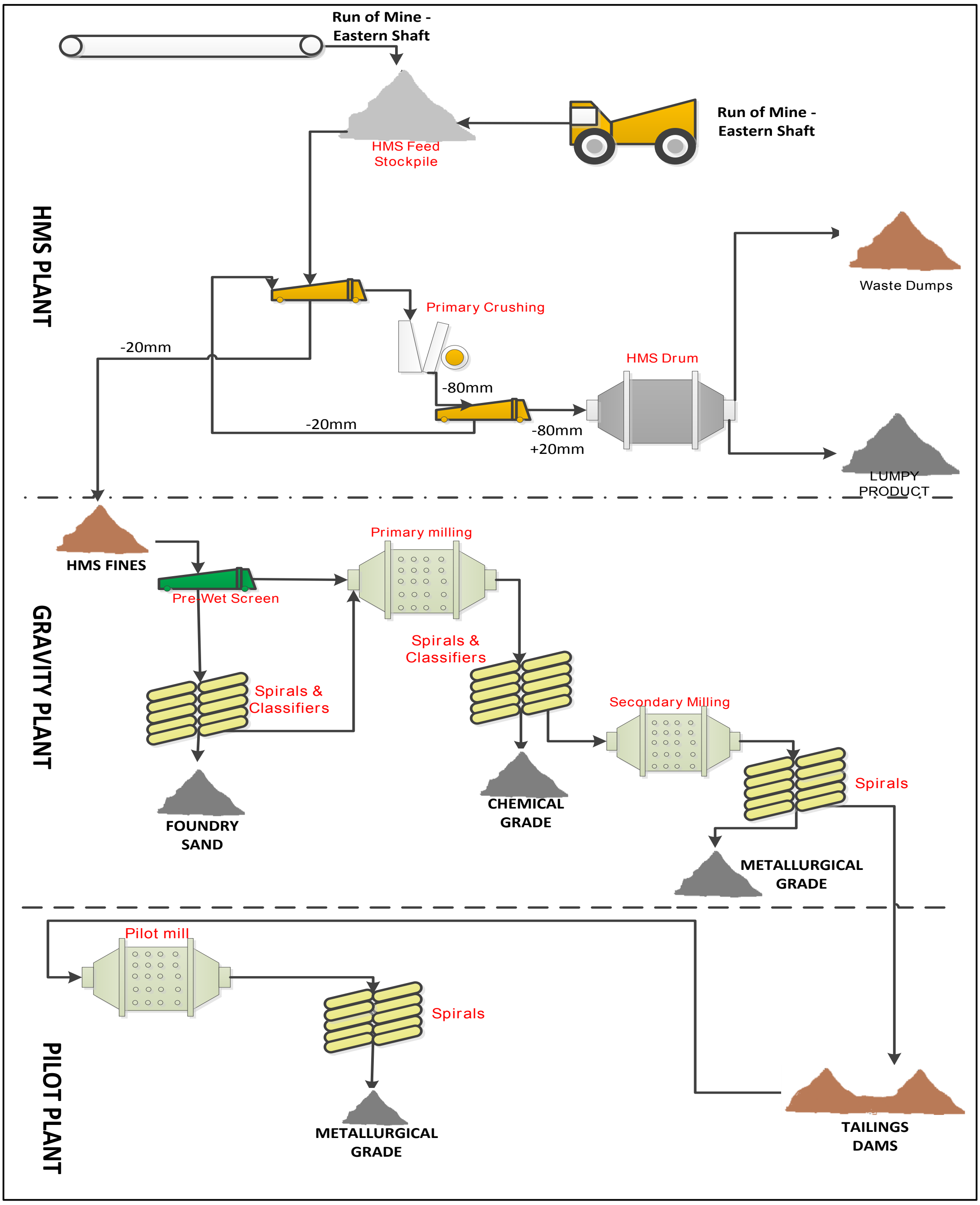

Figure 2: Flow diagram of the processing plant

2.2 Infrastructure Requirements

Lanxess is a well-established mine with existing infrastructure which has been operational since 1958. As a result minimal additional infrastructure will be required for the expansion of the activities as the plant has capacity for the proposed 80,000 tpm.

2.2.1 Current Surface Infrastructure

Currently the following infrastructure is in place on the mine and will remain in operation as shown in Table 2.

Table 2: Infrastructure in place on the mine

Infrastructure	Associated Activities
Incline and Shafts (vertical and ventilation)	Provide access to the underground workings.
Underground workings	Drilling and blasting. Loading and transfer of ore to conveyors. Conveyor belt transport ore to plant.
Processing facilities ■ Crusher ■ Settlers ■ HMS (Heavy Medium Separator) ■ Gravity plant ■ Reclamation plant	Beneficiation. Crushing and screening. HMS Plant: The coarse fraction >19 mm is fed into a heavy media separation plant in order to separate the remaining waste from lumpy ore which is then sold as lumpy ore into the ferrochrome industry. Gravity Plant: The fine fraction of ROM (<19 mm) is upgraded to foundry sand (CO4) and chemical grade (CO1) by milling, screening spiralling and hydro-classification. Regrinding of the waste material leaving from the foundry sands and chemical grade circuits and subsequently re-classification, results in the metallurgical grade products (CO6). Plant for the reclamation of 12 year old tailings dam.
Waste rock dumps	Dumping of waste rock.
Stockpiles: ■ ROM ■ Lumpy Ore ■ Crusher Fines ■ HMS Fines ■ CO1 ■ CO4 ■ CO6	Stockpiling of material before use or transport. (Bunded).

Infrastructure	Associated Activities
Tailings dams	Tailings material from processing is pumped by pipeline to the tailings dam. Tailings deposition. Waste management facility.
Transport infrastructure ■ Conveyor belt ■ Roads	Load-Haul-Dump vehicles transport broken ore to the nearest conveyor belt loading point. Ore is then transported to a central point on surface by a network of conveyor systems, with a total length of more than 18 km, where it is dumped on the run of mine stockpile. Earthworks. Transport of material (road to siding for further transport via rail).
Water management facilities ■ Sewage treatment ■ Settling ponds ■ Return water dams ■ Boreholes	Treatment of sewage generated on the site (hostels, villages, change rooms). Chemicals are used at sewage treatment plant. Spillages (solids) are picked up and suspended with water to be transferred to the settling ponds. A flocculent is used to produce sludge to be transferred to the tailings dam. A cyclone is used to remove ultra-fine chrome. Return water dams to manage water from tailings dam and recycle.
Support infrastructure ■ Stores (including magazines) ■ Workshops ■ Offices ■ Power lines ■ Access roads	Storage of materials, equipment and explosives. Maintenance. Administration and management.
Housing	The mine's employees do not live on the mine property.

2.2.2 Proposed Surface Infrastructure

The following associated surface infrastructure will be constructed in support of the additional mining activities proposed for the site:

- Haul Roads and Service Road – Approximately 3 km of haul roads to accommodate two lanes of traffic. A service road will be constructed to provide access to opencast pit from the southern boundary of the site. These roads will be gravel or tarred;

- Dump – An additional waste rock dump will be required alongside the opencast pit for overburden removed during mining;
- Stockpile – An additional topsoil stockpile will be located between the waste rock dump and the N4 highway. This will be screened off by trees; and
- A small workshop, office block and parking area will be built in the area of the opencast pit.

No additional infrastructure is required for the underground areas.

3 Baseline Hydrogeological Conditions

3.1 Climate

Lanxess Chrome Mine falls within the middle-veld climatic zone with hot summers and mild winters. Regional mean annual precipitation (MAP) varies between 558 mm and 730 mm. Precipitation occurs primarily during the summer months in the form of high intensity, short duration thunderstorms, between November and March with the climax occurring in January. Climatic data used was recorded at weather station 0511399X, Rustenburg.

Mean temperatures range between 14^{o}C and 30^{o}C during the summer months and between 5^{o}C and 20^{o}C during the winter months. The prevailing winds blow predominantly from the north-west and north at an average speed of 2.4 m/s.

The mean annual evaporation (MAE) is almost four times higher than the MAP at 2,374 mm. Lanxess is therefore located in a water deficit climate in which evaporation and evapotranspiration exceed rainfall.

The amount of rainfall that the area receives every year fluctuates. In Figure 3 it can be seen that the year with the highest recorded rainfall was 2000, with very dry periods in 1999 and 2001.

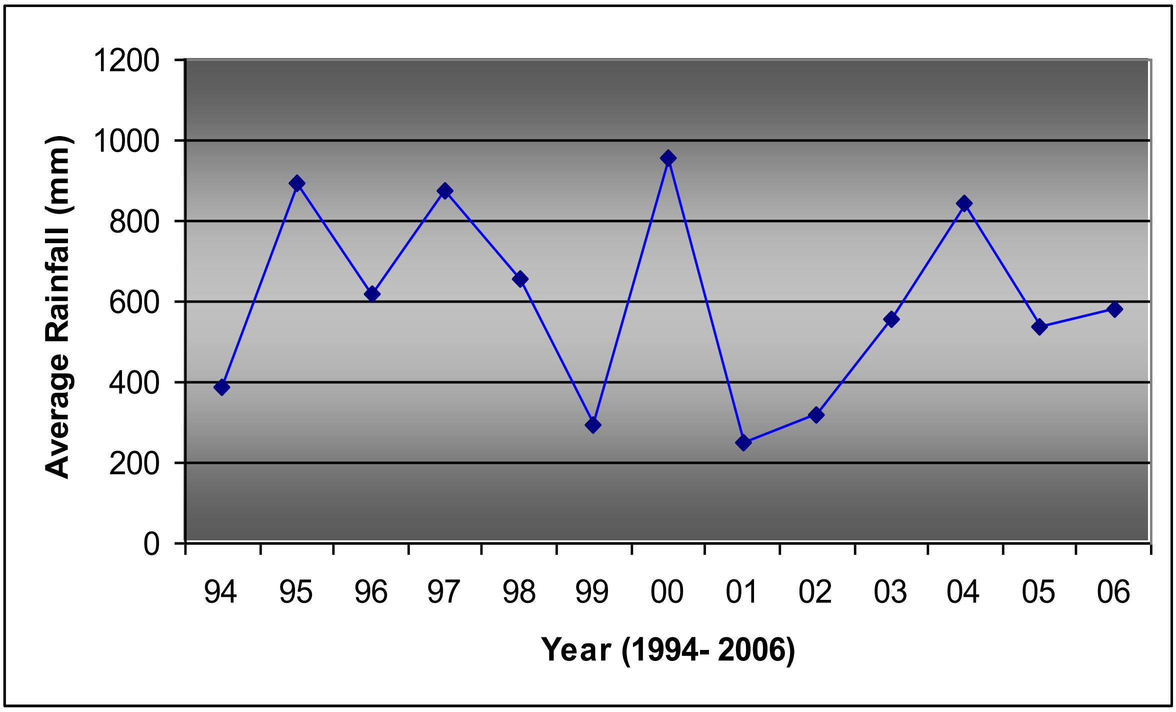

Figure 3: Rainfall fluctuations over ten years

3.2 Topography and Drainage

The topography of the mine area is fairly flat to gently undulating with a westerly slope varying between 1 and 2 degrees. The surface elevation varies between 1180 m above mean sea level (mamsl) in the west and 1220 m above mean sea level in the east.

Non-perennial streambeds, between 1.5 m and 2.0 m below general surface elevation, occur generally as small, occasionally wide, incisions in an otherwise flat landscape. The main water course in the A22H quaternary catchment is the Hex River found on the western side of the project area, this river joins the Elands River which is a tributary to Crocodile River.

There are two major tributaries to the Hex River namely the Sandspruit and Waterkloofspruit. The Sandspruit flows from the south of the project area in a north-west direction towards the Hex River. The Waterkloofspruit is located on the western side of the Hex River, and flows in an eastern direction towards the Hex River.

The A21K quaternary catchment, on eastern corner of the project area consist of three rivers/streams namely the Sterkstroom, Kleinwater, Tshukutswe and the Maretlwana Rivers. The Sterkstroom River is the main river within this catchment and it drains in a north-easterly direction towards the Crocodile River, a tributary to the Limpopo River.

The presence of numerous slag dumps, slimes dams, quarries and mine dumps have altered the localised topography of the relatively flat site topography which makes up the northern parts of the study area. These surface activities have altered the surface drainage patterns of the rivers, as well as the natural discharge volumes of these rivers.

3.3 Regional Geology

The regional geology discussed below was summarised from the JMA (2009) report.

The regional geology of the area is given in Figure 4. The larger study area is underlain by norite and anorthosite of the mafic to ultramafic Bushveld Igneous Complex (BIC) which dip at an angle of 10^{o} to the north. Numerous faults, some of which contain intruded material, traverse the study area.

The faults are predominantly dextral, many of which have later been intruded by dykes. The majority of the dykes have north-north-west trending strikes and form part of the Pilanesberg dyke swarm. A major dyke flanks the west of the project area, and is associated with a major fault in the area and constitutes the most noticeable topographic feature. This syenite dyke dips to the east and forms a no-flow groundwater boundary.

The western parts of the BIC have been extensively mined for chromite and platinum group elements (PGE's) by both opencast and underground mining methods. Some of the more important and economically exploitable horizons within the BIC include the LG-6, UG-2, UG-1 and MG-1 chromititic layers, as well as the Merensky Reef. The UG-2 and Merensky Reef have been predominantly mined for platinum and associated PGE's, whereas the LG-6 has been mined for chromite. The Merensky Reef and UG-2 layers have east-west strikes and dip to the north, whereas the LG-6 layer has a north-east to south-west strike and dips to the northwest. All three layers are, however, laterally very extensive and homogenous with regards to average thickness across the area.

The Lower Group (LG) chromitite layers form the base of the critical zone. Seven main layers are recognized, of which the so-called LG-6 is the most economically important. The LG-6 seams vary in thickness (120 centimetres (cm) to 35 cm thick) and are divided or separated by a band of waste rock of about 35 to 40 cm thick. They dip at approximately 9^{o} to the north, below the site where it was mined out by underground methods.

3.4 Regional Hydrogeology

This excerpt was taken from the published 1:500 000 Hydrogeological map series of the Republic of South Africa – Sheet 2526 – Johannesburg.

The regional hydrogeological attributes of the study area are a function of the geological formation distribution. The study area is underlain by ultramafic/mafic intrusive rocks of the Rustenburg Layered Suite. Within this zone, the primary groundwater occurrences are in the joints and fractures occurring in the contact zones related to the heating and cooling of the country rocks, as well as in fractures in the transitional zones between the weathered and un-weathered rocks. The host rocks in this area are disturbed by a major N-S trending fault.

Groundwater and movement thereof will be influenced by the fault and associated shear zones.

The borehole yielding potential within this geohydrological zone is classified as d3, which implies an average yield which varies between 0.5 Litres per second (L/s) to and 2 L/s.

Large volumes of groundwater (more than 10 million m^3/annum) are extracted for irrigation from these intergranular and fractured rock aquifers within the bounds of the greater study area.

The groundwater potential for this area is given as less than 40%, which indicates the probability of drilling a successful borehole with yield of more than 1 L/s. The probability of obtaining a yield in excess of 2 L/s is given as between 20% and 30%.

The mean annual recharge (MAR) to the groundwater system for the major part of the study area is estimated to be between 37 mm and 50 mm per annum, which also relates to between 5% and 10% of the mean annual precipitation (MAP). The groundwater contribution to surface stream base flow is relatively low, between 10 mm to 25 mm per annum with the depths to groundwater levels estimated to be 8 metres below ground level (mbgl). The aquifer storativity (S) for these intergranular and fractured aquifers are estimated to be less than 0.001.

The groundwater quality is good with a Total Dissolved Solids (TDS) range of between 300 mg/L to 500 mg/L and an Electrical Conductivity (EC) range of between 70 mS/m to 300 mS/m. There is a potential nitrate risk in the area, with nitrate concentrations exceeding 10 mg/L (as N) across the area. The groundwater will be of the hydrochemical, with dominant cations Ca^{2+} and Mg^{2+} and dominant anions Cl^- or SO_4^{2-}.

3.5 Presence of Boreholes

Digby Wells (2014) undertook a hydrocensus as part of the groundwater impact assessment for the proposed open pit mine assessment. Nine boreholes were found during the hydrocensus. Three groundwater boreholes were also drilled as part of the open pit mining study. The JMA 2009 report was reviewed to identify boreholes within the proposed expansion areas. Table 3 lists all boreholes found within the database. Analysis and interpretation in the sections that follow are based on data obtained from the boreholes listed in Table 3.

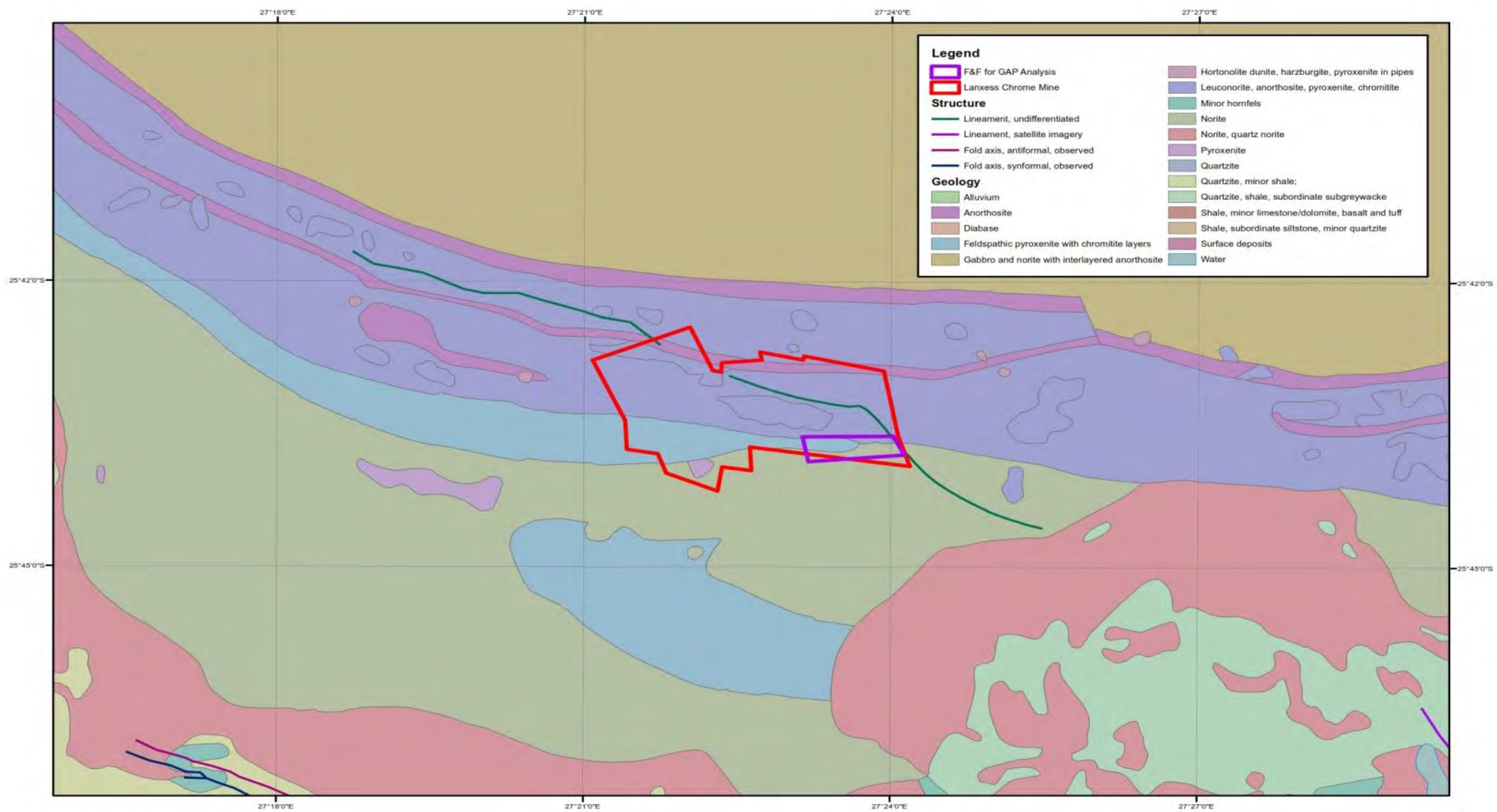

Figure 4: Regional Geology

Table 3: Summary of boreholes from previous reports

Borehole Name	X	Y	Z	Water Level (m)	Date	Water Strike (mbgl)	Yield (m^3/h) unless given in L/s	Owner
BH (2527CB2)	40408	-2847591	1224.3	24.44	Jul-01		About 5m	Mr P J J Geyer
BH258	40436	-2847549	1219.8	16.5	Jul-01		43.2	Mr P J J Geyer
BH257	39478	-2847704	1216.4	11.38	Jul-01		1.35	Mr P J J Geyer
RCM V111	38267	-2847521	Not given					Lanxess Chrome Mine
RCM 1X	38619	-2847338	Not given					Lanxess Chrome Mine
GCS13	38850	-2847269	1219.4	23.69	Jul-01	28	0.36	Aquarius Marikana
GCS14	39026	-2847825	1222.3	23.94	Jul-01	29	0.68	Aquarius Marikana
BH252 (2527CB5)	40871	-2846315	1210.6	14.83	Jun-96	About 15m (in shaft)	0.22	Lanxess Crhome Mine
GCS5 (SPT-H8)	44750	-2840683	1210	7.3		13; 20; 90	3.9	Aquarius Marikana
GCS15	42635	-2847630	1201.2	10.91	Jan-02	11-12 & 33-34	0.004	Aquarius Marikana
GCS 7	41913	-2847025	1201.8	7.12	Jan-00	8 to 9 & 30m	0.18	Aquarius Marikana
GCS 8	41044	-2847177	1209.9	12.61	Jan-00	13	2.88	Aquarius Marikana
BH42	Located from map			13.7	Jan-00	Unknown		
GCS 9	Located from map							Aquarius Marikana
GCS 10	Located from map							
GCS 11	Located from map							
GW35 (SPT H3; EM21)	41397.9	-2843683	1196	29.91; 21.67; 30.5	May 2003 (Report date); 21-Feb-01; 23-July-01	12-13; 19	Seepage	Rustenburg Platinum Mines
W_GCS1	40998	-2844154	1183	12.43	Jun-96	15-16	5.4	Xstrata monitoring borehole

Borehole Name	X	Y	Z	Water Level (m)	Date	Water Strike (mbgl)	Yield (m^3/h) unless given in L/s	Owner
W_GCS2	40826	-2843884	1181.8	12.39	Jun-96	15	Low	Xstrata monitoring borehole
SPT H12 (W_GCS5)	40659.54	-2845337	1200	seepage; 5.77	June 1996; May2003 (Report date)	37.9	Seepage	Xstrata monitoring borehole
SPT H13 (W_GCS3)	40839.94	-2845599	1211	seepage; 6.53	03-Mar	37.7	Seepage	Xstrata monitoring borehole
SPT H14	41474.77	-2844958	1204	9.4				Salplats Platinum
SH1	43534.09	-2844395	1119	13.39	May 2003 (Report date)			Mr W VanRensburg
SH3	43010.47	-2842332	1175	23.59	May 2003 (Report date)			Salplats Platinum
SPT X1	41941.39	-2844627	1210	13.52	May 2003 (Report date)			Salplats Platinum
SPT X2	42010.77	-2844729	1212	14.63	May 2003 (Report date)		7.2 to 10.8 for all SPT X boreholes	Salplats Platinum
SPT X3	42359.5	-2844631	1208	11.97	May 2003 (Report date)			Salplats Platinum Mine
SPT X4	42209.54	-2844471	1210	12.5	May 2003 (Report date)			Salplats Platinum
SPT X5	42256.69	-2844548	1208	27.38	May 2003(Report date)			Salplats Platinum Mine
SPT X6	42521.53	-2844552	1201	10.67	May 2003 (Report date)			Salplats Platinum Mine
SPT X7	42775.61	-2844439	1204	8.65	May 2003 (Report date)			Salplats Platinum Mine
SPT X8	42892.45	-2844516	1203	8.9	May 2003 (Report date)			Salplats Platinum Mine

Borehole Name	X	Y	Z	Water Level (m)	Date	Water Strike (mbgl)	Yield (m^3/h) unless given in L/s	Owner
SPT H1	42985.44	-2844215	1197		May 2003 (Report date)			Farmer P Erasmus
SPT H2	42998.76	-2841824	1196	6.88	May 2003 (Report date)			Rustenburg Platinum mine
GW33 (EM22)	42160	-2841630			Mar-02	3-8 and 8.5		Rustenburg Platinum mine
RPM_SKR1	41636.41	-2841531.3	1170.8	3.2	Feb-02	7,8,10,11,13,14	2.5	Rustenburg Platinum mine
GW34	41600	-2841550			Mar-02	8; 14.5	"Strong"	Rustenburg Platinum mine
RPM_SRK11	40987.46	-2841103.5	1167.3	5.9	Nov-02	8 to 9	Seepage	Rustenburg Platinum mine
WLTR1	Located from map					19-21	Seepage	Rustenburg Platinum mine
GW25	37420	-2842035	1170			6 to 7		Rustenburg Platinum mine
GW26	37205	-2843965	1180		Mar-02	no water strike		Rustenburg Platinum mine
EM54	37631.08	-2843564.5	1174.2					Rustenburg Platinum mine
EM55	37632.45	-2843561.3	1174.3					Rustenburg Platinum mine
GW21	37320	-2843470			Mar-02	10		Rustenburg Platinum mine
EM56	37079.53	-2843125.2	1165.2					Rustenburg Platinum mine
EM57	37076.63	-2843125.9	1165.1					Rustenburg Platinum mine
D150	35337.83	-2842270.67	1146.3	46.75; 37.12; 49.2; 54.44	28 Apr 94; 1996;19 Nov 98; 19 Nov 2001	3.1		Rustenburg Platinum mine
SRK13S	34862.26	-2845063	1173.9	3.2	Oct-03	9_14		Kroondal Platinum mine
SRK13D (BHKA2/1)	34865.98	-2845061	1173.8	3.4	Oct-03	Unknown	Seepage	Kroondal Platinum mine
SRK2	35689.59	-2844364	1195	dry hole		None		Kroondal Platinum mine
SRK 12	36067.95	-2845197	1191.7		Oct-03	Dry		Kroondal Platinum mine
SRKE5	35757.48	-2845518	1185.8	11.66	Oct-03	10,0	Dry	Kroondal Platinum mine
SRKE6	36232.1	-2845531	1192.3	dry hole	Oct-03	Dry		Kroondal Platinum mine
SRKE7	36083.91	-2845853	1186.7	18.1	Oct-03	Dry		Kroondal Platinum mine
SRKE8	36658.37	-2845769	1194.2	40.34	Oct-03	Dry		Kroondal Platinum mine

Borehole Name	X	Y	Z	Water Level (m)	Date	Water Strike (mbgl)	Yield (m^3/h) unless given in L/s	Owner
SRK14	36362.86	-2846007	1190.6	S = dry; D = 24.45	Oct-03	30-42	10	Kroondal Platinum mine
BHKN1 (Adjacent toSRK 14)	36364.98	-2846005	1190.6	23.89; 24.45	01/07/2003;27/10/2003			Mr Paul Ottoman
BHWMBV1 (FH3)	34923.99	-2844897.1	1169.14	Blocked /Dry	July 2001 – Oct 2003		Very low	Mr Rudolf Ottorman
BH ASMV1	35671.89	-2846745.15	1188	Equipped	Jul-03			Lanxess Rustenburg ?
BHRCM	35776.89	-2846882.07	1189	11.08; 3.4	Jul-03		10.6 L/s	Lanxess Rustenburg Chrome mine (Mr P Smit)
BH RO1 (BH2/ FH1)	35082.59	-2846966.99	1186	Equipped (Historical RWL of 17m)	Jul-03	Possibly 17	Unknown	Farmer, Mr Rudolf Ottorman
BH RO2 (FH1)	35133.06	-2846856.34	1179	Equipped				Farmer, Mr RudolfOttorman
BH RO3 (FH2)	35184.11	-2846525.97	1196	Equipped	Jul-03			Farmer, Mr RudolfOttorman
WKG-1	41085.8	-2844404	1182.65	3.6	Feb-09	11-12; 17-18	5 L/s	Xstrata monitoring borehole
WKG-10	40516.5	-2846185	1209.98	25.18	Feb-09			Xstrata monitoring borehole
WKG-11	40318.2	-2845480	1201.19	1.48	Feb-09			Xstrata monitoring borehole
WKG-12	40377.1	-2845435	1199.54	0.91	Feb-09			Xstrata monitoring borehole
WKG-13	39922.7	-2844773	1197.56	11.08	Feb-09			Xstrata monitoring borehole
WKG-14	40328.6	-2846609	1219.64	19.02	Feb-09			Xstrata monitoring borehole
WKG-15	40239.9	-2844962	1196.53	6.26	Feb-09	12 - 12.5	0.02 L/s	Xstrata monitoring borehole
WKG-16	40728.2	-2844937	1189.29	9.74	Feb-09	-	-	Xstrata monitoring borehole
WKG-17	40243.2	-2844381	1190.29	22.17	Feb-09	6.3m - 6.5m	0.02 L/s	Xstrata monitoring borehole
WKG-18	40606.1	-2844400	1187.33	2.63	Feb-09	7m - 7.5m	0.02 L/s	Xstrata monitoring borehole
WKG-19	40019.9	-2843779	1190.85			DRY	DRY	Xstrata monitoring borehole

Borehole Name	X	Y	Z	Water Level (m)	Date	Water Strike (mbgl)	Yield (m^3/h) unless given in L/s	Owner
WKG-2	40793.8	-2844179	1183.1	1.71	Feb-09	-	-	Xstrata monitoring borehole
WKG-20	40593.1	-2843506	1188.14	4	Feb-09	DRY	DRY	Xstrata monitoring borehole
WKG-21	41186.6	-2843932	1177.36	13.07	Feb-09	DRY	DRY	Xstrata monitoring borehole
WKG-22	41167.4	-2844157	1179.87	16.59	Feb-09	10m - 11m	0.2 L/s	Xstrata monitoring borehole
WKG-23	40874.9	-2846343	1210.15	8.74	Feb-09	-	-	Xstrata monitoring borehole
WKG-24	40563.3	-2846513	1214.81			-	-	Xstrata monitoring borehole
WKG-25	40802.2	-2846764	1213.57			11m - 14m	5 L/s	Xstrata monitoring borehole
WKG-3	40658.9	-2845565	1199.51	2.75	Feb-09	-	-	Xstrata monitoring borehole
WKG-4	40838.1	-2845829	1202.51	6.43	Feb-09	-	-	Xstrata monitoring borehole
WKG-5	40615.3	-2845268	1194.84	3.4	Feb-09	9.5m - 10.5m	1.5 L/s	Xstrata monitoring borehole
WKG-6	40384.9	-2845828	1206.35	1	Feb-09	9.5m - 10.0m	0.5 L/s	Xstrata monitoring borehole
WKG-7	40124.7	-2845824	1210	4.24	Feb-09	9.5 to10	0.02 L/s	Xstrata monitoring borehole
WKG-8	40642.5	-2845372	1195.95	3.55	Feb-09			Xstrata monitoring borehole
WKG-9	40778.6	-2845404	1196.38	3.17	Feb-09			Xstrata monitoring borehole
LANBH01	38805.7	-2847001.4	1220.85			31	0.44 L/s	Lanxess Chrome Mine
LANBH02	39742.3	-2846561.0	1231.08	23.7	Jun-14			Lanxess Chrome Mine
LANBH03	40280.4	-2847149.8	1225.06	22.4	Jun-14	18	0.5 L/s	Lanxess Chrome Mine
LANBH1	38320.9	-2847398.8	1222.19					Lanxess Chrome Mine
LANBH2(17)	37933.3	-2847475.2	1210.42	11.1	Apr-14			Lanxess Chrome Mine
LANBH4(18)	37826.5	-2846954.2	1209.46	11.4	Apr-14			Lanxess Chrome Mine
LANBH5	38415.6	-2845183.4	1197.2					Lanxess Chrome Mine
LANBH6	37409.1	-2846199.7	1204.41					Lanxess Chrome Mine
LANBH7	38181.4	-2846357.0	1212.58					Lanxess Chrome Mine
LANBH8	36451.0	-2846496.2	1192.15					Lanxess Chrome Mine
LANUG01	38031.5	-2846478.4	1211.38					Lanxess Chrome Mine

3.6 Aquifer Characterisation

The regional aquifer systems consist of weathered, fractured and fresh pyroxenite and norite, with a thin overburden/soil cover.

3.6.1 Weathered Aquifer

The predominant aquifer type in the Lanxess area is a shallow, weathered zone aquifer, which occurs in the weathered and weathering related fractured zones within the pyroxenite and norite. The weathered aquifer stores the bulk of the groundwater in the area and also forms the main recharge zone.

This aquifer occurs across the entire surface area of the proposed pit. With a saturated thickness of up to 26 m, this aquifer dips towards the south eastern portion of the proposed pit.

JMA (2009) stated that the weathering depth at the Wonderkop segment varies between 9 and 25 mbgl, with an average of 15 m. The weathering profile is unevenly distributed across the Wonderkop site, but it does appear as if the depth of weathering could be slightly deeper towards the north. In view of the data gaps for Klipfontein and Kroondaal sections, a conceptual weathering depth of 20 mbgl is assumed.

The weathered aquifer is unconfined to semi-confined and is highly susceptible to surface induced anthropogenic influences.

3.6.2 Deep Fractured Aquifer

Mining occurs within the deep fractured aquifer. Groundwater occurrence within this aquifer is restricted to geological contact zones and linear geological features. Simultec (2009) investigated the influence of groundwater on pillar instability in a deep north central portion of the existing underground mine. After modelling several hypotheses, it was concluded that there exists higher yielding groundwater bearing fractures north of the east-west dyke that traverse the mine voids. However, the north-south dykes in the study area are very low yielding.

The yield of boreholes drilled into the syenite dyke was less than 0.02 L/s to dry JMA (2009).

3.6.3 Borehole Yields

Digby Wells (2014) recorded blow yields for 2 out of 3 boreholes drilled. JMA (2009) recorded yields from 9 out of 15 boreholes drilled (6 were recorded as dry). The blow yields vary between 0.02 and 5 L/s. The yields were all obtained in the shallow weathered and fractured aquifer and none of the yields could be correlated with specific structural features. The dry boreholes also recorded weathering and fracturing, but were dry due to the fact that the shallow weathered zone aquifers were probably dewatered.

3.6.4 Hydraulic Properties

The hydraulic conductivities at the Wonderkop Segment vary between 0.45 m/d and 6.7 m/d with a geometric mean of 1.5 m/d (JMA, 2009).

The impermeable property of the dyke that forms the catchment divide east of the project area was confirmed after an aquifer test on borehole LANBH01 (Digby Wells, 2014). The transmissivity of relatively higher yielding water strikes was estimated at 6.8 m^2/d and the transmissivity of the aquifer matrix is estimated at 3.5 m^2/d.

3.6.5 Recharge

Recharge is defined as the process by which water is added to the zone of saturation or aquifers. Recharge in the study area depends on the saturation of the shallow, weathered aquifer. Recharge to the fractured aquifer is indirect by vertical drainage and downward percolation from the overlying weathered aquifer.

Rainfall recharge to the groundwater system is expressed as a percentage of the mean annual precipitation (MAP). The MAP used for the site is 645 mm/annum. The mean annual recharge (MAR) to the groundwater systems for the study area is estimated to be between 3% and 7% of the mean annual precipitation (MAP), putting it in the recharge range of 20 mm/annum to 45 mm/annum (JMA, 2009).

3.6.6 Groundwater Levels

Groundwater levels are not monitored at Lanxess Chrome Mine. However, from the most recent studies conducted by Digby Wells, the depth to groundwater within the project area ranges between 10 and 24 m, with an average of 16 mbgl. Based on the depth of weathering recorded during drilling, the deeper groundwater levels in LANBH01 and LANBH02 indicate that the weathered aquifer is unsaturated, most likely due to mine dewatering impacts. The water level in LANBH01 also indicates that seepage from the adjacent waste rock dump is not towards the proposed pit as infiltration from the waste rock dump would have elevated the groundwater level in borehole LANBH01.

The shallow groundwater level in LANBH01 (10 mbgl) indicates the thick weathered aquifer south east of the proposed pit is saturated and mine dewatering is less significant in this area. The groundwater elevation data indicates that groundwater flows from the south eastern perimeter of the pit in north-westerly direction.

Historical boreholes, with water levels less than 11 mbgl, were plotted against surface elevations. As depicted Figure 5, it can be concluded that the regional shallow groundwater levels are less influenced by underground mining and correlate with topography. Therefore, the groundwater levels below 11 mbgl can be used for steady model calibration purposes.

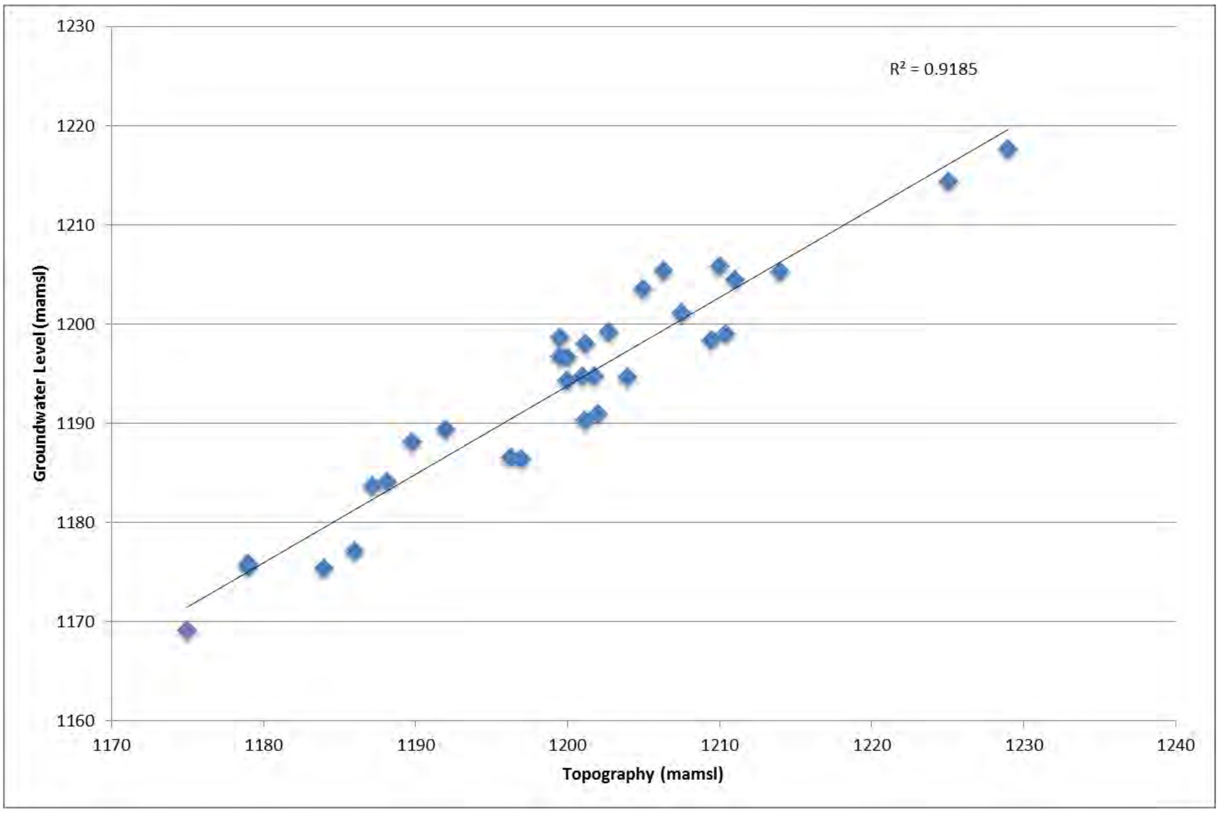

Figure 5: Correlation between long term water levels and topography

3.7 Baseline Groundwater Quality

The groundwater quality results (Table 4) have been compared to the South African National Standards (SANS 241:2005) for Drinking Water and have been grouped into Classes in accordance with the above stated standard.

According to the SANS241:2005 standards, water quality have two benchmarks: Class I and Class II:

- Concentrations below the Class I limits are considered of good quality;
- Concentrations between Class I and II are considered as marginal. This is the maximum allowable concentration if consumed for not more than 7 years; and
- Concentrations exceeding Class II limits (also referred as Class III) are unacceptable for human consumption.

The following conclusions are drawn:

- The neutral to alkaline pH of the groundwater system implies that condition for heavy metal solubility are not favourable, hence there is restricted migration for potential heavy metals in groundwater system;

- All boreholes show drinking water compliance in terms of electrical conductivity (EC) and total dissolved solids (TDS) levels;
- LANUG1 represents water discharged from the old underground workings at the concrete pipe, slimes dam drain. The Class II levels for EC and TDS indicate that some form of impact could potentially exist on the groundwater quality in the old working;
- The Class II sulphate concentration (LANUG1 at 520 mg/L) accounts for the elevated EC and TDS noted above;
- Calcium occurs naturally in the groundwater system and all boreholes are fully compliant with the calcium Class I limit;
- The non-compliant magnesium levels in groundwater can be attributed to a high solubility of the magnesium contents in the rock matrix. No other external sources of magnesium can be justified at this stage;
- In terms of nitrate it is only borehole LANBH02 that falls within the acceptable water quality limits. Five of the eight boreholes indicate groundwater not suitable for human consumption due to the high nitrate concentrations;
- The total chromium content in groundwater is below detection limit; and
- The published groundwater quality information for the regional aquifers indicated that nitrate could be elevated in the background groundwater quality and therefor it should not be used for impact identification. The results show that boreholes LANBH2 and LANBH3 are compliant, LANBH01 is marginally compliant and the rest are not compliant.

The Stiff diagram (Figure 6) depicts that all samples except LANUG1 have the same water type; dominated by magnesium and bicarbonates. The Piper diagram (Figure 7) indicates that boreholes LANBH6 and LANBH7 are being influenced by water from old underground working. It can be said that the current impacts on groundwater around the proposed pit lies in the vicinity of the old underground workings.

Table 4: Groundwater quality

Sample ID		pH-Value at 25° C	Conductivity at 25° C in mS/m	Total Dissolved Solids	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Chlorides as Cl	Sulphate as SO_4	Fluoride as F	Nitrate NO_3 as N	Total Alkalinity as $CaCO_3$	Iron as Fe	Manganese as Mn	Aluminium as Al	Chromium as Cr
Class I	(Recommended)	5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<1	<10	N/S	<0.2	<0.1	<0.3	<1
Class II	(Max. Allowable)	4-5 or 9.5-10	150-370	1000-2400	150-300	70-100	200-400	50-100	200-600	400-600	1-1.5	10-20	N/S	0.2-2	0.1-1	0.3-0.5	1-5
	Duration	No Limit	7 years	7 years	7 years	7 years	7 years	7 years	7 years	7 years	1 year	7 years	N/S	7 years	7 years	1 year	
LANBH6		7.93	135	974	71	**135**	38	7	71	243	0.25	**42**	367	0.00	0.00	0.00	0.00
LANBH2		7.61	113	766	64	**125**	15	3	15	108	0.17	**39**	432	0.00	0.00	0.00	0.00
LANBH3		7.73	123	779	43	**158**	8	4	49	109	0.22	**32**	441	0.00	0.00	0.00	0.00
LANBH7		8.10	127	925	86	**108**	45	10	58	228	0.17	**41**	344	0.00	0.00	0.00	0.00
LANUG1		7.85	**155**	**1226**	145	56	145	15	107	**520**	0.12	**27**	194	0.00	0.00	0.00	0.00
LANBH01		8.13	93	535	30	**110**	12	3	15	39	0.26	**14**	435	0.00	0.00	0.00	0.00
LANBH02		7.70	113	635	63	**102**	32	7	26	114	0.50	5	441	0.00	**0.39**	0.00	0.00
LANBH03		7.84	109	641	61	**121**	17	4	15	76	0.26	**10**	502	0.00	0.00	0.00	0.00

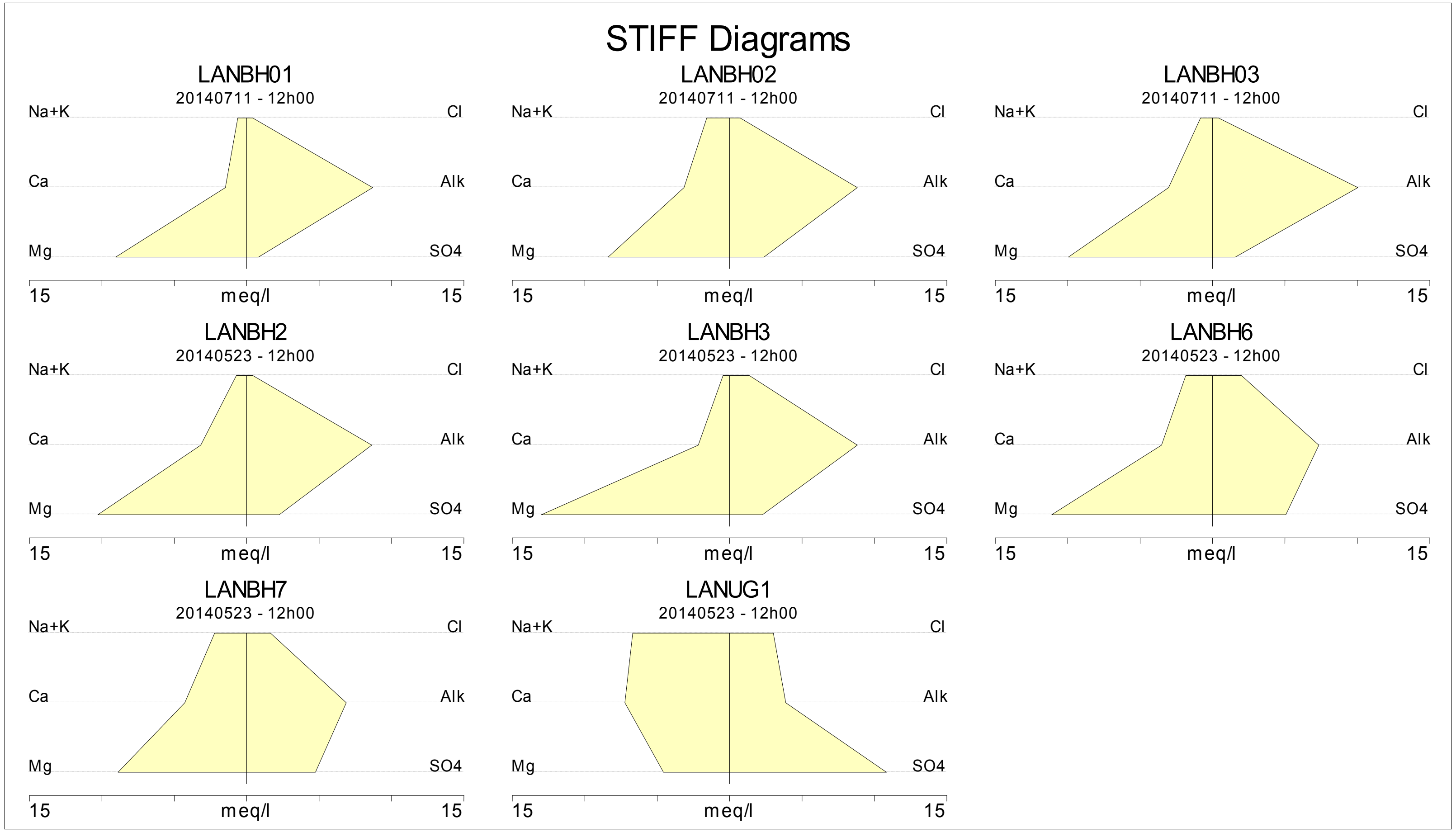

Figure 6: Stiff diagram of the baseline water chemistry

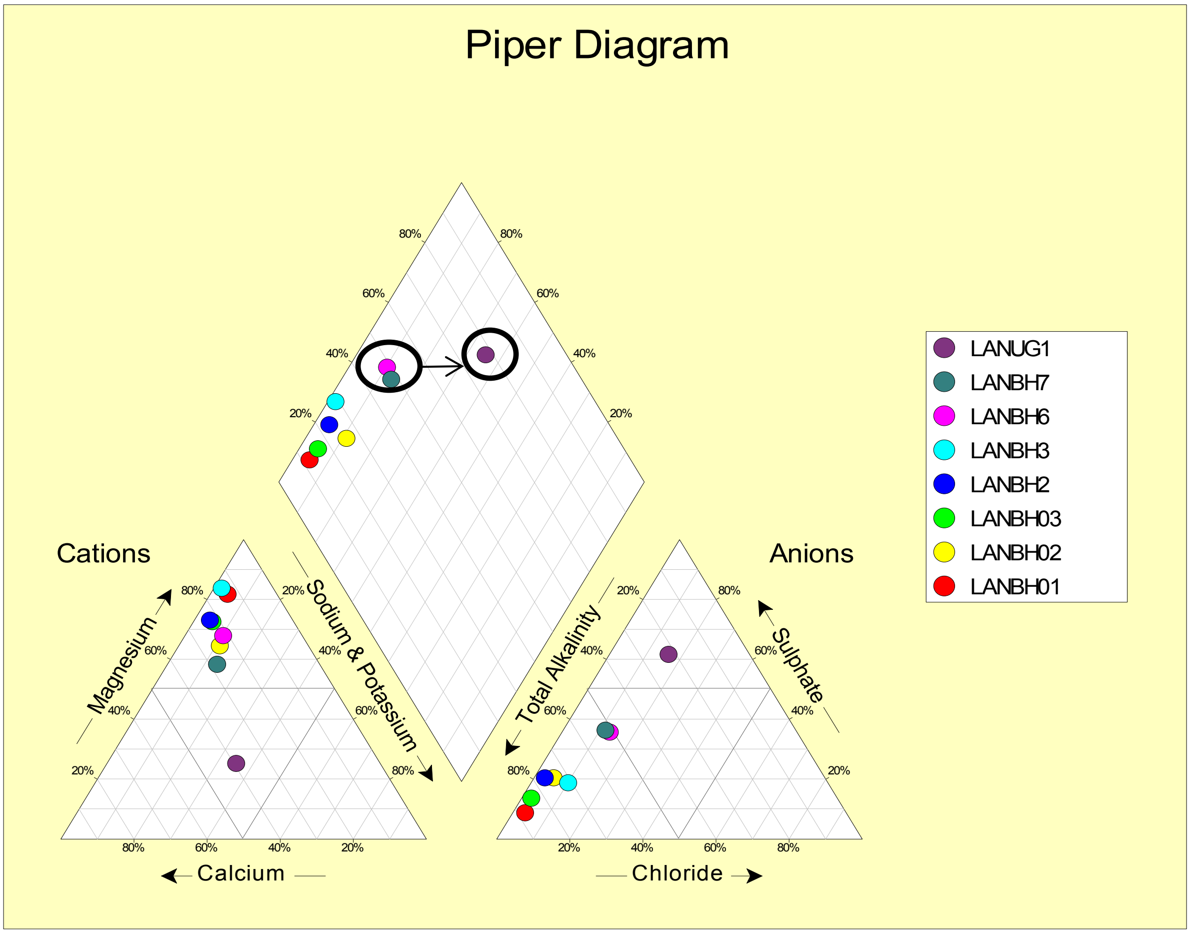

Figure 7: Piper diagram of the baseline water chemistry

3.8 Groundwater Use

Groundwater use in the study area is supplementary to formal water supply systems and does not represent the primary water sources for any of the groundwater users.

Based on the information obtained from historic reports, a number of boreholes within the zone of influence are used for groundwater abstraction. These boreholes can be defined as groundwater receptors and could be impacted on both with respect to availability of groundwater as well as groundwater quality.

At Wonderkop Mine, water abstracted from boreholes GCS-1, GCS-4, GCS-5, GCS-6, WH-6 and Bokamoso boreholes is used solely as process water during operation of the ferrochrome plant, as well as the Bokamoso Pelletizing Plant. The maximum permissible volume of groundwater than can be abstracted is 149,560 m^3 per annum (JMA, 2009).

According to both Aquarius and Anglo Platinum, no groundwater is abstracted from boreholes within the study area. Both Aquarius Platinum (No. 4 Shaft) and Anglo Platinum (Brakspruit Shaft) abstract their ground water directly from the mine workings. The water that is abstracted from Aquarius' No 4 shaft is used solely as process water during mining operations and is used on the tailings dam to the south of the Wonderkop property. Anglo Platinum's Brakspruit shaft uses an average of 430,848 L/d as process water during mining operations. A further 30,000 L of water is pumped out of the mine and used on the tailings dam to the north of the study area on a daily basis (JMA, 2009).

The boreholes that supply water to Lanxess Chrome Mine can be divide into the following three groups (Simultec, 2009):

- Rand Water boreholes;
- Lanxess near surface borehole; and
- Lanxess underground boreholes.

Table 5: Mean pumping rates at Lanxess Chrome Mine

ID	Name	Pumping Rates (m^3/d)
1	Bottom Village	13.5
2	Top Village	0.5
3	Plant Hostel & 7East	244.4
4	Hostel Water Tank	26.6
5	Plant Cement Dam	44.9
6	7East & Makook	52.2
19	Tennis Court	330.9
15	Pump in Village Dam	74.3
18	Behind Hostel	75.9
13	Behind Tailings Dam	129.6
17	7East Gen.Set	6.7
16	7West Dam	53.7
	7 West Water	6.5
22	Behind mountain (anglo)	227.6
	Water Arrie's Dam	0.1
12	Water Makook	192.3

4 Numerical Model

A numerical groundwater flow model was set up using the baseline conceptual model described in chapter 3.

PMWIN Pro 8, which is a MODFLOW based modelling software package, was used for the simulations. MODFLOW and PMWIN Pro are internationally recognised modelling packages that have been proven to be capable of simulating these types of groundwater flow and contaminant transport assessments to a high level of accuracy.

4.1 Model Limitations and Assumptions

Numerical models are commonly used to develop hydrogeological management solutions that include the prediction of contaminant plume migration and groundwater level changes over time. However, groundwater systems are often complex and the data input requirement is beyond our capability to evaluate in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical process (Spitz, 1996). Therefore, it is necessary to make several simplifying assumptions to simplify the complex, real world hydrogeological conditions into a simplified, manageable model. The following are the assumptions and limitations of the model:

- The model is a regional scale model and encompasses a wide area around Lanxess Chrome Mine to determine hydrogeological interaction between the mine site and surrounding regional groundwater systems;
- The current geological information is sufficient to describe the extent of the different aquifers;
- Site specific hydrogeological studies have not been carried out in proposed segments as such aquifer parameters that cover tested areas are assumed for areas with no site details;
- The regional dyke system separating the catchments is modelled as a no-flow boundary;
- Faults and fractures are not explicitly modelled. The assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REV, Representative Elemental Volume) this assumption should be acceptable;
- The model does not incorporate detailed historical mining. The underground mine voids at Wonderkop are represented, but the simulation does not include details on the timeline;
- The spatial distribution and amount of natural and artificial recharge is uncertain. So a uniform recharge is used to avoid over-complication of the model;
- A recharge rate of 50 mm/a is used for all slimes dumps adjacent to the existing and proposed Lanxess mining operations; and
- The complexities of fractured rock aquifers imply that the model can only be used as a guide to determine the order of magnitude of dewatering and contaminant transport.

4.2 Model Domain and Boundary Conditions

The model area and boundary conditions were defined taking into consideration the position of the existing underground mine and expansion areas, as well as natural groundwater flow boundaries such as rivers and topographical highs (Figure 8). The model covers an area of 26.2 km (east – west) by 24.4 km (north – south), and is bounded by the Hex River to the west and the Sterkstroom River to the east. The north and south central boundaries are formed by topographical highs. The natural flow boundaries used, were considered sufficient enough not to influence groundwater flow and contaminant transport across boundaries.

The individual cell sizes vary from 50 m by 50 m within the vicinity of the mining areas, to a maximum of 100 m by 100 m in the outer extremes of the model area where less accuracy is required. Vertically, the model was discretized into two layers, based on the aquifer types in the study area. The elevations used for the model layers can be summarised as follows:

- Layer 1 represents the upper weathered and fractured aquifer (20 m thick with topographical elevations obtained from SRTM database); and
- Layer 2 represents the fresh bedrock where underground mining takes place.

The numerical model design incorporates river/aquifer interaction features to enable representation of both baseflow and recharge from the streams to the groundwater. The rivers and streams within the model boundary were represented using the river package. This allows recharge and discharge between the surface and groundwater system.

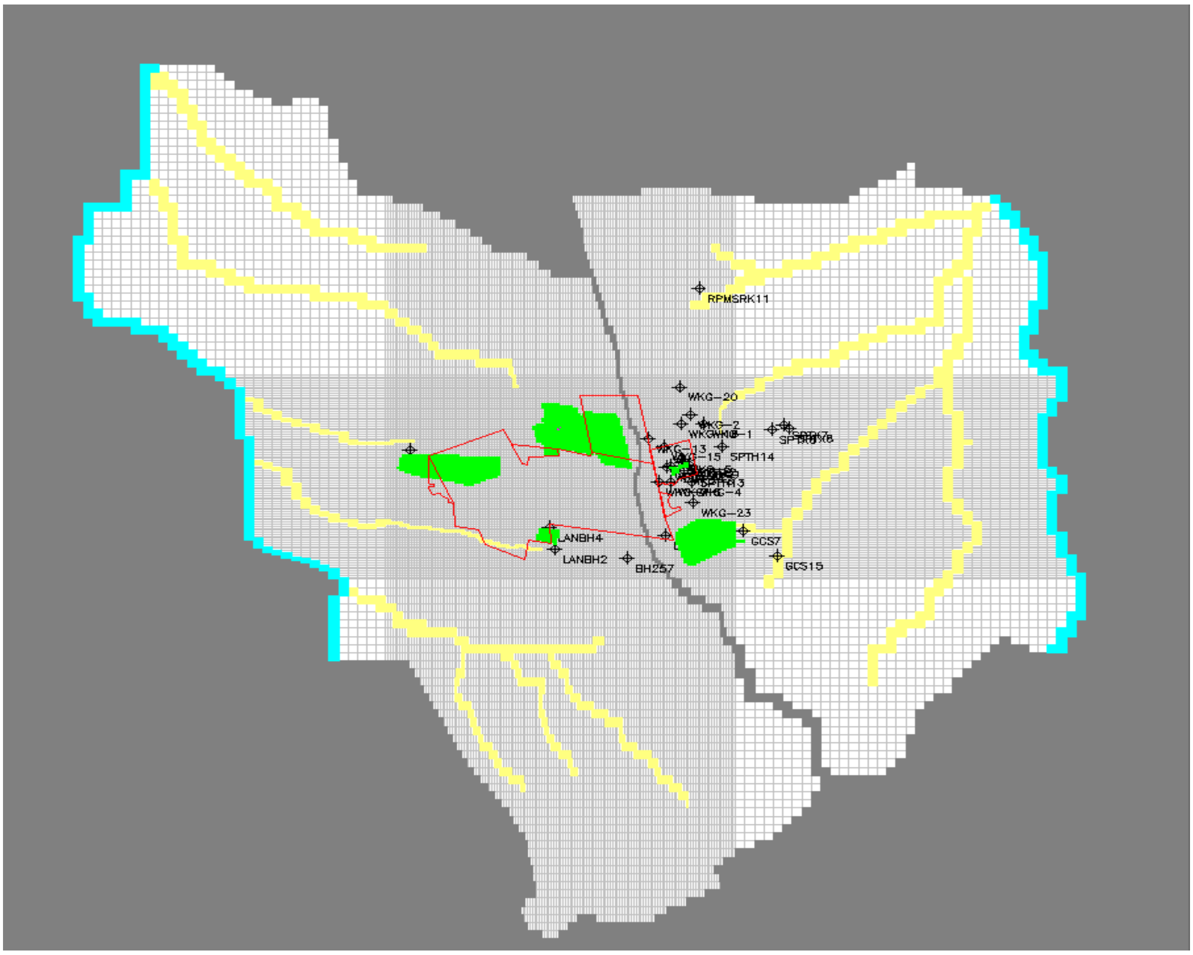

Figure 8: Model Setup

4.3 Model Calibration

Groundwater levels are not monitored at Lanxess Chrome Mine and this was a limitation in terms of model calibration. Simultec (2009) based it's calibration on the fact that groundwater levels in the weathered zone is shallower than 40 m and the total mine dewatering is approximately 500 m^3/d.

Observation of groundwater levels gathered from various reports indicate that the regional groundwater levels in the weathered aquifer are less influenced by underground mining, and therefore could be used to calibrate a first order steady state groundwater level.

The steady model was calibrated using the "trial-and-error" method where aquifer parameters are varied within realistic ranges until the model is able to produce site specific conditions. Hydraulic conductivity values obtained from historical reports were used to limit non-uniqueness during model calibration. The parameters for which the model was calibrated are given in Table 6. A total of 30 observation boreholes were used as calibration targets.

After model calibration, an acceptable correlation of 91.2% and a normalised root mean squared error (NRMSE) of 5.2% was obtained between the simulated and observed groundwater elevation (Figure 9).

The maximum residual (difference between calculated and observed groundwater level) is 8 m at borehole LANBH03. The minimum residual is -5 m at borehole SPTH13. The overall simulated heads coincide very well with the actual heads, confirming the model as a good predictive tool to simulate the aquifer system in the project area. The steady state groundwater table is given in Figure 10.

Table 6: Calibrated input parameters

Parameter	Layer/Aquifer	Value
Hydraulic Conductivity	Weathered Aquifer	0.5 m/d
Hydraulic Conductivity	Deep fractured aquifer	1e-4 m/d
Hydraulic Conductivity	East-west dyke (Layer 2)	0.05 m/d
Hydraulic Conductivity	North-south dyke (Layer 2)	0.001 m/d
Vertical Hydraulic Conductivity	Weathered Aquifer	0.05 m/d
Recharge	Highest Active Cell	3.53×10^{-5} m/d (2% of MAP)

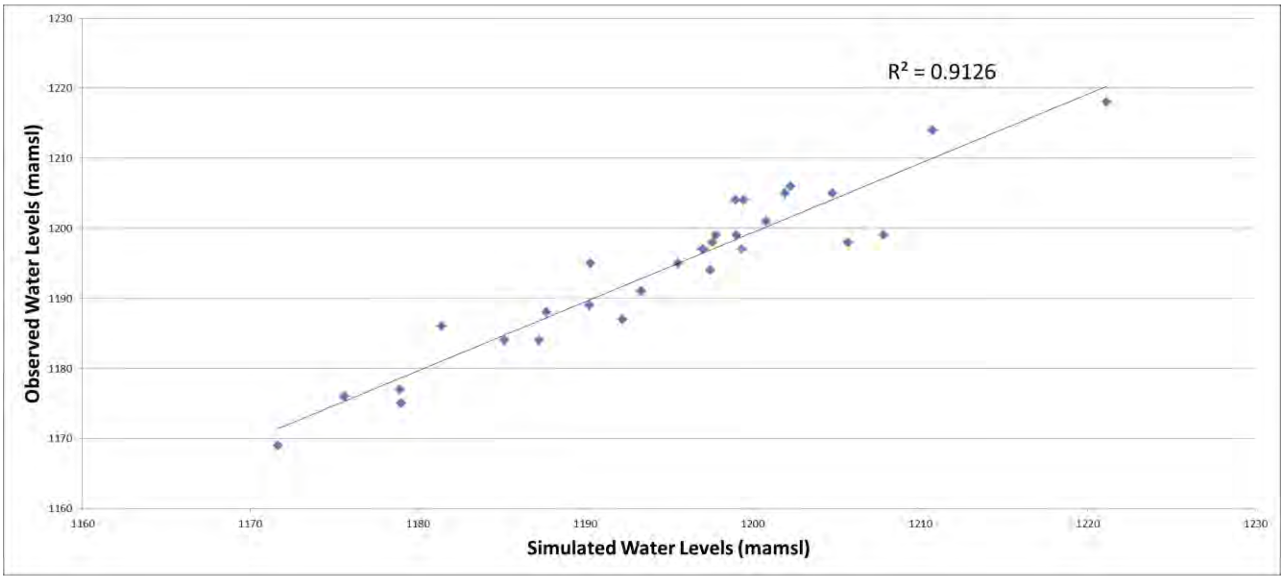

Figure 9: Correlation between observed versus simulated water levels

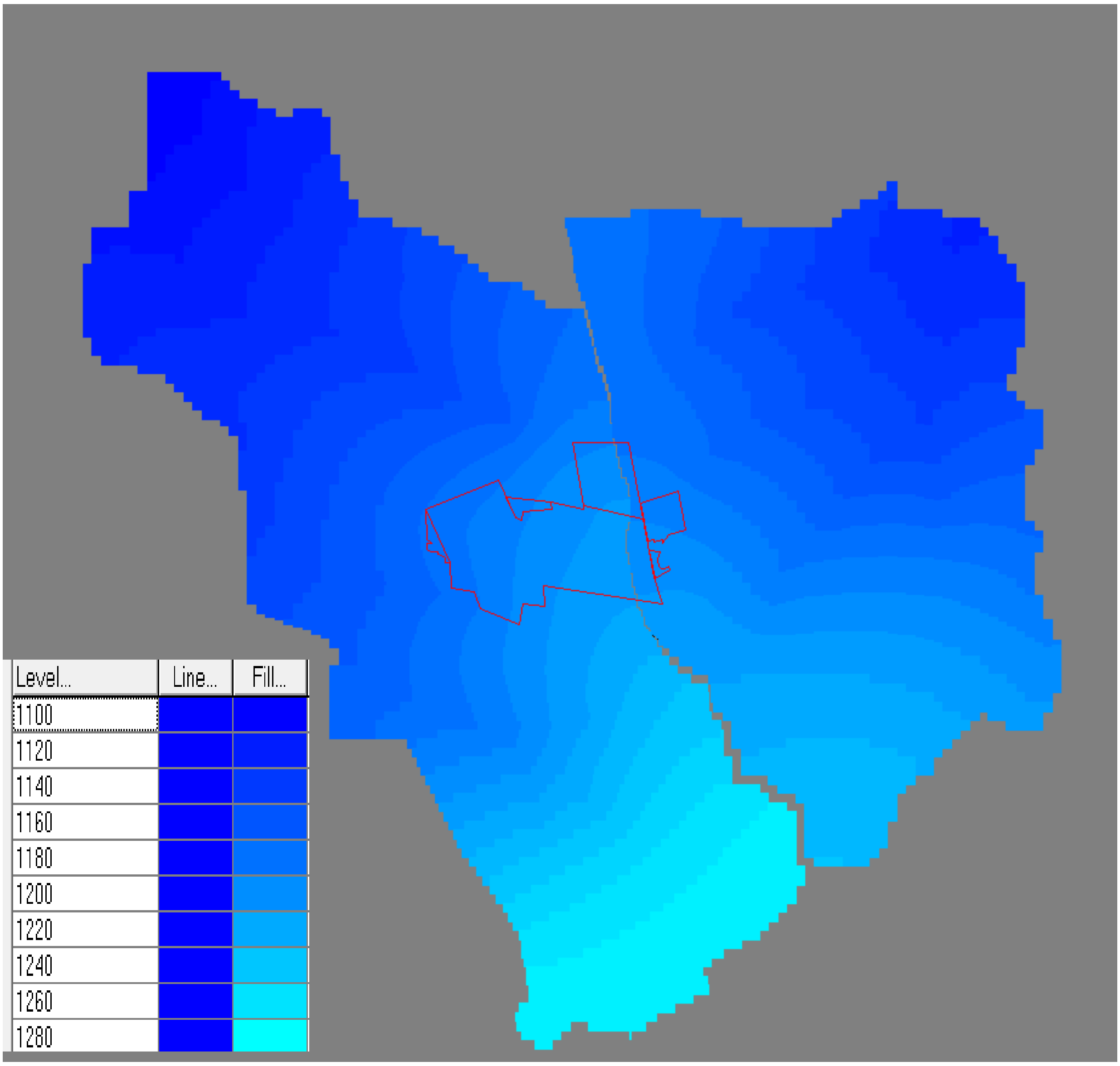

Figure 10: Steady state groundwater table

Simultec (2009) stated that the average long term inflow into the underground mine is approximately 500 m^3/d. It was therefore necessary to calibrate the model by using the existing mined voids as model input. The mine plan provided does not incorporate details on the timeline for worked areas. The timeline is only provided from 2015 till 2027.

Mining and dewatering activities were represented using drain cells. The drain elevations were set in accordance with the survey peg data. Areas with no peg data were interpolated using PMWin's Field Interpolator. The drain conductance applied to simulate mining was determined by multiplying the cell sizes (50 m) by the hydraulic conductivity of Layer 2.

The drain conductance value reflects the resistance to flow between the surrounding aquifers and the underground mine. A drain conductance of 0.005 m^2/d was therefore used.

Aquifer storage impacts the volume of water that must be dewatered and influences the relative drawdown due to the dewatering. To calibrate for storage, dewatering from the existing mine void was run for an arbitrary 10 year period. Based on

Table 7, the geometric mean of the long term inflow is 498 m^3/d. The following storage coefficients were used to achieve the calibration:

- Layer 1: 1E-4;
- Layer 2: 1E-5; and
- Mine void: 0.003.

Table 7: Calibrated Inflow into Lanxess underground

Arbitrary Years	Inflow (m^3/d)
Y1	1200
Y2	975
Y3	793
Y4	648
Y5	533
Y6	441
Y7	367
Y8	309
Y9	262
Y10	224
Average	**575**
Geometric Mean	**498**
Harmonic Mean	**434**

5 Impact Assessment

The potential groundwater impacts were assessed considering the three phases of the life of mine: the construction, operation and closure phases.

5.1 Impact Assessment Methodology

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified for various project activities. The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability

where

Consequence = Severity + Spatial scale + Duration

and

Probability = Likelihood of an impact occurring

The weight assigned to the various parameters for positive and negative impacts in the formula is presented in Table 8.

Table 8: Impact Rating

Rating	Severity			Spatial Scale	Duration	Probability
	Environmental	Social, Cultural and Heritage	Legal			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or ecosystem. Persistent severe damage.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	Potential jail terms for executives and/or very high fines for the company. Prolonged, multiple litigation. Withdrawal of permit / closure.	International	Permanent No Mitigation	Certain / Definite
6	Significant impact on highly valued species, habitat or ecosystem.	Irreparable damage to highly valued items of cultural significance or breakdown of social order.	Very significant fines and prosecutions. Multiple litigation.	National	Permanent Mitigated	Almost Certain / High Probability
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate	Very serious widespread social impacts. Irreparable damage to highly valued items.	Significant prosecution and fines. Very serious litigation, including class actions.	Province / Region	Project Life	Likely

4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year	On-going serious social issues. Significant damage to structures / items of cultural significance.	Major breach of regulation. Major litigation.	Municipal Area	Long Term	Probable
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month.	On-going social issues. Damage to items of cultural significance.	Serious breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible.	Local	Medium Term	Unlikely / Low Probability
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with / without help of external consultants.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Minor legal issues, non-compliances and breaches of regulation.	Limited	Short Term	Rare / Improbable
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Low-level repairable damage to commonplace structures.	Low-level legal issue.	Very Limited	Immediate	Highly Unlikely / None

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the Environmental Management Programme (EMP). The significance of an impact is then determined and categorised into one of four categories, as indicated in Table 9. The impact assessment methodology is applied to the four phases of mining (construction, operation, decommissioning and closure) for the identified mining activities.

Table 9: Significance threshold limits

Score	Description	Rating
< 35	An acceptable impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in either positive or negative short term effects on the social and/or natural environment.	Negligible
36 – 72	An important impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in either a positive or negative medium to long-term effect on the social and/or natural environment.	Minor
73 – 108	A serious impact, if not mitigated, may prevent the implementation of the project (if it is a negative impact). These impacts would be considered by society as constituting a major and usually long-term change to the (natural and/or social) environment and result in severe effects or beneficial effects.	Moderate
> 108	A serious impact, which if negative, may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects or very beneficial effects.	Major

5.2 Construction Phase Impact Assessment

During the construction phase, the establishment of the underground access shaft could have an impact on the groundwater system. The establishment of the shaft requires blasting which may negatively affect the groundwater quality if significant amounts of explosive are spilled or incompletely detonated. The chemical residues in the form of NH_4 and NO_3 may potentially leach to the groundwater table.

Minor seepage may be encountered during shaft construction. The groundwater inflows into the shafts may lead to localised dewatering. It is anticipated that the low permeability bedrock will naturally mitigate the progress of the cone of depression around the shafts. Therefore no significant groundwater cone of depression is expected around the shaft area.

Table 10: Construction phase impact quantification

Parameter	Description	Rating
Duration	Medium term	3
Spatial Scale	Limited	2
Severity	Moderate	3
Probability	Low Probability	3
Significance	**Negligible**	**24**

5.2.1 Mitigation and Management

Impacts from to mine dewatering during the construction phase are unlikely. The following mitigation and management measures are proposed to keep the impact to a minimum if it occurs:

- Undertake groundwater intrusive investigation around the shaft to optimise the position of the shaft and associated infrastructure to avoid major water bearing features;
- Handle and store blasting material according to manufacturing requirements;
- Establish the depth to groundwater table prior to construction;
- Grout or pump out any significant inflow of groundwater during shaft construction to ensure a dry and safe working environment;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Monitor quality of mine water.

5.3 Operational Phase

5.3.1 Mine Dewatering

Bord-and-pillar mining in the new underground segments was not modelled in isolation from the existing operations. Mining at the Kroondal and Overstep segments are due to commence from 2017 till 2020. The southern portion of the Wonderkop segment will be mined in 2018 and 2019. The northern portion of the Wonderkop segment is due from 2020 till 2025. Mining at the Klipfontein segment will run from 2020 till 2027.

In general, significant influxes of groundwater can occur during underground mining. This influx inevitably dewaters and lowers groundwater levels in the surrounding mining area. As more areas are mined, the zone of influence of the groundwater level drawdown migrates and expands as the groundwater system attempts to retain a state of equilibrium.

JMA (2009) stated the Wonderkop voids are partially flooded. It was assumed that barrier pillars will be left between the existing Wonderkop voids and the proposed mining the Wonderkop segments to avoid inrush of groundwater from the partially flooded voids.

The estimated rates into the current and underground mining operations are given in Figure 11. The groundwater model predicts the inflow to rise to a maximum of 540 m^3/d in 2025. This estimate is broadly comparable to anecdotal information from the historical mining activity at Lanxess which suggests that a dewatering rate of approximately 500 m^3/d was required to keep the underground workings dry.

Head difference plots of pre-mining versus water levels at the end of operations (2027) were used to assess the impact of dewatering the surrounding unmined aquifers. As depicted in Figure 12, the 5 m drawdown cone is not predicted to migrate more than 1 km from the proposed extension segments due to the low permeability associated with the deep fractured aquifer. The impact of mine dewatering in the new segments will also be mitigated by the fact that existing mining has already led to depleted aquifer storage in proposed segments.

In the weathered aquifer, mining in the new segments is not expected to cause additional dewatering, no more than already impacted. Interestingly, the model predicts that the 1 m drawdown cone will be limited to the west of the catchment diving dyke (Figure 13). As groundwater is used on ad hoc basis, the impacts on groundwater quantity during the operational phase rated as Minor.

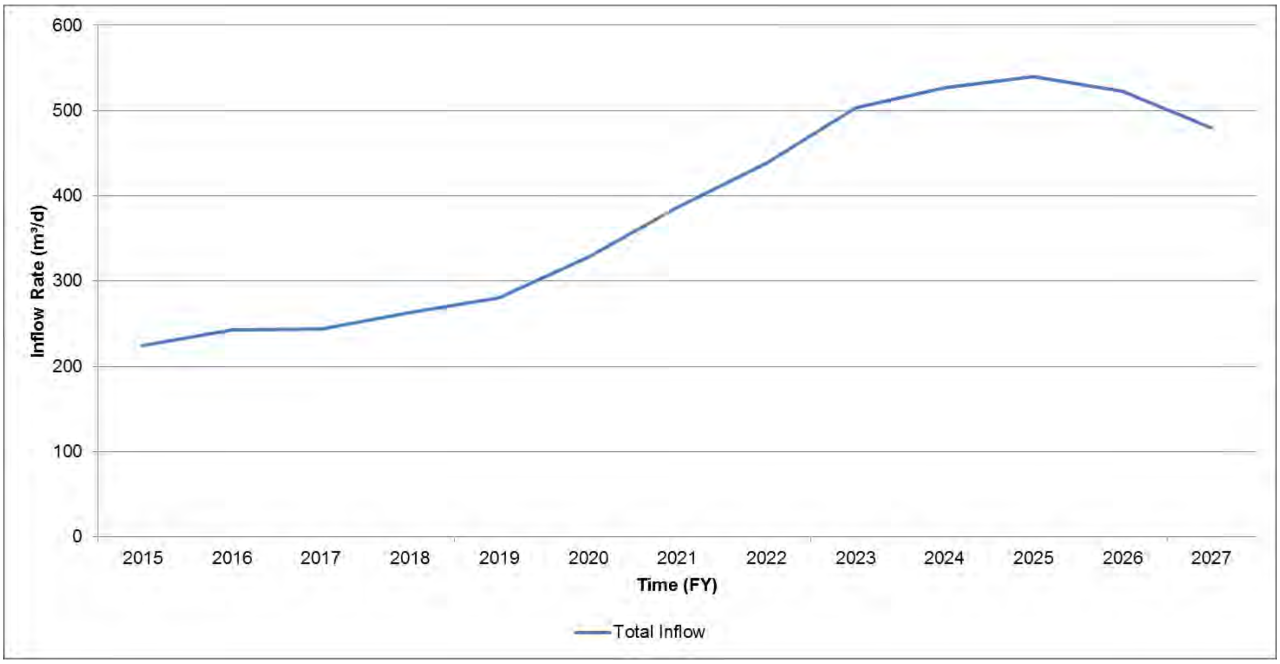

Figure 11: Predicted Inflow to Lanxess Chrome Mine

Table 11: Impact assessment during operation phase due to mine dewatering

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Project Life	5	Project Life	5
Extent	Local	3	Limited	2
Severity	Serious	4	Moderate	3
Probability	Probable	4	Low Probability	3
Significance	**Minor**	**48**	**Negligible**	**30**

5.3.2 Mitigation of and Management

- Dewater very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Monitor groundwater abstractions to ensure that the aquifer from which water is abstracted is not over-exploited;

- Pump excess underground water to appropriate surface storage facility according to manage and minimise the water quality impacts. When required by the process plant, the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use marginal mine water or grey water before using pristine groundwater; and
- Monitor water influx, water stored, water removed; and water levels in the underground mine and groundwater levels in the perimeter of the underground mine.

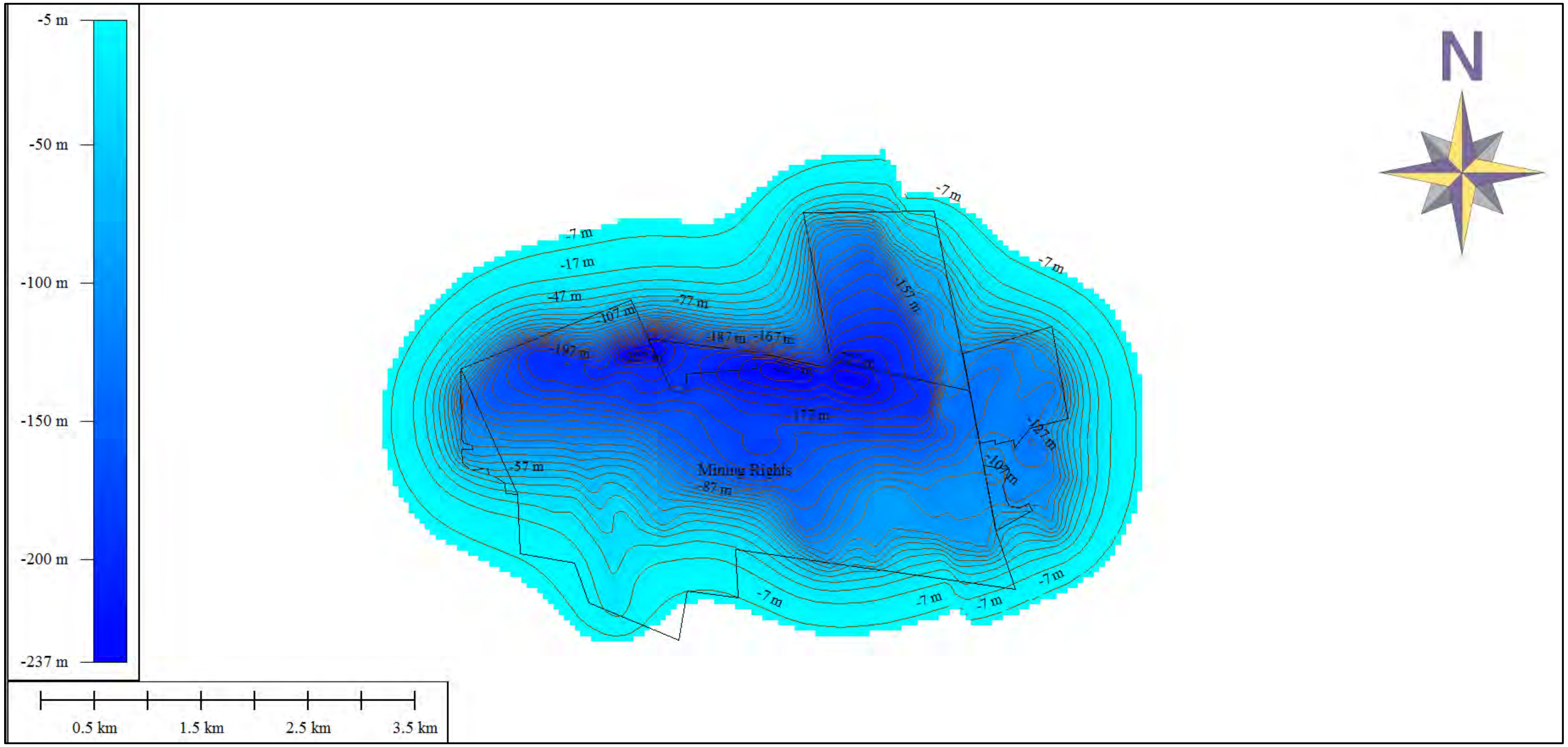

Figure 12: Deep fractured aquifer drawdown cone at end of operations (2027)

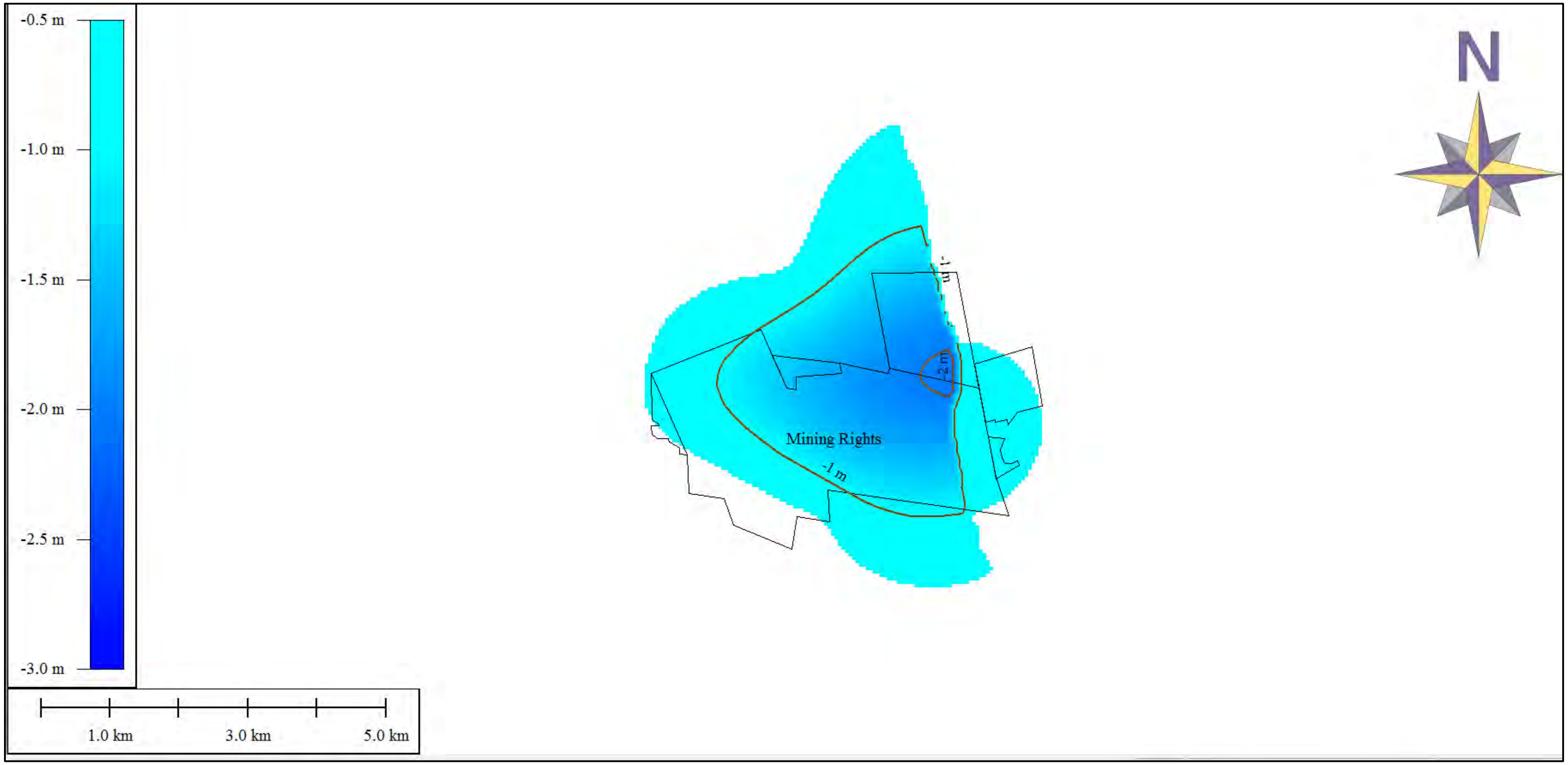

Figure 13: Weathered aquifer drawdown cone at end of operations (2027)

5.3.3 Mine Water Contamination

The current impact on groundwater quality lies in the vicinity of the old underground workings. Mining at the new segments is therefore predicted to increase the TDS levels of groundwater pumped from underground. Because this water will be pumped out as part of the dewatering, the impact of underground mining on groundwater quality will be minor.

A geochemical assessment done by Geostratum (2009) on waste rock and slimes dumps in the study area stated that most heavy metals other than chromium (Cr) will not be elevated in the leachate due to the neutral to slightly alkaline conditions. Cr leaches out at alkaline rather than neutral conditions. Under neutral reducing conditions Cr form the oxide Eskolaite. Under alkaline oxidation conditions Cr would be present as Cr(VI) species in solution.

Although conditions are very favourable for the formation of Cr(VI) during mineral processing (alkaline oxidation conditions), the pH will become more neutral in dumped wastes over time which may result in a slight decrease in total Cr and Cr(VI) concentrations in the seepage water.

No Cr was detected (above detection limit 0.01 mg/l) in the groundwater samples. This is mainly because Cr in soils and rocks strongly adsorbs to the mineral particles and as a result remains fairly immobile, and highly acidic or alkaline conditions are generally not present in the aquifer (Digby Wells, 2014).

There is a concern that mining underneath the slimes dam at Kroondal, Klipfontein and Wonderkop segments will induce seepage from these facilities to the underground mine. The groundwater model predicts that any seepage emanating from the overlying slimes dam will eventually join the underlying weathered zone and migrate towards the streams and not downward into the mine workings (Figure 14).

Table 12: Impact assessment during operation phase due to mine water contamination

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Project Life	5	Project Life	5
Extent	Local	3	Limited	2
Severity	Serious	4	Moderate	3
Probability	Likely	5	Low Probability	3
Significance	**Minor**	**60**	**Negligible**	**30**

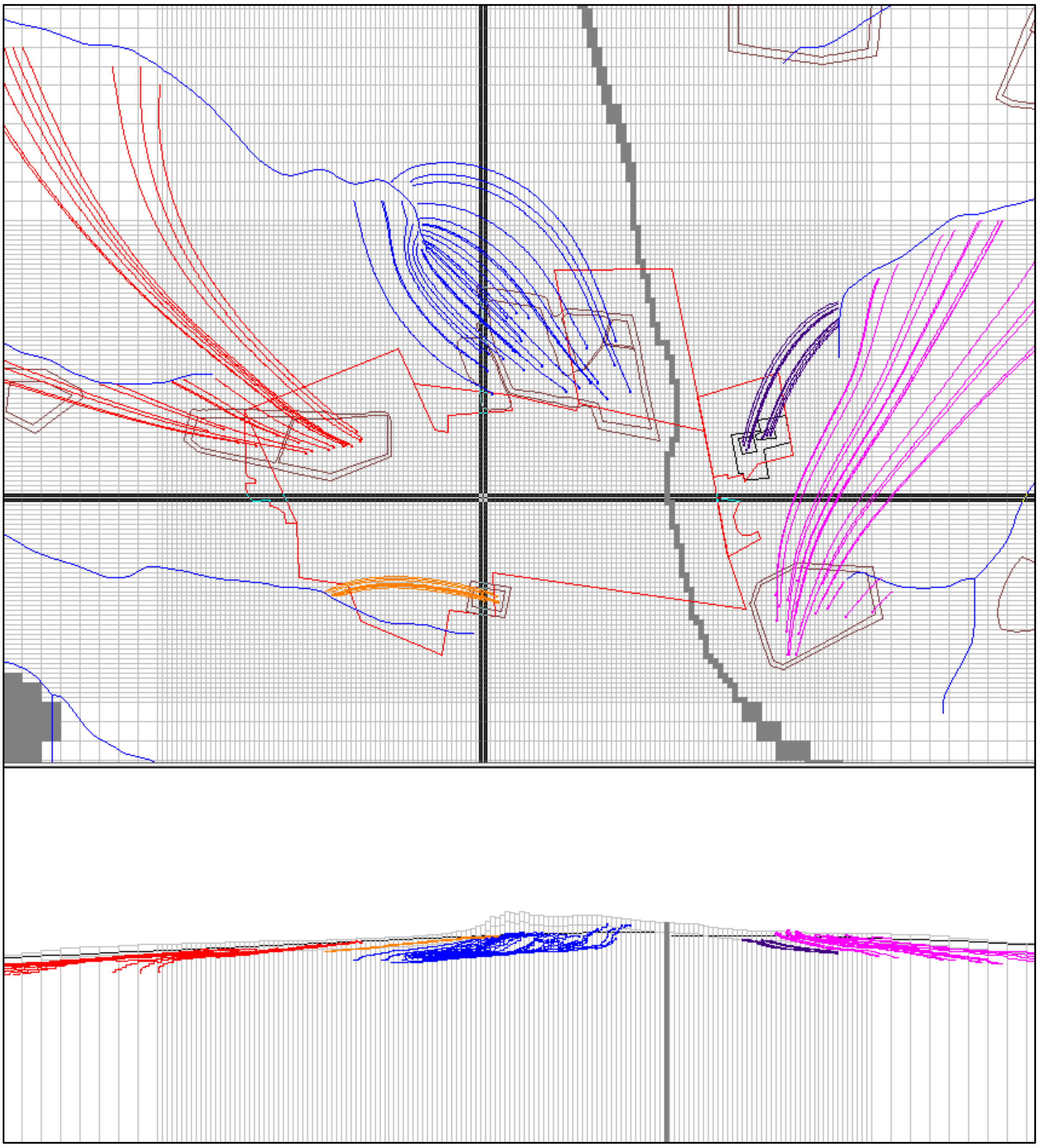

Figure 14: Flow lines from overlying slimes dam at end of operation

5.3.4 Mitigation and Management

- The mine water management measures recommended during construction phase should continue during the operational phase;
- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;

- Monthly or quarterly monitoring of groundwater qualities and water levels are recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to negligible.

5.4 Closure and Post-Closure Phases Impact Assessment

5.4.1 Mine Decant

After the operational phase, the underground mine will be left to flood. Water level rise and inflows during the rebound period in any one compartment will be a function of only two features:

- The total recharge to the compartment (i.e. the sum of rain-fed recharge and any head-dependent inflows from adjoining aquifers, and/or other compartment); and
- The distribution of storage capacity within the compartment.

As the underground mine floods, impacted groundwater levels will recover towards pre-mining levels. The initial rate of recovery is expected to be high due to fairly steep hydraulic gradients. Over time, as the groundwater levels rise and flow gradient decreases, the rate of recovery will decrease. Post closure groundwater levels should be monitored to accurately evaluate the rate of recovery.

In the post closure environment, if the hydraulic head in the mine void reaches equilibrium with the hydraulic head in the weathered aquifer, then the hydraulic head in the mine void fluctuate according to natural recharge patterns. If at this level, there exists an open shaft or an open borehole from the mine void to the surface, with the same collar elevation as the hydraulic head in the mine void, then decant would occur. The rate of decant would be equal to the rate of natural recharge to the underground panels.

At this stage, insufficient information exist for accurate prediction of decant, decant rates and time to decant. However, the probability of mine decant is not ruled out.

Table 13: Impact assessment during closure and post-closure phase due to mine decant

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Project Life	6	Project Life	6
Extent	Local	3	Limited	2
Severity	Very Serious	5	Moderate	3
Probability	Probable	4	Low Probability	3
Significance	**Minor**	**68**	**Negligible**	**33**

5.4.2 Mitigation of Mine Decant

- Monitor water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Seal all boreholes that connects the mine void to surface;
- Monitor groundwater levels in boreholes in the surrounding aquifers to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

5.4.3 Mine Water Contamination

The quality of groundwater in the post-closure environment will depend on background groundwater quality and the geochemical processes that occur in the mine void, above and below water level.

The current water quality from the old underground workings indicates that cation exchange processes will be dominant in the post-closure environment.

Contaminant migration away from the mine voids can only be induced by groundwater abstractions within the capture zone of the mine workings, and if decant occurs. The significance of mine water contamination in the post-closure environment is therefore rated as minor.

Table 14: Impact assessment during closure and post-closure phase due to mine water contaminant

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Permanent	6	Permanent	6
Extent	Local	3	Limited	2
Severity	Very Serious	5	Moderate	3
Probability	Probable	4	Low Probability	3
Significance	**Minor**	**56**	**Negligible**	**33**

5.4.4 Mitigation and Management

- No abstraction boreholes should be drilled in a 3 km radius from the underground workings in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and re-vegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

5.5 Cumulative Impacts

The impact assessment performed for the proposed underground expansion areas was done in an integrated approach that incorporated the existing underground mine voids and the waste facilities on site.

The Lanxess site represents a brown-fields mining and industrial site. The main complexity that has been introduced pertains to the extent of both opencast and underground mining, both within, as well as beyond the perimeter of the existing mineral rights boundaries and the proposed new segments.

Glencore, Aquarius, Lonmin and Anglo Platinum have mined extensively on the LG-6 reef, and the baseline hydrogeology has clearly identified regional aquifer dewatering due to mining.

Cumulative impacts from the surrounding activities are of two possible classes; impacts on groundwater quantity and impacts on groundwater quality.

As far as external impacts on groundwater quality are concerned, the available data depicts that mining operations do not cause significant levels of groundwater pollution, and the occurrence of groundwater pollution is very limited and isolated.

6 Monitoring Program

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and so that effective measures can be taken at an early stage before serious damage to the environment occurs.

6.1 Proposed Monitoring Boreholes

The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume migration.

As obtained from the desktop study, a couple of monitoring boreholes exist in the project area. No additional drilling is proposed for the Wonderkop segment. The existing WKG boreholes would be sufficient for groundwater monitoring in the Wonderkop segment. Apart from the existing Lanxess monitoring boreholes and the Wonderkop monitoring boreholes, the existence of all other boreholes listed in the DWS database could not be verified. It is therefore proposed to drill monitoring boreholes for Kroondal, Overstep and Klipfontein segments.

The location of monitoring boreholes for the Kroondal and Klipfontein segments is limited by the presence of overlying tailings dam.

Eight new monitoring boreholes are recommended based on the impact assessment. Each borehole is recommended to be drilled to a maximum depth of 60 m below surface to monitor the water level and quality in the weathered and fractured aquifer in the Kroondal, Klipfontein, and Overstep segments. In total, 44 monitoring points are recommended for the proposed groundwater monitoring as given in Table 15.

Table 15: List of proposed monitoring boreholes

BHID	Coordinates (LO 27 WGS84)	
	Y-Coordinate	X-Coordinate
DWE1	35379	-2845928
DWE2	34591	-2845731
DWE3	35312	-2844525
DWE4	37205	-2843965
DWE5	37280	-2844940
DWE6	39571	-2843993
DWE7	38870	-2844006
DWE8	38722	-2843272

BHID	Coordinates (LO 27 WGS84)	
	Y-Coordinate	X-Coordinate
LANBH02	39742	-2846565
LANBH03	40281	-2847152
9A	36451	-2846496
13	38321	-2847399
15	35672	-2846745
17	37933	-2847475
18	37826	-2846954
12	38181	-2846357
20	38032	-2846478
19	37409	-2846200
22	38416	-2845183
WKG-1	41086	-2844404
WKG-10	40517	-2846185
WKG-11	40318	-2845480
WKG-12	40377	-2845435
WKG-13	39923	-2844773
WKG-14	40329	-2846609
WKG-15	40240	-2844962
WKG-16	40728	-2844937
WKG-17	40243	-2844381
WKG-18	40606	-2844400
WKG-19	40020	-2843779
WKG-2	40794	-2844179
WKG-20	40593	-2843506
WKG-21	41187	-2843932
WKG-22	41167	-2844157
WKG-23	40875	-2846343
WKG-24	40563	-2846513
WKG-25	40802	-2846764
WKG-3	40659	-2845565
WKG-4	40838	-2845829
WKG-5	40615	-2845268
WKG-6	40385	-2845828
WKG-7	40125	-2845824
WKG-8	40643	-2845372
WKG-9	40779	-2845404

6.2 Water Level

Groundwater levels must be recorded on a quarterly basis using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater flow direction or head.

6.3 Water Sampling and Preservation

When sampling the following procedures are proposed:

- One (1) litre plastic bottles with a cap are required for the sampling exercises – provided by the water laboratory;
- Glass bottles are required if organic constituents are to be tested; and
- Sample bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a SANAS accredited laboratory.

6.4 Sampling Frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Monitoring should be conducted on a quarterly basis. Samples should be collected by an independent groundwater consultant, using best practice guidelines and should be analysed by an accredited laboratory.

It is suggested that the quarterly samples be collected, including up to 10 years post closure and based on the results it can be adjusted accordingly. Monitoring should continue until an acceptable water quality situation is reached.

6.5 Parameters to be Monitored

Analyses of the following constituents are recommended:

- EC, pH, TDS;
- Macro Analysis i.e. Ca, Mg, Na, K, SO_4, NO_3, F, Cl; and
- Heavy metals As, Al, Ba, Co, Cr, Zn, Cd, Cu, Fe, Ni, V, Mn, Se.

6.6 Data Storage

In any project, good hydrogeological decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the minimisation of groundwater contamination it is necessary to utilize all relevant groundwater data.

The generation and collection of this data is very expensive as it requires intensive hydrogeological investigations and therefore has to be managed in a centralised database if funds are to be used in the most efficient way. Digby Wells has compiled a WISH-based database during the course of this investigation and it is highly recommended that Lanxess utilise this database and continuously update and manage as new data becomes available.

7 Conclusions and Recommendations

7.1 Baseline Hydrogeology

Lanxess Chrome Mine falls within the middle-veld climatic zone with hot summers and mild winters. Regional mean annual precipitation (MAP) varies between 558 mm and 730 mm. The surface elevation varies between 1180 m above mean sea level (mamsl) in the west and 1220 mamsl in the east. The main water courses in the study area are the Hex River and the Sterkstroom River.

The larger study area is underlain by norite and anorthosite of the mafic to ultramafic Bushveld Igneous Complex (BIC) which dip at an angle of 10^{o} to the north. Numerous faults, some of which contain intruded material, traverse the study area. A major dyke flanks the west of the project area, and is associated with a major fault in the area and constitutes the most noticeable topographic feature. This syenite dyke dips to the east and forms a no-flow groundwater boundary. The regional aquifer systems consist of weathered, fractured and fresh pyroxenite and norite, with a thin overburden/soil cover.

The predominant aquifer type in the Lanxess area is a shallow, weathered zone aquifer, which occurs in the weathered and weathering related fractured zones within the pyroxenite and norite. The weathering profile is unevenly distributed across the project area, with an average weathering depth of 20 m below ground level (mbgl).

Mining occurs within the deep fractured aquifer. Groundwater occurrence within this aquifer is restricted to geological contact zones and linear geological features. There exists higher yielding groundwater bearing fractures north of the east-west dyke that traverse the mine voids. However, the north-south dykes in the study area are very low yielding. The yield of boreholes drilled into the syenite dyke was less than 0.02 L/s to dry.

In general, blow yields in the study area vary between 0.02 and 5 L/s, with hydraulic conductivities between 0.45 and 6.7 m/d. The mean annual recharge (MAR) to the groundwater systems for the study area is estimated to be between 3% and 7% of the mean annual precipitation. The depth to groundwater within the project area ranges between 10 and 24 m, with an average of 16 mbgl.

Historical boreholes, with water levels less than 11 mbgl, plotted against surface elevation indicate that the regional shallow groundwater levels are less influenced by underground mining and correlate with topography.

In terms of groundwater quality, chromium levels in groundwater are below detection limits. The general groundwater quality is characterised by elevated and non-compliant magnesium levels. Specifically, the current impacts on groundwater quality around the proposed pit lies in the vicinity of the old underground workings at Makuku informal settlement.

7.2 Impact Assessment

7.2.1 Construction Phase

Minor seepage may be encountered during shaft construction. The groundwater inflows into the shafts may lead to localised dewatering. It is anticipated that the low permeability bedrock will naturally mitigate the progress of the cone of depression around the shafts. Therefore no significant groundwater cone of depression is expected around the shaft area. The impact is therefore negligible.

7.2.2 Operational Phase

7.2.2.1 Impact of Mine Dewatering

The groundwater model predicts the inflow to rise to a maximum of 540 m^3/d in 2025. This estimate is broadly comparable to anecdotal information from the historical mining activity at Lanxess which suggests that a dewatering rate of approximately 500 m^3/d was required to keep the underground workings dry.

The 5 m drawdown cone is not predicted to migrate more than 1 km from the proposed extension segments due to the low permeability associated with the deep fractured aquifer. The impact of mine dewatering in the new segments will also be mitigated by the fact that existing mining has already led to depleted aquifer storage in proposed segments.

In the weathered aquifer, mining in the new segments is not expected to cause additional dewatering, no more than already impacted. Interestingly, the model predicts that the 1 m drawdown cone will be limited to the west of the catchment diving dyke. As groundwater is used on ad hoc basis, the impacts on groundwater quantity during the operational phase rated as minor.

7.2.2.2 Impact of Mine Water Contamination

There is a concern that mining underneath the slimes dam at Kroondal, Klipfontein and Wonderkop segments will induce seepage from these facilities to the underground mine. The groundwater model predicts that any seepage emanating from the overlying slimes dam will eventually join the underlying weathered zone and migrate towards the streams and not downward into the mine workings.

The current impact on groundwater quality lies in the vicinity of the old underground workings. Mining at the new segments is therefore predicted to increase the TDS levels of groundwater pumped from underground. Because this water will be pumped out as part of the dewatering, the impact of underground mining on groundwater quality will be minor.

7.2.3 Closure and Post Closure Impact Assessment

7.2.3.1 Impact of Mine Decant

After the operational phase, the underground mine will be left to flood. As the underground mine floods, impacted groundwater levels will recover towards pre-mining levels. If the hydraulic head in the mine void reaches equilibrium with the hydraulic head in the weathered aquifer, then the hydraulic head in the mine void fluctuate according to natural recharge patterns. If at this level, there exists an open shaft or an open borehole from the mine void to the surface, with the same collar elevation as the hydraulic head in the mine void, then decant would occur. The rate of decant would be equal to the rate of natural recharge to the underground panels.

At this stage, insufficient information exist for accurate prediction of decant, decant rates and time to decant. However, the probability of mine decant is not ruled out and therefore rated as minor.

7.2.3.2 Impact of Mine Water Contamination

The quality of groundwater in the post-closure environment will depend on background groundwater quality and the geochemical processes that occur in the mine void, above and below water level. The current water quality from the old underground workings indicates that cation exchange processes will be dominant in the post-closure environment. Contaminant migration away from the mine voids can only be induced by groundwater abstractions within the capture zone of the mine workings, and if decant occurs. The significance of mine water contamination in the post-closure environment is therefore rated as minor.

7.3 Groundwater Monitoring and Management Measures

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and effective measures can be taken at an early stage before serious damage to the environment occurs. Fourteen boreholes are proposed for the groundwater monitoring plan. The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume.
- The following groundwater management measures are proposed to mitigate the impacts assessed.

7.3.1 Mitigation and Management during Construction Phase

- Undertake groundwater intrusive investigation around the shaft to optimise the position of the shaft and associated infrastructure to avoid major water bearing features;
- Handle and store blasting material according to manufacturing requirements;
- Establish the depth to groundwater table prior to construction;
- Grout or pump out any significant inflow of groundwater during shaft construction to ensure a dry and safe working environment;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Monitor quality of mine water.

7.3.2 Mitigation of and Management of Mine Dewatering during Operation Phase

- Dewater very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Monitor groundwater abstractions to ensure that the aquifer from which water is abstracted is not over-exploited;
- Pump excess underground water to appropriate surface storage facility according to manage and minimise the water quality impacts. When required by the process plant, the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use marginal mine water or grey water before using pristine groundwater; and
- Monitor water influx, water stored, water removed; and water levels in the underground mine and groundwater levels in the perimeter of the underground mine.

7.3.3 Mitigation and Management of Mine Water Contamination during Operation Phase

- The mine water management measures recommended during construction phase should continue during the operational phase;
- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;

- Monthly or quarterly monitoring of groundwater qualities and water levels are recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to negligible.

7.3.4 Mitigation and Management of Mine Decant during Closure and Post-closure Phase

- Monitor water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Seal all boreholes that connects the mine void to surface;
- Monitor groundwater levels in boreholes in the surrounding aquifers to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

7.3.5 Mitigation and Management of Mine Water Contamination during Closure and Post-closure Phase

- No abstraction boreholes should be drilled in a 3 km radius from the underground workings in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and re-vegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

8 References

Digby Wells., (2006): Environmental Impact Assessment and Management Programme. Bayer Rustenburg, Chrome Mine.

Digby Wells., (June 2014): Lanxess Mining Groundwater Gap Analysis Report;

Digby Wells., (August 2014): Groundwater Report for the Proposed Opencast at Lanxess Chrome Mine.

Geostratum., (July 2009): Quantification of seepage from and classification of waste, Xstrata Alloys Wonderkop Operations.

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Groundwater Report for the Proposed Opencast at Lanxess Chrome Mine

Draft Report

Project Number:

LAN2558

Prepared for:

Lanxess Chrome Mining (Pty) Ltd

August 2014

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Project Name:	**Groundwater Report for the Proposed Opencast at Lanxess Chrome Mine**
Project Code:	**LAN2558**

Name	Responsibility	Signature	Date
Stephen Fonkem	Report writer		28 August 2014
Robel Gebrekristos	Reviewer		29 August 2014

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been requested by Lanxess Mining (Pty) Ltd (hereafter Lanxess) to conduct a hydrogeological specialist study as part of an Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) for the proposed opencast at their Lanxess Chrome Mine near Rustenburg.

The objective of the hydrogeological study is to provide a reference point (current conditions) against which potential mining impacts on the groundwater system can be identified and measured in future. The scope of work includes:

- A description of the groundwater flow system and the main processes that influence system behaviour;
- An assessment of potential impacts (type, degree, extent) related to various project components (e.g. dewatering of the proposed opencast mine; potential reduction in local groundwater level and degradation of groundwater quality during and after mining); and
- An assessment of potential mitigation options related to groundwater use, abstraction or contamination.

Baseline Hydrogeology

In observation of the geological setting of the site and based on the geological and geohydrological information generated during drilling, and historical studies, two aquifer types occur in the study area.

The aquifer system consists predominantly of weathered, fractured and fresh pyroxenite and norites, with a thin overburden/soil. An average blow yield of 0.5 L/s was recorded from two of the three boreholes drilled. The yields were all obtained in the shallow weathered/fractured profile. Water bearing fractures below 40 m were uncommon.

The weathered aquifer occurs across the entire surface area of the proposed pit. With a saturated thickness of up to 26 m, this aquifer dips towards the south eastern portion of the proposed pit.

The fractured aquifer is restricted to contact zone and linear geological features present in the study area. Both aquifers are bounded by a NNW-SSE striking syenite dyke along the eastern perimeter of the pit. The groundwater level is on average 16 m below ground level (mbgl). Deeper groundwater levels (> 20 mbgl) along the northern and western fringes of the proposed pit are attributed to mine dewatering due to underground mining.

Natural groundwater recharge is estimated at an average of 32 mm/a (which is 5% of the mean annual precipitation). Relatively high yielding water strikes in the pit area have an estimated transmissivity value of 6.8 m^2/d.

In terms of groundwater quality, chromium levels in groundwater are below detection limits. The general groundwater quality is characterised by elevated and non-compliant magnesium levels. Specifically, the current impacts on groundwater quality around the proposed pit lies in the vicinity of the old underground workings at Makuku informal settlement.

Impact Assessment

Construction Phase

Impact of Activity 1: Mine Dewatering

The initial excavation is unlikely to breach the water table and the impacts due to mine dewatering are unlikely during construction phase.

Impact of Activity 2: Mine Water Contamination

Site clearing and removal of topsoil may lead to puddles of surface water in the cleared areas during the wet season and potentially lead to increased infiltration to the weathered aquifers. Oil or fuel spillages from site machinery may collect in the soils. During rainfall events, hydrocarbon compounds from oil and fuel in the soils may migrate to the aquifers with water infiltrating through these polluted areas.

Groundwater influxes into initial excavation are not expected. Deterioration in groundwater quality due to the increased suspended solids during construction phase is unlikely. The overall significance of mining activities on groundwater quality during construction phase is negligible.

Operation Phase

Impact of Activity 1: Mine Dewatering

Groundwater from both A21K and A22H quaternary catchments will flow towards the pit during the operation phase. The predicted inflow rates range between 1027 and 1684 m^3/d. The zone of influence due an inflow rate of 1027 m^3/d is predicted to extend some 2.1 km from the pit centre. The worst case zone of influence is predicted to extend 2.5 km from the pit centre. The syenite dyke east of the pit is impermeable; hence the aquifers on the opposite site of the dyke are not expected to be influence by mining of the proposed pit

The properties and boreholes within the zone of influence belong to Lanxess Mining. Therefore the dewatering is unlikely to affect external private groundwater users. Because there are no external receptors within the zone of influence, the decrease in the volume of groundwater in natural storage due to mine dewatering is rated Negligible.

Impact of Activity 2: Mine Water Contamination

The current impact on groundwater quality around the proposed pit lies in the vicinity of the old underground workings. No Cr was detected (above detection limit 0.01 mg/l) in the groundwater samples. This is mainly because Cr in soils and rocks strongly adsorbs to the mineral particles and as a result remains fairly immobile, and highly acidic or alkaline conditions are generally not present in the aquifer.

Any seepage emanating from the adjacent waste rock dump will eventually join the underlying saturated zone and migrate towards the pit due to hydraulic gradient. Due to the historical mining activities onsite, the impact of groundwater quality deterioration is rated as Minor.

Closure and Post-Closure Phases Impact Assessment

Impact of Activity 1: Mine Decant

After the operational phase all the pit will be left open. The groundwater table will rise again to its pre-mining position and water will accumulate in the pits due to cessation of dewatering. A pit lake will develop.

Groundwater influx will decrease as the pit lake fills. The steady state inflow is predicted to decrease to about 60 m^3/d as the pit lake approaches equilibrium pre-mining groundwater levels.

It is unlikely that the pit lake will rise to equilibrium pre-mining groundwater levels during 100 years after closure. And because the Mean Annual Evaporation (2347 mm/a) is more than three times the mean annual precipitation, it is unlikely that the pit will fill up and decant. The significance of decant is therefore rated as Negligible.

Impact of Activity 2: Mine Water Contamination

The final open pit, the waste dumps and old underground workings will be the major contamination sources in the post closure environment

The current water quality from the old underground workings indicates that cation exchange processes will be dominant in the post-closure environment, especially in the pit lake and the defunct underground voids. Evaporation of the pit water might lead to increased concentration of chemicals in the pit lake water. Contaminant migration away from the pit lake can only be induced by groundwater abstractions within the capture zone of the pit. The significance of mine water contamination in the post-closure environment is therefore rated as Minor.

Groundwater Monitoring and Management Measures

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and effective measures can be taken at an early stage before serious damage to the environment occurs. Fourteen boreholes are proposed for the groundwater monitoring plan. The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume.

The following groundwater management measures are proposed to mitigate the impacts assessed.

Mitigation of and Management Activity 1: Mine Dewatering during Construction Phase

- Establish the depth to groundwater table prior to construction;
- Minimise penetration into the groundwater table;
- If groundwater table is to be penetrated to significant depth, dewater aquifer prior to excavations;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Obtain permission from regulating authority.

Mitigation and Management of Activity 2: Mine Water Contamination during Construction Phase

- Implement and train drivers to adhere to traffic rules;
- Implement a vehicle maintenance schedule;
- Install oil collection pans under vehicles;
- Handle and store blasting material according to manufacturing requirements;
- Minimise external contamination sources in the pit (diesel, oils, chemicals) as far as possible to ensure that groundwater flowing into the mine is contaminated; and
- Monitor quality of mine water.

Mitigation of and Management Activity 1: Mine Dewatering during Operation Phase

- Minimise groundwater influx into pit through optimisation of mining layout to minimise structural disturbance;
- Dewater aquifer prior to further excavations. Dewatering is more effective when operated very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Perform monitored groundwater abstractions to ensure that the aquifer from which water is abstracted is no over-exploited;
- Pump excess pit water to appropriate surface storage facility according to water quality. When required by the process plant the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use “marginal” mine water before using pristine groundwater; and
- Monitor water influx, water stored, water removed; water level in the pit and groundwater levels in the perimeter of the pit.

Mitigation and Management of Activity 2: Mine Water Contamination during Operation Phase

- The mine water management measures recommended during construction phase should continue during the operational phase;
- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;
- Divert surface flows away from the open pit areas through channels, drains and culverts;
- Monitoring of groundwater quality and water levels is recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to Negligible.

Mitigation and Management of Activity 1: Mine Decant during Closure and Post-closure Phase

- Monitor pit water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Monitor groundwater level elevation in boreholes in the surrounding aquifer to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

Mitigation and Management of Activity 2: Mine Water Contamination during Closure and Post-closure Phase

- No abstraction boreholes should be drilled in 2.5 km radius from the pit in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and revegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

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1 Introduction

Digby Wells Environmental (hereafter Digby Wells) has been requested by Lanxess Mining (Pty) Ltd (hereafter Lanxess) to conduct a hydrogeological specialist study as part of an Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) for the proposed opencast at their Lanxess Chrome Mine near Rustenburg (Plan 1).

Lanxess Mine is located 7km east of Kroondal and 12 km south-east of Rustenburg. The mine falls within the Rustenburg Local Municipality of the North West Province (Plan 2)

1.1 Project Description

Lanxess is interested in obtaining authorisation for an opencast operation on the south eastern portion of their mineral rights area. The proposed project is obligated to comply with the requirements of the Minerals and Petroleum Resources Development Act, Act 28 of 2002 (MPRDA) and National Environmental Management Act, Act 107 of 1998 (NEMA).

Lanxess currently has an Environmental Impact Assessment and Environmental Management Plan (EIA/EMP) in line with the MPRDA and would, therefore, need to amend the existing EIA/EMP to include the opencast mining operations as part of a section 102 amendment.

In terms of NEMA, listed activities triggered by the proposed development of the opencast operations must be authorised and an EIA/EMP completed.

1.2 Objectives and Scope of Work

The objective of the hydrogeological study is to provide a reference point (current conditions) against which potential mining impacts on the groundwater system can be identified and measured in future. The scope of work includes:

- A description of the groundwater flow system and the main processes that influence system behaviour;
- An assessment of potential impacts (type, degree, extent) related to various project components (e.g. dewatering of the proposed opencast mine; potential reduction in local groundwater level and degradation of groundwater quality during and after mining); and
- An assessment of potential mitigation options related to groundwater use, abstraction or contamination.

Specific phases and tasks within the scope of work included the following:

Phase 1 – Gap Analysis and Fieldwork

- Task 1: Gap Analysis;
- Task 2: Site visit, hydrocensus and groundwater sampling;
- Task 3: Ground geophysical survey;

- Task 4: Drilling of groundwater characterisation and monitoring boreholes, as well as core boreholes for the geochemical assessments; and
- Task 5: Aquifer testing and sampling.

Phase 2 - Reporting

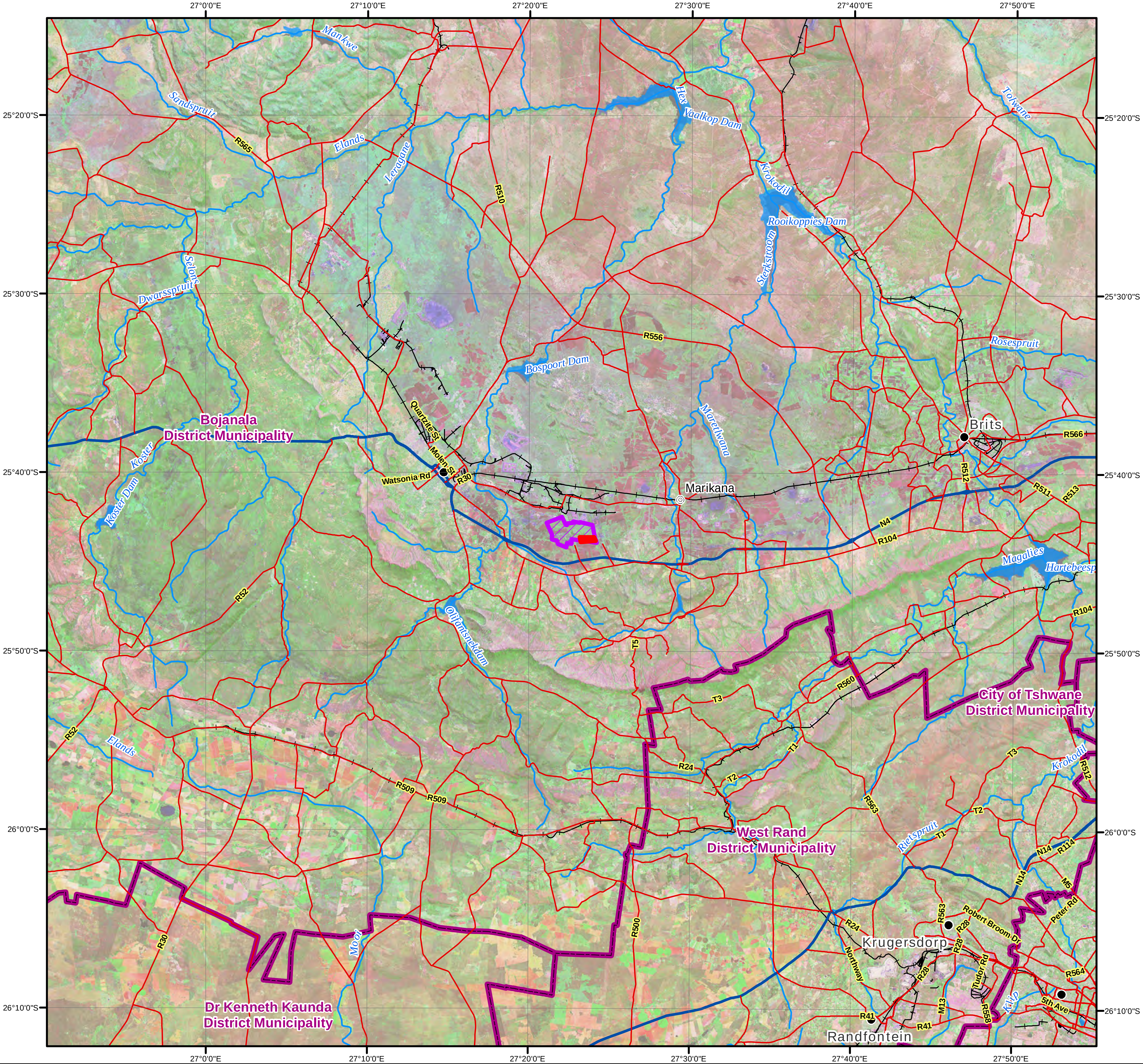
- Task 1: Hydrogeological baseline description;
- Task 2: Analytical modelling;
- Task 3: Impact identification and risk assessment;
- Task 4: Propose groundwater management measures; and
- Task 5: Propose a groundwater monitoring program.

1.3 Information Sources

In order to develop a reliable conceptual hydrogeological understanding, it was necessary to characterise the geological and hydrogeological conditions in the project area by reviewing historical investigations which were then supported or assessed with further field studies. Information from the following documents was assessed:

- Digby Wells, 2006. Environmental Impact Assessment and Management Programme. Bayer Rustenbug, Chrome Mine;
- Geostratum, July 2009. Quantification of seepage from and classification of waste, Xstrata Alloys Wonderkop Operations;
- JMA Consulting, August 2009. Groundwater Specialist Study Report, Xstrata Alloys Wonderkop Operations; and
- Digby Wells, June 2014. Lanxess Mining Groundwater Gap Analysis Report.

Plan 1: Regional Setting



Plan 1

Lanxess EIA Gap Analysis

Regional Setting

Legend

- GAP Analysis Project Area
- Lanxess Chrome Mine
- Major Town
- Secondary Town
- Main Roads
- National Roads
- Railway Line
- River
- Dam
- District Municipalities

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Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
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Ref #: sdp.LAN2558.201408.024
Revision Number: 1
Date: 08/08/2014

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Kilometres

1:400 000

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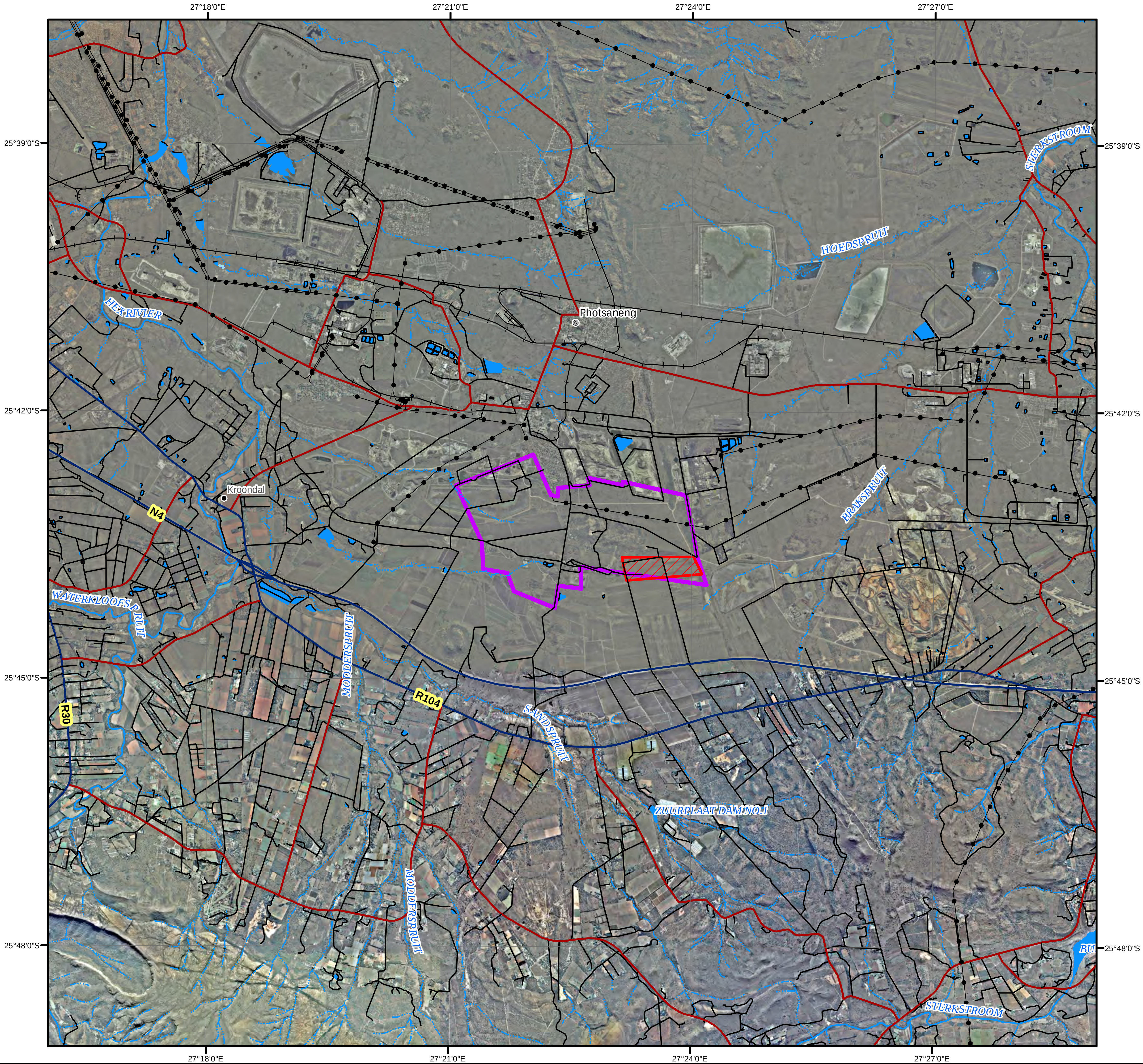
Plan 2: Local Setting



Plan 2

Lanxess EIA
Gap Analysis

Local Setting

Legend

- Gap Analysis Project Area
- Lanxess Chrome Mine
- Other Town
- Settlement
- Power Line
- Arterial / National Route
- Main Road
- Minor Road
- Railway Line
- Dam Wall
- Non - Perennial Stream
- Perennial Stream

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2 FIELD INVESTIGATIONS METHODOLOGY

2.1 Hydrocensus

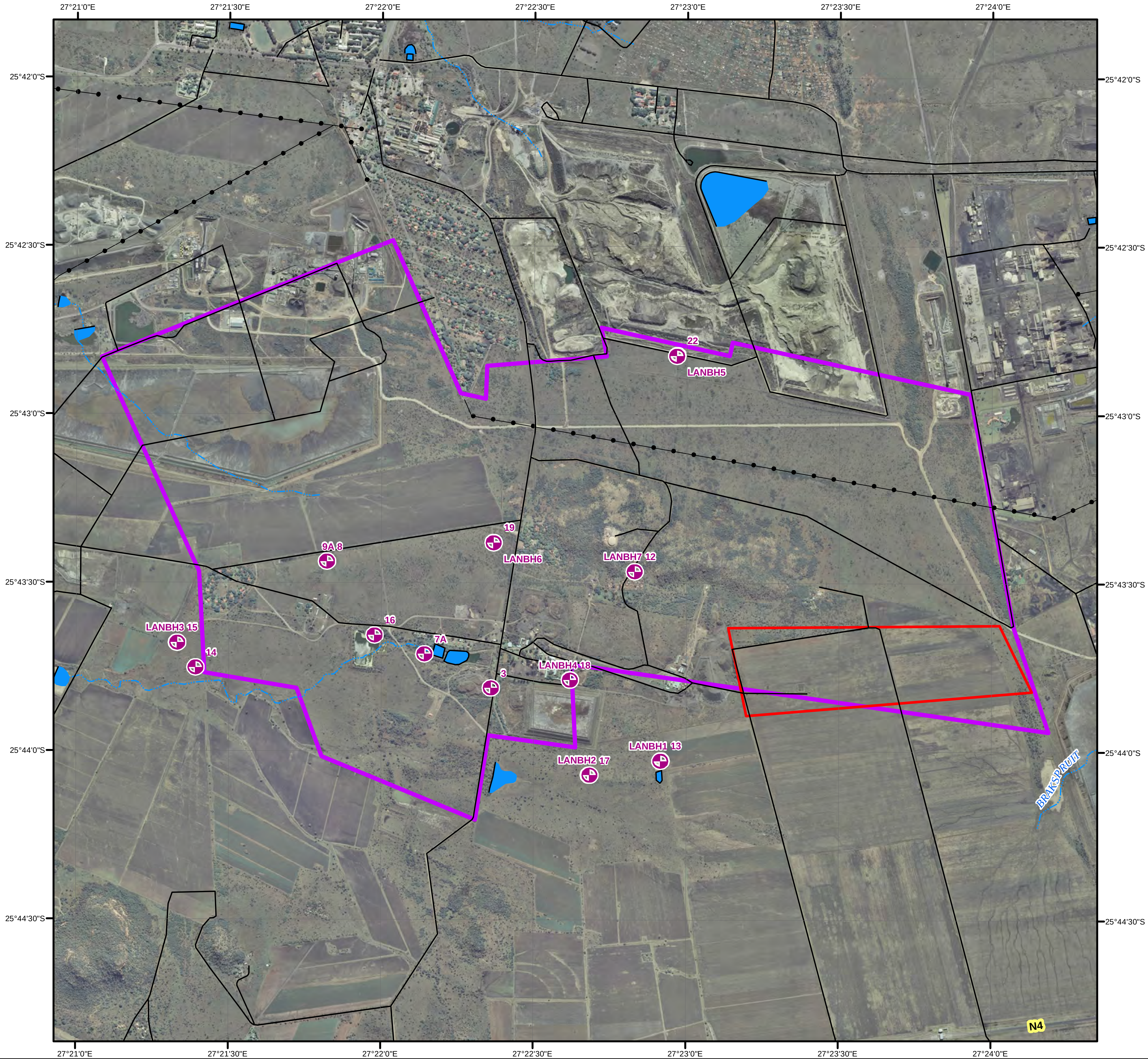
The hydrocensus was conducted between the 22nd and 24th of April 2014. During the hydrocensus important data pertaining to the current groundwater conditions and use were collected. These include:

- Borehole name (new ID given if no existing ID);
- Borehole coordinate (X,Y and Z position);
- Farm name where the borehole is located;
- Borehole use and abstraction volume (if known);
- Equipment installed in the boreholes (if any);
- Water level;
- Water sample taken if possible; and
- Owner name and contact details.

Nine boreholes were identified in the project area considering access and permit issues. The hydrocensus boreholes are listed in Table 1 and displayed in Plan 3.

Five of the hydrocensus boreholes were selected for water quality analysis. The sites selected for sampling were chosen in an attempt to best represent the area within and bordering the mine site. Samples were taken using single valve, decontaminated bailers, in the case of accessible boreholes and from pumps or taps in the case of boreholes which were in use; in which case a grab sample was taken. Standard 1 L sample bottles were used and filled to the top. Samples were delivered to Aquatico Laboratory in Pretoria for analysis. The results are given in Appendix A and discussed in section 2.

Plan 3: Hydrocensus Boreholes



Plan 3

Lanxess EIA Gap Analysis

Hydrocensus Borehole Locations

Legend

- Gap Analysis Project Area
- Lanxess Chrome Mine
- Hydrocensus Borehole Locations
- Power Line
- Minor Road
- Dam Wall
- Non - Perennial Stream
- Perennial Stream
- Dam / Lake

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Revision Number: 1
Date: 06/08/2014

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Table 1: Summary of the hydrocensus boreholes

BH ID	Alternative ID	Coordinates (Datum in WGS 84)			BH depth (m)	Water level (mbgl)	Description	Sampled
		Latitude	Longitude	Altitude (mamsl)				
LANBH1	13	-25.7338	27.3819	1222.19	-	-	B/H South of No 3 Slimes Dam	No
LANBH2	17	-25.7345	27.37804	1210.42	-	11.1	B/H 7 East Standby Generator	Yes
LANBH3	15	-25.728	27.35551	1184.7	-	-	B/H Pump to No 10 Bottom Village Dam	Yes
LANBH4	18	-25.7298	27.37696	1209.46	-	11.4	B/H Next to Hostel at West side of it	No
LANBH5	22	-25.7138	27.38278	1197.2	-	-	B/H Anglo Plats Slims Dam (Water from U/G old workings)	No
LANBH6	19	-25.723	27.37278	1204.41	-	-	B/H Tennis Court	Yes
LANBH7	12	-25.7244	27.38048	1212.58	-	-	B/H Makuku. (Water from old workings, Makuku-informal settlement)	Yes
LANBH8	9A	-25.7257	27.36324	1192.15	-	-	B/H 7 West # Next to servitude Road	No
LANUG01	20	-25.7255	27.37899	1211.38	-	-	(Old workings U/G, Discharge at concrete pipe slimes dam drain).	Yes
7A		-25.7285	27.36901	-	-	-	B/H Dam Skoon Plaas Village - borehole not found	No
14		-25.7292	27.35652	-	-	-	borehole not found	No
16		-25.7276	27.36629	-	-	-	B/H Next to 7 West Dam Pump in Dam No 8- borehole not found	No
3		-25.7302	27.37264	-	-	-	B/h Sewage Plant -borehole covered by waste rock	No

2.2 Geophysical Survey

A ground geophysical survey was conducted between the 20th and 21st of May 2014, after completion of the hydrocensus. The purpose of the geophysical survey was to identify borehole sites for characterisation and monitoring of the proposed mining area where very little groundwater information existed.

The survey was conducted using a frequency domain electromagnetic instrument (EM34-3) and a G5 Proton Magnetometer (MAG). The magnetic and electromagnetic methods where chosen as the method is cost effective and can be utilised to identify weathered zones and structures present in the project area. The geophysical data recorded was interpreted in terms of the local geological and hydrogeological conditions. A handheld GPS was used to record the location of each data station. The survey had a station spacing set at ten meters to ensure that possible vertical to sub-vertical features could be detected.

Based on the interpretation of the geophysical data, three potential targets for the drilling of characterisation boreholes were identified and are summarised in Table 2. The ground geophysical data is attached in Appendix B.

Table 2: Summary of the selected targets for borehole drilling derived from the geophysical survey

Target ID	Coordinates (Datum in WGS 84)		Method	Comments
	Latitude	Longitude		
Target01	-25.730208	27.386723	EM34-3 &Mag	Drilled
Target02	-25.726238	27.39604	EM34-3 &Mag	Drilled
Target03	-25.731523	27.401422	EM34-3 &Mag	Drilled

2.3 Percussion drilling programme

The percussion drilling programme was carried out between the 24th and 27th of June 2014 and was supervised by a hydrogeologist from Digby Wells. All three targets were drilled by Geosphere Drilling using the air rotary percussion drilling method.

Two boreholes were drilled to a depth of 70 mbgl and one borehole drilled to a depth of 48 mbgl. During drilling the following information were recorded:

- Lithological profile in 1 m intervals;
- Degree of rock weathering, as weathering may contain or aid groundwater movement;
- Penetration rates;
- Positions of water strikes and corresponding blow yields;
- Details of the borehole construction:

- The boreholes were drilled using conventional percussion drilling of 205 mm diameter to the final borehole depth;
- 177 mm (internal diameter) steel casing was installed across the top section of the borehole; across the unconsolidated and unstable sections of the geology to avoid borehole collapse;

- Water level; and
- Final borehole blow yield.

Plan 4 shows the locality of the new boreholes. A summary of the drilling programme is given in Table 3. The geological logs are given in Appendix C.

Table 3: Summary of newly drilled boreholes

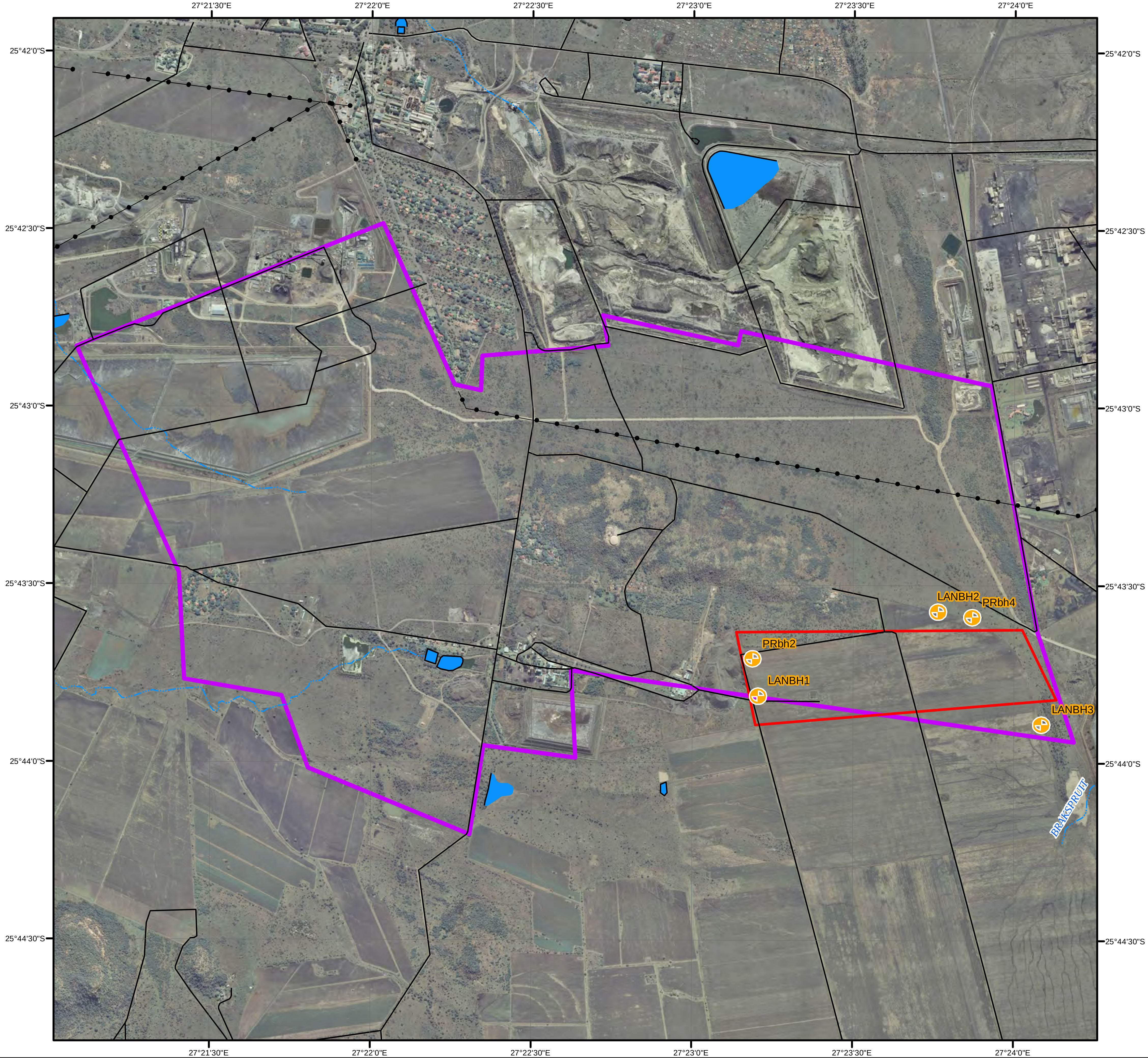
	Borehole ID	LANBH01	LANBH02	LANBH03
Borehole Location	Latitude	-25.730208	-25.726238	-25.731523
	Longitude	27.386723	27.39604	27.401422
	Elevation (m amsl)	1220.85	1231.08	1225.06
Borehole Data	Borehole Depth (m)	70	48	70
	Blow Yield (L/s)	0.44	-	0.5
	Water Strike depth (m)	31	-	18
	Static Water Level (m bgl)	23.7	22.4	10.7
	water level (m amsl)	1197.15	1208.68	1214.36
Borehole Construction Data	Solid Steel casing (Diameter - INT mm)	177	177	177
	Depth from, to (m)	0-28,40-64	0-32	0-16, 22-28, 34-64
	Perforated Steel casing (Diameter -INT mm)	177	177	177
	Depth from, to (m)	28-40,64-70	32-38	16-22,28-34, 64-70

Plan 4: Borehole Locality Map

Plan 4

Lanxess EIA Gap Analysis

Drilled Borehole Locations



Legend

- Gap Analysis Project Area
- Lanxess Chrome Mine
- Drilled Borehole Locations
- Power Line
- Minor Road
- Dam Wall
- Non - Perennial Stream
- Perennial Stream
- Dam / Lake

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2.4 Aquifer Testing

Aquifer tests were conducted on two of the new boreholes. Digby Wells conducted the aquifer tests between 9th and 11th July 2014. Constant discharge and recovery tests were conducted on each borehole. The aquifer test data given in Appendix D were analysed with the FC and Cooper- Jacob methods. The results are shown in Table 5 and discussed in section 3.

Table 4: Results of aquifer tests

BH ID	Constant Rate Test		Methods			
			FC-Method		Cooper-Jacob Method	
	Pumping Rate (L/s)	Constant Test period (hours)	Early Time T(m^2/d)	Late Time T(m^2/d)	Early Time T(m^2/d)	Late Time T(m^2/d)
LAN01	1.5	12	8.4	2.8	6	4.4
LAN03	1.2	12	7.22	0.61	6.2	1.9

3 BASELINE HYDROGEOLOGICAL CONDITIONS

3.1 Climate

Lanxess Chrome Mine falls within the middle-veld climatic zone with hot summers and mild winters. Regional mean annual precipitation (MAP) varies between 558 mm and 730 mm. Precipitation occurs primarily during the summer months in the form of high intensity, short duration thunderstorms between November and March with the climax occurring in January. Climatic data used was recorded at the weather station 0511399X Rustenburg.

Mean temperatures range between 14°C and 30°C during the summer months and between 5°C and 20°C during the winter months. The prevailing winds blow predominantly from the north-west and north at an average speed of 2.4 m/s.

The mean annual evaporation (MAE) is almost four times higher than the MAP at 2 374 mm. Lanxess is therefore located in a water deficit climate in which evaporation and evapotranspiration exceed rainfall.

The amount of rainfall that the area receives every year fluctuates. In Figure 1, it can be seen that the year with the highest recorded rainfall is 2000, with very dry periods in 1999 and 2001.

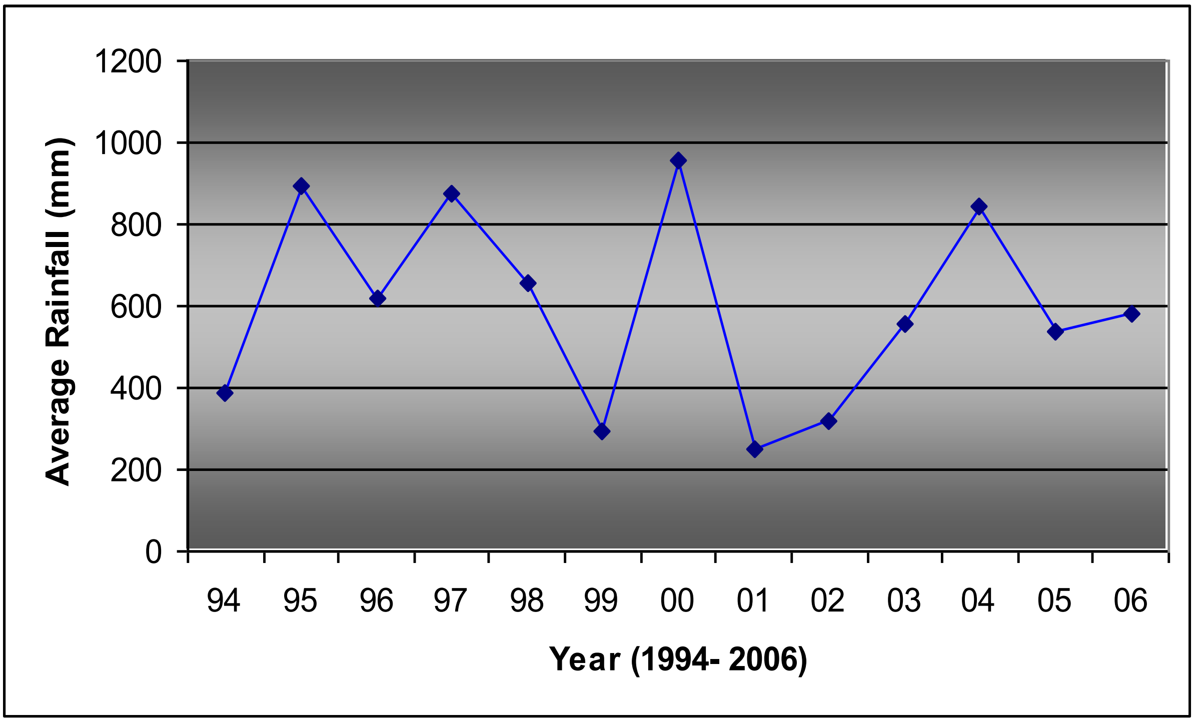


Figure 1: Rainfall fluctuations over ten years

3.2 Topography and Drainage

The topography of the mine area is fairly flat to gently undulating with a westerly slope varying between 1 and 2 degrees. The surface elevation varies between 1180 m above mean sea level in the west and 1220 m above mean sea level in the east.

There is a distinct north-south trending geological lineament to the east of the study area which manifests on surface as an elevated alignment of hills and ridges (Figure 2). This lineament forms the watershed that separates the A22H and the A21K quaternary sub-catchment areas.

Non-perennial streambeds, between 1.5 m and 2.0 m below general surface elevation, occur generally as small, occasionally wide, incisions in an otherwise flat landscape. The topography of the site indicates a slope towards the west causing runoff to be taken by two tributaries of the Sandspruit, which flow into the Hex River. One non-perennial tributary of the Sandspruit drains from the east to the west and originates on the property. The presence of numerous slag dumps, slimes dams, quarries and mine dumps has altered the localised topography of the relatively flat site topography which makes up the north parts of the study area. These surface activities have altered the surface drainage patterns of the rivers as well as the natural discharge volumes of these rivers.

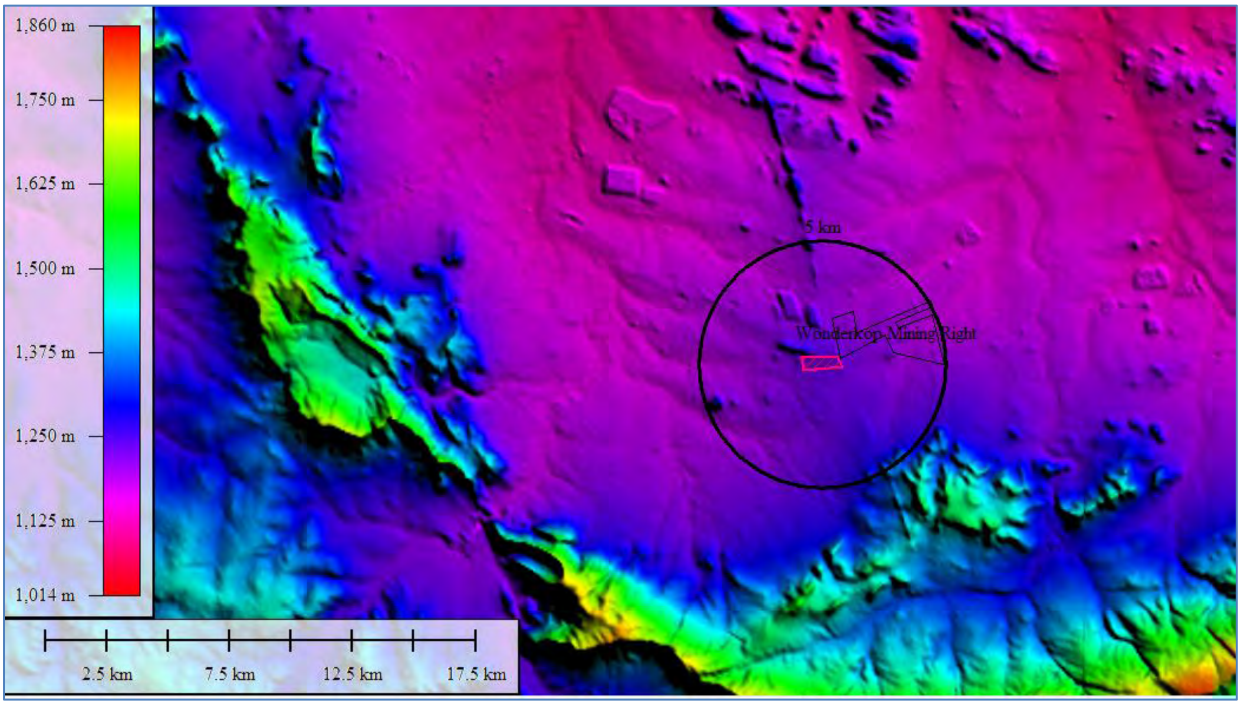


Figure 2: Slope shaded relief map

3.3 Regional Geology

The regional geology discussed below was summarised from the JMA (2009) report.

The regional geology of the area is given in Figure 3. The larger study area is underlain by norite and anorthosite of the mafic to ultramafic Bushveld Igneous Complex (BIC) which dip at an angle of 10^{o} to the north. Numerous faults, some of which contain intruded material traverse the study area.

There is clear evidence that faults and dykes exist in the area. The faults are predominantly dextral, many of which have later been intruded by dykes. The majority of the dykes have north-north-west trending strikes and form part of the Pilanesberg dyke swarm. A major dyke flanks the west of the project area, and is associated with a major fault in the area and constitutes the most noticeable topographic feature. This syenite dyke dips to the east and forms a no-flow groundwater boundary.

The western parts of the BIC have been extensively mined for chromite and platinum group elements (PGE's) by both opencast and underground mining methods. Some of the more important and economically exploitable horizons within the BIC include the LG-6, UG-2, UG-1 and MG-1 chromititic layers as well as the Merensky Reef. The UG-2 and Merensky Reef have been predominantly mined for platinum and associated PGE's, whereas the LG-6 has been mined for chromite. The Merensky Reef and UG-2 layers have east-west strikes and dip to the north, whereas the LG-6 layer has a north-east to south-west strike and dips to the northwest. All three layers are, however, laterally very extensive and homogenous with regards to average thickness across the area.

The Lower Group (LG) chromitite layers form the base of the critical zone. Seven main layers are recognized, of which the so-called LG-6 is the most economically important. The LG-6 seams vary in thickness (120 cm to 35 cm thick) and are divided or separated by a band of waste rock of about 35 - 40 cm thick. They dip at approximately 9^{o} to the north below the site where it was mined out by underground methods.

3.4 Regional Hydrogeology

This excerpt was taken from the published 1:500 000 Hydrogeological map series of the Republic of South Africa – Sheet 2526 – Johannesburg.

The regional hydrogeological attributes of the study area are clearly a function of the geological formation distribution. The study area is underlain by ultramafic/mafic intrusive rocks of the Rustenburg Layered Suite. Within this zone, the primary groundwater occurrences are in the joints and fractures occurring in the contact zones related to the heating and cooling of the country rocks as well as in fractures in the transitional zones between the weathered and un-weathered rocks. The host rocks in this area are disturbed by a major N-S trending fault. The groundwater and movement thereof will be influenced by the fault and associated shear zones.

The borehole yielding potential within this geohydrological zone is classified as d3, which implies an average yield which varies between 0.5 L/s to and 2 L/s.

Large volumes of groundwater (>10 million m^3/annum) are extracted for irrigation from these intergranular and fractured rock aquifers within the bounds of the greater study area.

The groundwater potential for this area is given as less than 40%, which indicates the probability of drilling a successful borehole with yield of more than 1 L/s, whilst the probability of obtaining a yield in excess of 2 L/s is given as between 20% and 30%.

The mean annual recharge (MAR) to the ground water system for the major part of the study area is estimated to be between 37 mm and 50 mm per annum, which also relates to between 5% and 10% of the mean annual precipitation (MAP). The groundwater contribution to surface stream base flow is relatively low, between 10 mm to 25 mm per annum with the depths to ground water levels estimated to be 8 mbgl. The aquifer storativity (S) for these intergranular and fractured aquifers are estimated to be less than 0.001.

The groundwater quality is good with a Total Dissolved Solids (TDS) range of between 300 mg/L to 500 mg/L and an Electrical Conductivity (EC) range of between 70 mS/m to 300 mS/m. There is a potential nitrate risk in the area, with nitrate concentrations exceeding 10 mg/L as N across the area. The groundwater will be of the hydrochemical , with dominant cations Ca^{2+} and Mg^{2+} and dominant anions Cl^{-} or SO_4^{2-}.

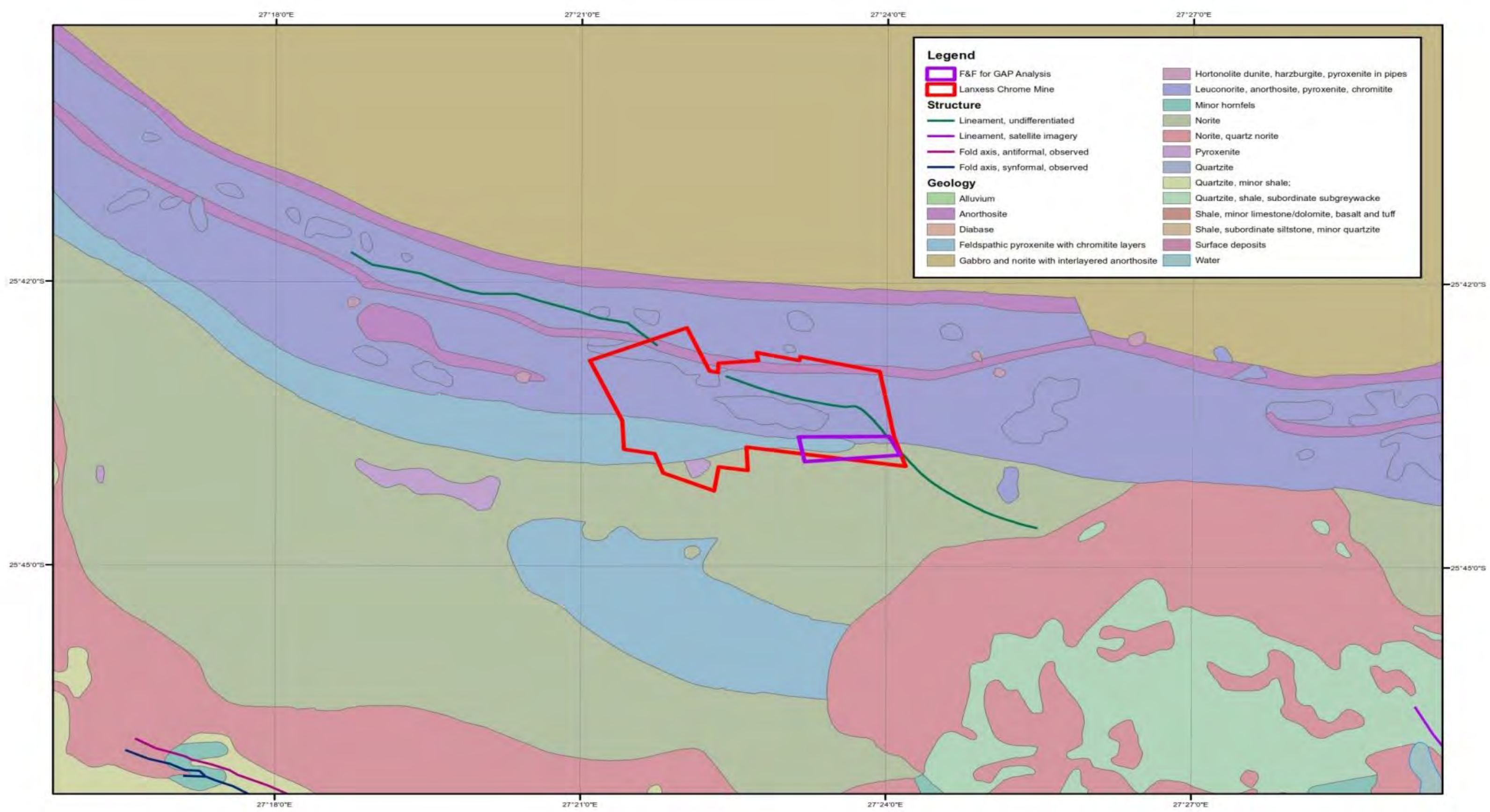


Figure 3: Regional Geology

3.5 Aquifer Characterisation

The characterisation of the aquifers underlying the study area will be based on the geological and geohydrological information derived during field investigations. Digby Wells drilled 3 boreholes during the study as described in section 2.

In observation of the geological setting of the site and based on the geological and geohydrological information generated during drilling, and historical studies, two aquifer types occur in the study area.

The aquifer system consists predominantly of weathered, fractured and fresh pyroxenite and norite, with a thin overburden/soil. An average blow yield of 0.5 L/s was recorded from two of the three boreholes drilled. The yields were all obtained in the shallow weathered/fractured profile. Water bearing fractures below 40 m were uncommon. Weathering and fractures were also recorded in the dry borehole, but most probably due to mine dewatering, the borehole was dry.

3.5.1 Weathered Aquifer

The predominant aquifer type present is a shallow weathered zone aquifer, which occurs in the weathered and weathering related fractured zones within the pyroxenite and norite host rock matrix. This aquifer occurs across the entire surface area of the proposed pit. With a saturated thickness of up to 26 m, this aquifer dips towards the south eastern portion of the proposed pit.

The weathered aquifer stores the bulk of the groundwater in the area and also forms the main recharge body for natural recharge. The weathered aquifer is unconfined to semi-confined and as such it is highly susceptible to surface induced anthropogenic influences such as pollutant infiltration from sources located on surface.

3.5.2 Fractured Aquifer

The fractured aquifer is restricted to contact zone and linear geological features present in the study area. The occurrence and distribution of linear geological features in the study area are significant in the sense that they control groundwater occurrences (high yields due to fracturing associated with contact zones in the host rock), represent potential preferential groundwater flow zones (along their contact zones), and lastly define the lateral extent of the groundwater zone that could be influenced by proposed pit activities in the sense that they represent impermeable physical aquifer boundaries perpendicular to their strikes. There is potential for the fractured aquifer to transmit surface induced pollution over great distances.

With reference to the regional geology map and the shaded relief map given above, the size, extent and relative location of the syenite dyke (striking NNW-SSE) west of the proposed pit, qualifies it as an impermeable physical aquifer boundary. The yield of boreholes drilled into the syenite dyke was less than 0.02 L/s to dry JMA (2009). The Waterberg age dyke that runs along the west and north of the pit boundary is not a significant groundwater preferential flow zone either.

3.6 Groundwater levels

The depth to groundwater levels within the project area ranges between 10 and 24 m, with an average of 16 mbgl (Table 5). In relation the depth of weathering logged during drilling, the deeper groundwater levels in LANBH01 and LANBH02 indicate that weathered aquifer within these boreholes is unsaturated, most likely due to mine dewatering impacts. The water level in LANBH01, also depicts that seepage from the adjacent waste rock dump is not towards the proposed pit as infiltration from the waste rock dump would have elevated the groundwater level in LANBH01. This may change during the active mining in the pit.

The shallow water level in LANBH01 (10 mbgl) indicate the thick weathered aquifer south east of the proposed pit is saturated and mine dewatering is less significant in this area. The groundwater level elevation data indicates that groundwater flows from the south eastern perimeter of the pit in north-westerly direction.

Table 5: Water level in Lanxess

BH ID	Coordinates (Datum in WGS84)			Water Level (mbgl)	Piezometric Head (mamsl)
	Latitude	Longitude	Elevation		
LANBH01	-25.730208	27.386723	1220.85	23.7	1197.15
LANBH02	-25.726238	27.39604	1231.08	22.4	1208.68
LANBH03	-25.731523	27.401422	1225.06	10.7	1214.36
LANBH04(BH18)	-25.7298	27.37696	1209.46	11.4	1198.06
LANBH02(BH17)	-25.7345	27.37804	1210.42	11.1	1199.32

3.7 Recharge

Recharge is defined as the process by which water is added to the zone of saturation of an aquifer. Recharge in the study area depends on the saturation of the shallow weathered aquifer. Recharge to the fractured aquifer is indirect by vertical drainage and downward percolation from the overlying weathered aquifer.

Rainfall recharge to the groundwater system is expressed as a percentage of the mean annual precipitation (MAP). The MAP used for the site is 645 mm/annum. The mean annual recharge (MAR) to the groundwater system for the study area is estimated to be between 3% and 7% of the mean annual precipitation (MAP), putting it in the recharge range of 20 mm/annum to 45 mm/annum (JMA, 2009). An average value of 32 mm (5% of MAP) will be used for general calculations.

3.8 Hydraulic Properties

The behaviour and properties of the aquifers in the vicinity of the proposed pit was evaluated using constant rate tests on boreholes LANBH01 and LANBH03.

Diagnostic plots indicate that the aquifer in the vicinity of LANBH01 is a limited closed reservoir. The effect of the NNW-SSE syenite dyke is depicted in the drawdown time plot of LANBH03 (Figure 4), where the steep increase in drawdown at late time confirms its impermeable properties. There is no much heterogeneity in aquifer properties around the proposed pit. The geometric mean of the early time transmissivity (relatively higher yielding water strikes) is estimated at 6.8 m^2/d. The late time transmissivity (dominated by matrix flow) is 3.5 m^2/d.

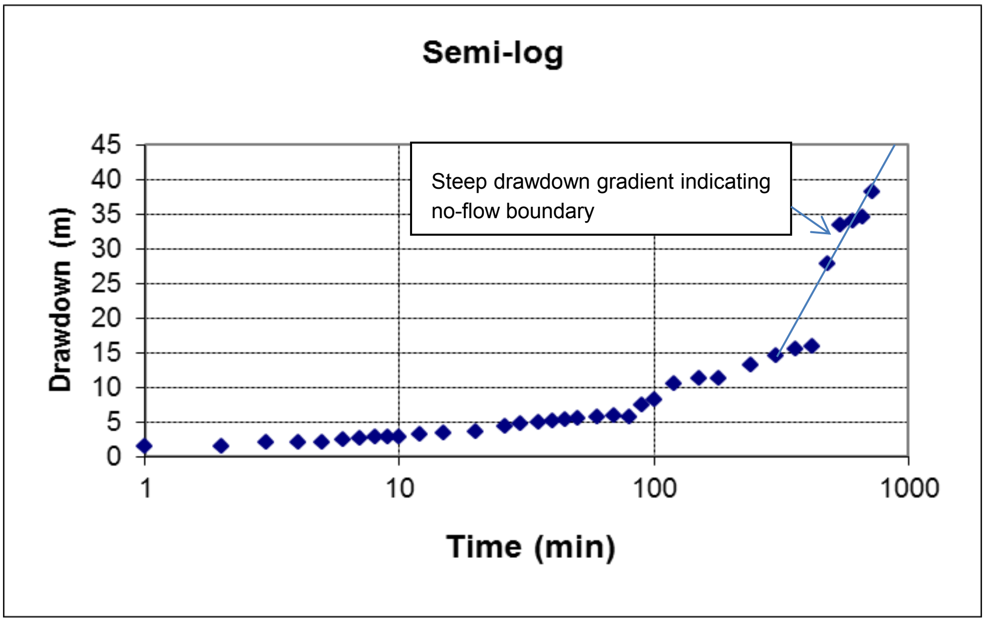


Figure 4: LANBH03 semi-log graph

3.9 Baseline Groundwater Quality

The groundwater quality results (Table 6) have been compared to the South African National Standards (SANS241:2005) for Drinking Water and have been grouped into Classes in accordance with the above stated standard.

According to the SANS241:2005 standards, water quality has two benchmarks: Class I and Class II:

- Concentrations below the Class I limits are considered of good quality;
- Concentrations between Class I and II are considered as marginal. This is the maximum allowable concentration if consumed for not more than 7 years; and
- Concentrations more than the Class II limits (also referred as Class III) are unacceptable for human consumption.

The following conclusions are drawn;

- The neutral to alkaline pH of the groundwater system implies that condition for heavy metal solubility are not favourable, hence there is restricted migration for potential heavy metals in groundwater system;
- All boreholes show full compliance in electrical conductivity (EC) and total dissolved solids (TDS);
- LANUG1 represents water discharged from the old underground working at the concrete pipe slimes dam drain. The marginal compliance in EC and TDS indicates that some form of impact could potentially exist on the groundwater quality in the old working;
- The lone marginal sulphate concentration observed (LANUG1 at 520 mg/L) accounts for the elevated EC and TDS noted above;
- Calcium occurs naturally in the groundwater system and all boreholes are fully compliant with the calcium Class I limit;
- The non-compliant magnesium levels in groundwater can be attributed to a high solubility of the magnesium contents in the rock matrix. No other external sources of magnesium can be justified at this stage;
- The total chromium content in groundwater is below detection limit; and
- The published groundwater quality information for the regional aquifers indicated that nitrate could be elevated in the background groundwater quality and therefor it should not be used for impact identification. The results show that boreholes LANBH2 and LANBH3 are compliant, LANBH01 is marginally compliant and the rest are not compliant.

The Stiff diagram (Figure 5) depicts that all samples except LANUG1 have the same water type dominated by magnesium and bicarbonates. The Piper diagram (Figure 6) further indicates that boreholes LANBH6 and LANBH7 are being influenced by water from old underground working. It can be said that the current impacts on groundwater around the proposed pit lies in the vicinity of the old underground workings.

Table 6: Groundwater quality

Sample ID		pH-Value at 25° C	Conductivity at 25° C in mS/m	Total Dissolved Solids	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Chlorides as Cl	Sulphate as SO_4	Fluoride as F	Nitrate NO_3 as N	Total Alkalinity as $CaCO_3$	Iron as Fe	Manganese as Mn	Aluminium as Al	Chromium as Cr
Class I	(Recommended)	5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<1	<10	N/S	<0.2	<0.1	<0.3	<1
Class II	(Max. Allowable)	4-5 or 9.5-10	150-370	1000-2400	150-300	70-100	200-400	50-100	200-600	400-600	1-1.5	10-20	N/S	0.2-2	0.1-1	0.3-0.5	1-5
	Duration	No Limit	7 years	7 years	7 years	7 years	7 years	7 years	7 years	7 years	1 year	7 years	N/S	7 years	7 years	1 year	
LANBH6		7.93	135	974	71	**135**	38	7	71	243	0.25	**42**	367	0.00	0.00	0.00	0.00
LANBH2		7.61	113	766	64	**125**	15	3	15	108	0.17	**39**	432	0.00	0.00	0.00	0.00
LANBH3		7.73	123	779	43	**158**	8	4	49	109	0.22	**32**	441	0.00	0.00	0.00	0.00
LANBH7		8.10	127	925	86	**108**	45	10	58	228	0.17	**41**	344	0.00	0.00	0.00	0.00
LANUG1		7.85	**155**	**1226**	145	56	145	15	107	**520**	0.12	**27**	194	0.00	0.00	0.00	0.00
LANBH01		8.13	93	535	30	**110**	12	3	15	39	0.26	**14**	435	0.00	0.00	0.00	0.00
LANBH02		7.70	113	635	63	**102**	32	7	26	114	0.50	5	441	0.00	**0.39**	0.00	0.00
LANBH03		7.84	109	641	61	**121**	17	4	15	76	0.26	10	502	0.00	0.00	0.00	0.00

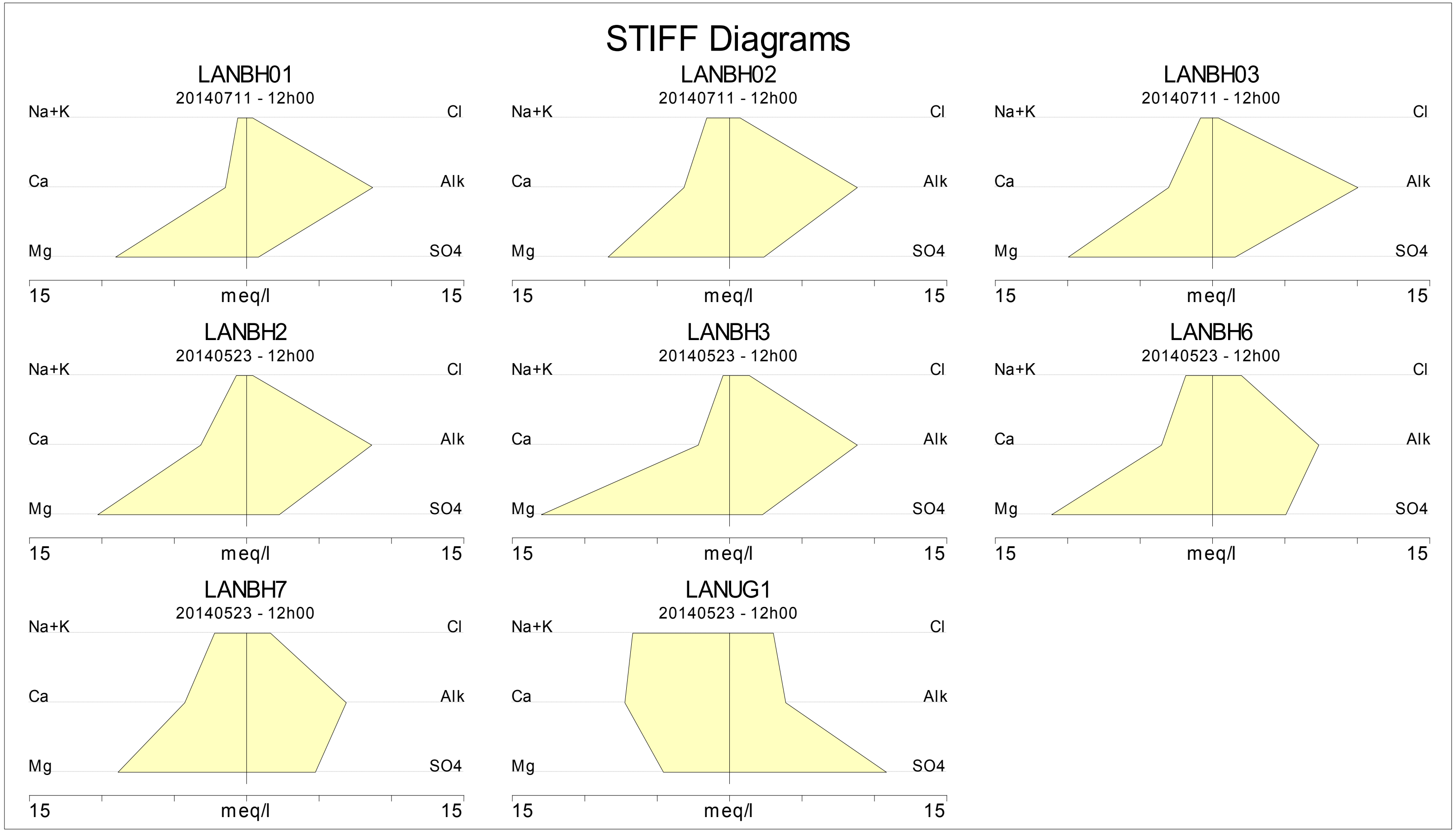


Figure 5: Stiff diagram of the baseline water chemistry

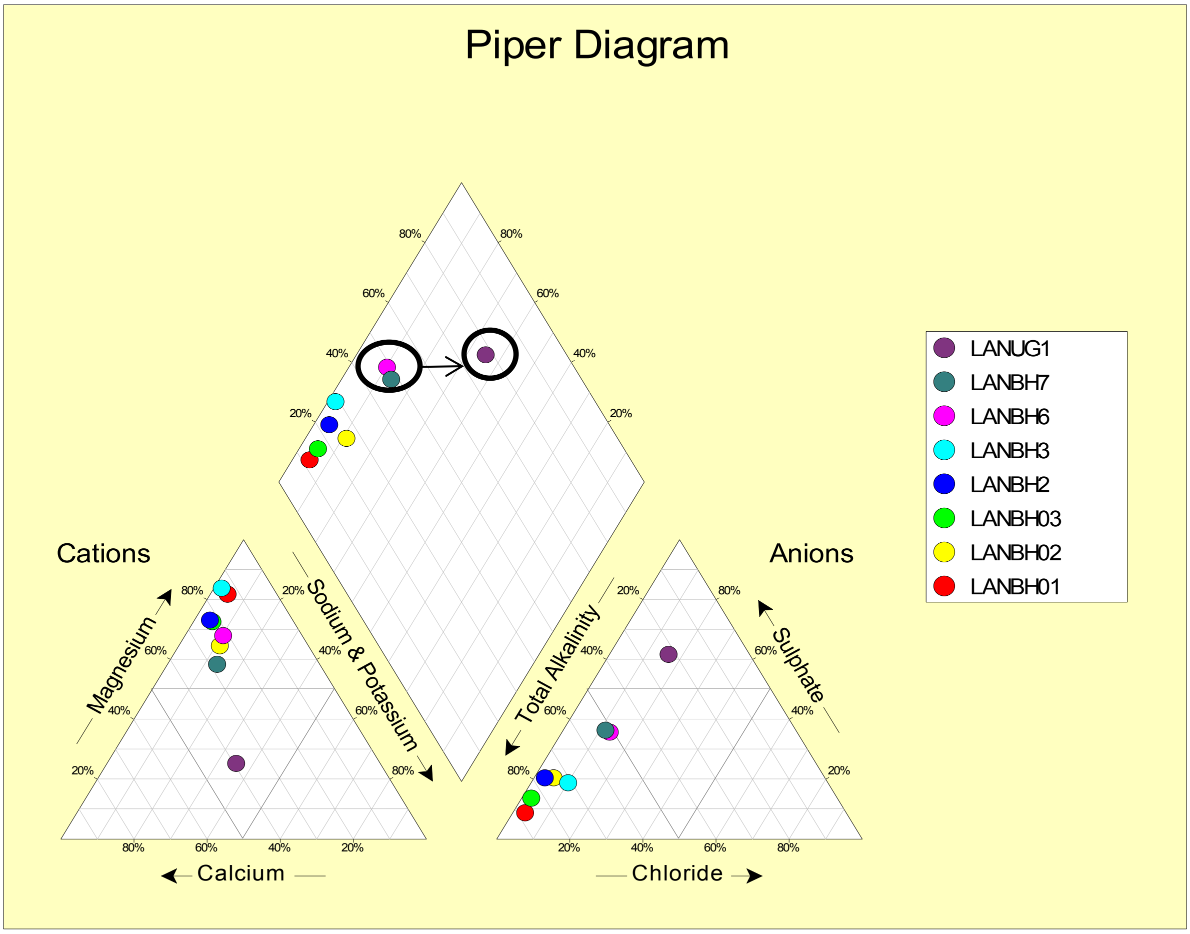


Figure 6: Piper diagram of the baseline water chemistry

4 Analytical Model

The conceptual interpretation of the groundwater system in the proposed mining area is depicted in Figure 7. The corresponding steady state analytical model adopted to quantify the potential impacts, due to mining, on the groundwater system considers the effect of a decrease in saturated thickness near the pit walls and distributed recharge to the water table.

The model assumes that unconfined, steady state, horizontally radial flow conditions exist near the pit. Therefore the Dupuit-Forchheimer approximation (McWhorter and Sunada 1977) has been used to account for change in saturated thickness due to depression of the water table. The following equation applies (Figure 7):

$$(1) h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 Ln\left(\frac{r_o}{r_p}\right) - \frac{(r_0^2 - r_p^2)}{2}\right]}$$

h_o is the initial (pre mining) water level above the pit floor;

W is the distributed recharge (estimated at 5% of rainfall),

r_p is the effective pit radius,

h_p is the water level above the pit floor at r_p (dry pit to achieve dewatering)

r_o is the radius of influence (maximum extent of the cone of depression)

K_{h1} is the horizontal hydraulic conductivity (geometric mean of 0.01 m/d)

Given input values of W, K_{h1}, r_p, h_p and h_o, the radius of influence (ro) was determined by iteration. Once r_o was determined, the pit inflow from the pit walls (Q) was computed by:

(2) $Q = \boldsymbol{W\pi}(\boldsymbol{r_o^2} - \boldsymbol{r_p^2})$

After applying the equations and assumptions described above, the radius of influence of the steady state inflow expected in the pit are given in Table 7. The results are discussed as part of the Impact Assessment in Section 5.

Table 7: Pit inflow and radius of influence

Pre-mining water above pit floor (h_o) m		Estimated pit radius (r_p) m	Pit Depth (m)	Radius of Influence from pit centre (m)	Radius of influence from pit wall (m)	Inflow from pit walls Q_1 (m^3/d)
Minimum	27	750	50	2071	1321	1027
Maximum	39	750	50	2584	1834	1684

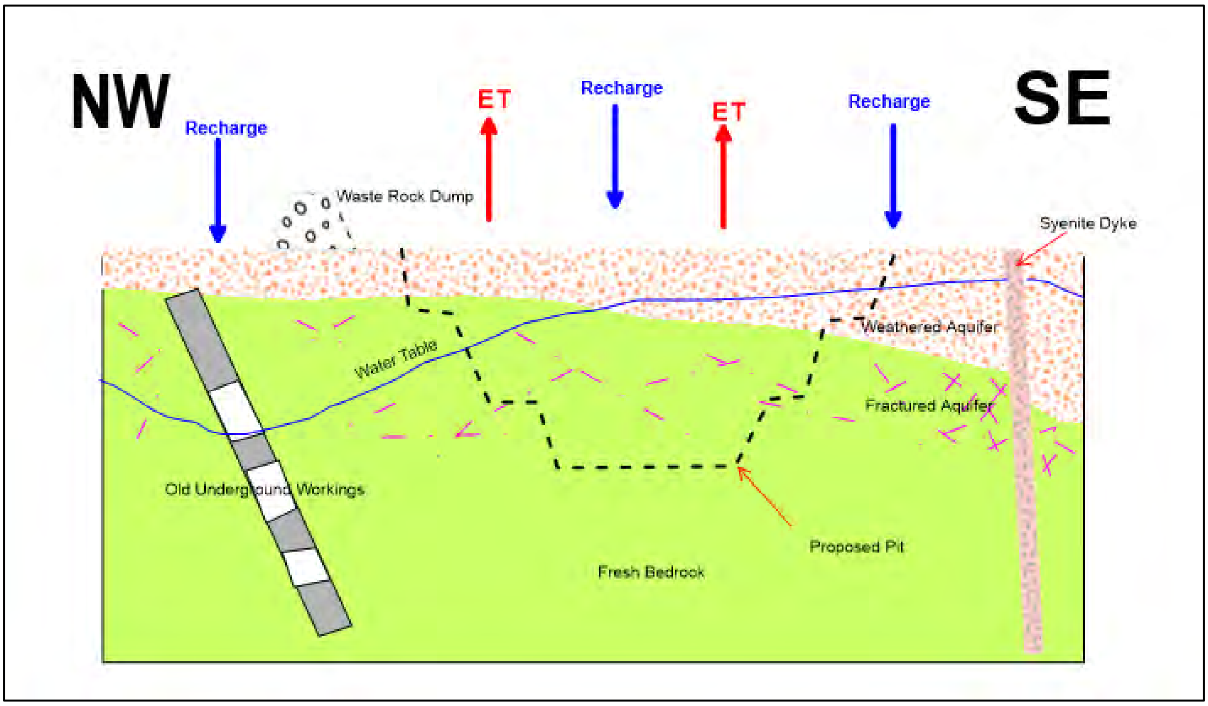


Figure 7: Planar hydrogeological conceptual model

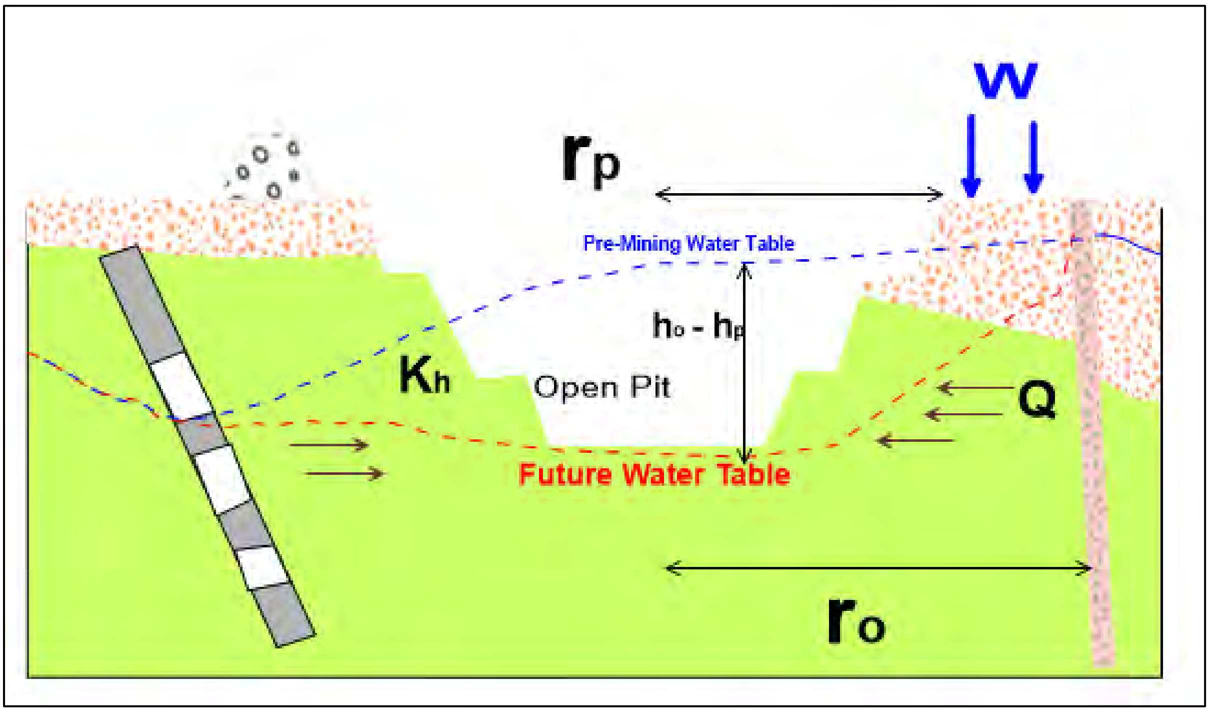


Figure 8: Pit inflow analytical model illustration

5 Impact Assessment

The potential groundwater impacts were assessed considering the three phases of the life of mine: the construction, operation and closure phases.

5.1 Impact Assessment Methodology

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified for various project activities. The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability

where

Consequence = Severity + Spatial scale + Duration

and

Probability = Likelihood of an impact occurring

The weight assigned to the various parameters for positive and negative impacts in the formula is presented in below Table 8.

Table 8: Impact Rating

Rating	Severity			Spatial Scale	Duration	Probability
	Environmental	**Social, Cultural and Heritage**	**Legal**			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or ecosystem. Persistent severe damage.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	Potential jail terms for executives and/or very high fines for the company. Prolonged, multiple litigation. Withdrawal of permit / closure.	International	Permanent No Mitigation	Certain / Definite
6	Significant impact on highly valued species, habitat or ecosystem.	Irreparable damage to highly valued items of cultural significance or breakdown of social order.	Very significant fines and prosecutions. Multiple litigation.	National	Permanent Mitigated	Almost Certain / High Probability
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate	Very serious widespread social impacts. Irreparable damage to highly valued items.	Significant prosecution and fines. Very serious litigation, including class actions.	Province / Region	Project Life	Likely

4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year	On-going serious social issues. Significant damage to structures / items of cultural significance.	Major breach of regulation. Major litigation.	Municipal Area	Long Term	Probable
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month.	On-going social issues. Damage to items of cultural significance.	Serious breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible.	Local	Medium Term	Unlikely / Low Probability
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with / without help of external consultants.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Minor legal issues, non-compliances and breaches of regulation.	Limited	Short Term	Rare / Improbable
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Low-level repairable damage to commonplace structures.	Low-level legal issue.	Very Limited	Immediate	Highly Unlikely / None

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the Environmental Management Programme (EMP). The significance of an impact is then determined and categorised into one of four categories, as indicated in Table 9. The impact assessment methodology is applied to the four phases of mining (construction, operation, decommissioning and closure) for the identified mining activities.

Table 9: Significance threshold limits

Score	Description	Rating
< 35	An acceptable impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in either positive or negative short term effects on the social and/or natural environment.	Negligible
36 – 72	An important impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in either a positive or negative medium to long-term effect on the social and/or natural environment.	Minor
73 – 108	A serious impact, if not mitigated, may prevent the implementation of the project (if it is a negative impact). These impacts would be considered by society as constituting a major and usually long-term change to the (natural and/or social) environment and result in severe effects or beneficial effects.	Moderate
> 108	A serious impact, which if negative, may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects or very beneficial effects.	Major

5.2 Construction Phase Impact Assessment

5.2.1 Impact of Activity 1: Mine Dewatering

The catchment boundary between quaternary catchments A21K and A22H transects the proposed pit some 450 m west of the eastern pit boundary. Excavation of the proposed pit will change the topography. As a result groundwater from both catchments will flow towards the pit centre in response to hydraulic gradient. This impact will be more significant during the operational phase as the groundwater table in the pit area is at least 11 mbgl. Therefore it is expected that the initial excavation is unlikely to breach the water table and the impacts due to mine dewatering are unlikely during construction phase.

Table 10: Construction phase mine dewatering impact quantification

Parameter	Description	Rating
Duration	Medium term	3
Spatial Scale	Limited	2
Severity	Moderate	3
Probability	Low Probability	3
Significance	**Negligible**	**24**

5.2.2 Mitigation of and Management Activity 1: Mine Dewatering

Although the impacts due to mine dewatering during construction phase are unlikely, the following mitigation and management measures are proposed to keep the impact to a minimum if it occurs;

- Establish the depth to groundwater table prior to construction;
- Minimise penetration into the groundwater table;
- If groundwater table is to be penetrated to significant depth, dewater aquifer prior to excavations;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Obtain permission from regulating authority.

5.2.3 Impact of Activity 2: Mine Water Contamination

Site clearing and removal of topsoil may lead to puddles of surface water in the cleared areas during the wet season and potentially lead to increased infiltration to the weathered aquifers. Oil or fuel spillages from site machinery may collect in the soils. During rainfall events, hydrocarbon compounds from oil and fuel in the soils may migrate to the aquifers with water infiltrating through these polluted areas.

Groundwater influxes into initial excavation are not expected. Deterioration in groundwater quality due to the increased suspended solids during construction phase is unlikely. The overall significance of mining activities on groundwater quality during construction phase is negligible (Table 11).

Table 11: Construction phase groundwater quality impact quantification

Parameter	Description	Rating
Duration	Medium term	3
Spatial Scale	Limited	2
Severity	Moderate	3
Probability	Low Probability	3
Significance	**Negligible**	**24**

5.2.4 Mitigation and Management of Activity 2: Mine Water Contamination

- Implement and train drivers to adhere to traffic rules;
- Implement a vehicle maintenance schedule;
- Install oil collection pans under vehicles;
- Handle and store blasting material according to manufacturing requirements;
- Minimise external contamination sources in the pit (diesel, oils, chemicals) as far as possible to ensure that groundwater flowing into the mine is contaminated; and
- Monitor quality of mine water.

5.3 Operation Phase

5.3.1 Impact of Activity 1: Mine Dewatering

As stated above groundwater from both A21K and A22H quaternary catchments will flow towards the pit during the operation phase. Groundwater inflow into the proposed pit will not only depend on the aquifer properties. The mine plan, mined area, depth and mining rate will also affect the groundwater inflow rates. Two scenarios were simulated analytically, based on the minimum and maximum groundwater level expected above the final pit floor level (50 mbgl), to predict the steady state groundwater inflow rate during mining.

The predicted inflow rates range between 1027 and 1684 m^3/d. When groundwater flows towards the pit (during mining) it inevitably dewaters and lowers the groundwater levels in the surrounding area. As the pits develop, the zone of influence of the groundwater level drawdown migrates and expands as the groundwater system attempts to retain a state of equilibrium.

The zone of influence due an inflow rate of 1027 m^3/d is predicted to extend some 2.1 km from the pit centre. The worst case zone of influence is predicted to extend 2.5 km from the pit centre. The syenite dyke east of the pit is reportedly impermeable; hence the aquifers on the opposite site of the dyke are not expected to be influenced by mining of the proposed pit. The resultant pit capture zone is depicted in **Error! Reference source not found.**.

The properties and boreholes within the zone of influence belong to Lanxess Mining. Therefore the dewatering is unlikely to affect external private groundwater users. Because there are no external receptors within the zone of influence, the decrease in the volume of groundwater in natural storage due to mine dewatering is rated Negligible.

Table 12: Impact assessment during operation phase due to mine dewatering

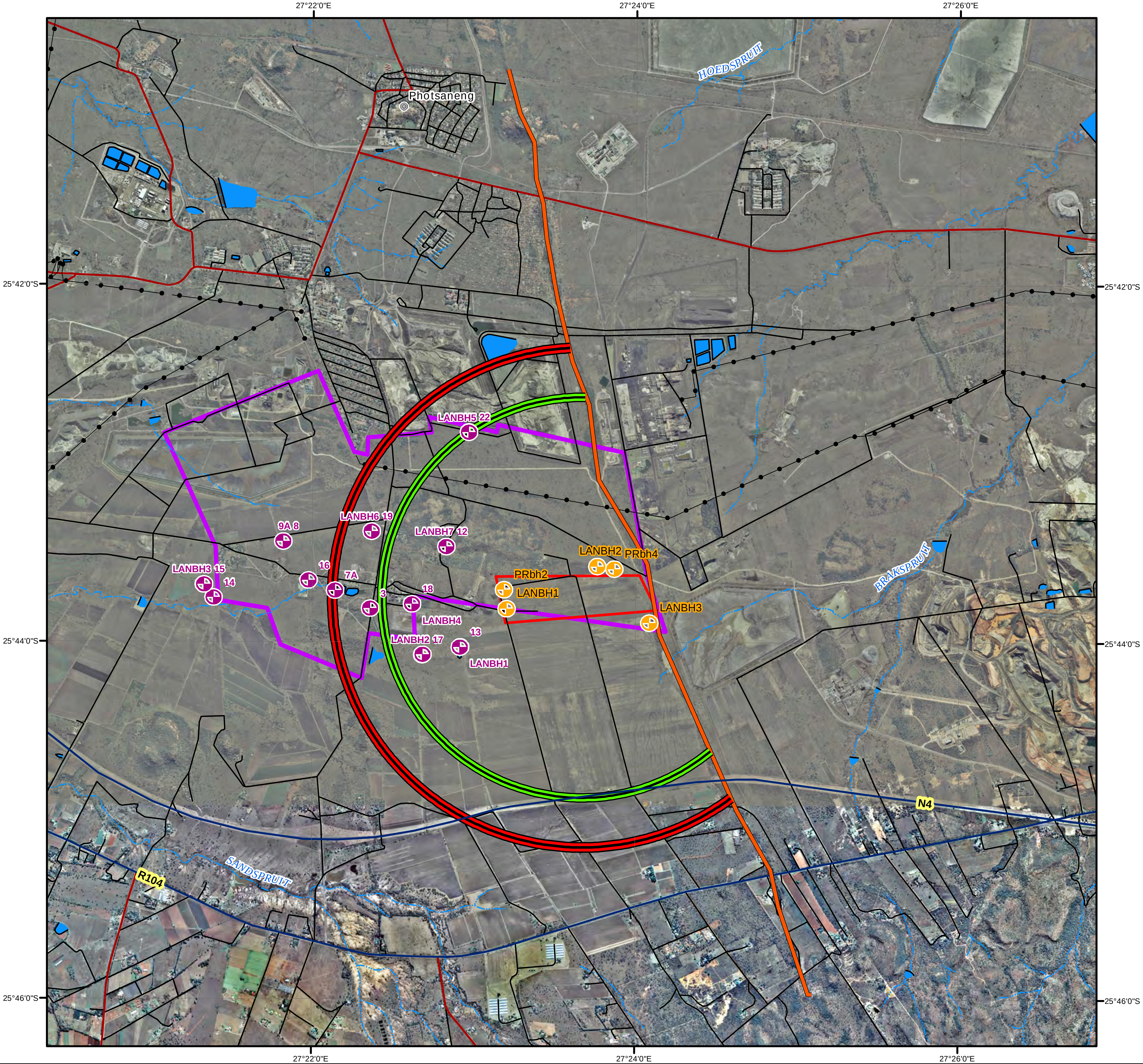
Parameter	Description	Rating
Duration	Project Life	5
Spatial Scale	Limited	2
Severity	Moderate	3
Probability	Low probability	3
Significance	**Negligible**	**30**

5.3.2 Mitigation of and Management Activity 1: Mine Dewatering

- Minimise groundwater influx into pit through optimisation of mining layout to minimise structural disturbance;
- Dewater aquifer prior to further excavations. Dewatering is more effective when operated very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Perform monitored groundwater abstractions to ensure that the aquifer from which water is abstracted is not over-exploited;

- Pump excess pit water to appropriate surface storage facility according to water quality. When required by the process plant the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use “marginal” mine water before using pristine groundwater; and
- Monitor water influx, water stored, water removed; water level in the pit and groundwater levels in the perimeter of the pit.

Plan 5: Zone of Influence



Plan 5

Lanxess EIA Gap Analysis

Zones of Influence

Legend

- Gap Analysis Project Area
- Lanxess Chrome Mine
- Hydrocensus Borehole Locations
- Power Line
- Arterial / National Route
- Main Road
- Minor Road
- Dam Wall
- Non - Perennial Stream
- Perennial Stream
- Dam / Lake
- Dyke
- Maximum Zone of Influence
- Minimum Zone of Influence

DIGBY WELLS
ENVIRONMENTAL

• Sustainability • Service • Positive Change • Professionalism • Future Focused • Integrity

Projection: Transverse Mercator
Datum: WGS84
Central Meridian: 27°E

Ref #: sdp.LAN2558.201405.007
Revision Number: 1
Date: 06/08/2014

N

0 0.5 1 2
Kilometres
1:40 000

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5.3.3 Impact of Activity 2: Mine Water Contamination

The current impact on groundwater quality around the proposed pit lies in the vicinity of the old underground workings. A geochemical assessment done by Geostratum (2009) on waste rock and slimes dumps in the study area stated that most heavy metals other than chromium (Cr) will not be elevated in the leachate due to the neutral to slightly alkaline conditions. Cr leaches out at alkaline rather than neutral conditions. Under neutral reducing conditions Cr form the oxide Eskolaite. Under alkaline oxidation conditions Cr would be present as Cr(VI) species in solution.

Although conditions are very favourable for the formation of Cr(VI) during mineral processing (alkaline oxidation conditions), the pH will become more neutral in dumped wastes over time which may result in a slight decrease in total Cr and Cr(VI) concentrations in seepage.

No Cr was detected (above detection limit 0.01 mg/l) in the groundwater samples. This is mainly because Cr in soils and rocks strongly adsorbs to the mineral particles and as a result remains fairly immobile, and highly acidic or alkaline conditions are generally not present in the aquifer.

Any seepage emanating from the adjacent waste rock dump will eventually join the underlying saturated zone and migrate towards the pit due to hydraulic gradient. Due to the historical mining activities onsite, the impact of groundwater quality deterioration is rated as Minor.

Table 13: Impact assessment during operation phase due to mine water contamination

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Project Life	5	Project Life	5
Extent	Local	3	Limited	2
Severity	Very Serious	5	Moderate	3
Probability	Probable	4	Low Probability	3
Significance	**Minor**	**40**	**Negligible**	**30**

5.3.4 Mitigation and Management of Activity 2: Mine Water Contamination

- The mine water management measures recommended during construction phase should continue during the operational phase;

- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;
- Divert surface flows away from the open pit areas through channels, drains and culverts;
- Monitoring of groundwater quality and water levels is recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to Negligible.

5.4 Closure and Post-Closure Phases Impact Assessment

5.4.1 Impact of Activity 1: Mine Decant

After the operational phase all the pit will be left open. The groundwater table will rise again to its pre-mining position and water will accumulate in the pits due to cessation of dewatering. A pit lake will develop. Groundwater flow will be directed to towards the pit lake as evaporation from the pit water causes it to act as a groundwater sink. In addition to precipitation, surface water runoff from the surrounding area will flow to the pit and add to the rise of the pit lakes.

As time progresses, groundwater influx into the pit lake will vary as a function of the elevation of the water in the pit lake. Groundwater influx will decrease as the pit lake fills. The steady state inflow is predicted to decrease to about 60 m^3/d as the pit lake approaches equilibrium pre-mining groundwater levels.

The decrease of influx with rising pit lakes is due to the reduction in head difference between the surrounding groundwater and the pit water as the pit fills; hence the hydraulic gradient decreases as the pit water elevation rises to equilibrate with the groundwater table. Groundwater outflow will only occur if groundwater inflow exceeds evaporation loses.

Depending on the shape of the pit, groundwater hydraulics, precipitation relative to pit lake evaporation, and the area from which surface water runoff to the pit occurs, the pits may never fill up, may fill rapidly, or may take decades to rise to an equilibrium position. If the pit waters rise above the long-term equilibrium groundwater table, there will be down-gradient groundwater seepage, and eventually decant to surface water courses.

As shown in Figure 10, it is unlikely that the pit lake will rise to equilibrium pre-mining groundwater levels during 100 years after closure. And because the Mean Annual Evaporation (2347 mm/a) is more than three times the mean annual precipitation, it is unlikely that the pit will fill up and decant. The significance of decant is therefore rated as Negligible.

Table 14: Impact assessment during closure and post-closure phase due to mine decant

Parameter	Impact Pre-Mitigation	
Duration	Permanent	6
Extent	Local	3
Severity	Very Serious	5
Probability	Improbable	2
Significance	**Negligible**	**30**

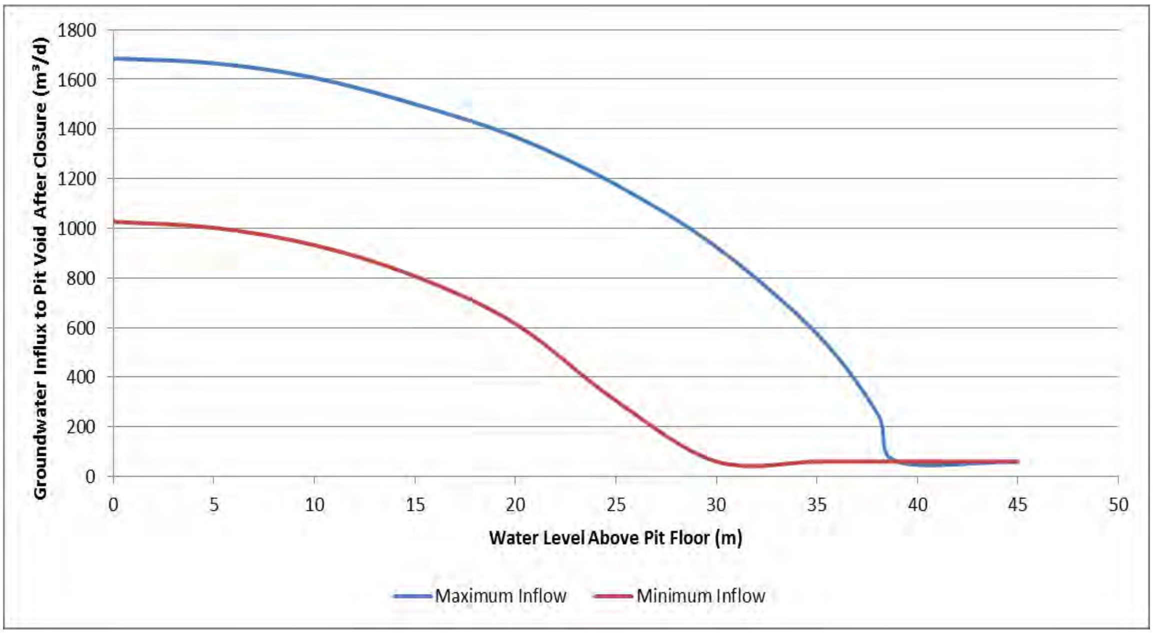

Figure 9: Inflow reduction against pit water level after closure

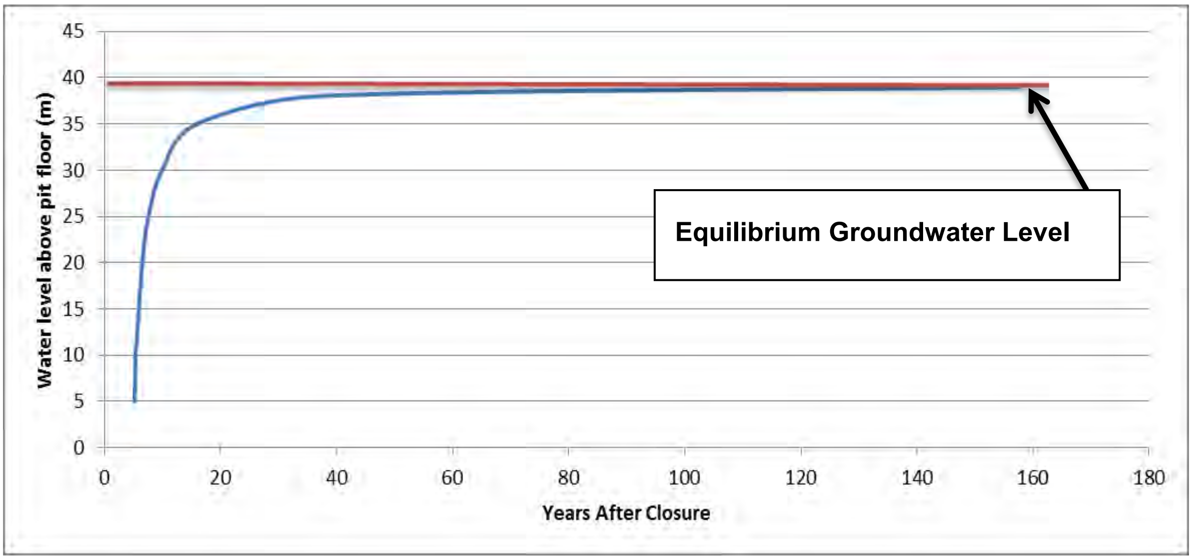

Figure 10: Water level rise in Pit Lake

5.4.2 Mitigation and Management of Activity 2: Mine Decant

- Monitor pit water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Monitor groundwater level elevation in boreholes in the surrounding aquifer to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

5.4.3 Impact of Activity 2: Mine Water Contamination

The final open pit, the waste dumps and old underground workings will be the major contamination sources in the post closure environment. The quality of groundwater in the post-closure environment will depend on background groundwater quality, the quality and quantity of surface water flowing into the pit and the geochemical processes that occur on the walls of the pit, above and below the pit lake.

At the waste rock dump, uncontrolled leachates that emanates will flow down-gradient as surface runoff until it percolates into the weathered soil profile. The distance that such surface runoff covers before entering the underlying aquifer is dependent on the seepage volume, permeability of the underlying material and the topographic slope in the immediate vicinity of the dump.

The current water quality from the old underground workings indicates that cation exchange processes be dominant in the post-closure environment, especially in the pit lake and the defunct underground voids. Evaporation of the pit water might lead to increased concentration of chemicals in the pit lake water. Contaminant migration away from the pit lake can only be induced by groundwater abstractions within the capture zone of the pit. The significance of mine water contamination in the post-closure environment is therefore rated as Minor.

Table 15: Impact assessment during closure and post-closure phase due to mine water contaminant

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration	Permanent	6	Permanent	6
Extent	Local	3	Limited	2
Severity	Very Serious	5	Moderate	3
Probability	Probable	4	Low Probability	3
Significance	**Minor**	**56**	**Negligible**	**33**

5.4.4 Mitigation and Management of Activity 2: Mine Water Contamination

- No abstraction boreholes should be drilled in 2.5 km radius from the pit in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and revegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

5.5 Cumulative Impacts

The impact assessment performed for the proposed pit was done in an integrated approach that incorporated the underground mine voids and the waste facilities on site.

Cumulative impacts from the surrounding activities are of two possible classes; impacts on groundwater quantity and impacts on groundwater quality.

Dewatering caused by underground mining activities was evident in the north and western perimeters of the pit. Mining at the proposed pit area would further drawdown the groundwater levels in the vicinity of the pit.

As far as external impacts on groundwater quality are concerned, the available data depicts that mining operations do not cause significant levels of groundwater pollution, and the occurrence of groundwater pollution is very limited and isolated.

6 MONITORING PROGRAMME

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and effective measures can be taken at an early stage before serious damage to the environment occurs.

6.1 Proposed Monitoring Boreholes

The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume.

As obtained from the hydrocensus survey and desktop study, a couple of monitoring boreholes exist in the project area. Six existing boreholes can be used to monitor any additional impacts due to mining of the proposed pit.

The three successful percussion boreholes drilled during this study were primarily for aquifer characterisation and were properly constructed for long term monitoring. At this stage two of percussion holes are recommend for long term monitoring.

Six new monitoring boreholes are recommended based on the impact assessment. Each borehole is recommended to be drilled to a maximum depth of 60 m to monitor the water level and quality in the weathered and fractured aquifer in the vicinity of the proposed pit. In total, 14 monitoring points are recommended for the proposed groundwater monitoring as given in Table 16 and Plan 6.

Table 16: List of proposed monitoring boreholes

BH ID	Coordinates (LO 27 WGS 84)	
	Y-Coordinate	X-Coordinate
LANBH02	-2846565	39742
LANBH03	-2847152	40281
17	-2847475	37933
18	-2846954	37826
12	-2846357	38181
20	-2846478	38032
19	-2846200	37409
22	-2845183	38416
DWE01	-2849348	40980
DWE02	-2848556	37306
DWE03	-2846137	36895
DWE04	-2845429	39860
DWE05	-2847990	40908
DWE06	-2847656	39264

Plan 6: Position of proposed monitoring boreholes

6.2 Water level

Groundwater levels must be recorded on quarterly basis using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater flow direction or head.

6.3 Water sampling and preservation

When sampling the following procedures are proposed:

- One (1) litre plastic bottles with a cap are required for the sampling exercises – provided by the water laboratory;
- Glass bottles are required if organic constituents are to be tested; and
- Sample bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a SANAS accredited laboratory.

6.4 Sampling frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Monitoring should be conducted on a quarterly basis. Samples should be collected by an independent groundwater consultant, using best practice guidelines and should be analysed by an accredited laboratory.

It is suggested that the quarterly samples be collected, including up to 10 years post closure and based on the results it can be adjusted accordingly. Monitoring should continue until an acceptable water quality situation is reached.

6.5 Parameters to be monitored

Analyses of the following constituents are recommended:

- Ec, pH, TDS;
- Macro Analysis i.e. Ca, Mg, Na, K, SO4, NO_3, F, Cl; and
- Heavy metals As, Al, Ba, Co, Cr, Zn, Cd, Cu, Fe, Ni, V, Mn, Se.

6.6 Data storage

In any project, good hydrogeological decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the minimisation of groundwater contamination it is necessary to utilize all relevant groundwater data.

The generation and collection of this data is very expensive as it requires intensive hydrogeological investigations and therefore has to be managed in a centralised database if funds are to be used in the most efficient way. Digby Wells has compiled a WISH-based database during the course of this investigation and it is highly recommended that Lanxess utilise this database and continuously update and manage as new data becomes available.

7 Conclusions and Recommendations

7.1 Baseline Hydrogeology

In observation of the geological setting of the site and based on the geological and geohydrological information generated during drilling, and historical studies, two aquifer types occur in the study area.

The aquifer system consists predominantly of weathered, fractured and fresh pyroxenite and norites, with a thin overburden/soil. An average blow yield of 0.5 L/s was recorded from two of the three boreholes drilled. The yields were all obtained in the shallow weathered/fractured profile. Water bearing fractures below 40 m were uncommon.

The weathered aquifer occurs across the entire surface area of the proposed pit. With a saturated thickness of up to 26 m, this aquifer dips towards the south eastern portion of the proposed pit.

The fractured aquifer is restricted to contact zone and linear geological features present in the study area. Both aquifers are bounded by a NNW-SSE striking syenite dyke along the eastern perimeter of the pit. The groundwater level is one average 16 m below ground level (mbgl). Deeper groundwater levels (> 20 mbgl) along the northern and western fringes of the proposed pit are attributed to mine dewatering due to underground mining.

Natural groundwater recharge is estimated at an average of 32 mm/a (5 % of mean annual precipitation). Relatively high yielding water strikes in the pit area have an estimated transmissivity value of 6.8 m^2/d.

In terms of groundwater quality, chromium levels in groundwater are below detection limits. The general groundwater body has elevated and non-compliant magnesium levels. Specifically, the current impacts on groundwater quality around the proposed pit lies in the vicinity of the old underground workings at Makuku informal settlement.

7.2 Impact Assessment

7.2.1 Construction Phase

7.2.1.1 *Impact of Activity 1: Mine Dewatering*

The initial excavation is unlikely to breach the water table and the impacts due to mine dewatering are unlikely during construction phase.

7.2.1.2 *Impact of Activity 2: Mine Water Contamination*

Site clearing and removal of topsoil may lead to puddles of surface water in the cleared areas during the wet season and potentially lead to increased infiltration to the weathered aquifers. Oil or fuel spillages from site machinery may collect in the soils. During rainfall events, hydrocarbon compounds from oil and fuel in the soils may migrate to the aquifers with water infiltrating through these polluted areas.

Groundwater influxes into initial excavation are not expected. Deterioration in groundwater quality due to the increased suspended solids during construction phase is unlikely. The overall significance of mining activities on groundwater quality during construction phase is negligible.

7.2.2 Operation Phase

7.2.2.1 Impact of Activity 1: Mine Dewatering

Groundwater from both A21K and A22 H quaternary catchments will flow towards the pit during the operation phase. The predicted inflow rates range between 1027 and 1684 m^3/d. The zone of influence due an inflow rate of 1027 m^3/d is predicted to extend some 2.1 km from the pit centre. The worst case zone of influence is predicted to extend 2.5 km from the pit centre. The syenite dyke east of the pit is impermeable; hence the aquifers on the opposite site of the dyke are not expected to be influence by mining of the proposed pit

The properties and boreholes within the zone of influence belong to Lanxess Mining. Therefore the dewatering is unlikely to affect external private groundwater users. Because there are no external receptors within the zone of influence, the decrease in the volume of groundwater in natural storage due to mine dewatering is rated Negligible.

7.2.2.2 Impact of Activity 2: Mine Water Contamination

The current impact on groundwater quality around the proposed pit lies in the vicinity of the old underground workings. No Cr was detected (above detection limit 0.01 mg/l) in the groundwater samples. This is mainly because Cr in soils and rocks strongly adsorbs to the mineral particles and as a result remains fairly immobile, and highly acidic or alkaline conditions are generally not present in the aquifer.

Any seepage emanating from the adjacent waste rock dump will eventually join the underlying saturated zone and migrate towards the pit due to hydraulic gradient. Due to the historical mining activities onsite, the impact of groundwater quality deterioration is rated as Minor.

7.2.3 Closure and Post-Closure Phases Impact Assessment

7.2.3.1 Impact of Activity 1: Mine Decant

After the operational phase all the pit will be left open. The groundwater table will rise again to its pre-mining position and water will accumulate in the pits due to cessation of dewatering. A pit lake will develop.

Groundwater influx will decrease as the pit lake fills. The steady state inflow is predicted to decrease to about 60 m^3/d as the pit lake approaches equilibrium pre-mining groundwater levels.

It is unlikely that the pit lake will rise to equilibrium pre-mining groundwater levels during 100 years after closure. And because the Mean Annual Evaporation (2347 mm/a) is more than three times the mean annual precipitation, it is unlikely that the pit will fill up and decant. The significance of decant is therefore rated as Negligible.

7.2.3.2 Impact of Activity 2: Mine Water Contamination

The final open pit, the waste dumps and old underground workings will be the major contamination sources in the post closure environment

The current water quality from the old underground workings indicates that cation exchange processes will be dominant in the post-closure environment, especially in the pit lake and the defunct underground voids. Evaporation of the pit water might lead to increased concentration of chemicals in the pit lake water. Contaminant migration away from the pit lake can only be induced by groundwater abstractions within the capture zone of the pit. The significance of mine water contamination in the post-closure environment is therefore rated as Minor.

7.3 Groundwater Monitoring and Management Measures

Groundwater monitoring has to continue during all phases of the mine operation to identify the impact on the groundwater environment over time, and effective measures can be taken at an early stage before serious damage to the environment occurs. Fourteen boreholes are proposed for the groundwater monitoring plan. The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area;
- Monitor the lowering of the water table and the radius of influence; and
- Monitor post closure groundwater recovery and pollution plume.

The following groundwater management measures are proposed to mitigate the impacts assessed.

7.3.1 Mitigation of and Management Activity 1: Mine Dewatering during Construction Phase

- Establish the depth to groundwater table prior to construction;
- Minimise penetration into the groundwater table;
- If groundwater table is to be penetrated to significant depth, dewater aquifer prior to excavations;
- Depending on the quality of the groundwater, discharge, store or recycle as appropriate; and
- Obtain permission from regulating authority.

7.3.2 Mitigation and Management of Activity 2: Mine Water Contamination during Construction Phase

- Implement and train drivers to adhere to traffic rules;
- Implement a vehicle maintenance schedule;
- Install oil collection pans under vehicles;
- Handle and store blasting material according to manufacturing requirements;
- Minimise external contamination sources in the pit (diesel, oils, chemicals) as far as possible to ensure that groundwater flowing into the mine is contaminated; and
- Monitor quality of mine water.

7.3.3 Mitigation of and Management Activity 1: Mine Dewatering during Operation Phase

- Minimise groundwater influx into pit through optimisation of mining layout to minimise structural disturbance;
- Dewater aquifer prior to further excavations. Dewatering is more effective when operated very closely to the active mining face;
- Manage groundwater abstraction rates and volumes in accordance with borehole sustainable yields;
- Perform monitored groundwater abstractions to ensure that the aquifer from which water is abstracted is no over-exploited;
- Pump excess pit water to appropriate surface storage facility according to water quality. When required by the process plant the abstracted water can be discharged into the return water dam;
- Reuse water as far as possible. An off-take can be installed from the reservoir to the vehicle maintenance bay for use in dust suppression activities and general usage at the bay. However, for dust suppression it is good practice to first use “marginal” mine water before using pristine groundwater; and
- Monitor water influx, water stored, water removed; water level in the pit and groundwater levels in the perimeter of the pit.

7.3.4 Mitigation and Management of Activity 2: Mine Water Contamination during Operation Phase

- The mine water management measures recommended during construction phase should continue during the operational phase;
- It is recommended that abstraction from boreholes that are close to the mine workings should be avoided so that contaminants will not migrate away from the mine, towards the abstraction boreholes;

- Divert surface flows away from the open pit areas through channels, drains and culverts;
- Monitoring of groundwater quality and water levels is recommended (particularly down gradient of the mine site) with continuous refining and updating of the monitoring network based on the results obtained;
- Annual audits of monitoring and management systems should be conducted by independent environmental consultants; and
- With the application of the above-stated mitigation plans, the impact of the contaminant migration during construction phase can be lowered to Negligible.

7.3.5 Mitigation and Management of Activity 1: Mine Decant during Closure and Post-closure Phase

- Monitor pit water level rise and apply stage curves to assess the rate of flooding;
- Seal mine shafts to prevent surface water from flowing into the defunct underground voids;
- Monitor groundwater level elevation in boreholes in the surrounding aquifer to assess groundwater table responses; and
- Groundwater monitoring should continue up to 5 years after closure.

7.3.6 Mitigation and Management of Activity 2: Mine Water Contamination during Closure and Post-closure Phase

- No abstraction boreholes should be drilled in 2.5 km radius from the pit in the post closure environment;
- Perform effective rehabilitation and closure of redundant facilities through material placing and shaping, capping with appropriate capping liners and revegetation to prevent post closure infiltration through sources; and
- Consider groundwater plume remediation only if post closure monitoring indicates a persistent pollution plume at unacceptable concentrations.

Appendix A: Laboratory Certificates

aquatico Laboratories (Pty). Ltd.

sanas Testing Laboratory T0374

Test Report

Client:	Digby Wells & Associates	**Date of certificate:**	05 May 2014
Address:	359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg	**Date accepted:**	30 April 2014
Report no:	17951	**Date completed:**	05 May 2014
Project:	Digby Wells & Associates	**Revision:**	0

Lab no:				168664	168665	168666	168667	168668
Date sampled:				23-Apr-14	23-Apr-14	23-Apr-14	23-Apr-14	23-Apr-14
Sample type:				Water	Water	Water	Water	Water
Locality description:				LANBH6	LANBH2	LANBH3	LANBH7	LANUG1
	Analyses	**Unit**	**Method**					
A	pH	pH	ALM 20	7.93	7.61	7.73	8.10	7.85
A	Electrical conductivity (EC)	mS/m	ALM 20	135	113	123	127	155
A	Total dissolved solids (TDS)	mg/l	ALM 26	974	766	779	925	1226
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	367	432	441	344	194
A	Chloride (Cl)	mg/l	ALM 02	70.9	15.2	48.5	58.4	107
A	Sulphate (SO_4)	mg/l	ALM 03	243	108	109	228	520
A	Nitrate (NO_3) as N	mg/l	ALM 06	41.6	38.8	31.5	40.6	27.4
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.033	0.031	0.026	0.019	0.035
A	Orthophosphate (PO_4) asP	mg/l	ALM 04	0.020	0.015	<0.008	0.042	<0.008
A	Fluoride (F)	mg/l	ALM 08	0.252	0.169	0.221	0.168	0.122
A	Calcium (Ca)	mg/l	ALM 30	70.6	63.6	43.4	85.7	145
A	Magnesium (Mg)	mg/l	ALM 30	135	125	158	108	55.5
A	Sodium (Na)	mg/l	ALM 30	38.4	14.9	8.43	45.0	145
A	Potassium (K)	mg/l	ALM 30	7.19	2.77	3.52	10.2	15.1
A	Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Total chromium (Cr)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Copper (Cu)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Nickel (Ni)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Cadmium (Cd)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004
A	Total hardness	mg $CaCO_3$/l	ALM 26	733	676	761	658	590

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

aquatico Laboratories (Pty). Ltd.

Client:	Digby Wells & Associates	**Date of certificate:**	17 July 2014
Address:	359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg	**Date accepted:**	14 July 2014
Report no:	19358	**Date completed:**	16 July 2014
Project:	Digby Wells & Associates	**Revision:**	0

Lab no:				177478	177479	177480
Date sampled:				11-Jul-14	11-Jul-14	11-Jul-14
Sample type:				Water	Water	Water
Locality description:				LANBH1	LANBH2	LANBH3
	Analyses	**Unit**	**Method**			
A	pH	pH	ALM 20	8.13	7.70	7.84
A	Electrical conductivity (EC)	mS/m	ALM 20	92.6	113	109
A	Total dissolved solids (TDS)	mg/l	ALM 26	535	635	641
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	435	441	502
A	Chloride (Cl)	mg/l	ALM 02	14.8	26.1	14.8
A	Sulphate (SO_4)	mg/l	ALM 03	39.0	114	75.5
A	Nitrate (NO_3) as N	mg/l	ALM 06	13.7	4.95	9.55
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.026	0.042	0.029
A	Orthophosphate (PO_4) asP	mg/l	ALM 04	0.010	<0.008	<0.008
A	Fluoride (F)	mg/l	ALM 08	0.258	0.502	0.256
A	Calcium (Ca)	mg/l	ALM 30	29.6	63.1	60.9
A	Magnesium (Mg)	mg/l	ALM 30	110	102	121
A	Sodium (Na)	mg/l	ALM 30	12.3	32.4	16.6
A	Potassium (K)	mg/l	ALM 30	3.24	6.61	4.17
A	Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003	<0.003	<0.003
A	Manganese (Mn)	mg/l	ALM 31	<0.001	0.390	<0.001
A	Total chromium (Cr)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Copper (Cu)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Nickel (Ni)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Cadmium (Cd)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004
A	Total hardness	mg $CaCO_3$/l	ALM 26	526	578	648

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
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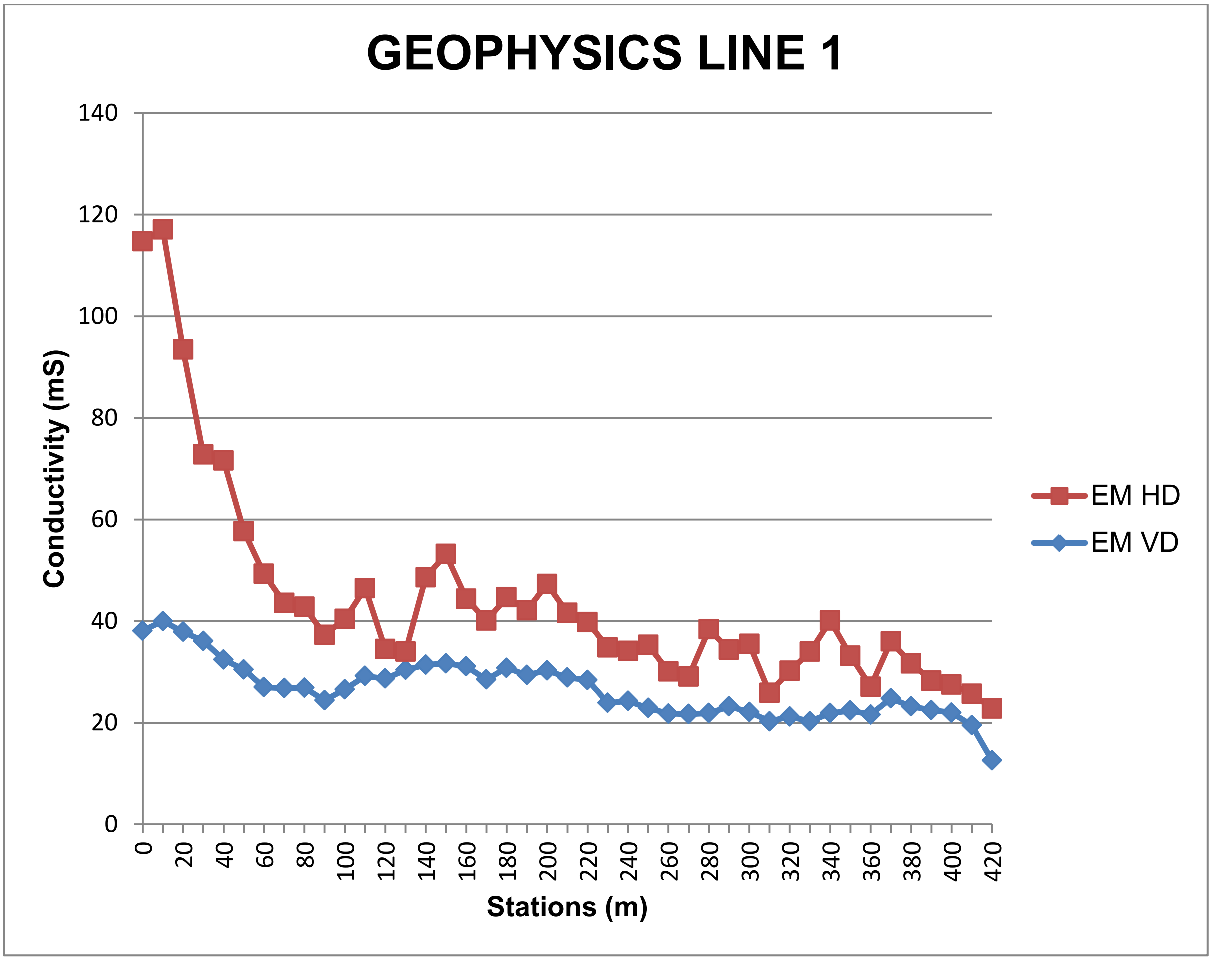
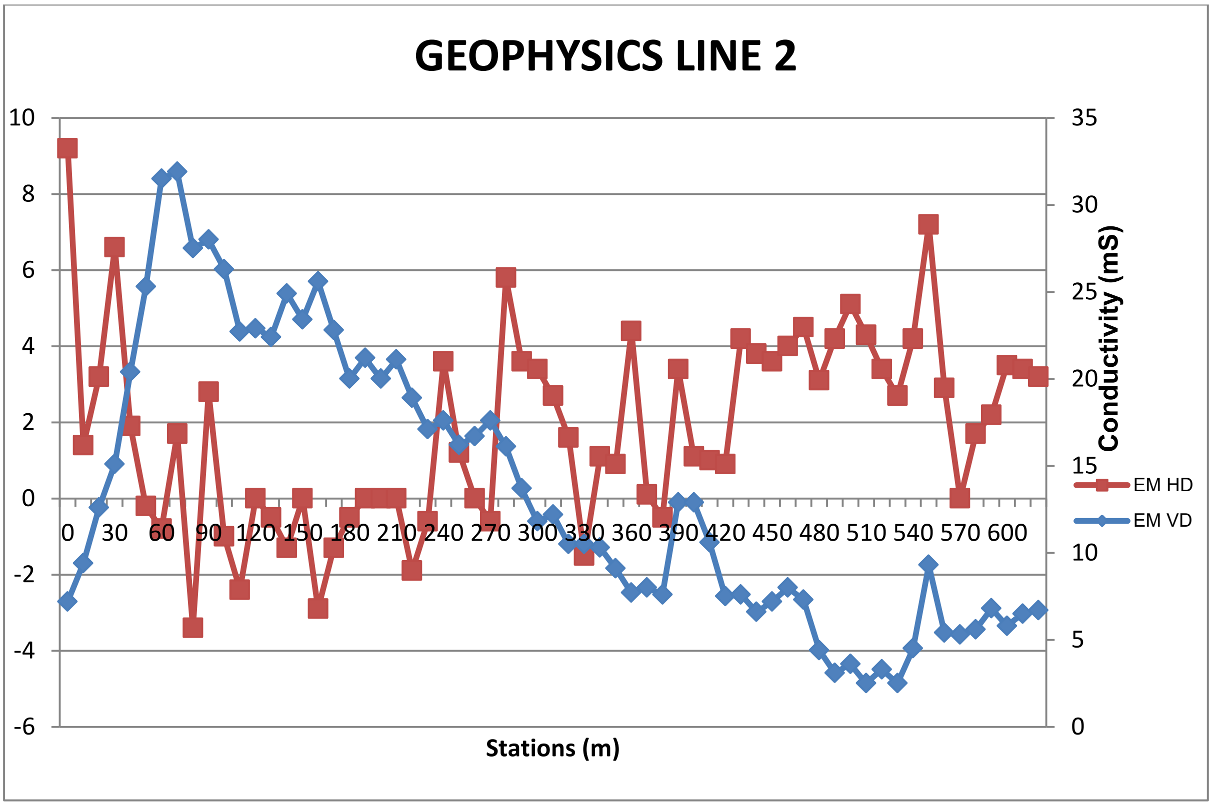
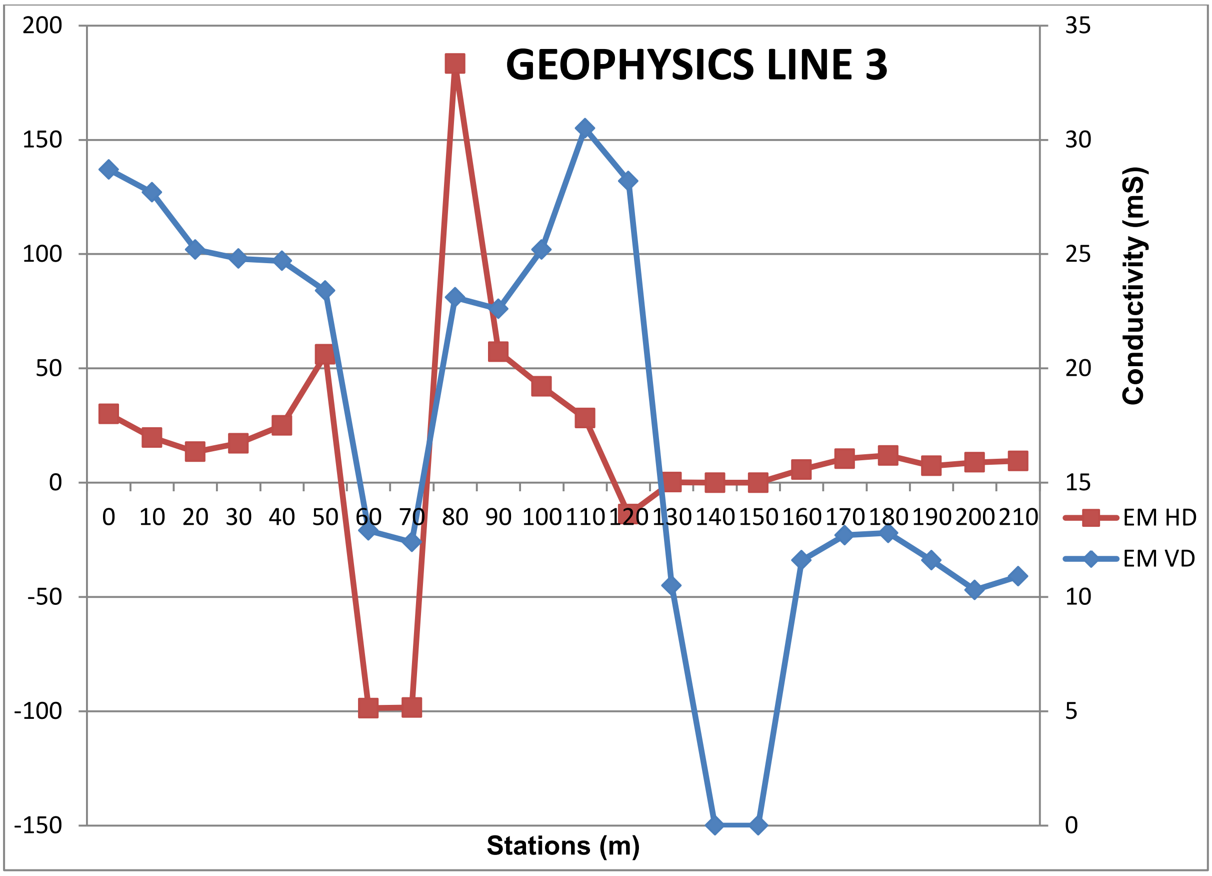
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

Appendix B: Geophysics


GEOPHYSICS LINE 1
Conductivity (mS)
Stations (m)
EM HD
EM VD
0
20
40
60
80
100
120
140
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420


GEOPHYSICS LINE 2
Conductivity (mS)
Stations (m)
EM HD
EM VD
10
8
6
4
2
0
-2
-4
-6
35
30
25
20
15
10
5
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570 600



GEOPHYSICS LINE 3
200
150
100
50
0
-50
-100
-150
35
30
25
20
15
10
5
0
Conductivity (mS)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
Stations (m)
EM HD
EM VD

Appendix C: Borehole Logs

DIGBY WELLS ENVIRONMENTAL

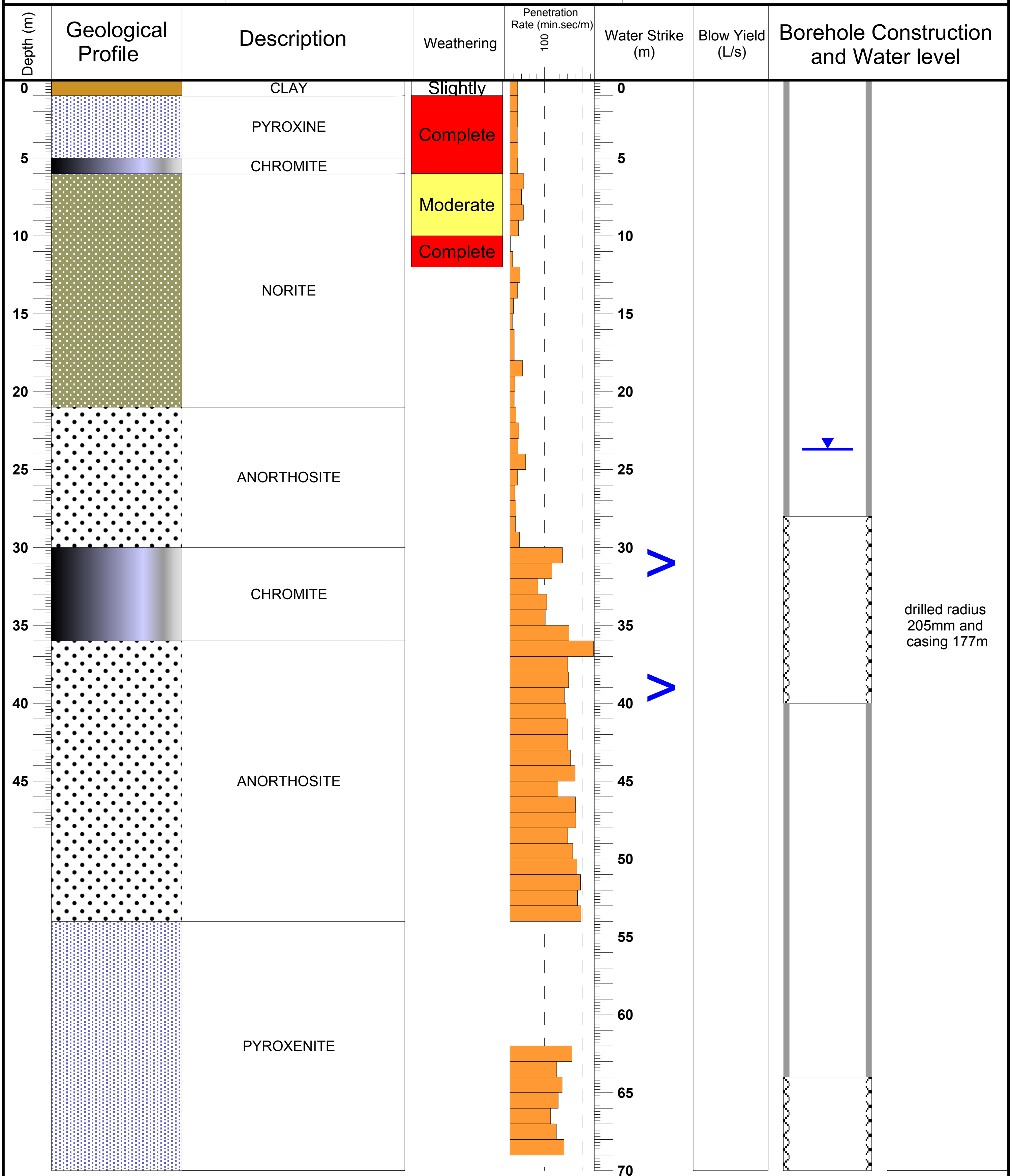
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT: Lanxess

Project Name: Lanxess Gap analysis
Project Code: Lan2558
Location: Kroondal
Drilled By: Geosphere
Date Drilled: 6/24/2014
Logged By: E Simango

BOREHOLE ID: LanBH01

Coordinate System: WSG84
X-Coordinate: 27.386723
Y-Coordinate: 25.730208
Z-Coordinate: 1220.85
Final Depth (m): 70
Collar Height (m):

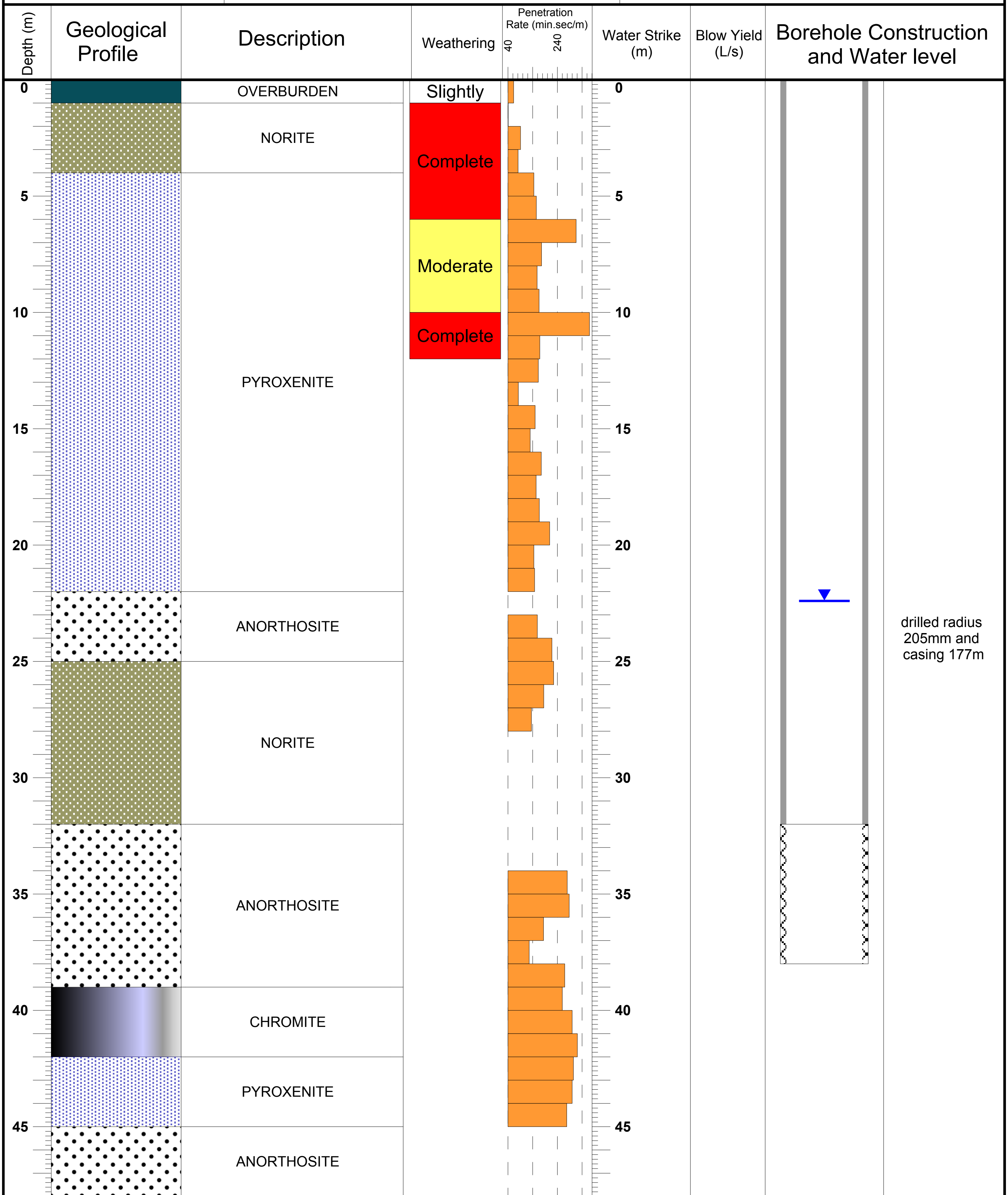


Comment:

DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**Lanxess**	**BOREHOLE ID:**	**LanBH02**
Project Name:	Lanxess Gap analysis	Coordinate System:	WSG84
Project Code:	Lan2558	X-Coordinate:	27.39604
Location:	Kroondal	Y-Coordinate:	25.726238
Drilled By:	Geosphere	Z-Coordinate:	1231.08
Date Drilled:	6/26/2014	Final Depth (m):	48
Logged By:	E Simango	Collar Height (m):	



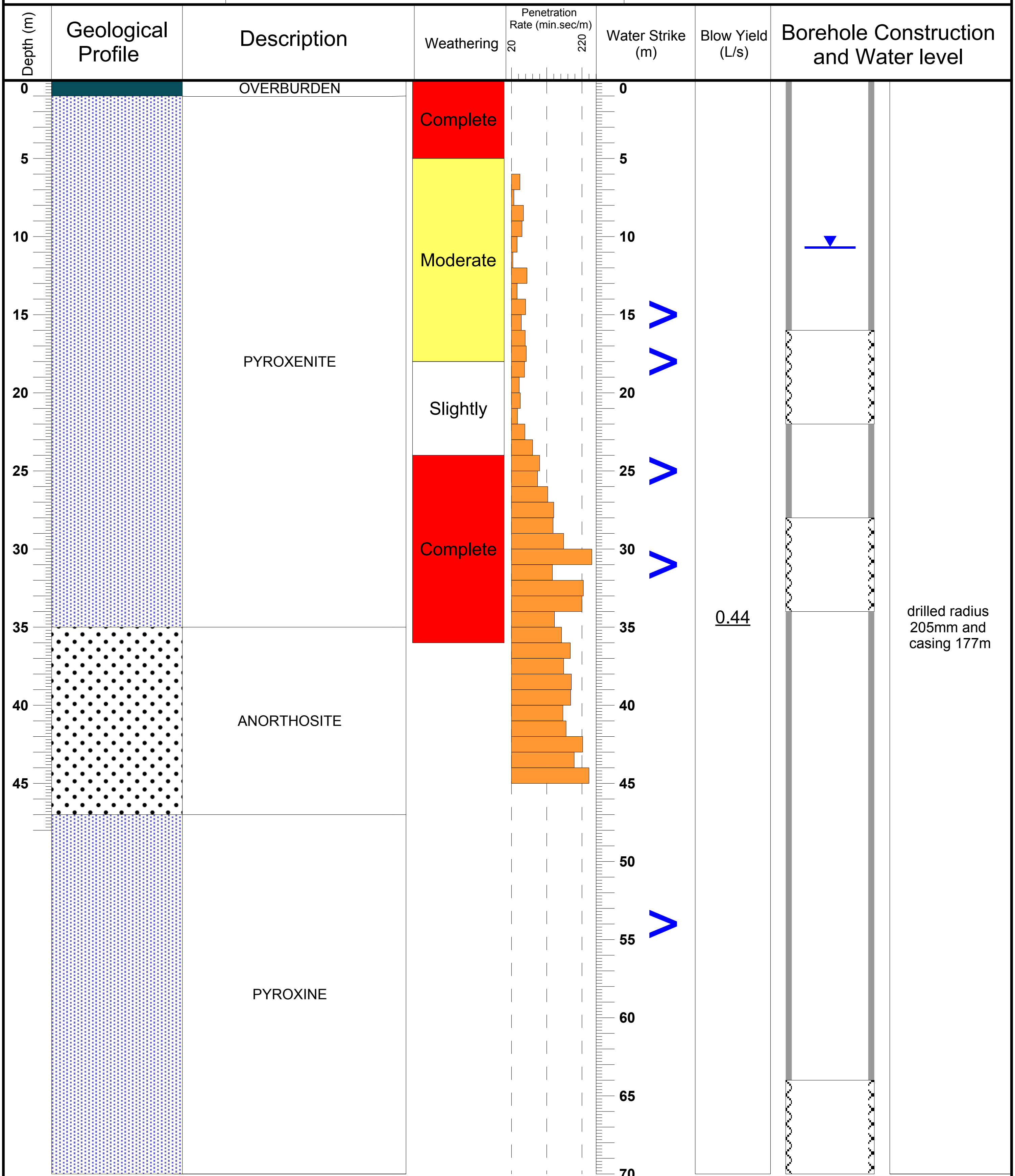
Comment:

DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**Lanxess**
Project Name:	Lanxess Gap analysis
Project Code:	Lan2558
Location:	Kroondal
Drilled By:	Geosphere
Date Drilled:	6/27/2014
Logged By:	E Simango

BOREHOLE ID:	**LanBH03**
Coordinate System:	WSG84
X-Coordinate:	27.401422
Y-Coordinate:	25.731523
Z-Coordinate:	1225.06
Final Depth (m):	70
Collar Height (m):	



Comment:

Appendix D: Aquifer Test

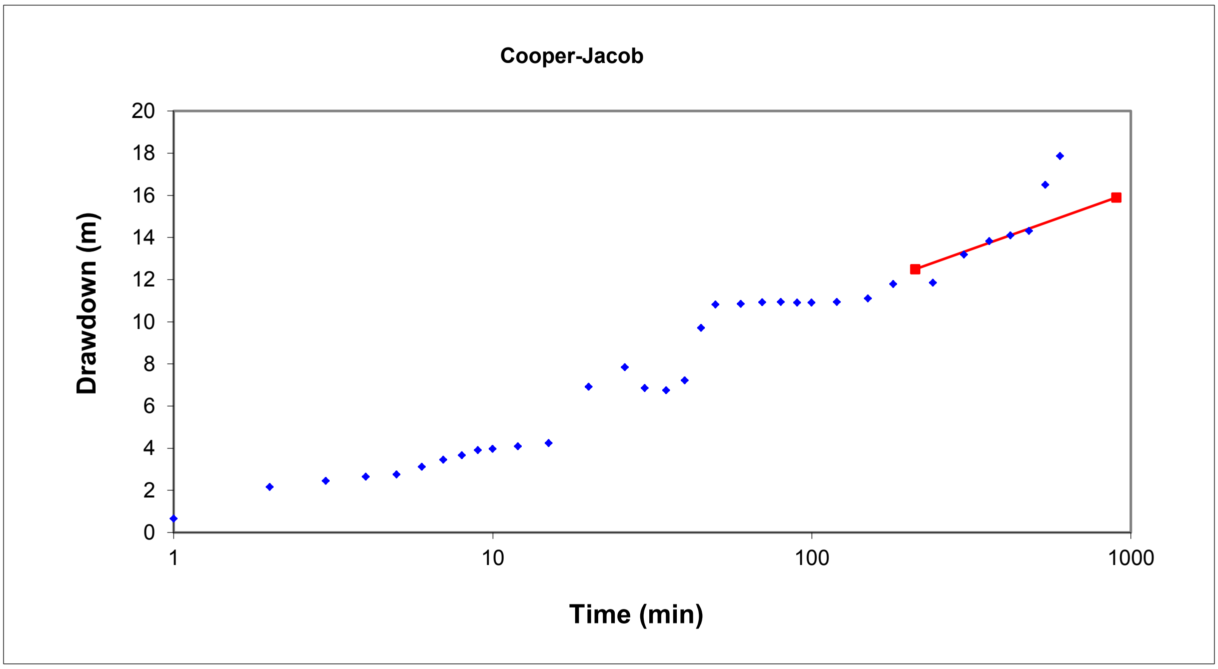
Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

LANBH01

$T(m^2/d)$ =	4.4	r_e (m)=	0.91	0.91	91
S =	8.44E-03	Q (l/s) =	1.5		

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	1.22	0.61	0.40	0.31	including influence of bh's
Avg. Q_sust =		**0.63**	std. dev =	0.41	



Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

LANBH03

T(m²/d) =	**7.5**	r_e (m)=	0.91	**0.91**	9 1
S =	**5.68E-03**	Q (l/s) =	1.19		

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	3.35	1.68	1.11	0.84	including influence of bh's
Avg. Q_sust =	**1.74**	std. dev =	1.13