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TECHNICAL ENGINEERING DESIGN OF THE STORM WATER MANAGEMENT PLAN TO SUPPORT THE WULA

RIETFONTEIN PLANT

CLOVER ALLOYS

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LIST OF ABBREVIATIONS

MineLock	MineLock Environmental Engineers (Pty) Ltd
RCM	Rustenburg Chrome Mine (Pty) Ltd
WULA	Water Use License Application
PCD	Pollution Control Dam
OMC	Optimum Water Content
MMD	Maximum Dry Density
SANS	South African National Standard
NEMWA	National Environmental Management Waste Act
NEMA	National Environmental Management Act
NGL	Natural Ground Level
MAP	Mean Annual Precipitation
RD	Relative Density
SG	Specific Gravity

1. INTRODUCTION

MineLock Environmental Engineers (Pty) Ltd (MineLock) was appointed by Rustenburg Chrome Mine (Pty) Ltd (RCM) to provide a Technical Engineering Design of the Storm Water Management Plan (SWMP) of Rietfontein Plant to support their Water Use License Application (WULA).

Rietfontein Plant currently has a WUL in place with licence number 07/A22H/AG/5292 issued 11 June 2017. It was decided that the product stockpile area should increase in size and a Pollution Control Dam (PCD) with various channels should be included in the SWMP at Rietfontein Plant to ensure clean and dirty water separation. Additionally, it was decided that Rietfontein Plant will pump their slurry through a slurry pipeline to RCM, which will be discussed in this report.

MineLock set up a project initiation meeting on 11 December 2024 for a brief discussion and to determine what is required to complete the design work. Several meetings were held in the beginning of 2025 to identify the requirements for Rietfontein Plant. The following list of requirements was established to guide the design:

- Survey of the site;
- Geotechnical investigation for the Pollution Control Dam (PCD), stockpile areas and pipeline route;
- Site-wide water balance to size the PCD required;
- 50- and 100-year Floodline investigation; and
- Waste classification to determine the barrier system required.

Figure 1 presents the proposed general site overview of Rietfontein Plant which will be discussed in detail in this report. This report provides a Stage 3 Technical Engineering Design of the SWMP, PCD, river crossing slurry and return water pipeline details, as well as the stockpile areas, to support the WULA.

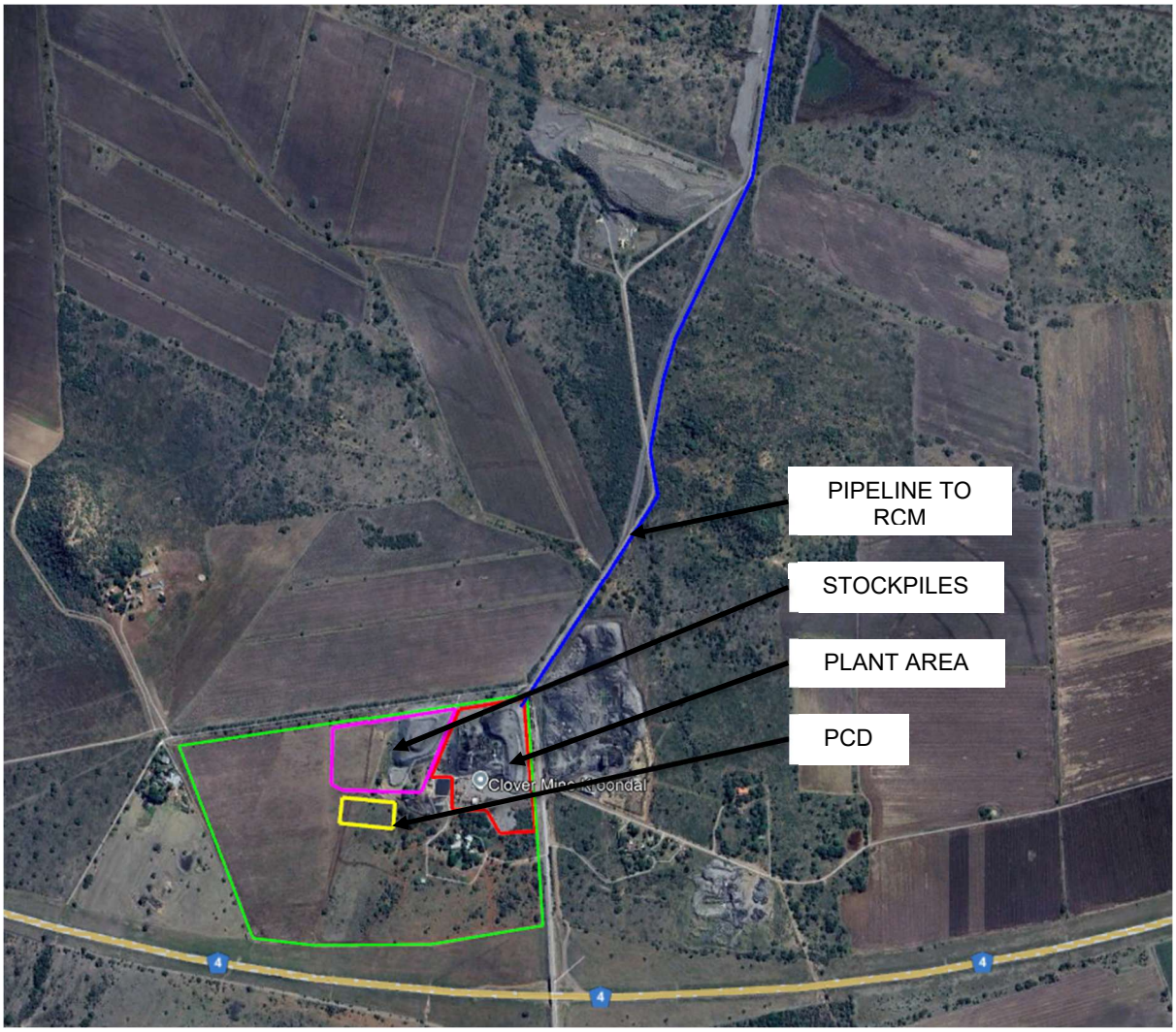


Figure 1: General site overview of Rietfontein Plant

1.1 Objectives

The overall project objective is to develop a design compliant with the National Environmental Management: Waste Act (NEM:WA) Regulations and Norms and Standards. The detail design includes the following key items:

- Technical Engineering Design of the SWMP to support the WULA;
- Sizing and Technical Engineering Design of the PCD;
- Required barrier system designs;
- High level cost estimation; and
- Technical Specification and Construction Quality Assurance Plan.

Duty of care and a diligent approach was applied during the design process to generate the design work aligned with the requirements of the relevant legislation and compliance to the applicable Regulations.

1.2 Regulatory Framework

Particular attention is given to inter alia the following regulations in respect of design stages and standards:

- Engineering Professions Act, Act 46 of 2000, Board Notice 41 of 2017
- Engineering Professions Act, Act 46 of 2000, Board Notice 138 of 2015
- National Water Act, Act 36 of 1998, WULA Regulations 2017
- National Water Act, Act 36 of 1998, GN704 of 1999
- Regulations in terms of NEMA and NEMWA:
  - GN 636 Norms and Standards for Disposal of Waste to Landfill (prescribe barrier design requirements, waste acceptance criteria (Type 0, 1, 2, and 3) and waste disposal restrictions.
- The Dam Safety Regulations No. R 139, 24 February 2012.

1.3 Scope of Work

The scope of work includes the following:

- Project initiation:
  - Receipt and review of all required information from relevant parties;
  - Setup of dedicated digital models using information provided by the Client; and
  - Conducting a project initiation meeting with the Client and the project team to discuss a project schedule and relevant technical aspects.
- Water balance of the site and to determine the capacity of the PCD;
- Geotechnical Investigation including a desktop investigation, sample test pits and collection of samples and laboratory testing of the relevant soils;
- Floodline calculations to investigate the river crossing of the slurry pipeline and to inform the location of the facilities;
- A Technical Engineering Design of the supporting infrastructure for the WULA.

1.4 Site Location and Description

Rietfontein plant is located Northwest of Pretoria as shown in Figure 2. Rietfontein Plant is located approximately 5.8 km South of gauge number 0511672 – Klipfontein.

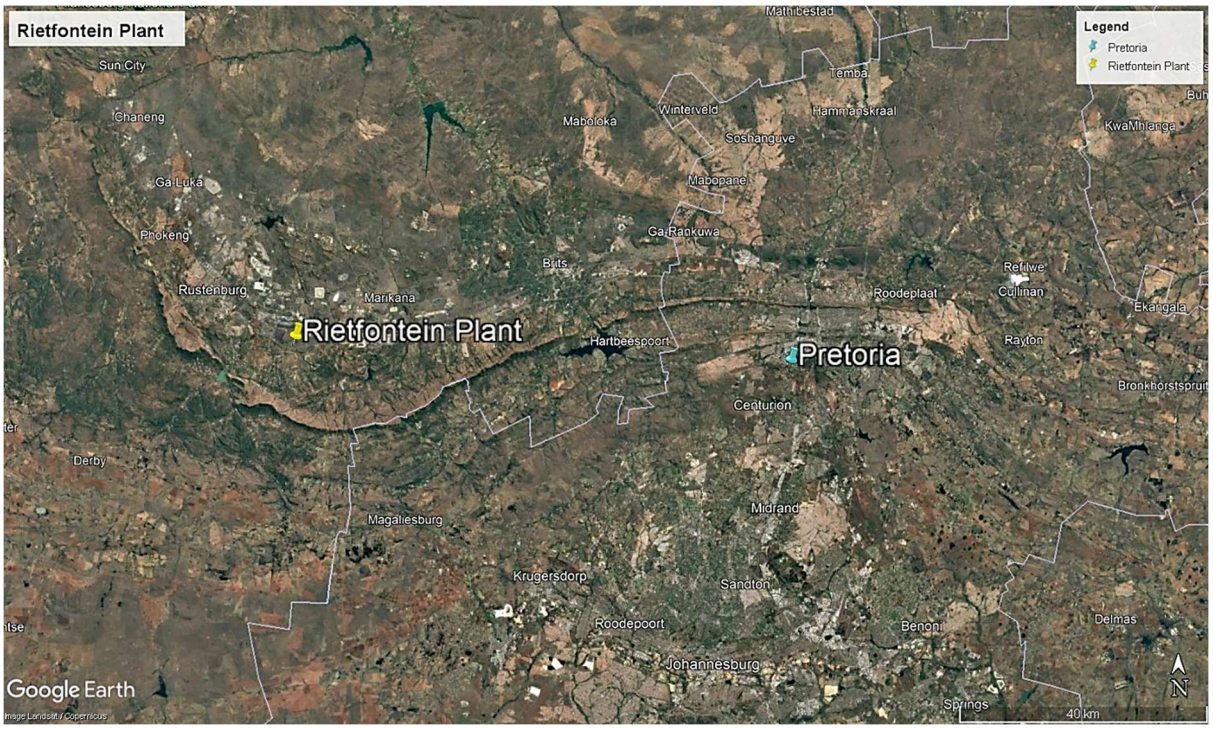


Figure 2: General site location

2. ASSUMPTIONS AND EXCLUSIONS

The following information was provided by the client:

- The Waste Classification test results were completed in September 2022 and April 2024 which can be seen in Appendix D;
- The pit at Rustenburg Chrome Mine (RCM) will be mined and the material will be transported to Rietfontein Plant for processing;
- The client confirmed that the plants yield on product is 22% and on the slurry is around 25%. The slurry is transported via a slurry pipeline back to RCM;
- The slurry is sent back to RCM's Tailings Storage Facility (TSF);
- The return water is also conveyed back to RCM via two return water pipelines;
- The remaining sand component (product) is stockpiled at Rietsfontein Plant to be sold to other processing plants;
- There will be no discard dump located at Rietfontein Plant;
- The client confirmed that 35 000 tons/month are being processed and an ore moisture content of 7% was confirmed;
- Rietfontein Plant has various boreholes and approximately 30 m^3/day are being used in the plant;
- Approximately 50 m^3/day are from Rand Water and;
- Approximately 10 m^3/day are being used for dust suppression.

The following assumptions and exclusions were made for the design development (but not limited to):

- It is assumed that this report will be read in conjunction with the design drawings (Appendix A), Quality Assurance Plan (Appendix G1) and Technical Specifications (Appendix G2).
- The survey provided by the client on 23 January 2025 is sufficient for this study.
- The pipeline design between the Rietfontein Plant and RCM was submitted by the client. MineLock is to provide the proposed plan for the pipe placement at the floodline intersection and has completed the geotechnical assessment of the pipeline alignment.

3. SITE-WIDE WATER BALANCE

3.1 Introduction

MineLock was commissioned by the client to calculate the water balance for the proposed Rietfontein operations. The operations consist of a PGM minerals processing plant, product and ROM stockpiles, drying ponds, and two pollution control dams and a silt trap. PGM ore is trucked into the plant from the nearby Rustenburg Chrome Mines. All of this infrastructure is considered dirty and requires dedicated pollution control dams. The operations are a brownfields project. Most of the land is currently being used for PGM processing.

The study objectives are as follows:

- Recommend a pollution control dam capacity to comply with GN 704.
- Calculate the water balance using probabilistic analysis.

3.1.1 Battery limits

The battery limits and proposed key infrastructure footprints are shown in Figure 3.

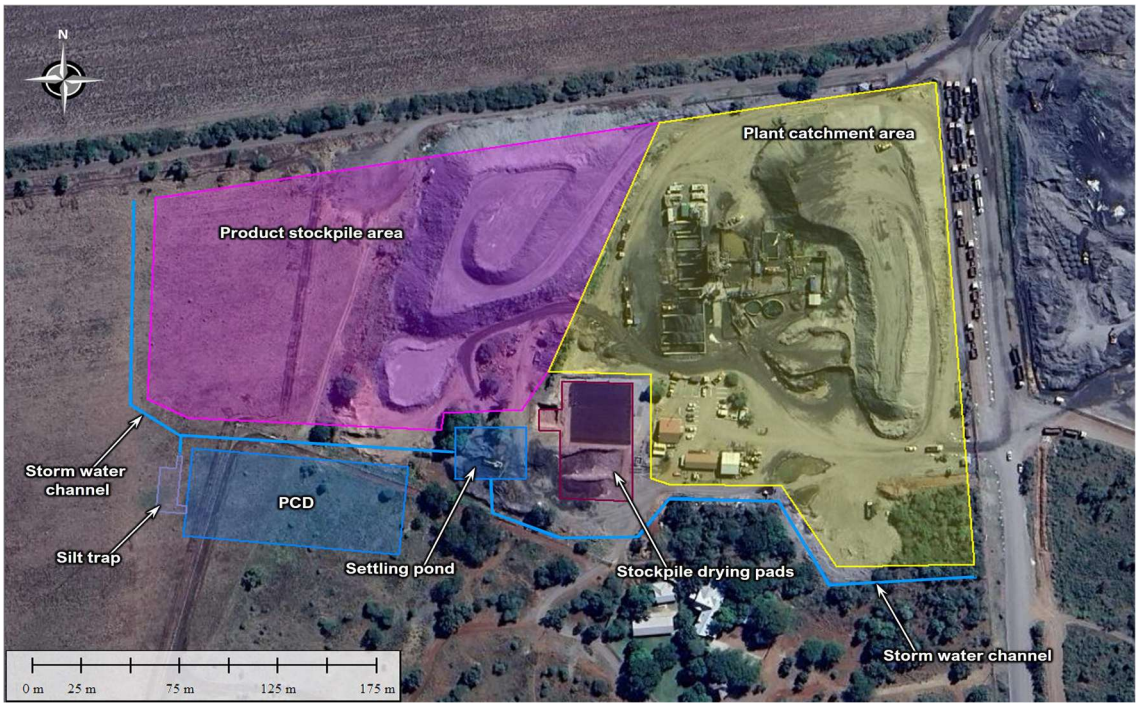


Figure 3: Battery limits and key infrastructure

3.2 Legislative Requirements and Design Criteria

GN 704 of the South African National Water Act, Act 36 of 1998 is used as the legislative requirements and the design criteria is that these legislative requirements are met.

GN 704 specifies, among other things that:

- Clean water may not spill into dirty systems more than once in fifty years on average.
- Dirty water may not spill into clean systems more than once in fifty years on average.

3.3 Climate Data

The climate data is summarised in Figure 4.

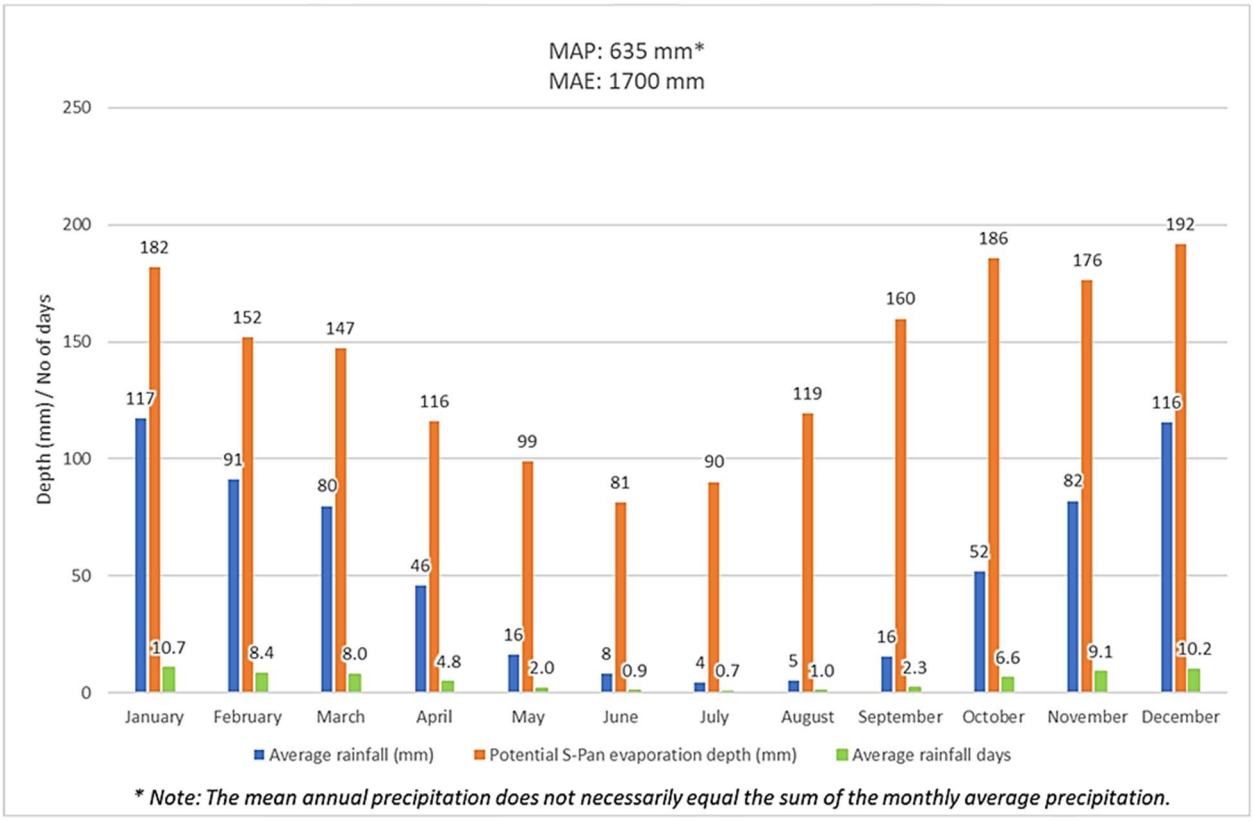


Figure 4: Climate data summary

3.3.1 Sources of rainfall and evaporation data

Daily rainfall data was sourced from the CCWR (Computing Centre for Water Research, Natal University) rainfall database (gauge number 0511672 – Klipfontein). The gauge is located approximately 5.8 km north of the operations. The CCWR data that was used contains daily records and patched records between November 1928 and July 2000 and is considered representative of the rainfall data on site.

The mean annual evaporation was sourced from the average evaporation for quaternary catchment A22H, documented in the Water Resources of South Africa, 2005 Study (Middleton and Bailey, 2009). Its monthly distribution was sourced from the Water Resources of South Africa Study data set, zone 3B (Midgley et al., 1990). The data is considered representative

of the study area.

3.3.2 Stochastic rainfall

A stochastic rainfall generator was calibrated on the daily rainfall record discussed in section 3.3.1. The monthly average rainfall and rainfall days calibration are shown in Figure 5 and Figure 6 respectively. The mean annual precipitation of the stochastic rainfall record is 634.8 mm. This compares well with the mean annual rainfall of the recorded data of 634.7 mm.

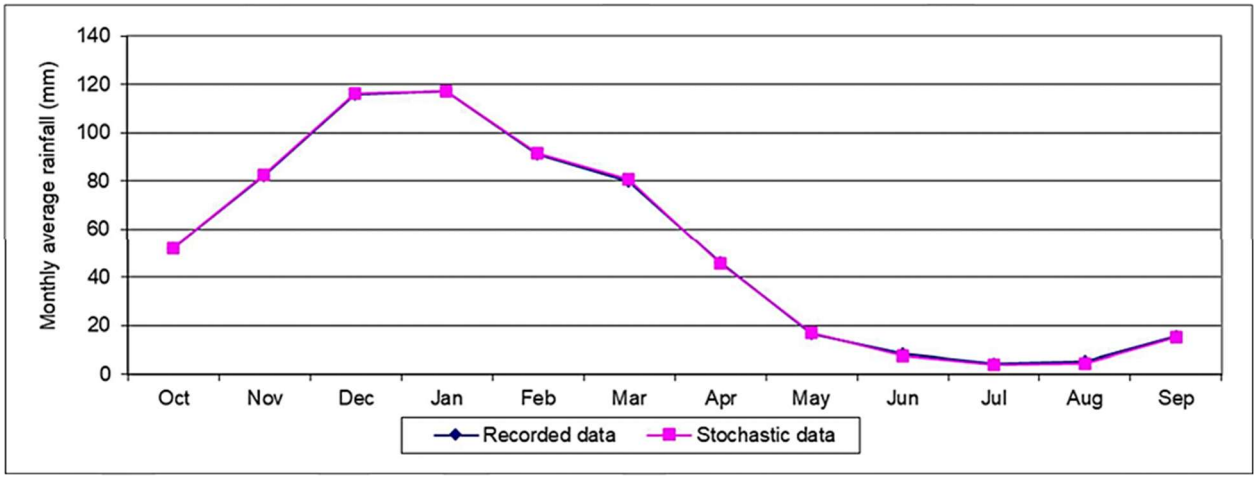


Figure 5: Monthly average rainfall calibration

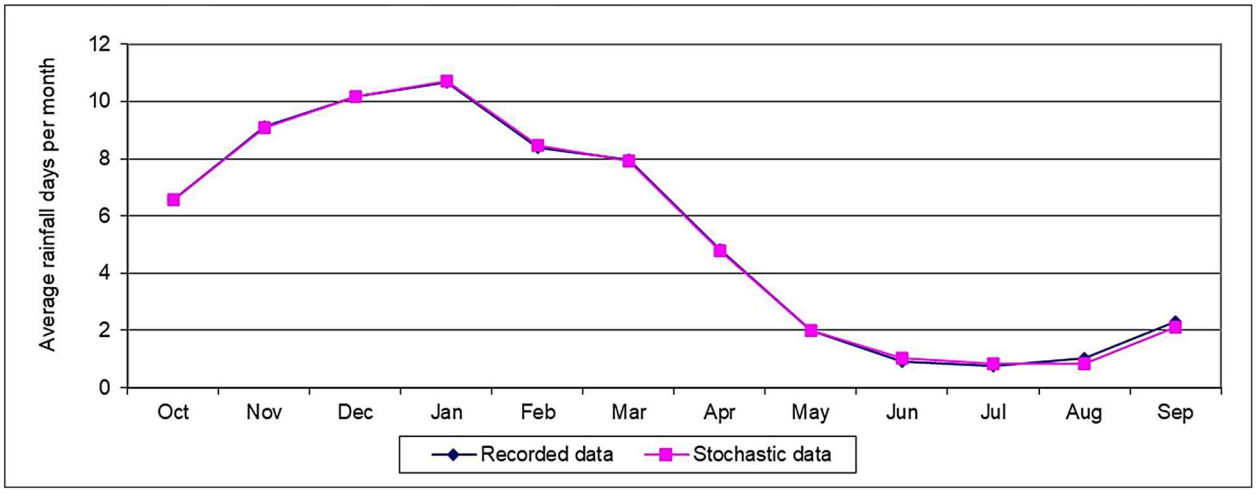


Figure 6: Monthly average rainfall days calibration

3.3.3 Peak 24-hr rainfall data

The peak 24-hr rainfall depths are presented in Table 1.

Table 1: Peak 24-hr rainfall depths for operations

Recurrence Interval (year)	24-hour rainfall depth (mm)
2	56

10	93
20	107
50	126
100	140
200	155

The daily rainfall record, discussed in section 3.3.1, was analysed and the annual maximum series was extracted from the data. This annual maximum series was statistically analysed to determine various T-year recurrence interval 24-hour storm depths. A Log Normal distribution fitted the data the best. This fit is shown in Figure 7. The resulting peak rainfall is presented in Table 1.

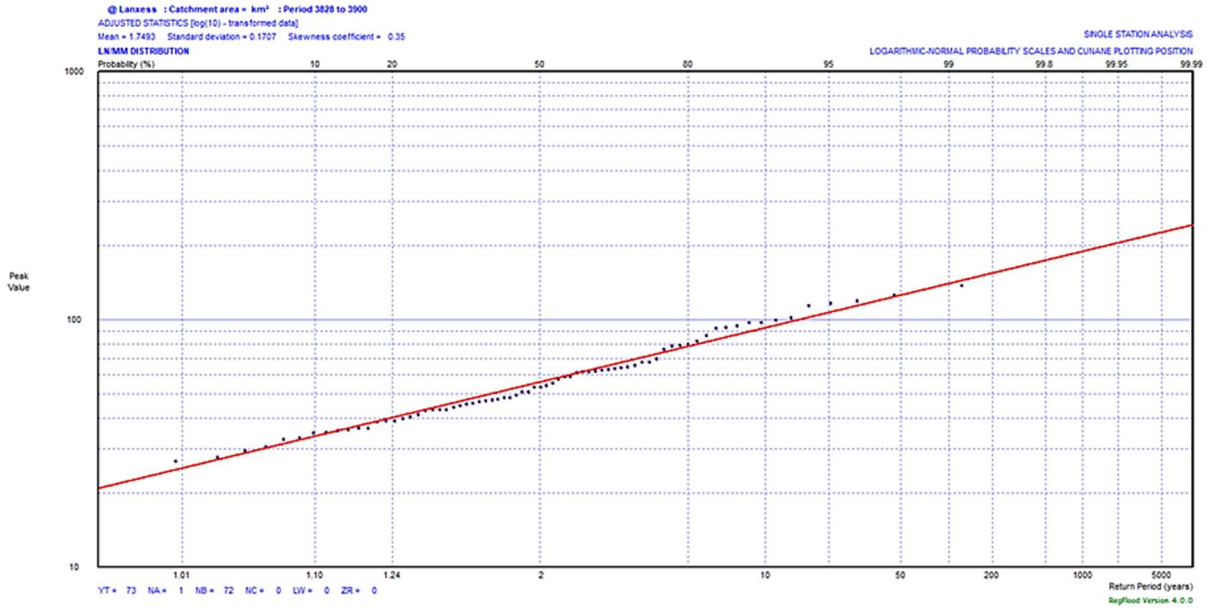


Figure 7: Log Pearson type 3 statistical fit to the annual maximum series

3.4 Water Balance

3.4.1 Modelling

A daily time step GoldSim model was constructed to simulate the water balance for the operations within the battery limits discussed in section 3.1.1. The model includes a stochastic rainfall generator to generate rainfall sequences required for probabilistic analysis. The model simulates the facilities and the water dams in detail.

Catchments are modelled using a modified SCS model, accounting for antecedent moisture conditions. The catchments incorporate a 3-layer cascading system which accounts for interception and depression storage, moisture budgeting in the vadose zone, interflow, and

deep seepage.

Dams are modelled in detail with daily evaporation losses, direct rainfall, and storm water inflows being accounted for. The pollution control dam was sized in accordance with GN 704 of the South African National Water Act, Act 36 of 1998. The settling dam has an installed capacity of 3 775 m^3. An 8 000 m^3 pollution control dam is proposed, which will provide an additional 2 400 m^3 operational storage capacity.

3.4.2 Probabilistic modelling

A probabilistic analysis was used to determine how the operations behave under various rainfall conditions. The results are detailed in section 3.5. 300 stochastically generated rainfall sequences were modelled, with annual rainfall ranging from 167 mm to 1 507 mm. The stochastic rainfall generator and its calibration is discussed in section 3.3.2.

The model simulates a 30-year period 2027 to 2057, with a 2-year model warm-up period prior to 2027. This warm-up period is required to ensure that all assumed start moisture conditions in the catchment modules have no influence on the water balance calculations post 2027. The results during this warm up period is not relevant. The model accounts for antecedent moisture conditions in all catchments so this is pertinent.

The facility footprints are modelled statically as these footprints will not change during the life of the operations. These footprints are sourced from the operations layout plan. The plant product tonnes are also static during the simulation.

3.4.3 Time series modelling

A scenario was modelled to produce water balance diagrams and to calculate average flows.

The 71.5-year recorded daily rainfall record (discussed in section 3.3) was passed over the operations. These average water balance values are required for environmental authorisations and provide the reader with typical system flows across the operations.

3.4.4 Process flow inputs

The process inputs are shown in Figure 8. These values are also reflected in the water balance diagram in Appendix B.

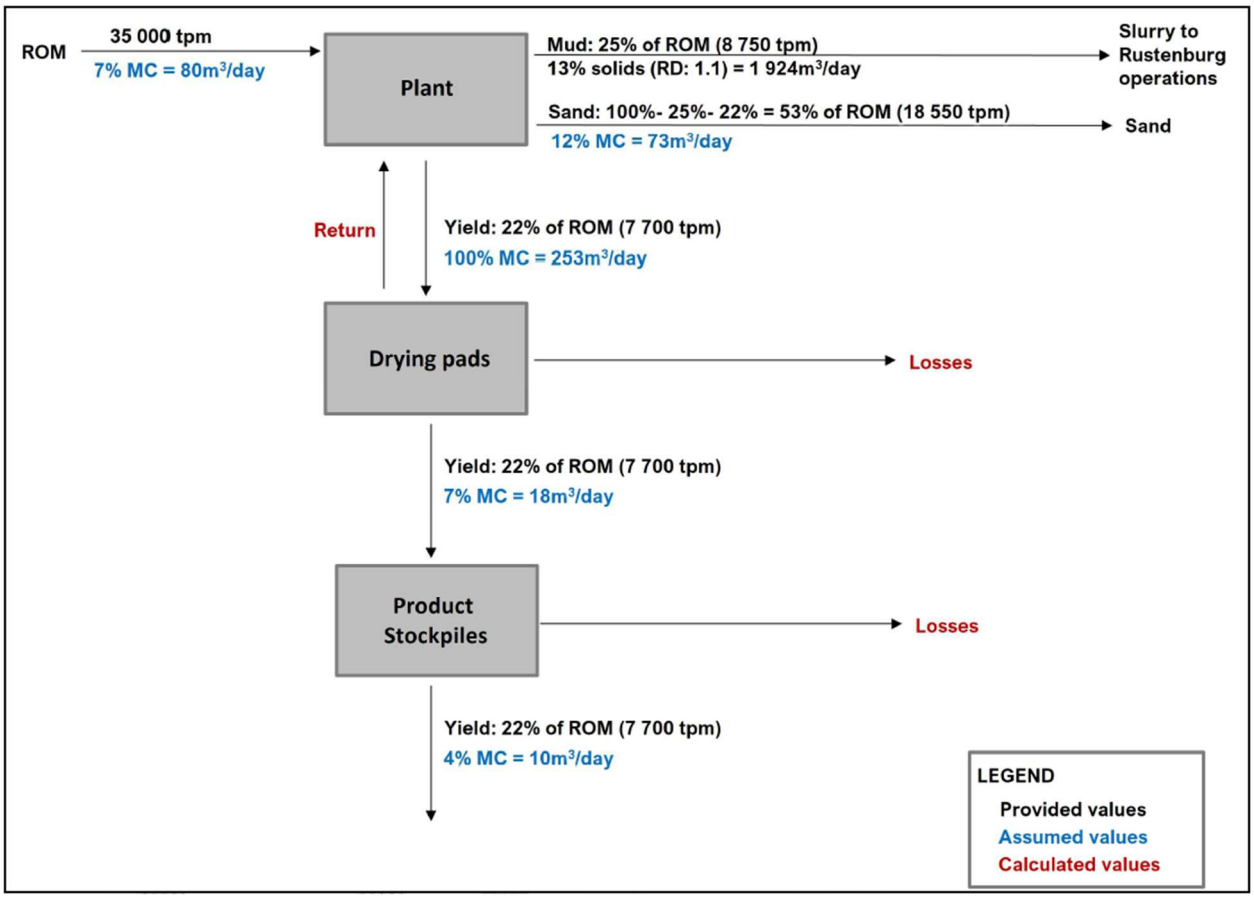


Figure 8: Process inputs

3.5 Results

3.5.1 Pollution control dam sizing

The minimum pollution control dam storage capacity required to comply with GN 704 is 5 600 m^3. However, this storage assumes that it will be operated dry at all times. It is recommended that additional operational storage be installed above this volume to provide operational flexibility. An 8 000 m^3 pollution control dam will provide this operational storage.

The pollution control dam sizing is a function of the catchment size and the rate at which excess water is abstracted from the pollution control dam, to be recycled. The operations have a strong deficit because ore is delivered relatively dry, and slurry is pumped away from the site. As a result of this, and relatively small footprints, the demand on the pollution control dam is high compared to storm water inflows. This means the pollution control dam is expected to be operated empty most of the time.

In order to comply with the requirements of GN 704, the pollution control dam must be the larger of the 50-yr design storm volume, and the capacity required to not spill more than once in 50-years on average. The probabilistic modelling determines the storage associated with the 50-yr spillage frequency. In this case, because of the strong deficit water balance, the 50-yr design storm volume (5 600 m^3) exceeds the capacity required for a 50-year spillage frequency (3 200 m^3) and is therefore used.

3.6 Water Balance Diagram

The inflows are presented on the left of the water balance figures. The facilities and inter-facility flows are shown in the centre of the water balance figures. The outflows are shown on the right of these figures. The water balance is presented in Appendix B.

The direction of water movement is illustrated with black arrows. The values adjacent to the arrows represent average flows in m^3/day. Clean water flows are shown in blue, while dirty flows are shown in red.

One of the fundamental principles of a water balance is that inflows must equal outflows unless the difference is accommodated in storage changes. The pollution control dam is small and will not accommodate significant storage changes over a season, so start storage changes are set to match simulated end storage changes. Daily storage changes occur in practice, and are modelled as such, but will not be seen when viewed in the context of a static water balance over a year.

4.GEOTECHNICAL INVESTIGATION

MineLock undertook a geotechnical investigation for the existing Rietfontein Plant of Rustenburg Chrome Mine, required for the development of a Stormwater Management Plan for the plant.

The Rietfontein Plant is located just north of National Route N4 and about 15 kilometres south-east of the Rustenburg CBD in the North-West Province.

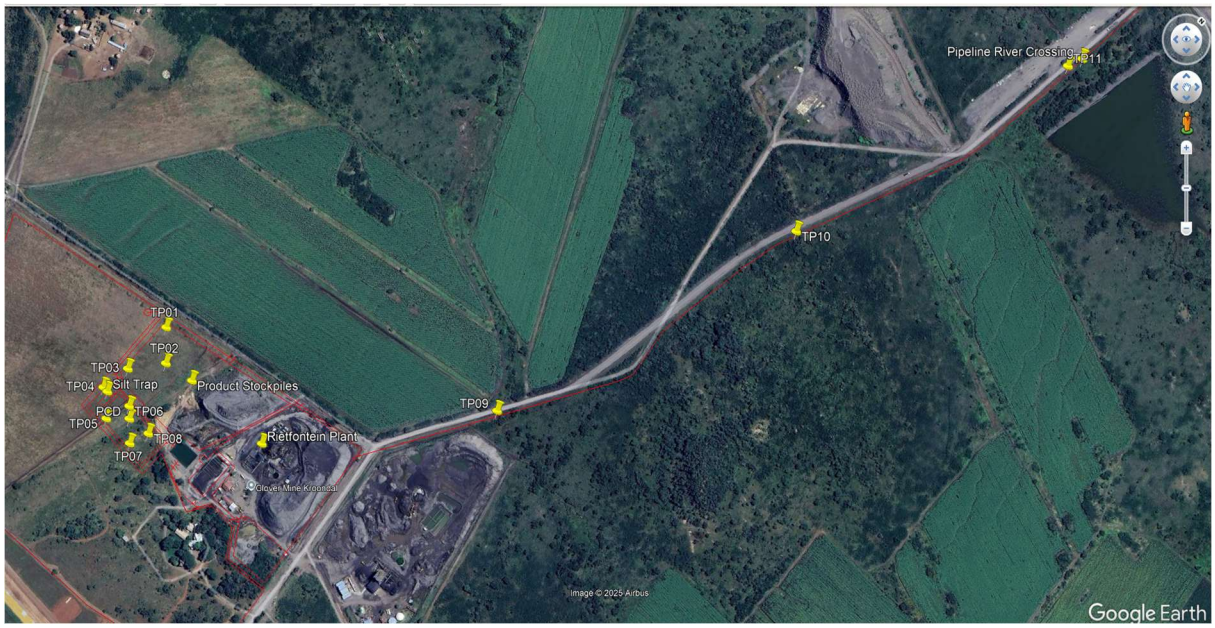


Figure 9: Google Earth image of the plant area and above ground pipeline

The area where the investigation was undertaken is mostly flat with a field grass covering.



Figure 10: Close up Google Earth image view of plant area and test pit positions



Figure 11: Close up Google Earth image of the above ground pipeline route from the Rietfontein Plant to the thickener and test pit positions



Figure 12: The site area is mostly undeveloped, flat, and covered by field grasses and occasional trees. No salient geological features (outcrops etc.) were noticed during the fieldwork

4.1 Geotechnical Fieldwork

A total of 11 test pits were excavated, profiled and sampled by an engineering geologist at the approximate positions as indicated in Figure 10 and Figure 11 above. The following areas were covered:

- Future product stockpile area (see Test pits 01, 02 and 03),
- Silt trap to PCD (see Test pit 04),
- Pollution Control Dam (PCD) (see Test pits 05, 06, 07 and 08),
- Above ground pipeline from Rietfontein plant to the thickener (see Test pits 09, 10 and 11).

The test pits were excavated with a TLB to the maximum depth reach or refusal within the plant area. The test pits along the pipeline route were terminated at maximum 1.5 m deep. The soil profiles are included in Appendix C1. Disturbed soil samples were collected for the following laboratory testing (results included in Appendix C2):

- Foundation Indicator (sieve and hydrometer and Atterberg limits),
- Moisture density relationship and CBR tests,
- Falling head permeability on disturbed samples re-compacted to 93% Mod. AASHTO density.

4.2 Results of the Investigation

4.2.1 General geology of the area

According to the 1:250 000 scale geological map 2526 Rustenburg, the general site area is underlain by norite of the Rustenburg Layered Suite, Bushveld Complex (code Vl below).

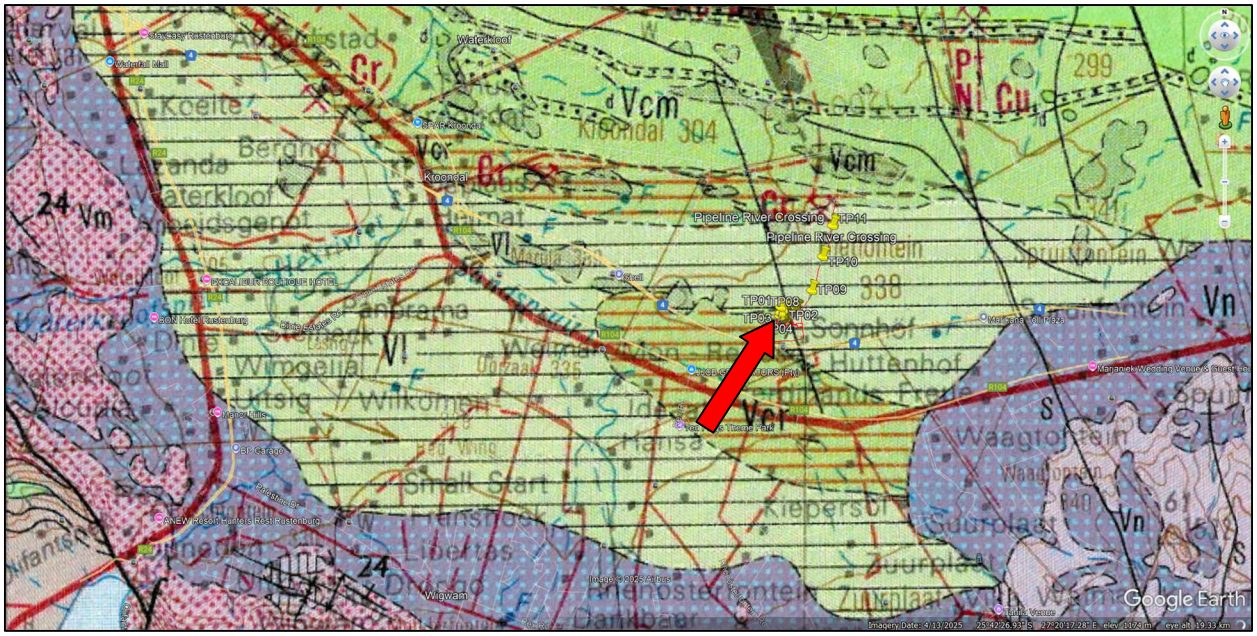


Figure 13: Extract from the 1:250 000 scale geological map 2526 Rustenburg

4.2.2 Near surface soil conditions encountered within test pits

Table 2 summarises the near surface geology as encountered within the test pits.

Table 2: Summary of soil conditions encountered within the test pit excavations

TP No.	Final depth *S – stopped GR – Gradual R - refusal*	Depth to base of layer (m)				Ground - water
		Transport-ed hillwash	Reworked residual norite	Residual norite	Norite rock	
01	2.5 (GR)	-	0 – 0.9	0.9 – 1.3	1.3 – 2.5 +	None
02	2.6 (GR)	-	0 – 1.0	1.0 – 1.6	1.6 – 2.6 +	None
03	2.5 (GR)	-	0 – 1.0	1.0 – 1.6	1.6 – 2.5 +	None
04	2.4 (GR)	-	0 – 0.6	0.6 – 1.4	1.4 – 2.4 +	None
05	2.5 (GR)	-	0 – 0.6	0.6 – 1.1	1.1 – 2.5 +	None
06	2.3 (GR)	-	0 – 0.9	0.9 – 1.3	1.3 – 2.3 +	None
07	2.5 (GR)	0 – 0.5	-	0.5 – 1.1	1.1 – 2.5 +	None

08	2.8 (GR)	0 – 0.3	-	0.3 – 1.3	1.3 – 2.8 +	None
09	1.2 (S)	-	0 – 1.2 +	-	-	Surface
10	1.3 (S)	-	0 – 0.7	0.7 – 1.3 +	-	None
11	1.2 (S)	-	0 – 1.2 +	-	-	Surface
Min		***0.3***	***0.6***	***1.1***	***2.3***	
Mean		***0.7***	***0.9***	***1.3***	***2.5***	
Max		***1.0***	***1.2***	***1.6***	***2.8***	

Transported hillwash:

Encountered at 2 (TP 7 and TP 8) of the 11 test pits as a thin surface layer. Typically described as: Moist, reddish brown, loose, slightly shattered, silty clayey SAND with trace quantities of thin roots and matrix supported sub-rounded gravels of mixed origin.

Reworked residual norite ('black turf' clay):

Encountered at 9 of the 11 test pits. Typically described as: Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete.

Residual norite:

Encountered at 9 of the 11 test pits. Typically described as: Slightly moist, khaki brown, khaki yellowish brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles.

Norite rock:

Test pits 1 to 8 all refused within this material. Test pits 9 to 11 did not reach into this material.

Typically described as: Olive greyish brown, and orange-brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; HIGHLY TO MODERATELY WEATHERED, COARSELY GRAINED, VERY SOFT- TO SOFT ROCK NORITE.



Figure 14: Typical soil profile consisting of reworked residual norite (black turf) at surface, underlain by residual norite, underlain by norite rock

4.3 Laboratory Test Results

4.3.1 Foundation indicator test results

Table 3: Summary of foundation indicator test results

TP No.	Sample Depth (m)	Origin	Material description	GM	PI	LL	% CLAY	Heave class
2	1.0 – 1.6	Residual norite	Silty GRAVEL	2.4	SP	-	5.1	Low
3	1.2 – 1.5	Residual norite	Silty/clayey SAND	2.0	7	28	2.9	Low

5	0.1 – 0.6	Reworked residual norite	Inorganic clay	0.6	42	61	38	Very high
7	0.3 – 0.5	Hillwash	Clayey SAND	1.1	23	42	8.5	Low
8	1.5 – 2.5	Norite rock	Gravel	2.6	11	30	1.0	Low
10	0.3 – 0.7	Reworked residual norite	Clayey SAND	1.5	37	59	11.4	Low/ medium
Min				*0.6*	*SP*	*-*	*1.0*	
Mean				*1.7*	*20*	*37*	*11*	
Max				*2.6*	*42*	*61*	*38*	

***GM** = Grading Modulus; **PI** = Plasticity Index; **LL** = Liquid limit; **NP** – Not plastic, **Clay** defined as material with grain size smaller than 0.002 mm,*

The surface layer of reworked residual norite soils is fine-grained and HIGHLY expansive (PI of 42 and LL values of 61). All other soil materials that will be encountered on site are much coarser grained and LOW in potential expansiveness. Hillwash soils comprises a clayey sand soil which is also LOW in potential expansiveness.

4.3.2 Moisture density relationship strength and compaction

Table 4: Summary of moisture density relationship and CBR strength test results

TP No.	Sample Depth (m)	Material Origin	MDD (kg/m3)	OMC (%)	CBR at 95%	COLTO
2	1.0 – 1.6	Residual norite	2 283	7.7	19	G7
5	0.1 – 0.6	Reworked residual norite	1 728	17.7	2	< G9
8	1.5 – 2.5	Residual Norite	2 354	7.2	24	G7
Min.			1 728	7.7	2	<G9
Mean			2 122	10.9	15	
Max.			2 354	17.7	24	G7

As expected, reworked residual norite soils (also known as 'black turf'), recorded very low CBR penetration results and in conjunction with a very high PI values were rated as less than G9 quality. Residual norite soils recorded much higher CBR values and were rated as G7 quality.

4.3.3 Permeability

Constant head permeability tests on samples re-compacted to 93% of Mod. AASHTO MDD recorded the following results:

Table 5: Summary of moisture density relationship and CBR strength test results

TP No.	Sample Depth (m)	Material origin	Coefficient of permeability (m/s)
5	0.1 – 0.6	Reworked residual norite (black turf)	2.1×10^{-10}
8	1.5 – 2.5	Residual norite	6.9×10^{-7}

The surface layer of reworked residual norite soils when compacted to 93% of MOD. ASSHTO MDD recorded a very low permeability of 2.1 x 10-10 m/s. However, the material has a very high plasticity index, indicating a high potential for desiccation cracking, which could significantly increase the permeability of the compacted layer, potentially by orders of magnitude.

4.4 Geotechnical Evaluation

4.4.1 Expansive soils

Based on laboratory test results and visual observations, the surface layer of reworked residual norite soils (black turf), are highly expansive and where possible must be completely removed from below and/or around any infrastructure development. Residual norite and deeper norite rock materials are not expansive.

4.4.2 Collapsible and compressible soils

The site area is not underlain by any highly collapsible soils such as to necessitate extensive remedial measures.

Reworked residual norite soils are fine grained and prone to long term consolidation settlements/compression under loads. As this material is also highly expansive, preferably no infrastructure must be founded on/within this material.

4.4.3 Ground and surface water conditions

No groundwater was encountered within the depth reach of the test pits at all the test pits excavated within the plant area (TP's 1 to 8). The depth to a groundwater level within the plant area is thus unknown but it is not expected that any excavations here, to at least 2.0 m to 2.5

m deep, will encounter any groundwater.

Test pits 9 and 11 were excavated in areas where standing water at surface drained into the test pits and hence cannot be considered as a true groundwater level.

4.4.4 Construction materials

Reworked residual norite soils (black turf) can be considered for use as a Compacted Clay Liner (CCL) material since the permeability of this material, when compacted to say 98% of Proctor MDD, is expected to be less than 10-9 m/s meeting the requirements for both Classes A and B facilities (minimum 10-9 m/s required), and Class C facility (minimum 10-8 m/s required).

However, the plasticity index of this material is very high suggesting desiccation cracking can develop that will increase the permeability of the compacted layer by orders of magnitude. **It is thus recommended that the reworked residual norite soils NOT be used in a CCL layer and must be removed to spoil.**

Residual norite soils can generally be expected to comply with G7 quality and can thus be used as general fill and in lower and upper selected subgrade layers for roads and parking areas.

4.4.5 Illustrative stability of PCD embankments

The following hypothetical layout was considered in the stability analysis:

- Cut slope into naturally occurring soils with a maximum vertical depth of 4.0 m and slope of 1.0 (v):3.0 (h),
- Fill embankment above surrounding ground level with a maximum vertical height of m, fill slope of 1.0 (v):1.5 (h), and crest width of 2.0 m,
- Uniformly distributed load of 10 kPa at crest level.

For the stability assessment, the Canadian Dam Association (CDA) Dam Safety Guidelines of 2013 was used. The guidelines specify different loading conditions against which a dam's stability must be assessed. These loading conditions are:

- Drained and undrained behaviour directly after construction, before first filling,
- Long term drained loading (reservoir full),
- Pseudo static analysis (earthquake),
- Post seismic analysis with residual shear strength,
- Draw down scenario.

Due to the impermeable liner, a rapid draw down scenario is unlikely to occur and will not be considered further. CDA recommends the following minimum factor of safety values for each loading condition:

- Drained / undrained directly after construction, before first filling, 1.3

- Long term drained loading, 1.5
- Pseudo static analysis (earthquake), 1.1
- Post seismic analysis with residual shear strength, 1.1.

The following material parameters were used in the stability assessment:

Table 6: Material parameters used in stability assessment

Description	Unit weight (saturated) kN/m3	Drained		Undrained	
		Cohesion *(kPa)*	Friction *(deg)*	Peak strength *(kPa)*	Residual Strength *(kPa)*
Compacted fill embankment	18 (19)	1	32	-	-
In-situ black turf	16 (17)	10	20	25	5
Residual norite	18 (19)	2	34	-	-
Norite rock	21 (22)	Infinite strength			

A Dilation angle of zero degrees were used in all cases.

Table 7: Calculated Factor of Safety values and verdict

Case	FoS	Verdict
After construction – Drained *DS*	1.5	Acceptable
After construction – Drained *US*	1.55	Acceptable
After construction – Undrained *DS*	1.56	Acceptable
After construction – Undrained *US*	1.52	Acceptable
Long term – Drained *DS*	3.4	Acceptable
Pseudo static (0.15 g)	1.8	Acceptable
Post seismic with residual strength	2.5	Acceptable

All the cases summarised in *Table 7* above suggest that the PCD will be stable under all the load cases considered.

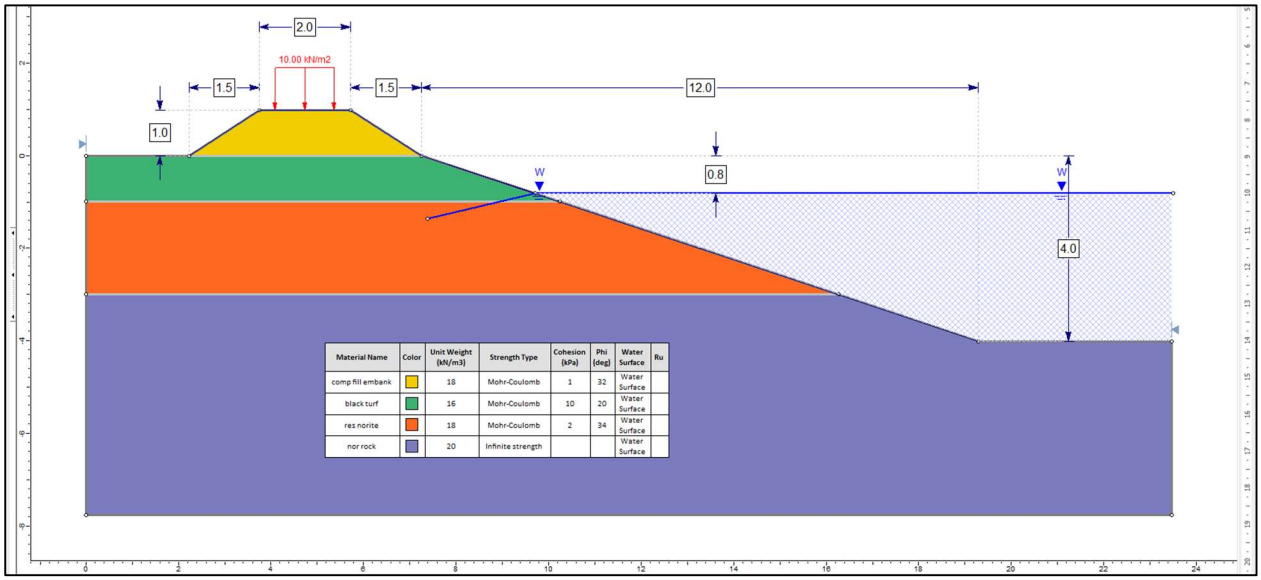


Figure 15: The model that was used in the stability assessment

4.5 Recommendations

4.5.1 Product stockpiles

Test pits 1 to 3 excavated in the general area of the product stockpiles suggest a surface layer of reworked residual norite soils (black turf) of on average about 1.0 m thick. Although these fine-grained clayey soils are considered mostly highly impermeable, fractures, fissures and slickensided surfaces within the soil structure may render the in-situ soil formations on a macro scale much more permeable. Furthermore, thick layers of these soils acting as foundation strata for heavy stockpile loads may result in long term consolidation movements / settlements, even to the point of resulting in large scale instabilities. Considering these aspects, the following is recommended for the founding of the product stockpiles:

- Remove the upper layer of topsoil (say up to 150 mm thick) with all roots and plant matter to temporary stockpile for later use in landscaping applications,
- Remove around another 450 to 500 mm mm thick layer of black turf soils to spoil so that about a 300 mm thick layer of these soils remain in place,
- Loosen / scarify the surface of the remaining black turf soils and compact to at least 93% of Mod. AASHTO MDD. The stockpiles can be founded directly on the thin layer of compacted soils. The relatively thin layer of in-situ compacted soils will provide an effective barrier to the contamination of groundwater whilst at the same time more stable and less prone to movements and general instabilities.

4.5.2 Pollution control dam and silt trap

The PCD must be shaped with upstream excavation slopes formed into the in situ soils of not steeper than 1.0 (v):3.0 (h) for vertical depths not exceeding 4.0 m. Fill embankments constructed with residual norite soils of at least G7 quality and compacted in maximum 150 mm thick layers can be build up with side slopes not steeper than 1.0 (v):1,5 (h) for vertical heights not exceeding 1.5 m. Bulk fill must be placed in maximum 150 mm thick layers with each layer compacted to at least 93 % of Mod. AASHTO MDD at a moisture content of OMC

to OMC +2 %.

The basin and upstream surface of the dam basin must be ripped to at least 100 mm deep and re-compacted to at least 93 % of Mod. AASHTO MDD prior to placing any layer works and/or liners.

Reworked residual norite soils (black turf) must NOT be used as a Compacted Clay Liner (CCL) and as such it is recommended that a double liner system be used to contain contaminants (2 layers HDPE geomembrane).

The inside basin of the PCD must be lined with a primary HDPE geomembrane liner of suitable thickness installed by a specialist contractor. The outer edges of the liner must be anchored into suitably sized anchor trenches.

The geomembrane can be covered by a layer of geocells filled with a cement stabilised soil or other stable covering layer.

The silt trap must NOT be founded on/within the surface layer of reworked residual norite soils, and this must be removed from the entire footprint area of the silt trap. The foundation must thus be established within the deeper residual norite soils. Any backfill below the silt trap must comprise at least G7 quality soils, placed and compacted in maximum 150 mm thick layers. It is recommended that the concrete floor slab of the silt trap be founded directly on a minimum 2 x 150 mm thick layers of compacted G5 material.

4.5.3 Above ground pipeline

Where possible, the above ground foundations (typically concrete sleepers) must not be founded on top / within any of the reworked residual norite surface soils. This material must be removed until the residual norite soils are exposed at the base of the excavation. The excavation must be backfilled with residual norite soils of at least G7 quality that is placed and compacted in maximum 150 mm thick layers. The pipeline can be founded on top of the compacted soils at an allowable bearing capacity not exceeding 75 kPa.

Where the surface layer of reworked residual norite (black turf) soils are NOT removed, founding can take place within this material at an allowable bearing capacity not exceeding 25 kPa. Even then, probable saturation of these surface soils will result in excessive swell deformations and/or long-term consolidation settlements that will require frequent maintenance and to re-alignment of the horizontal and vertical curvatures of the pipeline.

4.6 Concluding Remarks

A geotechnical investigation of this nature must by necessity has to rely on some interpolation between relatively widely spaced test positions and limited laboratory testing. As such it is possible that actual geological/geotechnical conditions encountered on site during the construction phase may be at variance to those described and assumed in this report. Should this situation occur, this office must be informed immediately for a re-assessment of our conclusions and recommendations.

5. Waste Classification

The material that is being mined at RCM is transported to Rietfontein Plant for processing. The product and the sand component from the re-processing are being stockpiled at Rietfonetin Plant to be sold. The remaining material and slurry are transported back to RCM via a slurry pipeline and by truck, which are placed on RCM's tailings facility.

The waste classification on the tailings material at RCM was completed in April 2024. A summary of the inorganic concentrations of constituents are presented in Table 2 (TCs) and Table 3 (LCs), report named Waste Classification and Assessment of Tailings Rustenburg Chrome Mine, see Appendix D. These results show that the total concentrations of Cu and Ni exceeded TCT0 levels but were <TCT1 levels. The leachable concentrations of all constituents in the Tailings was <LCT0 levels and in most cases below detection. According to the GN R. 635 assessment methodology, the Tailings is Type 3 due to the total Cu and Ni concentrations exceeding TCT0 levels. Although it is assessed as Type 3, it acts as Type 4 due to low leachable concentrations of constituents (all constituents < LCT0).

The waste classification on the sand component at Rietfontein Plant was carried out in September 2022 and it was decided to apply for a waste exclusion of this material in terms of GN R. 715 "Regulations Regarding the Exclusion of a Waste Stream or a Portion of a Waste Stream from the Definition of Waste" (18 July 2018). The detailed report and laboratory results are available for reference in Appendix D.

Section 4 of GN R. 634 states waste must be classified according to SANS 10234 (SANS 10234:2019, Edition 2). As per SANS 10234, the percentage concentration of chemical constituents of the waste material must be screened in terms of physical, human health and environmental hazards as per the cut off limits presented in Table 8. The SANS 10234 classification is based on analytical results as well as intrinsic properties of the waste stream.

- Physical hazards – re-processed/washed sand is not explosive, flammable (combustible through friction), pyrophoric (ignite when in contact with air) or oxidising and does not release toxic gases when in contact with water or acid. Therefore, it is not hazardous in terms of physical characteristics.
- Health hazards – The percentage concentration of constituents obtained from the XRF and acid digestion analysis was compared to the cut-off values/concentration limits for hazard classes. Elements exceeding the 1% cut-off value include Si, Al, Ca, Fe, Mg and Cr(III). Only the Si is of potential concern to human health, mainly through inhalation of respirable dust which may cause long-term health effects. Although the material is not considered to be hazardous, care should be taken to prevent long-term exposure to respirable dust particles through personal protection and exposure control.
- Environmental hazard – The solubility of constituents in the materials are low (< 0.1%), therefore it is not likely to be harmful to the aquatic environment.

MineLock opted for a Class C barrier system for the PCD. Given that the product and sand stockpiles are temporary, the decision was made not to line the stockpile areas, considering that they will only be temporary until the material is sold.

Table 8: Hazard classes and associated cut-off concentration limits

Hazard class	Cut-off value %	Comments
Acute toxicity	> 1.0	No constituents present that may cause acute toxicity

Skin corrosion	pH ≤ 2 or ≥ 8.5	pH = 8.1
Skin irritation	pH ≤ 2 or ≥ 8.5	pH = 8.1
Serious damage to eyes	> 1.0	No constituents present that may cause serious damage to eyes
Eye irritation	> 1.0	Dust may cause eye irritation but not the sand itself
Respiratory sensitization	> 1.0	Dust may cause respiratory sensitization but not the sand itself
Skin sensitization	> 1.0	No constituents present that may cause skin sensitization
Mutagenicity: Category 1 Category 2	> 0.1 > 1.0	None present
Carcinogenicity	> 0.1	None present
Reproductive toxicity	> 0.1	None present
Target organ systemic toxicity	> 1.0	No constituents present that may cause organ systemic toxicity
Hazardous to aquatic environment	> 1.0	Low leachability of constituents indicates no hazard to aquatic environment

(d) Class D Landfill:

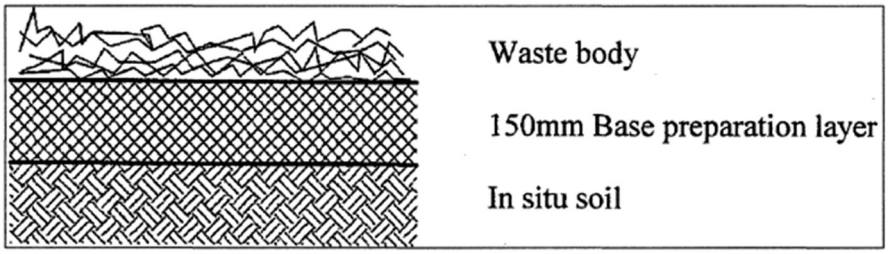


Figure 16: Class D barrier system

(c) Class C Landfill:

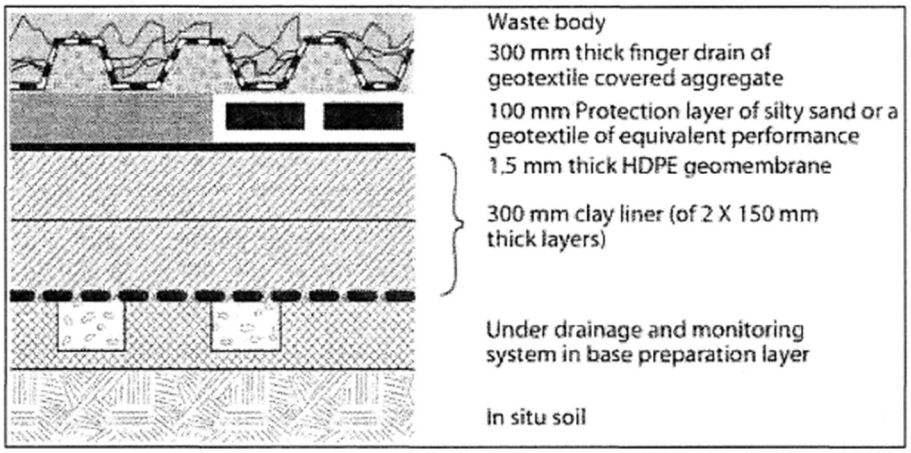


Figure 17: Class C barrier system

6. ENGINEERING DESIGN

Based on the findings from the specialist studies, the PCD and associated infrastructure were sized as an integrated system. The PCD was designed according to Best Practice Guidelines and Government Notice GN 704 as well as the NEMWA regulations of 2013, 2015 as amended in 2018 as applicable on mine waste. Figure 18 presents the general arrangement of the new PCD and the associated infrastructure for Rietfontein Plant.

6.1 Operating Procedure and Stormwater Philosophy

The PCD will collect dirty water from the site footprint area via various channels as shown in the design drawings (Appendix A) and Figure 18. The new channels divert all the water around the stockpiles and the plant area towards the PCD. All channel sizes are discussed in detail in section 6.4.

The PCD is designed and sized not to spill more than once in 50 years on average. It was decided to size the PCD for a total volume of 8000 m^3, which will result in the following approach according to the water balance study (see section 3):

- Pollution control dam capacity = 8000 m^3;
- Temporary product stockpile catchment size = 3.19 ha;
- Dust suppression = 10 m^3/day.

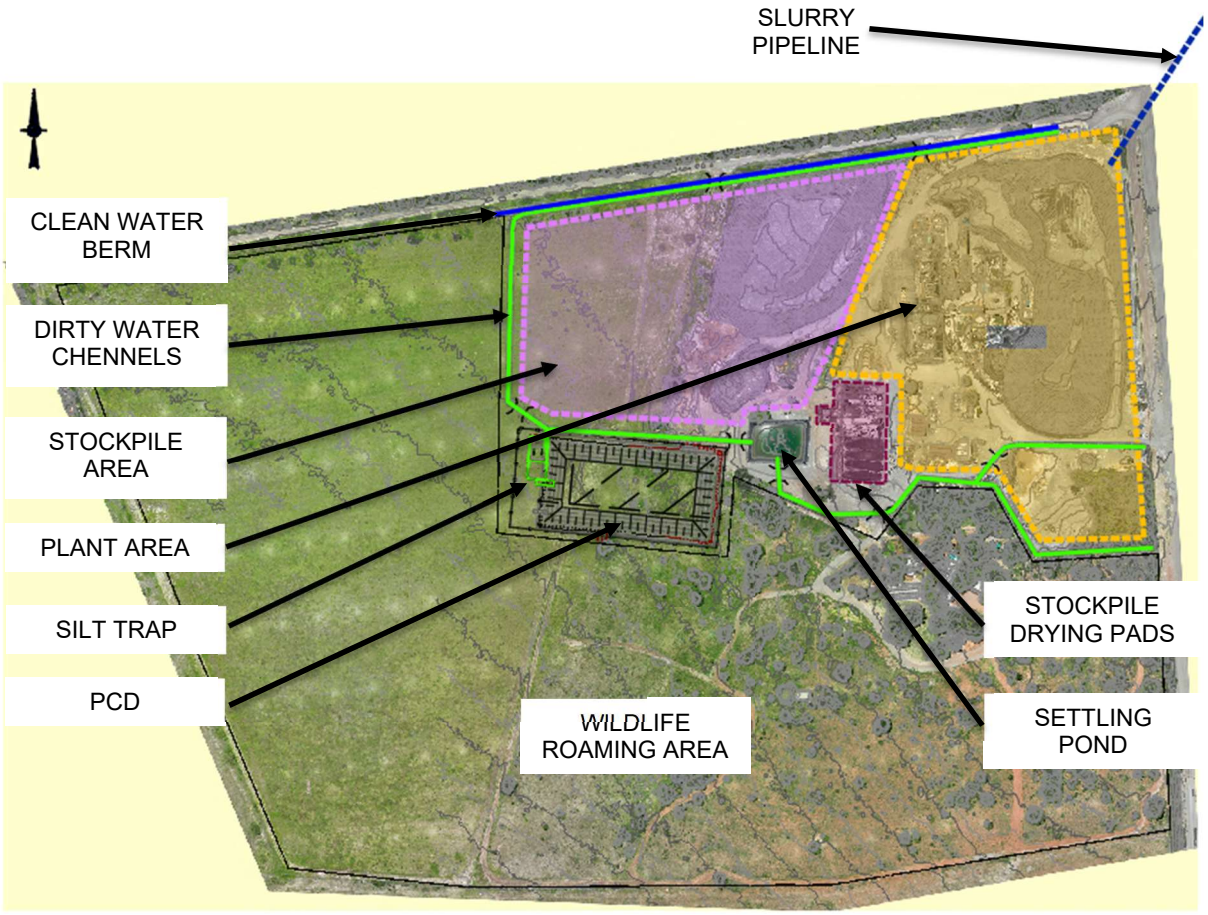


Figure 18: General arrangement of the new infrastructure and PCD

6.2 Pollution Control Dam

The following key design criteria were considered during the technical engineering design of the PCD:

- The Waste Classification on the tailings indicated a Type 3 waste, acting as a Type 4 waste. MineLock opted for a Class C barrier system for the PCD;
- Compliance with GN 704 of the South African National Water Act (requiring that the PCD may not spill more than once in 50 years on average, and not only accommodate the 50-year storm volume, refer to the stochastic modelling covered in section 3.3.2 of the report);
- GN 704 requires a minimum freeboard of 0.8 m above the spillway, which was also accounted for in the design (see design drawings in Appendix A); and
- The PCD must be maintained through regular removal of materials, such as silt, from the silt trap.

6.2.1 Capacity requirements

The PCD was sized for a capacity of 8000 m^3 as discussed in section 6.1. The PCD can be operated at a capacity of 2400 m^3, which is additional capacity above the 50 year design storm volume of 5 600 m^3.

6.2.2 PCD Embankment design and barrier system

An adjusted class C barrier system is proposed as the lining system for the PCD, consisting of the following components, see Figure 19:

PCD Slopes:

- Upstream excavation slopes into in situ soils must not be steeper than 1V:3H for vertical depths ≤ 4.0 m.
- Fill embankment side slopes must not be steeper than 1V:1.5H for heights ≤ 1.5 m, using residual norite soils (≥ G7 quality).

Compaction Requirements:

- Bulk fill to be placed in ≤ 150 mm thick layers.
- Each layer must be compacted to ≥ 93% of Modified AASHTO MDD at moisture content OMC to OMC +2%.

Dam Basin Preparation:

- Basin and upstream surfaces to be ripped to a depth of ≥ 100 mm and re-compacted to ≥ 93% of Modified AASHTO MDD before placing any layerworks or liners.

Secondary Liner:

- Non-Woven (NW) protection geotextile of at least 750g/m^2 must be installed by a specialist.
- A 1.5mm smooth HDPE geomembrane liner must be installed by a specialist.

Primary Liner:

- Cuspated sheets should be placed in between the two liners for leakage detection.
- A 2mm smooth HDPE geomembrane liner must be installed by a specialist as the final layer of the barrier system.

Anchor trenches:

- The secondary and primary liner systems should be anchored in appropriately sized anchor trenches.

The area and embankments to be lined must be free of all protrusions, stones, roots, vegetation and other materials which may be detrimental to the performance of the liner. A particle size of 3 mm diameter is permissible. All embankment preparations are to be done according to SANS-10409-2020-(Ed.-2.00).

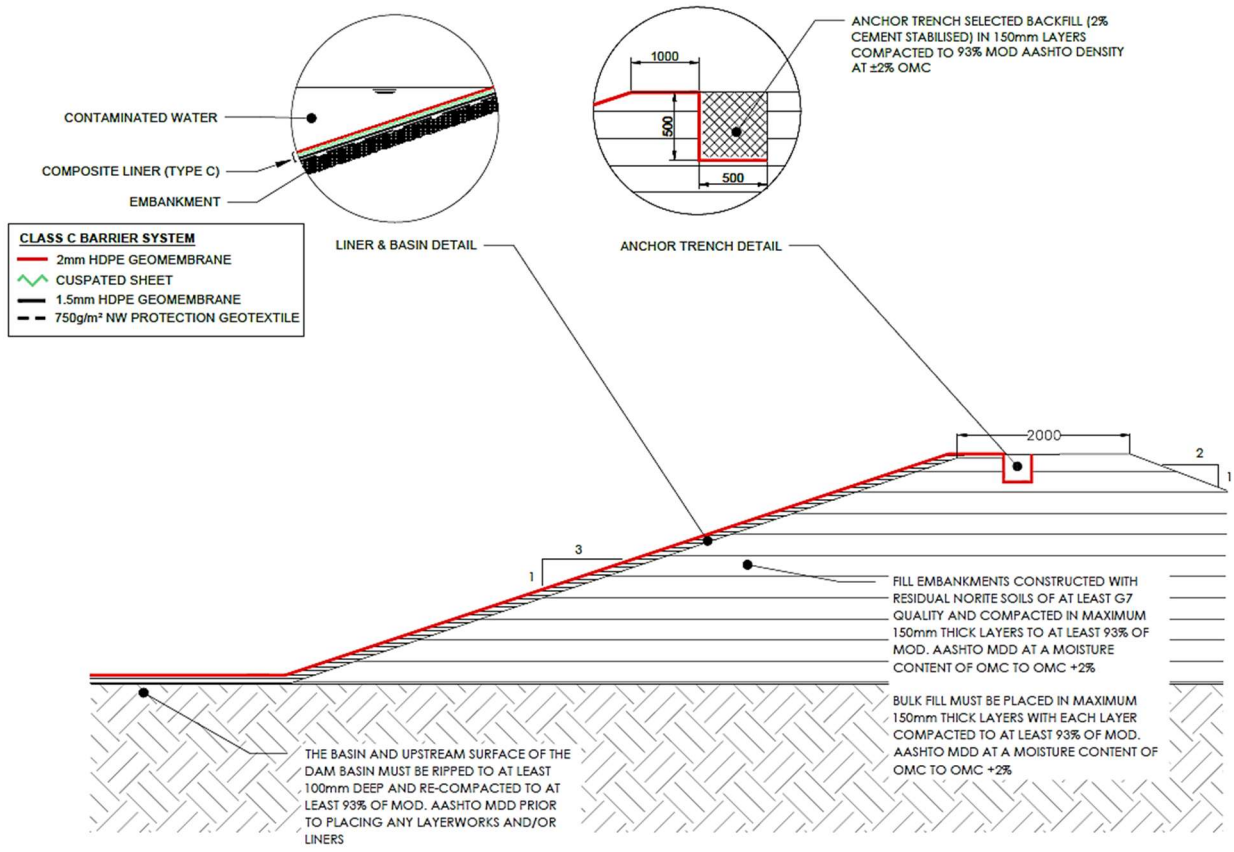


Figure 19: Embankment barrier detail of PCD

Figure 20 presents the cross section of the PCD, also see the design drawings in Appendix A.

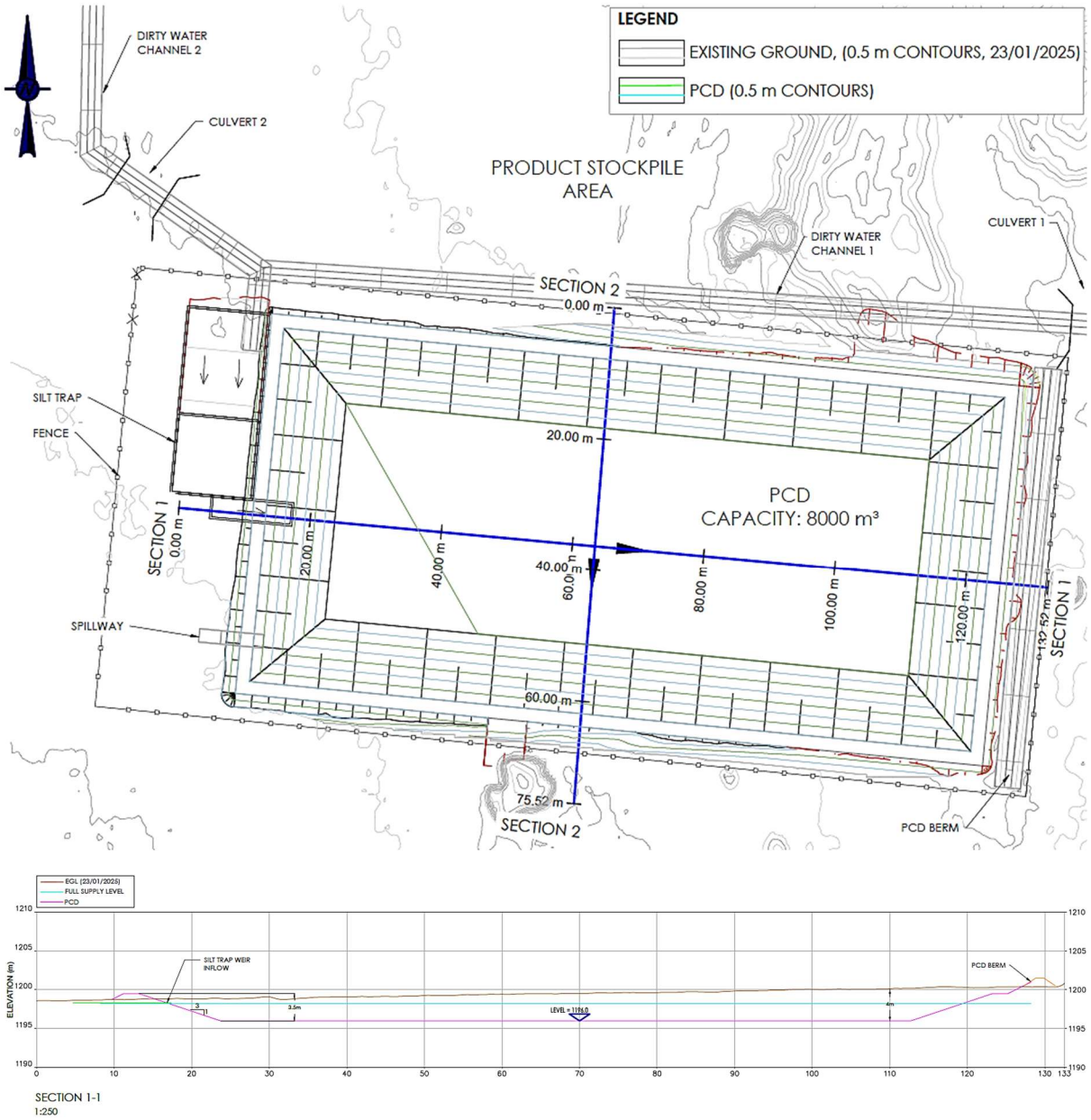


Figure 20: Cross section of the PCD

6.2.3 Service Life

Based on research work conducted by the Geosynthetics Institute in Philadelphia, USA, (Koerner, et al., 2011) a good quality HDPE geomembrane that is not exposed to UV, as depicted in this barrier system design, will have a service life of more than 106 years at 35°C.

This is based on the HDPE geomembrane complying with the requirements of specification GRI-GM13 (Rev 15 – 2019). This service life is considerably longer than the expected Life of Mine of the PCD which is assumed to be in the range of 30 years.

6.2.4 Anchor trench design

As can be seen in the drawings (Appendix A) the outer edges of the geosynthetic materials are to be anchored in the same anchor trench at the top of the slope.

A stability calculation was carried out to confirm that sliding failure of the liner system will not occur. The anchor trench was designed with the methodology outlined in “Designing with Geosynthetics – 6th edition – Robert M Koerner” (Koerner, 2012). A cement stabilised soil is specified as the backfill material within the anchor trench. The anchor trench is to be backfilled in 150 mm layers and compacted to 93% MOD AASHTO at ± 2% OMC.

The anchor trench is 0.5 m deep and 0.5 m long, with a 1 m gap between the anchor and the crest line, see Figure 21. The factor of safety is calculated to be 8.66 which can be seen in Appendix E.

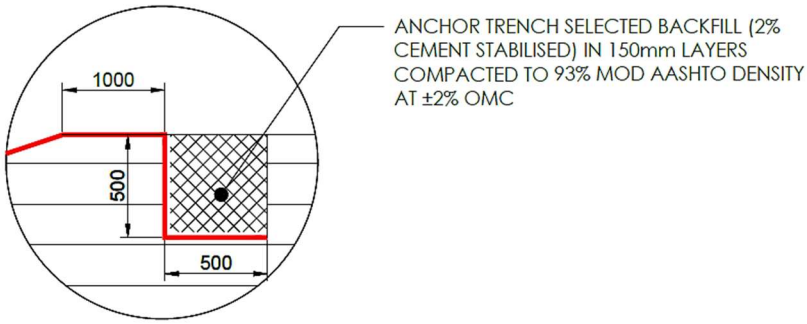


Figure 21: PCD anchor trench detail

6.2.5 Leakage Rates

For the PCD it is necessary to determine the action leakage rate (ALR) for the primary leakage management system, in addition to the estimated leakage through the secondary geomembrane liner.

The ALR is defined as the amount of leakage that would occur through the geomembrane liner, based on a number of holes per hectare. In addition the ALR must not be greater than the flow capacity of the leakage and drainage system, with a factor of safety of at least 2 applied (Jordan & Ruhl, 2017). This includes the leakage drainage layer and outlet pipe(s).

In the case of a double liner, the rate of leakage through the primary liner (which can be measured thanks to the leakage detection layer) can be calculated using the equations presented below.

The leakage rate was calculated considering a geomembrane resting on a permeable medium (leakage detection layer) by using Bernoulli’s equations (Giroud, 1984).

A geomembrane liner at end of installation with construction quality assurance can be expected to have 4 holes per hectare with a hole area of 4 mm² (Giroud, 2016). This is not far from the recommendation made in 1989 by Giroud & Bonaparte (Giroud & Bonaparte, 1989): 2.5 holes per hectare with a hole size of 3.1 mm² (i.e. a diameter of 2 mm).

It is important to note that the rate of leakage through the primary liner is not the rate of leakage into the ground. In the case of a double liner, the determination of the rate of leakage into the ground requires three steps: (i) determination of the rate of leakage through the primary liner; (ii) analysis of the flow in the leakage detection layer and determination of the hydraulic head on the secondary liner; and (iii) determination of the rate of leakage through the secondary liner, which is the rate of leakage into the ground (Giroud, 2016).

Using the above methodology, the ALR for the PCD was calculated as follows:

- Primary Leakage drainage system ALR (1 m depth) 2 847 ℓ/ha/day
- Primary Leakage drainage system ALR (2.7 m depth) 4 678 ℓ/ha/day
- Primary Leakage drainage system capacity 4 704 ℓ/ha/day
- Primary Leakage drainage system ALR (2.7 m depth) 3 483 ℓ/PCD/day

For the secondary liner, the estimated leakage rate would be **150 ℓ/PCD/day**.

The leakage rates were considered in the plume modelling for the various PCD's as summarised in section 7, see full Groundwater Impact Study in Appendix H.

6.2.6 Total tensile strain in geomembrane

The contributors to the total tensile strain in the geomembrane are listed as follow:

- Inside embankment slope of the dam (1 in 3 in the design);
- Maximum depth of water pressure;
- Interface between geotextile and embankment; and
- Interface between geomembrane and geotextile.

Considering these factors, it is important to note that this may not exceed 3% as per DWS requirements.

The following anticipated conditions may be suggested/recommended by the appropriate authorities:

- Interface shear strength testing of the critical liner interface (likely the internal shear strength of the geotextile in contact with geomembrane) under the site specific loading and saturation conditions.
- Estimation of the total strain consisting of localised strain induced to loading of the protection layer on the PCD. It is suggested that a trial pad be implemented on site with the recommended design and loaded to the expected total load to demonstrate conformance to the limitation of strain requirement.

6.2.7 Subsoil Drainage Design

The subsoil drainage system consists of a collector drain collecting any water from the interception drains and routing it towards the sump manhole for frequent monitoring and dewatering, see Figure 22. The collector and interception drains consist of 110 mm (perforated) and 160 mm (perforated) pipes respectively, as shown in Figure 23 and Figure 24. The pipes are then encased in ±19mm diameter washed stone and boxed with a 210 g/m² filtration geotextile. Figure 25 presents the sump manhole detail for the PCD. By performing a provisional pipe flow calculation, it is confirmed that the pipeline can accommodate 64 400 l/hr.

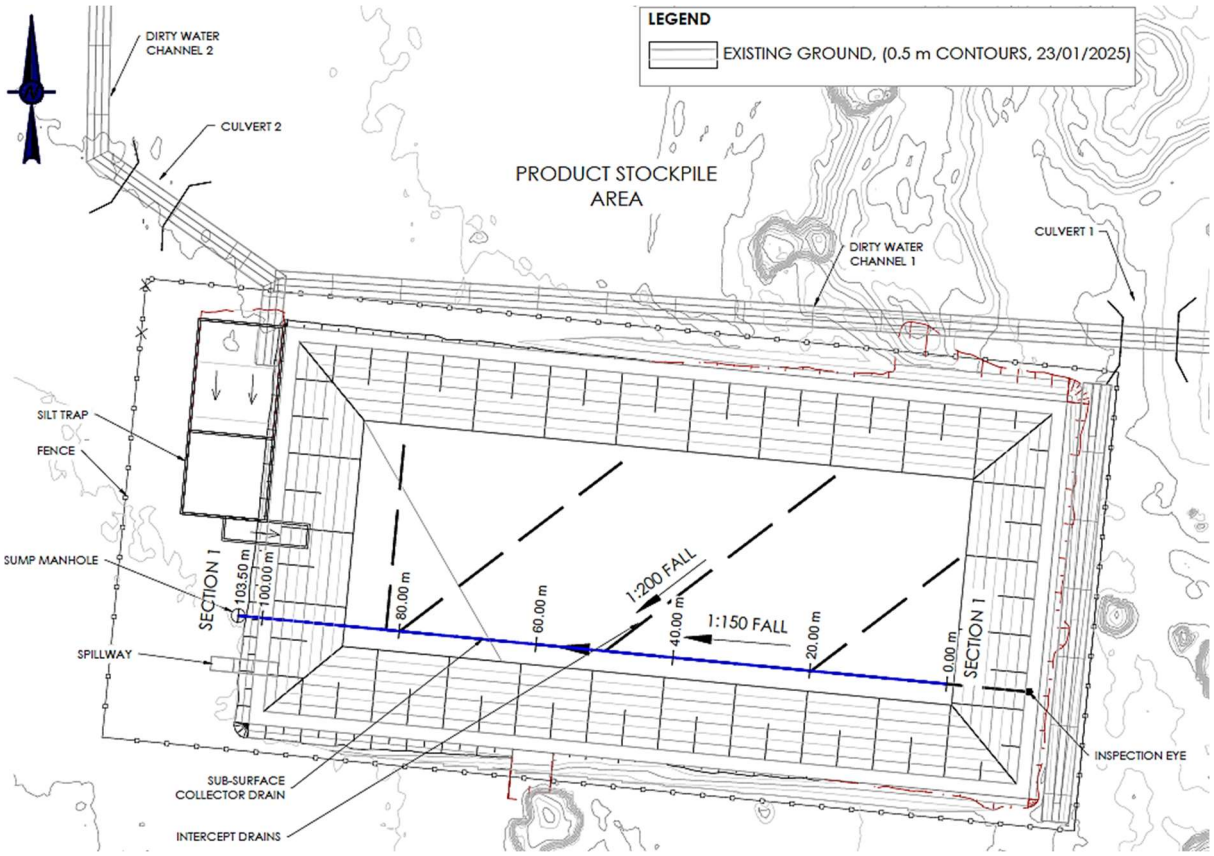


Figure 22: Subsoil drain locations

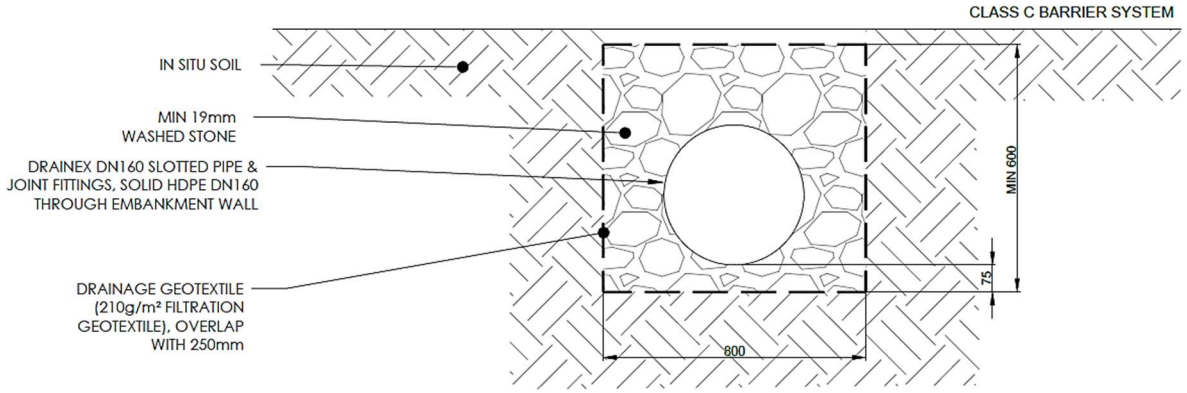


Figure 23:Typical cross sectional view of the collector drain

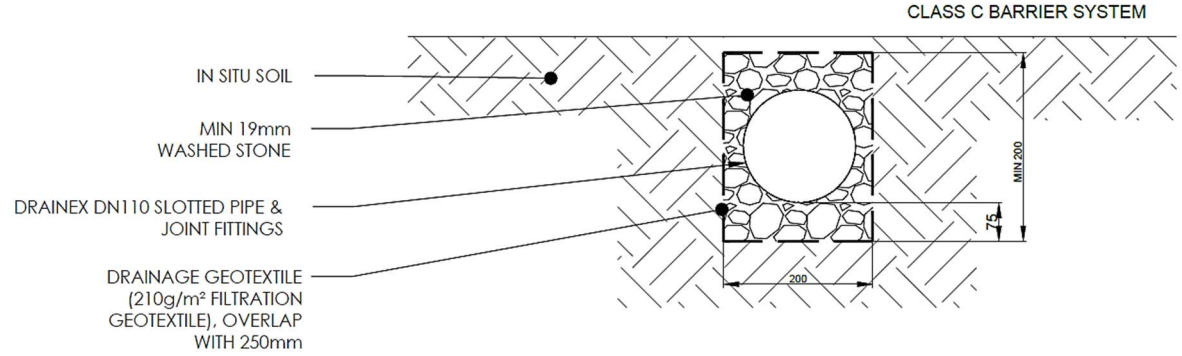


Figure 24: Typical cross sectional view of the intercept drains

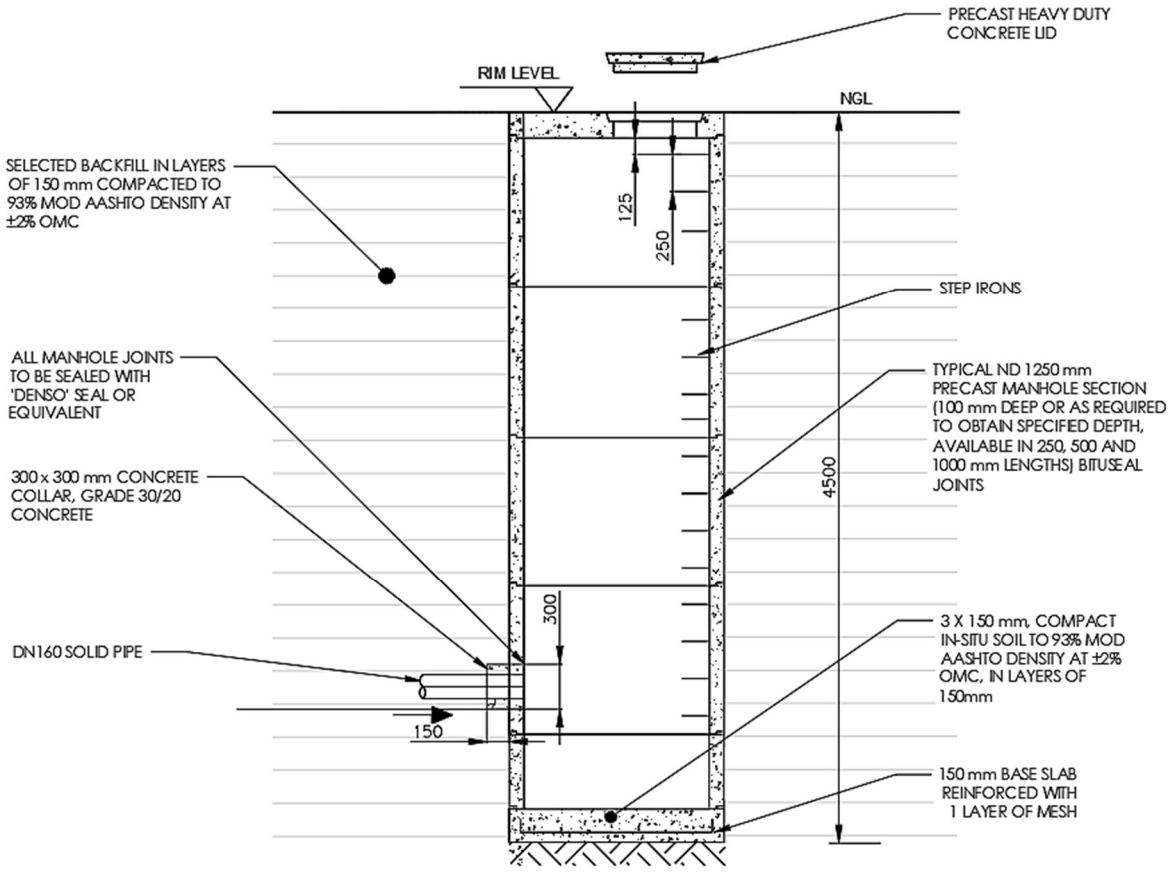


Figure 25:Sump manhole details for the PCD

6.2.8 Leakage detection sump

Due to the absence of suitable clay material on site, it was proposed that a double liner system be installed for the PCD to ensure no leakage occurs. The cuspated sheets within the primary liner system will collect any leakage, which is then directed to a sump located beneath the liner system. Any water detected in the sump will be collected in the manhole (the same manhole used for the subsoil drains). This pipe should remain dry at all times. If any water is detected from the leakage detection pipe, the dam must be emptied, and the liner system inspected for potential leaks. The location of the leakage detection sump is shown in Figure 26. The sump consists of the following components (see Figure 27):

- The sump is proposed to be 5x5 m in plan and approximately 0.5 m deep.
- The base of the sump is to be covered with a 100 mm no-fines concrete slab.
- The sump should be filled with 19 mm washed stone.
- The secondary liner system will follow the bottom contour of the sump.
- The primary liner system will be placed over the sump and continue up the embankment of the PCD.
- The leakage detection pipe will connect to the manhole at a maximum gradient of 1:100.

The detailed drawings are provided in Appendix A.

It is proposed that the drainage pipe and pump for the PCD be located near the manhole, as shown in Figure 26.

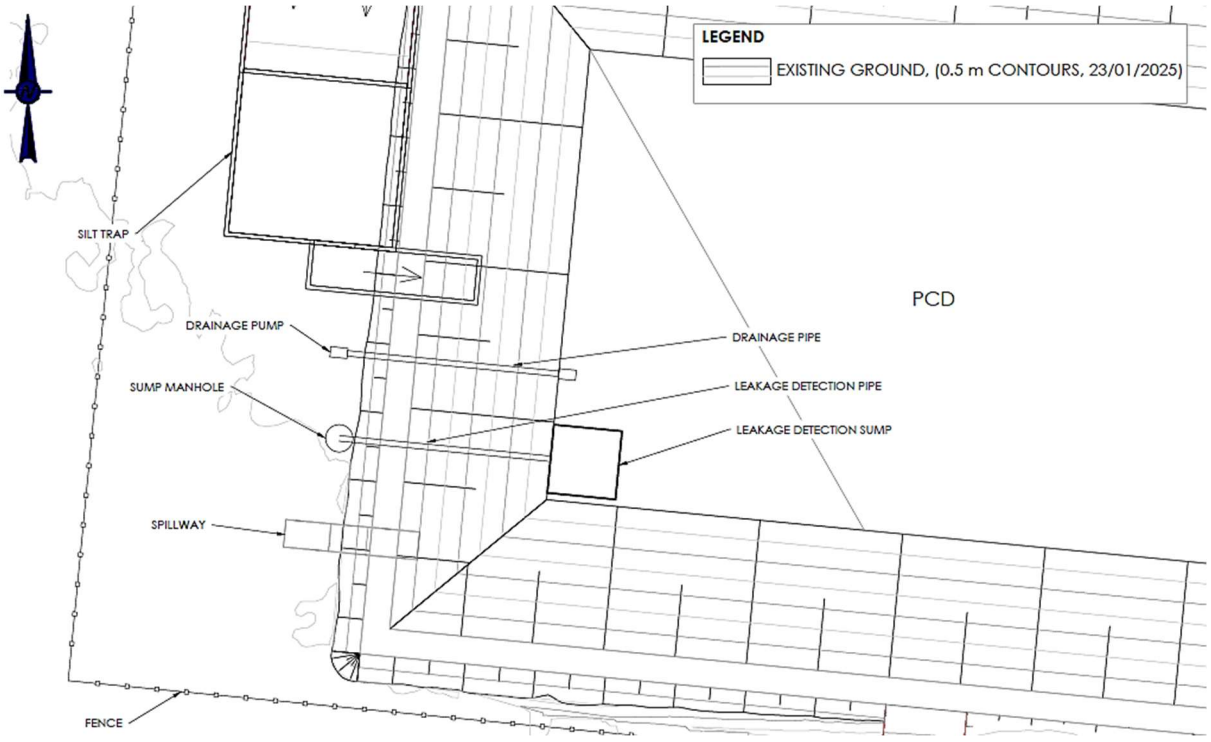


Figure 26: Location of the leakage detection sump

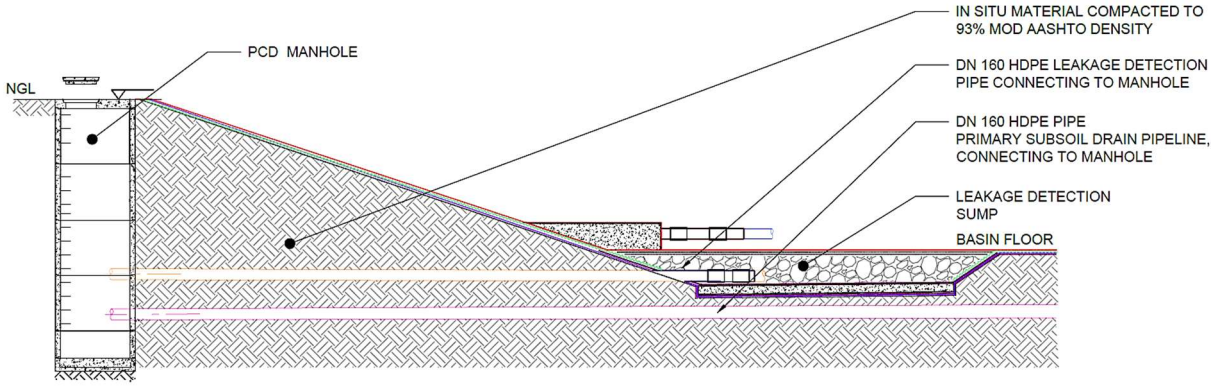


Figure 27: Typical cross section of the leakage detection sump and pipe outflow into the PCD manhole

6.2.9 Emergency spillway design

The emergency spillway was sized according to the required flow of 2.6 m³/s (100 year flood peak), using the broad crested weir formula as shown below (see all calculations in Appendix E). The concrete lined rectangular spillway has a base width of 2 m and a minimum depth of 1.3 m (minimum freeboard of 800 mm), see Figure 28. The outlet structure of the spillway will consist of a reno mattress floor, 300 mm thick, which will be lined with a 550 g/m^2 protection geotextile for erosion control, see Figure 29.

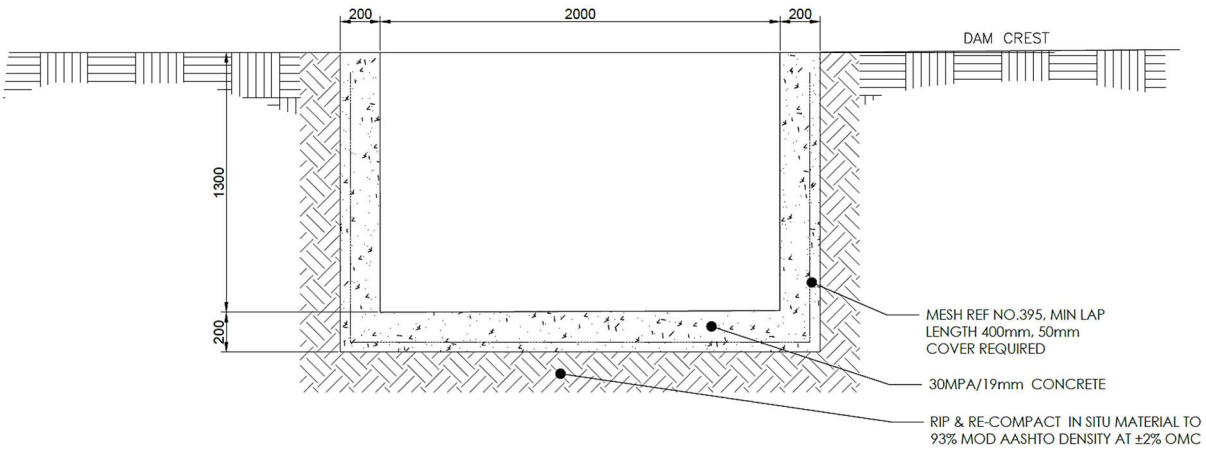


Figure 28: Proposed detail of the spillway

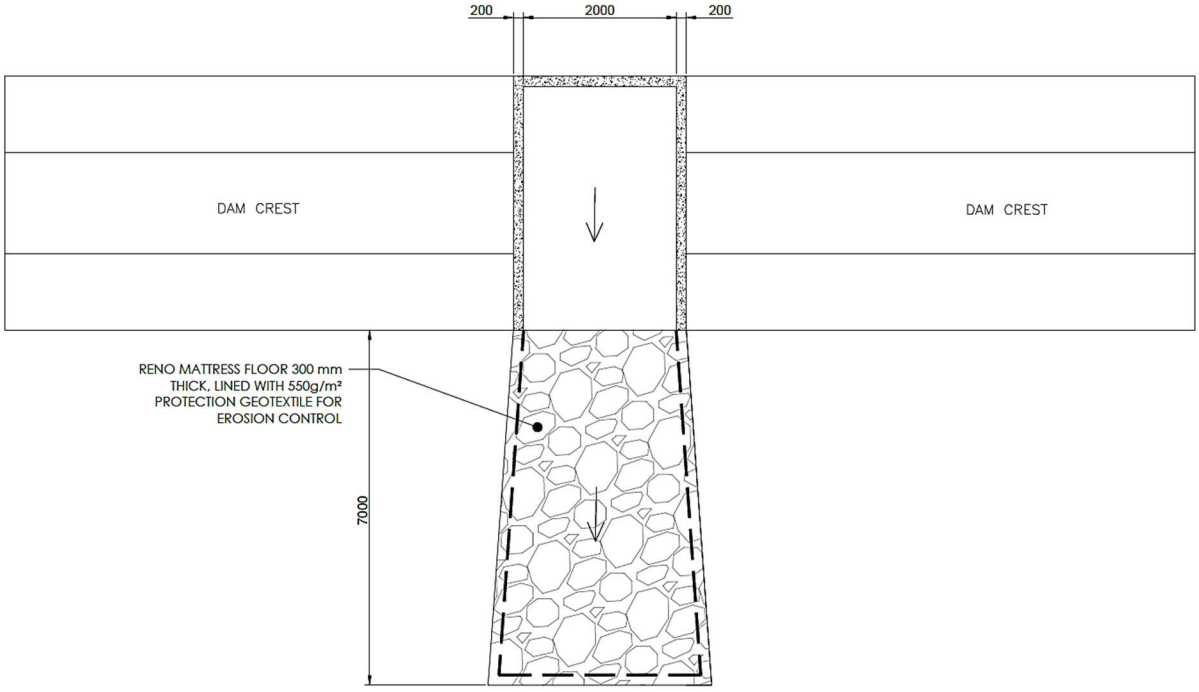


Figure 29: Proposed detail of the spillway outlet structure

6.3 Silt Trap Design

6.3.1 Particle settling velocity

A particle density of 1100 kg/m³ was provided by the client. The settling velocities for different particle sizes using the Stokes law were computed and reflected in Figure 30.

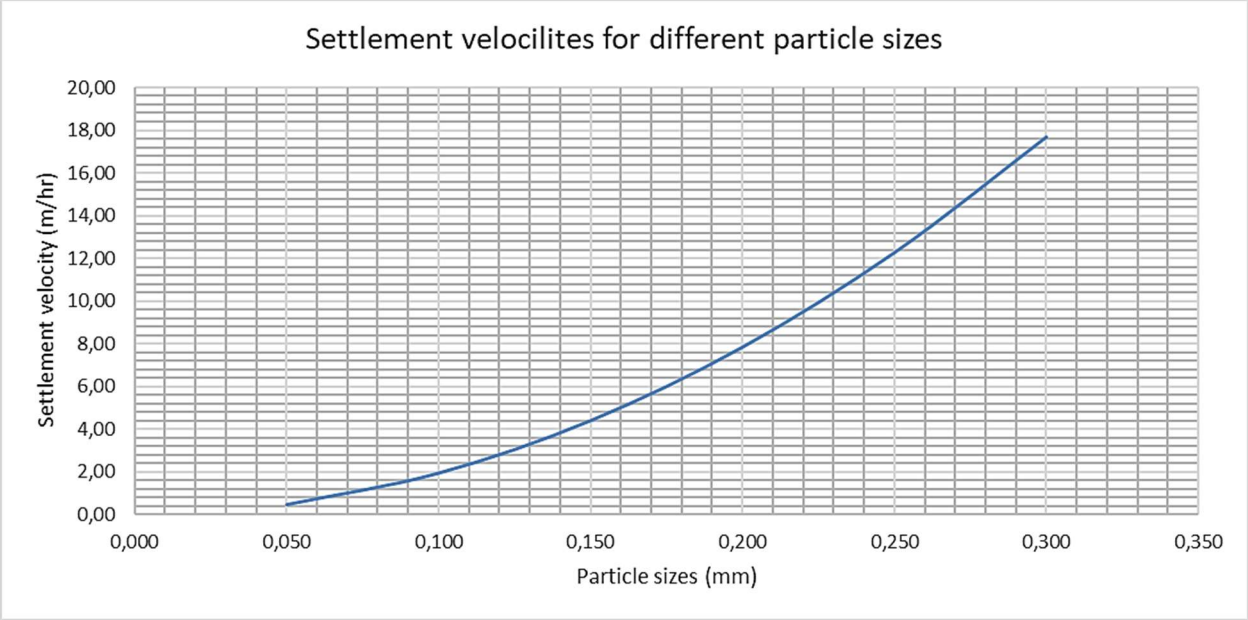


Figure 30: Settlement velocities for different particle sizes

6.3.2 Silt trap sizing

The silt trap assessment was based on the areas' 1:2 year flood event. A flow rate of 0.78 m^3/s was calculated using the Rational Method for the entire footprint area which the silt trap needs to cater for.

A silt trap with the shape as can be seen in Figure 31 below is proposed. The rectangular shaped silt trap will give access with a 1:8 sloped ramp into the silt trap for cleaning purposes. The silt trap basin floor is 1.55 m deep, 12 m wide and 12 m in length. The total capacity of the silt trap is 400 m^3. Dirty water channel 1 and 2 will flow into the silt trap with a settling distance longer than 25 m to the weir which will flow into the PCD.



Figure 31: Silt trap layout plan

Given this, particles larger than 0.1 mm will settle during this runoff event as indicated in Figure 32. A weir of 1.2 m in height and 3 m in width will be introduced at the silt trap as the overflow into the proposed PCD. All detailed drawings for the silt trap can be seen in Appendix A.

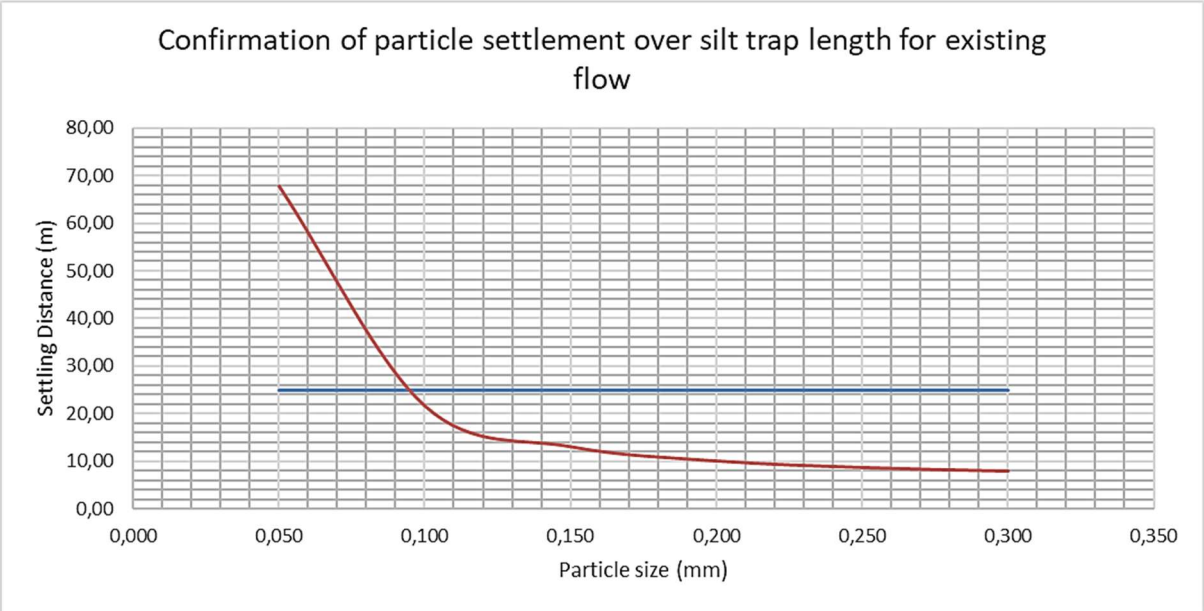


Figure 32: Confirmation of particle settlement over silt trap length

6.3.3 Construction of silt trap

- The silt trap must not be founded on or within reworked residual norite soils (turf material).
- Reworked residual norite soils must be completely removed from the entire footprint of the silt trap.
- The foundation must be established within deeper, undisturbed residual norite soils.
- Any backfill below the silt trap must:
  - Be of at least G7 quality;
  - Be placed in maximum 150 mm thick layers;
  - Be properly compacted.
- The concrete floor slab of the silt trap should be founded directly on a minimum of two 150 mm thick layers of compacted G5 material.

6.4 Dirty Water Channels Design

The channels required were identified and sized according to the topography, activities and respective catchment sizes. Refer to Appendix A for the related technical design drawings and Appendix E for the design calculations. Figure 18 shows the general arrangement of the channels for the site which will be discussed in detail in this section.

6.4.1 Catchment delineation

The catchments were delineated (see Figure 33) using survey point data, which was carried out by the client on 23 January 2025. Catchments 1 to 4 are 50105 m^2, 23010 m^2, 12050 m^2 and 3773 m^2, respectively. All the dirty water channels and the clean water diversion berm are indicated in the layout below. All the dirty water channels direct water towards the silt trap which will then flow into the PCD.

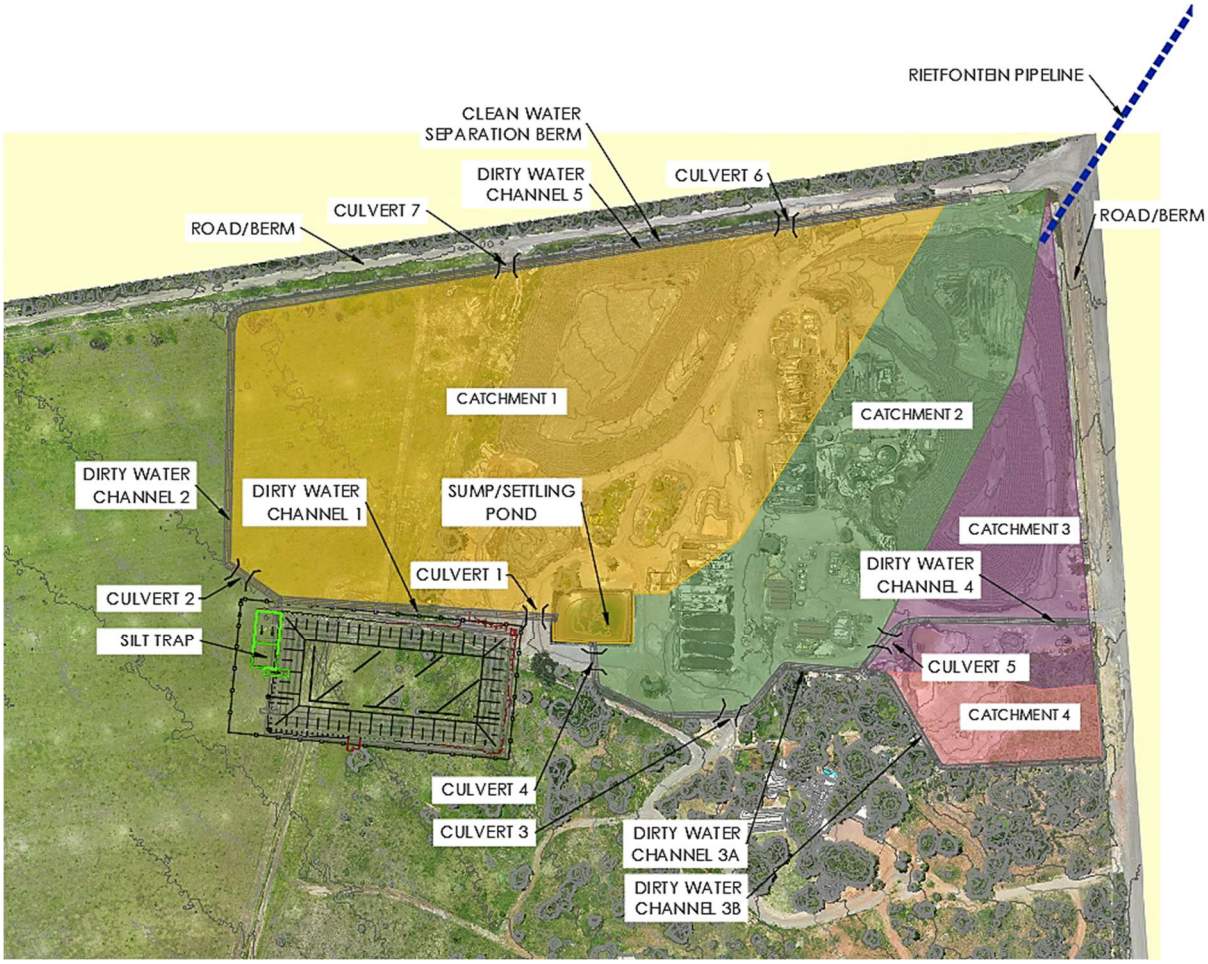


Figure 33: Catchment delineation

6.4.2 Peak rainfall

Daily rainfall data was sourced from the CCWR (Computing Centre for Water Research, Natal University) rainfall database (gauge number 0511672 – Klipfontein). The gauge is located approximately 5.8 km north of the operations. The CCWR data that was used contains daily records and patched records between November 1928 and July 2000 and is considered representative of the rainfall data on site. The peak 24-hr rainfall depths are presented in Table 1, see section 3.3.3.

6.4.3 Flood peak calculation and channel sizing

The mean annual precipitation (MAP) for this site is 635 mm. This data was interpolated to allow for the simulation of a 24 hour storm event with a return period up to 50 years.

The Rational Method was used to determine the peak floods for the simulated 24 hour storm event. The sixth edition of the Drainage Manual was used to determine the runoff coefficients (Kruger, Drainage Manual Sixh Edition, 2013). The flow depth in the channels were calculated with the Mannings open channel flow equation. A manning n of 0.011 was used for all the dirty water channels as it will be HDPE lined channels. A 0.3 m freeboard was used to allow for wave action and flow surges in the channels (Bosman, Basson, Tente, & Basson, 2011).

All the dirty water channel velocities were below 8 m/s, which means HDPE lined channels

will be suitable for this design. Refer to Table 9 for a summary of the channel sizes required for this design.

Table 9: Catchment and channel sizing for all channels

Channel	Catch-ment area	Area (m²)	Length (m)	50-yr flood peak (m³/s)	Max velocity (m/s)	Channel depth (m)	Flow type at max flow velocity
Dirty Water Channel 1	C1 + C2 + C3 + C4	88 938	670	0,94	2,36	0,70	Supercritical flow
Dirty Water Channel 2	C1	50 105	420	0,99	2,35	0,70	Supercritical flow
Dirty Water Channel 3A	C2 + C3 + C4	38 833	600	0,82	2,20	0,60	Supercritical flow
Dirty Water Channel 3B	C4	3 773	420	0,09	1,31	0,40	Supercritical flow
Dirty Water Channel 4	C3	12 050	330	0,26	1,71	0,50	Supercritical flow
Dirty Water Channel 5	C1	50 105	425	1,16	2,65	0,70	Supercritical flow

6.4.4 Typical details of channels

The following is recommended for the founding and construction of the dirty water channels:

- Suitably sized and shaped channels must be excavated with side slopes not steeper than 1(v):1.5(h) for depths not exceeding 800 mm and all vegetation and roots must be removed from within the footprint of the channel.
- All turf material should be removed. Rip and re-compacted soil to 93% Mod. AASHTO at +-2% OMC.
- The inside of the channel must be covered / lined with a protection geotextile (750 g/m^2) and an impermeable barrier such as a HDPE type gemembrane (2mm HDPE geomembrane). The liner must be anchored in an anchor trench, 500 x 500 mm.

The proposed detail of dirty water channels 1 and 2 can be seen in Figure 34. The proposed detail of dirty water channels 3A and 3B can be seen in Figure 35 and Figure 36 respectively. Figure 37 presents the proposed detail of dirty water channel 4. Figure 38 shows the proposed detail of dirty water channel 5 and a clean water separation berm to ensure all clean water

coming from the north is diverted away from the site. All design drawings can be seen in Appendix A and all channel calculations can be seen in Appendix E.

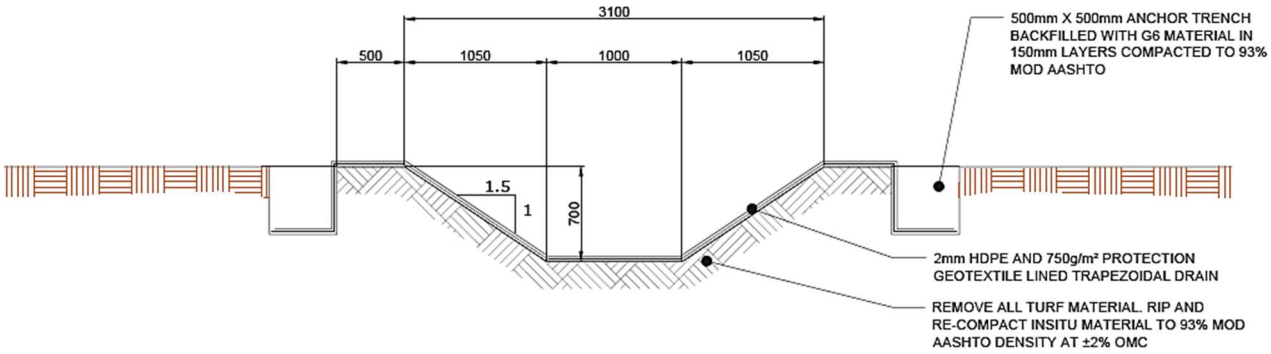


Figure 34: Proposed detail of dirty water channels 1 and 2

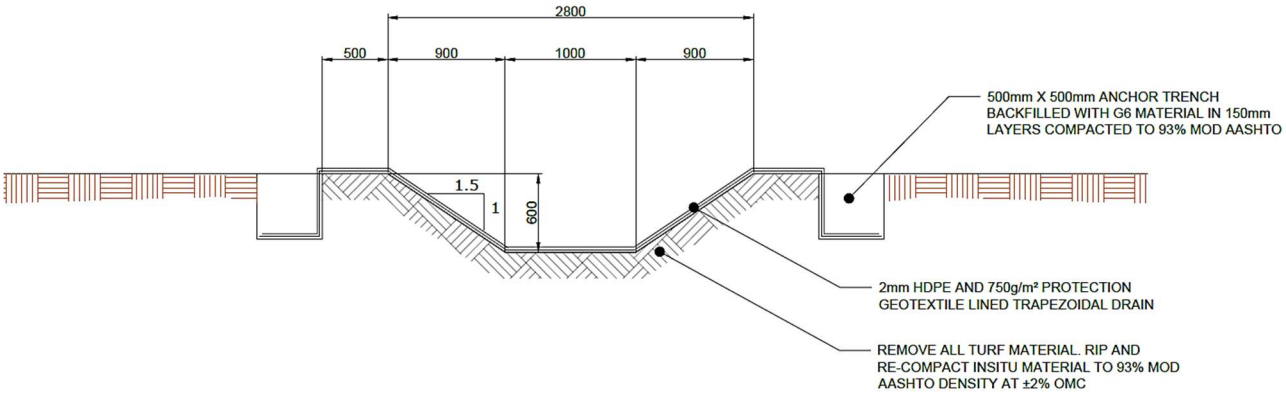


Figure 35: Proposed detail of dirty water channel 3A

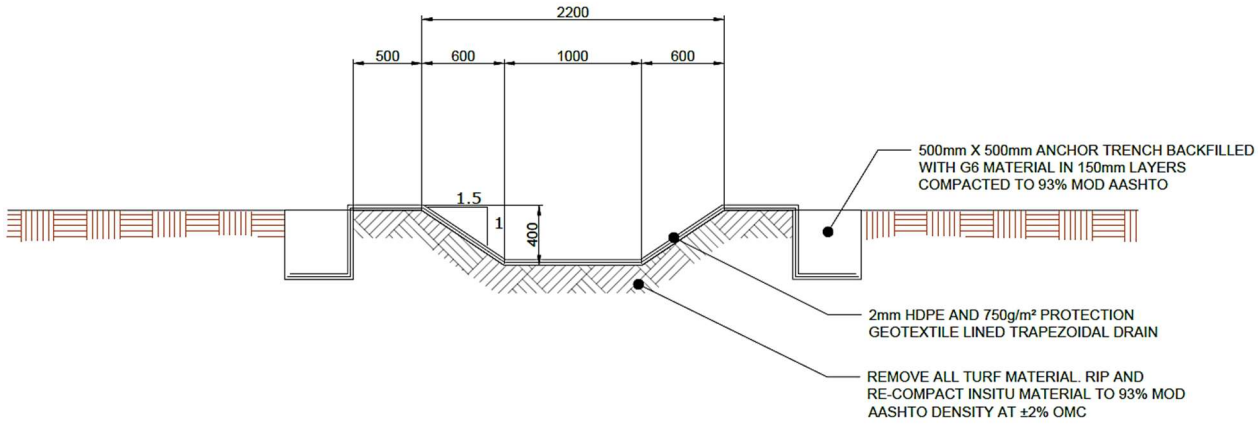


Figure 36: Proposed detail of dirty water channel 3B

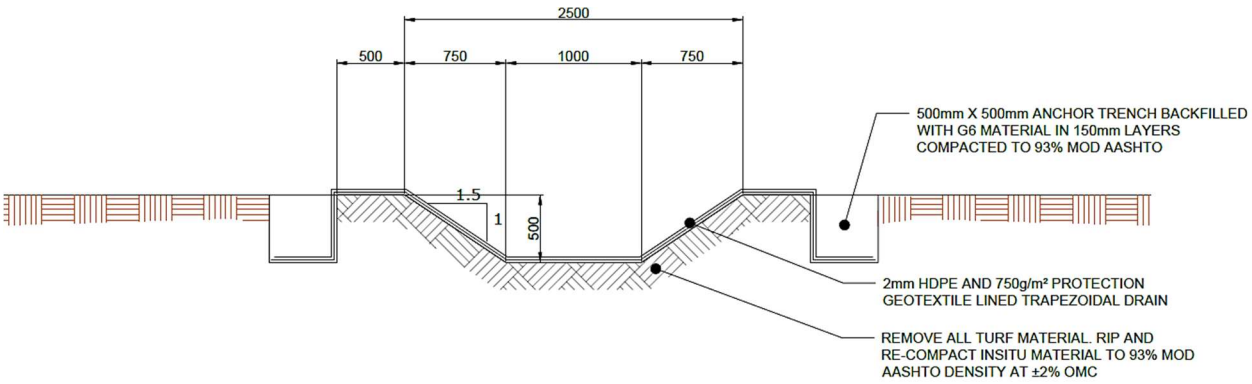


Figure 37: Proposed detail of dirty water channel 4

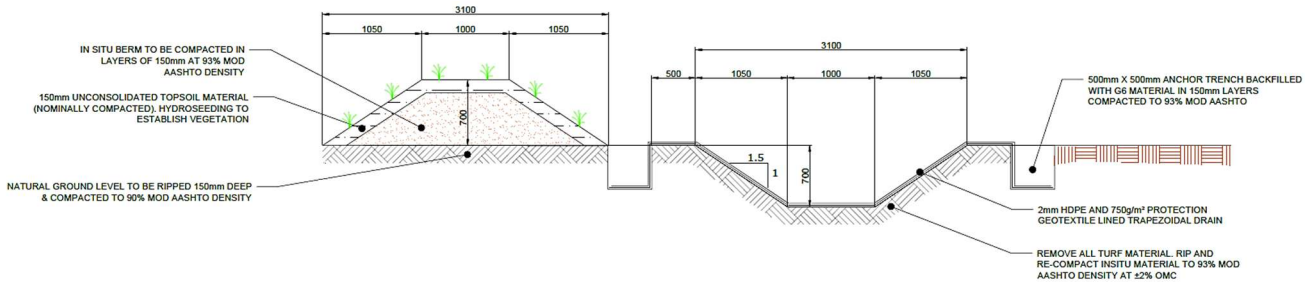


Figure 38: Proposed detail of dirty water channel 5 and clean water separation berm

6.5 Culvert Designs

It is proposed to install seven culverts along the dirty water channels to provide access to various areas of the Rietfontein Plant site. The locations of all proposed culverts are illustrated in Figure 39. Rectangular portal culverts are recommended and designed to accommodate Class 1 loading (SANS 986). The culvert sizes are detailed in

Table 10 and

Culvert Name	Channel Associated with Culvert	Culvert Width (m)	Culvert Heigth (m)	Culvert Length (m)
Culvert 1	Dirty Water Channel 1	0,75	0,75	10
Culvert 2	Dirty Water Channel 2	0,75	0,75	10
Culvert 3	Dirty Water Channel 3A	0,75	0,6	10
Culvert 4	Dirty Water Channel 3A	0,75	0,6	10
Culvert 5	Dirty Water Channel 4	0,75	0,45	10
Culvert 6	Dirty Water Channel 5	0,75	0,75	10
Culvert 7	Dirty Water Channel 5	0,75	0,75	10

Table 11 outlines the wingwall units required at each portal culvert's inlet and outlet. All design calculations are provided in Appendix E, and detailed drawings can be found in Appendix A.

All culvert installations must comply with the requirements of SANS 1200.

Culvert Name	Channel Associated with Culvert	Culvert Width (m)	Culvert Heigth (m)	Culvert Length (m)
Culvert 1	Dirty Water Channel 1	0,75	0,75	10
Culvert 2	Dirty Water Channel 2	0,75	0,75	10
Culvert 3	Dirty Water Channel 3A	0,75	0,6	10
Culvert 4	Dirty Water Channel 3A	0,75	0,6	10
Culvert 5	Dirty Water Channel 4	0,75	0,45	10
Culvert 6	Dirty Water Channel 5	0,75	0,75	10
Culvert 7	Dirty Water Channel 5	0,75	0,75	10

Table 10: Rectangular portal culvert design specifications

Table 11: Wingwall units for portal culvert sections at Rietfontein Plant

Culvert Name	Culvert Width (m)	Culvert Heigth (m)	Wingwall Units for Portal Culvert Sections		
			Code	Series / Size	Mass (Kg)
Culvert 1	0,75	0,75	S2	675-900	2100
Culvert 2	0,75	0,75	S2	675-900	2100
Culvert 3	0,75	0,6	D1	300-600	1130
Culvert 4	0,75	0,6	D1	300-600	1130
Culvert 5	0,75	0,45	D1	300-600	1130
Culvert 6	0,75	0,75	S2	675-900	2100
Culvert 7	0,75	0,75	S2	675-900	2100



Figure 39: Proposed culvert locations

6.6 Product Stockpile Area

As discussed in section 5, the waste classification of the temporary product stockpiles is Type 4, which requires a Class D barrier system. The location of the product stockpile area can be seen in Figure 40.

Recommended base preparation of the temporary product stockpile area:

- Remove the top 150 mm of topsoil, including roots and plant matter, and stockpile it for future landscaping.
- Excavate and remove an additional 450–500 mm of black turf soils to spoil, leaving ~300 mm in place.
- Loosen/scarify the surface of the remaining black turf layer.
- Compact to ≥93% of Modified AASHTO MDD.
- Stockpiles can be founded directly on this thin, compacted soil layer, providing both groundwater protection and greater stability.



Figure 40: Location of the prodict stockpile area

6.7 Settling Pond

The settling pond collects water from channels 3A, 3B, and 4, which flows into channel 1, and then discharges into the silt trap before reaching the PCD. It is proposed that the settling pond be lined with 150 mm cement-stabilised soil-filled geocells to facilitate easier cleaning and maintenance. Regular cleaning of the settling pond is recommended, especially after rainfall events, to ensure its capacity is not compromised and to prevent unnecessary sediment from entering the PCD. Figure 41 shows the location of the settling pond.



Figure 41: Location of the settling pond

6.8 Slurry Pipeline River Crossing Design

As discussed in section 2, around 25% of the material processed will be slurry which will be transported via two slurry pipelines back to RCM. Two return water lines will also run between Rietfontein Plant and RCM. Figure 42 shows the location of the slurry and return water pipelines running from the Rietfontein Plant to RCM. From the wetland delineation study two streams were identified along the pipeline route. The 50 and 100-year floodlines can be seen in Figure 42, for the stream crossings (intersections 1 and 2). The pipeline design report submitted by the client can be seen in Appendix F.

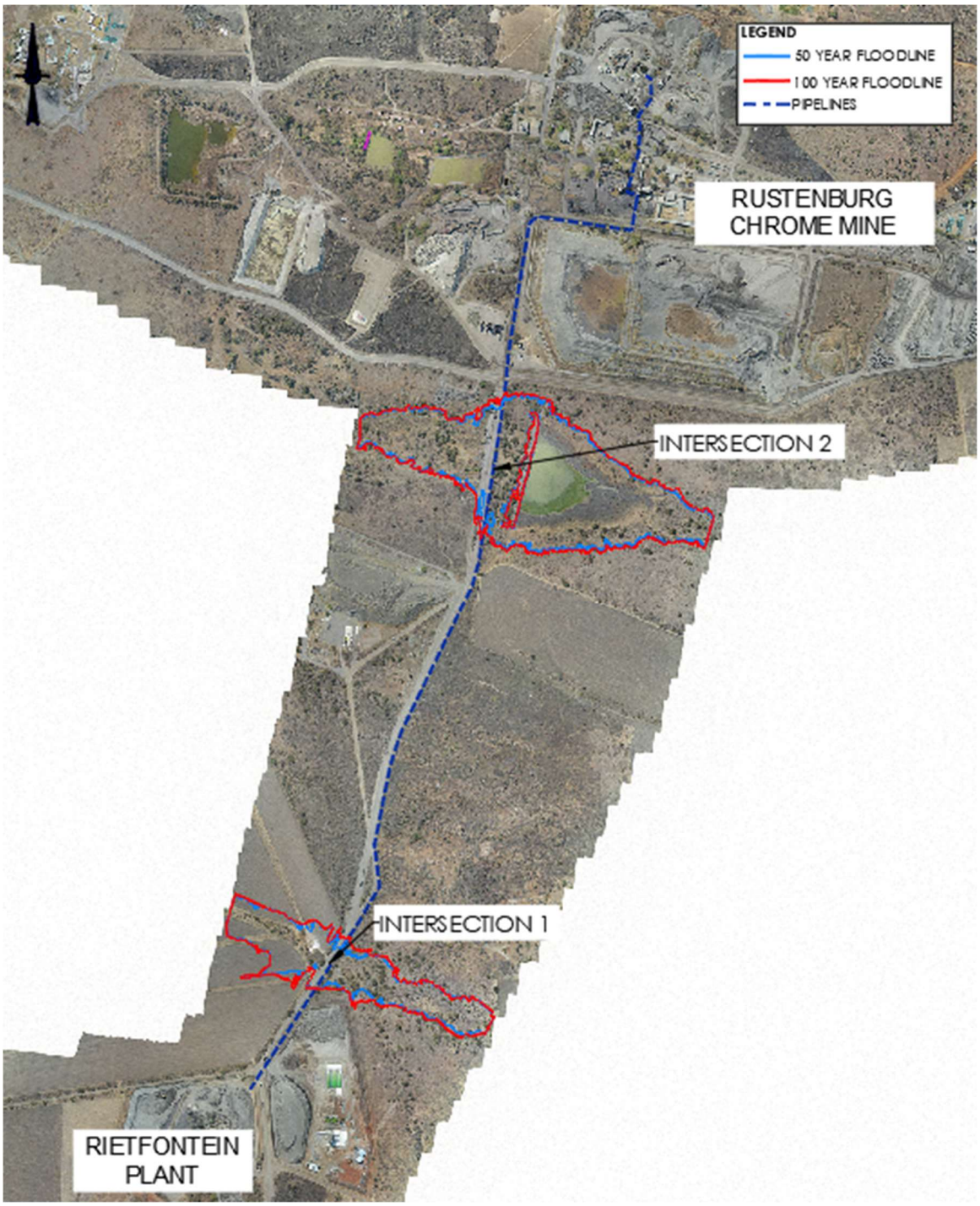


Figure 42: Location of slurry and water pipelines and 1:50 & 1:100 year floodline delineation

6.8.1 Hydrology

The flood peaks were estimated using the Rational Method 3 (Kruger, The South African National Roads Agency SOC Limited Drainage Manual, 6th Edition, 2013).

A triangular hydrograph was generated by making use of the flood peak and Time of Concentration calculated from the Rational Method to be simulated within the HEC-RAS 6.5 software. The flood peaks used are summarised as follows:

Table 12: Flood Peaks

Reach description	50-yr flood peak (m^3/s)	100-yr flood peak (m^3/s)
Rietfontein & RCM Pipeline	42	57

6.8.2 Hydraulics

The backwater analysis was performed using HEC-RAS 6.5 by performing a 2D analysis. The survey was provided by the client, which was conducted on 23 January 2025, with 0.5m contours.

The landcover was sourced from the 2022 South African National Land Cover database. The Mannings n values were appropriately updated according to vegetation found on site.

6.8.3 River crossings

The intersections with the floodlines and the 500m buffer zone along the pipeline route was observed. The location of the intersections can be seen in Figure 43.

Figure 44 show the water depths of the 50 and 100-year floodlines along the length of intersection 1. As can be seen from Figure 44, the maximum height at which the 1:100 year flood intersects with the pipelines is approximately 0.70 meter for intersection 1.

Figure 45 show the water depths of the 50 and 100-year floodlines along the length of intersection 2. As can be seen from Figure 45, the maximum height at which the 1:100 year flood intersects with the pipelines is approximately 0.46 meter for intersection 2.

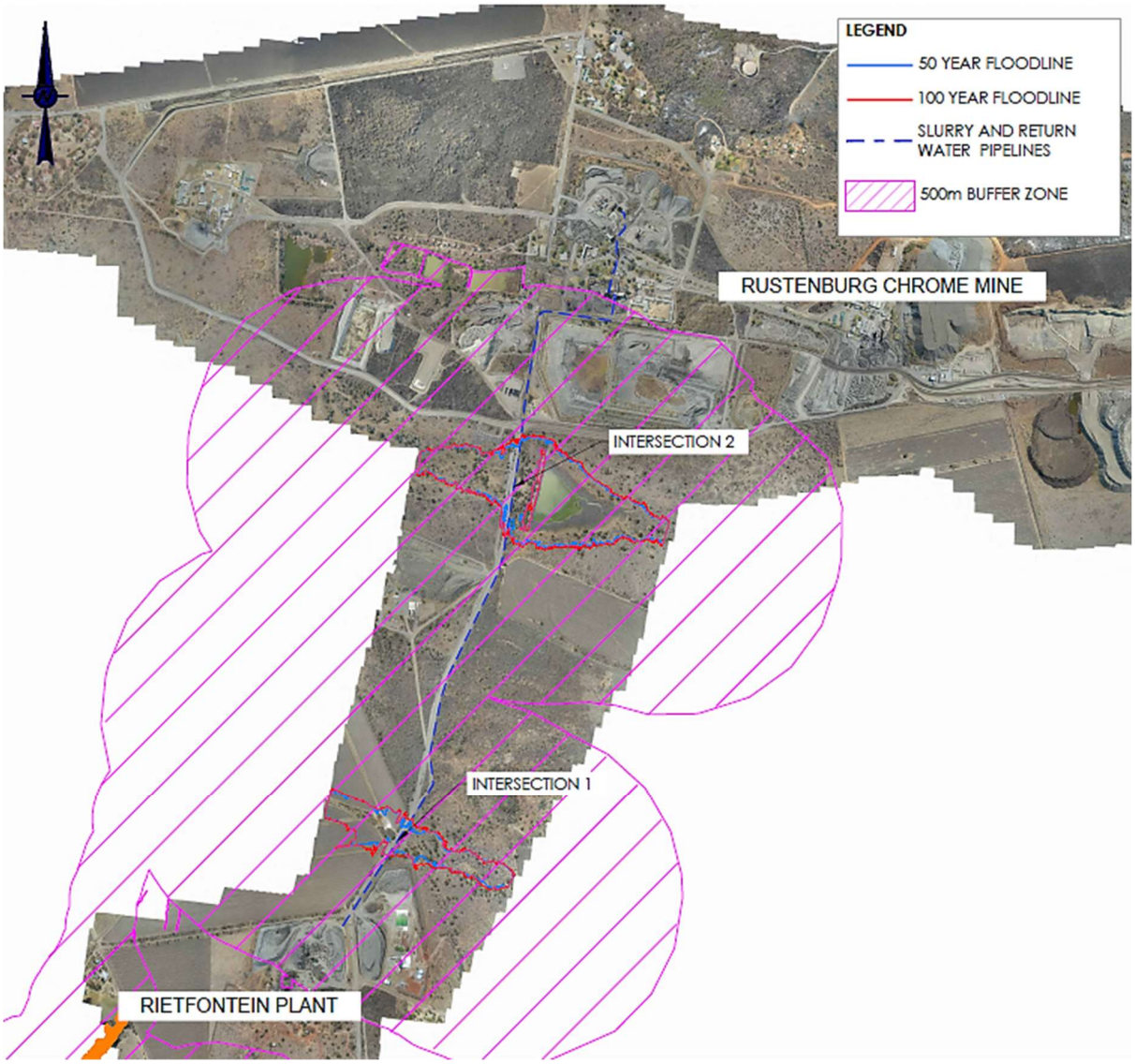


Figure 43: Pipelines intersections with floodlines and 500m buffer zone

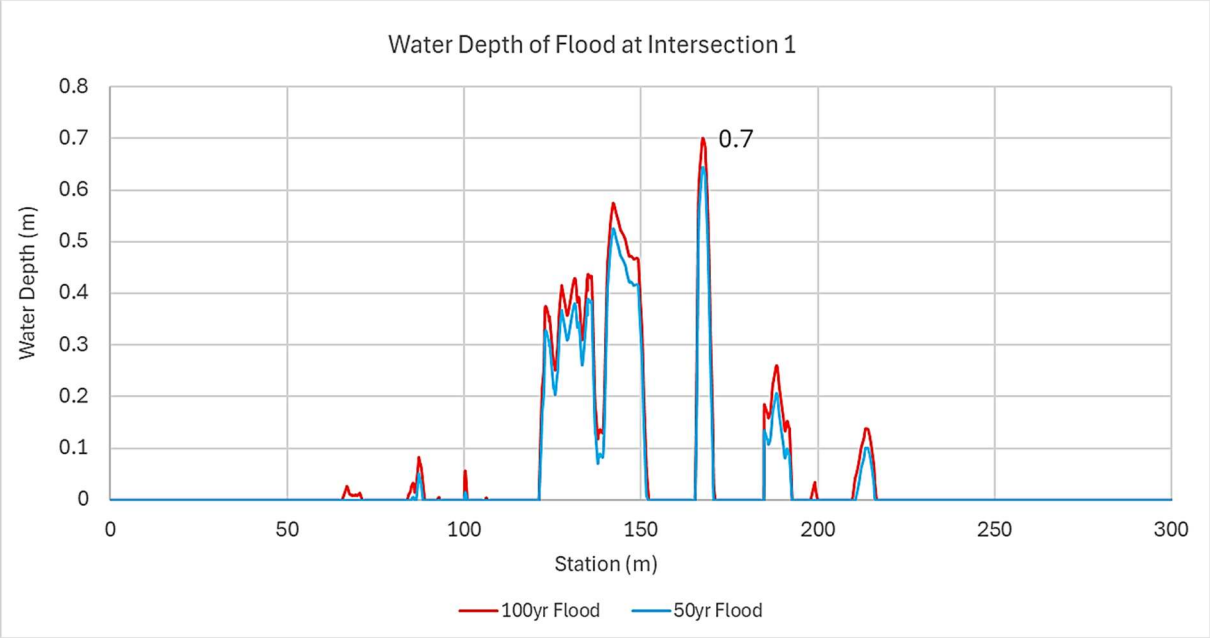


Figure 44: Graph depicting water depth along the pipeline intersection 1

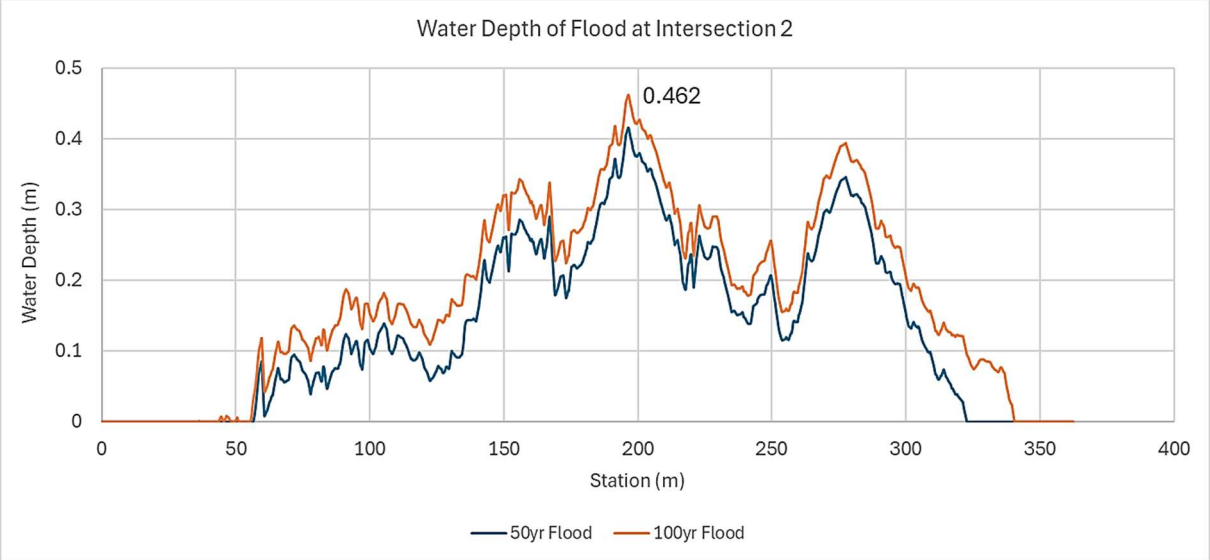


Figure 45: Graph depicting water depth along the pipeline intersection 2

6.8.4 STRUCTURAL CONSIDERATIONS

By proposing a standard F4 1065mm gauge precast sleeper (reclaimed or newly constructed) to be placed underneath the pipeline within the 500-meter wetland areas (buffer zone), the following weight will be applied on the foundation:

- Weight of the slurry within the pipelines at a density of 1400 kg/m^3 (assuming worst case) and density of 1000 kg/m^3 for the water pipelines;
- Weight of:
  - 2x 180 mm OD HDPE SDR 11 pipelines of 8.5 kg/m for the water conveyance;
  - 2x 180 mm OD HDPE SDR9 pipelines of 10.17 kg/m for the slurry conveyance; and

- Weight of an F4 1065mm gauge of 2.32 kPa.

The sleeper must not be placed on reworked residual norite (black turf) soils. These soils must be removed to expose natural residual norite, then backfilled with compacted G7-quality material in 150 mm layers. The pipelines may be founded on this foundation at a bearing capacity of up to 75 kPa. If the black turf soils are not removed, the maximum allowable bearing capacity is limited to 25 kPa. Additionally, if the pipelines are placed on the black turf material, saturation may cause swell or settlement, leading to ongoing maintenance and realignment of the pipeline.

A comparison was done between the placement of all four pipes on one sleeper in intervals versus two pipes per sleeper (return water pipes on one sleeper and slurry pipes on a separate sleeper) to assess the weight that will be applied on the ground.

By placing all four pipes (return water and slurry pipelines) on one single sleeper (Option 1) per interval, a sleeper will be required every 3.5 meters to adhere to the maximum allowable bearing capacity of 75 kPa, see Figure 46. By placing the return water pipes and slurry pipes on separate sleeper per interval (Option 2), a sleeper will be required every 8.5 meters for the return water pipes and every 6 meters for the slurry pipes, to adhere to the maximum allowable bearing capacity of 75 kPa, see Figure 47. It can also be seen that when placing the pipes on the black turf material the intervals per sleeper increase significantly (not advised).

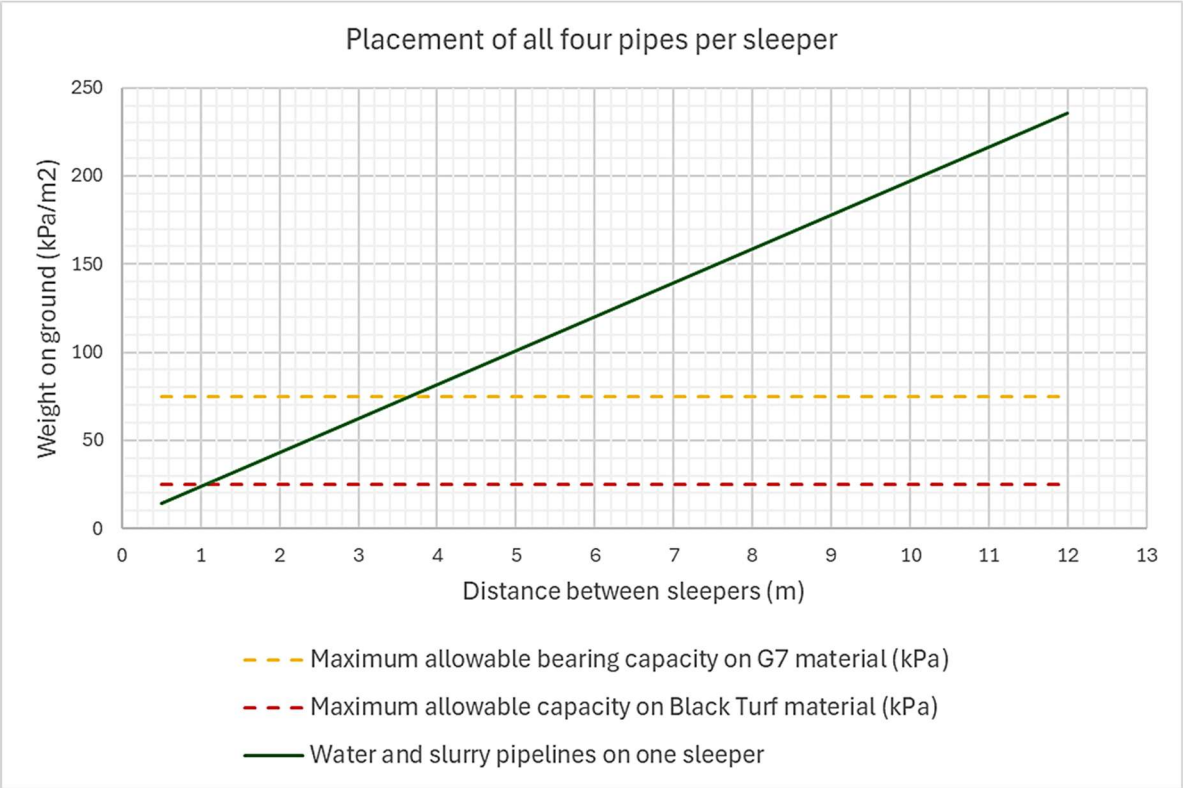


Figure 46: Distance between sleepers and weight on the ground for the placement of all four pipes per sleeper per interval (Option 1)

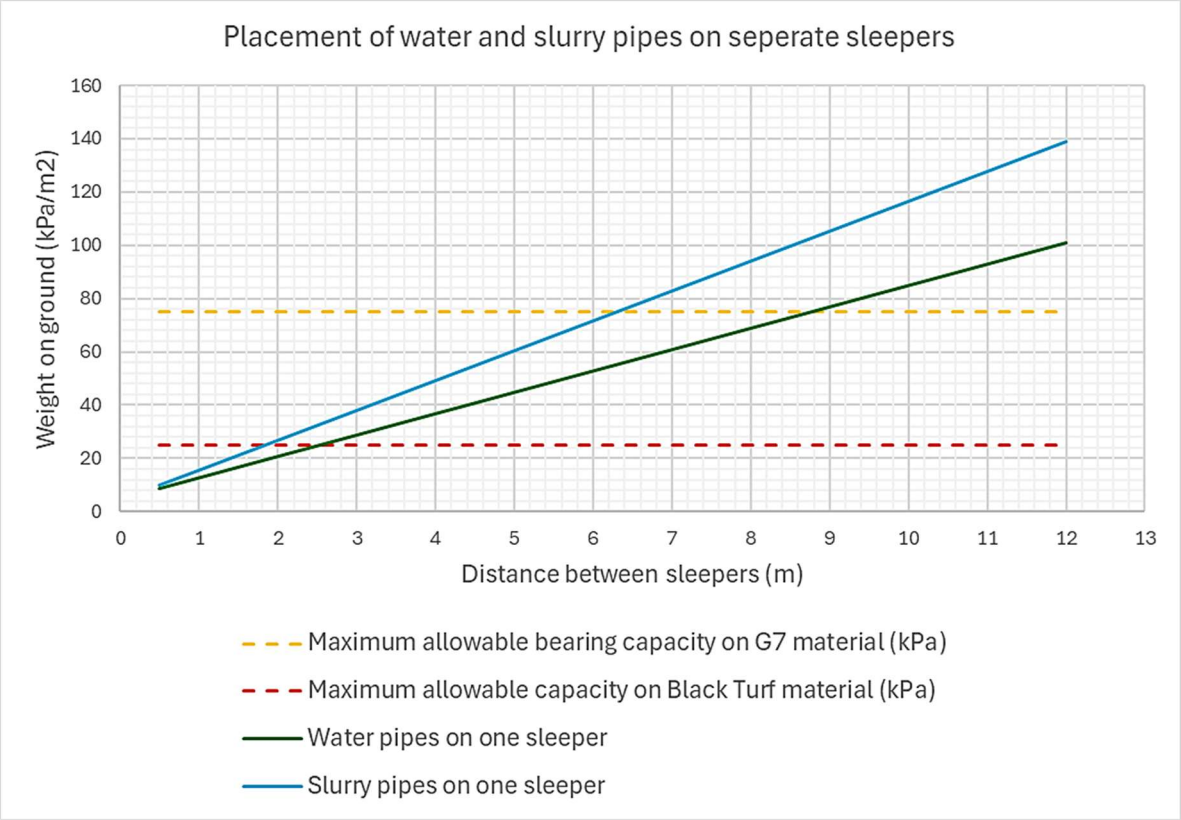


Figure 47: Distance between sleepers and weight on the ground for the placement of two pipes per sleeper per interval (Option 2)

Given the total length of the pipelines within the 500-meter wetland buffer zone of 2016m (excluding the 1:100 year floodline areas), a total of 576 sleepers will be required for both the slurry and water pipelines in total (Option 1). If the return water and slurry pipelines are placed on separate sleepers with the intervals discussed above, then a total of 237 sleepers will be required for the return water pipelines and 336 sleepers will be required for the slurry pipelines, which gives a total amount of 573 sleepers (Option 2). Both options will be sufficient, however, it would be quicker to install all four pipes on a single sleeper compared to installing the water and slurry pipelines on separate sleepers.

Figure 48 and Figure 49 presents the installation detail of both options. All detailed drawings can be seen in Appendix A. It is important to note that the black turf material underneath the sleepers will have to be removed and a suitable G7 material should be placed in 150 mm layers and compacted to 93% MOD AASHTO, to ensure a bearing capacity of 75 kPa.

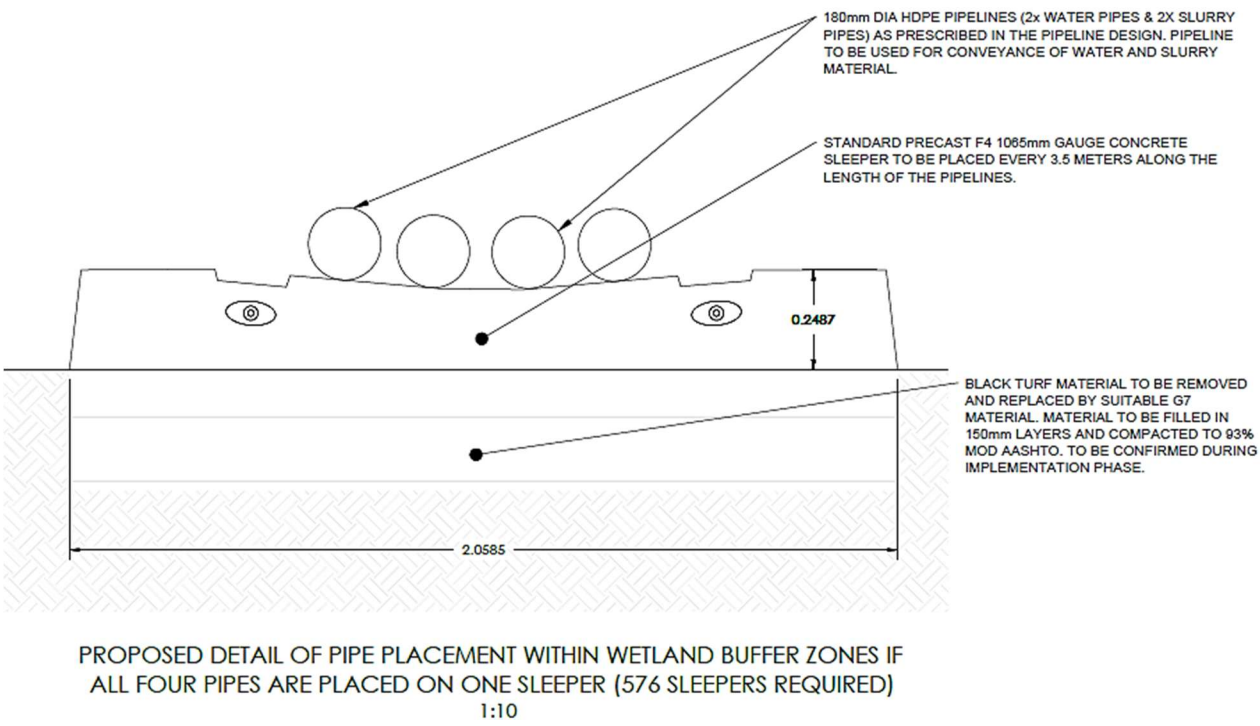


Figure 48: Proposed detail of placement of all four pipes (return water and slurry pipes) per sleeper (Option 1)

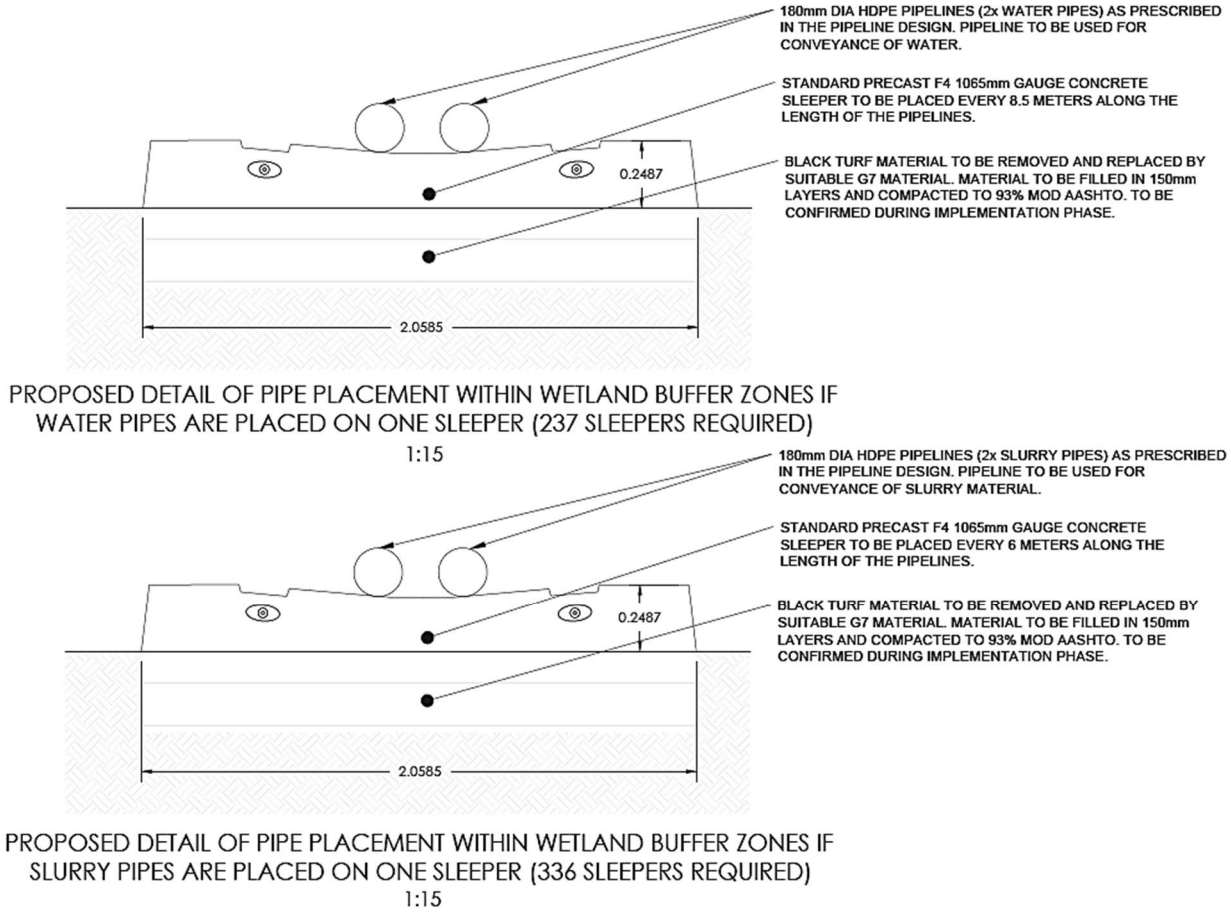


Figure 49: Proposed detail of placement of water and slurry pipes on separate sleepers (Option 2)

6.8.5 STORM WATER AND EROSION MANAGEMENT CONSIDERATIONS

As discussed in section 6.8.4 a standard F4 1065mm gauge precast sleeper is proposed to be used to place the pipelines on, in a specified interval within the 500-meter wetland buffer zone. The purpose of placing the pipes on top of the sleepers is to aid in stormwater management by not restricting the flow of water around and underneath the pipelines. By elevating the pipelines with the height of the sleepers (248 mm), the effect on the surface water drainage will be alleviated to have limited effect on the surrounding soil. The sleeper placement design was done in such a manner that there is no impact on the Mannings coefficient. Therefore, it is foreseen that there will be no increase in velocities and subsequently no erosion effects.

Where the pipelines cross the wetlands and intersect floodlines, as discussed in section 6.8.3, a more robust concrete footing is proposed. A conservative approach was followed to ensure that, even when the pipes are fully submerged during high rainfall events, the pipes will stay intact. A 0.8 m footing/plinth (above the road level) at intersection 1 is proposed to allow for the 1:100 year flood to flow underneath the pipelines (maximum flow height of 0.70 m). Additionally, a 0.5 m footing/plinth (above the road level) at intersection 2 is proposed to allow for the 1:100 year flood to flow underneath the pipelines (maximum flow height of 0.46 m).

The footings will be spaced in 4 meter intervals at intersection 1 and 4.5 meter intervals at intersection 2. The footings will be cut into the existing ground with the following arrangement from top to bottom:

- The HDPE pipes fixed to the concrete stub column by means of steel plate bent over the pipes and fastened by means of HD galvanized bolts cast into the concrete stub column;
- Intersection 1: 1300mm x 200mm x 800mm high reinforced 25 MPa concrete stub column connected to the concrete foundation below;
- Intersection 2: 1300mm x 200mm x 500mm high reinforced 25 MPa concrete stub column connected to the concrete foundation below;
- 1500mm x 500mm x 250mm high 25 MPa concrete foundation poured into excavated area; and
- Removal of all black turf material and importing suitable G7 material placed in 150 mm layers and compacted to 93% MOD AASHTO.

The length of the pipelines within the 1:100 year floodline crossing areas are 70 and 164 meters for intersections 1 and 2, respectively. This gives a total of 54 footings required within the crossing areas. Figure 50 and Figure 51 shows the proposed detail of the stub columns/footings for intersections 1 and 2, respectively. All detailed drawings can be referenced in Appendix A.

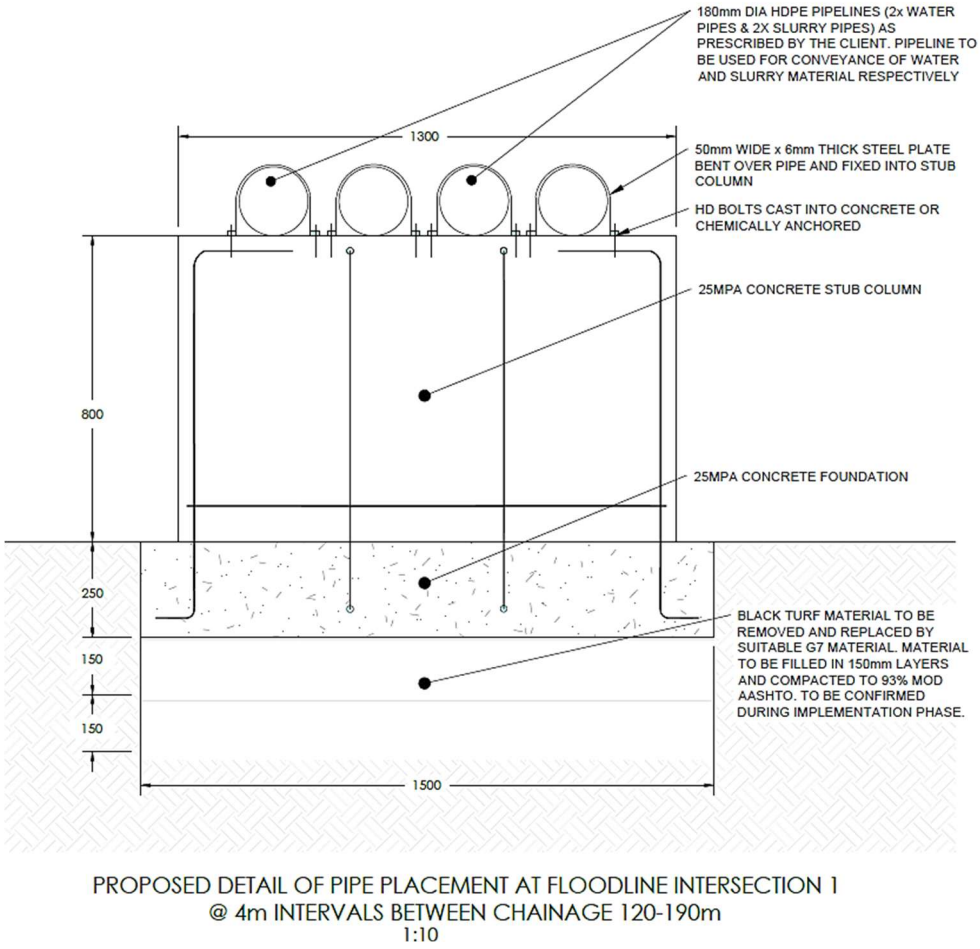


Figure 50: Proposed detail of stub columns to be placed within the 1:100 year floodline, intersection 1

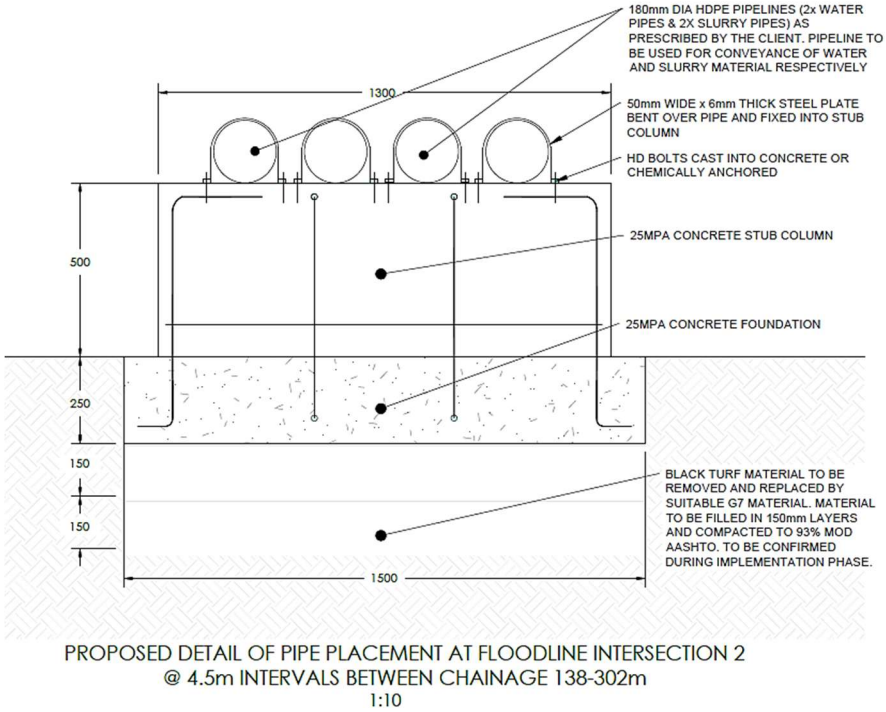


Figure 51: Proposed detail of stub columns to be placed within the 1:100 year floodline, intersection 2

Where the pipelines will cross a wetland/streams, the pipelines should be accompanied by an earth constructed berm and paddock system for management of any leaks experienced upstream of the crossing as well as management of pumping any spillage within the stream itself. The detailed design of this should be investigated during the Stage 4 design for construction (Paterson and Cooke, 2017).

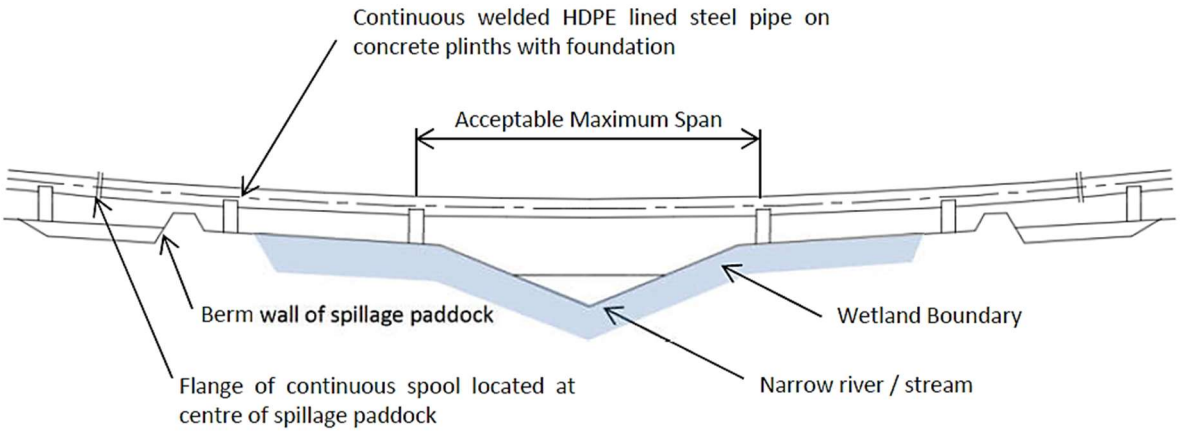


Figure 52: Small river crossing cross sectional view

It is recommended that the pipeline sections within the 500-meter buffer zones should not contain any flanges for the full length of the wetland or river crossing and it should ideally contain a continuous HDPE internal liner for internal wear or corrosion protection.

6.8.6 CONSTRUCTION PHASE REHABILITATION PLAN

The rehabilitation plan focuses primarily on the Construction Phase of the project. A maintenance plan is required for the operational phase of the project.

The rehabilitation plan is typically implemented at the end of construction, but is still seen as part of the construction phase. However, it needs to be noted that certain rehabilitation may be required or conducted during the construction phase of the project. For example, if erosion occurs after heavy downpours as a result of construction related activities, then this must be rectified / rehabilitated immediately and monitored further. This rehabilitation may be temporary measures implemented until end of construction or because the impact will disappear after further construction / development.

Note: *The Project Owner / Landowner is ultimately responsible in ensuring that the rehabilitation is complied with. It is also suggested that they only sign-off on final construction after the rehabilitation has also been completed to standard.*

Table 13: High level Rehabilitation plan

REHABILITATION PLAN		
	ACTIVITY	RESPONSIBILITY
1	**Vegetation (Reinstatement of denuded areas)**	

REHABILITATION PLAN		
	ACTIVITY	RESPONSIBILITY
	1. Denuded and disturbed areas to be re-grassed (revegetated) with locally indigenous grasses only. 2. Areas to be revegetated (re-grassed) must first be properly cleared of debris; excess building materials such as building sand and gravel; and equipment. 3. Cleared, denuded and disturbed areas to then be roughly levelled to blend in with pre-construction topography and contours. This includes the removal of mounds of sand / topsoil etc. and the closing up of open trenches, etc. Care must be taken not to alter contour heights or create berms / mounds or depressions that might impede or redirect surface stormwater waterflow (typically by vehicle tracks as an example) or causing ponding of stormwater previously ending up in the wetland areas, stream and dams. 4. The area can then be lightly loosened / ripped if heavily compacted. If not possible, the area can simply be loosened and at the same time aerated by using garden forks to poke the area full of holes. The depth of the holes should be at least 10cm to 20cm. Once prepared no vehicles should drive across the area and no people should unnecessarily walk across the area. The area should be cordoned off with danger tape (or something similar) to restrict movement across it. 5. Some super phosphate quick-release fertilizer or a 3:2:1 fertilizer should then be spread evenly over the area by hand or fertilizer spreader and watered in well a day or two prior to the seeding of the area. The directions for use on the packaging must be followed, and may differ between different brands, so check first. 6. The grass seed can then be evenly spread by hand or by using the fertilizer spreader. Once the grass seed is spread it can be gently, lightly and very shallowly racked into the	Contractor

REHABILITATION PLAN		
	ACTIVITY	RESPONSIBILITY
	soil surface. Some seed will still be showing but most will be just under and in the soil. Then firm the seeded area by walking up and down over it. Do not compact it with a heavy roller or machine. Finally the area must be well watered, but with care not to wash away the newly spread seed. There is no need to cover the grass seed with a layer of soil. The area must be kept damp for at least a week, which might require a few more water applications depending on weather conditions. Thereafter the area should be watered once a week for about a month. During this time any erosion damage to area must be rectified. A heavy rain downpour could also cause this damaged. 7. Once the new grass is established watering can be tampered off and natural conditions allowed to take over. Surrounding grasses will also start to colonise the area, which can be left to continue.	
2	**Soils**	
	1. On completion of the construction phase all ground / soil must be levelled and / or recontoured to the original contours. 2. Topography (slope, contours) of the disturbed areas, slopes, etc. must be well blended / married into and with existing contours and new contours. For example where new embankments or raised surfaces have been constructed as part of the project. 3. Extra care must be taken to ensure any disturbed soils within the buffer zones or along the edges of the buffer zones have been well restored and contoured to ensure that stormwater run-off is not increase or channelled into watercourse as this may lead to cutting, erosion, excessive siltation of watercourses.	Contractor

REHABILITATION PLAN		
	ACTIVITY	**RESPONSIBILITY**
	4. No soil stockpiles to remain on completion of construction. All excess soils, gravel brought onto the site must be removed and the area rehabilitated. 5. Any stockpiled topsoil from the actual site must also be removed, or preferably levelled across the project area and rehabilitated. 6. There is no need to import soils or compost to rehabilitated denuded areas.	
3	**Temporary storage sites, office sites and work areas**	
	1. All construction debris, litter, materials brought on to site to be removed and the area cleaned up. This includes in work areas where concrete was mixed, gravel stockpiled, and temporary access roads and vehicles tracks created. Once cleaned up the area must be revisited to remove any remaining foreign objects typically left behind such as pieces of wire, nails, screws, etc. 2. If the site is large and badly denuded, creating the potential for erosion and stormwater run-off, then it must be re-seeded with locally indigenous grasses to prevent erosion and soil loss. For this follow instructions given above in 1. Vegetation. 3. During the rehabilitation of temporary laydown areas, office sites and work areas there is no need to plant any trees or shrubs.	Contractor
4	**Stormwater Management**	
	1. The stormwater may be released into the buffer area. However, no large concrete structures may be within the buffer area. 2. Surface stormwater flow may be diverted around the project areas where applicable. 3. Stormwater velocity must be reduced at points of release, or just before points of release to ensure that released	Contractor, Project owner, Landowner

REHABILITATION PLAN		
	ACTIVITY	RESPONSIBILITY
	water does not cause erosion and gully formation where applicable. 4. All stormwater movement must be continually monitored during the construction phase of the project. Any serious erosion gully formation to be immediately rectified. In some cases the rectification measures can be temporary. For example, where work is still in progress on the stormwater system, or embankments are still be constructed.	

6.8.7 OPERATIONAL REHABILITATION PHASE

Placement of the pipeline over any existing streams or wetland areas should be done with great care and due diligence so as not to impede any streamflow. Regular maintenance/inspections of the entire pipeline should be done to confirm the effectiveness of the sleeper placement and that there are no hindrances along the pipeline that can impede waterflow.

During these regular inspections, the pipelines should also be checked for any leakages. If a leak is to be identified, then the sludge/silt material should be effectively cleaned up and the construction phase rehabilitation plan, as discussed in section 6.8.6, should be applied.

A monitoring system should be put in place by the client during the operational phase to ensure that any and all breakages, pipe bursts, and spillages along the pipeline be identified and rectified as soon as possible.

In the event of extreme rainfall conditions, in exceedance of a 1:100 year flood, where damage to the pipeline could potentially occur, the following steps are to be taken:

- Entire pipeline is to be investigated to establish any and all damage points;
- Stop the pump system in a timeously manner if repairs need to occur;
- Commit to repair identified damage;
- Have backup pipes in storage that are readily available for any repair work identified; and
- Clean-up of the sites where spillage and or vegetation build-up occurred due to a flooding event.

7. GROUNDWATER IMPACT STUDY SUMMARY

The groundwater impact assessment and numerical model prepared by Hydrogeek Consulting for the Rietfontein Plant evaluate both the current and future impacts of site activities on local groundwater resources. The study incorporated a hydrocensus, groundwater sampling, and the development of a numerical groundwater flow and contaminant transport model using FEFLOW.

A key component of the assessment was the pollution plume modelling associated with stockpiles and the Pollution Control Dam (PCD). The model results indicate that plume migration from both current and future stockpile areas is expected to remain contained, largely due to ongoing abstraction from boreholes RP01, RP02, and RP03. The modelling accounted for the hydraulic behaviour of local aquifers and predicted contaminant transport under different scenarios, including potential seepage to nearby receptors such as the Sandspruit tributary.

The report confirms that the PCD design, in conjunction with the lined infrastructure and groundwater abstraction, will mitigate risks to the aquifer. Continued monitoring and potential refinement of the model are recommended to verify containment over time.

This assessment supports the implementation of the proposed infrastructure and informs the operational groundwater monitoring strategy. The detailed groundwater impact report can be referenced in Appendix H (Report number 202501-2).

8. HIGH LEVEL COST ESTIMATE

A high-level cost estimation was done with the allowance of 10% contingencies and 10% P's and G's. Table 14 shows an estimate of the costing which was calculated to R13 607 716.13 for implementing this design.

Table 14: High level cost estimation

SUMMARY	
POLLUTION CONTROL DAM	R5 692 376,26
PRODUCT STOCKPILE AREA	R853 325,00
SILT TRAP	R1 936 951,11
DIRTY WATER CHANNELS	R1 947 367,74
PIPELINE RIVER CROSSING	R816 026.29
SUBTOTAL A	**R11 246 046.39**
10% P's & G's	R1 124 604.64
SUBTOTAL B	**R12 370 651.03**
10% Contingency allowance	R1 237 065.10
TOTAL (EXCL. VAT)	**R13 607 716.13**

9. CONCLUSION

Rustenburg Chrome Mine (Pty) Ltd (RCM) commissioned MineLock to develop a Technical Engineering Design of the Storm Water Management Plan for Rietfontein Plant to support their Water Use License Application (WULA). MineLock, performed numerous investigations for the technical design. These studies consisted of the hydrology and water balances, floodline calculations and geotechnical studies.

The pollution control dam has been sized to meet the regulatory requirements of GN 704, with a minimum capacity of 5 600 m³ based on the 50-year design storm. To provide operational flexibility and accommodate daily variations in water movement, a total storage volume of 8 000 m³ is recommended. Due to the site's water deficit and relatively small contributing catchments, the pollution control dam is expected to operate dry for extended periods, with low risk of spillage.

The water balance confirms that inflows, outflows, and inter-facility transfers are appropriately accounted for, with flow directions and magnitudes clearly illustrated. Given the limited storage capacity of the pollution control dam, seasonal storage changes are minimal and balanced across the simulation period. The static water balance aligns with the expected operational conditions, ensuring effective water management and compliance with regulatory requirements.

The waste classification assessments for both the RCM tailings and the re-processed sand stockpiled at Rietfontein Plant have been completed in accordance with applicable legislation. The RCM tailings are classified as Type 3 waste based on total concentrations of Cu and Ni, although they behave like Type 4 due to very low leachability. The sand component at Rietfontein was found to pose no significant physical, health, or environmental hazards, and an application for waste exclusion was submitted.

Given the temporary nature of the sand and product stockpiles, lining of the stockpile areas was considered unnecessary. However, a Class C barrier system has been selected for the pollution control dam to ensure compliance and environmental protection. The classification outcomes confirm that appropriate management measures are in place to mitigate potential risks associated with waste handling, storage, and disposal.

The stormwater channels and diversion structures were designed based on detailed topographical data, site activities, and defined catchment areas. The clean and dirty water management infrastructure has been clearly defined, with all dirty water channels conveying runoff toward the silt trap before discharge into the Pollution Control Dam. The design is supported by technical drawings in Appendix A and hydraulic calculations in Appendix E, ensuring compliance with best practice for water separation and containment.

The geotechnical assessment has identified that the black turf soils, generally impermeable, pose risks related to permeability through fissures and long-term settlement under load. For the product stockpiles, it is recommended that the upper layers be selectively removed, and the remaining subgrade be compacted to improve stability and reduce contamination risks. The Pollution Control Dam and the silt trap must be constructed with appropriate slope geometries, compaction to standards, and a robust double HDPE liner system to ensure structural integrity and environmental protection. For the above ground pipelines, founding should ideally occur on compacted residual norite soils, avoiding the black turf soils where possible, to reduce the risk of excessive settlement and maintenance demands.

A Construction Quality Assurance (CQA) plan was compiled to be read in conjunction with this report, to ensure that risks are further mitigated to ensure that the design specifications are met, as well as to ensure that all barrier systems are implemented in accordance with best

practise in particular to minimise the number of holes in geomembranes.

10. REFERENCES

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    - A5 – Water Management for Surface Mines;
    - G1 – Stormwater Management;
    - H1 – Integrated Mine Water Management; and
    - H2 – Pollution Prevention and Minimisation of Impacts.

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Douglas Richards
Director
Design Engineer



Francois Marais
Senior Engineer (Final Sign-off)

APPENDIX A

TECHNICAL ENGINEERING DRAWINGS

TECHNICAL ENGINEERING STORM WATER MANAGEMENT PLAN OF RIETFONTEIN PLANT

LIST OF DRAWINGS		
DRAWING NR	**DRAWING NAME**	**REV**
00	COVER PAGE AND LIST OF DRAWINGS	0
01	GENERAL ARRANGEMENT	0
02	CATCHMENT AREAS LAYOUT	0
03	PCD BARRIER SYSTEM LAYOUT AND DETAIL	0
04	PCD SUBSOIL DRAINAGE LAYOUT AND DETAIL	0
05	PCD LEAKAGE DETECTION SUMP LAYOUT AND DETAIL	0
06	SILT TRAP LAYOUT AND DETAIL	0
07	SILT TRAP REINFORCEMENT DETAIL	0
08	SPILLWAY LAYOUT AND DETAIL	0
09	PCD EMERGENCY INFRASTRUCTURE	0
10	DIRTY WATER CHANNEL 1 LAYOUT AND DETAIL	0
11	DIRTY WATER CHANNEL 2 LAYOUT AND DETAIL	0
12	DIRTY WATER CHANNEL 3A LAYOUT AND DETAIL	0
13	DIRTY WATER CHANNEL 3B LAYOUT AND DETAIL	0
14	DIRTY WATER CHANNEL 4 LAYOUT AND DETAIL	0
15	DIRTY WATER CHANNEL 5 LAYOUT AND DETAIL	0
16	CULVERTS LOCATIONS	0
17	CULVERTS LAYOUT AND DETAIL	0
18	WATER AND SLURRY PIPELINES LOCATION	0
19	WATER AND SLURRY PIPELINES SLEEPER LAYOUT AND DETAIL	0
20	WATER AND SLURRY PIPELINES PLINTHS LAYOUT AND DETAIL	0

ISSUED FOR INFORMATION

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

MineLock Pty Ltd
54 Via Salara Cres, Irene Corporate Corner
Building 54, First Floor
Irene
0157
www.minelock.co.za

CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: COVER PAGE AND LIST OF DRAWINGS

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	**DRAWING NO:**		**REVISION:**
284	00		0



GENERAL ARRANGEMENT OF SITE
1:1250

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

MineLock Pty Ltd
54 Via Salara Cres, Irene Corporate Corner
Building 54, First Floor
Irene
0157
www.minelock.co.za

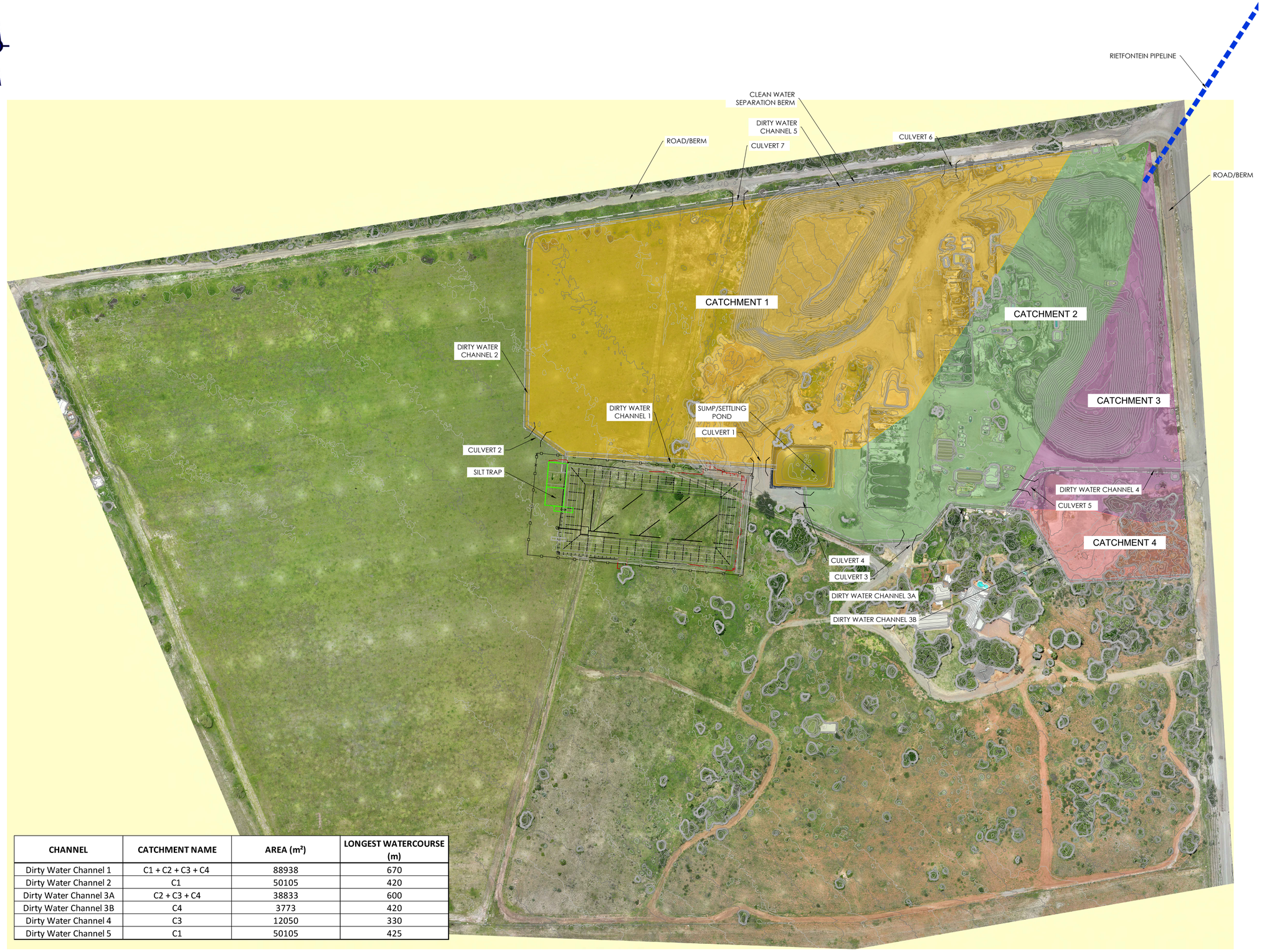
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: GENERAL ARRANGEMENT

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	01		0



CHANNEL	CATCHMENT NAME	AREA (m^2)	LONGEST WATERCOURSE (m)
Dirty Water Channel 1	C1 + C2 + C3 + C4	88938	670
Dirty Water Channel 2	C1	50105	420
Dirty Water Channel 3A	C2 + C3 + C4	38833	600
Dirty Water Channel 3B	C4	3773	420
Dirty Water Channel 4	C3	12050	330
Dirty Water Channel 5	C1	50105	425

LOCATION OF CATCHMENTS
1:1250

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:

STATUS: ISSUED FOR INFORMATION

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Building 54, First Floor
Irene
0157
www.minelock.co.za

CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

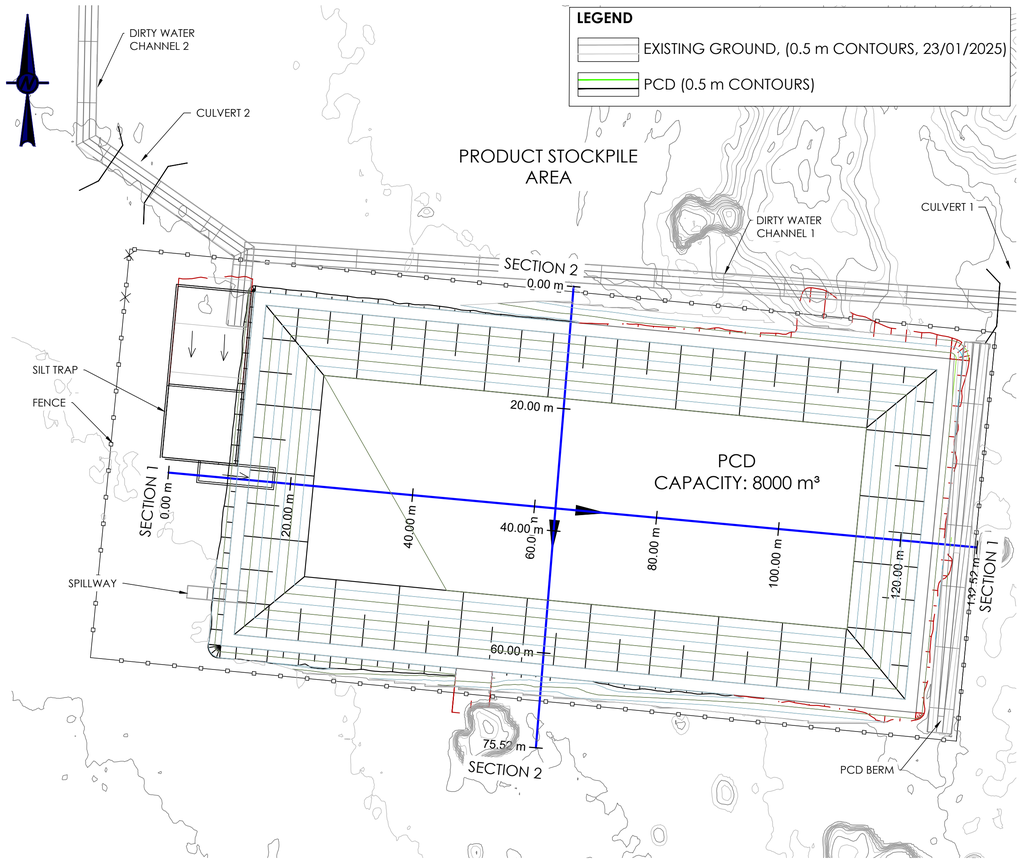
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

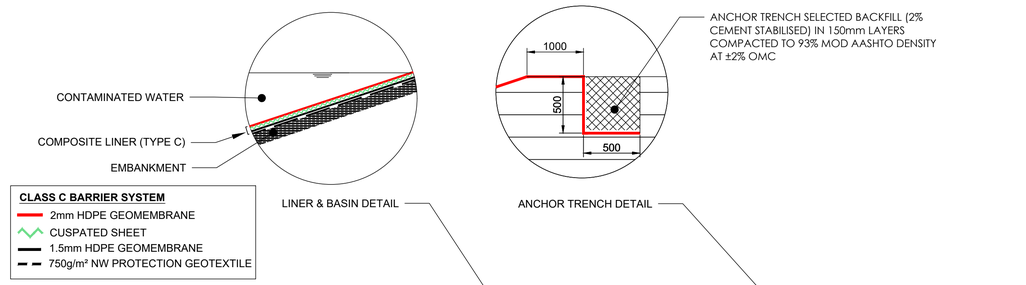
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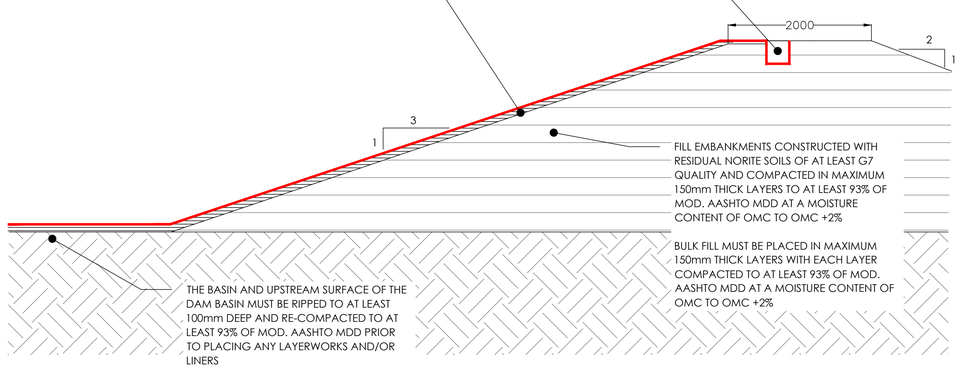
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AS SHOWN	20/08/25	MLR	JLR

PROJECT NO:	DRAWING NO:	REVISION:
284	02	0

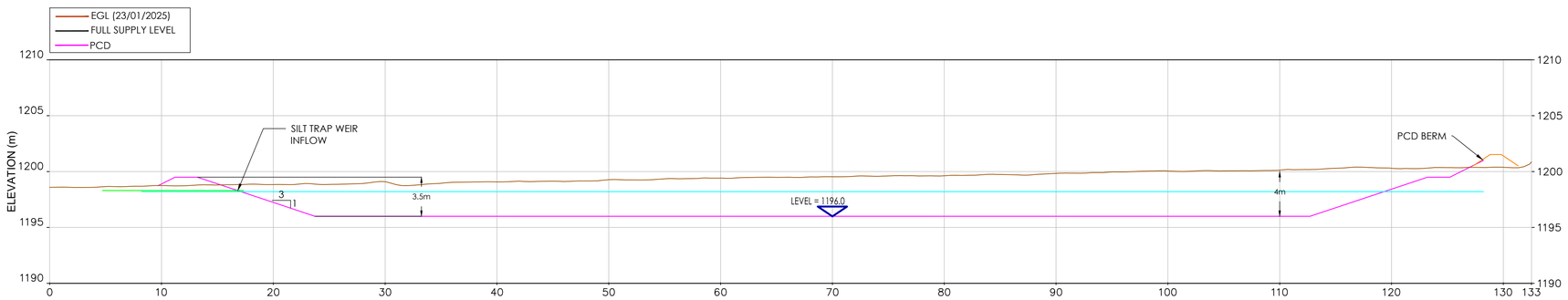


LOCATION OF PCD
1:500

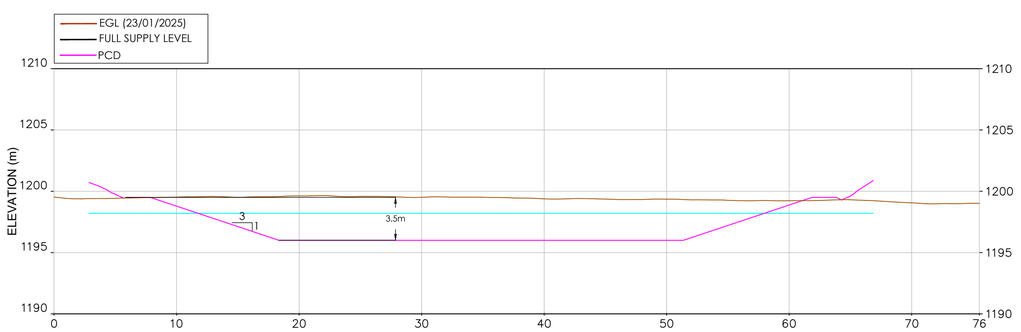




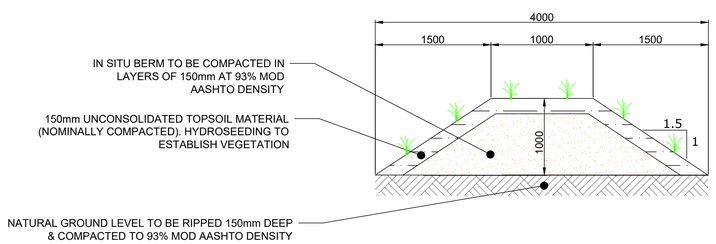
EMBANKMENT TYPICAL EARTHWORKS AND DETAILS
1:200



SECTION 1-1
1:250



SECTION 2-2
1:250



TYPICAL DETAIL OF POLLUTION CONTROL DAM BERM
1:30

Notes:

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STATUS: ISSUED FOR INFORMATION

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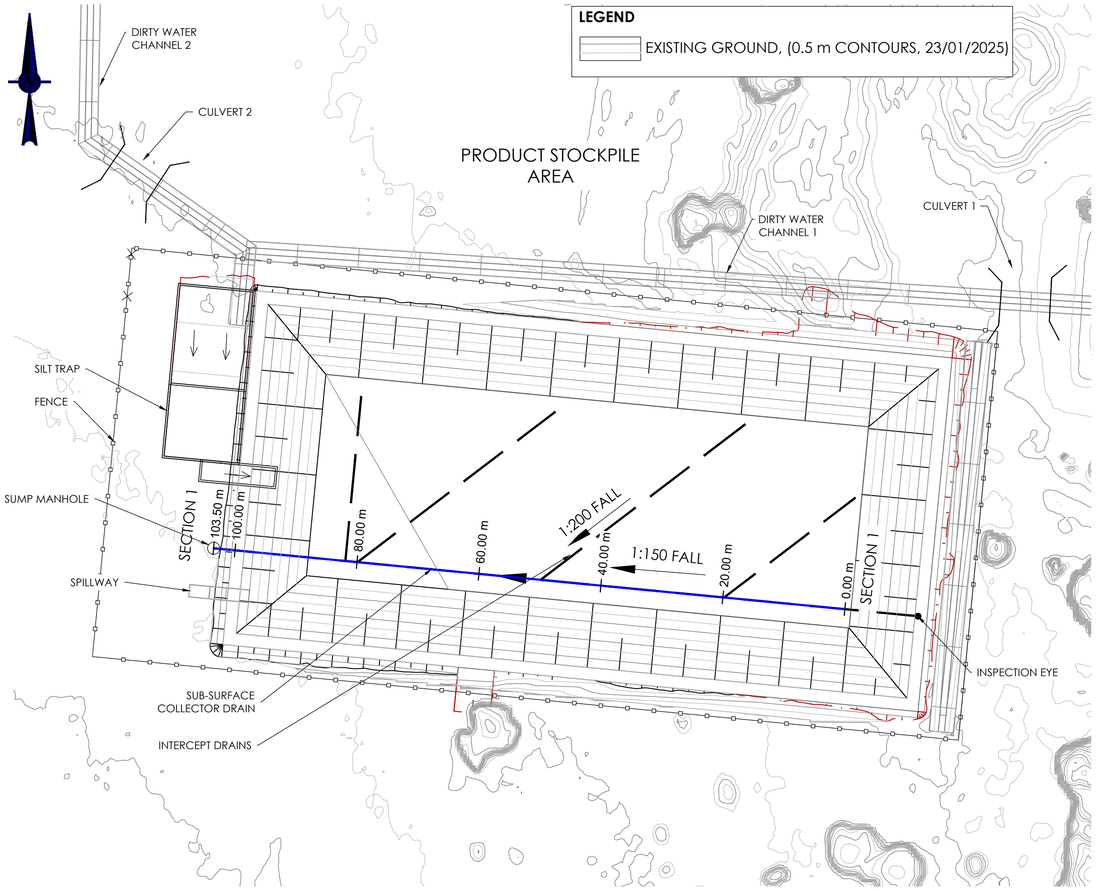
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

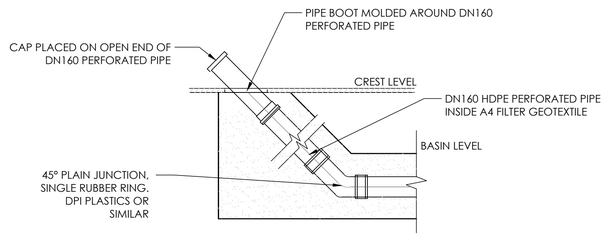
SITE: RIETFONTEIN PLANT

TITLE: PCD BARRIER SYSTEM LAYOUT AND DETAIL

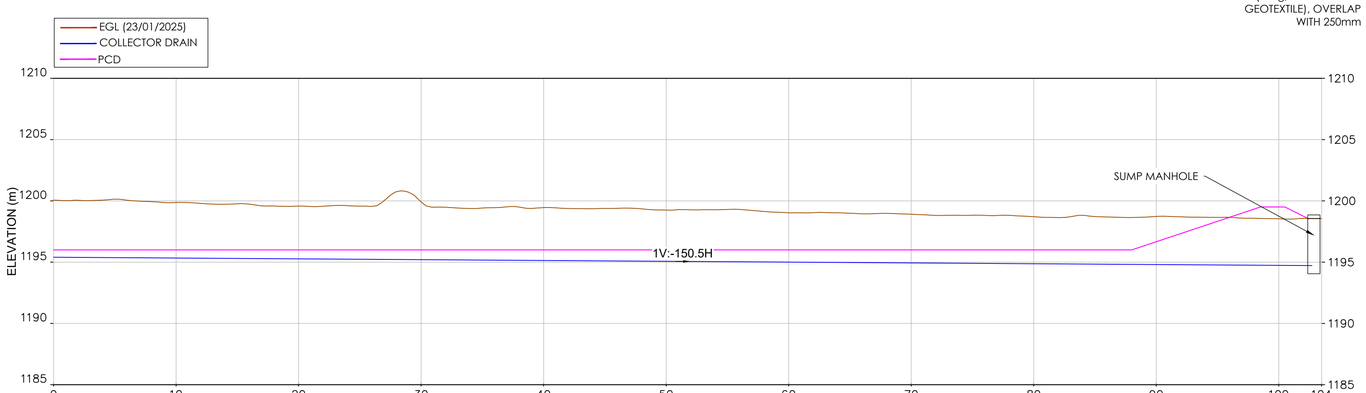
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AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	03		0



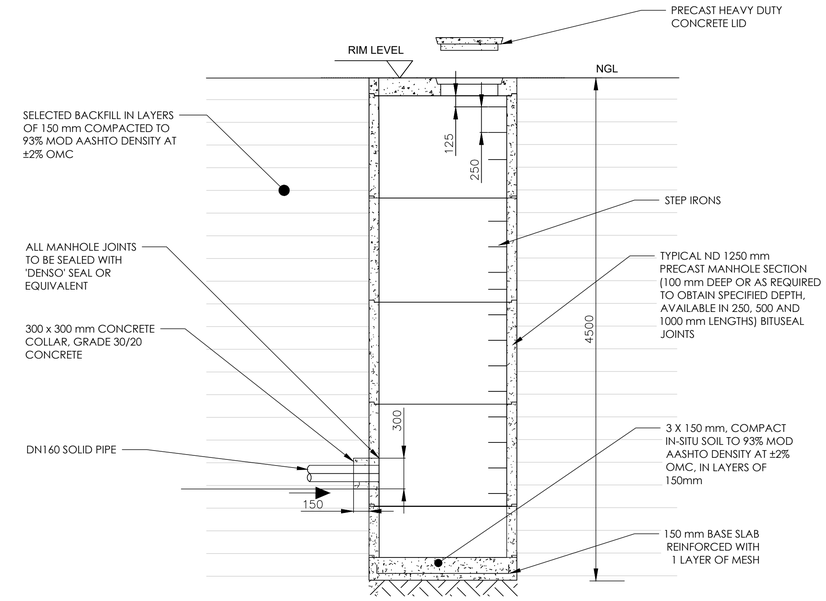
LOCATION OF SUBSOIL DRAINS
1:500



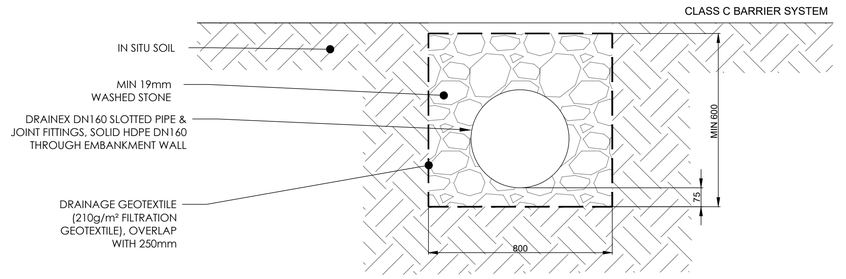
INSPECTION EYE DETAIL
1:5



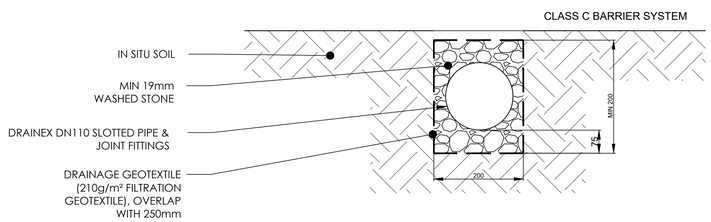
SECTION 1-1
1:250



DETAIL OF SUMP MANHOLE
1:30



TYPICAL CROSS SECTIONAL VIEW OF COLLECTOR DRAIN
1:5



TYPICAL CROSS SECTIONAL VIEW OF INTERCEPT DRAINS
1:5

Notes:

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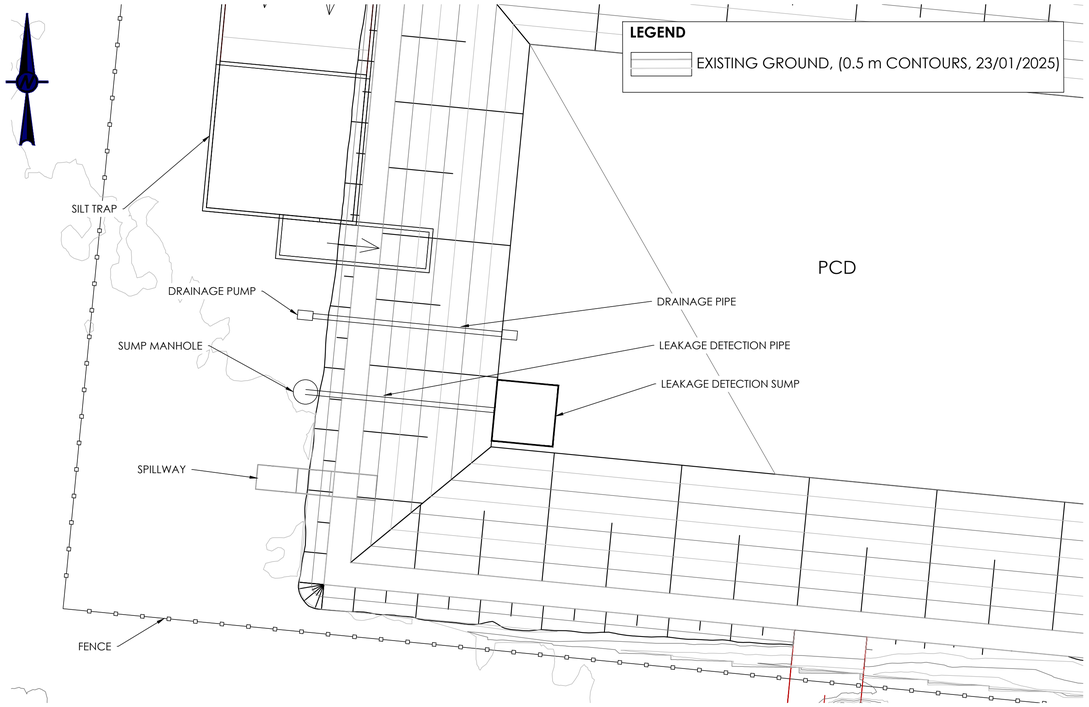
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

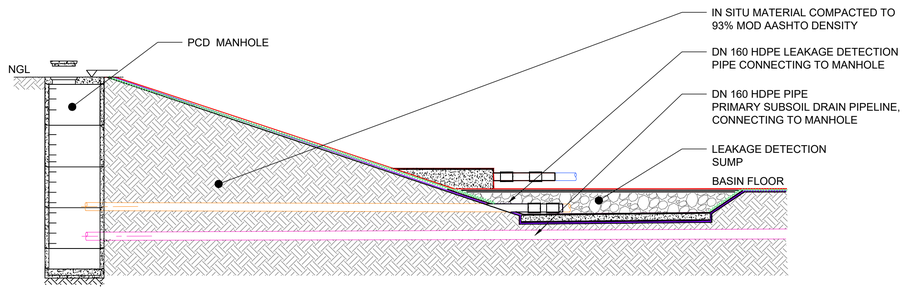
SITE: RIETFONTEIN PLANT

TITLE: PCD SUBSOIL DRAINAGE LAYOUT AND DETAIL

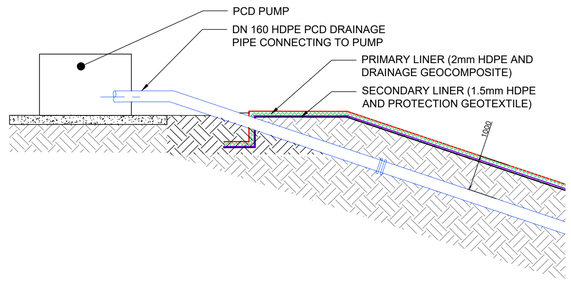
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PROJECT NO:	DRAWING NO:		REVISION:
284	04		0



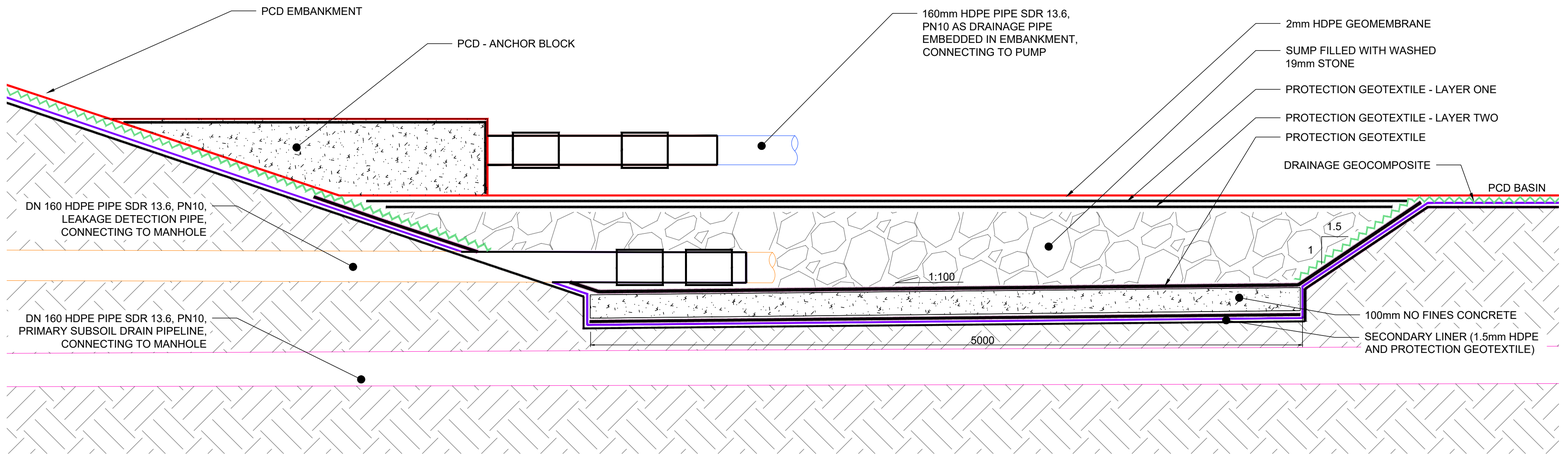
LOCATION OF LEAKAGE DETECTION SUMP
1:250



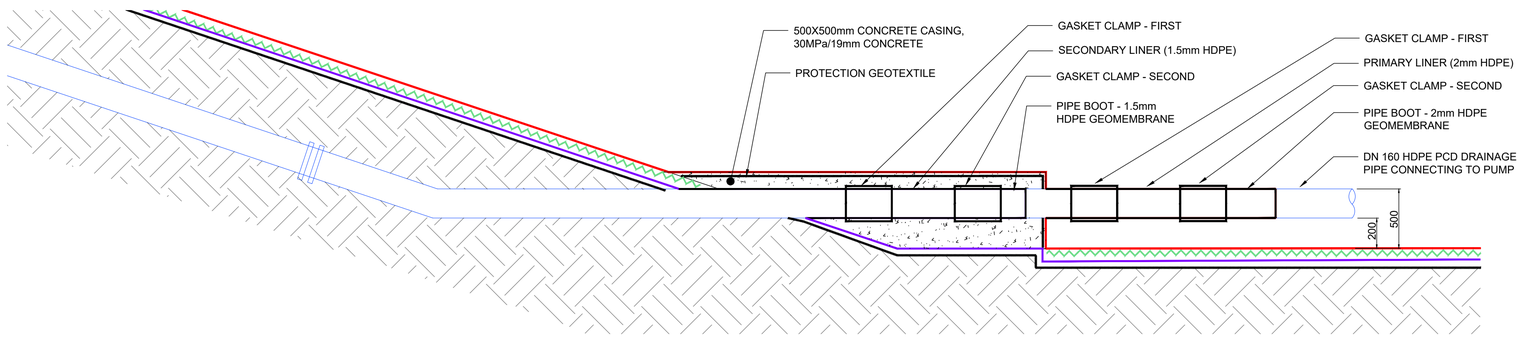
TYPICAL SECTION OF EMBANKMENT WALL DETAIL
1:75



TYPICAL SECTION OF PCD DRAINAGE PIPE
1:50



TYPICAL SECTION OF LEAKAGE DETECTION PIPE AND SUMP
1:20



TYPICAL SECTION OF PCD DRAINAGE PIPE
1:20

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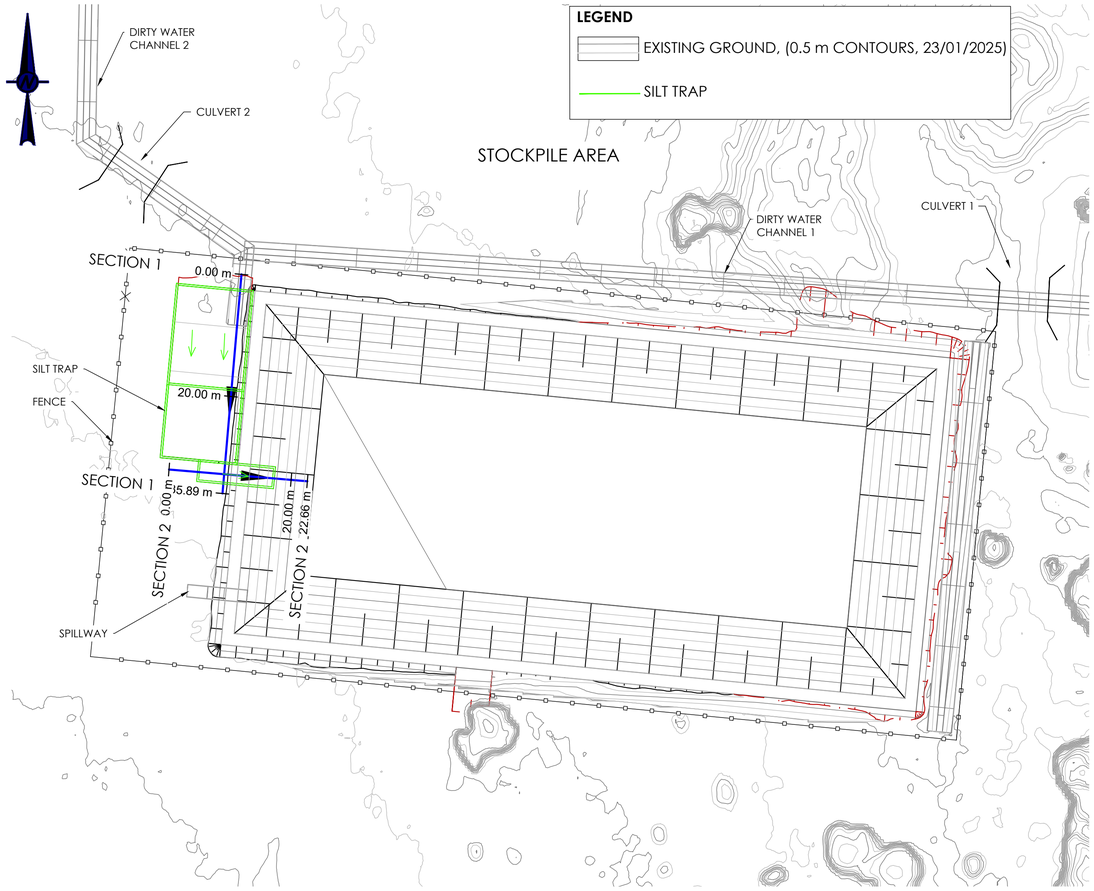
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: PCD LEAKAGE DETECTION SUMP LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

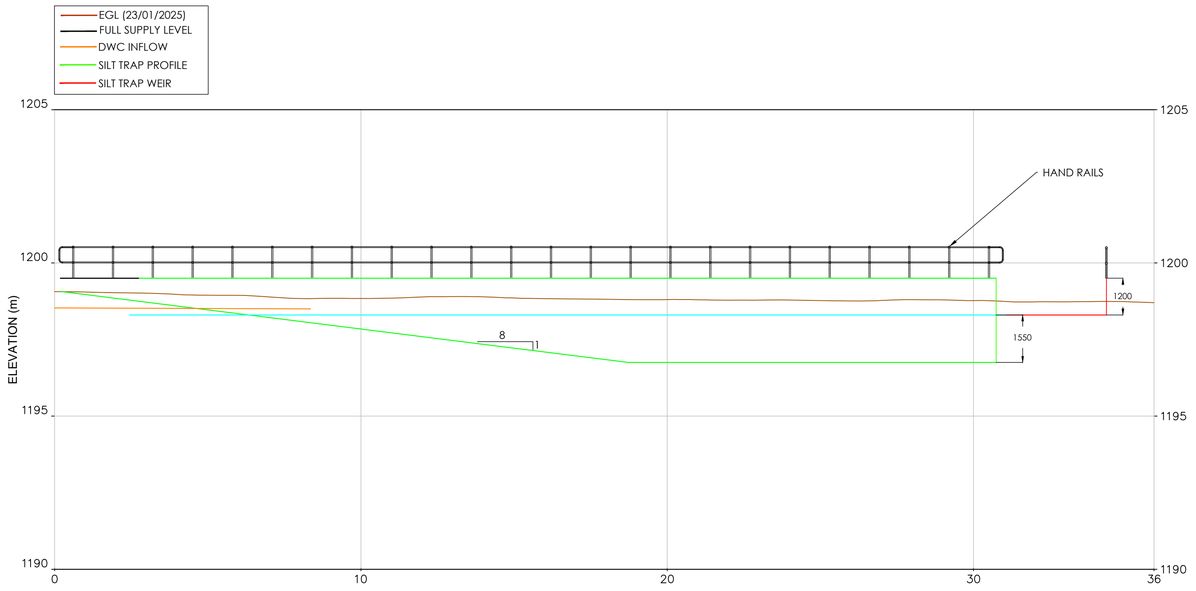
PROJECT NO:	DRAWING NO:	REVISION:
284	05	0



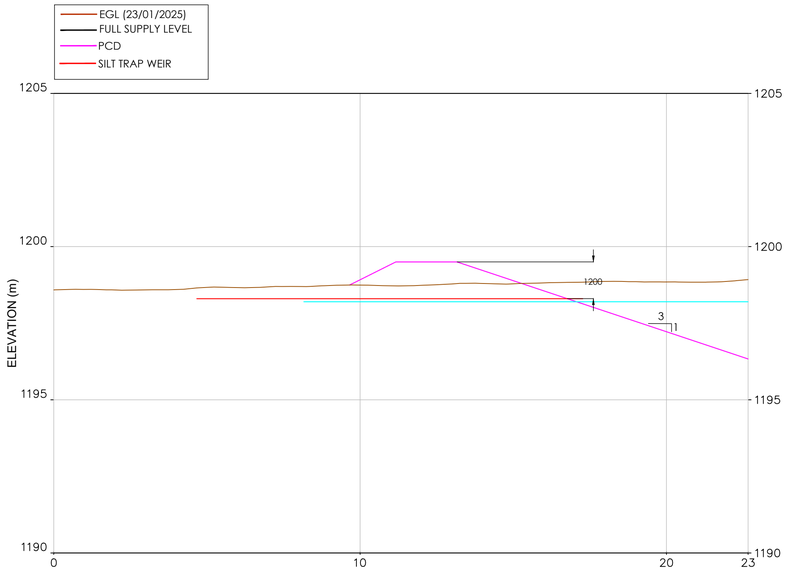
LOCATION OF SILT TRAP
1:500



SILT TRAP DETAIL
1:200



SECTION 1-1
1:100



SECTION 2-2
1:100

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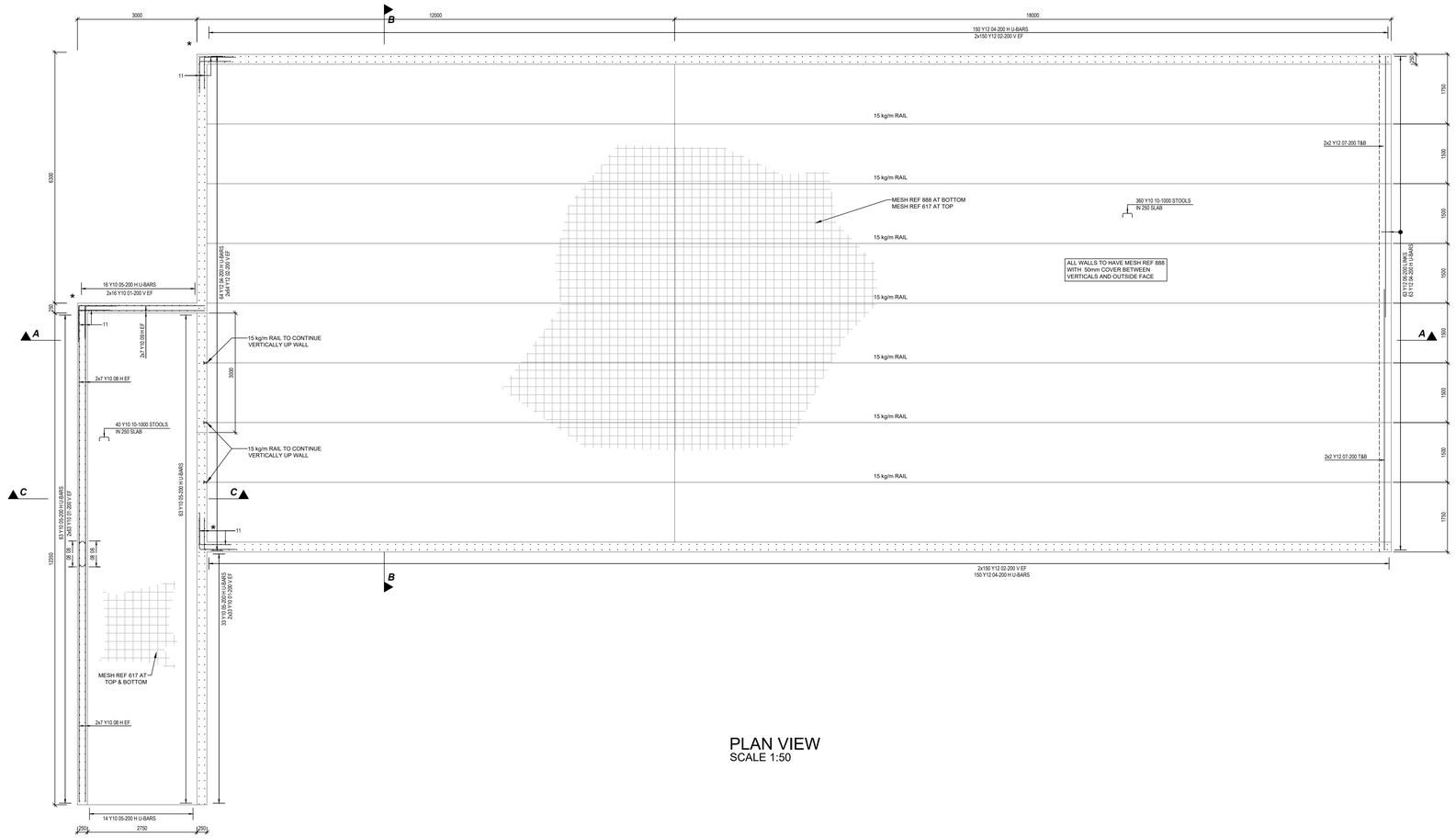
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

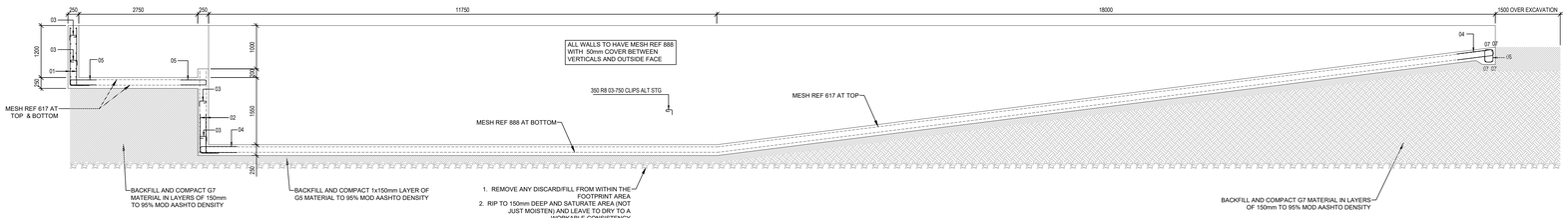
TITLE: SILT TRAP LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

PROJECT NO:	DRAWING NO:	REVISION:
284	06	0



PLAN VIEW
SCALE 1:50



SECTION A
SCALE 1:50

MEMBER	NO OF	NO BARS	DIA	CUT LENGTH	TOTAL	BAR MARK	SC	A	B	C	D	E/R	Ton
ST1	1	224	Y10	1625	224	01	37	300	(1340)				0.226
	1	728	Y12	1175	728	02	37	300	(900)				0.761
	1	350	R8	375	350	03	85	120	150	50	(85)		0.051
	1	427	Y12	1800	427	04	38	850	150	(850)			0.684
	1	189	Y10	1275	189	05	38	600	125	(600)			0.149
	1	63	Y12	1125	63	06	60	300	200				0.063
	1	8	Y12	6675	8	07	37	150	(6550)				0.048
	1	28	Y10	6550	28	08	20						0.114
	1	14	Y10	3175	14	09	20						0.028
	1	400	Y10	950	400	10	83	250	100	300	300		0.236
	1	66	Y12	1575	66	11	37	800	(800)				0.093

REINFORCEMENT NOTES:

1. STRENGTH OF REINFORCEMENT:

REFERENCE	TYPE	STRENGTH (MPa)
R	A	250
Y	C	450

2. CONCRETE COVER (mm)

GROUND FLOOR SLAB (BOT)	75mm
GROUND FLOOR SLAB (TOP)	50mm
WALLS	50mm

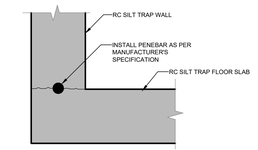
3. ALL REINFORCEMENT TO BE CHECKED AND APPROVED BY THE ENGINEER PRIOR TO CASTING OF CONCRETE
4. ALL BENDING OF REINFORCEMENT TO BE IN ACCORDANCE WITH SABS 282 (OR THE LATEST CORRESPONDING SANS SPECIFICATION)
5. ALL PLACING OF REINFORCEMENT TO BE IN ACCORDANCE WITH SABS 0144 (OR THE CORRESPONDING SANS SPECIFICATION)
6. MINIMUM SPLICE LENGTHS:
   10mm Ø = 500mm
   12mm Ø = 600mm
   16mm Ø = 800mm
   20mm Ø = 1000mm
7. AT LEAST 48 HOURS NOTICE TO BE GIVEN TO THE ENGINEER FOR REINFORCEMNT INSPECTION.
8. UNDER NO CIRCUMSTANCES MAY REINFORCING BE WELDED.
9. PROVIDE CLIPS IN WALLS AT EVERY 1m2 c/c
10. PROVIDE STOOLS IN FLOOR AT EVERY 1m2 c/c
11. UNDER NO CIRCUMSTANCES MAY REINFORCING BE WELDED.

CONCRETE NOTES:

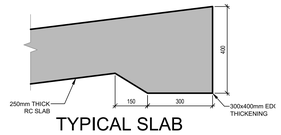
1. ALL CONCRETE TO BE IN ACCORDANCE WITH THE LATEST ADDITIONS OF SANS 2001-CC1, SANS 10100-1 AND SANS 10100-2.
2. ALL CONCRETE TO BE STRENGTH CONCRETE.
3. GRADES OF CONCRETE:

GROUND FLOOR SLAB	35/19
WALLS	35/19

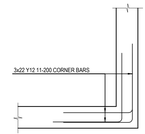
4. IF REQUIRED ALL COLUMN AND WALL KICKERS SHALL BE CAREFULLY FORMED WITH THE SAME GRADE OF CONCRETE AS CORRESPONDING COLUMNS OF WALLS ABOVE.
5. WIRE CONNECTORS THROUGH CONCRETE SHALL NOG BE ALLOWED. ALL FERRULES OF OTHER FASTENING DEVICES SHALL PRESENT A NEAT AND UNIFORM PATTERN.
6. ALL FOUNDATIONS MUST BE INSPECTED AND APPROVED BY THE ENGINEER BEFORE ANY CONCRETE IS CAST.
7. ALLOWABLE FOUNDATION BEARING PRESSURE: 100kPa
8. ALL EXPOSED CONCRETE SURFACES ARE OFF-SHUTTER FINISHES TO DEGREE OF ACCURACY 2.
9. ALL EXPOSED CONCRETE CORNERS MUST BE CHAMFERED WITH 20 x 20mm.
10. CONCRETE CUBES SHALL BE MADE, CURED AND TESTED IN ACCORDANCE WITH SABS METHOD 861. A SAMPLE SHALL CONSIST OF 6 CUBES AND SHALL BE TAKEN FOR EACH INDIVIDUAL CONCRETING OPERATING AND AT LEAST ONE PER 50m³ CONCRETE OF THE SAME OPERATING CAST. 3 CUBES SHALL BE TESTED AT 7 DAYS AND 3 AT 28 DAYS.



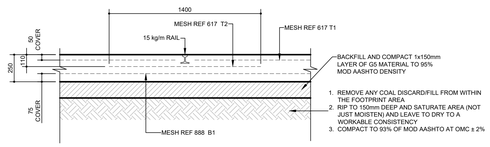
TYPICAL CONSTRUCTION JOINT DETAIL
SCALE 1:10



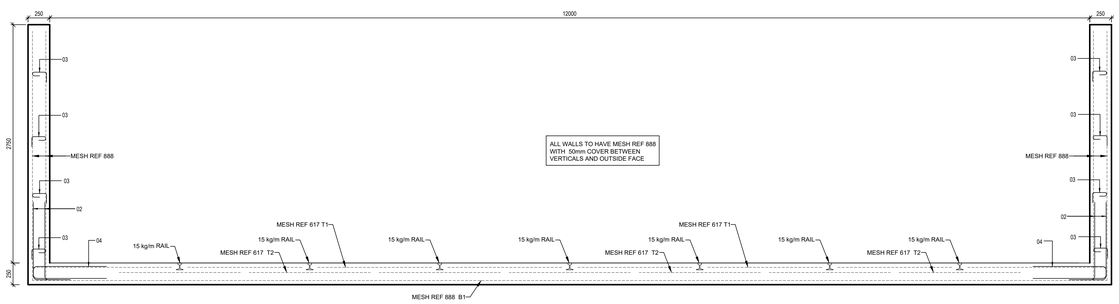
TYPICAL SLAB EDGE DETAIL
SCALE 1:10



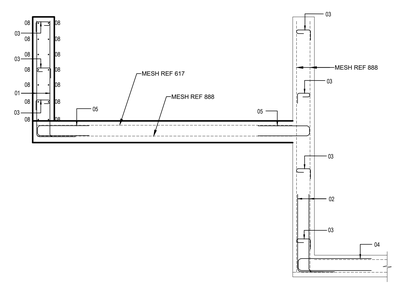
TYPICAL CORNER BARS (*)
SCALE 1:25



TYPICAL RAIL/FLOOR REINFORCEMENT DETAIL
SCALE 1:20



SECTION B
SCALE 1:25



SECTION C
SCALE 1:25

Notes:

GENERAL NOTES:

1. DO NOT SCALE FROM THIS DRAWING. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT ARCHITECT'S AND ENGINEER'S DRAWINGS.
2. ANY DISCREPANCIES, AMBIGUITIES, OR ANOMALIES IN THE INFORMATION PROVIDED ON THIS OR ANY OF THE ENGINEERING DRAWINGS PACKAGE MUST BE REPORTED PRIOR TO WORK PROCEEDING.
3. IT IS THE CONTRACTOR'S RESPONSIBILITY TO LOCATE ALL EXISTING SERVICES AND VERIFY THEIR LEVEL & LOCATION PRIOR TO COMMENCING ANY WORKS. SHOULD THEY BE AFFECTED BY THE WORKS THEN THE RESPECTIVE STATUTORY UNDERTAKER SHOULD BE CONTACTED AND ANY SPECIAL PROTECTION REQUIREMENTS AGREED.
4. THE CONTRACTOR IS TO KEEP A FULL SET OF THE LATEST DRAWINGS ON SITE.
5. THE CONTRACTOR IS RESPONSIBLE FOR CORRECT SETTING OUT OF BUILDINGS ON SITE WITH PARTICULAR REFERENCE TO BOUNDARIES & BUILDING LINES.
6. THE CONTRACTOR IS RESPONSIBLE FOR MAINTAINING THE REINFORCEMENT IN THE CORRECT POSITION AT ALL TIMES.
7. ALL CONCRETE WORKS TO BE IN ACCORDANCE WITH SANS 1200 OR LATEST AMENDMENT THEREOF.
8. NO CONCRETE PLACEMENT IS TO BE UNDERTAKEN WITHOUT THE ENGINEERS APPROVAL.
9. ALL REINFORCEMENT TO BE INSPECTED BY THE ENGINEER PRIOR TO POURING CONCRETE.
10. ALL WORKS MUST COMPLY WITH CURRENT HEALTH AND SAFETY GUIDANCE & STANDARDS.
11. ALL PRODUCTS ARE TO BE INSTALLED AND MAINTAINED STRICTLY IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS & GUIDELINES.
12. INSITU SOIL TO BE CONFIRMED BY ENGINEER PRIOR TO CONSTRUCTION.

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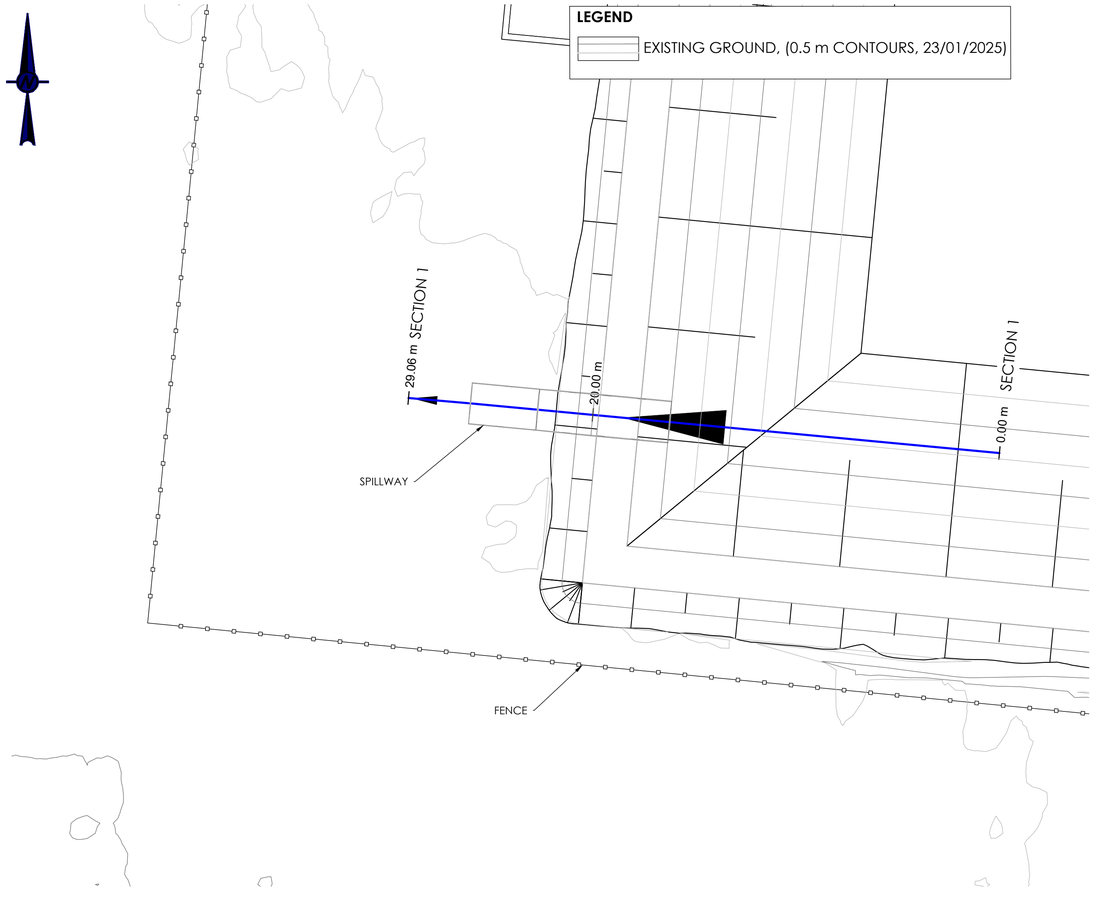
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: JOHANNES HANEKOM
PR nr. 2018300065

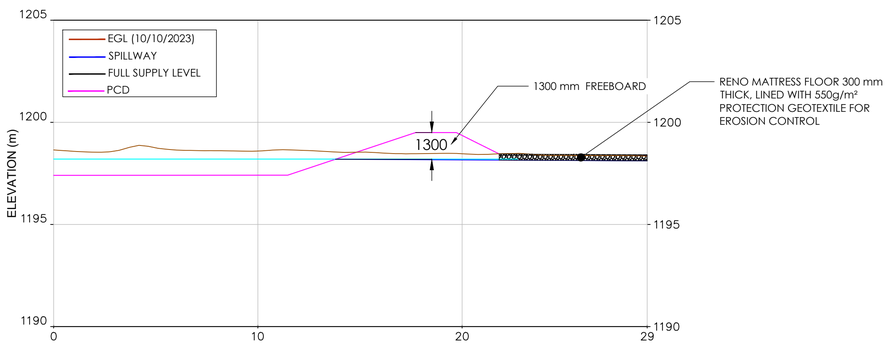
SITE: RIETFONTEIN PLANT

TITLE: SILT TRAP REINFORCEMENT DETAILS

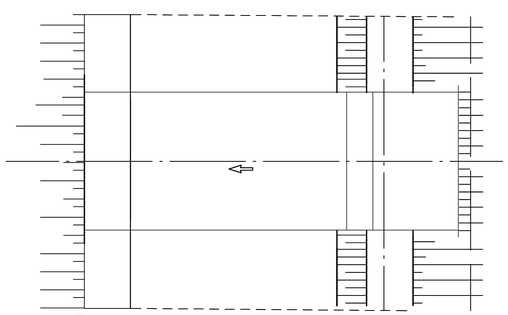
SCALE AT A1:	DATE:	DRAWN:	CHECKED:
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PROJECT NO:	DRAWING NO:		REVISION:
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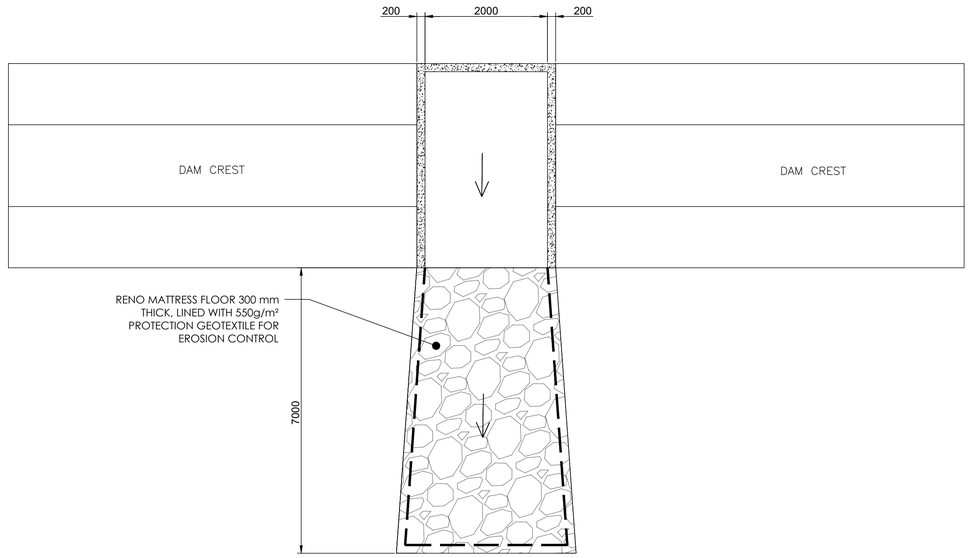
LOCATION OF PCD SPILLWAY
1:150



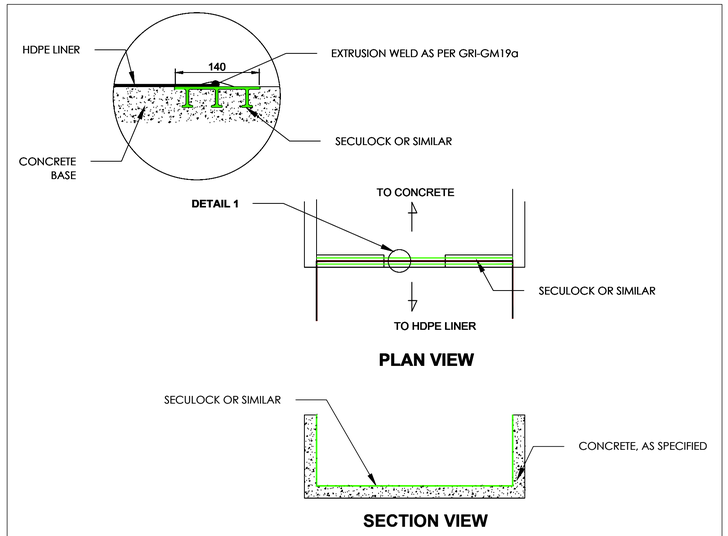
SECTION 1-1
1:150



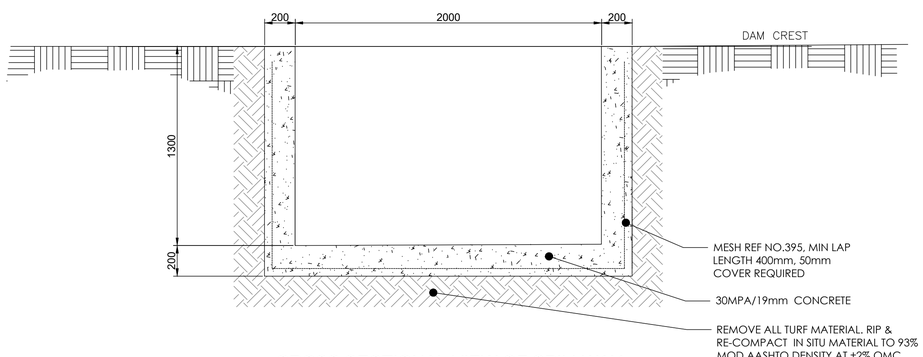
EMERGENCY SPILLWAY PLAN VIEW
NOT TO SCALE



DETAIL OF SPILLWAY OUTLET STRUCTURE
1:100



TYPICAL DETAIL OF CONCRETE AND HDPE CONNECTION
TO SUIT EXISTING CHANNEL



CROSS SECTIONAL VIEW OF SPILLWAY
1:20

Notes:

1. CONCRETE CLASS: 30 / 19 MPa
2. FINISING OFF SHUTTER FLOOR FLOATED
3. CURING SPESIFICATIONS TO SANS 1200
4. CONSTRUCTION JOINTS TO SANS 1200
5. COMPACTION SHOULD BE CONFIRMED WITH ENGINEER ON SITE
6. HDPE GEOMEMBRANE TO BE SEALED TO CONCRETE AS PER DETAIL
7. MESH REF. NO. 395 PLACED IN CENTER OF SLAB AND WALLS OF SPILLWAY WITH 50mm COVER

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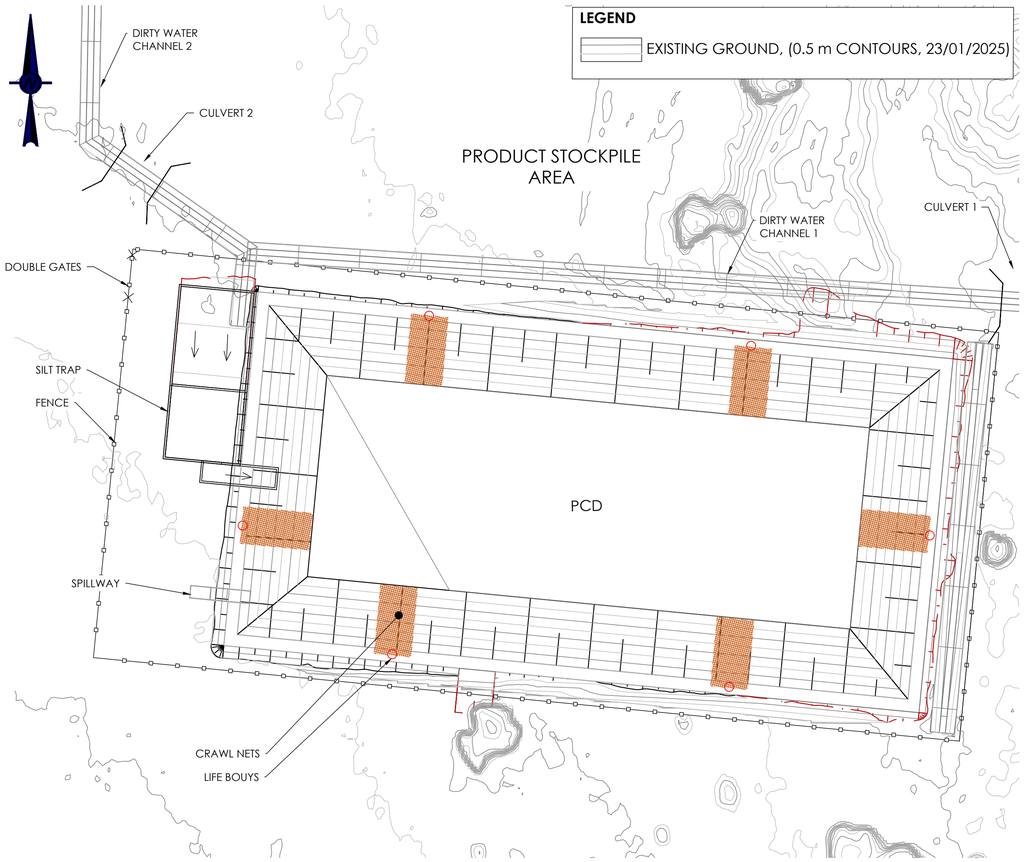
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

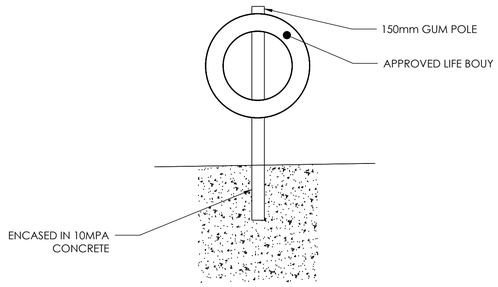
TITLE: SPILLWAY LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

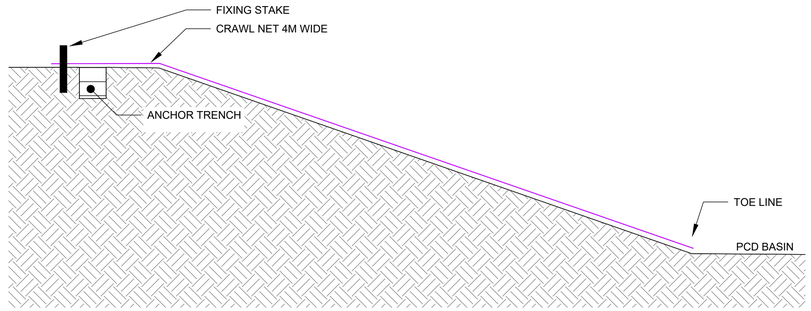
PROJECT NO:	DRAWING NO:	REVISION:
284	08	0



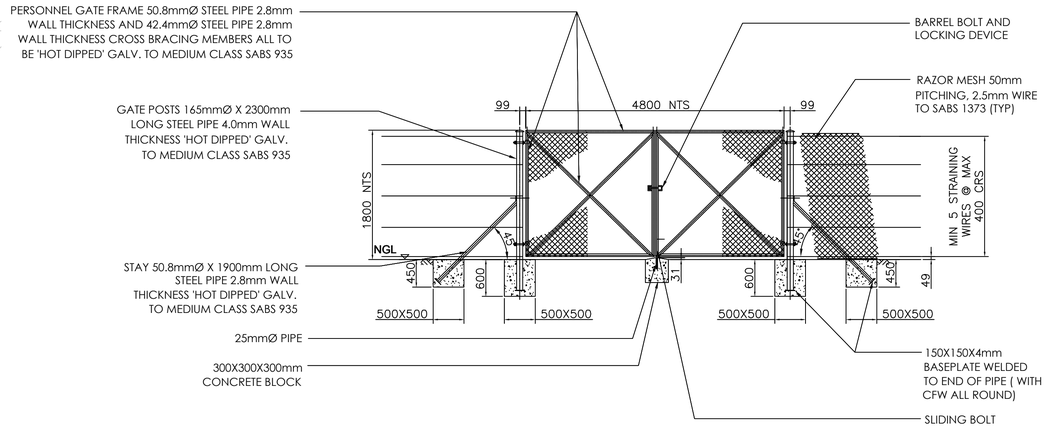
LOCATION OF EMERGENCY INFRASTRUCTURE
1:500



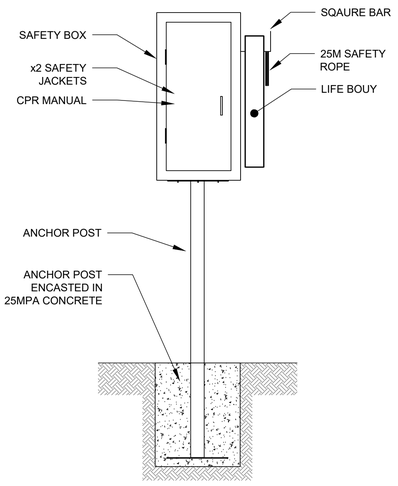
LIFE BOUY DETAIL
NOT TO SCALE



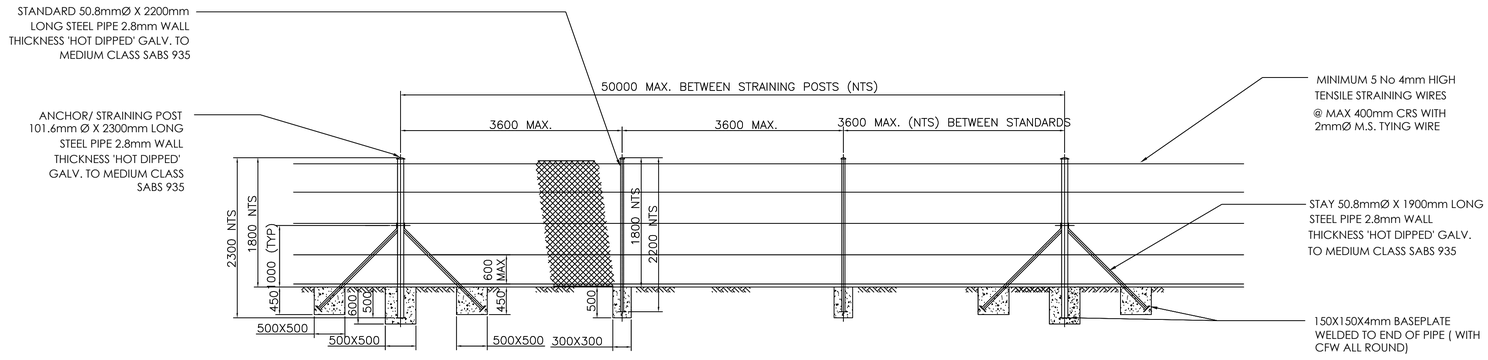
CRAWL NET DETAIL
NOT TO SCALE



DOUBLE GATES FOR VEHICULAR ACCESS
1:50



SAFETY BOX DETAIL
NOT TO SCALE



PERIMETER FENCE DETAIL
1:50

Notes:

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STATUS:	ISSUED FOR INFORMATION		

MineLock Pty Ltd
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0157
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CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

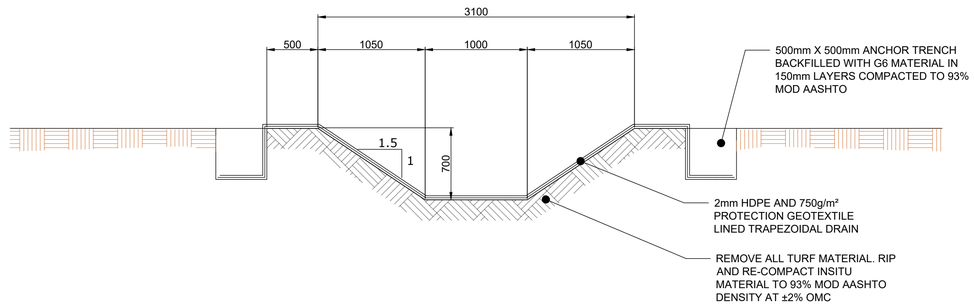
TITLE: PCD EMERGENCY INFRASTRUCTURE

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

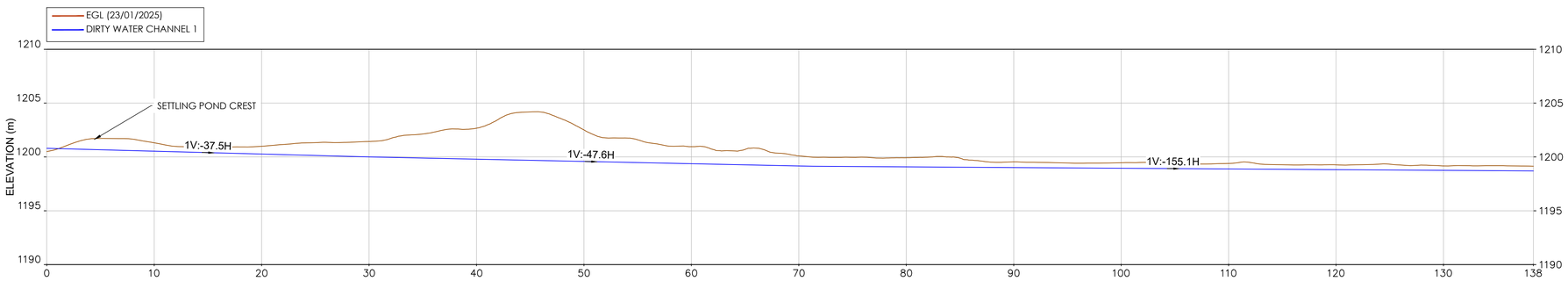
PROJECT NO:	DRAWING NO:	REVISION:
284	09	0



LOCATION OF DIRTY WATER CHANNEL 1
1:500



TYPICAL DETAIL OF DIRTY WATER CHANNEL 1
1:30



SECTION 1-1
1:250

Notes:

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CLOVER ALLOYS

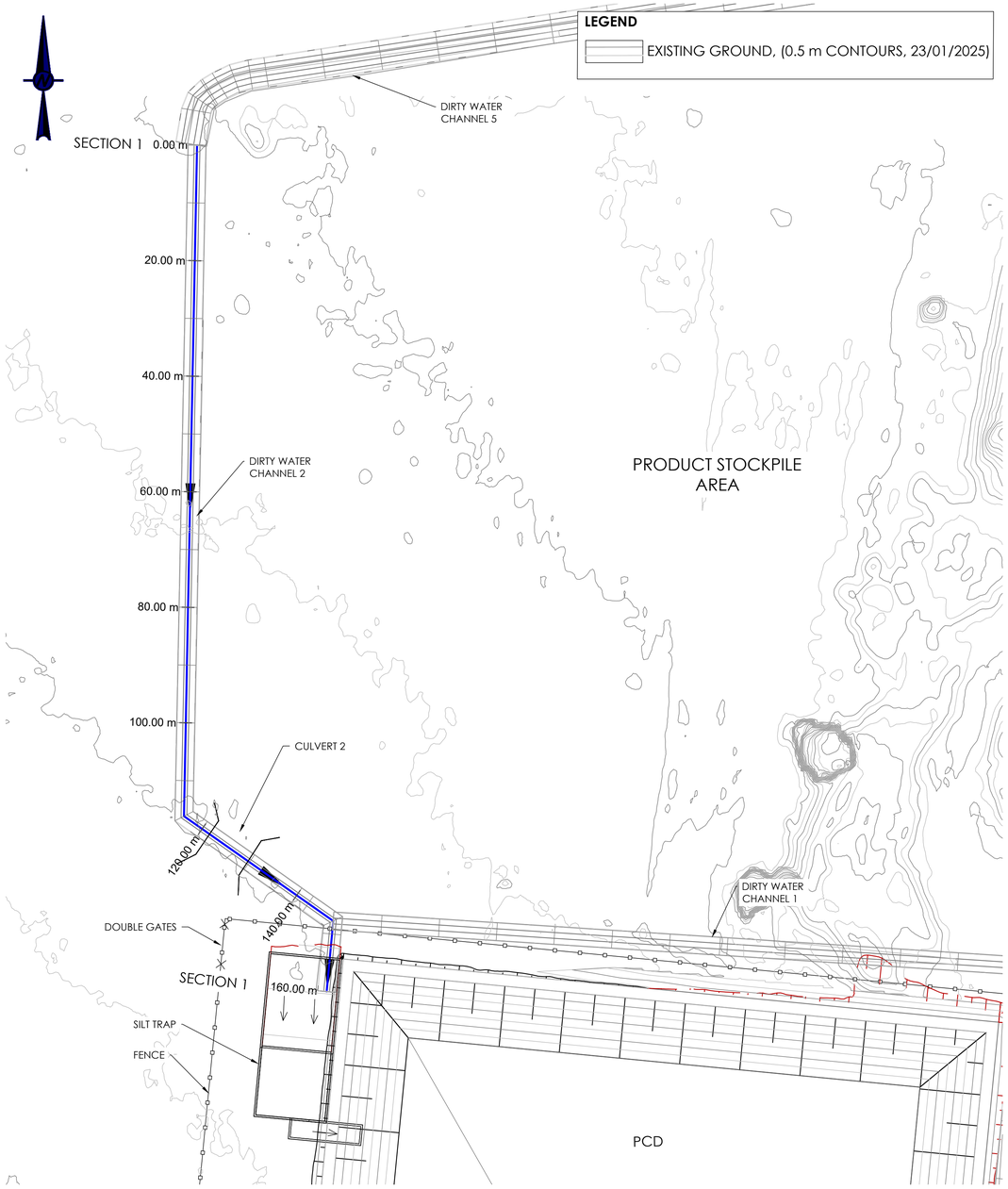
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

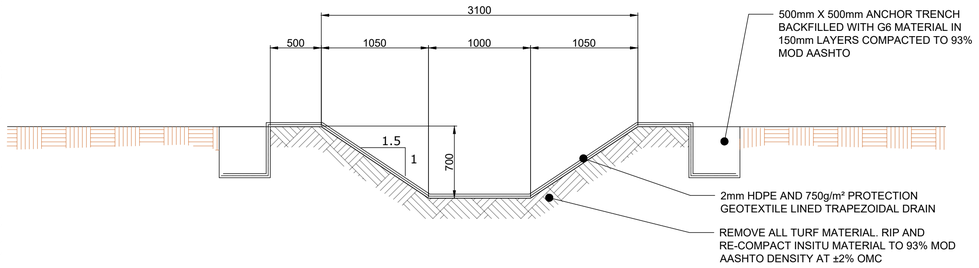
TITLE: DIRTY WATER CHANNEL 1
LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

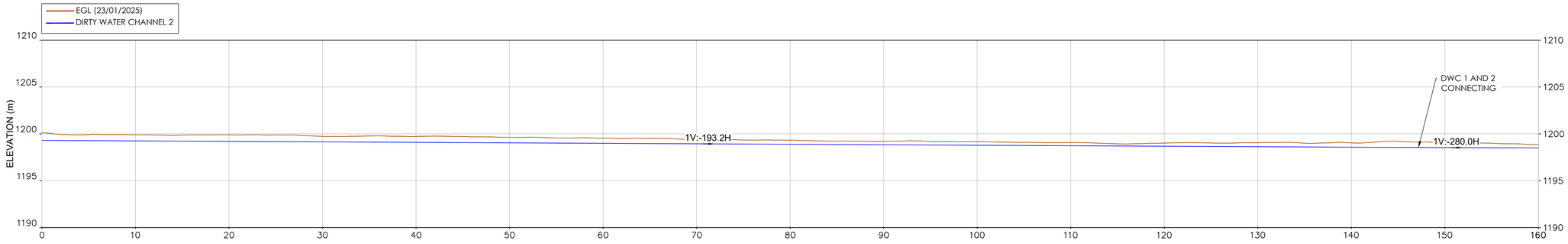
PROJECT NO:	DRAWING NO:	REVISION:
284	10	0



LOCATION OF DIRTY WATER CHANNEL 2
1:500



TYPICAL DETAIL OF DIRTY WATER CHANNEL 2
1:30



SECTION 1-1
1:250

DWC 2

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

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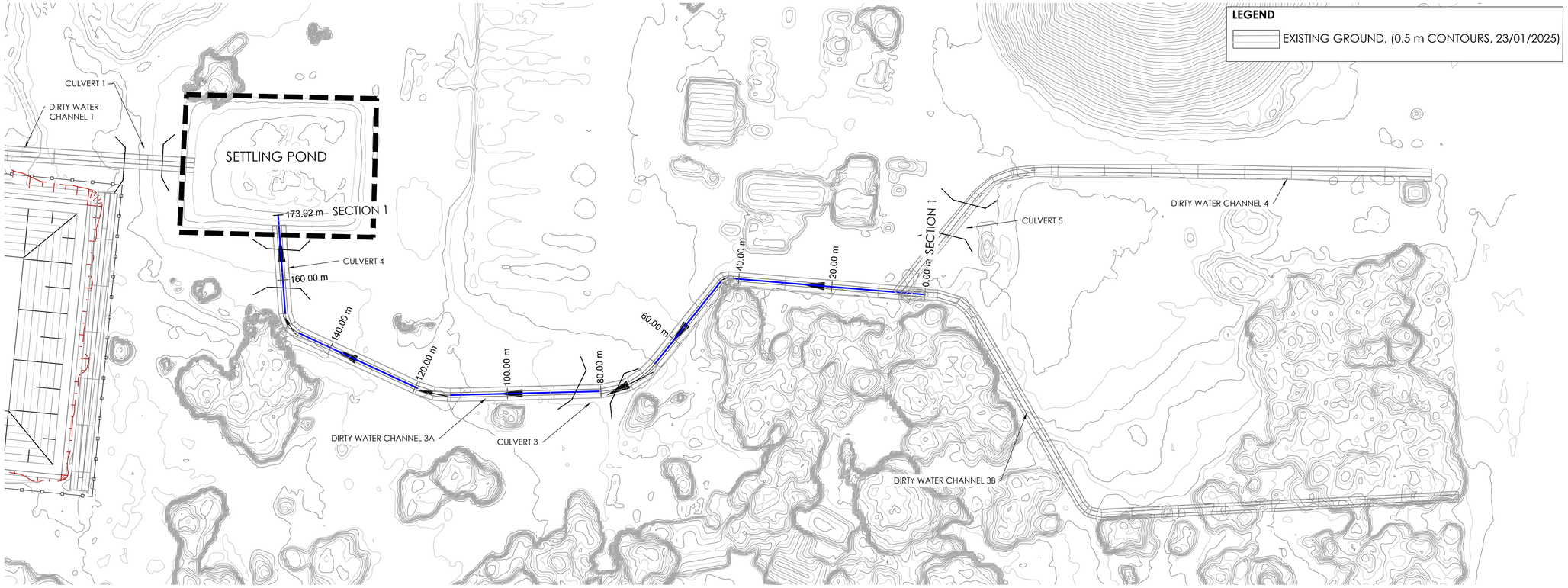
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

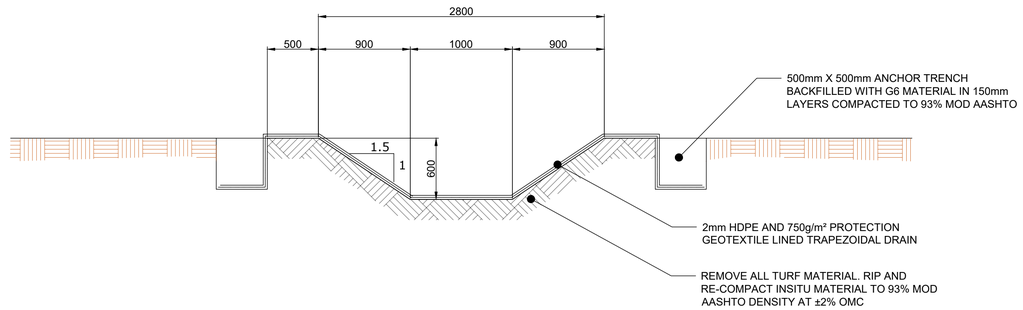
SITE: RIETFONTEIN PLANT

TITLE: DIRTY WATER CHANNEL 2 LAYOUT AND DETAIL

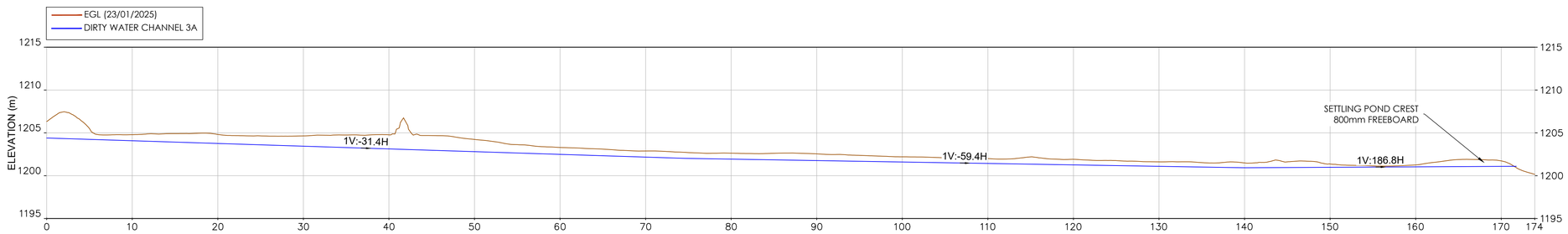
SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	11		0



LOCATION OF DIRTY WATER CHANNEL 3A
1:500



TYPICAL DETAIL OF DIRTY WATER CHANNEL 3A
1:30



SECTION 1-1
1:300

Notes:

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STATUS:	ISSUED FOR INFORMATION		

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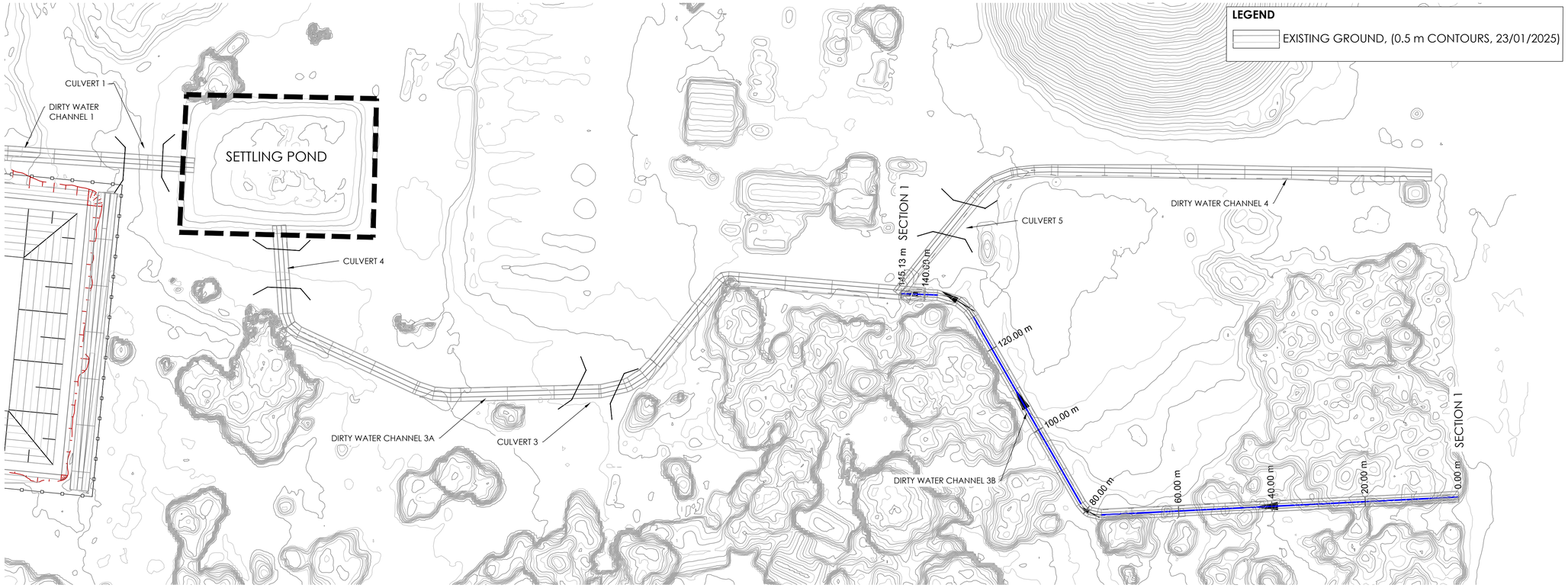
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

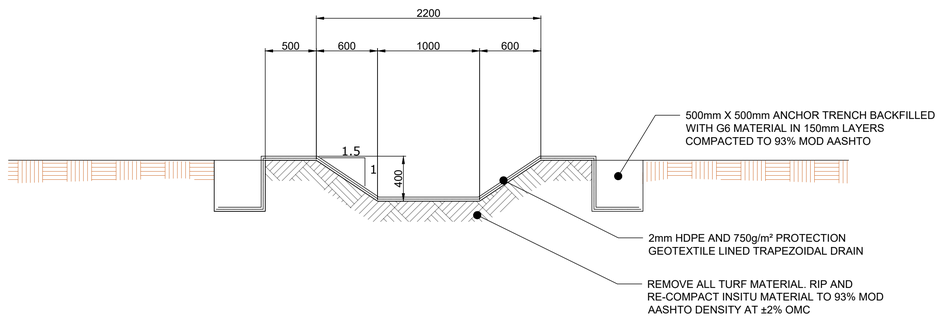
SITE: RIETFONTEIN PLANT

TITLE: DIRTY WATER CHANNEL 3A
LAYOUT AND DETAIL

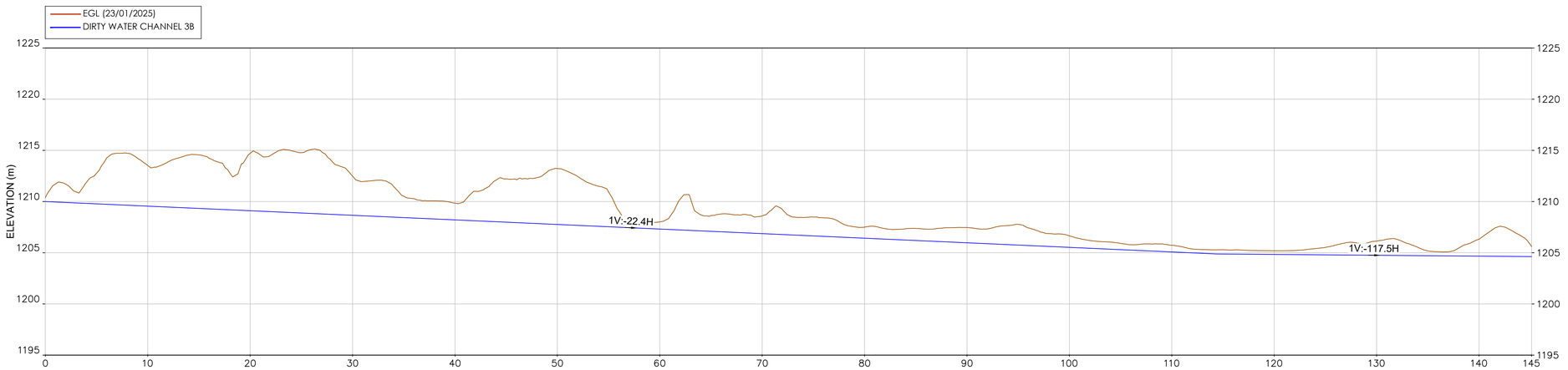
SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	12		0



LOCATION OF DIRTY WATER CHANNEL 3B
1:500



TYPICAL DETAIL OF DIRTY WATER CHANNEL 3B
1:30



SECTION 1-1
1:250

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

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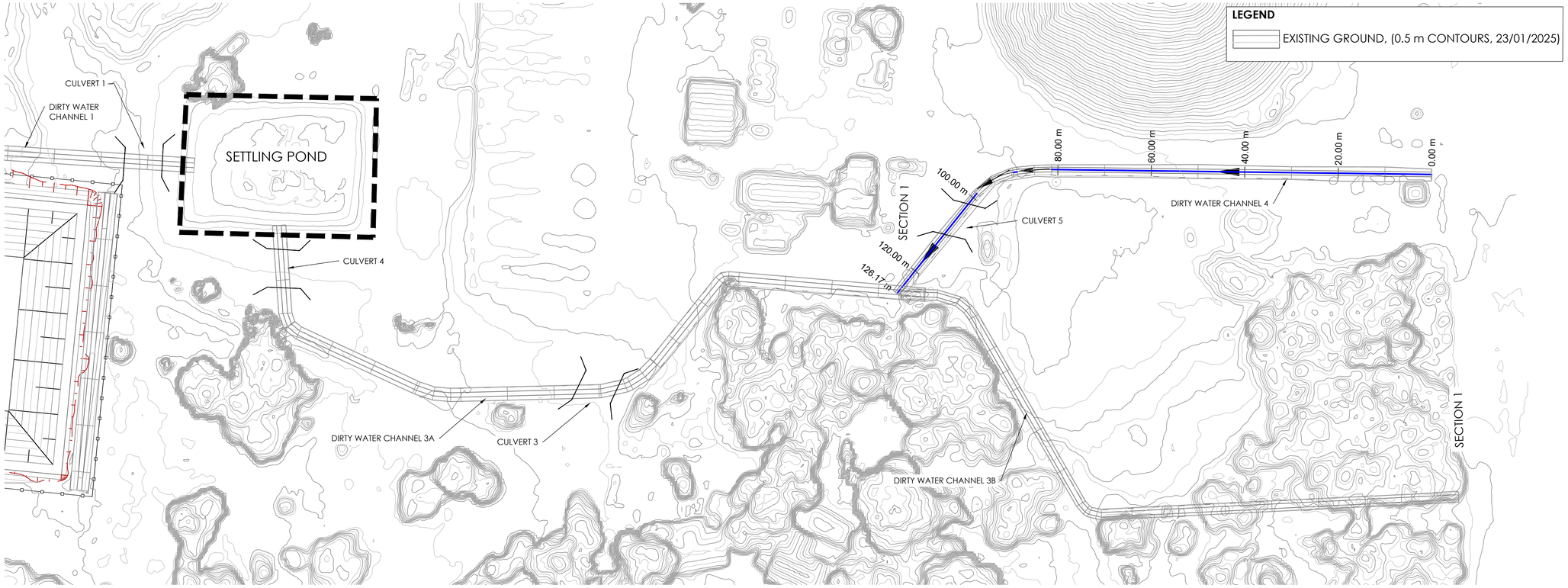
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

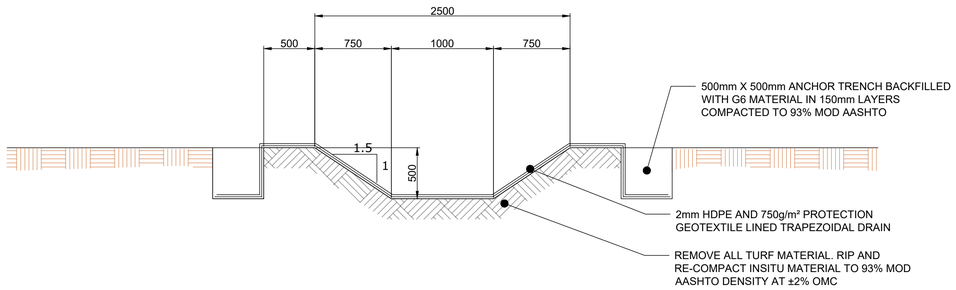
SITE: RIETFONTEIN PLANT

TITLE: DIRTY WATER CHANNEL 3B LAYOUT AND DETAIL

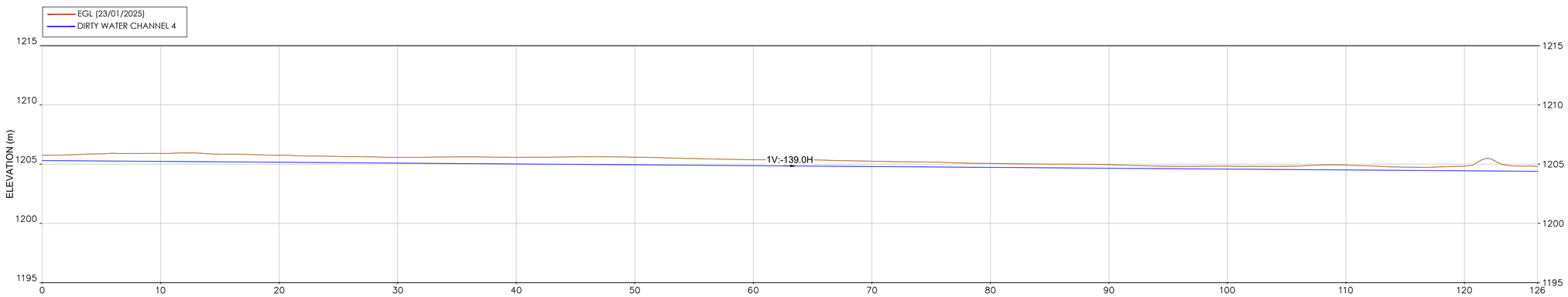
SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	13		0



LOCATION OF DIRTY WATER CHANNEL 4
1:500



TYPICAL DETAIL OF DIRTY WATER CHANNEL 4
1:30



SECTION 1-1
1:200

Notes:

0	ISSUED FOR INFORMATION	MLR	20/08/25

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STATUS:	ISSUED FOR INFORMATION		

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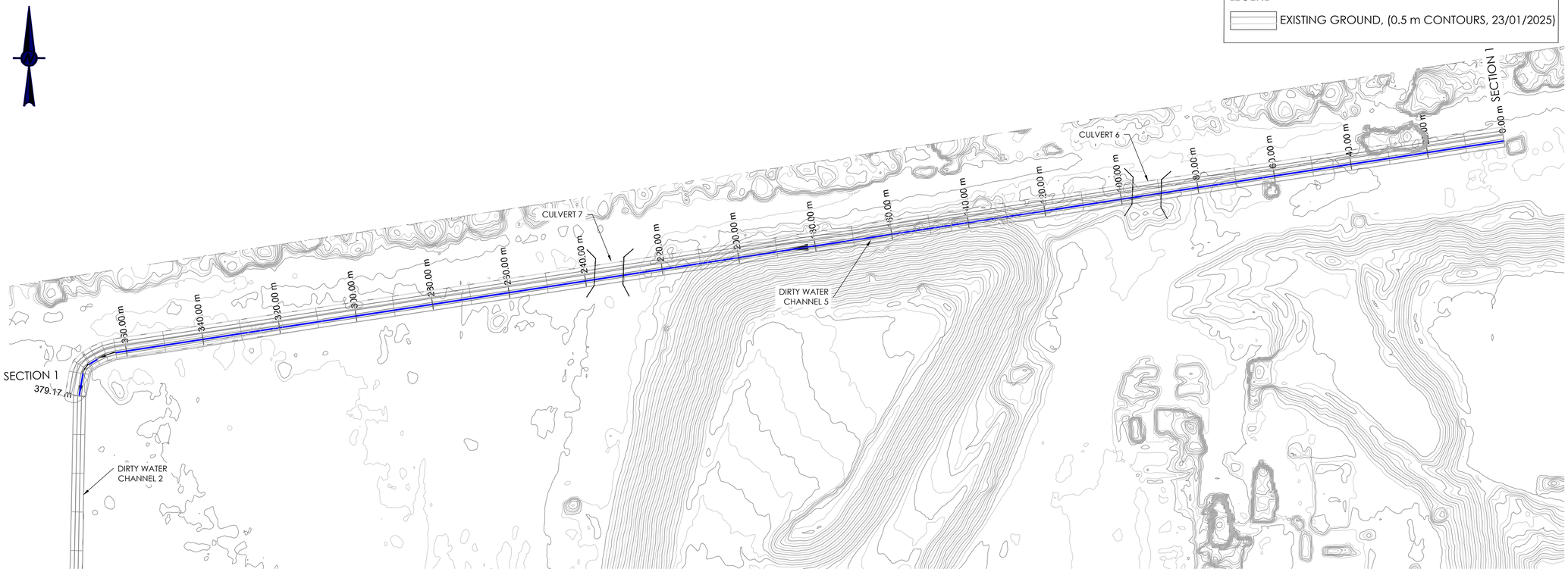
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

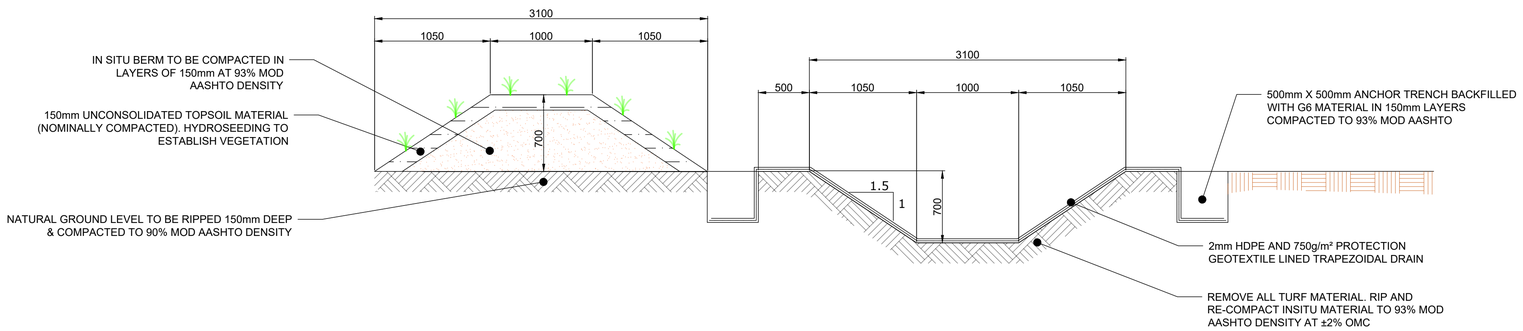
TITLE: DIRTY WATER CHANNEL 4
LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	14		0



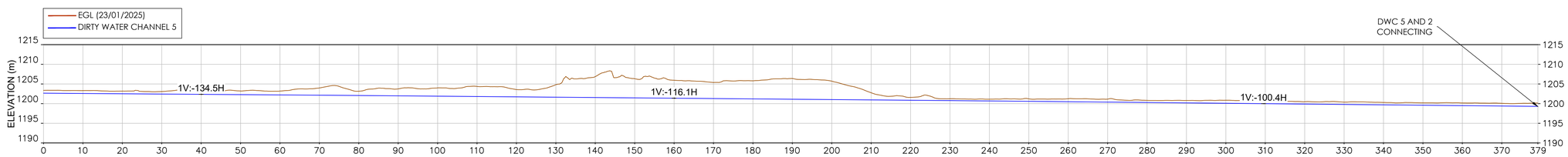
LOCATION OF DIRTY WATER CHANNEL 5 AND CLEAN WATER SEPARATION BERM

1:600



TYPICAL DETAIL OF DIRTY WATER CHANNEL 5 AND CLEAN WATER SEPARATION BERM

1:30



SECTION 1-1

1:600

Notes:

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CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: DIRTY WATER CHANNEL 5
LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	15		0



LOCATION OF CULVERTS
1:850

Notes:

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CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

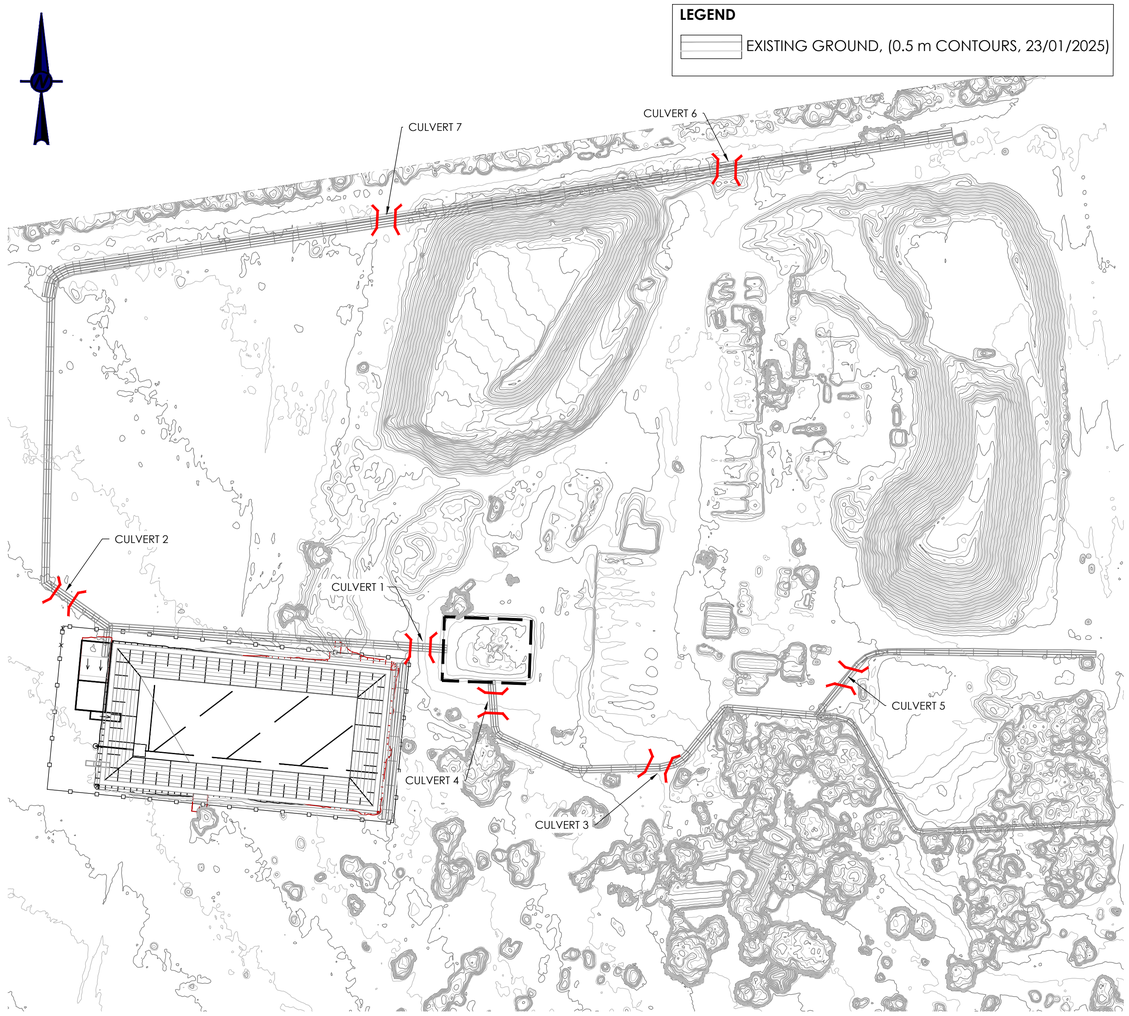
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: CULVERTS LOCATIONS

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

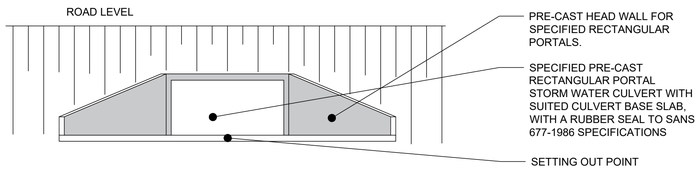
PROJECT NO:	DRAWING NO:	REVISION:
284	16	0



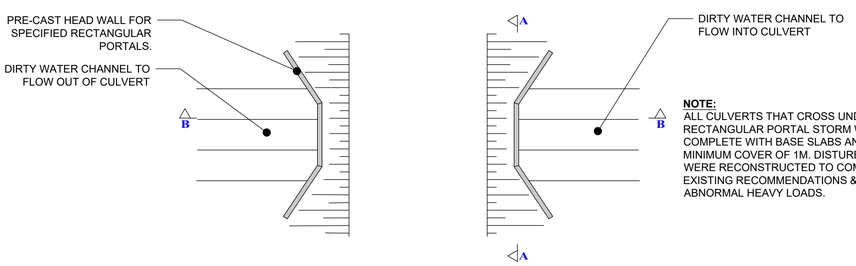
LOCATION OF CULVERTS
1:1250

Culvert Name	Channel Associated with Culvert	Culvert Width (m)	Culvert Heigth (m)	Culvert Length (m)
Culvert 1	Dirty Water Channel 1	0,75	0,75	10
Culvert 2	Dirty Water Channel 2	0,75	0,75	10
Culvert 3	Dirty Water Channel 3A	0,75	0,6	10
Culvert 4	Dirty Water Channel 3A	0,75	0,6	10
Culvert 5	Dirty Water Channel 4	0,75	0,45	10
Culvert 6	Dirty Water Channel 5	0,75	0,75	10
Culvert 7	Dirty Water Channel 5	0,75	0,75	10

Culvert Name	Culvert Width (m)	Culvert Heigth (m)	Wingwall Units for Portal Culverts Sections		
			Code	Series / Size	Mass (Kg)
Culvert 1	0,75	0,75	S2	675-900	2100
Culvert 2	0,75	0,75	S2	675-900	2100
Culvert 3	0,75	0,6	D1	300-600	1130
Culvert 4	0,75	0,6	D1	300-600	1130
Culvert 5	0,75	0,45	D1	300-600	1130
Culvert 6	0,75	0,75	S2	675-900	2100
Culvert 7	0,75	0,75	S2	675-900	2100

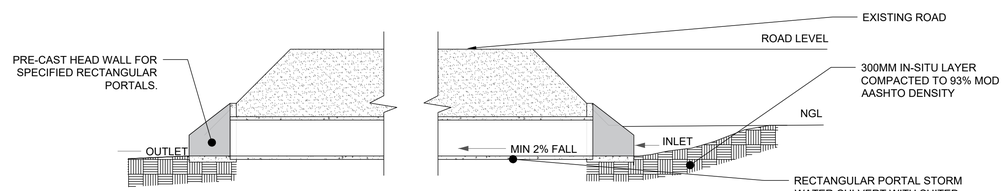


TYPICAL DIRTY WATER CULVERT STRUCTURE - FRONT VIEW
1:50



NOTE:
ALL CULVERTS THAT CROSS UNDER ROADS ARE PRE-CAST RECTANGULAR PORTAL STORM WATER CULVERTS COMPLETE WITH BASE SLABS AND GROUT SEALS & HAS A MINIMUM COVER OF 1M. DISTURBED ROAD'S LAYER WORKS WERE RECONSTRUCTED TO COMPLY WITH CLIENT'S EXISTING RECOMMENDATIONS & SPECIFICATIONS FOR ABNORMAL HEAVY LOADS.

TYPICAL DIRTY WATER CULVERT STRUCTURE - PLAN VIEW
1:100



TYPICAL DIRTY WATER CULVERT - SIDE VIEW
1:50

Notes:

ALL CULVERT CONSTRUCTION SHALL BE CARRIED OUT IN ACCORDANCE WITH SANS 1200 AND SANS 986.

PIPE CLASS AND BEDDING DETAILS MUST CONFORM TO THE DESIGN REQUIREMENTS AND MANUFACTURER SPECIFICATIONS.

PROPER COMPACTION AROUND AND BENEATH THE CULVERT MUST BE ENSURED TO PREVENT SETTLEMENT AND STRUCTURAL FAILURE.

MINIMUM COVER AND CLASS 1 LOADING CONDITIONS TO BE ADHERED TO.

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CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

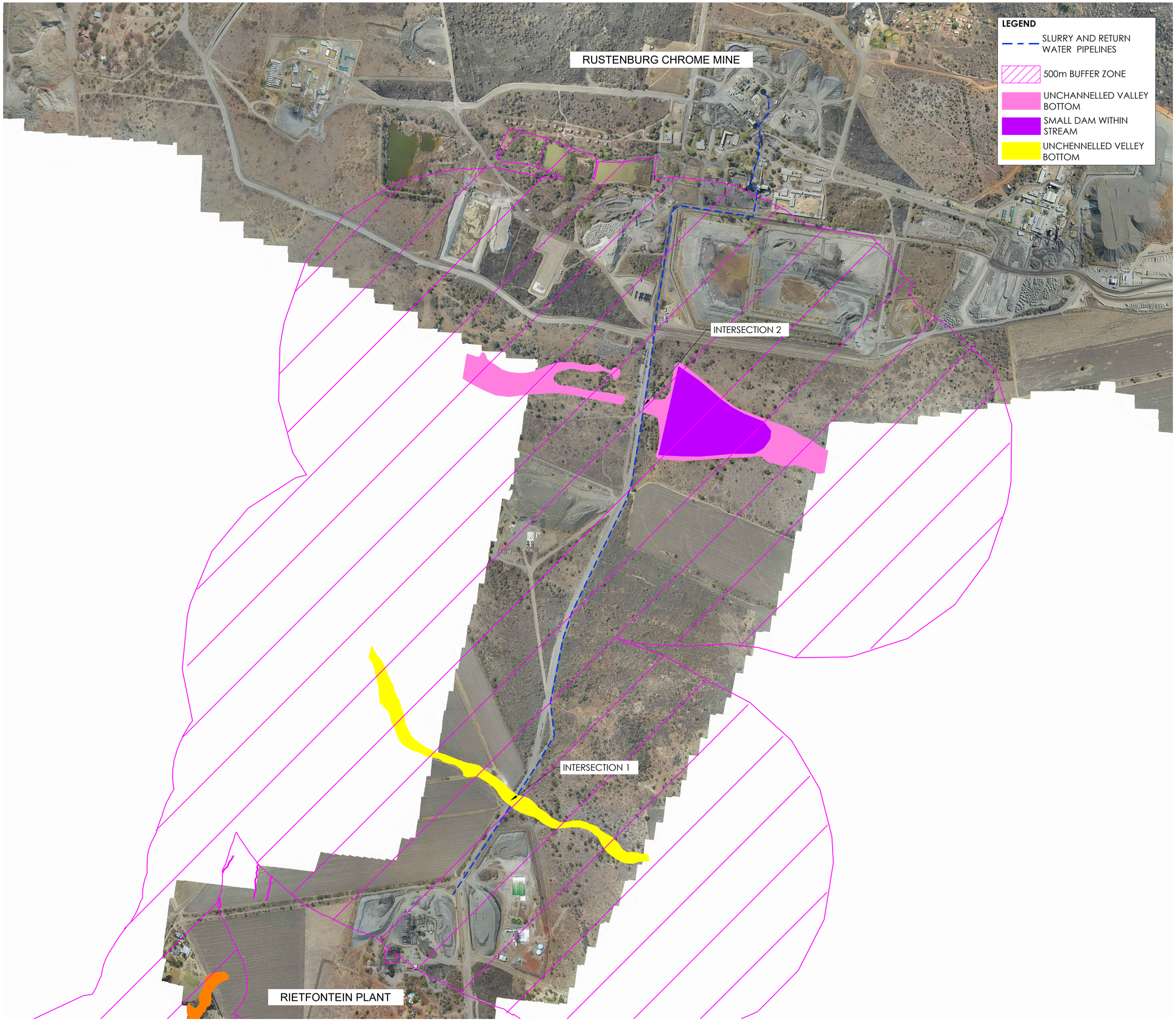
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: CULVERTS LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

PROJECT NO:	DRAWING NO:	REVISION:
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LOCATION OF THE PIPELINES WITHIN STREAMS AND BUFFER ZONES
1:5000

Notes:

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REV:	DESCRIPTION:	BY:	DATE:
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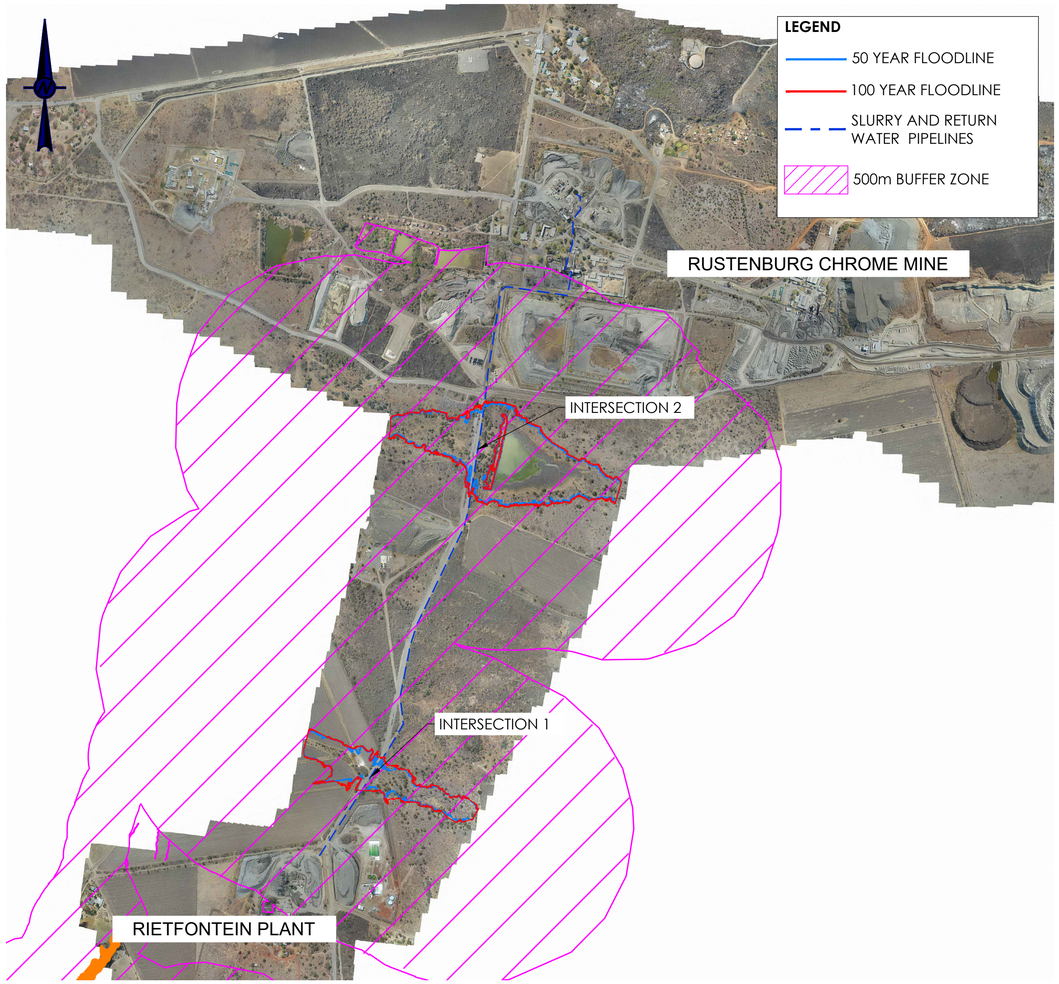
CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

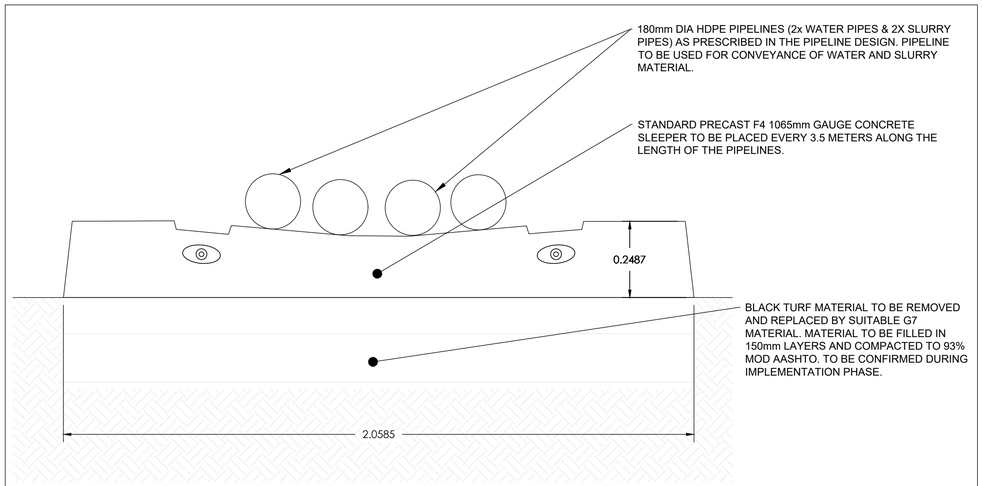
SITE: RIETFONTEIN PLANT

TITLE: WATER AND SLURRY PIPELINES LOCATION

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR
PROJECT NO:	DRAWING NO:		REVISION:
284	18		0

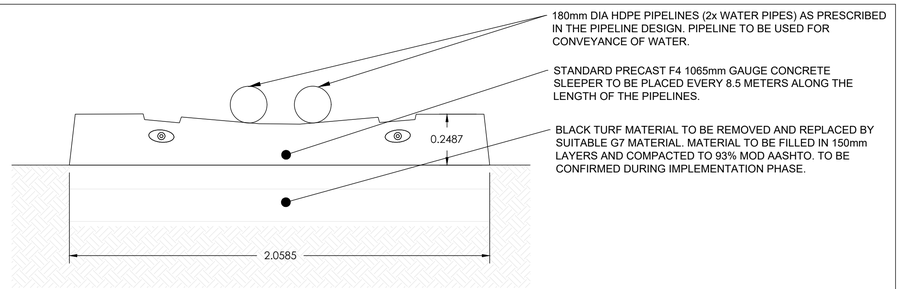


LOCATION OF PIPELINE
1:10000

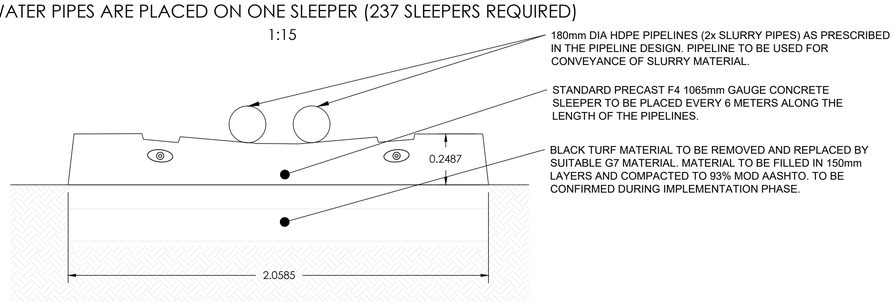


PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF ALL FOUR PIPES ARE PLACED ON ONE SLEEPER (576 SLEEPERS REQUIRED)
1:10

PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES (OPTION 1)



PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF WATER PIPES ARE PLACED ON ONE SLEEPER (237 SLEEPERS REQUIRED)
1:15



PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF SLURRY PIPES ARE PLACED ON ONE SLEEPER (336 SLEEPERS REQUIRED)
1:15

PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES (OPTION 2)

Notes:

GENERAL NOTES:

All concrete shall confirm to the requirements of the latest editions of SANS 2001-CC1, SANS 10100-1 and SANS 10100-2

CONCRETE SPECIFICATIONS:

Foundation - 25MPa after 28 days
Stub Column - 25MPa after 28 days

All concrete mixes for structural work shall be designed by a competent concrete technologist in an approved laboratory. Proof of these mixes will be submitted to the Engineer for his records only. The contractor remains fully responsible to achieve the prescribed compressive strengths.

CONCRETE COVER TO REINFORCEMENT:

Foundations - 50mm sides, 75mm bottom
All columns - 30mm

The degree of accuracy shall be Grade III for foundations, Grade II for general concrete work.

All reinforcement MUST be inspected by the engineer before concrete is cast.

NOTES:

BEARING CAPACITY - 75kPA
MAX LOADING - 4 x 180DIA HDPE PIPES

EROSION MANAGEMENT CONSIDERATIONS:

Where the pipelines will cross a wetland/stream, the pipelines should be accompanied by an earth constructed berm and paddock system for management of any leaks experienced upstream of the crossing as well as management of pumping any spillage within the stream itself. The detailed design of this should be investigated during the Stage 4 design for construction (Paterson and Cooke, 2017).

It is recommended that the pipeline sections within the 500 meter buffer zones should not contain any flanges for the full length of the wetland or river crossing and it should ideally contain a continuous HDPE internal liner for internal wear or corrosion protection.

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

MineLock Pty Ltd
54 Via Salara Cres, Irene Corporate Corner
Building 54, First Floor
Irene
0157
www.minelock.co.za

CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

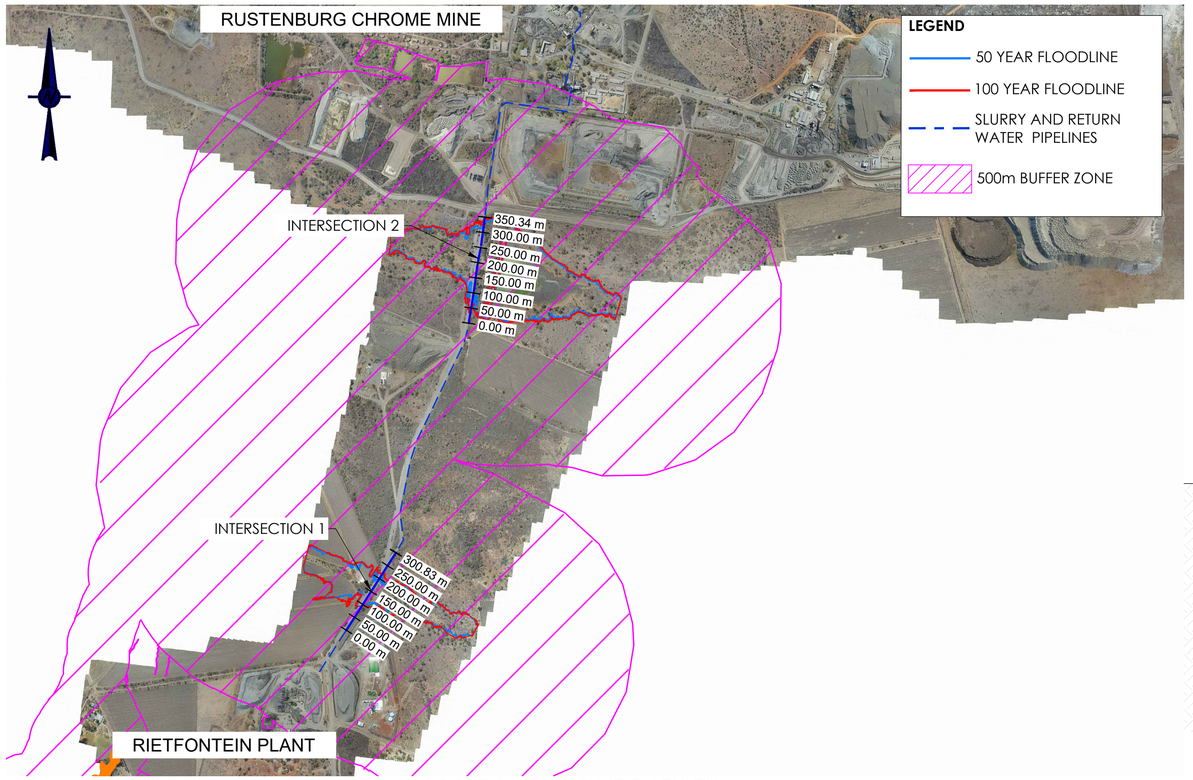
ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

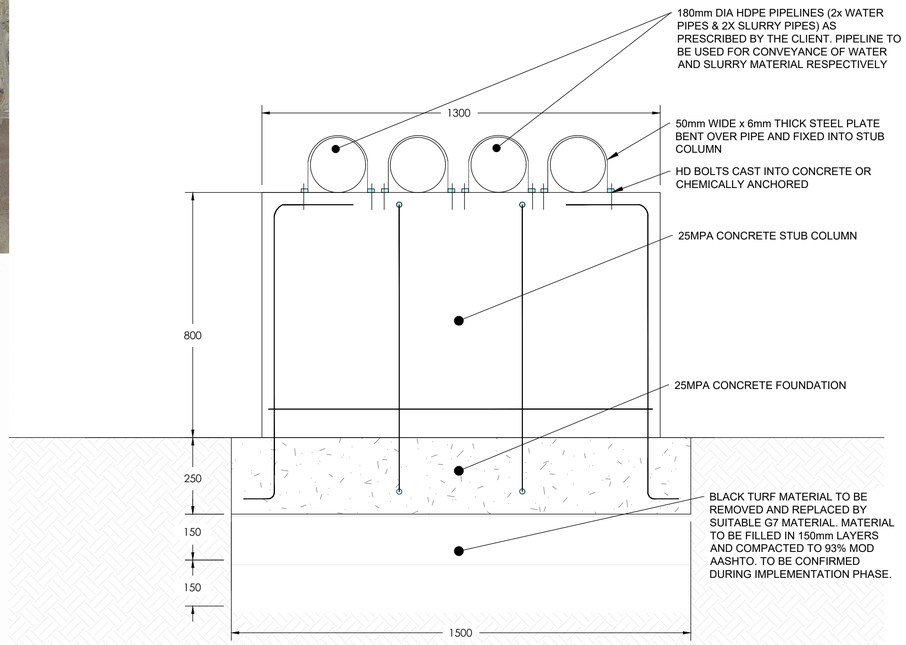
TITLE: WATER AND SLURRY PIPELINES SLEEPER LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

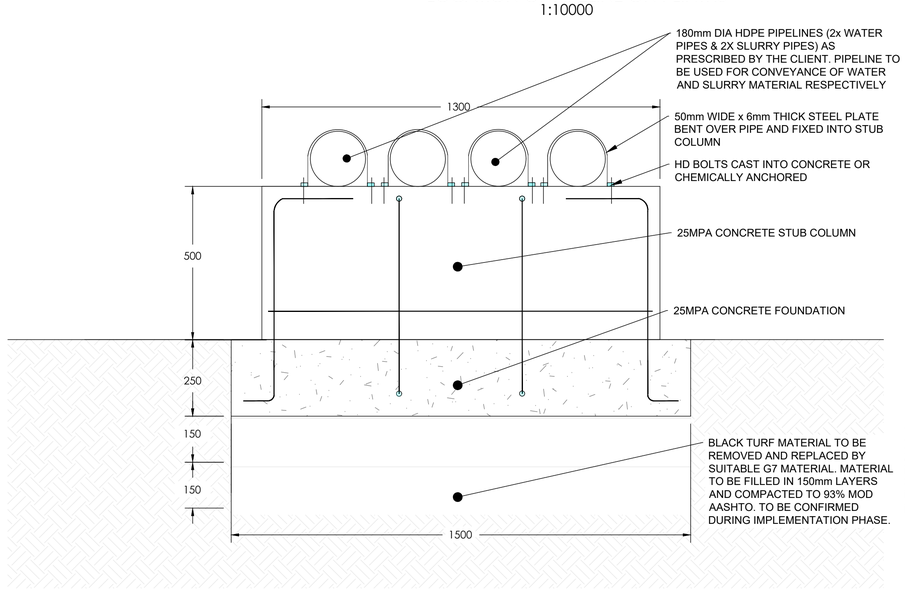
PROJECT NO:	DRAWING NO:	REVISION:
284	19	0



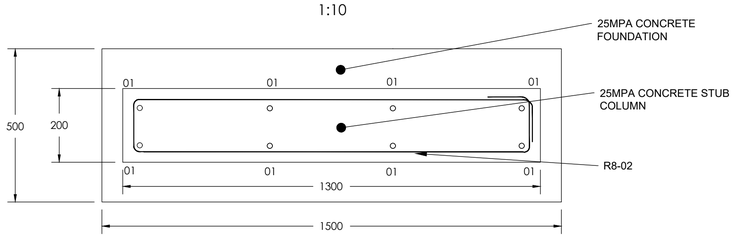
LOCATION OF PIPELINE ON PLINTHS
1:10000



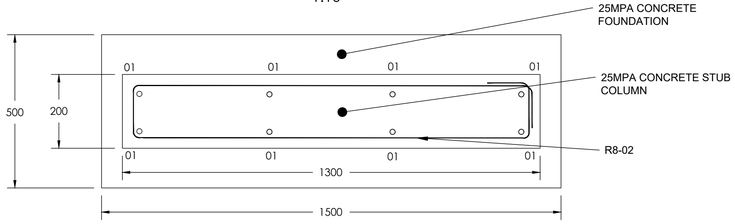
PROPOSED DETAIL OF PIPE PLACEMENT AT FLOODLINE INTERSECTION 1
@ 4m INTERVALS BETWEEN CHAINAGE 120-190m
1:10



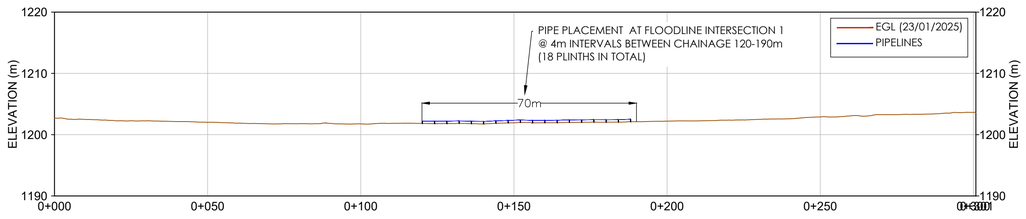
PROPOSED DETAIL OF PIPE PLACEMENT AT FLOODLINE INTERSECTION 2
@ 4.5m INTERVALS BETWEEN CHAINAGE 138-302m
1:10



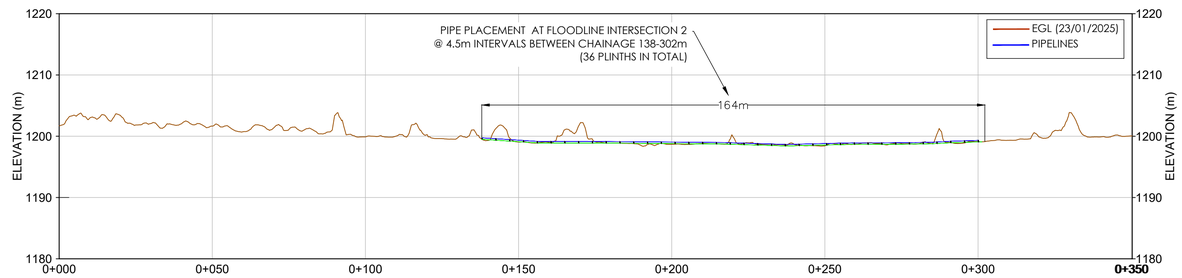
PROPOSED PLAN VIEW OF PIPE PLACEMENT AT FLOODLINE
INTERSECTION 2 @ 4.5m INTERVALSBETWEEN CHAINAGE 138-302m
1:10



PROPOSED PLAN VIEW OF PIPE PLACEMENT AT FLOODLINE
INTERSECTION 1 @ 4m INTERVALS BETWEEN CHAINAGE 120-190m
1:10



SECTION ALONG INTERSECTION 1 (EXAGGERATED X2)
1:1000



SECTION ALONG INTERSECTION 2 (EXAGGERATED X2)
1:1000

Notes:

GENERAL NOTES:

All concrete shall confirm to the requirements of the latest editions of SANS 2001-CC1, SANS 10100-1 and SANS 10100-2

CONCRETE SPECIFICATIONS:

Foundation - 25MPa after 28 days
Stub Column - 25MPa after 28 days

All concrete mixes for structural work shall be designed by a competent concrete technologist in an approved laboratory. Proof of these mixes will be submitted to the Engineer for his records only. The contractor remains fully responsible to achieve the prescribed compressive strengths.

CONCRETE COVER TO REINFORCEMENT:

Foundations - 50mm sides, 75mm bottom
All columns - 30mm

The degree of accuracy shall be Grade III for foundations, Grade II for general concrete work.

All reinforcement MUST be inspected by the engineer before concrete is cast.

NOTES:

BEARING CAPACITY - 75kPA
MAX LOADING - 4 x 180DIA HDPE PIPES

EROSION MANAGEMENT CONSIDERATIONS:

Where the pipelines will cross a wetland/stream, the pipelines should be accompanied by an earth constructed berm and paddock system for management of any leaks experienced upstream of the crossing as well as management of pumping any spillage within the stream itself. The detailed design of this should be investigated during the Stage 4 design for construction (Paterson and Cooke, 2017).

It is recommended that the pipeline sections within the 500 meter buffer zones should not contain any flanges for the full length of the wetland or river crossing and it should ideally contain a continuous HDPE internal liner for internal wear or corrosion protection.

0	ISSUED FOR INFORMATION	MLR	20/08/25

REV:	DESCRIPTION:	BY:	DATE:
STATUS:	ISSUED FOR INFORMATION		

MineLock Pty Ltd
54 Via Salara Cres, Irene Corporate Corner
Building 54, First Floor
Irene
0157
www.minelock.co.za

CLIENT: RUSTENBURG CHROME MINE
CLOVER ALLOYS

ENGINEER: FRANCOIS MARAIS
PR NR. 830215

SITE: RIETFONTEIN PLANT

TITLE: WATER AND SLURRY PIPELINES
PLINTHS LAYOUT AND DETAIL

SCALE AT A1:	DATE:	DRAWN:	CHECKED:
AS SHOWN	20/08/25	MLR	JLR

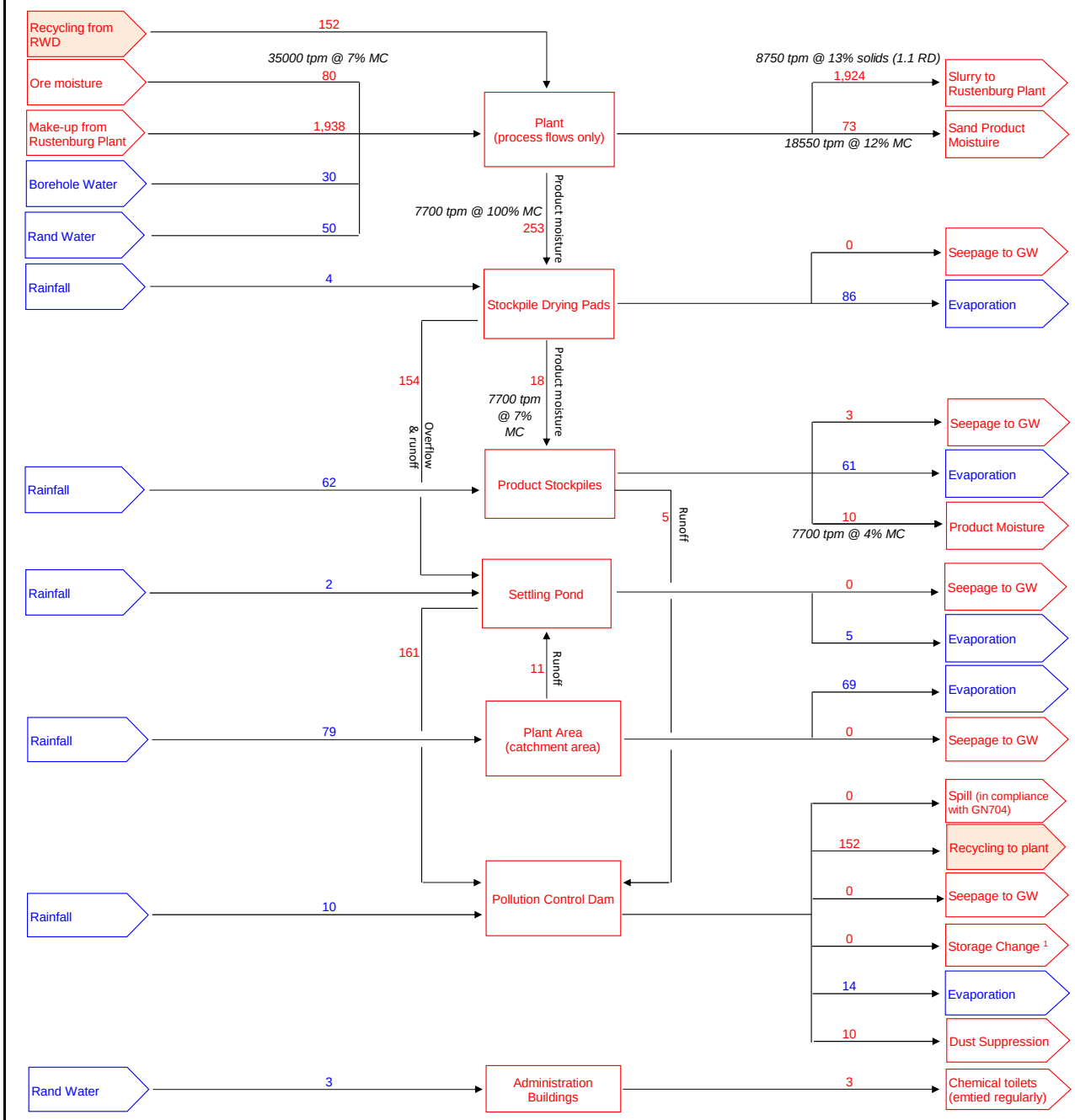
PROJECT NO:	DRAWING NO:	REVISION:
284	20	0

APPENDIX B

WATER BALANCE DIAGRAMS

Daily Average: m³ /day **Rev 0**

Rietfontein Operations
Water balance



Prepared by

MineLock Environmental Engineers

Total Inflows
2,259

Total Outflows
2,259

Legend

000 Dirty Flow (m³/day)

000 Clean Flow (m³/day)

Note 1: Delta storage is the difference between the volumes at the start and end of the simulation.

General Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance

Plant (process flows only)				
	In	Out		Diff
From RWD	151.7	1,923.9	Slurry to Rustenburg	
Ore moisture	80.5	73.1	Sand product moisture	
Make-up	1,937.8	253.0	Prodect moisture	
Borehole water	30.0			
Rand water	50.0			
	2,250.0	2,250.0		0.0

Stockpile drying pads				
	In	Out		Diff
Rainfall	4.5	0.0	Seepage	
Prodect moisture	253.0	86.0	Evaporation	
		0.0	Interstitial lockup	
		17.7	Product moisture	
		153.8	Overflow and runoff	
	257.4	257.4		0.0

Product stockpiles				
	In	Out		Diff
Product moisture	17.7	60.9	Evaporation	
Rainfall	61.8	3.5	Seepage	
		10.1	Product moisture	
		5.0	Runoff	
	79.5	79.5		0.0

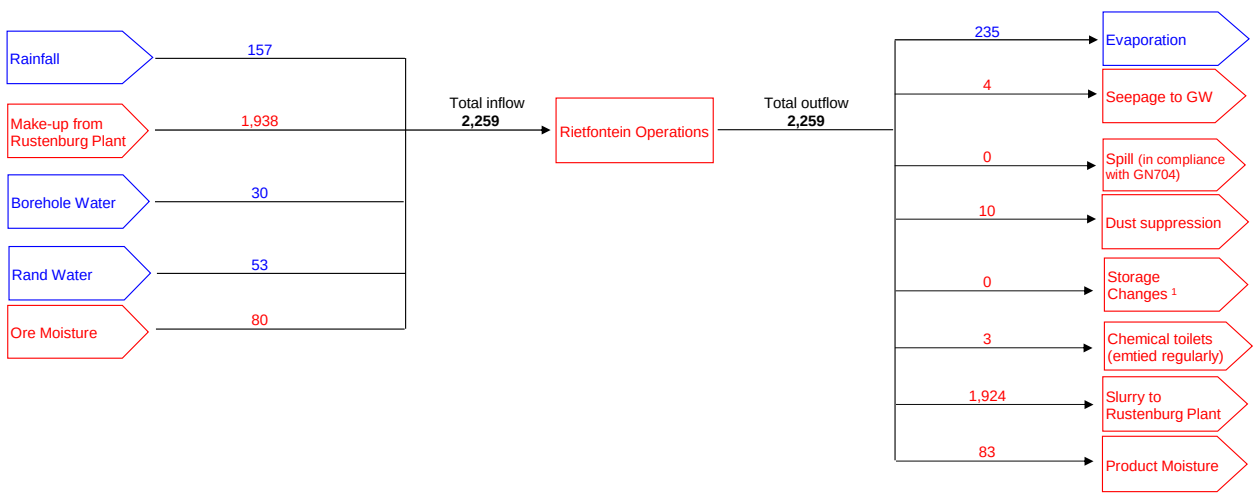
Settling pond				
	In	Out		Diff
Overflow and runoff	153.8	4.9	Evaporation	
Rainfall	1.8	0.1	Seepage	
Plant catchment RO	10.6	161.3	Transfer to PCD	
	166.2	166.2		0.0

Plant area				
	In	Out		Diff
Rainfall	79.4	68.8	Evaporation	
		0.0	Seepage	
		10.6	Runoff	
	79.4	79.4		0.0

Pollution control dam				
	In	Out		Diff
Product stockpiles RO	5.0	0.0	Spill	
Transfer from settling pond	161.3	151.7	Dust suppression	
Rainfall	9.9	0.3	Seepage	
		0.0	Storage change	
		14.2	Evaporation	
		10.0	Recycling	
	176.2	176.2		0.0

Daily Average: m³ /day **Rev 0**

Rietfontein Operations
Summary water balance



Prepared by

MineLock Environmental Engineers

Legend

000 Dirty Flow (m³/day)

000 Clean Flow (m³/day)

Note 1: Delta storage is the difference between the volumes at the start and end of the simulation.
These need to be accounted for to ensure the inflows = outflows

General Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance

APPENDIX C1

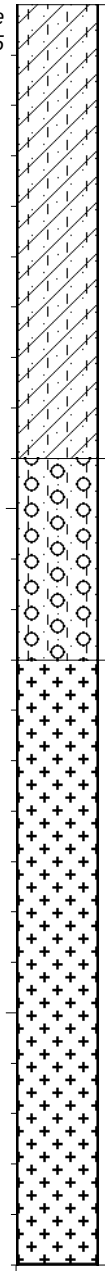
GEOTECHNICAL ASSESSMENT SOIL PROFILES

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 01
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

0.90 Slightly moist, dark olive brown, khaki-brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles; **RESIDUAL NORITE**.

1.30 Olive brown, khaki-brown and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.50

NOTES

1) EOH in dense to very dense; high to moderately weathered, -fractured and -jointed, coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) No samples taken.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION : Horizontal
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 48.85"S
Y-COORD : 27° 21' 47.84"E

HOLE No: TP 01

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

DATE : 19/05/2025 14:37
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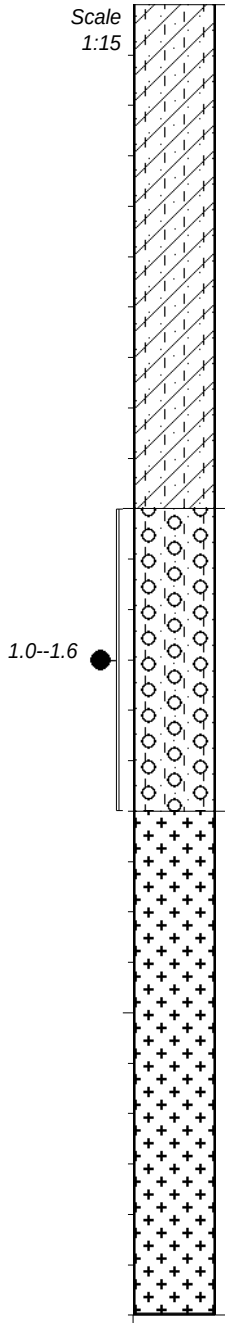
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 02
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

1.00 Slightly moist, dark olive brown, khaki-brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles; **RESIDUAL NORITE**.

1.60 Olive brown, khaki-brown and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.60

NOTES

1) EOH in dense to very dense; high to moderately weathered, -fractured and -jointed coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) Bulk disturbed sample taken from 1.0--1.6 m deep.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 50.31"S
Y-COORD : 27° 21' 49.24"E

HOLE No: TP 02

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

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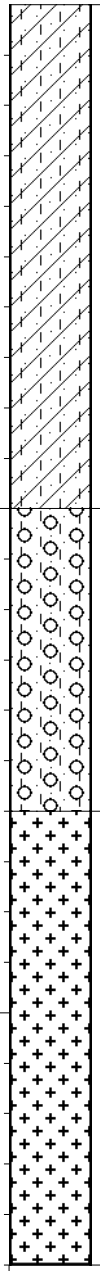
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 03
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

1.00 Slightly moist, khaki brown, khaki yellowish brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles; **RESIDUAL NORITE**.

1.60 Khaki brown, khaki yellowish brown and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.50

NOTES

1) EOH in dense to very dense; high to moderately weathered, -fractured and -jointed, coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) Disturbed sample taken from 1.2--1.5 m deep.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 51.95"S
Y-COORD : 27° 21' 47.67"E

HOLE No: TP 03

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

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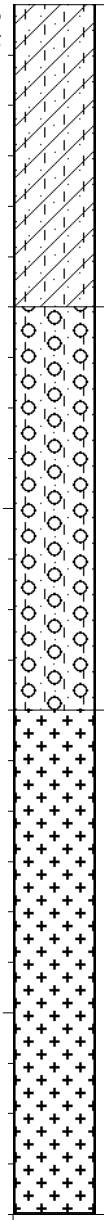
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 04
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

0.60 Slightly moist, khaki brown, khaki yellowish brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles; **RESIDUAL NORITE**.

1.40 Khaki brown, olive brown and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.40

NOTES

1) EOH in dense to very dense; highly to moderately weathered, -fractured and -jointed coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) No samples taken.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie
TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025
DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

ELEVATION :
X-COORD : 25° 44' 53.63"S
Y-COORD :

HOLE No: TP 04

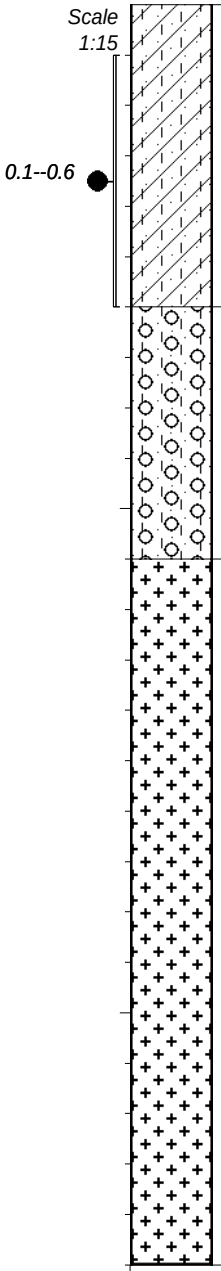
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 05
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00

Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

0.60

Slightly moist, khaki brown, khaki yellowish brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels and cobbles; **RESIDUAL NORITE**.

1.10

Khaki brown, olive brown and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.50

NOTES

1) EOH in dense to very dense; highly to moderately weathered, -fractured and -jointed coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable Sidewalls.
4) Bulk sample taken from 0.1--0.6 m deep.
5) Disturbed sample taken from 0.1--0.6 m deep.
6) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 53.63"S
Y-COORD : 27° 21' 48.61"E

HOLE No: TP 05

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

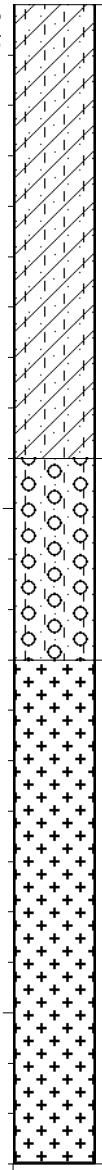
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 06
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

0.90 Slightly moist, khaki brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels with occasional cobbles; **RESIDUAL NORITE**.

1.30 Olive greyish brown, and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.30

NOTES

1) EOH in dense to very dense; highly to moderately weathered, -fractured and -jointed, coarsely grained, very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) No samples taken.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 53.42"S
Y-COORD : 27° 21' 49.20"E

HOLE No: TP 06

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

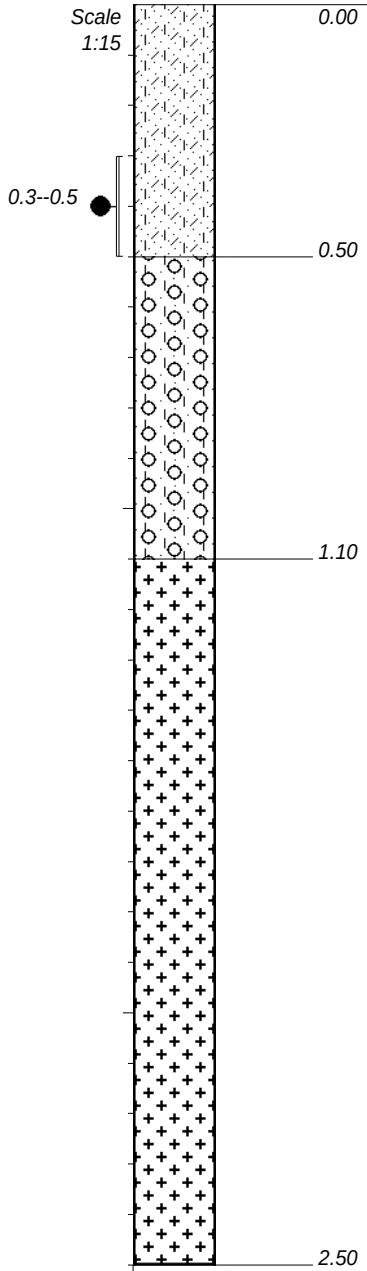
DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 07
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 — Moist, reddish brown, loose, slightly shattered, silty clayey SAND with trace quantities of thin roots and matrix supported sub-rounded gravels of mixed origin; **HILLWASH**.

0.50 — Slightly moist, dark olive brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels with occasional cobbles; **RESIDUAL NORITE**.

1.10 — Olive greyish brown, and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.50

NOTES

1) EOH in dense to very dense; highly to moderately weathered, -fractured and -jointed coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) Disturbed sample taken from 0.3--0.5 m deep.
5) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 27° 21' 49.20"E
Y-COORD : 27° 21' 50.69"E

HOLE No: TP 07

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

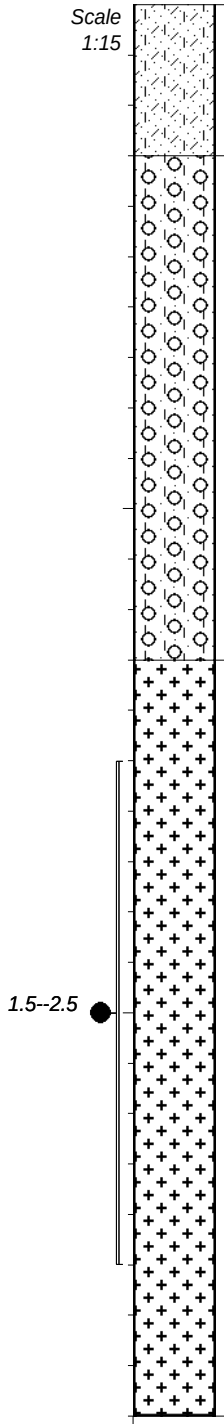
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 08
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist, reddish brown, loose, slightly shattered, silty clayey SAND with trace quantities of thin roots and matrix supported sub-rounded gravels of mixed origin; **HILLWASH**.

0.30 Slightly moist, dark olive brown and orange brown speckled black and off-white occasionally stained black or dark red, medium dense, intact, silty sandy GRAVEL with abundant quantities of clasts supported high to moderately weathered gravels with occasional cobbles; **RESIDUAL NORITE**.

1.30 Olive greyish brown, and orange brown speckled black and off-white occasionally stained black or dark red, dense to very dense, highly fractured and -jointed; **HIGHLY TO MODERATELY WEATHERED COARSELY GRAINED VERY SOFT- TO SOFT ROCK NORITE**.

2.80

NOTES

1) EOH in dense to very dense; highly to moderately weathered, -fractured and -jointed coarsely grained very soft- to soft rock norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) Bulk sample taken from 1.5--2.5 m deep.
5) Disturbed sample taken from 1.5--2.5 m deep.
6) Excavator gradual refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

ELEVATION :
X-COORD : 25° 44' 53.81"S
Y-COORD : 27° 21' 51.18"E

HOLE No: TP 08

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

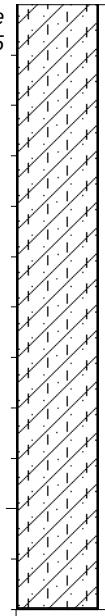
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TEXT : ..Plant^LJRustenburgPO.txt

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Rietfontein Plant, Rustenburg

HOLE No: TP 09
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00

Very moist to wet, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

1.20

NOTES

1) EOH in firm; reworked residual norite.
2) Seepage from surface, excavated within saturated soils due to excessive rain.
3) Stable sidewalls.
4) No samples taken.
5) No excavator refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

ELEVATION :
X-COORD : 25° 44' 39.89"S
Y-COORD : 27° 22' 6.65"E

HOLE No: TP 09

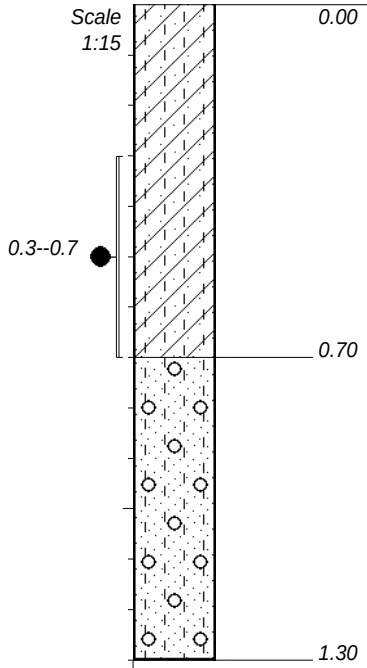
SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 10
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00 Moist to very moist, dark brown to black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

0.70 Moist, orange brown and light yellowish khaki brown, medium dense, intact, silty gravelly SAND with minor quantities of complete to highly weathered matrix or clasts supported gravels; **RESIDUAL NORITE**.

1.30

NOTES

1) EOH in medium dense residual norite.
2) No water seepage encounter.
3) Stable sidewalls.
4) Disturbed sample taken from 0.3--0.7 m deep.
5) No excavator refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

ELEVATION :
X-COORD : 25° 44' 21.58"S
Y-COORD : 27° 22' 13.58"E

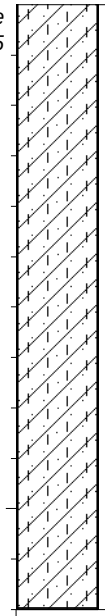
HOLE No: TP 10

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

HOLE No: TP 11
Sheet 1 of 1

JOB NUMBER: 2503

Scale 1:15



0.00

Very moist to wet, black, firm, fractured and slickensided, silty sandy CLAY with trace quantities of thin roots and very occasional calcrete nodules; **REWORKED RESIDUAL NORITE (BLACK TURF)**.

1.20

NOTES

1) EOH in firm reworked residual norite.
2) Seepage from surface, excavated within river crossing floodplain/wetland.
3) Stable sidewalls.
4) No samples taken.
5) No excavator refusal.

CONTRACTOR :
MACHINE : Excavator (40 Ton)
DRILLED BY :
PROFILED BY : Andre Fourie

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : Trench
DATE :
DATE : 15 April 2025

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

ELEVATION :
X-COORD : 25° 44' 4.75"S
Y-COORD : 27° 22' 19.82"E

HOLE No: TP 11

SOUTHERN GEOTECHNICAL ENGINEERING

MineLock Environmental Engineers (Pty) Ltd.
Rietfontein Plant, Rustenburg

LEGEND
Sheet 1 of 1

JOB NUMBER: 2503

	GRAVEL	{SA02}
	GRAVELLY	{SA03}
	SAND	{SA04}
	SANDY	{SA05}
	SILTY	{SA07}
	CLAY	{SA08}
	CLAYEY	{SA09}
	PLUTONIC/norite/syenite	{SA17}
	DISTURBED SAMPLE	{SA38}

Name

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

INCLINATION :
DIAM :
DATE :
DATE :

ELEVATION :
X-COORD :
Y-COORD :

LEGEND
SUMMARY OF SYMBOLS

TYPE SET BY : Andre Fourie
SETUP FILE : STANDARD.SET

DATE : 19/05/2025 14:37
TEXT : ..Plant^LJRustenburgPO.txt

APPENDIX C2

GEOTECHNICAL ASSESSMENT LABORATORY TEST RESULTS

LABWORX Civil Engineering Materials Laboratory

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Reg. No: 2003/007845/23 Vat No: 4500204070

Test Report

Attention :	Mr Pieter Oosthuizen	**Client :**	Southern Geotechnical Engineering
Project :	*Rietfontein Mine ,Rustenburg*	**Contact No. :**	082 823 7794
Report Date :	05-05-2025	**Address :**	357 Olivier Street Waterkloof 0181
Pages :	7		
Report No. :	SGE/RM 25 05-001		

1. Contents :

p 2 , 4 , 6 MDD/OMC, CBR & Foundation Indicator Results
p 3 , 5 , 7 Foundation Indicator Results

2. Deviation / Addition / Exclusion from test method / sampling method : None

3. Decision rule agreed on : None

4. Remarks : Information typed in "*Italic*" font is supplied by the Client.

Hope you find all in order.

Regards,

Bernard Conradie
Technical Signatory

Disclaimer:

This test report relates to the area/s and/or sample/s tested or as received only. Where information is supplied by the client, it may affect the validity of the test results.
If a test report is published or reproduced, it will be done so in full, without any omittance and without any manual or electronic alterations.
Everything possible is done to ensure that tests are representative and are performed accurately, and reports and conclusions are quoted correctly.
Labworx or its officials can in no way be held liable for consequential damage or loss due to any erroneous statement or opinion contained in a report based on such tests.
The only information that will be placed in the public domain is upon written permission from you, or if it is required by Law or to SANAS Assessors,
Contracted Technical Signatories or Auditors who are equally bound by confidentiality undertakings.
Tests marked with a (#) are from external providers.

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GRAVEL, SOIL AND SAND ANALYSIS REPORT

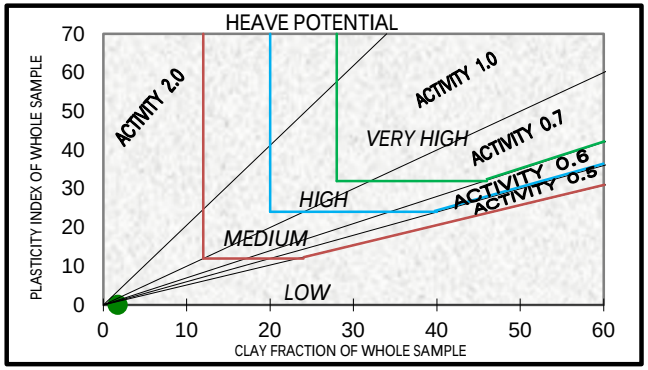
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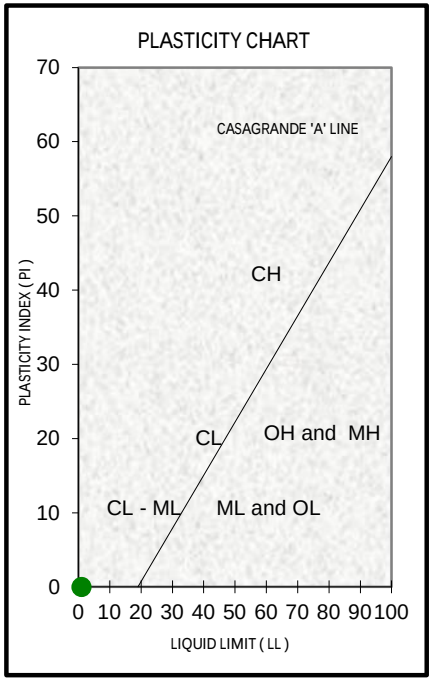
Project :	*Rietfontein Mine, Rustenburg*	**Date Received :**	17-04-2025
Client :	Southern Geotechnical Engineering	**Report Date :**	05-05-2025

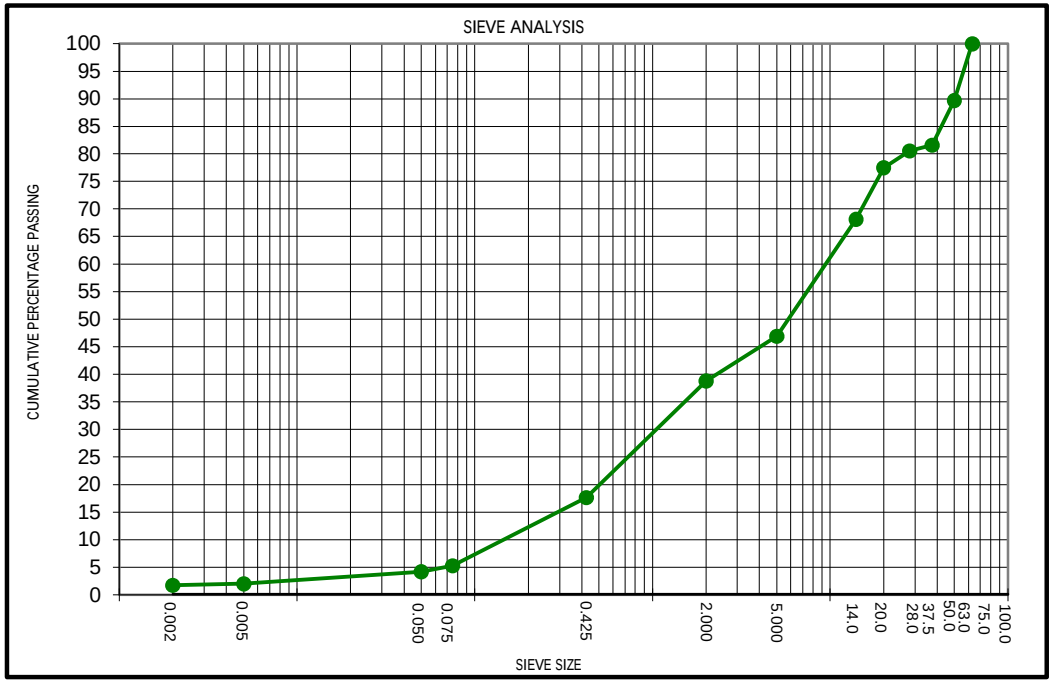
Your Reference :	*TP 2 , 1.0 - 1.6 m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	25/671
Sampled By :	Client			**Sampling Method:**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 & GR5 **Cumulative Percentage Passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10					**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plastic Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**PI of Whole Sample**	**Unified Soil**	**COLTO / COTO**	**US. Highway**	**Group Index**
Light Olive Brown Well Graded Silty Gravel	2283	7.7	-	-	100	90	82	81	78	68	47	39	18	5	4.2	2.0	1.7	2.4	54.5	34.8	5.6	5.1	-	-	SP	1.0	-	GW/ GM	G7/ G7	A-1-a	0

pH / Conductivity SANS 5854 & 6240		**CBR RESULTS :** SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	38
Conductivity (S/m) :	-	**@ 98% comp. :**	29
		@ 97% comp. :	25
GENERAL :		**@ 95% comp. :**	19
Oversize Index :	18	**@ 93% comp. :**	15
Shrinkage Product :	18	**@ 90% comp. :**	10
Grading co-eff. :	19.6	**Swell @ 100% :**	0.2







REMARKS:

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GRAVEL, SOIL AND SAND ANALYSIS REPORT

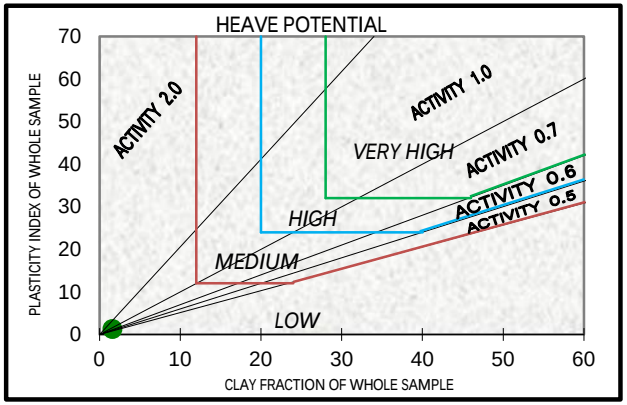
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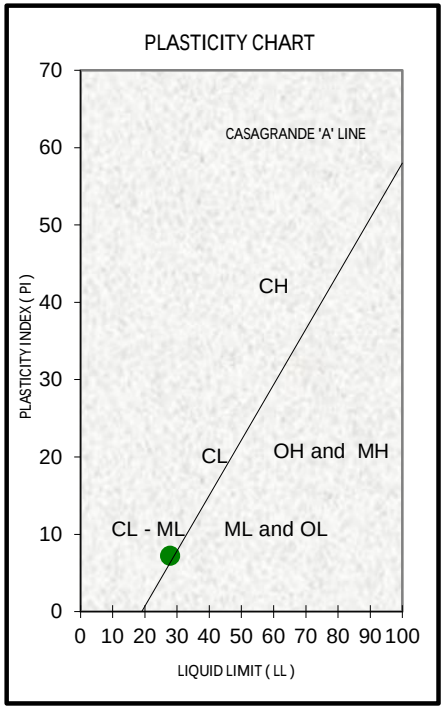
Project :	*Rietfontein Mine, Rustenburg*	**Date Received :**	17-04-2025
Client :	Southern Geotechnical Engineering	**Report Date :**	05-05-2025

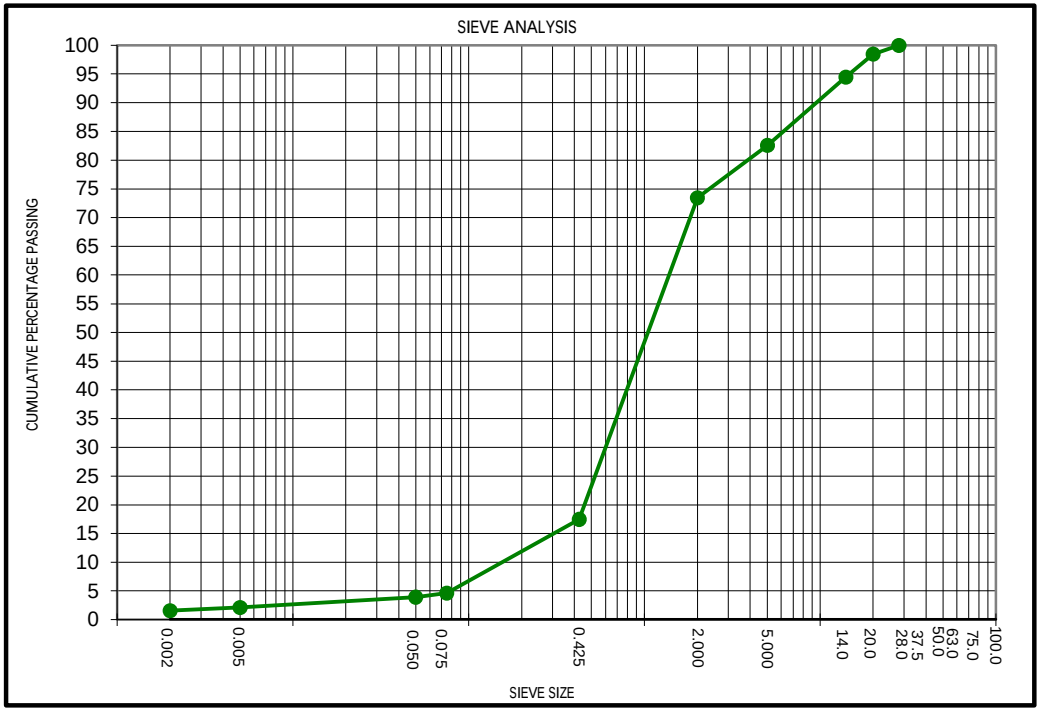
Your Reference :	*TP 3 , 1.2 - 1.5 m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	25/672
Sampled By :	Client			**Sampling Method:**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 & GR5 **Cumulative Percentage Passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10					**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plastic Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**PI of Whole Sample**	**Unified Soil**	**COLTO / COTO**	**US. Highway**	**Group Index**
Light Greyish Brown Well Graded Silty/Clayey Sand	-	-	-	-	-	-	-	100	98	94	83	73	17	5	3.9	2.2	1.6	2.0	76.2	18.5	2.4	2.9	28	21	7	3.3	1	SW/ SM/ SC	-	A-2-4	0

pH / Conductivity SANS 5854 & 6240		**CBR RESULTS :** SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	-
Conductivity (S/m) :	-	**@ 98% comp. :**	-
		@ 97% comp. :	-
GENERAL :		**@ 95% comp. :**	-
Oversize Index :	0	**@ 93% comp. :**	-
Shrinkage Product :	57	**@ 90% comp. :**	-
Grading co-eff. :	21.9	**Swell @ 100% :**	-







REMARKS:

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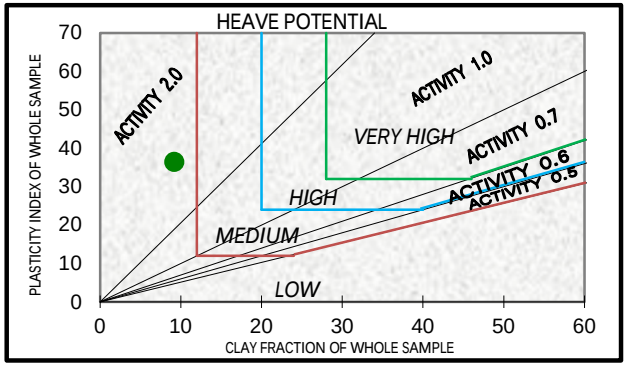
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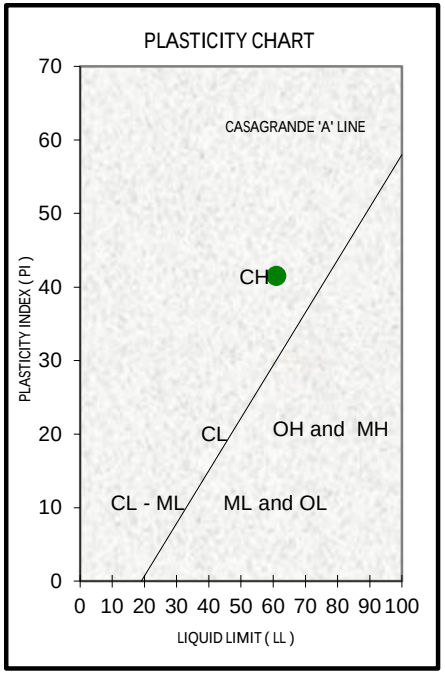
GRAVEL, SOIL AND SAND ANALYSIS REPORT

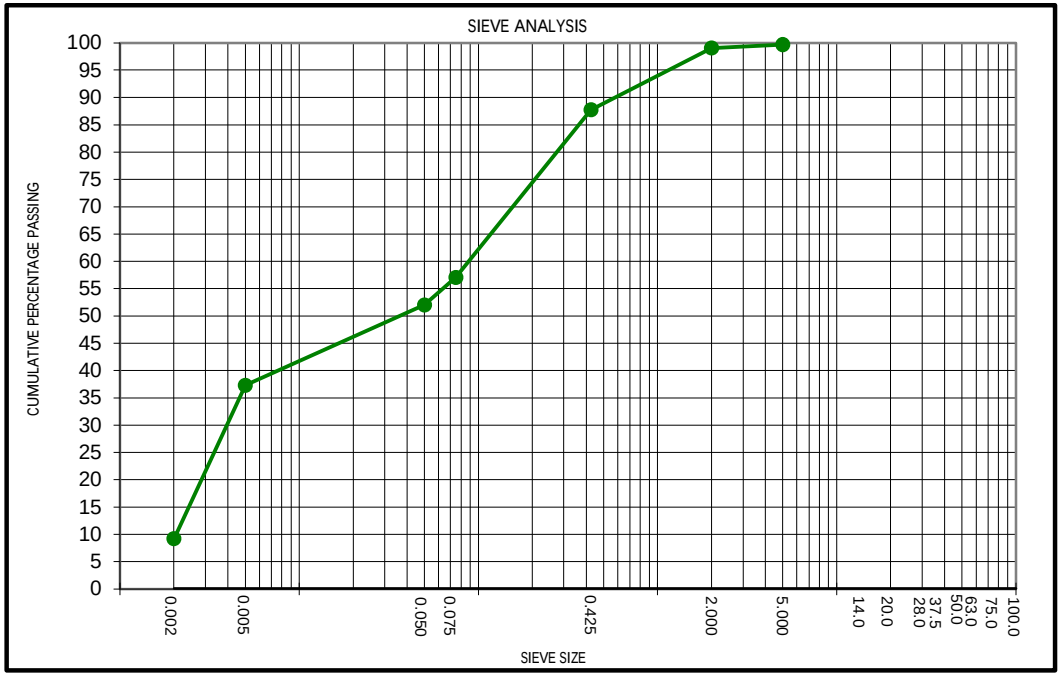
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Project :	*Rietfontein Mine, Rustenburg*	**Date Received :**	17-04-2025
Client :	Southern Geotechnical Engineering	**Report Date :**	05-05-2025
Your Reference :	*TP 5 , 0.1 - 0.6 m*	**Environmental Conditions :**	Not Specified
Sampled By :	Client	**Sample No. :**	25/673
		Sampling Method:	Not Specified

Description	MDD / OMC SANS 3001-GR20 & GR30		Sieve Analysis SANS 3001-GR1 & GR5 Cumulative Percentage Passing														Grading Modulus SANS 3001-PR5	Soil Mortar Analysis % of mat. <2,00 mm				Atterberg Limits SANS 3001-GR10					Classification			
(Unified Soil Classification)	Maximum Dry Density kg/m³	Optimum Moisture Content %	100.0mm	75.0mm	63.0mm	50.0mm	37.5mm	28.0mm	20.0mm	14.0mm	5.00mm	2.00mm	0.425mm	0.075mm	0.05 mm	0.005 mm	0.002 mm		Coarse - sand <2,0 >0,425mm	Fine - sand <0,425 >0,05mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Liquid Limit %	Plastic Limit %	Plasticity Index	Linear Shrinkage %	PI of Whole Sample	Unified Soil	COLTO / COTO	US. Highway	Group Index
Black Inorganic Clay	1728	17.7	-	-	-	-	-	-	-	-	100	99	88	57	52.0	37.3	9.2	0.6	11.4	36.1	14.9	37.7	61	19	42	22.5	36	CH	<G9/ <G9	A-7-6	15

pH / Conductivity SANS 5854 & 6240		CBR RESULTS : SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	3
Conductivity (S/m) :	-	**@ 98% comp. :**	2
		@ 97% comp. :	2
GENERAL :		**@ 95% comp. :**	2
Oversize Index :	0	**@ 93% comp. :**	1
Shrinkage Product :	1974	**@ 90% comp. :**	1
Grading co-eff. :	0.9	**Swell @ 100% :**	8.7







REMARKS:

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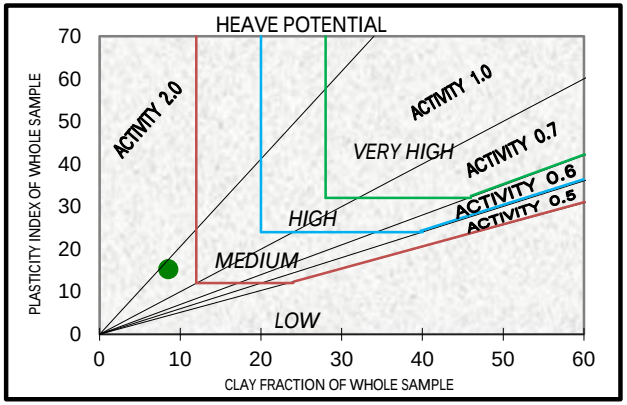
GRAVEL, SOIL AND SAND ANALYSIS REPORT

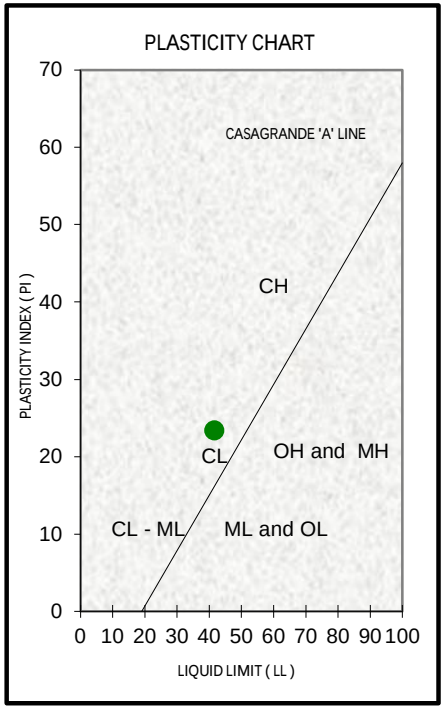
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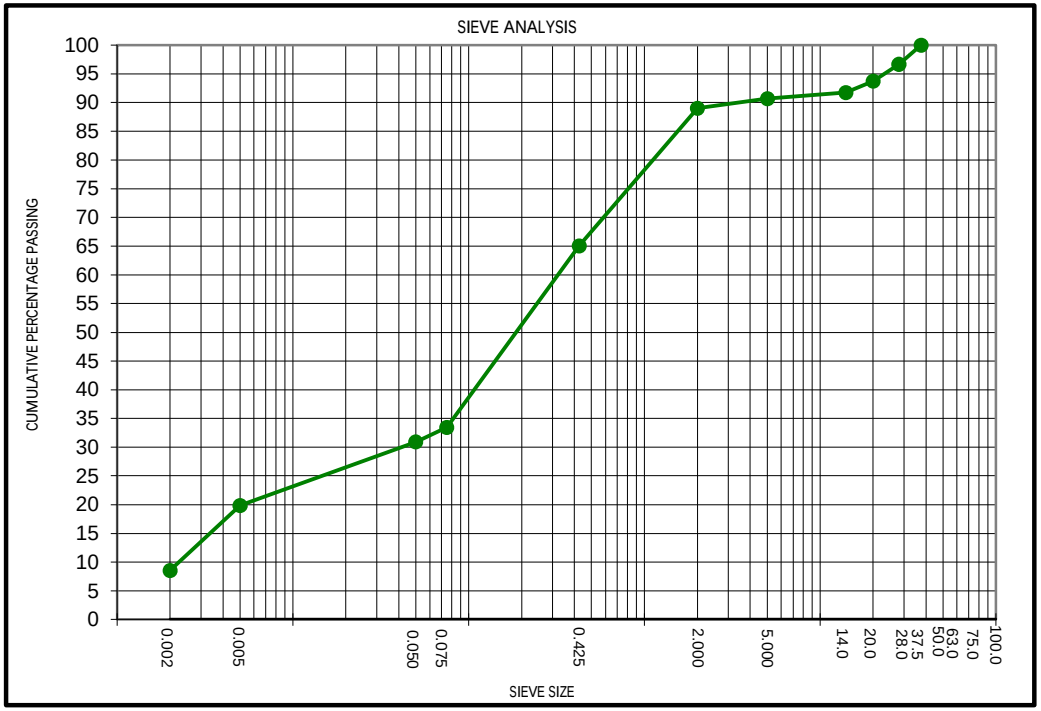
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Client :	Southern Geotechnical Engineering			**Report Date :**	05-05-2025
Your Reference :	*TP 7 , 0.3 - 0.5 m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	25/674
Sampled By :	Client			**Sampling Method:**	Not Specified

Description	MDD / OMC SANS 3001-GR20 & GR30		Sieve Analysis SANS 3001-GR1 & GR5 Cumulative Percentage Passing															Grading Modulus SANS 3001-PR5	Soil Mortar Analysis % of mat. <2,00 mm				Atterberg Limits SANS 3001-GR10					Classification			
(Unified Soil Classification)	Maximum Dry Density kg/m³	Optimum Moisture Content %	100.0mm	75.0mm	63.0mm	50.0mm	37.5mm	28.0mm	20.0mm	14.0mm	5.00mm	2.00mm	0.425mm	0.075mm	0.05 mm	0.005 mm	0.002 mm		Coarse - sand <2,0 >0,425mm	Fine - sand <0,425 >0,05mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Liquid Limit %	Plastic Limit %	Plasticity Index	Linear Shrinkage %	PI of Whole Sample	Unified Soil	COLTO / COTO	US. Highway	Group Index
Dark Brown Clayey Sand	-	-	-	-	-	-	100	97	94	92	91	89	65	33	30.9	19.8	8.5	1.1	26.9	38.3	12.5	22.3	42	19	23	9.7	15	SC	-	A-2-7	2

pH / Conductivity SANS 5854 & 6240		CBR RESULTS : SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	-
Conductivity (S/m) :	-	**@ 98% comp. :**	-
		@ 97% comp. :	-
GENERAL :		**@ 95% comp. :**	-
Oversize Index :	0	**@ 93% comp. :**	-
Shrinkage Product :	632	**@ 90% comp. :**	-
Grading co-eff. :	6.9	**Swell @ 100% :**	-







REMARKS:

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GRAVEL, SOIL AND SAND ANALYSIS REPORT

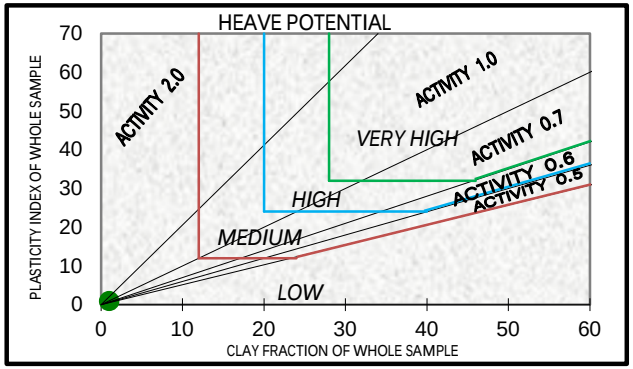
Report No.:	SGE/RM 25 05-001

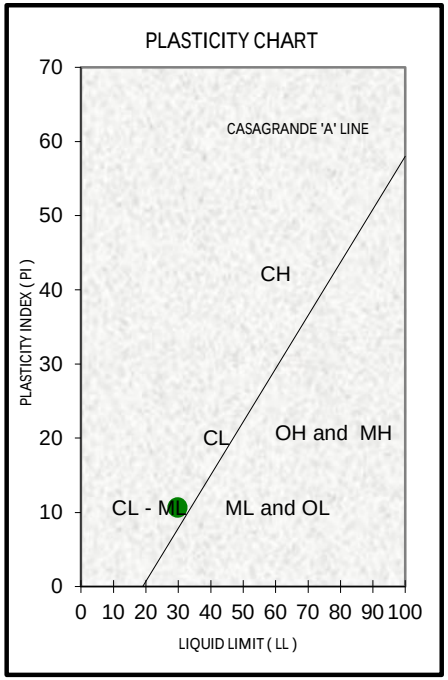
Project :	*Rietfontein Mine, Rustenburg*	**Date Received :**	17-04-2025
Client :	Southern Geotechnical Engineering	**Report Date :**	05-05-2025

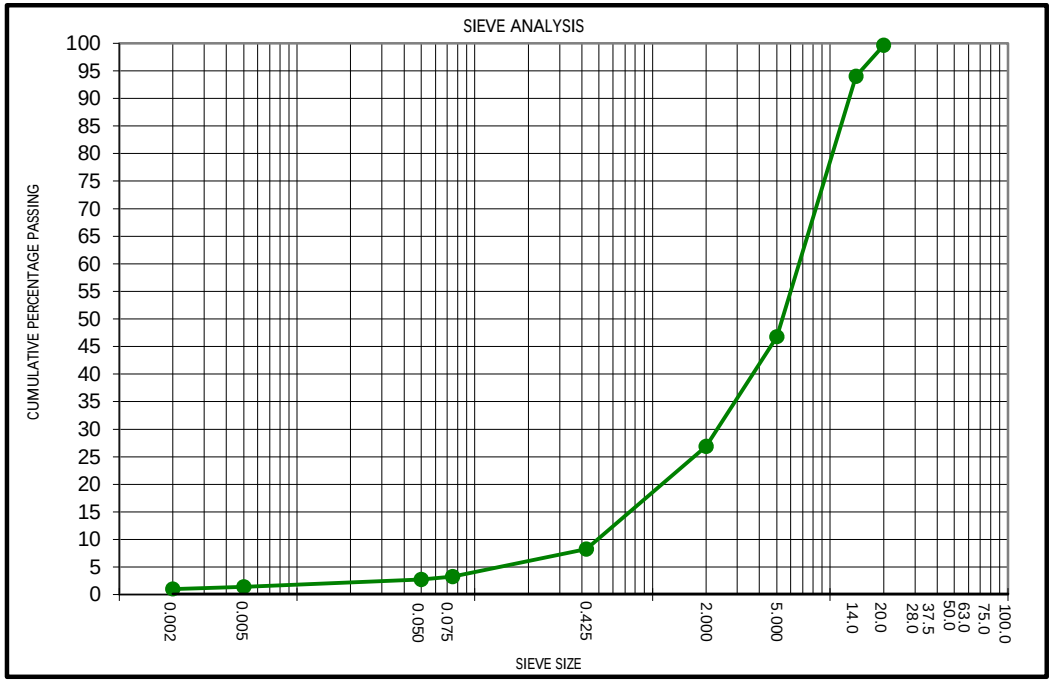
Your Reference :	*TP 8 , 1.5 - 2.5 m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	25/675
Sampled By :	Client			**Sampling Method:**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 & GR5 **Cumulative Percentage Passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10					**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plastic Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**PI of Whole Sample**	**Unified Soil**	**COLTO / COTO**	**US. Highway**	**Group Index**
Light Olive Brown Well Graded Gravel	2354	7.2	-	-	-	-	-	-	100	94	47	27	8	3	2.7	1.4	1.0	2.6	69.2	20.6	4.9	5.2	30	19	11	5.3	1	GW	G7/ G7	A-2-6	0

pH / Conductivity SANS 5854 & 6240		**CBR RESULTS :** SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	42
Conductivity (S/m) :	-	**@ 98% comp. :**	33
		@ 97% comp. :	30
GENERAL :		**@ 95% comp. :**	24
Oversize Index :	0	**@ 93% comp. :**	18
Shrinkage Product :	44	**@ 90% comp. :**	11
Grading co-eff. :	34.2	**Swell @ 100% :**	0.0







REMARKS:

LABWORX Civil Engineering Materials Laboratory

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GRAVEL, SOIL AND SAND ANALYSIS REPORT

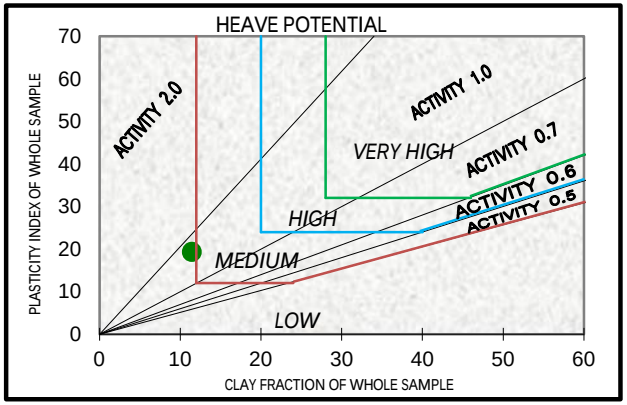
Report No.:	SGE/RM 25 05-001

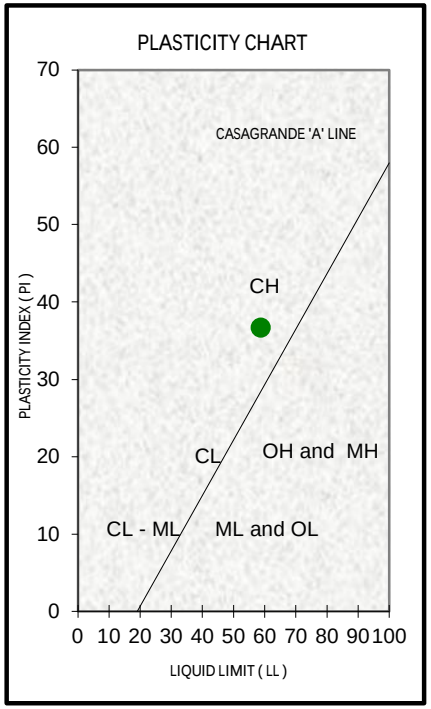
Project :	*Rietfontein Mine, Rustenburg*	**Date Received :**	17-04-2025
Client :	Southern Geotechnical Engineering	**Report Date :**	05-05-2025

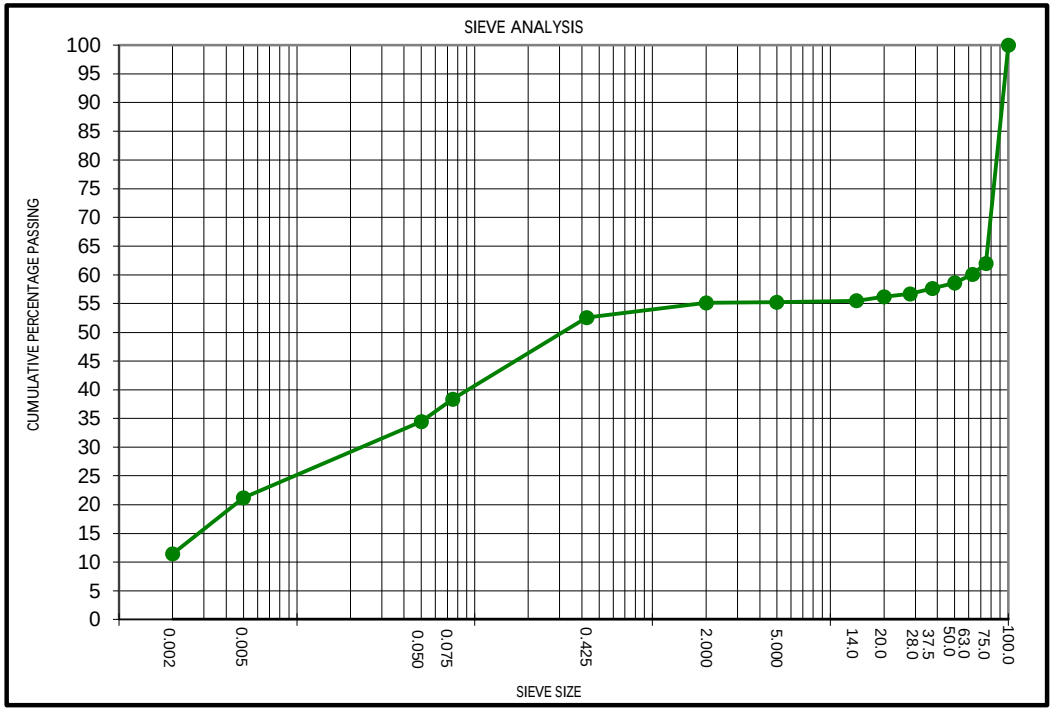
Your Reference :	*TP 10 , 0.3 - 0.7 m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	25/676
Sampled By :	Client			**Sampling Method:**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 & GR5 **Cumulative Percentage Passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10					**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plastic Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**PI of Whole Sample**	**Unified Soil**	**COLTO / COTO**	**US. Highway**	**Group Index**
Black Clayey Sand	-	-	100	62	60	59	58	57	56	55	55	55	53	38	34.5	21.2	11.4	1.5	4.7	32.8	24.1	38.4	59	22	37	24.0	19	SC	-	A-7-6	6

pH / Conductivity SANS 5854 & 6240		**CBR RESULTS :** SANS 3001-GR40	
pH :	-	**@ 100% comp. :**	-
Conductivity (S/m) :	-	**@ 98% comp. :**	-
		@ 97% comp. :	-
GENERAL :		**@ 95% comp. :**	-
Oversize Index :	42	**@ 93% comp. :**	-
Shrinkage Product :	1261	**@ 90% comp. :**	-
Grading co-eff. :	0.9	**Swell @ 100% :**	-







REMARKS:

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Test Report

Attention :	Mr Pieter Oosthuizen	**Client :**	Southern Geotechnical Engineering
Project :	*Rietfontein Mine, Rustenburg*	**Contact No. :**	082 823 7794
Report Date :	26-05-2025	**Address :**	357 Olivier Street Waterkloof 0181
Pages :	3		
Report No. :	SGE/RM 25 05-002		

1. Contents : p 2 - 3 # Constant Head Permeabilities

2. Deviation / Addition / Exclusion from test method / sampling method : None

3. Decision rule agreed on : None

4. Remarks : Information typed in "*Italic*" font is supplied by the Client.

Hope you find all in order.

Regards,

Bernard Conradie
Technical Signatory

Disclaimer:

This test report relates to the area/s and/or sample/s tested or as received only. Where information is supplied by the client, it may affect the validity of the test results.
If a test report is published or reproduced, it will be done so in full, without any omittance and without any manual or electronic alterations.
Everything possible is done to ensure that tests are representative and are performed accurately, and reports and conclusions are quoted correctly.
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Roelof | 072 674 6343 | roelof@stlab.co.za
Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za

Client Name:	Labworx CC	**Job Number:**	LBW-507
Project Name:	Rietfontein Mine, Rustenburg	**Lab Number:**	LBW-507-955
Sample:	25/673 - TP5	**Date:**	26-May-25
Depth: (m)	0.1 - 0.6		

CONSTANT HEAD PERMEABILITY TEST

General Test Data		
Type of Sample:	-	Remoulded to 93% of MDD (Supplied by client).
MDD (Mod AASHTO):	g/cm³	1.728
OMC:	%	17.7
Comments:	-	Scalped on 4.75mm sieve

Initial Specimen Details		
Diameter	mm	50.8
Length	mm	91.8
Area	mm²	2026.8
Volume	cm³	186.0
Moisture Content	%	24.8
Dry Density	g/cm³	1.509
Void Ratio	-	0.756
Degree of Saturation	%	86.8
Particle Density (SG)	-	2.65 - Assumed

Permeability Details			
Coefficient of Permeability		**Flow Rate (Q) (m^3/s)**	**Coefficient of Permeability ($k_{T)}$**
Run 1	m/s	1.16E-11	2.63E-10
Run 2		9.68E-12	2.19E-10
Run 3		8.75E-12	1.98E-10
Run 4		6.60E-12	1.49E-10
Run 5		6.93E-12	1.57E-10
Run 6		1.17E-11	2.65E-10
Run 7		1.05E-11	2.38E-10
Run 8		1.26E-11	2.86E-10
Run 9		8.80E-12	1.99E-10
Run 10		9.61E-12	2.18E-10

Coefficient of Permeability k_{T20}	**Min.**	**m/s**	**1.43E-10**
	Max.		**2.73E-10**
	Ave.		**2.09E-10**

Remarks:

Although everything possible is done to ensure testing is performed accurately, neither Specialised Testing Laboratory (Pty) Ltd nor any of its directors, managers, employees or contractors can be held liable for any damages whatsoever arising from any error made in performing any tests, nor from any conclusions drawn therefrom. Test results are to be published in full. Samples will be kept for 1 month after the submission of test results due to limited storage space, unless other arrangements are in place.

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Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za

Client Name:	Labworx CC	**Job Number:**	LBW-507
Project Name:	Rietfontein Mine, Rustenburg	**Lab Number:**	LBW-507-956
Sample:	25/675 - TP8	**Date:**	26-May-25
Depth: (m)	1.5 - 2.5		

CONSTANT HEAD PERMEABILITY TEST

General Test Data		
Type of Sample:	-	Remoulded to 93% of MDD (Supplied by client).
MDD (Mod AASHTO):	g/cm³	2.354
OMC:	%	7.2
Comments:	-	Scalped on 4.75mm sieve

Initial Specimen Details		
Diameter	mm	50.8
Length	mm	92.3
Area	mm²	2026.8
Volume	cm³	187.0
Moisture Content	%	8.4
Dry Density	g/cm³	2.075
Void Ratio	-	0.277
Degree of Saturation	%	80.3
Particle Density (SG)	-	2.65 - Assumed

Permeability Details			
Coefficient of Permeability		**Flow Rate (Q) (m^3/s)**	**Coefficient of Permeability ($k_{T)}$**
Run 1	m/s	3.13E-08	7.11E-07
Run 2		3.13E-08	7.11E-07
Run 3		2.94E-08	6.70E-07
Run 4		2.94E-08	6.70E-07
Run 5		3.33E-08	7.59E-07
Run 6		2.78E-08	6.32E-07
Run 7		4.00E-08	9.11E-07
Run 8		3.23E-08	7.34E-07
Run 9		3.33E-08	7.59E-07
Run 10		2.86E-08	6.50E-07

Coefficient of Permeability k_{T20}	**Min.**	**m/s**	**6.03E-07**
	Max.		**8.69E-07**
	Ave.		**6.88E-07**

Remarks:

Although everything possible is done to ensure testing is performed accurately, neither Specialised Testing Laboratory (Pty) Ltd nor any of its directors, managers, employees or contractors can be held liable for any damages whatsoever arising from any error made in performing any tests, nor from any conclusions drawn therefrom. Test results are to be published in full. Samples will be kept for 1 month after the submission of test results due to limited storage space, unless other arrangements are in place.

APPENDIX C3

GEOTECHNICAL ASSESSMENT TEST PIT PHOTOGRAPHS AND POSITIONS

Rietfontein plant

Geotechnical investigation



Test pit 01



Test pit 02



Test pit 03



Test pit 04

Rietfontein plant

Geotechnical investigation



Test pit 05



Test pit 06



Test pit 07



Test pit 08

Rietfontein plant

Geotechnical investigation



Test pit 09



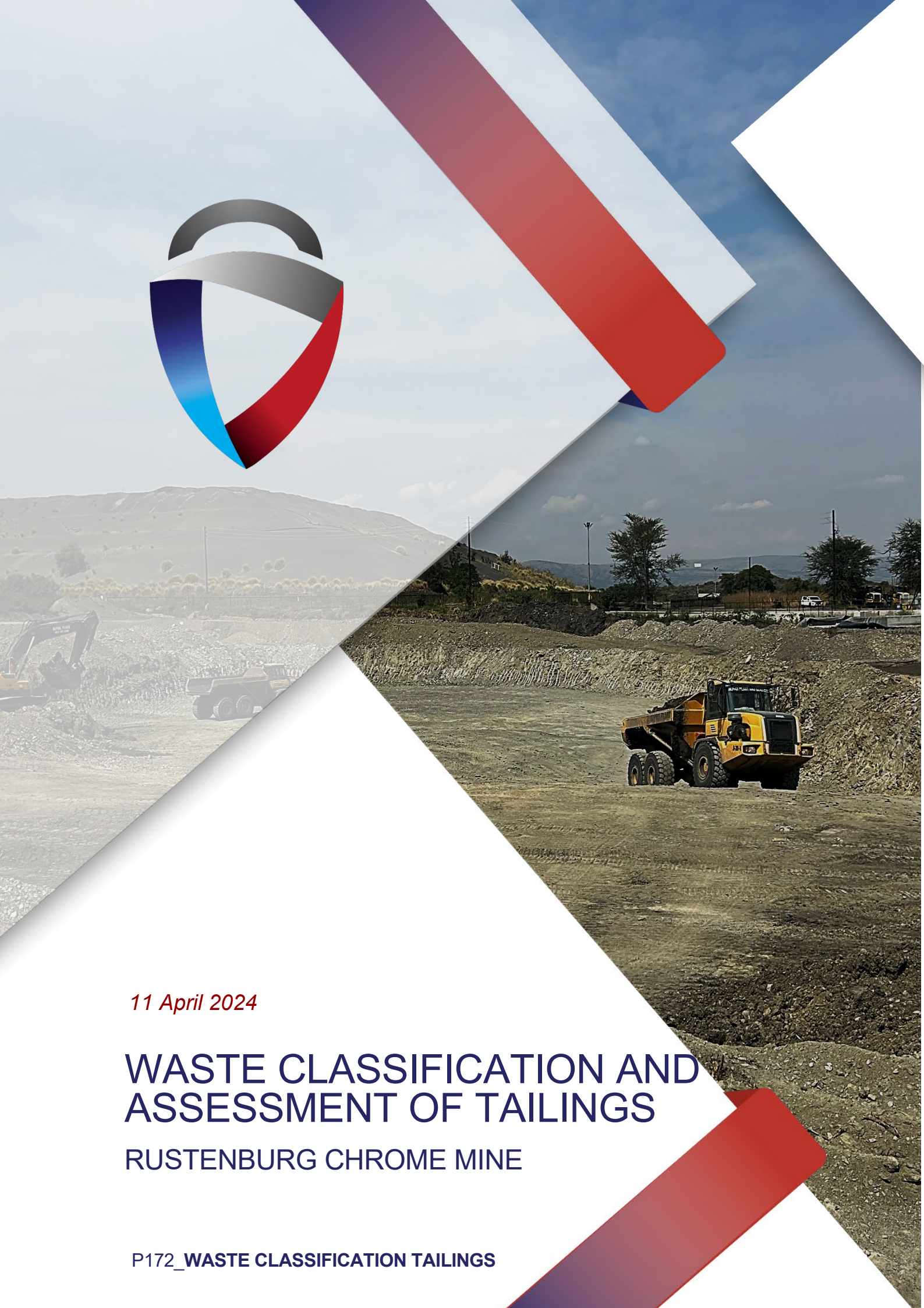
Test pit 10



Test pit 11

APPENDIX D

WASTE CLASSIFICATION TEST RESULTS



11 April 2024

WASTE CLASSIFICATION AND ASSESSMENT OF TAILINGS

RUSTENBURG CHROME MINE

P172_**WASTE CLASSIFICATION TAILINGS**

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1. INTRODUCTION

1.1 Background

MineLock Environmental Engineers was appointed by Rustenburg Chrome mine (RCM) to assess the Tailings from the existing TSF. This report provides the methodology, results and findings of the waste assessment.

2. OBJECTIVES

The study was underpinned by the legal provisions of the National Environmental Management Waste Act (NEM:WA) 59 of 2008 and the National Environmental Management: Waste Amendment Act (NEM:WAA) 26 of 2014 and include the following:

- Waste assessment according to the National Norms and Standards for the assessment of waste for landfill disposal (GN R.635 of 23 August 2013); and
- Identification of the barrier design requirements as per the National Norms and Standards for Disposal of Waste to Landfill (GN R.636 of 23 August 2013).

3. APPROACH

3.1 Waste Assessment (GN R. 635)

The purpose of the waste assessment is to determine the waste Type intended for land disposal. The findings of the waste assessment are used to determine the correct barrier design requirements. The assessment of waste must be done in terms of the procedures stipulated in GN R. 635 of 23 August 2013.

The potential level of risk associated with disposal of materials/wastes can be determined by following the prescribed and appropriate leach test protocols in terms of the GN R.635 of 23 August 2013. The analytical results need to be screened against the four levels of thresholds for leachable and total concentrations, which in combination, determines the waste type and associated barrier design / liner requirements. The thresholds for the total concentrations (TC in mg/kg) and leachable concentrations (LC in mg/l) are defined for the set of chemical constituents published in GN R.635 of 23 August 2013.

The waste type is defined as follows:

- Type 4: LC $\leq$ LCT0 and TC $\leq$ TCT0
- Type 3: LC $\geq$ LCT0 but $\leq$ LCT1 and TC $\leq$ TCT1
- Type 2: LC $>$ LCT1 but $\leq$ LCT2 and TC $\leq$ TCT1
- Type 1: LC $>$ LCT2 but $\leq$ LCT3 or TC $>$ TCT1 $\leq$ TCT2
- Type 0: LC $>$ LCT3 or TC $>$ TCT2

3.2 GN R. 636 Barrier Design Requirements

Waste assessed in terms of GN R.635 of 2013 must be disposed to disposal facilities barrier design requirements as provided in GN R. 636 of 2013 (Table 1).

Table 1: Landfill Disposal Requirements detailed in GN R. 636

Waste Type	Landfill Disposal Requirements
Type 1	Disposal to landfill is not allowed. The waste must be treated first and then re-assessed to determine Waste Risk Profile for disposal.
Type 2	Disposal only allowed at a Class A landfill in terms of these draft regulations, or at a HH / Hh landfill as specified in the Minimum Requirements Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 3	Disposal only allowed at a Class B landfill in terms of these draft regulations, or a GLB+ landfill as specified in the Minimum Requirements Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 4	Disposal allowed at a Class D landfill in terms of these draft regulations, or a at a GSB- landfill as specified in the Minimum Requirements Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

4. SAMPLING AND ANALYSES

A MineLock representative collected a composite sample of Tailings from the existing TSF. The sample was submitted to Element Materials Technology for the following analyses:

- Total digestion followed by semi-quantitative ICP scan, total Cr(VI) and total F analyses
- ASLP (deionized water extract) followed by ICP scan, determination of cations and anions including Ca, Na, K, Mg, SO_4^{2-}, $C\ell^-$, F^-, NH_4, NO_3, Cr(VI), TDS and pH (to determine leachable concentrations of potential constituents of concern)

5. RESULTS AND DICUSSION

The analytical certificates are included in Appendix A to this report.

5.1 GN R. 635 waste assessment

A summary of the inorganic concentrations of constituents are presented in Table 2 (TCs) and Table 3 (LCs). These results show that the total concentrations of Cu and Ni exceeded TCT0 levels but were <TCT1 levels. The leachable concentrations of all constituents in the Tailings was <LCT0 levels and in most cases below detection.

Table 2: Total concentrations of inorganic constituents in tailings compared to TCT

Constituents	TCT0	TCT1	TCT2	TAILINGS
	mg/kg			
As, Arsenic	5.8	500	2000	<0.5
B, Boron	150	15000	6000	1.74
Ba, Barium	62.5	6250	25000	61
Cd, Cadmium	7.5	260	1040	<0.1
Co, Cobalt	50	5000	20000	15.2
$Cr_{Total,}$ Chromium Total	46000	800000	N/A	939.9
Cr(VI), Chromium (VI) Total	6.5	500	2000	<0.3
Cu, Copper	16	19500	78000	38
Hg, Mercury	0.93	160	640	<0.1
Mn, Manganese	1000	25000	100000	342
Mo, Molybdenum	40	1000	4000	0.4
Ni, Nickel	91	10600	42400	229.1
Pb, Lead	20	1900	7600	<5
Sb, Antimony	10	75	300	<5
Se, Selenium	10	50	200	2
V, Vanadium	150	2680	10720	23
Zn, Zinc	240	160000	640000	13
Total Fluoride	100	10000	40000	<0.3
Total Cyanide as CN	14	10500	42000	<0.5

Notes *Grey: TC >TCT0 but < TCT1; Yellow: TC >TCT1 but < TCT2; Red: TC >TCT2*

Table 3: Leachable concentrations of inorganic constituents in tailings compared to LCT levels

Constituents	LCT0	LCT1	LCT2	LCT3	TAILINGS
	mg/l				
As, Arsenic	0.01	0.5	1	4	<0.0025
B, Boron	0.5	25	50	200	<0.012
Ba, Barium	0.7	35	70	280	<0.003
Cd, Cadmium	0.003	0.15	0.3	1.2	<0.0005
Co, Cobalt	0.5	25	50	200	<0.002
$Cr_{Total,}$ Chromium Total	0.1	5	10	40	0.0214

Constituents	LCT0	LCT1	LCT2	LCT3	TAILINGS
	mg/l				
Cr(VI), Chromium (VI)	0.05	2.5	5	20	<0.006
Cu, Copper	2.0	100	200	800	<0.007
Hg, Mercury	0.006	0.3	0.6	2.4	<0.001
Mn, Manganese	0.5	25	50	200	0.003
Mo, Molybdenum	0.07	3.5	7	28	<0.002
Ni, Nickel	0.07	3.5	7	28	<0.002
Pb, Lead	0.01	0.5	1	4	<0.005
Sb, Antimony	0.02	1.0	2	8	<0.002
Se, Selenium	0.01	0.5	1	4	<0.004
V, Vanadium	0.2	10	20	80	0.0052
Zn, Zinc	5.0	250	500	2000	<0.004
Total Dissolved Solids	1000	12 500	25 000	100 000	35
Chloride as Cl	300	15 000	30 000	120 000	1.6
Sulphate as SO4	250	12 500	25 000	100 000	8
Nitrate as N	11	550	1100	4400	0.3
Fluoride as F	1.5	75	150	600	<0.3
pH					7.39

Notes: *Grey: LC >LCT0 but <LCT1; Yellow: LC >LCT1 but <LCT2; Orange: LC >LCT2 but <LCT3; Red: LC>LCT3*

According to the GN R. 635 assessment methodology, the Tailings is Type 3 due to the total Cu and Ni concentrations exceeding TCT0 levels. Although it is assessed as Type 3, it acts as Type 4 due to low leachable concentrations of constituents (all constituents < LCT0).

5.2 Barrier design requirements

The GN R. 636 compliant barrier design requirements for the Type 3 Tailings is Class C (Figure 1). Since the Tailings has low leachable concentrations of constituents, it acts similar to Type 4 waste and relaxation of requirements can be motivated to the authorities, based on a risk based approach (Class D barrier, Figure 2).

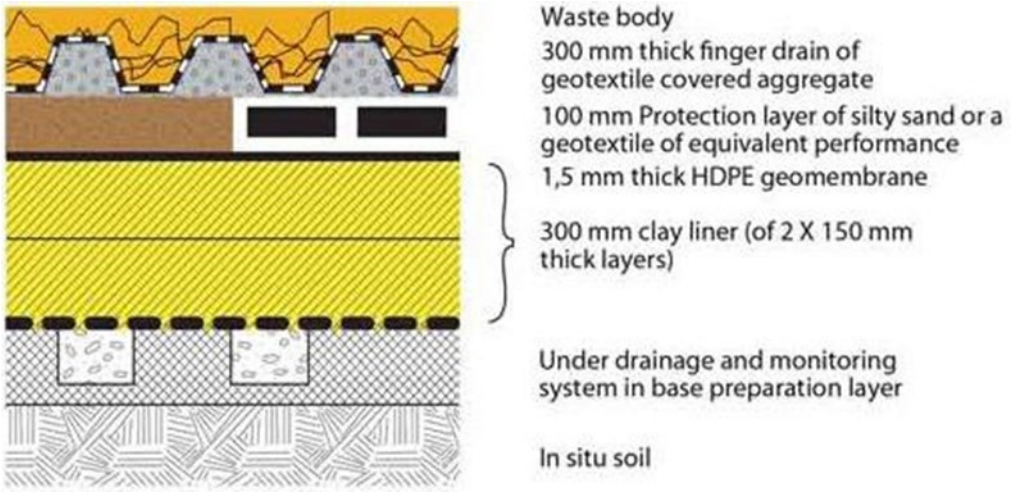


Figure 1: Class C barrier design requirements

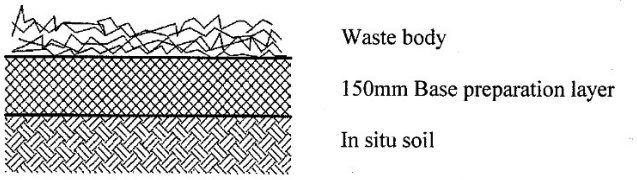


Figure 2: Class D barrier design requirements

6. CONCLUSIONS

The analytical results of the Tailings sample indicate that it is Type 3 due to the total Cu and Ni concentrations exceeding TCT0 levels. Although it is assessed as Type 3, it acts as Type 4 due to low leachable concentrations of constituents (all constituents < LCT0). The compliant barrier design is Class C, but due to low leachable concentrations, relaxation of the barrier design requirements can be motivated to the Authorities with a risk based approach.

7. LIST OF REFERENCES

- Department of Environmental Affairs, 2013. Government Gazette, Government Notice R634. National Environmental Management: Waste Act (59/2008): Waste Classification and Management regulations. Government Gazette No. 36784, 23 August 2013. The Government Printing Works: Pretoria.
- Department of Environmental Affairs, 2013. Government Gazette, Government Notice R635. National Norms and standards for the assessment of waste for landfill disposal. Government Gazette No. 36784, 23 August 2013. The Government Printing Works: Pretoria.
- Department of Environmental Affairs, 2013. Government Gazette, Government Notice R636. National Norms and standards for disposal of waste to landfill. Government Gazette No. 36784, 23 August 2013. The Government Printing Works: Pretoria.

APPENDIX A
ANALYTICAL CERTFICATE

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Unit D2 & D5
9 Quantum Road
Firgrove Business Park
Somerset West
7130
South Africa

W: www.element.com

Minelock Environmental Engineers
877 Kollie Street
Garsfontein
Johannesburg 0042

Attention :	Is-Mari Kretchmer
Date :	9th April, 2024
Your reference :	SA-30648
Our reference :	Test Report 24/4612 Batch 1
Location :	n/a
Date samples received :	15th March, 2024
Status :	Final report
Issue :	202404091527

One sample was received for analysis on 15th March, 2024 and was scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

The greenhouse gas emissions generated (in Carbon – Co2e) to obtain the results in this report are estimated as:

Scope 1&2 emissions - 7.023 kg of CO2

Scope 1&2&3 emissions - 16.597 kg of CO2

Authorised By:

Simon Gomery BSc
Senior Project Manager

Please include all sections of this report if it is reproduced

Element Materials Technology

Client Name: Minelock Environmental Engineers
Reference: SA-30648
Location: n/a
Contact: Is-Mari Kretchmer
EMT Job No: 24/4612

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

EMT Sample No.	2												
Sample ID	Tailings												
Depth													
COC No / misc													
Containers	B												
Sample Date	<>												
Sample Type	Solid												
Batch Number	1												
Date of Receipt	15/03/2024												

Please see attached notes for all abbreviations and acronyms

											LOD/LOR	Units	Method No.
Antimony	<5 $_{AA}$										<1	mg/kg	TM30/PM15
Arsenic	<0.5										<0.5	mg/kg	TM30/PM15
Barium	61										<1	mg/kg	TM30/PM15
Cadmium	<0.1										<0.1	mg/kg	TM30/PM15
Chromium	939.9 $_{AA}$										<0.5	mg/kg	TM30/PM15
Cobalt	15.2										<0.5	mg/kg	TM30/PM15
Copper	38										<1	mg/kg	TM30/PM15
Lead	<5										<5	mg/kg	TM30/PM15
Manganese	342										<1	mg/kg	TM30/PM15
Mercury	<0.1										<0.1	mg/kg	TM30/PM15
Molybdenum	0.4										<0.1	mg/kg	TM30/PM15
Nickel	229.1										<0.7	mg/kg	TM30/PM15
Selenium	2										<1	mg/kg	TM30/PM15
Vanadium	23										<1	mg/kg	TM30/PM15
Boron (Aqua Regia Soluble)	1.74										<0.25	mg/kg	TM30/PM15
Zinc	13										<5	mg/kg	TM30/PM15
Natural Moisture Content	29.2										<0.1	%	PM4/PM0
Fluoride	<0.3										<0.3	mg/kg	TM173/PM20
Hexavalent Chromium	<0.3										<0.3	mg/kg	TM38/PM20
Total Cyanide	<0.5										<0.5	mg/kg	TM89/PM45

Element Materials Technology

Client Name: Minelock Environmental Engineers
Reference: SA-30648
Location: n/a
Contact: Is-Mari Kretchmer
EMT Job No: 24/4612

Report : ASLP (20:1) - Reagent Water

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

EMT Sample No.	2												
Sample ID	Tailings												
Depth													
COC No / misc													
Containers	B												
Sample Date	<>												
Sample Type	Solid												
Batch Number	1												
Date of Receipt	15/03/2024												

Please see attached notes for all abbreviations and acronyms

											LOD/LOR	Units	Method No.
Dissolved Antimony	<2										<2	ug/l	TM30/PM14
Dissolved Arsenic	<2.5										<2.5	ug/l	TM30/PM14
Dissolved Barium	<3										<3	ug/l	TM30/PM14
Dissolved Boron	<12										<12	ug/l	TM30/PM14
Dissolved Cadmium	<0.5										<0.5	ug/l	TM30/PM14
Dissolved Calcium	3.4										<0.2	mg/l	TM30/PM14
Dissolved Chromium	21.4										<1.5	ug/l	TM30/PM14
Dissolved Cobalt	<2										<2	ug/l	TM30/PM14
Dissolved Copper	<7										<7	ug/l	TM30/PM14
Dissolved Lead	<5										<5	ug/l	TM30/PM14
Dissolved Magnesium	3.8										<0.1	mg/l	TM30/PM14
Dissolved Manganese	3										<2	ug/l	TM30/PM14
Dissolved Mercury	<1										<1	ug/l	TM30/PM14
Dissolved Molybdenum	<2										<2	ug/l	TM30/PM14
Dissolved Nickel	<2										<2	ug/l	TM30/PM14
Dissolved Potassium	1.7										<0.1	mg/l	TM30/PM14
Dissolved Selenium	<3										<3	ug/l	TM30/PM14
Dissolved Sodium	4.5										<0.1	mg/l	TM30/PM14
Dissolved Vanadium	5.2										<1.5	ug/l	TM30/PM14
Dissolved Zinc	<3										<3	ug/l	TM30/PM14
Sulphate as SO4	8.0										<0.5	mg/l	TM38/PM0
Fluoride	<0.3										<0.3	mg/l	TM173/PM0
Chloride	1.6										<0.3	mg/l	TM38/PM0
Nitrate as NO3	0.3										<0.2	mg/l	TM38/PM0
Hexavalent Chromium	<0.006										<0.006	mg/l	TM38/PM0
Total Dissolved Solids	35										<35	mg/l	TM20/PM0
pH	7.39										<0.01	pH units	TM73/PM0

Client Name: Minelock Environmental Engineers
Reference: SA-30648
Location: n/a
Contact: Is-Mari Kretchmer

EMT Job No.	Batch	Sample ID	Depth	EMT Sample No.	Analysis	Reason
No deviating sample report results for job 24/4612						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating. Only analyses which are accredited are recorded as deviating if set criteria are not met.
It is a requirement under ISO 17025 that we inform clients if samples are deviating i.e. outside what is expected. A deviating sample indicates that the sample 'may' be compromised but not necessarily will be compromised. The result is still accredited and our analytical reports will still show accreditation on the relevant analytes.

Please include all sections of this report if it is reproduced

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

EMT Job No.: 24/4612

SOILS and ASH

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. Asbestos samples are retained for 6 months.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C. Ash samples are dried at 35°C ±5°C.

Where Mineral Oil is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil is quoted, this refers to Total Aliphatics C10-C40.

STACK EMISSIONS

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation for Dioxins and Furans and Dioxin like PCBs has been performed on XAD-2 Resin, only samples which use this resin will be within our MCERTS scope.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a requirement of our Accreditation Body for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.
Laboratory records are kept for a period of no less than 6 years.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

Measurement Uncertainty

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

Customer Provided Information

Sample ID and depth is information provided by the customer.

Age of Diesel

The age of release estimation is based on the nC17/pristane ratio only as prescribed by Christensen and Larsen (1993) and Kaplan, Galperin, Alimi et al., (1996).
Age estimation should be treated with caution as it can be influenced by site specific factors of which the laboratory are not aware.

Tentatively Identified Compounds (TICs)

Where Tentatively Identified Compounds (TICs) are reported, up to 10 Tentatively Identified Compounds will be listed where there is found to be a greater than 80% match with the NIST library. The reported concentration is determined semi-quantitively, with a matrix specific limit of detection. Note, other compounds may be present but are not reported.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above quantitative calibration range. The result should be considered the minimum value and is indicative only. The actual result could be significantly higher.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x5 Dilution

EMT Job No: 24/4612

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
PM4	Gravimetric measurement of Natural Moisture Content and % Moisture Content at either 35°C or 105°C. Calculation based on ISO 11465:1993(E) and BS1377-2:1990.	PM0	No preparation is required.			AR	
TM20	Modified BS 1377-3:1990/USEPA 160.1/3 (TDS/TS: 1971) Gravimetric determination of Total Dissolved Solids/Total Solids	PM0	No preparation is required.			AR	No
TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry): WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009: SOILS by Modified USEP 6010B, Rev.2, Dec.1996; Modified EPA Method 3050B, Rev.2, Dec.1996	PM14	Preparation of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for Dissolved metals, and remain unfiltered for Total metals then acidified			AR	No
TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry): WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009: SOILS by Modified USEP 6010B, Rev.2, Dec.1996; Modified EPA Method 3050B, Rev.2, Dec.1996	PM15	Acid digestion of dried and ground solid samples using Aqua Regia refluxed at 112.5 °C. Samples containing asbestos are not dried and ground.			AD	Yes
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993) – All anions comparable to BS ISO 15923-1: 2013I	PM0	No preparation is required.			AR	No
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993) – All anions comparable to BS ISO 15923-1: 2013I	PM20	Extraction of dried and ground or as received samples with deionised water in a 2:1 water to solid ratio using a reciprocal shaker for all analytes except hexavalent chromium. Extraction of as received sample using 10:1 ratio of 0.2M sodium hydroxide to soil for hexavalent chromium using a reciprocal shaker.			AR	Yes
TM73	Modified US EPA methods 150.1 (1982) and 9045D Rev. 4 - 2004) and BS1377-3:1990. Determination of pH by Metrohm automated probe analyser.	PM0	No preparation is required.			AR	No
TM89	Modified USEPA method OIA-1667 (1999). Determination of cyanide by Flow Injection Analyser. Where WAD cyanides are required a Ligand displacement step is carried out before analysis.	PM45	As received solid samples are extracted with 1M NaOH by orbital shaker for Cyanide, Sulphide and Thiocyanate analysis.			AR	Yes
TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 9214 - 340.2 (EPA 1998)	PM0	No preparation is required.			AR	No
TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 9214 - 340.2 (EPA 1998)	PM20	Extraction of dried and ground or as received samples with deionised water in a 2:1 water to solid ratio using a reciprocal shaker for all analytes except hexavalent chromium. Extraction of as received sample using 10:1 ratio of 0.2M sodium hydroxide to soil for hexavalent chromium using a reciprocal shaker.			AR	Yes



Rustenburg Chrome Mining

Motivation for exclusion of sand from re-processed tailings from the definition of waste

REPORT NO: 172_Rustenburg Chrome Mining (Pty) Ltd

MineLock
Environmental Engineers

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Appendices

APPENDIX A……Analytical certificate of waste assessment

APPENDIX B…… SDS

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1. INTRODUCTION

Rustenburg Chrome Mining (Pty) Ltd (RCM) wish to apply to the National Department of Forestry, Fisheries and the Environment (DFFE) to exclude the sand from the re-processing of tailings from their Tailings Dam from the definition of waste in terms of GN R. 715 "Regulations Regarding the Exclusion of a Waste Stream or a Portion of a Waste Stream from the Definition of Waste" (18 July 2018).

The following beneficial downstream use of the waste include:

- Cement, bricks and block making; and
- Road Construction.

2. OBJECTIVES

The objectives of this project are as follows:

- Compile the motivation document and required forms on behalf of RCM;
- Specialist input for the motivation for beneficial use;
- Conduct a risk assessment; and
- Compile a risk management plan for the motivation of the application.

3. APPLICANT DETAILS

The details of the applicant are shown in Table 1.

Table 1: Applicant details

APPLICANT	Rustenburg Chrome Mining (Pty) Ltd
WASTE STREAM OR PORTION OF A WASTE STREAM TO BE EXCLUDED FROM THE DEFINITION OF WASTE	Sand from re-processing of mine tailings
BENEFICIAL USE/S	• Cement, bricks and block making • Road Construction
WASTE GENERATING FACILITY OR FACILITIES	
PHYSICAL ADDRESS OF FACILITY OR FACILITIES	Farm Rietfontein 338 JQ, Bleskop, Rustenburg
GPS CO-ORDINATES OF WASTE GENERATING FACILITY OR FACILITIES	25° 43' 37.36862" S 27° 22' 25.66044" E

CONTACT PERSON		
NAME	Johan Bensch	
ADDRESS	PO Box 8, Kroondal, 0350	
EMAIL ADDRESS	johan@cloveralloys.co.za	
TELEPHONE	+27 (14) 536 0604 +27(0)83 447 9826	
*** DETAILED DESCRIPTION OF WASTE GENERATING PROCESS**	The fine fraction of ROM (<19mm) is upgraded to foundry sand (CO4) and chemical grade (CO1) by milling, screening spiraling and hydro-classification. Regrinding of the waste material leaving from the foundry sands and chemical grade circuits and subsequently reclassification, results in the metallurgical grade products (CO6)	
PRODUCTION PROCESS FLOW CHART ATTACHED	**YES**	**NO**
WASTE CLASSIFICATION	**GENERAL**	**HAZARDOUS**
IF WASTE IS HAZARDOUS LIST THE HAZARDS OF THE WASTE	Potential hazard: Inhalation of respirable dust containing Si and Cr	

4. SITE AND ENVIRONMENTAL DESCRIPTION

RCM (previously known as Lanxess Chrome Mine) is located on the farm Rietfontein 388 JQ, 7 km east of Kroondal and 11 km south-east of Rustenburg (Figure 1). The TSF consists of an active compartment (TSF ext 3) and a dormant compartment which is currently being mechanically remined to extract the chrome left in the tailings. Washed sand is produced as a by-product of the remining process which could be beneficially used in the building industry and road construction.

A summary of the environmental status quo of the mine is presented in Table 2.

.



Figure 1 Location of RCM and sand stockpile area

Table 2 Summary of RCM environmental status quo

Climate:	Hot summer and mild winter.
Precipitation:	Thunderstorms in summer. Wet season: November - March Mean Annual Precipitation (MAP): 558 - 730 mm
Evaporation:	Mean Annual Evaporation (MAE): 2 374 mm
Temperature:	Mean temperature in summer: 14 - 30°C (hottest in January) Mean temperature in winter: 5 - 20°C (coldest in July)
Soils:	Dark, well-structured clays.
Topography:	Fairly flat to gently undulating Slope: Westerly slope between 1 and 2 degrees. High: 1 220 mamsl in the east Low: 1 180 mamsl in the west
Surface water:	WMA 3 – Crocodile West and Marico Quaternary catchment: A22H (579 km^2) No streams are located within the project boundary. RCM is not using surface water for operations. Municipal water is supplied.
Geology:	Norite and anorthosite of the mafic to ultramafic Bushveld Igneous Complex (BIC). A major dyke flanks the west of the project area and is associated with a major fault, constituting the most noticeable topographic feature. This syenite dyke dips to the east and forms a no-flow groundwater boundary.
Geohydrology:	Map: 2526 Johannesburg 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. The host rocks in this area are disturbed by a major N-S trending fault influencing groundwater movement.
Aquifer:	Shallow, weathered zone aquifer, which occurs in the weathered and weathering related fractured zones within the pyroxenite and norite (9 – 25 mbgl). The weathered aquifer stores the bulk of the groundwater in the area and forms the main recharge zone.
Groundwater:	Recharge: 3-7% of MAP (20-45 mm/a) Levels: 10-24 mbgl. Average 16 mbgl Flow direction: south-east to north-west Used for process water

5. WASTE PRODUCTION PROCESS

The waste production flow diagram for the washed sand is shown in Figure 2. The tailings are processed through roughers and a series of washing processes to remove any remaining Cr. The sand fraction remaining after the washing process is the by-product which can be beneficially used in the building industry and road construction.

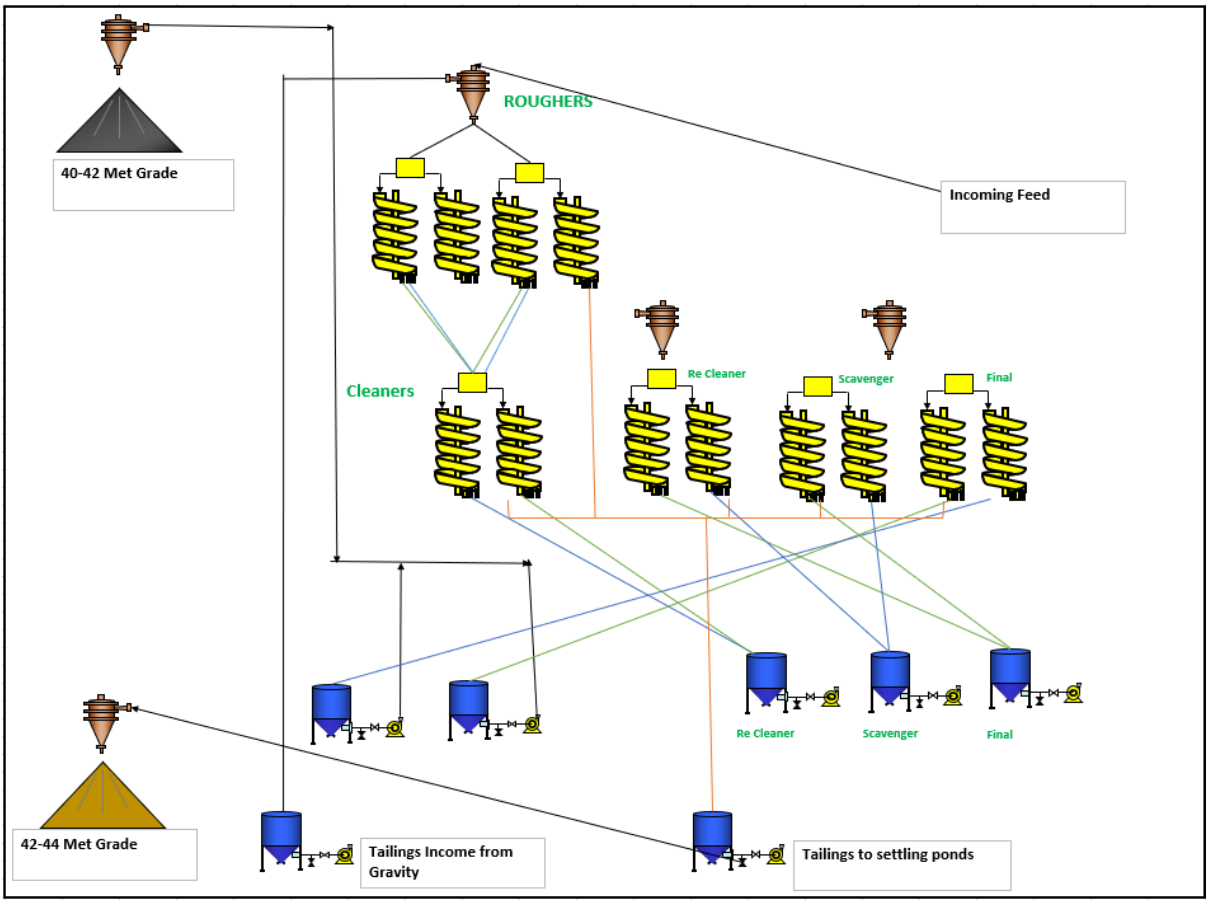


Figure 2 Washed sand process flow diagram

6. ACCOUNTING OF BENEFICIATED WASTE

RCM is required to account for the volumes of washed sand being re-used and recycled. The following accounting system will be in place to document the volume of sand beneficiated from the facility:

- Trucks/tippers will enter and exit the RCM premises through a weighbridge and tonnages will be recorded.
- Records of volumes removed will be kept on-site.

7. SUPPORT FOR PREVIOUSLY DISADVANTAGED COMPANIES

The sand will be stockpiled and sold to the local communities for construction/building material at a lower rate as provided by contractors in the area, which will benefit the communities. The mine already has interested parties that would like to buy the sand for construction purposes.

8. WASTE CLASSIFICATION AND ASSESSMENT

The composite sand sample collected from RCM was submitted to Waterlab for analyses according to the National Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R.635 of 23 August 2013), including:

- Total digestion (aqua-regia) analysis followed by ICP OES to determine the concentration of metals as well as Cr (IV);
- ASLP (deionized water extract) followed by ICP OES analyses, determination of cations and anions including Ca, Cr(VI), Na, K, Mg, SO_4^{2-}, $C\ell^-$, F^-, NH_4, NO_3 and pH and TDS (to determine leachable concentrations of potential constituents of concern); and
- Whole element analyses (XRF).

Analytical certificates are attached in Appendix A.

8.1 Whole element concentrations

The whole element concentrations show the main oxide minerals present in the sand (Table 3). These results show that the sand consist mainly of quarts (SiO_2), iron oxide, magnesium oxide and chromium oxide which is part of the geological formations of the area.

Table 3 Whole element concentrations in RCM sand

Major Elements		**Concentration (%)**
Silica	SiO_2	31.08
Titanium	TiO_2	0.43
Aluminium	Al_2O_3	9.4
Iron	Fe_2O_3	19.72
Manganese	MnO	0.36
Magnesium	MgO	14.82
Calcium	CaO	2.92
Sodium	Na_2O	0.48
Potassium	K_2O	0.16
Phosphorous	P_2O_5	0.07
Chromium	Cr_2O_3	17.3
Sulphur	SO_3	0.73

8.2 Waste assessment (GN R. 635)

The purpose of the waste assessment is to determine the potential level of risk associated with disposal or beneficial use of materials/wastes. The analytical results indicate that the sand is a Type 3 waste due to elevated total Cu and Ni concentrations exceeding TCT0 levels (Table 4). However, the LCs of all constituents are below LCT0 and most constituents are below detection limits (Table 5).

Table 4 Total concentrations of constituents in RCM sand compared to TCT levels

Constituents	TCT0	TCT1	TCT2	RCM Sand
	mg/kg			
As, Arsenic	5.8	500	2000	0.4
B, Boron	150	15000	6000	<10
Ba, Barium	62.5	6250	25000	49.1
Cd, Cadmium	7.5	260	1040	<0.400
Co, Cobalt	50	5000	20000	22.5
$Cr_{Total,}$ Chromium Total	46000	800000	N/A	10800
Cr(VI), Chromium (VI) Total	6.5	500	2000	<2
Cu, Copper	16	19500	78000	16.2
Hg, Mercury	0.93	160	640	<0.400
Mn, Manganese	1000	25000	100000	399.8
Mo, Molybdenum	40	1000	4000	<10
Ni, Nickel	91	10600	42400	167.3
Pb, Lead	20	1900	7600	1.6
Sb, Antimony	10	75	300	<0.400
Se, Selenium	10	50	200	<0.400
V, Vanadium	150	2680	10720	54.0
Zn, Zinc	240	160000	640000	37.6

Table 5 Leachable concentrations of constituents in RCM sand compared to LCT levels

Constituents	LCT0	LCT1	LCT2	LCT3	WCA sample
	mg/ℓ				
As, Arsenic	0.01	0.5	1	4	<0.001
B, Boron	0.5	25	50	200	0.031
Ba, Barium	0.7	35	70	280	<0.025
Cd, Cadmium	0.003	0.15	0.3	1.2	<0.001
Co, Cobalt	0.5	25	50	200	<0.025
$Cr_{Total,}$ Chromium Total	0.1	5	10	40	0.035
Cr(VI), Chromium (VI)	0.05	2.5	5	20	<0.010
Cu, Copper	2	100	200	800	<0.010
Hg, Mercury	0.006	0.3	0.6	2.4	<0.001

Constituents	LCT0	LCT1	LCT2	LCT3	WCA sample
	mg/ℓ				
Mn, Manganese	0.5	25	50	200	<0.025
Mo, Molybdenum	0.07	3.5	7	28	<0.025
Ni, Nickel	0.07	3.5	7	28	<0.025
Pb, Lead	0.01	0.5	1	4	<0.001
Sb, Antimony	0.02	1	2	8	<0.001
Se, Selenium	0.01	0.5	1	4	<0.001
V, Vanadium	0.2	10	20	80	<0.025
Zn, Zinc	5	250	500	2000	0.027
Inorganic Anions					
Total Dissolved Solids*	1000	12 500	25 000	100 000	30
Chloride as Cl	300	15 000	30 000	120 000	<2
Sulphate as SO_4	250	12 500	25 000	100 000	<2
Nitrate as N	11	550	1100	4400	<0.1
Fluoride as F	1.5	75	150	600	<0.2
pH					8.1

8.3 Waste classification (GN R. 634)

Section 4 of GN R. 634 states waste must be classified according to SANS 10234 (SANS 10234:2019, Edition 2). As per SANS 10234, the percentage concentration of chemical constituents of the waste material must be screened in terms of physical, human health and environmental hazards as per the cut off limits presented in Table 6. The SANS 10234 classification is based on analytical results as well intrinsic properties of the waste stream.

- Physical hazards – re-processed/washed sand is not explosive, flammable (combustible through friction), pyrophoric (ignite when in contact with air) or oxidising and does not release toxic gases when in contact with water or acid. Therefore, it is not hazardous in terms of physical characteristics.

- Health hazards – The percentage concentration of constituents obtained from the XRF and acid digestion analysis was compared to the cut-off values/concentration limits for hazard classes summarized in Table 6. Elements exceeding the 1% cut-off value include Si, Al, Ca, Fe, Mg and Cr(III). Only the Si is of potential concern to human health, mainly through inhalation of respirable dust which may cause long-term health effects. Although the material is not considered to be hazardous, care should be taken to prevent long-term exposure to respirable dust particles through personal protection and exposure control.

- Environmental hazard – The solubility of constituents in the materials are low (< 0.1%), therefore it is not likely to be harmful to the aquatic environment.

Table 6 Hazard classes and associated cut-off concentration limits

Hazard class	Cut-off value %	Comments
Acute toxicity	> 1.0	No constituents present that may cause acute toxicity
Skin corrosion	pH ≤ 2 or ≥ 8.5	pH = 8.1
Skin irritation	pH ≤ 2 or ≥ 8.5	pH = 8.1
Serious damage to eyes	> 1.0	No constituents present that may cause serious damage to eyes
Eye irritation	> 1.0	Dust may cause eye irritation but not the sand itself
Respiratory sensitization	> 1.0	Dust may cause respiratory sensitization but not the sand itself
Skin sensitization	> 1.0	No constituents present that may cause skin sensitization
Mutagenicity: Category 1 Category 2	 > 0.1 > 1.0	None present
Carcinogenicity	> 0.1	None present
Reproductive toxicity	> 0.1	None present
Target organ systemic toxicity	> 1.0	No constituents present that may cause organ systemic toxicity
Hazardous to aquatic environment	> 1.0	Low leachability of constituents indicates no hazard to aquatic environment

9. CASE STUDIES OF SIMILAR BENEFICIAL USES

9.1 Approved exclusions

The DFFE published a list of waste streams or portions of such waste streams which had been excluded from the definition of waste for the purpose of beneficial use (GN 1021 of 2021, October 2021). The list includes beneficial uses of slag, silica aggregates, coal combustion products (CCP) such as fly ash, clinker ash and bottom ash for brickmaking, block making, road construction, mine backfilling, treatment of acid mine drainage, treatment of leachate at landfill site and soil amelioration. A summary of waste streams excluded from the definition of waste and the associated beneficial uses are listed in the table below.

Table 7: Waste streams and associated beneficial uses, excluded from the definition of waste (Government Gazette Vol. 676, No. 45293, published 8 October 2021)

Facility name (Applicant)	Waste stream or portion of waste stream	Beneficial use(s)
African Rainbow Minerals	FeCr Slag	Aggregate Brick making Road building

Facility name (Applicant)	Waste stream or portion of waste stream	Beneficial use(s)
Enstra Paper Mill	Ash	Brick making Block making
Thabazimbi Iron Ore Mine	Iron ore plant discard	Aggregate Cement
Samancor Chrome – TC Smelters	Slag	Aggregate Road building Backfilling
Samancor Cr - Tubatse	Slag	Aggregate Road building Backfilling
Hernic Ferrochrome	Slag	Aggregate Road building Backfilling

9.2 Local and international applications

In South Africa, extraction of valuable metals from tailings dumps, residues or low grade stockpiles has been extensively researched by metallurgists. Developments in mineral processing technology makes the retreatment-re-processing of numerous tailings dumps a profitable proposition, particularly tailings created from the processing of platinum group elements (PGEs) from the UG2 reef in the Bushveld Complex (BC) to recover chrome and tailings from the processing of chrome ore in the Lower Group reefs of the BC. The sand remaining after extraction of the valuable metals is a inert by-product which can be used beneficially in the building industry (https://www2.deloitte.com/za/en/pages/energy-and-resources/articles/converting-tailings-dumps-into-mineral-resources.htm).

Internationally, Vale is using sand from ore processing, described by the term “ore-sand”, as a sustainable source of sand and at the same time reduce the volume of tailings generated by mining. Characterisation of the sand indicate that the material is inert and non-toxic, and can be suitable for various applications, either on its own or as a part of a blend. Furthermore, separating and repurposing these sand-like materials before they are added to the waste stream significantly reduce the volume of waste being generated (http://www.vale.com/EN/aboutvale/news/Pages/study-about-sustainable-sand-in-mining.aspx).

10. RISK ASSESSMENT AND MANAGEMENT PLAN

The Risk Assessment and Risk Management Plan has been prepared in accordance with section 8 and 9 of GN R. 715 of 2018.

10.1 Risk assessment

The criteria supplied by DFFE as indicated in Table 8 and Table 9 were used to assess the potential risk to human health and the environment. The significance rating calculation is as follows: *Significance points (SP) = (Magnitude + Duration + Scale) * Probability*

Table 8: Risk assessment criteria

Magnitude/Severity	**Duration**
10 – Very high	5 - Permanent
8 – High	4 – Long term (5 – 10 years)
6 - Moderate	3 – Medium term (1 – 5 years)
4 - Low	2 – Short term (< 12 months)
2 - Minor	1 - Immediate
Scale	**Probability/Likelihood**
5 - International	5 - Definite
4 - National	4 – Highly probable
3 - Regional	3 – Medium probability
2 – Site only	2 – Low probability
1 - None	1 - Improbable

Table 9: SP ratings and description prescribed by DFFE

Rating		**Description**
SP > 60	High significance	An impact which could influence the decision whether to proceed or not to proceed with the activities regardless any possible mitigation
SP 30 - 60	Moderate significance	An impact or benefit which is sufficiently important to require management and which could have an influence on the decision unless it is mitigated
SP < 30	Low significance	Impacts with little real effect and which will not have an influence on or require modification of the activities
+	Positive	An impact likely to result in positive consequences

Table 10 show the potential risk associated with specific activities associated with handling and use of the sand without any mitigation measures, assessed according to the prescribed criteria. The main impact on the environment and human health (moderate risk without mitigation) are through:

- Dust generation during transport and handling
- Inhalation of respirable dust particles could cause respiratory tract irritation
- Dust particles could cause eye damage

Table 10: Risk Assessment without mitigation

Activity	Risk Description	Environmental Receptors	Magnitude	Saptial scale	Duration	Probability/Likelihood	Significance	Risk Rating
Loading of sand onto trucks	Dust generation during loading sand onto trucks resulting in an air quality impact due to increase in particulate matter concentrations	Air	4	1	1	**5**	**30**	M
	Spillage of sand outside designated loading areas contaminating surface runoff and storm water	Surface water	4	2	2	**3**	**24**	L
	Spillage of sand outside designated loading areas contaminating soils	Soil	2	1	2	**3**	**15**	L
	Dust inhalation (respirable fraction)	Humans	6	1	3	**3**	**30**	M
	Dust causing eye irritation	Humans	4	1	1	**3**	**18**	L
Transportation of sand	Dust generation during transportation of sand	Air	4	2	1	**3**	**21**	L
	Spillage of sand during transportation along roads contaminating surface runoff and storm water	Surface water & Aquatic life	4	2	1	**2**	**14**	L
	Spillage of sand during transportation along roads contaminating soil	Soil	4	2	1	**2**	**14**	L
Handling of sand	Dust generation during handling of sand	Air	4	1	1	5	**30**	M
	Dust inhalation	Humans	6	1	3	3	**30**	M

Activity	Risk Description	Environmental Receptors	Magnitude	Saptial scale	Duration	Probability/Likelihood	Significance	Risk Rating
	Dust causing eye irritation	Humans	4	1	3	3	**24**	L
Off-loading of sand	Dust generation during transfer of sand from trucks to new storage area	Air	4	1	1	5	**30**	M
Storage of sand	Poor/no lining of storage area resulting in contaminants of concern leaching to groundwater	Groundwater	6	3	4	2	**26**	L
	Contaminated surface runoff or leachate from sand during rainfall entering stormwater system	Surface water	4	1	3	2	**16**	L
	Poor/no lining of storage area resulting in contaminants of concern leaching into soil	Soil	6	3	4	2	**26**	L
	Dust generation during conducive weather conditions	Air	4	1	1	3	**18**	L

Other potential risks to the environment with SP< 30 include spillage of sand during transportation which could impact on soils, ground-, storm- and surface water. No high risk (SP > 60) activities have been identified.

10.2 Risk management plan

According to section 9 of GN R. 715 of 2018, the risk management plan as a minimum must include:

- A Safety Data Sheet which complies with the requirements of SANS 10234, where the waste material is classified as hazardous (included in Appendix B although material is not hazardous);
- Permitted uses for which the waste material may be used; and
- A mechanism to record the amount of waste distributed to specific users for a permitted use; including the number of enterprises established or supported and the extent to which previously disadvantaged individuals have been supported.

The risk mitigation actions and measures for all moderate risk activities as well as responsibilities are shown in Table 11 and can be summarised as follows:

- Generation of dust during handling of the sand (loading onto trucks, transportation, and off-loading) must be limited to prevent the impact on air quality and inhalation of respirable dust particles by workers
- Transportation vehicles should be adequately equipped to prevent dust generation and spillage during transportation
- Supply of PPE to workers to protect them from dust inhalation and skin contact with sand and provide training on the potential risks associated with handling of the sand
- Appropriately designed on-site storage/stockpile area to avoid soil, surface- and groundwater contamination.

The mechanism to record the volumes of sand distributed to specific users are discussed in section 7 of this report and support to previously disadvantaged communities are indicated in section 8.

Table 11: Risk Management Plan

Activity	Risk Description	Action(s) to minimise/ manage the risk	Responsibility (Who is responsible to carry out the action)
Loading of sand onto trucks	Dust generation during loading of sand onto trucks resulting in an air quality impact due to increase in particulate matter concentrations	Sand should be slightly wet during the loading of sand onto trucks. No loading of sand should be undertaken during inclement weather conditions (high winds, severe dust storms, extreme high temperatures or any combination).	Sand generator
	Spillage of sand outside designated loading areas contaminating surface runoff and storm water	Avoid loading sand during inclement weather which could promote sand spillage outside of designated loading areas. Ensure that the designated loading area has appropriate stormwater infrastructure to separate clean and dirty storm water. If spillages occur, ensure that spills are timeously removed and area cleaned to prevent environmental impact.	Sand generator
	Dust inhalation (respirable fraction)	Workers should be issued with the required Personal Protective Equipment including (but not limited to) the following: Disposable dust mask (changed regularly); protective dust-proof goggles; PVC or rubber gloves, overalls. Ensure workers are appropriately trained for handling sand material and that regular (daily) toolbox talks are conducted to ensure regular familiarization of potential risks and hazards.	Sand generator and Sand Transporter

Activity	Risk Description	Action(s) to minimise/ manage the risk	Responsibility (Who is responsible to carry out the action)
	Skin contact and eye irritation	Workers should be issued with the required Personal Protective Equipment including (but not limited to) the following: Disposable dust mask (changed regularly); protective dust-proof goggles; PVC or rubber gloves, overalls. Ensure workers are appropriately trained for handling sand material and that regular (daily) toolbox talks are conducted to ensure regular familiarization of potential risks and hazards.	Sand generator and Sand Transporter
Transportation of sand	Dust generation during transportation of sand	Ensure that vehicles intended for transportation of sand is equipped with tightly fitted tarpaulin to reduce the sand dust uplift potential.	Sand transporter
	Spillage of sand during transportation along roads contaminating surface runoff and storm water	Ensure that vehicles intended for transportation of sand is equipped with tightly fitted tarpaulin to reduce the sand dust uplift potential.	Sand transporter
Handling of sand	Dust generation during handling of sand	Appropriate dust suppression should be exercised during the handling of sand. No handling of sand should be done during inclement weather conditions, including, but not limited to, high winds, severe dust storms, extreme high temperatures or any combination.	Sand generator and Sand user

Activity	Risk Description	Action(s) to minimise/ manage the risk	Responsibility (Who is responsible to carry out the action)
	Dust inhalation	Workers should be issued with the required Personal Protective Equipment including (but not limited to) the following: Disposable dust mask (changed regularly); protective dust-proof goggles; PVC or rubber gloves, overalls. Ensure workers are appropriately trained for handling sand material and that daily toolbox talks are conducted to ensure regular familiarization of potential risks and hazards.	Sand generator and Sand user
	Skin contact and eye irritation	Workers should be issued with the required Personal Protective Equipment including (but not limited to) the following: Disposable dust mask (changed regularly); protective dust-proof goggles; PVC or rubber gloves, overalls. Ensure workers are appropriately trained for handling sand material and that regular (daily) toolbox talks are conducted to ensure regular familiarization of potential risks and hazards.	Sand generator and Sand user
Off-loading of sand	Dust generation during transfer of sand from trucks to new storage area	Appropriate dust suppression should be exercised during off-loading of sand. No off-loading of sand should be done during inclement weather conditions, including, but not limited to, high winds, severe dust storms, extreme high temperatures or any combination.	Transporter and Sand user
Storage of sand	Contaminated surface runoff or leachate from Sand during rainfall entering stormwater system	Ensure that storage/stockpile area has adequate stormwater infrastructure to separate clean and dirty storm water.	Sand generator

Activity	Risk Description	Action(s) to minimise/ manage the risk	Responsibility (Who is responsible to carry out the action)
		Ensure that storage/stockpile area is adequate to prevent wash-away of sand during heavy rain.	
	Dust generation during conducive weather conditions	Appropriate dust suppression should be exercised at storage/stockpile area Ensure that no handling of sand should be done during inclement weather conditions, including, but not limited to, high winds, severe dust storms, extreme high temperatures or any combination.	Sand generator

11. CONCLUSIONS

The washed sand by-product of tailings reprocessing has several beneficial uses. The sand poses limited risk to human health, mainly through inhalation of respirable dust containing Si and Cr. Potential moderate risks can be mitigated as indicated in the Risk Management Plan (Table 11) to limit the potential negative impact on the environment and human health.

The beneficial use of the sand will have the following positive effects:

- Impact on the environment will be limited since no disposal facility will be required
- The washed sand is a sustainable source of sand, limiting the demand for quarry sand
- Economic benefit to local brick makers and road builders who can substitute other natural resources by using the sand which will be cheaper.

12. LIST OF REFERENCES

- Integrated Environmental Authorisation NW 30/5/1/2/3/2/1 (336) EM (dated 24 May 2018)
- Digby Wells, 2017. Environmental Impact Assessment and Environmental Management Plan
- Digby Wells, 2015. Section 102 EMP Amendment for Lanxess Chrome Mine Groundwater Assessment Report
- Digby Wells, 2015. Section 102 EMP Amendment for Lanxess Chrome Mine Surface Water Assessment Report
- Minelock Environmental Engineers, 2022. Optimisation of storm water management plan. Report No. 154_Optimised SWMP Report

We trust you find the above in order and remain available should you have any queries.

Yours sincerely,



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Soil Scientist

APPENDIX A

Analytical certificates of waste assessment

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received:	**2022/04/06**	**Date completed:**	**2022/04/25**
Project number:	**1000**	**Report number: 108882**	**Order number:**

Client name:	**Minelock**	**Contact person:**	**Douglas Richards**
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		Cell:	**084 548 2787**

Analyses		Sample Identification
		WCA sample
Sample Number		158038
Major Elements		Major Element Concentration (wt %)[o]
Silica	SiO_2-	31.08
Titanium	TiO_2	0.43
Aluminium	Al_2O_3	9.4
Iron	Fe_2O_3	19.72
Manganese	MnO	0.36
Magnesium	MgO	14.82
Calcium	CaO	2.92
Sodium	Na_2O	0.48
Potassium	K_2O	0.16
Phosphorous	P_2O_5	0.07
Chromium	Cr_2O_3	17.3
Sulphur	SO_3	0.73
Loss on Ignition (1000 °C)	LOI	2.15
Total	Total	99.71
Loss of Moisture (105 °C)	H_2O-	0.08

[o] = Outsourced

Notes: % g/g is equivalent to wt %; mg/kg is equivalent to ppm; n.d. = not determined; bold italicised font represents semi-quantitative data; * represents measurements reported in % g/g or wt%.

Analyses		Sample Identification
		WCA sample
Sample Number		158038
Trace Element		Trace Element Concentration (ppm) [o]
Arsenic	As	<0.43
Barium	Ba	77.2
Bismuth	Bi	3.03
Cadmium	Cd	<3.04
Cerium	Ce	<3.08
Chlorine	Cl	<2.59
Cobalt	Co	125
Caesium	Cs	0.68
Copper	Cu	47.5
Galium	Ga	<3.21
Germanium	Ge	<0.50
Hafnium	Hf	11.8
Mercury	Hg	<1.00
Lanthanum	La	15
Lutetium	Lu	5.56
Molybdenum	Mo	3.21
Niobium	Nb	<2.15
Neodymium	Nd	948
Nickel	Ni	708
Lead	Pb	36.8
Rubidium	Rb	1.34
Antimony	Sb	14.9
Scandium	Sc	10.5
Selenium	Se	3.06
Samarium	Sm	6.88
Tin	Sn	<0.08
Strontium	Sr	59.3
Tantalum	Ta	3.32
Tellurium	Te	<0.16
Thorium	Th	<0.88
Thallium	Tl	4.5
Uranium	U	2.19
Vanadium	V	503
Tungsten	W	5.93
Yttrium	Y	3.77
Ytterbium	Yb	<1.05
Zinc	Zn	512
Zirconium	Zr	14.8

[o] = Outsourced

XRF: Major Element Analysis (Geological)

The samples were prepared by first drying the samples at 100oC for ~3 hours in order to determine loss of moisture content (H_2O-), followed by ashing of the sample at 1000oC until completely ashed, to determine the loss on ignition (LOI). XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using a number of international and national certified reference materials (CRMs).

XRF: Trace Element Analysis (Geological)

XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using international and national certified reference materials (CRMs).

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES QUANTITATIVE ANALYSIS

Date received: 2022/04/06 **Date Completed:** 2022/04/28
Project number: 1000 **Report number:** 108882

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Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Aqua Regia	0.25	100	2.5	400

Sample Id	Sample number	Ag	Ag	Al	Al	As*	As*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.100	<40	<0.001	<0.400
WCA sample	158038	<0.025	<10	55	22000	0.001	0.400

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10	<0.025	<10
WCA sample	158038	<0.025	<10	0.123	49	<0.025	<10

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd*	Cd*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.001	<0.400
WCA sample	158038	<0.025	<10	41	16400	<0.001	<0.400

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10	<0.010	<4.00
WCA sample	158038	0.056	22	27	10800	0.041	16

Sample Id	Sample number	Fe	Fe	Hg*	Hg*	K	K
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.001	<0.400	<0.5	<200
WCA sample	158038	59	23600	<0.001	<0.400	1.4	556

Sample Id	Sample number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.025	<10
WCA sample	158038	<0.025	<10	79	31600	0.999	400

Sample Id	Sample number	Mo	Mo	Na	Na	Ni	Ni
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<1	<400	<0.025	<10
WCA sample	158038	<0.025	<10	6	2400	0.418	167

Sample Id	Sample number	P	P	Pb*	Pb*	Sb*	Sb*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.001	<0.400	<0.001	<0.400
WCA sample	158038	0.026	10	0	1.600	<0.001	<0.400

Sample Id	Sample number	Se*	Se*	Si	Si	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.400	<0.2	<80	<0.025	<10
WCA sample	158038	<0.001	<0.400	7.51	3006	0.122	49

Sample Id	Sample number	Ti	Ti	Tl	Tl	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<10	<0.025	<10	<0.025	<10
WCA sample	158038	1.19	475	<0.025	<10	0.135	54

Sample Id	Sample number	Zn	Zn
		mg/l	mg/kg
Det Limit		<0.025	<10
WCA sample	158038	0.094	38

[*] = Element analysed on ICP-MS Instrument

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES QUANTITATIVE ANALYSIS

Date received: 2022/04/06 **Date Completed:** 2022/04/21
Project number: 1000 **Report number:** 108882

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Email: johann@minelock.co.za
Telephone: --- **Cell:** 084 548 2787

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Distilled Water	50	1000	50	20

Sample Id	Sample number	Ag	Ag	Al	Al	As*	As*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.100	<2.00	<0.001	<0.020
WCA sample	158038	<0.025	<0.500	0.195	3.90	<0.001	<0.020

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.025	<0.500
WCA sample	158038	0.031	0.613	<0.025	<0.500	<0.025	<0.500

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd*	Cd*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.001	<0.020
WCA sample	158038	<0.025	<0.500	3	60	<0.001	<0.020

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.010	<0.200
WCA sample	158038	<0.025	<0.500	0.035	0.700	<0.010	<0.200

Sample Id	Sample number	Fe	Fe	Hg*	Hg*	K	K
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.001	<0.020	<0.5	<10.0
WCA sample	158038	0.418	8.36	<0.001	<0.020	<0.5	<10.0

Sample Id	Sample number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.025	<0.500
WCA sample	158038	<0.025	<0.500	3	60	<0.025	<0.500

Sample Id	Sample number	Mo	Mo	Na	Na	Ni	Ni
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<1	<20	<0.025	<0.500
WCA sample	158038	<0.025	<0.500	<1	<20	<0.025	<0.500

Sample Id	Sample number	P	P	Pb*	Pb*	Sb*	Sb*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.001	<0.020	<0.001	<0.020
WCA sample	158038	<0.025	<0.500	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample number	Se*	Se*	Si	Si	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.2	<4.0	<0.025	<0.500
WCA sample	158038	<0.001	<0.020	1.4	28	<0.025	<0.500

Sample Id	Sample number	Ti	Ti	Tl	Tl	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.025	<0.500
WCA sample	158038	<0.025	<0.500	<0.025	<0.500	<0.025	<0.500

Sample Id	Sample number	Zn	Zn
		mg/l	mg/kg
Det Limit		<0.025	<0.500
WCA sample	158038	0.027	0.540

[*] Analysed on ICP-MS instrument

APPENDIX B
SDS

MineLock
Environmental Engineers

SAFETY DATA SHEET: SAND FROM REPROCESSING OF CHROME TAILINGS

1.0 IDENTIFICATION

Product Name: Sand from reprocessed chrome tailings

Supplier: Rustenburg Chrome Mine

PO Box 8, Kroondal, 0350

Telephone: 014 536 0604

2.0 HAZARD(S) IDENTIFICATION

Hazards classification: The sand by-product from reprocessing of chrome tailings is **non-hazardous**.

Dust generated when the by-product is handled may be hazardous to human health since it contains crystalline silica and chrome, some of which may be respirable (particles small enough to go into the deep parts of the lung when breathed in). Recommendations on Exposure Controls / Personal Protection (see Section 8 below) should be followed.

Hazard Statements (SANS 10234):

- H320 May cause eye irritation (dust)
- H335 May cause respiratory irritation (dust)
- H350 May cause cancer (long-term inhalation of respirable dust)

3.0 COMPOSITION/INFORMATION ON INGREDIENTS

Contains the following constituents:

Constituent	Content (%)	CAS number
Quartz (crystalline silica) (SiO_2)	>30%	14808-60-7
Aluminium oxide (Al_2O_3)	≈9%	142844-00-6
Iron oxide (Fe_2O_3)	≈20%	1309-37-1
Calcium oxide (CaO)	≈2%	1305-78-8
Magnesium oxide (MgO)	≈15%	1309-48-4
Chromium (III) oxide (Cr_2O_3)	≈17%	1308-38-9

4.0 FIRST-AID MEASURES

Eye: Do not rub eyes, as the material is abrasive and may scratch the surface of the eye. Immediately and thoroughly irrigate with eye wash solution or clean water. If symptoms develop or persist, seek medical attention.

Skin: Wash skin thoroughly with cool water and mild soap or detergent. Seek medical advice if rash or irritation occurs.

Ingestion: Rinse mouth and lips with water. Do not induce vomiting. If symptoms persist, seek medical attention.

Inhalation (dust): Immediately remove to fresh air. If breathing difficulties are experienced, seek medical attention.

5.0 FIRE-FIGHTING MEASURES

Extinguishing media: Use extinguishing media appropriate for surrounding fire.

Firefighting procedures: The product is non-flammable.

Hazardous Decomposition Products: None reported.

6.0 ACCIDENTAL RELEASE MEASURES

Personal Precautions: Avoid breathing in dust. Keep dust out of eyes. See Section 8 for guidance on personal protective equipment. See Section 7 for guidance on handling the product.

Environmental Precautions: Avoid release to the environment.

7.0 HANDLING AND STORAGE

Handling: The product should be handled to minimise the creation of airborne dust. Respirable dusts can be generated during processing, handling and storage. Use control measures such as ventilation, enclosure of materials, covered loads on trucks, and wetting down material while in use.

Storage: When stockpiling and handling large quantities of sand, care should be taken to avoid steep faces on the stockpile, which can fall without warning. Ensure that storage/stockpile area has adequate stormwater infrastructure to separate clean and dirty storm water. Ensure that storage/stockpile area is adequate to prevent wash-away of sand during heavy rain.

8.0 EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure to dust should be kept as low as practicable.

Protective clothing (gloves, coveralls, boots, etc.) should be worn to protect skin.

Safety glasses with side shields or safety goggles or a face shield should be worn to protect the eyes.

Always wash hands before smoking, eating, drinking or using the toilet

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Grey, dark grey and black sand
Boiling Point:	Not determined
Melting Point:	Not determined
Vapour pressure:	Not applicable
Bulk density:	Not determined
Flash Point:	Not relevant
Flammability Limits:	Not relevant
Solubility in water:	Not soluble

10.0 STABILITY AND REACTIVITY

Chemical stability:	Stable under normal temperatures and pressures
Hazardous reactions:	None reported
Incompatible materials:	None reported
Conditions to avoid:	None reported

Hazardous decomposition products: None reported

11.0 TOXICOLOGICAL INFORMATION

Acute Potential Health Effects:

Skin:	Dust may be mildly irritating and abrasive to the skin due to its physical properties.
Inhalation:	Dust is mildly irritating to the nose, throat and lungs, resulting in coughing and sneezing. Pre-existing upper respiratory and lung diseases including asthma and bronchitis may be aggravated

Ingestion: Unlikely to occur under normal conditions of use. Swallowing of dust may cause abdominal discomfort.

Chronic Potential Health Effects:

Eyes: Dust may cause irritation and inflammation of the eyes and aggravate pre-existing eye conditions.

Skin: Repeated heavy contact with dust may cause drying of the skin and can result in a rash (irritant contact dermatitis) typically affecting the hands. Over time this may become chronic and can also become infected.

Inhaled: Repeated exposure to dust may result in increased nasal and respiratory secretions and coughing. High level exposures can increase the risk of bronchitis and pneumonia. Repeated inhalation of dust containing crystalline silica may result in an irreversible pulmonary fibrosis (scarring of the lung) termed silicosis, including acute or accelerated silicosis.

12.0 ECOLOGICAL INFORMATION

Ecotoxicity: Non-toxic to aquatic and terrestrial organisms.

Persistence and Degradability: Persistent and non-degradable.

Mobility: Low mobility of chemical constituents are expected.

13.0 DISPOSAL CONSIDERATIONS

Dispose in compliance with applicable regulations (GN R. 636 of 2013).

Suitable for disposal on licensed Class C / G:L:B+ landfill sites.

14.0 TRANSPORT INFORMATION

SANS 10228 classification: None – not classified as dangerous for transport

15.0 REGULATORY INFORMATION

Classification: Not classified as hazardous. However, consideration of the following risk & safety phrases is recommended:

Hazard Statements (SANS 10234):

- H320 May cause eye irritation (dust)
- H335 May cause respiratory irritation (dust)
- H350 May cause cancer (long-term inhalation of respirable dust)

Precautionary statement:

- P261 Avoid breathing dust
- P262 Do not get in eyes, on skin or on clothing
- P281 Use personal protective equipment as required

National legislation: Waste Classification and Management Regulations (GN R.634 of 23 August 2013)

National Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R.635 of 23 August 2013)

SANS 10228:2010 The identification and classification of dangerous goods for transport (Edition 5)

SANS 10234- A List of classification and labelling of chemicals in accordance with the Globally Harmonized System (GHS)

National Road Traffic Act (Act 93 of 1996)

16.0 OTHER INFORMATION

The data in this SDS relates only to the specific material designated herein and does not relate to use in combination with other materials and in any process. Rustenburg Chrome Mine assumes no responsibility for any physical or chemical changes, which the Buyer/User may make to the material designated in this SDS. Since use of this SDS information and the opinions and conditions of the use of the product are not within the control of Rustenburg Chrome Mine, the Buyer/User is obliged to determine the conditions of safe use of the product.

APPENDIX E

CALCULATIONS

CHANNEL	CATCHMENT AREA NAME	CATCHMENT AREA SIZE (m^2)	LONGEST WATERCOURSE LENGTH (m)	50-yr FLOOD PEAK (m^3/s)	MAX VELOCITY (m/S)	CHANNEL DEPTH (m)	FLOW TYPE AT MAX FLOW VELOCITY
Dirty Water Channel 1	C1 + C2 + C3 + C4	88 938	670	0,94	2,36	0,70	Supercritical flow
Dirty Water Channel 2	C1	50 105	420	0,99	2,35	0,70	Supercritical flow
Dirty Water Channel 3A	C2 + C3 + C4	38 833	600	0,82	2,20	0,60	Supercritical flow
Dirty Water Channel 3B	C4	3 773	420	0,09	1,31	0,40	Supercritical flow
Dirty Water Channel 4	C3	12 050	330	0,26	1,71	0,50	Supercritical flow
Dirty Water Channel 5	C1	50 105	425	1,16	2,65	0,70	Supercritical flow

Rational Method

Description of catchment				C1 + C2 + C3 + C4				
River Detail				Dirty Water Channel 1				
Calculated by				MLR	**Date**	26/03/2025		
Physical characteristics								
Size of catchment (A)	0,088938	km^2						
Longest watercourse (L)	0,67	km						
Average slope (Sav)	0,000364179	m/m	569,5					
Height at 0.85 of length (H0.85L)	0,915	m	67					
Height at 0.1 of length (H0.1L)	0,732	m	**Area distribution factors**					
Dolomite area (D%)	0	%	Rural (α)	Urban (β)	Lakes (γ)			
			100	0	0			
Rural				**Urban**				
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**	
Vleis and pans	0	0,05	0	**Lawns**				
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0	
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0	
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0	
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0	
Permiability	**%**	**Factor**	**Cp**	**Residential areas**				
Very permiable	5	0,05	0,0025	Houses	0	0,5	0	
Permeable	50	0,1	0,05	Flats	0	0,7	0	
Semi-permiable	40	0,2	0,08	**Industry**				
Impermeable	5	0,3	0,015	Light industry	0	0,8	0	
Total	100	-	0,1475	Heavy industry	0	0,9	0	
Vegetation	**%**	**Factor**	**Cv**	**Business**				
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0	
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0	
Grasslands	0	0,25	0	Streets	0	0,95	0	
No vegetation	100	0,3	0,3	Maximum flood	0	1	0	
Total	100	-	0,3	**Total (C_2)**	0	-	0	
Time of concentration (Tc)				Notes:	t=Tc*60			
Overland flow		Define watercourse						
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$		$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$						
hous		1,03	hours	61,63643004				
Run-off coefficient								
Retun period (years), T			**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 (= Cs + Cp + Cv)			0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}			0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)			0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} (=C_{10} x Ft)			0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT	$(=\alpha C_{1T} + \beta C_2 + \gamma C_3)$		0,47		0,53		0,52	0,6225	0,6225
Rainfall									
Retun period (years), T			**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)			33,78		56,10		76,01	84,46	0,00
Point rainfall (mm/hr)			32,89		54,61		73,99	82,2	0,0
Peak flow (m^3/s)	$Qt = \frac{Ct\,It\,A}{3.6}$		0,38		0,71		0,94	1,3	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,94	m3/s		Slope 1	1,5
Channel width	1	m	Flat		
Slope	0,00615	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,281541746	m	Solve with Manning equation		
Right side of mannings equation	0,011322338				
Freeboard	0,3	m			
Channel depth	0,581541746	m	1		
Velocity	2,358644843	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,616267311		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,94	m3/s		Slope 1	1,5
Channel width	1	m	Steep		
Slope	0,01000	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,246065524	m	Solve with Manning equation		
Right side of mannings equation	0,011308275				
Freeboard	0,3	m			
Channel depth	0,546065524	m	1		
Velocity	2,803593318	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	2,03323351		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Colour coding

**Designer must choose*
**Spreadsheet calculates*
**Value from input sheet*
**Value calculated in other sheets*
** Final answer*
** Use Goal Seek*

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

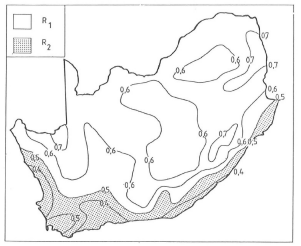
*Drainage manual, 6th edition, chapter 3

Table 3.7: Recommended values of run-off factor C for use in the Rational method

Rural (C_1)					Urban (C_2)	
		Mean annual rainfall (mm)				
Component	Classification	< 600	600 - 900	> 900	Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30		
					Industry	
					- Light industry	0,50 – 0,80
					- Heavy industry	0,60 – 0,90
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05		
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	**R1**	**R2**
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

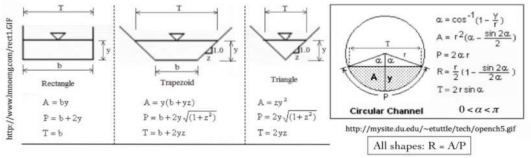


1,03	want
1	first
2	second
0,6	firstcor
0,72	seccor
0,603	x

A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Rational Method

Description of catchment				C1				
River Detail				Dirty Water Channel 2				
Calculated by				MLR	**Date**	26/03/2025		
Physical characteristics								
Size of catchment (A)		0,050105	km^2					
Longest watercourse (L)		0,42	km					
Average slope (Sav)		0,002533333	m/m	357				
Height at 0.85 of length (H0.85L)		1,04	m	42				
Height at 0.1 of length (H0.1L)		0,242	m	**Area distribution factors**				
Dolomite area (D%)		0	%	Rural (α)	Urban (β)	Lakes (γ)		
				100	0	0		
Rural				**Urban**				
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**	
Vleis and pans	0	0,05	0	**Lawns**				
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0	
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0	
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0	
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0	
Permiability	**%**	**Factor**	**Cp**	**Residential areas**				
Very permiable	5	0,05	0,0025	Houses	0	0,5	0	
Permeable	50	0,1	0,05	Flats	0	0,7	0	
Semi-permiable	40	0,2	0,08	**Industry**				
Impermeable	5	0,3	0,015	Light industry	0	0,8	0	
Total	100	-	0,1475	Heavy industry	0	0,9	0	
Vegetation	**%**	**Factor**	**Cv**	**Business**				
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0	
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0	
Grasslands	0	0,25	0	Streets	0	0,95	0	
No vegetation	100	0,3	0,3	Maximum flood	0	1	0	
Total	100	-	0,3	**Total (C_2)**	0	-	0	
Time of concentration (Tc)				Notes:	t=Tc*60			
Overland flow		Define watercourse						
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$		$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$						
hous		0,34	hours	20,38668283				

Run-off coefficient

Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_t (= Cs + Cp + Cv)	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)	0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} (=C_{10} x Ft)	0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT ($=\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0,47		0,53		0,52	0,6225	0,6225

Rainfall

Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)	20,74		34,44		46,65	51,84	0,00
Point rainfall (mm/hr)	61,03		101,35		137,31	152,6	0,0
Peak flow (m^3/s) $Qt = \frac{Ct\,It\,A}{3.6}$	0,40		0,75		0,99	1,3	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,99	m3/s		Slope	1	1,5
Channel width	1	m	Flat		
Slope	0,00500	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,292508026	m	Solve with Manning equation		
Right side of mannings equation	0,010472271				
Freeboard	0,3	m			
Channel depth	0,592508026	m	1		
Velocity	2,346225248	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,582211653		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,99	m3/s		Slope	1	1,5
Channel width	1	m	Steep		
Slope	0,01000	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,251666063	m	Solve with Manning equation		
Right side of mannings equation	0,011265136				
Freeboard	0,3	m			
Channel depth	0,551666063	m	1		
Velocity	2,8482656	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	2,046097519		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Colour coding

**Designer must choose*
****Spreadsheet calculates***
**Value from input sheet*
**Value calculated in other sheets*
**** Final answer***
**** Use Goal Seek***

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

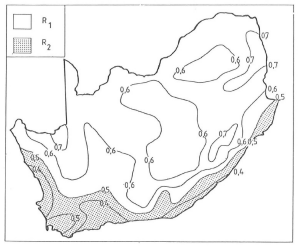
*Drainage manual, 6th edition, chapter 3

Table 3.7: Recommended values of run-off factor C for use in the Rational method

Rural (C_1)					Urban (C_2)	
		Mean annual rainfall (mm)				
Component	Classification	< 600	600 - 900	> 900	Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30		
					Industry	
					- Light industry	0,50 – 0,80
					- Heavy industry	0,60 – 0,90
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05		
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	R1	R2
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

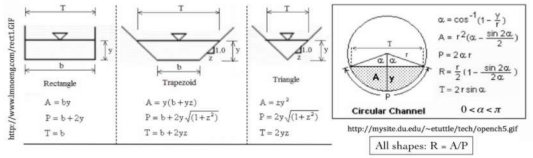


0,34	want
0,25	first
0,5	second
0,32	firstcor
0,46	seccor
0,370	x

A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an example of open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Rational Method

Description of catchment				C2 + C3 + C4				
River Detail				Dirty Water Channel 3A				
Calculated by			MLR	**Date**	26/03/2025			
Physical characteristics								
Size of catchment (A)		0,038833	km²					
Longest watercourse (L)		0,6	km					
Average slope (Sav)		0,007484444	m/m	510				
Height at 0.85 of length (H0.85L)		3,481	m	60				
Height at 0.1 of length (H0.1L)		0,113	m	**Area distribution factors**				
Dolomite area (D%)		0	%	Rural (α)	Urban (β)	Lakes (γ)		
				100	0	0		
Rural				**Urban**				
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**	
Vleis and pans	0	0,05	0	**Lawns**				
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0	
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0	
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0	
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0	
Permiability	**%**	**Factor**	**Cp**	**Residential areas**				
Very permiable	5	0,05	0,0025	Houses	0	0,5	0	
Permeable	50	0,1	0,05	Flats	0	0,7	0	
Semi-permiable	40	0,2	0,08	**Industry**				
Impermeable	5	0,3	0,015	Light industry	0	0,8	0	
Total	100	-	0,1475	Heavy industry	0	0,9	0	
Vegetation	**%**	**Factor**	**Cv**	**Business**				
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0	
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0	
Grasslands	0	0,25	0	Streets	0	0,95	0	
No vegetation	100	0,3	0,3	Maximum flood	0	1	0	
Total	100	-	0,3	**Total (C_2)**	0	-	0	
Time of concentration (Tc)				Notes:	t=Tc*60			
Overland flow		Define watercourse						
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$		$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$						
hous		0,29	hours	17,68036357				

Run-off coefficient							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 (= Cs + Cp + Cv)	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)	0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} ($=C_{10}$ x Ft)	0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT ($=\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0,47		0,53		0,52	0,6225	0,6225
Rainfall							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)	19,32		32,09		43,47	48,30	0,00
Point rainfall (mm/hr)	65,57		108,89		147,53	163,9	0,0
Peak flow (m^3/s) $Qt = \frac{Ct\,It\,A}{3.6}$	0,33		0,62		0,82	1,1	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,82	m3/s		Slope 1	1,5
Channel width	1	m	Flat		
Slope	0,00556	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,266732964	m	Solve with Manning equation		
Right side of mannings equation	0,011203279				
Freeboard	0,3	m			
Channel depth	0,566732964	m	1		
Velocity	2,201664142	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,543330798		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,82	m3/s		Slope 1	1,5
Channel width	1	m	Steep		
Slope	0,01667	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,194269529	m	Solve with Manning equation		
Right side of mannings equation	0,010998671				
Freeboard	0,3	m			
Channel depth	0,494269529	m	1		
Velocity	3,277326674	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	2,628245755		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Colour coding

**Designer must choose*
****Spreadsheet calculates***
**Value from input sheet*
**Value calculated in other sheets*
**** Final answer***
**** Use Goal Seek***

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

*Drainage manual, 6th edition, chapter 3

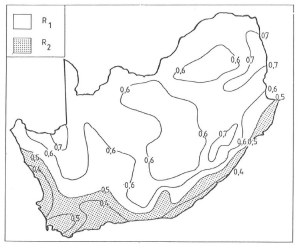
Table 3.7: Recommended values of run-off factor C for use in the Rational method

Rural (C_1)					Urban (C_2)	
Component	Classification	Mean annual rainfall (mm) < 600	600 - 900	> 900	Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30	*Industry*	
					- Light industry	0,50 – 0,80
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05	- Heavy industry	0,60 – 0,90
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
	Grasslands	0,17	0,21	0,25	- City centre	0,70 – 0,95
	No vegetation	0,26	0,28	0,30	- Suburban	0,50 – 0,70
					- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	**R1**	**R2**
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

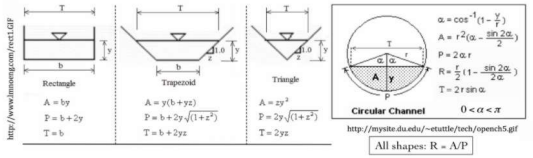
0,29	want
0,25	first
0,5	second
0,32	firstcor
0,46	seccor
0,345	x



A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an example of open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Rational Method

Description of catchment				C4			
River Detail				Dirty Water Channel 3B			
Calculated by			MLR	**Date**	26/03/2025		
Physical characteristics							
Size of catchment (A)	0,003773	km^2					
Longest watercourse (L)	0,42	km					
Average slope (Sav)	0,014742857	m/m	357				
Height at 0.85 of length (H0.85L)	5,06	m	42				
Height at 0.1 of length (H0.1L)	0,416	m	**Area distribution factors**				
Dolomite area (D%)	0	%	Rural (α)	Urban (β)	Lakes (γ)		
			100	0	0		

Rural				**Urban**			
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**
Vleis and pans	0	0,05	0	**Lawns**			
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0
Permiability	**%**	**Factor**	**Cp**	**Residential areas**			
Very permiable	5	0,05	0,0025	Houses	0	0,5	0
Permeable	50	0,1	0,05	Flats	0	0,7	0
Semi-permiable	40	0,2	0,08	**Industry**			
Impermeable	5	0,3	0,015	Light industry	0	0,8	0
Total	100	-	0,1475	Heavy industry	0	0,9	0
Vegetation	**%**	**Factor**	**Cv**	**Business**			
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0
Grasslands	0	0,25	0	Streets	0	0,95	0
No vegetation	100	0,3	0,3	Maximum flood	0	1	0
Total	100	-	0,3	**Total (C_2)**	0	-	0

Time of concentration (Tc)			Notes:	t=Tc*60
Overland flow		Define watercourse		
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$		$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$		
hous		0,25 hours	15	

Run-off coefficient							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 (= Cs + Cp + Cv)	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)	0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} (=C_{10} x Ft)	0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT ($=\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0,47		0,53		0,52	0,6225	0,6225
Rainfall							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)	17,92		29,76		40,32	44,80	0,00
Point rainfall (mm/hr)	71,68		119,04		161,28	179,2	0,0
Peak flow (m^3/s) $Qt = \frac{Ct\ It\ A}{3.6}$	0,04		0,07		0,09	0,1	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,09	m3/s		Slope	1	1,5
Channel width	1	m	Flat			
Slope	0,01000	m/m				
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek			Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011					
flow depth (yn)	0,060970146	m	Solve with Manning equation			
Right side of mannings equation	0,01096032					
Freeboard	0,3	m				
Channel depth	0,360970146	m	1			
Velocity	1,312378509	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE			
Froude	1,766602983		Supercritical flow			>1 => Supercritical flow
						<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,09	m3/s		Slope	1	1,5
Channel width	1	m	Steep			
Slope	0,03333	m/m				
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek			Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011					
flow depth (yn)	0,044484481	m	Solve with Manning equation			
Right side of mannings equation	0,011774895					
Freeboard	0,3	m				
Channel depth	0,344484481	m	1			
Velocity	1,840435333	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE			
Froude	2,8718189		Supercritical flow			>1 => Supercritical flow
						<1=> Subcritical flow

Colour coding

**Designer must choose*
****Spreadsheet calculates***
**Value from input sheet*
**Value calculated in other sheets*
**** Final answer***
**** Use Goal Seek***

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

*Drainage manual, 6th edition, chapter 3

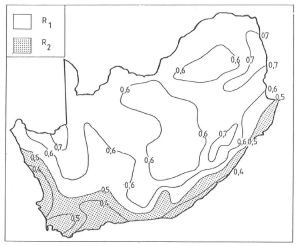
Table 3.7: Recommended values of run-off factor C for use in the Rational method

Rural (C_1)					Urban (C_2)	
		Mean annual rainfall (mm)				
Component	Classification	< 600	600 - 900	> 900	Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30		
					Industry	
					- Light industry	0,50 – 0,80
					- Heavy industry	0,60 – 0,90
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05		
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
	Grasslands	0,17	0,21	0,25	- City centre	0,70 – 0,95
	No vegetation	0,26	0,28	0,30	- Suburban	0,50 – 0,70
					- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	**R1**	**R2**
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

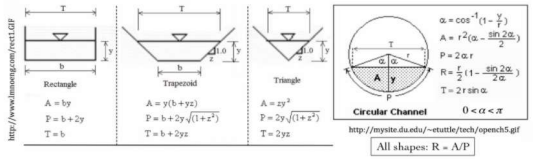
0,25	want
0,25	first
0,5	second
0,32	firstcor
0,46	seccor
0,320	x



A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an example of open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Rational Method

Description of catchment				C3				
River Detail				Dirty Water Channel 4				
Calculated by				MLR	Date	26/03/2025		
Physical characteristics								
Size of catchment (A)		0,01205	km^2					
Longest watercourse (L)		0,33	km					
Average slope (Sav)		0,002690909	m/m	280,5				
Height at 0.85 of length (H0.85L)		0,858	m	33				
Height at 0.1 of length (H0.1L)		0,192	m	**Area distribution factors**				
Dolomite area (D%)		0	%	Rural (α)	Urban (β)	Lakes (γ)		
				100	0	0		
Rural				**Urban**				
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**	
Vleis and pans	0	0,05	0	**Lawns**				
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0	
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0	
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0	
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0	
Permiability	**%**	**Factor**	**Cp**	**Residential areas**				
Very permiable	5	0,05	0,0025	Houses	0	0,5	0	
Permeable	50	0,1	0,05	Flats	0	0,7	0	
Semi-permiable	40	0,2	0,08	**Industry**				
Impermeable	5	0,3	0,015	Light industry	0	0,8	0	
Total	100	-	0,1475	Heavy industry	0	0,9	0	
Vegetation	**%**	**Factor**	**Cv**	**Business**				
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0	
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0	
Grasslands	0	0,25	0	Streets	0	0,95	0	
No vegetation	100	0,3	0,3	Maximum flood	0	1	0	
Total	100	-	0,3	**Total (C_2)**	0	-	0	
Time of concentration (Tc)				Notes:	t=Tc*60			
Overland flow		Define watercourse						
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$		$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$						
hous		0,28	hours	16,54286674				

Run-off coefficient							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 (= Cs + Cp + Cv)	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)	0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} ($=C_{10}$ x Ft)	0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT ($=\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0,47		0,53		0,52	0,6225	0,6225
Rainfall							
Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)	18,73		31,10		42,13	46,82	0,00
Point rainfall (mm/hr)	67,92		112,79		152,82	169,8	0,0
Peak flow (m^3/s) $Qt = \frac{Ct\,It\,A}{3.6}$	0,11		0,20		0,26	0,4	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,26	m3/s		Slope 1	1,5
Channel width	1	m	Flat		
Slope	0,00741	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,129422842	m	Solve with Manning equation		
Right side of mannings equation	0,011228232				
Freeboard	0,3	m			
Channel depth	0,429422842	m	1		
Velocity	1,710075604	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,63638504		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	0,26	m3/s		Slope 1	1,5
Channel width	1	m	Steep		
Slope	0,01000	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,117772796	m	Solve with Manning equation		
Right side of mannings equation	0,011090322				
Freeboard	0,3	m			
Channel depth	0,417772796	m	1		
Velocity	1,907145059	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,902836074		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Colour coding

**Designer must choose*
****Spreadsheet calculates***
**Value from input sheet*
**Value calculated in other sheets*
**** Final answer***
**** Use Goal Seek***

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

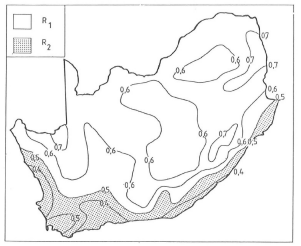
*Drainage manual, 6th edition, chapter 3

Table 3.7: Recommended values of run-off factor C for use in the Rational method

Component	Classification	Rural (C_1) Mean annual rainfall (mm) < 600	600 - 900	> 900	Urban (C_2) Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30	*Industry*	
					- Light industry	0,50 – 0,80
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05	- Heavy industry	0,60 – 0,90
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
	Grasslands	0,17	0,21	0,25	- City centre	0,70 – 0,95
	No vegetation	0,26	0,28	0,30	- Suburban	0,50 – 0,70
					- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	**R1**	**R2**
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

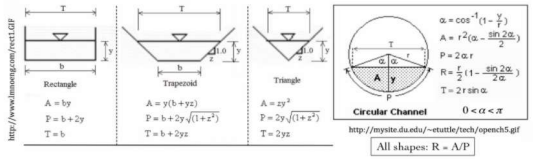


0,28	want
0,25	first
0,5	second
0,32	firstcor
0,46	seccor
0,334	x

A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an example of open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Rational Method

Description of catchment		C1	
River Detail		Dirty Water Channel 5	
Calculated by	MLR	**Date**	26/03/2025

Physical characteristics

Size of catchment (A)	0,050105	km²		
Longest watercourse (L)	0,425	km		
Average slope (Sav)	0,008367059	m/m	361,25	
Height at 0.85 of length (H0.85L)	2,889	m	42,5	
Height at 0.1 of length (H0.1L)	0,222	m		
Dolomite area (D%)	0	%	**Area distribution factors**	
			Rural (α)	Urban (β)	Lakes (γ)
			100	0	0

Rural				**Urban**			
Surface slope	**%**	**Factor (T3.7)**	**Cs**	**Desciption**	**%**	**Factor (T3.7)**	**C_2**
Vleis and pans	0	0,05	0	**Lawns**			
Flat areas	50	0,11	0,055	Sandy, flat (<2%)	0	0,1	0
Hilly	30	0,2	0,06	Sandy, steep (>7%)	0	0,2	0
Steep areas	20	0,3	0,06	Heavy soil, flat (<2%)	0	0,17	0
Total	100	-	0,175	Heavy soil, steep (>7%)	0	0,35	0
Permiability	**%**	**Factor**	**Cp**	**Residential areas**			
Very permiable	5	0,05	0,0025	Houses	0	0,5	0
Permeable	50	0,1	0,05	Flats	0	0,7	0
Semi-permiable	40	0,2	0,08	**Industry**			
Impermeable	5	0,3	0,015	Light industry	0	0,8	0
Total	100	-	0,1475	Heavy industry	0	0,9	0
Vegetation	**%**	**Factor**	**Cv**	**Business**			
Thick bush and plantation	0	0,05	0	City centre	0	0,7	0
Light bush and farm-lands	0	0,15	0	Suburban	0	0,7	0
Grasslands	0	0,25	0	Streets	0	0,95	0
No vegetation	100	0,3	0,3	Maximum flood	0	1	0
Total	100	-	0,3	**Total (C_2)**	0	-	0

Time of concentration (Tc)

Overland flow	Define watercourse	Notes:	t=Tc*60
$Tc = 0.604\left(\frac{rL}{\sqrt{Sav}}\right)^{0.467}$	$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385}$		
hous	0,25 hours	15	

Run-off coefficient

Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 (= Cs + Cp + Cv)	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted for dolomite aeas , C_{10}	0,6225		0,6225		0,6225	0,6225	0,6225
Adjusted factor for initial saturation, Ft (T3.8)	0,75		0,85		0,83	1	1
Adjusted run-off coefficient, C_{1T} (=C_{10} x Ft)	0,47		0,53		0,52	0,6225	0,6225
Combined run-off coefficient, CT (=$\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0,47		0,53		0,52	0,6225	0,6225

Rainfall

Retun period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point rainfall (mm) (mm rain falling in Tc)	17,92		29,76		40,32	44,80	0,00
Point rainfall (mm/hr)	71,68		119,04		161,28	179,2	0,0
Peak flow (m^3/s) $Qt = \frac{Ct\,It\,A}{3.6}$	0,47		0,88		1,16	1,6	0,0

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	1,16	m3/s	Slope	1	1,5
Channel width	1	m	Flat		
Slope	0,00769	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,301449473	m	Solve with Manning equation		
Right side of mannings equation	0,011687114				
Freeboard	0,3	m			
Channel depth	0,601449473	m	1		
Velocity	2,649374062	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,76427125		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	1,16	m3/s	Slope	1	1,5
Channel width	1	m	Steep		
Slope	0,01000	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,279812946	m	Solve with Manning equation		
Right side of mannings equation	0,011626206				
Freeboard	0,3	m			
Channel depth	0,579812946	m	1		
Velocity	2,919484692	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	2,005761134		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Using - TRAPEZOIDAL CHANNEL

Checking flow depth, channel depth, flow velocity and Froude				V	H
Q	1,16	m3/s	Slope	1	1,5
Channel width	1	m	Flat		
Slope	0,00862	m/m			
			Use goal seek to solve yn with mannings equation. Follow steps below to use goal seek		Mannings n for smooth HDPE 0,009-0,015
Manning (left side)	0,011				
flow depth (yn)	0,283176257	m	Solve with Manning equation		
Right side of mannings equation	0,011032717				
Freeboard	0,3	m			
Channel depth	0,583176257	m	1		
Velocity	2,874594834	m/s	If velocity is > 2m/s, channel needs to be lined with HDPE		
Froude	1,96504608		Supercritical flow		>1 => Supercritical flow
					<1=> Subcritical flow

Colour coding

**Designer must choose*
****Spreadsheet calculates***
**value from input sheet*
**Value calculated in other sheets*
**** Final answer***
**** Use Goal Seek***

Notes

*Sheet calculates Channel 1 peak flow
* Rational method alternative 2 is used

References

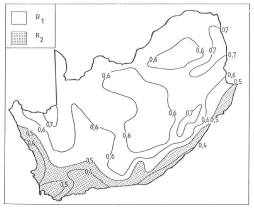
*Drainage manual, 6th edition, chapter 3

Table 3.7: Recommended values of run-off factor C for use in the Rational method

Rural (C_1)					Urban (C_2)	
		Mean annual rainfall (mm)				
Component	Classification	< 600	600 - 900	> 900	Use	Factor
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30		
					Industry	
					- Light industry	0,50 – 0,80
					- Heavy industry	0,60 – 0,90
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05		
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**
Ft - steep and impermeable	0,75	0,8	0,85	0,9	0,95	1
Ft - flat and permeable	0,5	0,55	0,6	0,67	0,83	1

Tc	**R1**	**R2**
0,10	0,17	0,14
0,25	0,32	0,23
0,50	0,46	0,32
1,00	0,60	0,41
2,00	0,72	0,53
3,00	0,78	0,60
4,00	0,82	0,67
5,00	0,84	0,71
6,00	0,87	0,75
8,00	0,90	0,81
10,00	0,92	0,85
12,00	0,94	0,89
18,00	0,98	0,96
24,00	1,00	1,00

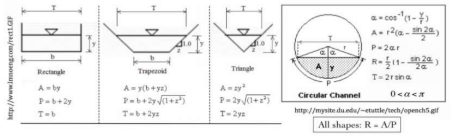


0,25	want
0,25	first
0,5	second
0,32	firstcor
0,46	seccor
0,320	x

A graphical summary of open-channel cross-section geometry is provided below.

(a) Show that the formulas for Area (A), Wetted Perimeter (P), and Top Width (T) for a trapezoid collapse to those for a rectangle as z approaches 0. This helps to explain why the formulation z:1 or 1:z is used for side slope rather than the more familiar rise-over-run that we typically use for slopes.

(b) A circular pipe that is not flowing full is an example of open-channel or free-surface flow. Calculate the hydraulic radius for a circular section with radius 0.5 m at depths 0.25 m, 0.5 m, and 0.75 m.



The Manning equation may be used.

$$Q = \frac{1}{n}\frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{S}$$

Using Broad crested weir in Hydraflow (Analyze - Design tab - Launch Express)

	Flow (100 year peak)	
	Inflow (m^3/s)	
Dirty Water Channel max flow	2,6	m^3/s in 100 year flood

Broad crested weir:

Qideal = 1.705bH^(3/2)		
Qideal	2,6	m^3/s in 100 year flood
b	1,028807061	
H	1,3	Height of Spillway
Q	2,6	m^3/s

Spillway designed to have an minimum 800mm freeboard.

Description	100-YR FLOOD PEAK (m^3/s)	SPILLWAY WIDTH (m)
DAM SPILLWAY	2,6	1

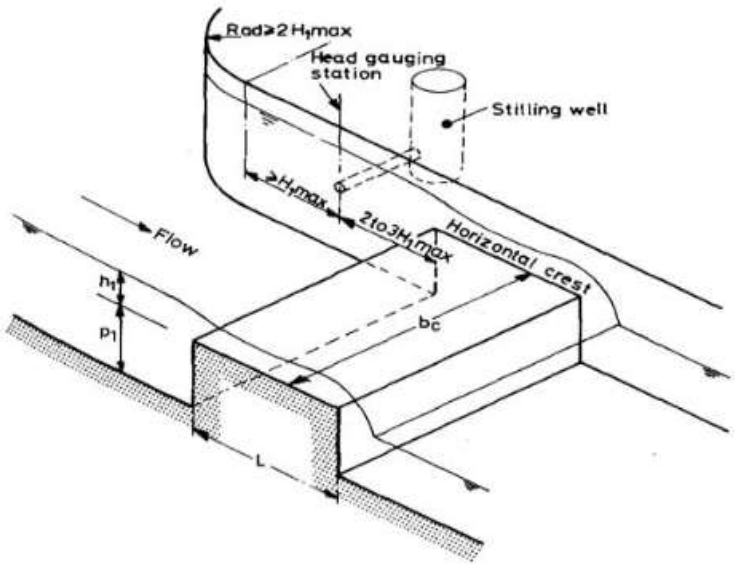


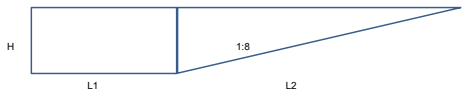
Figure 4.12 Broad-crested rectangular profile weir (after BSI 1969)

Kinematic viscosity (m2/s)	0,001	Assumed
Particle density (kg/m3)	1100	Assumed
Water density (kg/m3)	1000	

	Stokes law						Length of basin for material to settle
Particle size (mm)	Settlement velocity (m/s)	Settlement velocity (m/Hr)	Min required detention time (s)	Required total volume (m3)	L1 (m)	L1+L2 Effective required length (m)	Reference
0,050	0,0001	0,49	1467,89	1144,95	55,36	67,76	25,00
0,100	0,0005	1,96	366,97	286,24	9,19	21,59	25,00
0,150	0,0012	4,41	163,10	127,22	0,64	13,04	25,00
0,200	0,0022	7,85	91,74	71,56	-2,35	10,05	25,00
0,250	0,0034	12,26	58,72	45,80	-3,74	8,66	25,00
0,300	0,0049	17,66	40,77	31,80	-4,49	7,91	25,00

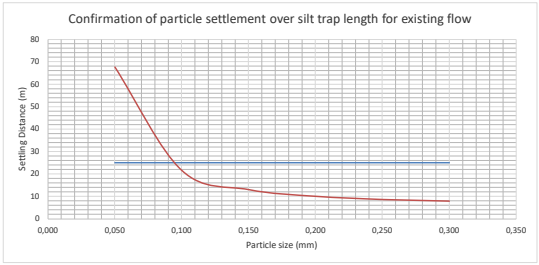
Effective settling depth (m) 0,2 Only needs to settle to below weir

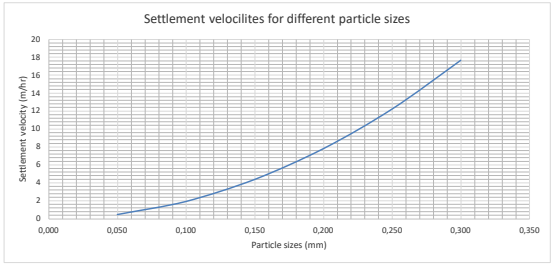
Q1:2	0,78	m3/s
Q1:50	1,94	m3/s



Vol of ST = (WxHxL1) + (0.5 x L2 x H x W)

W	12	m
H	1,55	m
L2	12,4	m
L1	?	m
Vol=	286	m3





Kindsvarter -Carter Formule

Overflow height for spillway

H=(Q/(Ce*2/3*(2*9.81)^0.5*L))^(1/1.5)

Q	0,78	Flow
Ce	0,602	Entrainment Coeficient

L	3	4	5	6	7	8	9	10	11	12	13	14
H	0,278	0,229	0,197	0,175	0,158	0,144	0,133	0,124	0,117	0,110	0,104	0,099

L	Wier Length
H	Overflow Height

Stokes Law - settlement dam

Assume Laminar Flow

Viscosity	0,001	kg/m/s	Assume
Radius of particle size	0,0002	m	Supe fine
Density of particle	3500	kg/m³	
Density of fluid	1000	kg/m³	
g	9,81	m/s	
Terminal velocity	0,0545	m/s	Assume terminal velocity will be reached instentaniously

Time to settle 1 meter 18,34862 seconds

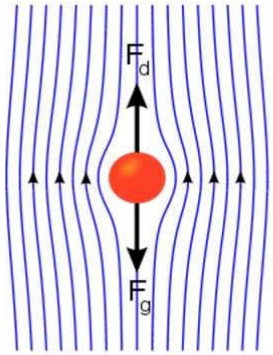
Stokes Law

- Drag force $F_d = 6\pi\eta\, ru$

  η = viscosity

- Force of gravity

$$F_g = \frac{4}{3}\pi r^3 (\rho_s - \rho_f) g$$



Source:
http://www.answers.com/topic/stokes-law

RIETFONTEIN SWMP - RECTANGULAR CULVERTS DESIGN				
Culvert Name	**Channel Associated with Culvert**	**Culvert Width (m)**	**Culvert Heigth (m)**	**Culvert Length (m)**
Culvert 1	Dirty Water Channel 1	0,75	0,75	10
Culvert 2	Dirty Water Channel 2	0,75	0,75	10
Culvert 3	Dirty Water Channel 3A	0,75	0,6	10
Culvert 4	Dirty Water Channel 3A	0,75	0,6	10
Culvert 5	Dirty Water Channel 4	0,75	0,45	10
Culvert 6	Dirty Water Channel 5	0,75	0,75	10
Culvert 7	Dirty Water Channel 5	0,75	0,75	10

RIETFONTEIN SWMP - RECTANGULAR CULVERTS WINGWALL UNITS					
Culvert Name	**Culvert Width (m)**	**Culvert Heigth (m)**	**Wingwall Units for Portal Culverts Sections**		
			Code	**Series / Size**	**Mass (Kg)**
Culvert 1	0,75	0,75	S2	675-900	2100
Culvert 2	0,75	0,75	S2	675-900	2100
Culvert 3	0,75	0,6	D1	300-600	1130
Culvert 4	0,75	0,6	D1	300-600	1130
Culvert 5	0,75	0,45	D1	300-600	1130
Culvert 6	0,75	0,75	S2	675-900	2100
Culvert 7	0,75	0,75	S2	675-900	2100

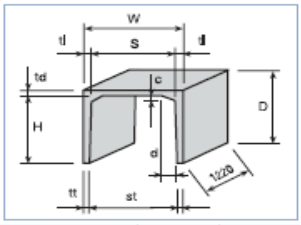
SATS SAR Rectangular Portals

(Rail Application Stormwater Culvert) - Class 1 Loading

Notes:

1. These culverts are available from a limited number of factories only. Please enquire about their availability from your nearest Rocla sales office.
2. These culverts are designed to meet the requirements of SATS class 1 loading, where "Z" is the effective fill height above the culverts.

NB: For lifting hole arrangements see page 9.



Nominal Size S x H	Z	W	D	St	td	tl	tt	r	Water Way area	Approx. Mass per unit
mm x mm	m	mm	mm	mm	mm	mm	mm	mm	m²	kg/unit
600 x 450	0 - 5	800	570	630	120	100	85	50/100	0.28	580
600	0 - 5	800	720	640	120	100	80	50/100	0.37	658
750 x 450	0 - 5	950	600	780	150	100	85	50/100	0.34	726
600	0 - 5	950	750	790	150	100	80	50/100	0.46	804
750	0 - 5	950	900	800	150	100	75	50/100	0.58	877
900 x 450	0 - 5	1100	570	930	120	100	85	50/100	0.41	696
600	0 - 5	1100	730	940	130	100	80	50/100	0.55	809
600	0 - 15	1100	790	990	190	100	80	50/100	0.57	998
750	0 - 5	1100	900	950	150	100	75	50/100	0.69	948
900	0 - 5	1100	1030	960	130	100	70	50/100	0.84	951
1200 x 450	0 - 5	1440	610	1240	160	120	100	50/100	0.55	1059
600	0 - 7.5	1440	760	1240	160	120	100	50/100	0.73	1171
1200	0 - 7.5	1440	1360	1280	160	120	80	50/100	1.49	1505
1500 x 600	0 - 5	1750	755	1540	155	125	105	75/225	1.14	1341
750	0 - 5	1750	905	1550	155	125	100	75/225	1.14	1438
900	0 - 5	1750	1055	1560	155	125	95	75/225	1.38	1540
1000	0 - 5	1860	1175	1566	175	180	147	150	1.53	2085
1000	5 - 10	1860	1225	1566	225	180	147	150	1.53	2380
1200	0 - 5	1860	1355	1580	155	180	140	75/225	1.85	1710
1500	0 - 5	1860	1675	1600	175	180	130	150	2.33	2520
1500	5 - 10	1860	1725	1600	225	180	130	150	2.33	2815
1800 x 600	0 - 5	2100	750	1800	150	150	120	100/300	1.62	1614
900	0 - 5	2100	1070	1880	170	140	100	100/300	2.21	1859
2000 x 1000	0 - 5	2420	1225	2066	225	210	177	200	2.03	2985
1000	5 - 10	2420	1275	2066	275	210	177	200	2.03	3385
1500	0 - 5	2420	1725	2100	225	210	160	200	3.08	3490
1500	5 - 10	2420	1775	2100	275	210	160	200	3.08	3875
1800	0 - 5	2420	2025	2120	225	210	150	200	3.45	4528
1800	5 - 10	2420	2075	2120	275	210	150	200	4.16	4896
2000	0 - 5	2420	2225	2134	225	210	143	200	4.13	3979
2000	5 - 10	2420	2275	2134	275	210	143	200	4.13	4350
2500 x 1500	0 - 5	2960	1725	2600	225	230	180	250	3.83	4120
1500	5 - 10	2960	1825	2600	325	230	180	250	3.83	5050
2000	0 - 5	2960	2225	2632	225	230	164	250	5.13	4660
2000	5 - 10	2960	2325	2632	325	230	164	250	5.13	5595
2500	0 - 5	2960	2725	2666	225	230	147	250	6.46	5150
2500	5 - 10	2960	2825	2666	325	230	147	250	6.46	6080
3000 x 1000	0 - 5	3570	1275	3128	275	285	252	300	3.06	4956
1000	5 - 10	3570	1375	3128	375	285	252	300	3.06	6081
1500	0 - 5	3570	1795	3096	275	285	237	300	4.63	5677
1500	5 - 10	3570	1875	3096	375	285	237	300	4.57	6802
2000	0 - 5	3570	2275	3130	275	285	220	300	6.09	6395
2000	5 - 10	3570	2375	3130	375	285	220	300	6.09	7520
2500	0 - 5	3570	2775	3166	275	285	202	300	7.66	7045
2500	5 - 10	3570	2875	3166	375	285	202	300	7.66	8170
3000	0 - 5	3570	3275	3200	275	285	185	300	9.26	7649
3000	5 - 10	3570	3375	3200	375	285	185	300	9.26	8775

Special SAR Culverts

Culvert Size S x H	Dimensions Z	W	D	St	td	tl	tt	c	d	e	f
3600 x 2100	0 - 7	4200	2500	3740	400	300	230	SAR Adjustabe Moulds			668
2400	0 - 15		2800	3760			220				755
750 x 2500	0 - 15		2900	3766			217	300	600	2300	784
3000	0 - 5		3400	3800			200				930

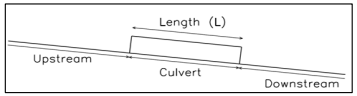
Please note: Mass is an approximation only. Rocla cannot guarantee the exact mass as listed on this table.

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 1	**DESIGNER / DATE:**	17/04/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 1	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	0,94	
Upstream velocity	v_1	(m/s)	2,36	
Upstream flow depth	y_{n1}	(m)	0,28	
Maximum available Head	H_{max}	(m)	0,7	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,28	
Downstream velocity	v_2	(m/s)	2,36	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

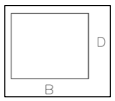


INLET CONTROL

Min Energy Head required	H_1	(m)	0,564

SIZING OF CULVERT

Culvert height	D	(m)	0,75	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,8	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,674	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,674	
Velocity in culvert	v	(m/s)	1,198	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,110	
Friction coefficient	λ	-	0,025	
Friction losses	h_f	(m)	0,025	
Downstream Energy level	H_2	(m)	0,464	

Min Energy Head required	H_1	(m)	0,60

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$ = average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control [7.2]

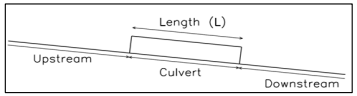
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For : **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** * *For $H_1/D > 1,2$, the orifice formulae applies* $Q = C_D A\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **$H_1/D > 1,2$** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 2	**DESIGNER / DATE:**	17/04/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 2	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	0,99	
Upstream velocity	v_1	(m/s)	2,35	
Upstream flow depth	y_{n1}	(m)	0,29	
Maximum available Head	H_{max}	(m)	0,7	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,29	
Downstream velocity	v_2	(m/s)	2,35	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

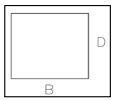


INLET CONTROL

Min Energy Head required	H_1	(m)	0,571

SIZING OF CULVERT

Culvert height	D	(m)	0,75	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,8	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,674	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,674	
Velocity in culvert	v	(m/s)	1,198	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,110	
Friction coefficient	λ	-	0,025	
Friction losses	h_f	(m)	0,025	
Downstream Energy level	H_2	(m)	0,471	

Min Energy Head required	H_1	(m)	0,61

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$ = average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control [7.2]

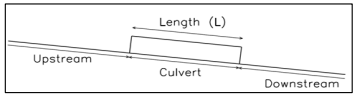
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For: **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** * *For $H_1/D > 1,2$, the orifice formulae applies* $Q = C_D A\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **$H_1/D > 1,2$** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 3A	**DESIGNER / DATE:**	17/04/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 3	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	0,82	
Upstream velocity	v_1	(m/s)	2,20	
Upstream flow depth	y_{n1}	(m)	0,27	
Maximum available Head	H_{max}	(m)	0,6	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,266	
Downstream velocity	v_2	(m/s)	2,2	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

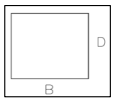


INLET CONTROL

Min Energy Head required	H_1	(m)	0,513

SIZING OF CULVERT

Culvert height	D	(m)	0,6	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,9	



H
S

Flow Rates if:

0 < H/D <= 1.2	Table 7.2			
Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,535	
H_1/D > 1.2	Table 7.2			
Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	
No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,535	
Velocity in culvert	v	(m/s)	1,189	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,108	
Friction coefficient	λ	-	0,027	
Friction losses	h_f	(m)	0,032	
Downstream Energy level	H_2	(m)	0,413	
Min Energy Head required	H_1	(m)	0,55	

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$ = average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control [7.2]

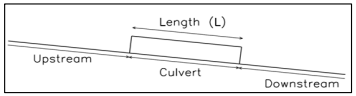
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For : **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** * *For $H_1/D > 1,2$, the orifice formulae applies* $Q = C_D A\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **$H_1/D > 1,2$** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 3A	**DESIGNER / DATE:**	02/05/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 4	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	0,82	
Upstream velocity	v_1	(m/s)	2,20	
Upstream flow depth	y_{n1}	(m)	0,27	
Maximum available Head	H_{max}	(m)	0,6	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,266	
Downstream velocity	v_2	(m/s)	2,2	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

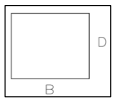


INLET CONTROL

Min Energy Head required	H_1	(m)	0,513

SIZING OF CULVERT

Culvert height	D	(m)	0,6	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,9	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,535	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,535	
Velocity in culvert	v	(m/s)	1,189	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,108	
Friction coefficient	λ	-	0,027	
Friction losses	h_f	(m)	0,032	
Downstream Energy level	H_2	(m)	0,413	

Min Energy Head required	H_1	(m)	0,55

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$= average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_2^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control (7.2)

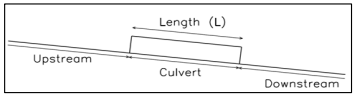
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For : **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** ** For H_1/D > 1,2, the orifice formulae applies* $Q = C_D A_1\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **H_1/D > 1,2** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 4	**DESIGNER / DATE:**	02/05/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 5	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	0,26	
Upstream velocity	v_1	(m/s)	1,71	
Upstream flow depth	y_{n1}	(m)	0,13	
Maximum available Head	H_{max}	(m)	0,50	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,13	
Downstream velocity	v_2	(m/s)	1,71	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

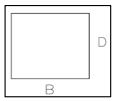


INLET CONTROL

Min Energy Head required	H_1	(m)	0,279

SIZING OF CULVERT

Culvert height	D	(m)	0,45	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,6	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,407	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,407	
Velocity in culvert	v	(m/s)	1,206	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,111	
Friction coefficient	λ	-	0,029	
Friction losses	h_f	(m)	0,048	
Downstream Energy level	H_2	(m)	0,179	
Min Energy Head required	H_1	(m)	0,34	

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$= average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_2^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control (7.2)

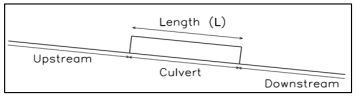
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For: **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity)	And for: **$H_1/D > 1,2$** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets
Note: ** For $H_1/D > 1,2$, the orifice formulae applies* $Q = C_D A_1\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 5	**DESIGNER / DATE:**	02/05/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 6	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	1,16	
Upstream velocity	v_1	(m/s)	2,87	
Upstream flow depth	y_{n1}	(m)	0,28	
Maximum available Head	H_{max}	(m)	0,7	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,28	
Downstream velocity	v_2	(m/s)	2,87	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

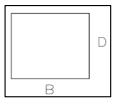


INLET CONTROL

Min Energy Head required	H_1	(m)	0,700

SIZING OF CULVERT

Culvert height	D	(m)	0,75	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,9	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,674	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,674	
Velocity in culvert	v	(m/s)	1,198	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,110	
Friction coefficient	λ	-	0,025	
Friction losses	h_f	(m)	0,025	
Downstream Energy level	H_2	(m)	0,600	

Min Energy Head required	H_1	(m)	0,73

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description	Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$= average velocity in conduit)	Protruding	0,9
	Oblique	0,7
	Blunt	0,5
	Well-rounded	0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden	1,0
	Cone 45° < θ < 180°	1,0
	θ = 30°	0,7
	θ = 15°	0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden	0,5
	Cone	0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°	0,4
	θ = 45°	0,3
Outlets $h_1 = \frac{k\bar{V}_2^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden	1,0

Table 7.2

Table 7.2: Relationships for the flow rate under inlet control (7.2)

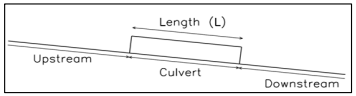
ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For: **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** ** For H_1/D > 1,2, the orifice formulae applies* $Q = C_D A_1\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **H_1/D > 1,2** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

PROJECT NAME:	Rietfontein SWMP	**RIVER/CANAL NAME:**	Dirty Water Channel 5	**DESIGNER / DATE:**	02/05/2025
PROJECT NUMBER:	284	**CULVERT NAME:**	Culvert 7	**SUPERVISOR / DATE:**	

RECTANGULAR CULVERT DESIGN

Required flow rate	Q	(m^3/s)	1,16	
Upstream velocity	v_1	(m/s)	2,90	
Upstream flow depth	y_{n1}	(m)	0,28	
Maximum available Head	H_{max}	(m)	0,7	
Slope through culvert	S_0	(m/m)	0,01	Note 1
Roughness of culvert	k_s	(m)	0,002	
Downstream flow depth	y_{n2}	(m)	0,28	
Downstream velocity	v_2	(m/s)	2,90	
Culvert length	L	(m)	10	

Assume: gravity (g) 9,81

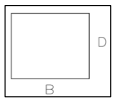


INLET CONTROL

Min Energy Head required	H_1	(m)	0,709

SIZING OF CULVERT

Culvert height	D	(m)	0,75	Note 2
Culvert width	B	(m)	0,75	Note 2
H/D ratio	H/D	-	0,9	



H
S

Flow Rates if:

0 < H/D <= 1.2 Table 7.2

Coefficient	C_B	-	0,9	Note 3
Flow rate	Q	(m^3/s)	0,674	

H_1/D > 1.2 Table 7.2

Coefficient	C_h		0,6	Note 4
Flow rate	Q	(m^3/s)	N/A	

No of culverts required	No	-	1	Determine if practical

OUTLET CONTROL

Flow rate per culvert	Q	(m^3/s)	0,674	
Velocity in culvert	v	(m/s)	1,198	Note 1
Transition losses (Inlet)	K_{inlet}	-	0,5	Table 4.8
Transition losses (Outlet)	K_{outlet}	-	1,0	Table 4.8
Secondary losses	h_l	(m)	0,110	
Friction coefficient	λ	-	0,025	
Friction losses	h_f	(m)	0,025	
Downstream Energy level	H_2	(m)	0,609	

Min Energy Head required	H_1	(m)	0,74

OUTLET CONTROL

Note 1 To achieve this, the flow velocities through culverts should, not be less than 1 m/s, and the slope of a culvert should accordingly not be less than about 1%. Where the stream returns to a natural watercourse, its erosive capacity should not be significantly higher than under the original conditions. If necessary, the velocity of flow should be reduced by means of energy dissipaters.

Note 2 The minimum acceptable recommended practical size for a culvert up to 30 m long is 600 mm in diameter or a rectangular section of 750 mm (wide) x 450 mm (high), and for a culvert longer than 30 m a minimum diameter of 900 mm or a rectangular section of 900 mm (wide) x 450 mm (high) should be considered with the aim of being able to conduct maintenance.

Note 3 Where: C_B = 1,0 for rounded inlets (r > 0,1B)
C_B = 0,9 for square inlets

Note 4 Where: C_h = 0,8 for rounded inlets
C_h = 0,6 for square inlets

Table 4.8

Table 4.8: Transition losses in pipe flows

Description		Sketch	k-value
Inlets $h_1 = \frac{k\bar{V}^2}{2g}$ ($\bar{V}$= average velocity in conduit)	Protruding		0,9
	Oblique		0,7
	Blunt		0,5
	Well-rounded		0,2
Diverging sections $h_1 = \frac{k(\bar{v}_1 - \bar{v}_2)^2}{2g}$	Sudden		1,0
	Cone 45° < θ < 180°		1,0
	θ = 30°		0,7
	θ = 15°		0,2
Converging sections $h_1 = \frac{k\bar{V}^2}{2g}$	Sudden		0,5
	Cone		0,25
Bends $h_1 = \frac{k\bar{V}_2^2}{2g}$	θ = 90°		0,4
	θ = 45°		0,3
Outlets $h_1 = \frac{k\bar{V}_2^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$	Sudden		1,0

Table 7.2

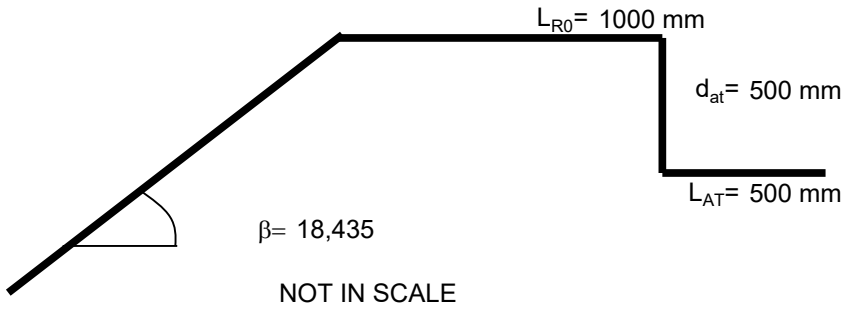
Table 7.2: Relationships for the flow rate under inlet control (7.2)

ROUND CULVERTS	RECTANGULAR CULVERTS
D = inside diameter (m)	D = height (inside) (m) B = width (inside) (m)
For: **$0 < H_1/D < 0,8$** $\frac{Q}{D^2\sqrt{gD}} = 0,48\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,9}$	For: **$0 < H_1/D \leq 1,2$** $Q = \frac{2}{3}C_B B H_1\sqrt{\frac{2}{3}gH_1}$ Where: C_B = 1,0 for rounded inlets (r > 0,1B) C_B = 0,9 for square inlets
And for: **$0,8 < H_1/D \leq 1,2$** * $\frac{Q}{D^2\sqrt{gD}} = 0,44\left[\frac{S_0}{0,4}\right]^{0,05}\left[\frac{H_1}{D}\right]^{1,5}$ (S_0 = slope of culvert bed with slight effect on capacity) ***Note:*** ** For $H_1/D > 1,2$, the orifice formulae applies* $Q = C_D A_1\sqrt{2g\left(H_1 - \frac{D}{2}\right)}$ *with* $C_D \approx 0,6$	And for: **$H_1/D > 1,2$** $Q = C_h BD\sqrt{2g(H_1 - C_h D)}$ Where: C_h = 0,8 for rounded inlets C_h = 0,6 for square inlets

DESIGN INFORMATION			
SYMBOL	VALUE	UNIT	DESCRIPTION
β	18,435	°	side slope angle (tan-1(H/B))
d_{cs}	0	m	thickness covering soil
γ_{soil}	25	kn/m^3	weight of soil
d_{at}	0,5	m	trench depth
L_{R0}	1	m	length of geosynthetic runout
L_{AT}	0,5	m	length of geosynthetic inside the trench
ϕ_{soil}	34	°	trench soil friction angle
δ_C	25	°	friction angle between thegeotextile and the underlying soil
δ_F	8	°	friction angle between thegeotextile and the HDPE
Tuts	1,0252	kN/m	Ultimate tensile strengh of thegeotextile
RF	1,5		Reduction factor ($RF=RF_{cr}xRF_{id}xRF_{env}xFS$)
Tall	0,00	kN/m	Allowable tensile strength

RESULTS			
SYMBOL	VALUE	UNIT	DESCRIPTION
$(F_{R0})_B$	0,00	KN/m	friction force beneath runout geosynthetics
$(F_{AT})_R$	0,19	KN/m	friction force between the right side of the geosynthetic and the side wall of anchor trench
$(F_{AT})_L$	0,64	KN/m	friction force between the left side of the geosynthetic and the side wall of ancho trench
$(F_{AB})_B$	2,91	KN/m	friction force between the right side of the geosynthetics and the underlying soil at the botton of anchor trench
$(F_{AB})_U$	0,88	KN/m	friction force between the right side of the geosynthetics and the overlying soil at the botton of anchor trench
T_{MAX}	8,88	KN/m	geosynthetic tensile force developed by the anchor trench

FoS	**8,66**



NOT IN SCALE

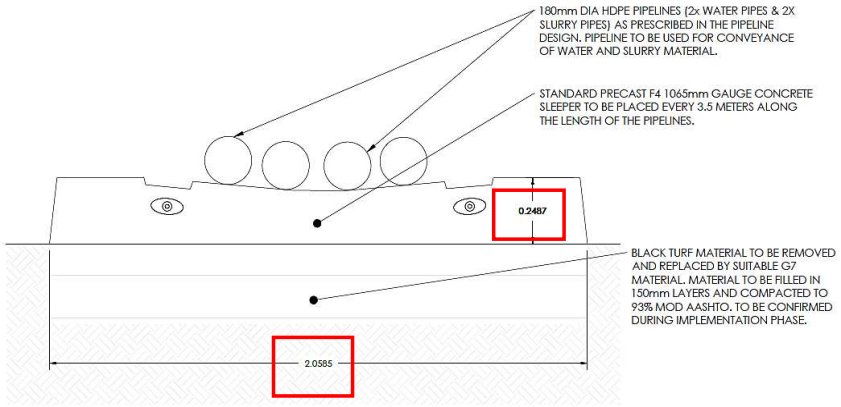
Distance between sleepers	3.5	m
Weight of water	1000	kg/m3
Weight of mud	1400	kg/m3
Weight of water pipeline (180mm OD HDPE SDR 11)	8.5	kg/m
Weight of mud pipeline (180mm OD HDPE SDR9)	10.167	kg/m
No of water lines	2	
No of mud lines	2	

Input	
Output	

Length of buffer zone	2250	m
Length of plinth footings zone	234	m
Total Sleepers needed	**576**	

Sleepers (All four pipes on one sleeper)

No of sleepers per point	1		
Sleep dimension L	2.057	m	
Sleep dimension W	0.254	m	
Sleeper Weight	2.32	pa	
Weight of sleeper/s	2.32	kpa	
Weight of 2 water lines	14.735	kPa	
Weight of 2 mud lines	20.50769	kPa	
Total weight on ground	71.89334	kPa/m2	
Bearing capacity	75	kPa	Sufficient



PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF ALL FOUR PIPES ARE PLACED ON ONE SLEEPER

1:10

Distance between sleepers	8.5	m
Weight of water	1000	kg/m3
Weight of mud	1400	kg/m3
Weight of water pipeline (180mm OD HDPE SDR 11)	8.5	kg/m
Weight of mud pipeline (180mm OD HDPE SDR9)	10.17	kg/m
No of water lines	2	
No of mud lines	0	

Input	
Output	

Length of buffer zone	2250	m
Length of plinth footings zone	234	m
Sleepers needed for two pipes	237	
Total Sleepers needed	**573**	

Sleepers (two water pipes per sleeper)

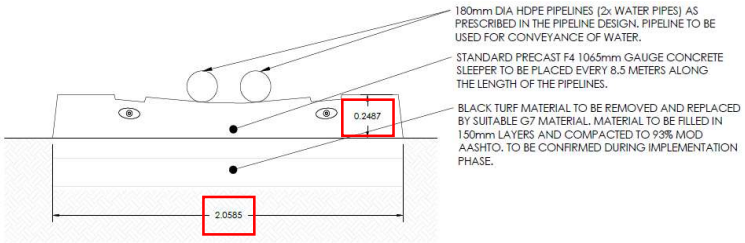
No of sleepers per point	1		
Sleep dimension L	2.057	m	
Sleep dimension W	0.254	m	
Sleeper Weight	2.32	pa	
Weight of sleeper/s	2.32	kpa	
Weight of 2 water lines	35.785	kPa	
Weight of 1 mud lines	0	kPa	
Total weight on ground	72.9313	kPa/m2	
Bearing capacity	75	kPa	Sufficient

Distance between sleepers	6	m
Weight of water	1000	kg/m3
Weight of mud	1400	kg/m3
Weight of water pipeline (180mm OD HDPE SDR 11)	8.5	kg/m
Weight of mud pipeline (180mm OD HDPE SDR9)	10.167	kg/m
No of water lines	0	
No of mud lines	2	

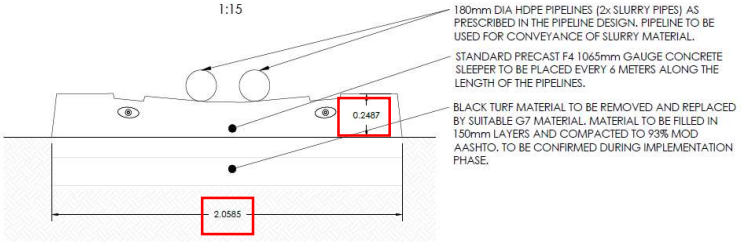
Length of buffer zone	2250	m
Length of plinth footings zone	234	m
Sleepers needed for two pipes	336	

Sleepers (two mud pipes per sleeper)

No of sleepers per point	1		
Sleep dimension L	2.057	m	
Sleep dimension W	0.254	m	
Sleeper Weight	2.32	pa	
Weight of sleeper/s	2.32	kpa	
Weight of water lines	0	kPa	
Weight of mud lines	35.15604	kPa	
Total weight on ground	71.7275	kPa/m2	
Bearing capacity	75	kPa	Sufficient



PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF WATER PIPES ARE PLACED ON ONE SLEEPER
1:15



PROPOSED DETAIL OF PIPE PLACEMENT WITHIN WETLAND BUFFER ZONES IF SLURRY PIPES ARE PLACED ON ONE SLEEPER
1:15

Distance between footings	4	m
Weight of water	1000	kg/m3
Weight of mud	1400	kg/m3
Weight of water pipeline (180mm OD HDPE SDR 11)	8.5	kg/m
Weight of mud pipeline (180mm OD HDPE SDR9)	10.167	kg/m
No of water lines	2	
No of mud lines	2	

Input
Output

Length of 100yr flood	70	m
Footings needed	18	

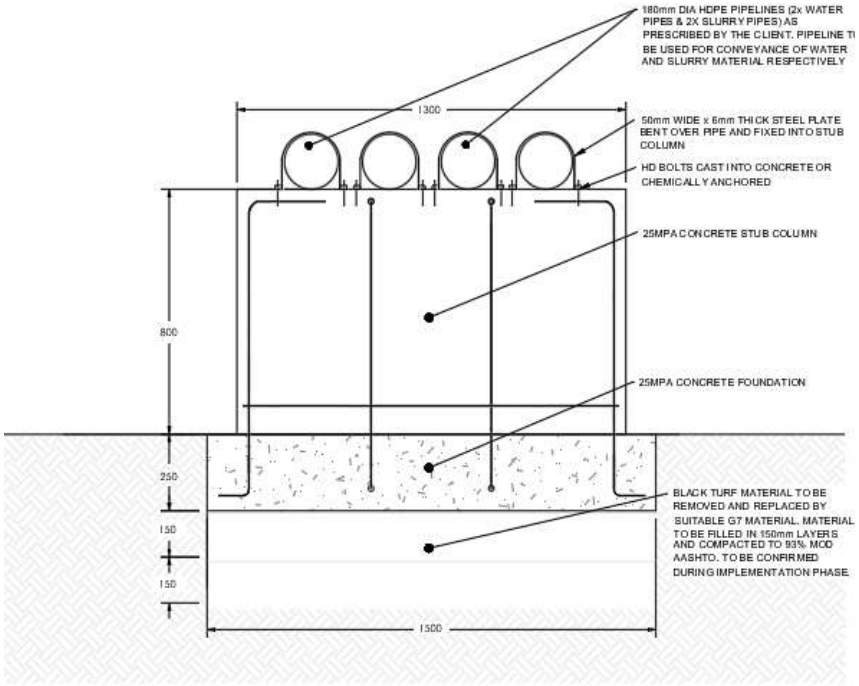
Footings within 100 year floodline (Intersection 1)

Cubes per stub column	0.21	m3
Height of stub column	0.80	m
Length of stub column	1.30	
Width of footing stub column	0.20	m
Area of stub column on ground	0.26	m2
Weight of stub column	499.20	kg/unit
Cubes per concrete foundation	0.19	m3
Height of concrete foundation	0.25	m
Length of concrete foundation	1.50	m
Width of concrete foundation	0.50	m
Area of concrete foundation on ground	0.75	m2
Weight of concrete foundation	450.00	kg/unit
Weight of stub column and foundation	949.20	kg/unit
Weight of stub column and foundation	12.41	kPa
Weight of 2 water lines	16.84	kPa
Weight of 2 mud lines	23.44	kPa
Total weight on ground	70.25	kPa/m2
Bearing capacity	75	kPa

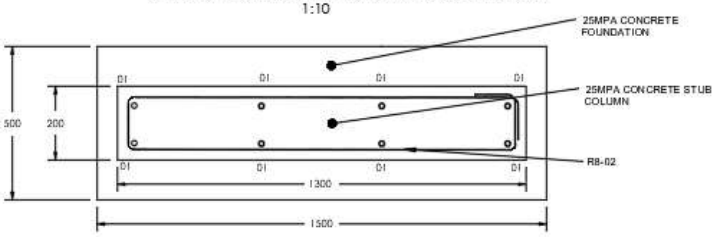
Sufficient

Conversion:

kg/cm2	kPa
1	98.0665
0.12656	12.4113



PROPOSED DETAIL OF PIPE PLACEMENT AT FLOODLINE INTERSECTION 1
@ 4m INTERVALS BETWEEN CHAINAGE 120-190m
1:10



PROPOSED PLAN VIEW OF PIPE PLACEMENT AT FLOODLINE
INTERSECTION 1 @ 4m INTERVALS BETWEEN CHAINAGE 120-190m

Distance between footings	4.5	m
Weight of water	1000	kg/m3
Weight of mud	1400	kg/m3
Weight of water pipeline (180mm OD HDPE SDR 11)	8.5	kg/m
Weight of mud pipeline (180mm OD HDPE SDR9)	10.167	kg/m
No of water lines	2	
No of mud lines	2	

Input
Output

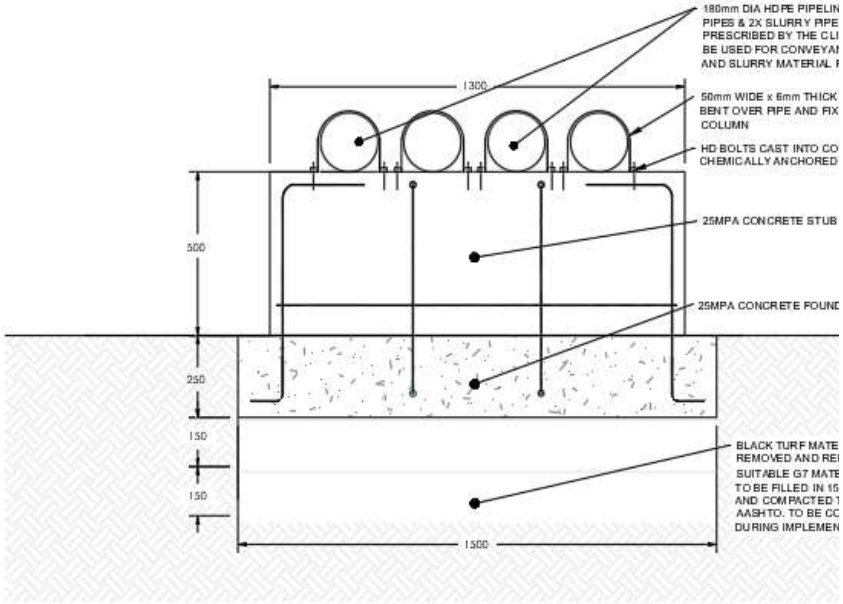
Length of 100yr flood	164	m
Footings needed	36	

Footings within 100 year floodline (Intersection 2)

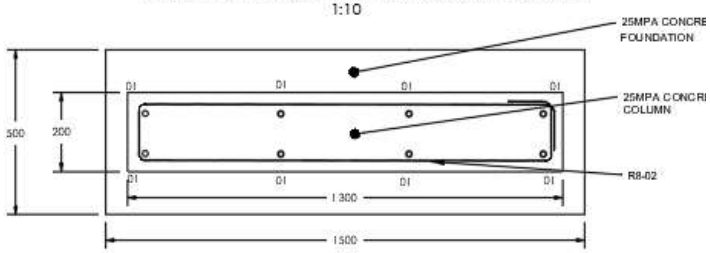
Cubes per stub column	0.13	m3
Height of stub column	0.50	m
Length of stub column	1.30	m
Width of footing stub column	0.20	m
Area of stub column on ground	0.26	m2
Weight of stub column	312.00	kg/unit
Cubes per concrete foundation	0.19	m3
Height of concrete foundation	0.25	m
Length of concrete foundation	1.50	m
Width of concrete foundation	0.50	m
Area of concrete foundation on ground	0.75	m2
Weight of concrete foundation	450.00	kg/unit
Weight of stub column and foundation	762.00	kg/unit
Weight of stub column and foundation	9.96	kPa
Weight of 2 water lines	18.95	kPa
Weight of 2 mud lines	26.37	kPa
Total weight on ground	73.70	kPa/m2
Bearing capacity	75	kPa Sufficient

Conversion:

kg/cm2	kPa
1	98.0665
0.1016	9.963556



PROPOSED DETAIL OF PIPE PLACEMENT AT FLOODLINE INTERSECTION 2
@ 4.5m INTERVALS BETWEEN CHAINAGE 138-302m
1:10



PROPOSED PLAN VIEW OF PIPE PLACEMENT AT FLOODLINE
INTERSECTION 2 @ 4.5m INTERVALSBETWEEN CHAINAGE 138-302m
1:10

APPENDIX F

PIPELINE DESIGN REPORT



RIETFONTEIN PUMP STATION

Design Report

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Table 3: Pump selection and design Stage 1 4
Table 4: Pump selection and design Stage 2 4
Table 5: Motor specifications Stage 1 5
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Overview

Stakeholders

- Clover Alloys- Rietfontein.
- Rustenburg Tailings and Mineral Recovery- RTMR.
- Clover Alloys- Rustenburg Chrome Mine- RCM

Project Background

Material from cyclone overflow at Rietfontein is used in the production of RTMR, a PGM facility located on RCM. This material is currently pumped into a concrete settling structure where the material is allowed to settle and dewater using screen panels. The dewatered material is then transported to RTMR using dump trucks where it is repulped for production. The current arrangement contributes to inefficient materials handling and increased production costs.

Project Objective

To minimize material handling and costs related to transport and repulping.

Proposed Solution

To construct a pump station where the material will be pumped directly from the cyclone overflow at Rietfontein to RTMR. The material will be pumped into an agitated tank which will pump to a thickener at RTMR. RTMR will recover the material, and the water will be returned to Rietfontein.

Refer to Appendix A for the process flow diagram (PFD).

Design Criteria

For design purposes, the pumping arrangement will be divided into two stages.

- Stage 1- Feed line
- Stage 2- Return Water Line

Requirements

Stage 1: Feed Line

Refer to Table 1 for the design requirements on Stage 1.

Design Requirements	
Material	Chrome tailings
SG	1.10
Flow Rates	140m^3/h
Distance	2800m
Elevation	20m
Max Particle Size	0.212mm

Table 1: Design requirements Stage 1

Stage 2: Return Water Line

Refer to Table 2 for the design requirements on Stage 2.

Design Requirements	
Material	Water
SG	1.00
Flow Rates	140m^3/h
Distance	2800m
Elevation	-20m

Table 2: Design requirements Stage 2

Pump Selection and Design

Stage 1: Feed Line

The pump selection and design for Stage 1 pumping was provided by an independent company with regards to the requirements submitted to them.

Their proposal and solution entailed the following, see Table 3.

Pump Selection and Design	
Pump Size	4/3
Number of pumps	4
Number of trains	2
Pumps per train	2
Pumping Configuration	Duty and standby
Pump Control	VSD/VFD (all 4 pumps)
Pipe Material	HDPE
Pipe Size	180mm OD (136.4mm ID)
Pipe Class	SDR9 (20 BAR)
Line Velocity	3.2m/s

Table 3: Pump selection and design Stage 1

Refer to Appendix B for the pump specification sheet.

Stage 2: Return Water Line

The pump selection and design for Stage 2 pumping was provided by an independent company with the design requirements submitted to them. The 8/6 pump was available for use on site.

Pump Selection and Design	
Pump Size	8/6
Number of pumps	1
Number of trains	1
Pumps per train	1
Pumping Configuration	Duty
Pump Control	DOL
Pipe Material	HDPE
Pipe Size	180mm OD (144.5mm ID)
Pipe Class	SDR11 (16 BAR)
Line Velocity	4m/s

Table 4: Pump selection and design Stage 2

Refer to Appendix C for the pump specification sheet and pump curve.

Electrical and Control Systems

Electrical

Stage 1: Feed Line

Stage 1 of the pumping will require all 4 pumps to be equipped with 55kw motors. Refer to Table 5 and Figure 1 for the motor specifications and the electrical control panel layout respectively.

Motors				
Make	KW	Voltage	RPM	Efficiency
AMG	55	380	2900	Ie3

Table 5: Motor specifications Stage 1

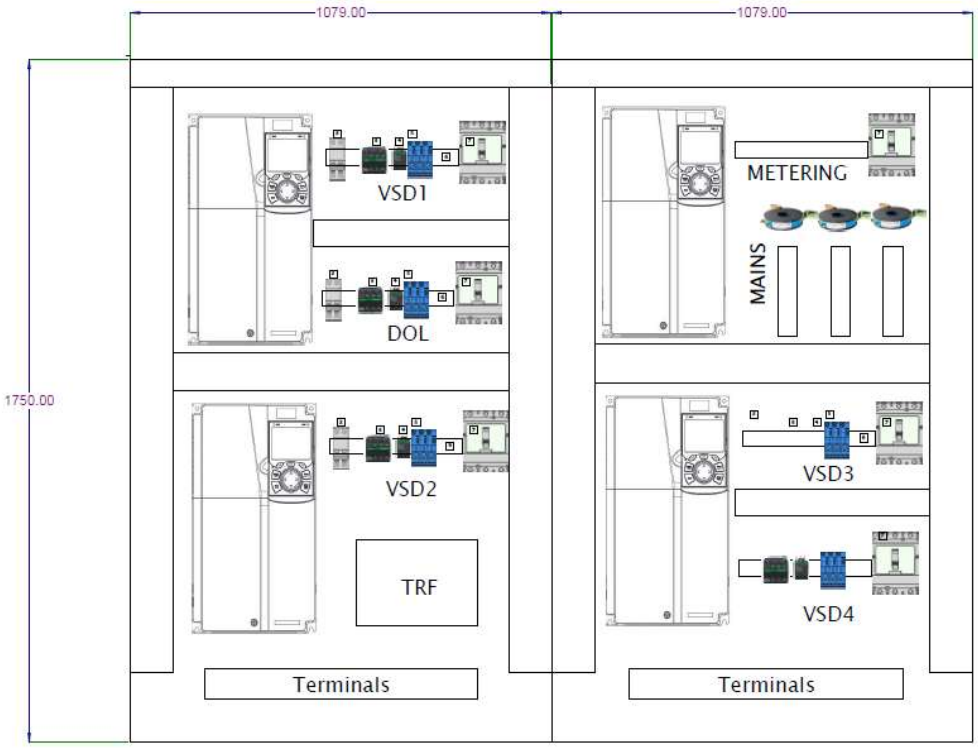


Figure 1: Electrical control panel design Stage 1

Stage 2: Return Water Line

Motors				
Make	KW	Voltage	RPM	Efficiency
Marathon	132	380	1485	Ie3

Table 6: Motor Specification Stage 2

Control

Stage 1: Feed Line

Stage will require all 4 pumps (duty and standby trains) to be equipped with VSD for pump speed control. Furthermore, a flowmeter will be installed on the feed line which will be totalized to account for the volume being pumped.

Initially, this system will be controlled manually, with the option of being automated.

Refer to Table and Appendix C for the control equipment specifications

Stage 2: Return Water Line

Stage 2 control will consist of a flowmeter installed in the return water line. As this pump will be running DOL the control will operate manually and as required. The flowmeter will be totalized to account for the volume of the return pumping.

Refer to Appendix C for the control equipment specifications

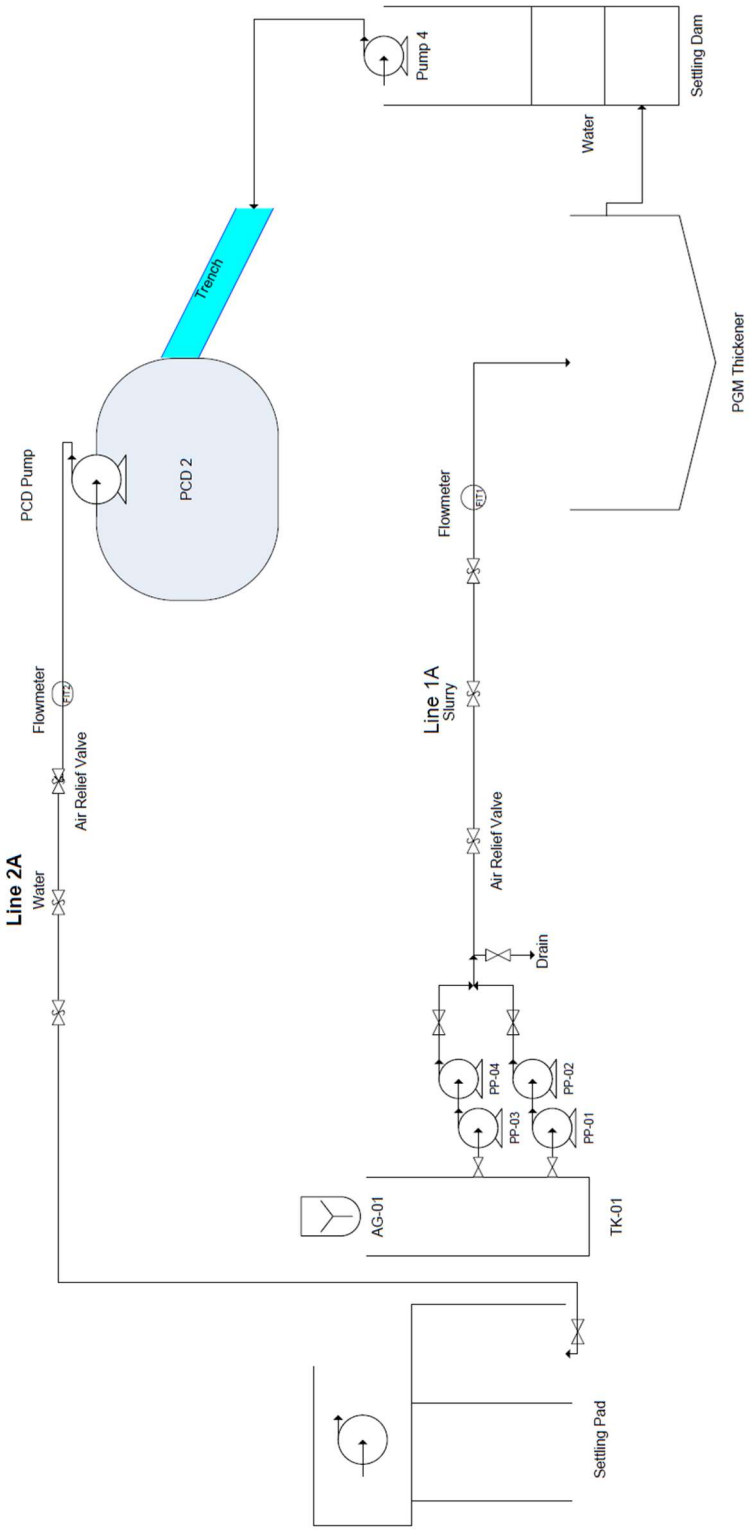
Structural and Civil Design

The structural and civil design will require the design and erection of a 50m^3 tank with a base and a bunded area.

Refer to Appendix E for Civils Design.

Appendices

Appendix A: PFD



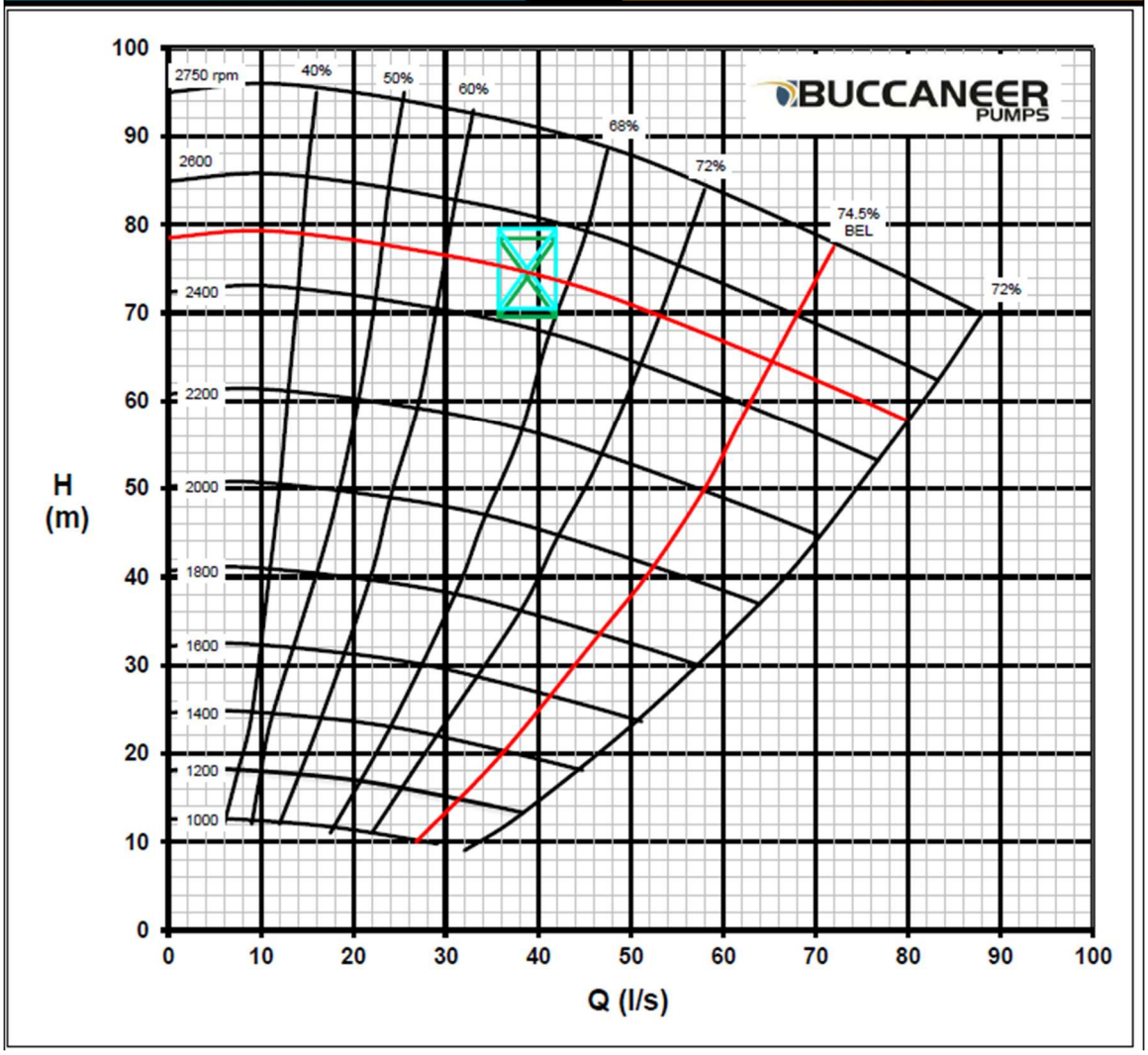
Appendix B: Pump Selection and Design Stage 1

Pump Selection

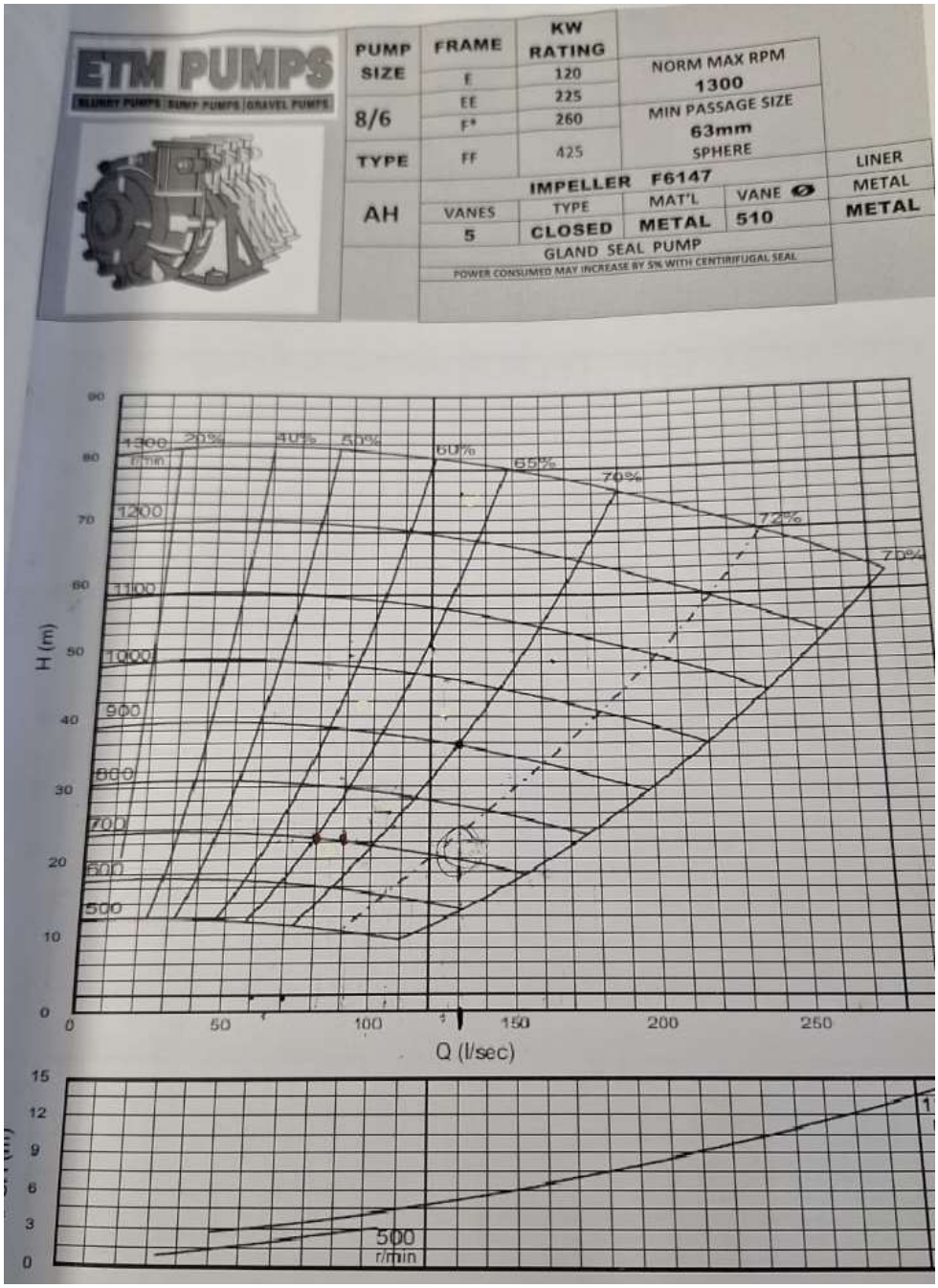
PUMP SELECTION DATA		
CUSTOMER	Mine Minerals	
PROJECT	Chrome Tailings	
DATE	28/01/2025	
Equipment Number	n/a	
Slurry Capacity	38,8	l/s
Slurry Capacity	140	m3/hr
Slurry Head per Stage	74	m
Water Head per Stage	75,0	m
Number of Stages	2	
Total Water Head	150	m
Pump Pressure	1666	kPa
Dry Density	3,01	g/lt
Carrying Media Density	1	g/lt
Slurry Density	1,10	g/lt
d50 Particle Size	0,106	mm
Max Particle Size	0,212	mm
% Conc wt/wt	13,04	%
% Conc vol/vol	4,75	%
pH	7,00	
Head De-Rate Factor	0,99	
Efficiency De-Rate Factor	0,99	
Water Efficiency	66	%
Slurry Efficiency	65,1	%
Pump Speed	2500	rpm
Water Absorbed power	46,76	kW
Slurry Absorbed power	47,41	79,1 % of Max Power
Proposed Safety Factor	1,16	
Power with Safety Factor	54,99	kW
Actual Safety Factor	1,160	
Impeller Peripheral Speed	34,0	m/s
Suction Size	100	mm
Suction Velocity	4,94	m/s
Discharge Size	80	mm
Discharge Velcoity	7,72	m/s
Motor Power	55	kW

Pump Curve

Typical Pump Performance Curve					HD80AM39-D-6VCM39-LFSTB-55kW@2500rpm			
					Date			2025/01/29
Pump Data			Bearing Data		Impeller Data			
Size	Type	Equivalent Size	Size	Max Power	Diameter	Type	No of Vanes	Max Solid/ Min passage width mm
80	A	4/3			260	Closed	6VC	
Shaft Sealing		LF Stuffing Box	D	60	Normal Max Speed (rpm)		2750	10 / 28
All curves are based on clear water tests to ISO2548 Class "C" with tolerances based on mass produced pumps								
Water Duty					Slurry Duty			



Appendix C: Pump Selection and Design Stage 2



Appendix D: Control Equipment Specifications

VSD/VFD

AD1000 Series
AC Variable Speed Drives

Motorelli
MOTORS · DRIVES · GEARBOXES

Technical Datasheet

3 Phase 380/400V 50/60Hz ***1.5~500kW***
3 Phase 525/550V 50/60Hz ***1.5~630kW***

- Torque Vector control
- Up to 150% starting torque
- HD rated for demanding applications
- Asynchronous & synchronous motor control
- Advanced LCD keypad (16 lines of text)
- Motor Auto-tune (static and dynamic)
- 2 motor parameter sets.

- DC Injection braking
- Flux braking
- Integral brake chopper (<37kW)
- Integral AC reactor (>220Kw)
- Integral DC reactor (18.5~110Kw)
- PID Control as standard
- Modbus RTU/RS485 built in
- PG Encoder control
- IP20 (all models)

- Wifi card
- Bluetooth card
- Profibus DP card
- CANopen card
- Profinet card.
- Multi I/O card

- 6 Digital Inputs
- 2 Analogue Inputs
- 1 Analogue Output
- 2 Relay Outputs
- 2 Digital Outputs

- Integral C3 filter
- Category C1 &C2 filter options
- CE & RCM Marked
- 2 Year warranty

CE TÜV SÜD RCM (AUS/NZ)



AD1000 Series
AC Variable Speed Drives
Technical Specifications
Three Phase 400V

Motorelli
MOTORS · DRIVES · GEARBOXES

Technical Datasheet

	Model	Rated Power kW	Carrier Frequency (kHz)	Input Current (A)	Output Current (A)	Contactor (A)	Fuse/ MCCB) (A)	Weight	Dimensions Width	Height	Depth	Frame Style
Three Phase 400V	AD1000-1.5G-4	1.5	8	5	3.7	10	17.4/16	2	126	186	184.4	1
	AD1000-2.2G-4	2.2	8	5.8	5	10	17.4/16	2	126	186	185	
	AD1000-4G-4	4	8	13.5	9.5	16	30/25	2.5	126	186	200.9	2
	AD1000-5.5G-4	5.5	8	19.5	14	16	45/25	2.5	126	186	200.9	
	AD1000-7.5G-4	7.5	8	25	18.5	25	60/40	3	146	256	191.9	3
	AD1000-11G-4	11	8	32	25	32	78/63	6	170	320	219.2	4
	AD1000-15G-4	15	4	40	32	50	105/63	6	170	320	219.2	
	AD1000-18.5G-4	18.5	4	47	38	63	114/100	8.5	200	340.6	207.2	5
	AD1000-22G-4	22	4	56	45	80	138/100	8.5	200	340.6	207.2	
	AD1000-30G-4	30	4	70	60	95	186/125	16	250	400	222.4	6
	AD1000-37G-4	37	4	80	75	120	228/160	16	250	400	222.4	
	AD1000-45G-4	45	4	94	92	135	270/200	25	282	560	257.1	7
	AD1000-55G-4	55	4	128	115	170	315/200	25	282	560	257.1	
	AD1000-75G-4	75	2	160	150	230	420/250	25	282	400	257.1	
	AD1000-90G-4	90	2	190	180	280	480/315	41	338	554	329.2	8
	AD1000-110G-4	110	2	225	215	315	630/400	41	338	554	329.2	
	AD1000-132G-4	132	2	265	260	380	720/400	85	500	870	360	9
	AD1000-160G-4	160	2	310	305	450	870/630	85	500	870	360	
	AD1000-185G-4	185	2	345	340	580	1110/630	85	500	870	360	
	AD1000-200G-4	200	2	385	380	580	1110/630	85	500	870	360	
	AD1000-220G-4	220	2	430	425	630	1230/800	135	680	960	379.5	10
	AD1000-250G-4	250	2	485	480	700	1380/800	135	680	960	379.5	
	AD1000-280G-4	280	2	545	530	780	1500/1000	135	680	960	379.5	
	AD1000-315G-4	315	2	610	600	900	1740/1200	135	680	960	379.5	
	AD1000-355G-4	355	2	625	650	960	1860/1280	350	620	1700	560	11
	AD1000-400G-4	400	2	715	720	1035	2010/1380	350	620	1700	560	
	AD1000-450G-4	450	2	840	820	1222	2445/1630	350	620	1700	560	
	AD1000-500G-4	500	2	890	860	1290	2505/1720	350	620	1700	560	

MSV INSTRUMENTATION AND SUPPLIES (PTY) LTD.

Calibration Certificate of Electromagnetic Flow Meter

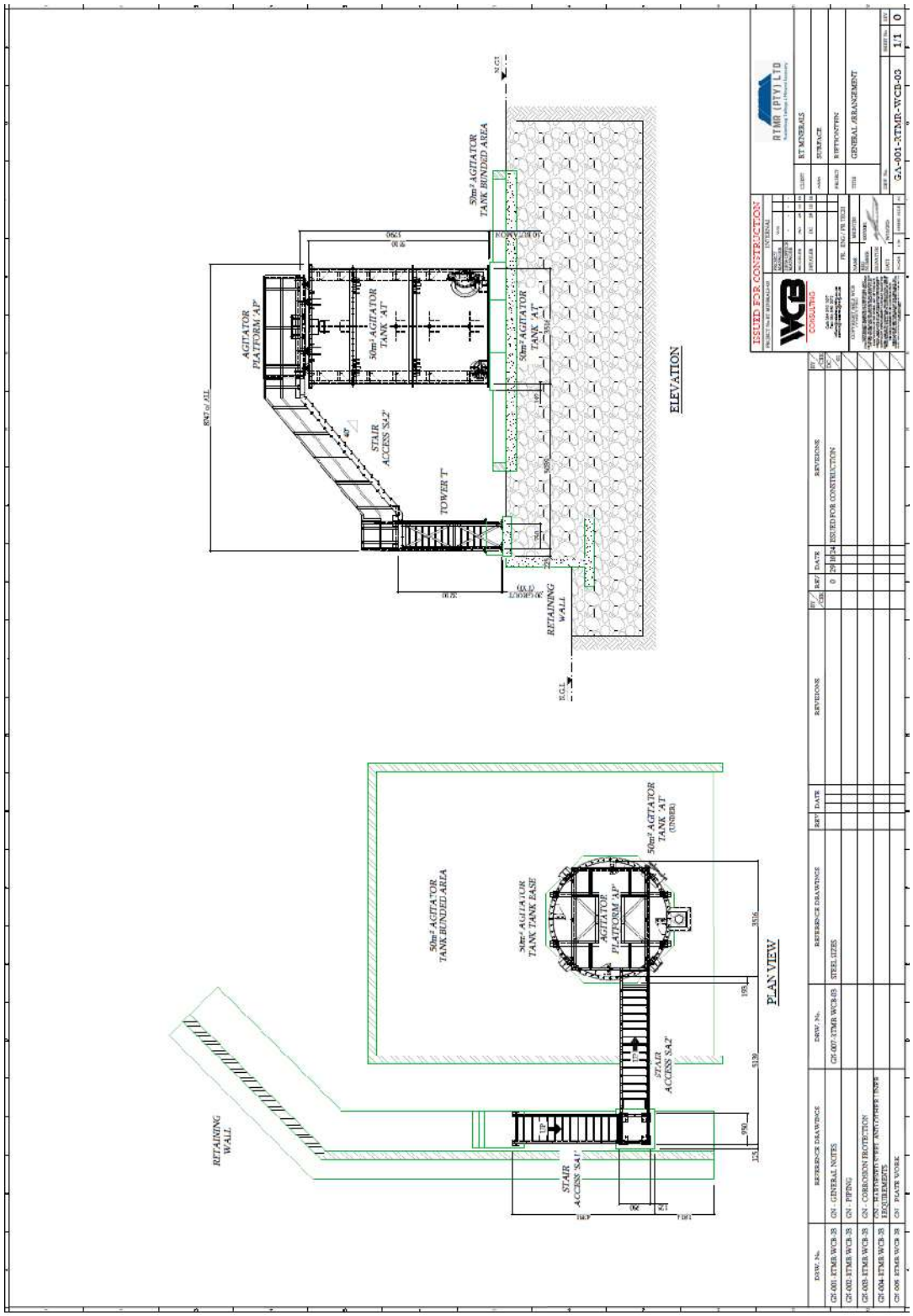
Meter Size: DN150 | Flow range: 35-635m3/h | Ambient:Normal Temperature

Accuracy:1.0% | Equipment status: Good | Serial No.250754

Flow Point	Times	Calibration Time	Master Meter		Tested Meter			Medium Parameters		Relative reading error	Average reading error	Repeatability
			Standard Instantaneous	Standard Volume	Current I	Instantaneous q	Gross Q	Temperature T_m	Density d	E_{ij}	E_i	Er_i
		s	m^3/h	m^3	mA	m^3/h	m^3	℃	t/m3	%		%
Qmax	1	30	305.6928	2.5474	11.707	305.8889	2.5491	13.7	999.309	0.0642	-0.0063	0.07
	2	30	306.2472	2.5521	11.711	306.0136	2.5501	13.7	999.310	-0.0763		
	3	30	305.6550	2.5471	11.701	305.6346	2.5470	13.7	999.309	-0.0067		
0.75*Qmax	1	30	155.0388	1.2920	7.908	155.0803	1.2923	13.6	999.321	0.0268	0.0244	0.015
	2	30	155.1102	1.2926	7.909	155.1236	1.2927	13.6	999.323	0.0086		
	3	30	155.0892	1.2924	7.909	155.1476	1.2929	13.6	999.323	0.0377		
0.10*Qmax	1	30	19.7000	0.1642	4.496	19.6854	0.1640	13.6	999.321	-0.0739	-0.1982	0.12
	2	30	19.6656	0.1639	4.494	19.6040	0.1634	13.6	999.321	-0.3132		
	3	30	19.6720	0.1639	4.495	19.6312	0.1636	13.6	999.323	-0.2074		

Result	Error(%)	±0.0244	Repeatability(%)	0.07	Measuring Range	635
Date	2025-3-25	Calibrated by	Sheila	Inspected by	Tommy	Conclusion ✓	Valid until 2026-3-25

Appendix E: Civils Design



APPENDIX G1

QUALITY ASSURANCE PLAN



10 June 2025

CONSTRUCTION QUALITY ASSURANCE PLAN FOR THE STAGE 3 ENGINEERING DESIGN OF THE SWMP

Rietfontein Plant

P284_Rietfontein Plant CQA Plan

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1. NTRODUCTION

MineLock Environmental Engineers (Pty) Ltd (MineLock) was appointed by Rustenburg Chrome Mine (Pty) Ltd (RCM) to provide a Technical Engineering Design of the Storm Water Management Plan (SWMP) of Rietfontein Plant to support their Water Use License Application (WULA). The Construction Quality Assurance Plan is developed for the submission of the Water Use License application process.

1.1 Objectives

The objective of this plan is to establish:

- Roles and responsibilities of parties involved with the construction works;
- Duties of parties responsible for the CQA program;
- Qualification requirements of the CQA Engineer(s);
- Inspection activities;
- Sampling procedures;
- Document control measures;
- Procedures for approving the materials used for construction;
- Methods for assuring compliance to design standards and Construction Specifications during construction;
- Communication protocols and procedures for resolving issues that may occur concerning the design and construction;
- Documentation of construction and testing for submittal to the regulatory authority for their review; and
- Sign-off procedures.

The objective of the CQA Plan is to assure that the intent of the design is met and that the **Contractor** follows the proper construction techniques and procedure and that the **Contractor** uses the proper materials compliant to the specifications. The CQA program alsointends to identify any problems that might occur during construction and to provide solutionsfor these problems.

The basis of the CQA Plan is to perform spot checks of the **Contractor's** and **Installer's** means and methods to demonstrate conformance with the design requirements (including their Quality Control programs). Quality checks should also be done at pre-scheduled and critical hold points during the implementation of the project.

The **Manufacturers**, **Installers** and **Contractors** conduct Quality Control (QC) programs. This refers to the actions taken by them to ensure that their workmanship and materials meetthe requirements of the scope of work. The CQA Plan is independent of the QC programs. The intent of the CQA Plan is to provide spot verification and testing of the Construction QualityControl (CQC) to assess whether the **Installer** and **Contractor** have met their obligations during the supply and installation of geosynthetic materials according to the design, project scope of work, contractual and regulatory requirements.

2. TECHNICAL DESIGN DRAWINGS AND SCOPE OF WORK

The CQA Plan should be read in conjunction with the project Drawings, Design Report and Specifications issued as the technical design to allow construction.

The requirements of the various components included in the Scope of Work section of the contract document shall be read and adhered to during the implementation of the construction works and aligned with this CQA Plan.

3. DESCRIPTION OF PARTIES AND TO CONSTRUCTION QUALITY ASSURANCE

3.1 Contractual Summary

The Technical Specification and CQA Plans are intended to be separate documents with the focus on defining the quality and performance of particular elements rather than the construction of the elements, and the testing of the quality and performance of the elements respectively.

The Project Specifications shall take precedence where there is any ambiguity between them and any part of this CQA Plan.

The roles, responsibilities and qualifications of the parties to this CQA Plan is described in the sections below. Once the work has been approved, specific personnel will be appointed within these positions.

3.2 Owner/Operator

In this CQA Plan the **Owner** refers specifically to the Client/Owner of the project as identified in the title, and in such is the license holder. The Owner is responsible for the following:

- Contract management from Client,
- Payment of certificates,
- Overview of construction works.

3.3 Project Manager

In this CQA Plan the **Project Manager** is appointed by the **Owner** and is the official representative of the **Owner**. He is responsible for all construction activities and oversight. He coordinates the construction and CQA activities for the project.

For the project initiating, pre-construction planning and resolution meetings the **Project Manager** shall serve as the communications coordinator. As communications coordinator, the **Project Manager** shall serve as a liaison between all parties involved in the project to ensurethat ongoing communications are maintained.

The resolution of all CQA issues that arise during the installation of the geosynthetics is the responsibility of the **Project Manager**, **Engineer** and **CQA Monitor**.

3.4 Engineering

The responsibility of the **Engineer** (individual or firm) includes the following:

- Design, preparation and approval for all construction design drawings
- Development of the Construction Quality Control and Quality Assurance Plan and project specifications,
- Verify the assumptions made during the design phase, as well as changes, modifications, or clarifications encountered during construction.
- Full time construction monitoring by a Resident Engineer and/or his/her assistant (perform CQA function),
- Carry out fortnightly routine inspections at least once every two weeks,
- Inspect all critical aspects of the construction works,
- Verify that materials used in the works meet the specification,
- Review implementation of the construction programme,
- Provide clarification on technical detail,
- Review of contractor's quality control,
- Collect construction records including topographical surveys and methodical method tests on all materials used,
- Verify and approve interim and final certificates for payment.

3.5 Construction Quality Assurance Monitor and CQA Engineering

The independent person responsible for verification of the CQC tasks outlined in this CQA Plan such as testing, monitoring, documentation and reporting, is referred to as the Construction quality assurance monitor (**CQA Monitor**). In consultation with the **Engineer**, the **CQA Monitor** has the authority to stop any aspect of the work that is not in compliance with the CQA Plan. Once the **Engineer** and the **CQA Monitor** approve the corrective action, the work would resume. The **CQA Engineer** will be the Engineer-of-Record and will stamp the final construction report. The implementation and reporting of this CQA Plan shall be conducted under the direct supervision of an appropriated qualified engineer registered with the Engineering Council of South Africa.

The specific responsibilities of the **CQA Monitor** include:

- Review the design drawings, scope of work (including the Design and specifications), and related guidance documents;
- Review all **Contractor/Installer** submittals e.g. work statement methods and make appropriate recommendations;
- Monitor earthworks preparations, excavations, preparation and placement of pipes, backfilling of trenches, preparation and construction of storm water trench, preparation and construction of Impoundment embankments and Access road and ramps, construction of associated infrastructure such as Decant system, Slurry distribution system, Silt trap, Return water dam, Seepage or PCD dams and return water pumping systems, manholes and outlet structures;
- All earthworks and other civil related construction will be monitored against the project scope of work;
- Assure that any soil related testing equipment used, and tests performed are conducted according to project scope of work and industry standards;

- Observe geosynthetics and pipe related material delivery, unloading, and storage and report any damage observed;
- Confirm geosynthetics and pipe related material's specifications to confirm that it meets the design requirements.
- Observe and verify suitability of prepared subgrade prior to geosynthetic deployment;
- Monitor geosynthetic material handling, storage, placement, trial seam testing, non-destructive testing, seaming and repair operations, and destructive testing;
- Identify seam samples for CQA destructive testing;
- Assure that testing equipment used, and tests performed are conducted according to project scope of work and industry standards;
- Observe, and report test results to the **Engineer** as required;
- Report any deficiencies to the **Engineer** that are not corrected to the satisfaction of the **CQA Monitor**, including design or project specification changes; and
- Observe and verify that all work carried out is done according to the project scope of work.
- Developing as-build drawings and final CQA documentation.

3.6 Independent Construction Quality Assurance Reviewer

The independent person responsible for the overall review of the CQA tasks, outlined in this CQA Plan, is referred to as the Construction Quality Assurance Reviewer, (**CQA Reviewer**). In consultation with the **Engineer**, the **CQA Reviewer** has the authority to change CQA methodology where and when required to ensure the best possible CQA process. The **CQA Reviewer** is also responsible for final review of the Construction Completion Report.

3.7 Geosynthetics Manufacturer

The **Manufacturer** responsible for the production of the geosynthetic components, outlined inthis CQA Plan, is referred to as the Geosynthetics Manufacturer (**Manufacturer**). The**Manufacturer** may be affiliated with the **Geosynthetics Installer**. Prior to construction each **Manufacturer** must verify that the **Manufacturer** can produce material that meets therequirements outlined in project scope of work.

3.8 Geosynthetics Installation Contractor (Installer)

The Sub-Contractor responsible for the installation of the geosynthetic components, outlined in this scope of work, is referred to as the Geosynthetics Installation Sub-Contractor (**Installer**). All requirements outlined in the SCOPE OF WORK, construction DRAWINGS and construction SPECIFICATIONS must be met by the **Installer**. The **Installer** may be affiliated with the **Manufacturer**.

The **Installer** will be responsible for storage, handling, deploying, temporary geomembrane anchoring, seaming, repairs and non-destructive testing, in accordance with the project plans, scope of work and the **Installer's** internal QC program. It is the **Installer's** responsibility to see that all submittals are received as outlined in the project SCOPE OF WORK.

A **Superintendent** shall be provided by the **Installer** who will provide full-time technical guidance

to the field crew. The **Superintendent** will represent the **Installer** at all site meetingsand will act as the spokesman for the **Installer** on the project. Welding technicians will be evaluated based on performance and credentials provided, which can be rejected by the **CQAEngineer** (through the **Manager**) if performance is unsatisfactory.

3.9 Civil Work Contractor (Contractor)

The **Contractor** responsible for proper delivery and placement of the earthworks and concrete components, outlined in this SCOPE OF WORK and accordance with the construction drawings and construction specifications, is referred to as the Civil Works Contractor (**Contractor**). The **Contractor** will be responsible for retaining a surveyor to set lines and grades required for excavation, construction, and preparation of as-built drawings. Surveying shall be performed under the direction of a registered Surveyor.

3.10 Independent CQA Laboratory

A third party laboratory, the Independent CQA Laboratory (**CQA Lab**) will be responsible for performing the quality assurance soil, concrete and/or geosynthetics laboratory testing tasks listed in this CQA plan as instructed by the **CQA Engineer**. The geosynthetics testing laboratory shall be accredited by the Geosynthetics Research Institute Laboratory Accreditation Program or similar approved by the regulatory body (GRI-LAP or similar). The **CQA Lab** shall not be affiliated with the **Contractor** nor **Installer** nor materials suppliers.

4. DRAWING REGISTER CONTROL

All drawings will be checked upon receipt against the accompanying drawing register. The following items are to be checked on the received drawing:

- Drawing number
- Revision number
- Date of revision
- Date drawings received
- Quantities of drawings
- Legibility of drawing, especially the scale
- Purpose of drawing,

A complete Master Set, containing the latest drawings, that have been issued by the Engineer will be held in the Contractor's site office. The drawings that have been superseded will be removed from this set and stored in a separate file, marked "SUPERCEDED DRAWINGS". The drawing register will be maintained and displayed in the Contractor's site office.

5. MEETINGS

To enhance coordination among various parties involved, meetings shall be held during the construction of the project. Meetings, such as a pre-construction planning meetings, progress meetings and resolution / intervention meetings will be held if necessary.

5.1 Pre-construction Meetings

Before construction commences or prior to the initiation of specialised tasks, a pre- construction meeting will be held between the **Engineer**, **Project Manager**, **CQA monitor**, **CQA Engineer**, **Installer**, **Contractor** and others designated by the **owner**. The purpose of a pre-construction meeting will at least:

- Define lines of communication, responsibilities and authority;
- Include a site visit and inspection to discuss relevant and all work areas, work plans, stockpiling, lay-down areas, access roads, haul roads and other related items;
- Review the project schedule;
- Review the construction drawings, CQA plan and specifications; and
- Review work area security and safety protocol

This pre-construction meeting will be documented by the **CQA Engineer** and minutes will be distributed to all relevant parties.

5.2 Process Meetings

Weekly progress meetings, as needed, will be held by at least the **CQA monitor** (responsible for organisation and conducting of the meeting), **CQA Engineer**, **Project Manager**, **Installer** and the **Contractor**. The purpose of the progress meetings will be to:

- Review the previous week's accomplishments and activities;
- Review upcoming scheduled work and project milestones;
- Discuss any problems or potential construction problems; and
- Review the results and status of CQA field and laboratory tests

The progress meetings will be documented by the **CQA Monitor** and minutes will be distributed to all relevant parties.

5.3 Resolution Meetings

A resolution or intervention meeting will be held as a special meeting, as needed, to discuss and resolve potential problems or deficiencies. These meetings will be attended by, at least, the **Manager**, **CQA Engineer**, **CQA Monitor**, the **Installer** and/or **Contractor** and the **Engineer** if the problem relates to a design issue. The meeting will be documented by the **CQA Engineer**.

The **CQA Monitor** shall immediately determine the nature and extent of the problem and notify the **Installer** and/or **Contractor**, when deficiencies (items that do not meet project requirements) are discovered. If unsatisfactory test results identify a deficiency, additional tests will be performed to define the extent of the deficient area.

Deficiencies shall be corrected by the **Installer** and/or **Contractor** to the satisfaction of the **CQA**

Monitor. The **CQA Monitor** will notify the **Manager** and **Engineer** who will assist in problem resolution if the **Installer** and/or **Contractor** are unable to correct the problem. The Design **Engineer** and **CQA Reviewer** shall be contacted and shall then suggest the appropriate CQA conformance if the solution involves a design revision.

Before the **Installer** and/or **Contractor** can resume with any additional related work, the corrected deficiency shall be retested and/or approved by the **Manager** and **Engineer**. The **CQA Monitor** and the **Engineer** shall record all retests and related documentation and shall include it in the final Construction Certification Report.

6. LINES OF COMMUNICATION

The **CQA Monitor** shall at all times be capable of direct communication with the **Employer, Engineer**, **CQA Reviewer**, **Installer** and **Contractor**. Deficiencies that can be easily remedied, such as unsatisfactory test results, will be dealt with directly between the **CQA Monitor**, **Installer** and/or **Contractor**.

If there is disagreement that cannot be resolved among the **CQA Monitor**, **Engineer**, **Installer** and/or **Contractor** themselves, the **Engineer** shall present the matter to the **Owner** with related recommendations. The **Owner** shall decide the matter with such decision being final.If required, the **CQA Reviewer** can provide an opinion.

7. CONSTRUCTION QUALITY ASSURANCE

The Works to be performed shall consist of supplying tools, materials, equipment, manufactured articles, supplies, all labour, transportation for materials and labour and services, including essential communications and perform all operations required to fulfil the stipulated Works. All materials, equipment and construction techniques shall be in accordancewith the SCOPE OF WORK, DRAWINGS and SPECIFICATIONS.

Where any materials, equipment or construction technique relating to general civil engineering construction is not expressively indicated in the SCOPE OF WORK or DRAWINGS and required to complete the necessary and proper construction of the Works, the Works shall beexecuted in accordance with SANS 1200. Quality assurance testing and observation is required during all earthwork and concrete aspects, such as excavation of subgrade, placement of engineered fill, concrete works and construction of liner system components.

The types of geosynthetics used in this project includes HDPE pipes, HDPE geomembranes and geotextiles.

The geosynthetics used in this project are defined in the SCOPE OF WORK. Some of these geosynthetics will be sampled prior to and during construction, to determine if they meet the project scope of work. The **Engineer** shall approve the geosynthetic laboratory where all thesetests shall be performed.

7.1 Review Quality Control Submittals

Prior to commencement of construction, the **Engineer** shall have a meeting with the **Contractor** to confirm that the scope of work and DRAWINGS relating to the Works are understood and that the **Contractor** can comply to these. Where required, the **Engineer** shall address any discrepancies. QC documentation and methodologies will be reviewed.

The **Installer's** QC submittals shall be reviewed, prior to geosynthetic installation, to evaluateand confirm that these materials meet project requirements. The QC submittals that are outlined in the scope of work shall be reviewed by the **CQA Monitor** and the **Engineer**.

7.2 Earthworks, Erosion control and Drainage Materials

The **CQA Monitor** shall ensure that QC documentation from the **Contractor** is submitted for approval and should include works methodologies, anticipated conformance testing and remedies on possible defects.

7.2.1 Scope of Work

Earthworks will be done according to the specifications listed in the scope of work relating to SANS 1200 Standards as well as project specific specifications as listed in the scope of work.

- SANS 1200 C Site clearance General;
- SANS 1200 D Earthworks;
- SANS 1200 L Medium pressure pipelines;
- SANS 1200 LB Bedding (Pipes);
- SANS 1200 LE Stormwater drainage; and
- SANS 1200 GA Concrete (Small Works).

7.2.2 Quality Control Submissions

QC testing shall be done by the **Contractor** as specified. The results shall be submitted to the

CQA Monitor for approval. Submittals to include the following:

- Date, project name, location, and weather data, including high and low daily temperatures and precipitation (if any);
- Descriptions of ongoing construction Work areas and equipment utilised by **Contractor**;
- Summary of test results, along with material sample values used and if any new material samples were obtained, with locations and elevations;
- Identification, description and resolution of deficient test results, including conformance/non-conformance reports;
- Test equipment calibration certificates, if/where applicable;
- Note and summary of meetings held on-site with regards to material testing;
- Signature or initials of the **CQA Monitor** on all CQA documentation; and
- Record keeping in the form of physical and electronic copies.

7.2.3 Construction Monitoring and additional testing

Earthworks and drainage

Tests related to all earthworks and drainage construction materials shall be monitored and observed by the **CQA Monitor** to verify that the construction is in accordance with the scope of work. Inadequate construction methodologies or materials that may adversely impact the performance or intended design of the facility and associated infrastructure being constructedshall be identified by the **CQA Monitor**. Visual observations (photographically recorded) and survey measurements shall be recorded by the **CQA Monitor** (reviewed by the **CQA Engineer**) throughout the construction process to ensure that the materials are placed to theminimum dimensions and scope of work as shown on the DRAWINGS and according to the scope of work.

Construction monitoring shall as a minimum include the following:

- Initial Clearing / Cleaning: Activities such as stripping and excavation required to remove any unsuitable material such as soil, loose or embedded rock, organic material and any other deleterious material (such as debris, roots, branches, vegetation, or mud). All unsuitable material will be documented by the **CQA Monitor** to ensure that all unsuitable material is removed and placed in an appropriate stockpile facility;
- Monitor and document the removal and stockpiling of topsoil;
- Stockpiling of unsuitable and temporary suitable stockpiles from excavated material to include verification of location of stockpile, material type, and dressing;
- Excavation depths as shown on the DRAWINGS and are reflected within the geotechnical report including but not limited to the anchor trench, subsoils and storm water outlets, all relevant drains and construction works. Excavation depths may vary depending on conditions encountered in the field, as determined by the **Contractor** and **CQA Monitor** by means of surveying the Existing Ground Level (EGL) and the excavation elevation to determine quantities. The **Contractor** and **CQA Monitor** shall determine depths of excavation in areas not explicitly shown on the DRAWINGS basedon field conditions and shall survey as stipulated above;
- Monitor and document the preparations of surface beds for storm water and spillway outlets, including material type, particle size, loose lift thickness, moisture conditioning process, compaction equipment, methods used to attain compaction, including numberof passes, uniformity of compaction coverage, compacted lift thickness, bonding of lifts, in-place moisture content, permeability values and dry density to ensure the material is in compliance with the scope of work;
- Monitor and document the fill of all relevant embankments, including material type, particle size, loose lift thickness, moisture conditioning process, compaction equipment, methods used to attain compaction, including number of passes, uniformityof compaction coverage, compacted lift thickness, bonding of lifts, in-place moisture content and dry density to ensure the material is in compliance with the scope of work;
- Monitor and document the seeding of the embankment side slopes to ensure that it complies with the vegetation requirements document and scope of work;
- Monitor and verify surface preparation to ensure the top surface is suitable forgeotextile and geomembrane installation as prescribed in the scope of work; and
- Monitor and document the placement of fill and drainage material to ensure that
- **Contractor** exercises care in the vicinity of the drainage and leakage collector pipes.

Engineered Fill and Anchor Trench Backfill

The CQA Monitor shall observe and document the subgrade preparation prior to placement of engineered fill and shall include:

- Monitoring the stripping of vegetated soil, and growth media to be stockpiled, if directed, in the area designated by the **owner**;
- Monitoring that appropriate dust control measures are implemented;
- Visually inspecting the excavation for moisture seeps, soft or excessively wet areas, and unstable slopes, supported with photographical evidence;
- Monitoring subgrade preparation and confirming that the surface of the subgrade is free of soft, organic, and otherwise deleterious materials, and that the surface is firm and unyielding;
- Verify that the subgrade is suitable for supporting any overlying geosynthetic layers as required by the SPECIFICATIONS. CQA observation and/or testing is required during construction to verify that the materials and construction are in accordance with the Construction Specifications. The tests to be performed, including testing frequency, are shown in Table 1. The testing frequencies specified in Table 1 may be increased when construction conditions warrant additional tests. Additional tests may be recommended by the **CQA Monitor** and approved by the **CQA Engineer**.

Table 1: Engineered fill and anchor trench backfill construction testing

Test Designation	Applicable test method	Frequency
Visual-Method SoilClassification	ASTM D2488	Continual during excavation and placement of soil
Moisture-Density	ASTM D1557	1 per 5000 m3 or eachmaterial type
Sieve Analysis	ASTM D422	1 per 1500 m^3 or each material type
Atterburg Limits	ASTM D4318	1 per 1500 m^3 or each material type
Nuclear Moisture/Density[1]	ASTM D6938	1 per 500 m^3, one per lift or one per day (whichever results in a higher number oftests)
Moisture content	ASTM D2216	1 per 20 nuclear moisturetest
Sand Cone Test/Drive Cylinder Test	ASTM D1556 / D2937	1 per 20 nuclear density test

1. *.Tests shall be performed on an even grid to provide adequate testing coverage. For large fills in small areas, the testing frequency shall be increased as necessary to insure testing for each lift of soil placed.*

7.2 Geosynthetic materials

All geosynthetic materials will be discussed within this section. Refer to project report and drawings for project specific geosynthetic materials to be used.

7.2.1 Review Quality Control Submittal

Prior to geosynthetic installation, the **CQA Monitor** and the **Engineer** shall review the **Installer's** QC submittals to evaluate and confirm that these materials meet project requirements. The **CQA Monitor** and the **Engineer** shall review the following submittals that are outlined in the Specifications:

- Geosynthetic material samples, name of Manufacturer, and minimum material specifications which shall include the Manufacturer's minimum physical properties of the material, test methods (ASTM Standards) used, and factory and site seaming methods;
- Manufacturer's Quality Control Manual followed during the manufacturing process;
- The origin (supplier's name and production plant), identification (brand name and number) and material properties of the resin used to manufacture the product;
- Geosynthetics Installer's Quality Control Manual, for the installation and testing of the geosynthetic;
- CV's of the Installer Superintendent, Master Welder, and Welders to be assigned to this project (geomembrane only) if applicable;
- A copy of each of the Quality Control Certificates on each lot of resin issued by the resin Supplier for the specific material for this project. Geomembrane submittals shall include certification of the resin for extrusion welding rod;
- The result of quality control testing conducted on the resin used in manufacturing the specific material for this project;
- A listing which correlates the resin to the individual geosynthetic rolls and extruded materials;
- A panel layout drawing for geomembrane showing the proposed installation layout identifying field seams as well as any variance or additional details which deviate from the Construction Drawings;
- A detailed installation schedule for the project; and
- Certification that the extrusion welding rod to be used is comprised of the same resin type as the geomembrane to be used (geomembrane only)

7.2.2 Geomembrane

During geomembrane installation, the **CQA Monitor** shall observe and document handling, storage, deployment, trial seams, field seaming, non-destructive and destructive seam testing,and repairs to assess that the installation is in compliance with the scope of work/specifications.

Specifications

The supply and installation of the HDPE liners will be according to the following specificationsand codes of practice (these specifications are available at the **Contractor's** expense from relevant companies. The **Contractor/Installer/CQA Monitor** should ensure that the newest revisions/edition is used):

- GRI-GM13: Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes;

- GRI-GM14: Selecting variable intervals for taking geomembrane destructive seam samples using the method of attributes;
- GRI-GM19: Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes;
- SANS 10409: Code of Practice for the Design, Selection and Installation of Geomembranes;
- SANS 1526: Thermoplastics sheeting for use as a geomembrane;
- GRI-GM6: Practice for Pressurized Air Channel Test for Dual Seamed Geomembranes;
- GRI-GM29: Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and/or Non-destructive Testing;
- GRI-GS15: Test Methods, Test Properties and Testing Frequency for Geocells Made From High Density Polyethylene (HDPE) Strips;
- ASTM D4354: Practice for Sampling of Geosynthetics for Testing;
- ASTM D4873: Guide for Identification, Storage and Handling of Geosynthetics;
- ASTM D5641/D5641M-16: Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber;
- ASTM D5820-95: Standard Practice for Pressurized Air Channel Evaluation of Dual- Seamed Geomembranes;
- ASTM D6365-99: Standard Practice for Non-destructive Testing of Geomembrane Seams Using the Spark Test;
- ASTM D7002-16: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Puddle Method;
- ASTM D7703-16: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance Method;
- ASTM D7953-14: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing Method; and
- ASTM 7865: Standard Guide for Identification, Packaging, Handling, Storage and Deployment of Fabricated Geomembrane Panels.

Geomembrane materials conformance

The **CQA Monitor**, prior to geosynthetic installation, shall obtain samples of the relevant geomembranes for conformance testing to confirm that these materials meet project requirements. One set of tests will be carried out at commencement, and as directed should the materials suppliers changed. 6 x samples each 300 mm x 300 mm are to be taken acrossthe entire width of a roll of the geomembrane (1 sample per 200 000 m2), not including the first 1.5m. The samples are to be marked with the machine direction, roll number on the sample, and date the sample was obtained. The samples are then to be sent to an accreditedGeosynthetics testing laboratory where the following conformance tests are to be performed prior to installation (according to the relevant ASTM standard test method):

Table 2: ASTM standard test method

Material Property	ASTM Test method
Density	D1505
Thickness	D5199

Tensile strength and enlongation at break	D6639
Stress Crack Resistance (SP-NCTL)	D5397, App
Standard Oxidative Induction Time (OIT)	D3895
High Pressure Oxidative Induction Time(HP-OIT)	D5885

- Specific Gravity Mass Comparison ASTM D792;
- Carbon black content ASTM D4218;
- Dispersion of carbon black content ASTM D5596;
- Test Method for Carbon Black in Olefin Plastics ASTM D1603;
- Nominal thickness of Geosynthetic ASTM D5199;
- Core thickness of textured sheets ASTM D5994;
- Asperity height of textured sheets ASTM D7466;
- Performance strength of geomembrane ASTM D6693;
- Air-Oven Aging ASTM D5721;
- Test Method for Initial Tear Resistance of Plastic Film and Sheeting ASTM D1004;
- Ultraviolet Fluorescent Weatherometer GRI-GM11; and

All conformance tests shall be performed in compliance with the specification requirements ofGRI Test Method GM13 “Test Methods, Test Properties and Testing Frequencies for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”, Table 1(b) and Table 2(b). The **Engineer** shall review the test results and shall report any non-conformance to the**Owner** and the **Installer**.

Packaging, Labelling, Transportation, Unloading and Storage

The geomembranes shall be packaged, transported, unloaded and stored in accordance withthe **Manufacturer’s** instructions or ASTM D4873 or per **Engineer** or **CQA Monitor instruction**.

The following shall be ensured by the **Installer** and shall be verified by the **CQA Monitor**:

- The rolls of geomembranes shall be packaged to protect them from mechanical damage during transportation and handling. Immediately prior to deployment, the packaging is to be carefully removed without damaging the product;
- Geomembranes rolls shall each be labelled on the surface of the package or printed on the material. Labels should be resistant to fading and moisture degradation such that they are legible at the time of installation. Labelling should include the **Manufacturer’s** name, product identification, roll number, Material thickness, roll dimensions and weight of the roll;
- Before off-loading on site, the **Installer** must ensure that the off-loading equipment is adequate for handling the geomembranes rolls without any risk of damaging them. The area where the geomembranes rolls are to be off-loaded and stored must have a smooth well-drained surface, free of rocks or any other protrusions which may damage the product;
- After off-loading, the **Installer** shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The **Installer** shall inform the **CQA Monitor** and the **Manufacturer** of any defects or damages. Repairs shall be made subject to approval by the

CQA Monitor; otherwise damaged rolls shall be replaced at the **Installer's** cost; and

- A designated storage area shall be established in a relevant location such that on-site transportation and handling is minimised. The storage area should be prepared as specified above protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined. If relocation of geomembranes rolls is necessary, the area should also be prepared in the same manner as mentioned above. The geomembranes rolls shall be stored lying flat and continuously supported above ground. Roles stacks should not exceed 4 roles packed on top of each other.

Deployment and installation

The **CQA Monitor** shall verify that only approved materials are used. The **Installer** shall submit a detailed proposal on the methods he proposes to use for installation of the geomembrane products. The **CQA Monitor** and **Engineer** will verify that the methods meetsthe scope of work. Some of the aspects to be covered and verified on site include:

- Placement of the geomembrane without disturbance to the layer being installed or any underlying layers;
- Equipment and procedures used to place the geomembrane;
- Placing of geomembrane should be such that no damage is incurred, by any means, to the underlying geotextile;
- Rate of installation;
- Temperature monitoring; and
- Relevant workforce certification.

Immediately prior to installation of the geomembrane lining, the subgrade or relevant underlaying surface shall be inspected by the **CQA Monitor**, **Contractor** and **Installer**, to confirm that it is in a condition to safely accept the geomembrane on top of it (as per SANS10409-2020 Edition 2). The **CQA Monitor**, **Contractor** and **Installer** shall sign acceptance of the surface condition of the subgrade.

- The area to be lined must be free of all protrusions, stones, roots, vegetation and other materials which may be detrimental to the performance of the liner. On the surface to be lined, a maximum particle size of 3 mm diameter is permissible;
- The final surface layer shall be left smooth and dense and finished levels shall be correct to engineers discretion for approval
- If the in-situ soil is unsuitable, a sand or fine gravel blinding layer of thickness at least 2,5 times the largest dimension of the largest particle in the in-situ soil, or 50 mm (whichever is the thicker), or a geotextile with properties sufficient to meet the above requirements, may be placed over the entire area to be covered at the discretion of the engineer; and
- Signed surface acceptance shall only be valid for a specified period agreed upon by the **CQA Monitor**, **Contractor** and **Installer**, before installation commences, as to maintain desired design specifications.

At the time of installation, each field panel or portion of a roll of geomembrane shall be given an "unique identification code" which will be correlated with the full manufacturer's roll number. The minimum details required on the panel placement form shall be in accordance with the detail in annex D (SANS 10409:2020 Edition 2). Field panels are to be located in a manner consistent with thespecification and best suited to the design layout. A floor plan clearly showing the intended layout of the geomembrane, including orientation of panels and positions of seams should be submitted prior to installation commencing to **Engineer**, **CQA Monitor** and **Contractor**.

Fieldpanels are to be placed one at a time, and each field panel is to be seamed as soon as the new panel has the same surface temperature as the panels already installed. Information relating to geomembrane panel placement, including date, time, panel number, and panel dimensions, shall be maintained on a site specific basis, on the panel placement form (refer to annex D (SANS 10409:2020 Edition 2)). If a portion of a roll is set aside to be used at another time, the roll number shall be written on the remainder of the roll in several places.

The **Installer** and **CQA Monitor** should ensure that the panels laid out can be seamed within the same workday (to minimise long term exposure and risk of wind uplift). Exposed geomembrane should at all times be secured by means of UV Stabilised, closed sandbags. The **Installer** shall record and the **CQA Monitor** shall verify the roll number, panel number, location, panelsize and date of installation of each geomembrane field panel.

The **CQA Monitor** shall verify that installation and seaming shall not take place in wet weatheror in the presence of excessive moisture, blowing dust, strong winds and temperatures below zero.

During installation, the **Installer** shall ensure and the **CQA Monitor** shall verify the following:

- Any equipment used shall not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means;
- The prepared surface has not deteriorated since the acceptance inspection and is still acceptable immediately prior to placement of the geomembrane;
- Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- All personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any activities which could damage the geomembrane;
- The method used to unroll the panels must not cause folds in the geomembrane and must not damage the supporting soil surface, especially textured liners;
- The method used to place the panels shall minimise wrinkles (especially differential wrinkles between adjacent panels);
- Adequate temporary loading and/or anchoring (e.g., closed UV stabilised sandbags (containing no material exceeding 3 mm) (SANS 10409), which will not damage the geomembrane, must be placed to prevent uplift by wind; and
- When liner is being installed, adequate care should be taken to ensure no unwanted.

Each geosynthetic and geomembrane layer shall be inspected by the **Installer**, **CQA Monitor**and **Contractor** for damage after placement, prior to seaming. Damaged areas shall be marked, removed and repaired in accordance with the scope of work/specifications. The locations of repaired sections shall be recorded in the quality control documentation. No vehicular traffic shall be allowed on the installed geomembranes.

Anchor trenches

The anchor trench shall comply with the **Engineer's** specifications and drawings. Anchor trenches shall be excavated and backfilled by the earthworks **Contractor** (unless otherwise specified) to the lines and widths shown on the design drawings. The **Engineer** shall verify that anchor trenches have been constructed according to the design drawings. The edge of the trench, over which the geomembrane enters or exits the trench, shall be constructed in such a way as not to damage the geomembrane. Water shall not be allowed to stand, or soften the soil in the anchor trench. The de-watering of the anchor trench shall be the responsibility of the earthworks **Contractor**.

As-built panel layout

The **Installer** shall attempt to install field panels as indicated on the layout drawing (refer to annex A for an example of a layout drawing). If the panels are deployed in a location other than that indicated on the layout drawing, the revised location shall be noted in the field (on the panel layout drawing) and the changes incorporated into a final "as-built" drawing on completion of the project.

Trial seaming and field seaming

Technicians performing seaming operations shall be suitably trained in the operation of the specific seaming equipment being used, and shall demonstrate their competence by successfully welding trial seams which meet the requirements of GRI Standard GM 19a and GM 19b to the satisfaction of the **Installer** and the **Engineer**.

Seaming equipment shall comply with the requirements of GRI Standard GM 19a and GRI Standard GM 19b. All equipment used shall comply with the relevant national legislation. All seaming equipment shall be regularly maintained and kept in good working order. All testing equipment shall have a valid calibration certificate.

Factors such as the geomembrane temperature, humidity, wind, precipitation, and seaming surface conditions (such as moisture and dust), can affect the integrity of field seams and shall be taken into account by carrying out trial seams when deciding whether or not seaming shall commence, or be allowed to proceed. Trial seams shall be made, before production seaming, in order to determine if the weather conditions will affect the installation contractor's ability to produce quality seams. Additional non-destructive and destructive testing of production seams (see 10.6 (SANS 10409:2020 Edition 2)) shall be done by the installation contractor to substantiate his decision to seam on that day.

The **CQA Monitor** shall verify that seaming conditions are performed in compliance with the scope of work and that tests are performed at required intervals. He shall also verify that specified test procedures are followed, and retests are performed in compliance with the scopeof work. It shall be verified by the **CQA Monitor** that only approved equipment and personnelperform welding.

The **Installer** shall ensure and the **CQA Monitor** shall verify the following:

- That field seams are orientated up/down the line of maximum slope;
- In corners and odd-shaped geometric locations, the number of seams should be minimised;
- No horizontal seams should be less than 1.5 m from the toe of the slope or areas of potential stress concentrations, unless otherwise authorised;
- When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel is cut at an angle of 45 degrees; and
- A seam numbering system compatible with the panel numbering system shall be established.

Seaming of field panels shall be carried out by means of a continuous heat extrusion welding process, or an electric double wedge fusion welding process, to produce a totally homogeneous seam. Typically, continuous heat extrusion welding will be used for patching, T-joints and repairs, while electric double wedge fusion welding will be used for panel seaming

The extrusion welding apparatus shall be equipped with gauges giving the temperature at the nozzle and extruder barrel. The fusion welding apparatus must be automated device which produces a double seam with an enclosed space for pressure testing. The fusion welding apparatus must also be fitted with gauges giving the applicable temperatures and speed. The**CQA**

Monitor shall verify the temperatures and speed of the relevant equipment.

The **Installer** shall ensure and the **CQA Monitor** shall verify that prior to seaming, the seam area is to be clean and free of moisture, dust dirt, debris of any kind, and foreign material. Seaming shall not take place in excessively high temperatures where the air pressure channels begin to close, or where passing welds are unobtainable. Similarly, no seaming shall be attempted at ambient temperatures below 0°C. In all cases, the geomembrane shall be dryand protected from the wind.

The **Installer** shall perform and the **CQA Monitor** shall verify that trial seams be made on fragment pieces of the same geomembrane liner, that is installed, to verify that seaming conditions are adequate and meets project specifications. Such trial seams shall be made at the beginning of each seaming period (morning and afternoon) for each seaming apparatus used or if the seaming apparatus has been switched off for more than one hour. Trial seams shall be made under the same conditions as the actual seams. The trial seam shall be approximately 1 m long by 300 mm wide, with the seam centred lengthwise.

Trial welds should be recorded with, but not limited to, the following information: Trial weld number, time, date, apparatus serial number, welder name, apparatus settings and ‘Pass’ or ‘Fail’. This is to be verified by the **CQA Monitor**.

With electric double wedge welding, ten specimens will be taken from the trial seam sample of which 5 will be tested in shear and the remaining 5 will be tested with peal on both sides (10 peal).

With continuous heat extrusion welding, ten specimens will be taken from the trial seam sample, of which 5 will be tested in shear and the remaining 5 will be tested in peal.

All specimens shall meet the criteria for film tearing bond (FTB), i.e. the geomembrane must fail before the weld fails, according to GRI-GM 19. Only after the Trial welds were deemed successful by the **CQA Monitor** can field seaming commence.

The **Installer** shall ensure and the **CQA Monitor** shall verify that field seams be made by overlapping adjacent sheets at least 75 mm for electric double wedge fusion welding and 30 mm for extrusion welding and that grinding techniques and extrudate meet project requirements. Seams must be aligned with the fewest possible number of wrinkles and “fishmouths”. Where wrinkles or “fishmouths” are unavoidable, they shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut wrinkles or “fishmouths” shall beseamed and any portion where the overlap is inadequate shall be patched with an oval or round patch of the same geomembrane, extending a minimum of 75 mm beyond the cut in all directions. All seaming shall be performed through the anchor trench.

For electric double wedge fusion welding, a protective layer of plastic should be placed directly below the overlapped membranes being seamed. Especially applicable when subgrade is damp or wet.

All field seaming shall be recorded, by the **CQA Monitor**, on field seaming log forms.

T-joints

T-joints are formed where a longitudinal seam is intersected by another seam (see Figure 2). Stagger T-joints between panels (i.e. in a brick pattern, see Figure 2) to avoid the formation of cross joints. Construct T-joints in such manner so as to ensure the watertightness of the point

where the two seams intersect. The procedure for forming a hot-wedge seamed T-joint shall be as illustrated in Figure 3. A hot-wedge seamed T-joint is formed as follows (see also Figure 3):

- Place sheet 2 over sheet 1, with an overlap of between 85 mm and 150 mm (see Figure 3, step 1 and Figure 4).
- Remove the lip of the loose portion of the overlap which remains after the weld is made, using a sharp cutting tool or by grinding, up to the edge of the closest wedge of the seam (see Figure 3, step 3), for a distance of 150 mm or sufficient to accommodate an extrusion welding machine.
- Prepare the area where the lip is cut away, for extrusion fillet seaming, then place sheet 3 on top of sheets 1 and 2, with an overlap of between 85 mm and 150 mm (see Figure 3, step 3).
- Join sheet 3 to sheets 1 and 2 by performing a double hot-wedge weld (see Figure 3, step 4).
- Remove the lip of the overlap as previously described in (b), and as shown in Figure 3, step 5. Prepare the area where the lip is cut away for extrusion fillet seaming.
- Perform an extrusion fillet seam along the crossbar portion of the "T" (see Figure 3, step 6), starting from where the lip was initially removed on sheet 3 and working towards the corresponding position on the other side of the seam which joins sheets 1 and 2.
- Perform another extrusion fillet seam on the intersecting leg of the "T", working from the start of the lip towards the intersection (see Figure 3, step 7).

The **Engineer** or his representative may instruct the CQC co-ordinator to take destructive samples from any seam, if defects are suspected. The CQC co-ordinator shall make periodic checks on seaming operations to verify sufficient overlap, general cleanliness and integrity of the seam.

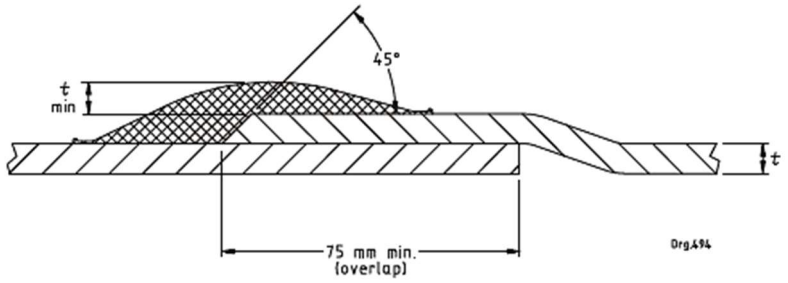


Figure 1: Extrusion fillet seam, SANS 10409:2020 Edition2

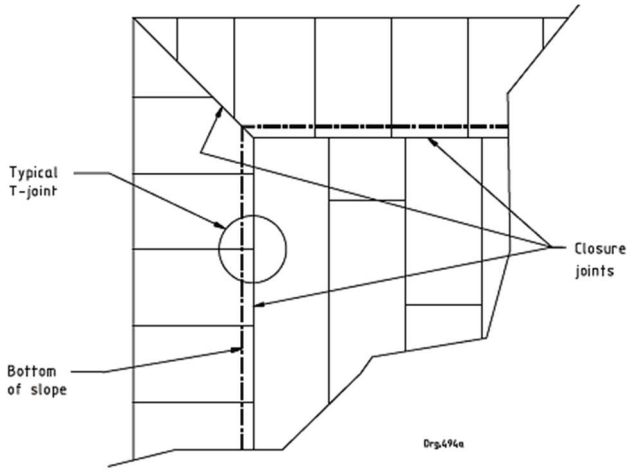


Figure 2: Typical panel Layout and joint position, SANS 10409:2020 Edition 2

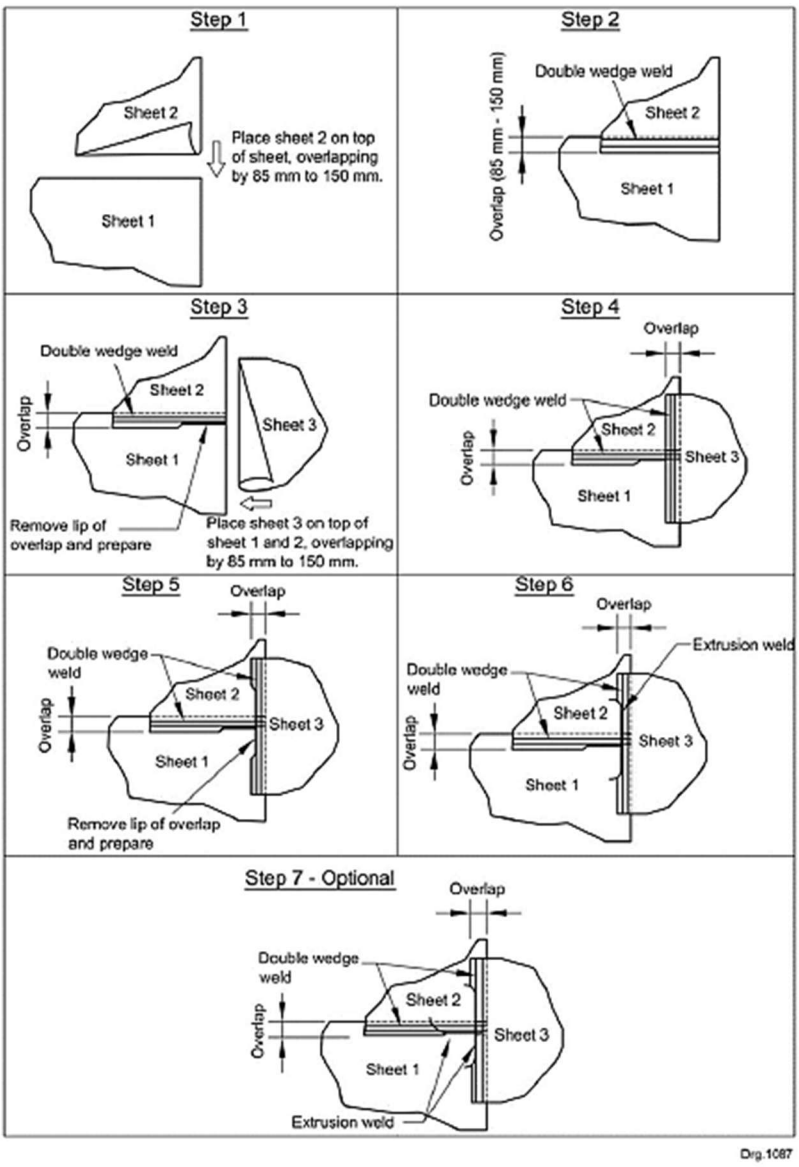


Figure 3: T-joints specifications by SANS 10409:2020 Edition2

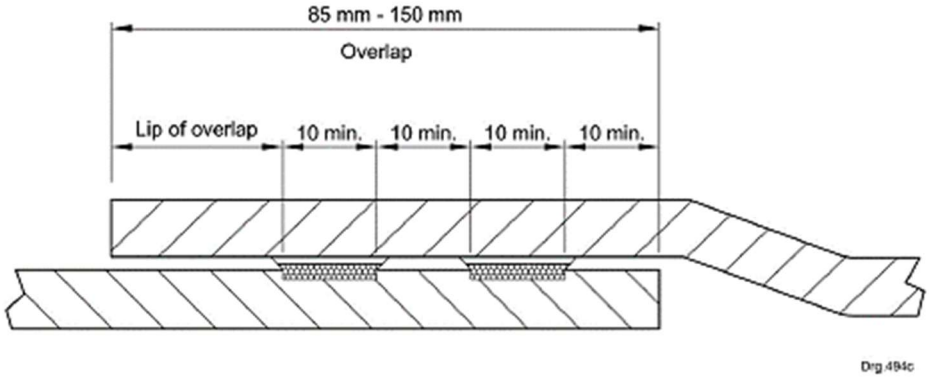


Figure 4: Double hot-wedge seam, SANS 10409:2020 Edition2

Seaming documentation

Seaming technicians shall mark on the liner (with permanent markers), at the start of all seams, information regarding date, time, seam number, seaming technician's identification number, machine number and set temperature. Seaming technicians shall periodically check operating temperature and speed and mark any deviations along the seam. The CQC co-ordinator shall record the minimum details required on the panel seaming form which shall be in accordance with the detail in annex E – SANS 10409:2020 Edition 2.

Non-destructive seam continuity testing

The **CQA Monitor** shall verify that the seams and repairs are non-destructively tested by CQC personnel in compliance with the project scope of work. The **CQA Monitor** shall ensure that CQC monitors observe cap strip operations, if a seam cannot be tested. The **CQA Monitor** shall verify that test equipment and gauges are functioning properly and that test procedures are in compliance with the project scope of work. The **CQA Monitor** shall also verify that the seams and repairs with failing test results are repaired and/or re-tested until passing results are achieved.

Air pressure testing shall be conducted on wedge-welded seams as described in ASTM D5820. Basic information regarding air pressure testing (i.e. date, time, pass/fail designation, and tester's reference number) shall be written on one end of the seam, or portion of seam tested (using a permanent marker). All the relevant information shall also be logged on the non-destructive testing form as shown in annex G (SANS 10409:2020 Edition 2) by the **Installer**. The hole made during the air pressure test shall be sealed after the test.

The **Installer** shall ensure and the **CQA Monitor** shall verify that the vacuum test is done during operations as an indicator of the performance of the extrusion weld but will be confirmedwith a spark test during independent quality assurance. This test creates a vacuum on one side of the joint. If a vacuum of minus 75 kPa can be maintained for three minutes the joint shall be considered effective. This test must be done where three or more sheets are lappedor where patching is done on straight runs at a rate of one test per 5 linear metres of welding.Vacuum testing should be performed as per ASTM D4437 and D5641 or spark testing. Special attention shall be exercised when vacuum testing "T" joints or intersections of patches with seams to ensure that the sides of the vacuum box are sealed to ensure no leakage occurs between the gaskets of the box and the geomembrane. All areas where soap bubbles appear shall be marked, and repaired in accordance with 11.2 (SANS 10409:2020 Edition 2). Repaired areas shall be retested. Vacuum testing personnel shall use permanent markers to mark the geomembrane, on all areas tested, with details of the tester's name, date and pass/fail designation of the seam. Records of vacuum testing shall also be logged on the non-destructive testing form as shown in annex G (SANS 10409:2020 Edition 2), by the Installer.

The **Installer** shall ensure and the **CQA Monitor** shall verify that Electric Double Wedge Welds is tested non-destructively by inflating the space between the two wedge welds and maintaining a certain pressure for a predetermined period as per GRI-GM 6 and ASTM D5820.All double wedge welded seams are to be tested.

The **Installer** shall ensure and the **CQA Monitor** shall verify that non-destructive spark testingbe performed on the relevant extrusion weld. A wire is embedded in the weld during the extrusion process. Spark testing shall be carried out on all extrusion welded seams in accordance with the test method specified in ASTM D6365.

The **CQA Reviewer** shall ensure and verify that non-destructive electric leak location testing be

performed on the relevant extrusion weld. ELL testing shall be carried out on all extrusionwelded seams in accordance with the test method specified in ASTM D8265.

Care should be taken if there are flammable gases or liquid present in the area to be tested. If a spark occurs (indicating a leak), the faulty area shall be located, repaired and retested by the **Installer** in accordance with 11.2 (SANS 10409:2020 Edition 2). The geomembrane shall be marked, and details recorded, as in 10.6.2.2 (SANS 10409:2020 Edition 2).

Destructive seam testing

Destructive test samples shall be tested by the **Installer** and preferably witnessed by the **Engineer** or **Third party Reviewer**. Samples shall be tested under site conditions, unless the engineer or the end user specifies laboratory testing. The frequency for destructive testing shall comply with the requirements of GRI Standard GM 19a, GM 19b and GRI Standard GM 14, unless otherwise agreed between the installation contractor and the Engineer.

The **Installer** shall obtain samples, at locations selected by the **CQA Monitor**, of the field seamed geomembrane approximately 600 mm along and 300 mm across the seam and centred over the seam as follows:

- A minimum of one sample per day;
- A minimum of one sample for each machine;
- A minimum of one sample every 150 m of seaming is required unless, in the opinion of the **CQA Monitor**, the seamer has demonstrated sufficient quality/experience to increase the seam sample interval. In no event shall the sampling interval exceed 300 m; and
- Seams that appear suspect to the **CQA Monitor**.

The **CQA Monitor** shall witness the testing of destructive seam samples by the **Installer's** CQC personnel. The **Installer** shall record the following information: roll and seam number, date, time, machine number, machine running speed, welding technician identification, extruder and nozzle/wedge temperature, ambient air temperature, tensiometer technician identification, tensiometer serial number, tensiometer speed, tensiometer tension, liner temperature, destructive test number and location. However, the agreed upon information shall be displayed on the sample.

The **Installer** shall test all destructive samples in compliance with the project scope of work in accordance with the relevant SANS code. The **Installer** shall be responsible for patching all areas cut for test samples in accordance with the scope of work and **Manufacturer's**requirements and performing non-destructive testing of the seams. The **CQA Monitor** shall track failing tests as described in the scope of work.

Detection of defects

All installation personnel shall, at all times, be on the lookout for any areas of damage to the geomembrane. Before handover (on completion of an area of responsibility of the work) by the **Installer** to any other party, the **Installer**, the **Engineer** and the **Third Party Reviewer** shall conduct a detailed walk-through of the lined facility and visually check all seams and non-seamed areas of the geomembrane for defects, holes, or signs of damage during installation. Damaged areas (for example, torn, twisted or crimped) shall be marked and repaired, by the Installer.

Repairs

The **CQA Monitor** shall observe and document that all repair materials, techniques, and procedures used for repairs are approved in advance and meet the requirements of the project scope of work. The **CQA Monitor** shall verify that all defects and repairs are marked, recorded, repaired, tested, and wrinkles are addressed, prior to being covered by other materials; and that repairs are performed as specified, including proper patch size or dimension.

Suitable procedures available for repair work include the following:

- Patching. A method whereby a patch is applied over large holes, tears, or destructive test sample locations, and extrusion-welded into place. All patches shall extend at least 150 mm beyond the edges of the defect, and all corners of the patches and defects shall be rounded.
- Spot extrusion. Welding whereby an extrusion welder is used to spot-weld over small tears, pinholes, or other minor localised flaws.
- Capping. A form of patching, used to repair long, narrow defects, using a long length of geomembrane material of constant width.
- Lip extrusion. An extrusion weld applied along the lip of the overlap of wedge-welded seams.
- Removal and replacement. Removal of a defective seam, and replacement with new material which is wedge-welded into place.

Protection

The **CQA Monitor** shall observe and document that all materials placed on top of the geosynthetics are done in such a manner as to ensure that the geosynthetics and underlying materials are not damaged.

Protection against mechanical damage

To reduce the risk of mechanical damage to the geomembrane (from vandalism or animal and pedestrian traffic), it is recommended that the entire complex be fenced off. When used, protective coverings shall be placed in position during the coolest part of the day, morning or late afternoon, in order to minimise trapping wrinkles as specified in the layer. Occurrences of wrinkles or waves trapped in the liner, shall not be permitted to propagate, shall be rectified, or each occurrence only allowed to remain subject to approval by the employer representative.

Care shall be taken in the selection of earth moving equipment operating on top of the protection layer to avoid damaging the geomembrane or other geosynthetic layers. Sharp turns or pivots with earth moving equipment as well as sudden starts or stops shall be avoided. Major damage can be inflicted by the bucket or scraper of earth moving equipment.

Drawing-down precautions

Should it be necessary to draw a reservoir down regularly, it is recommended that, where possible, suitable precautions shall be taken to protect and maintain functionality of the geomembrane.

Fire precautions

Vegetation on the berm shall be removed to eliminate the risk of damage of the exposed parts of the geomembrane by fire.

Acceptance

The **CQA Engineer** shall approve areas of the geomembrane prior to coverage of the geomembrane by other materials. Acceptance of areas shall follow these procedures:

- As-built panel layout survey;
- Full documentation of all seams;
- Full documentation of non-destructive testing on all seams and repairs;
- Full documentation of repairs on all defects;
- Full documentation of passing destructive tests;
- A final "walk-over" of the area to observe any subsequent damages or non- addressed items; and
- All submittals required by this CQA Plan or the Construction Specifications

7.2.3 Geotextile

The **CQA Monitor** shall, during geotextile installation, observe and document deployment, overlaps, field seaming, and repairs to assess that the installation is in compliance with the scope of work.

Specification

The geotextile to be used shall be a non-woven, needle punched geofabric as specified in the DRAWINGS, or an equivalent product as approved by the **Engineer**. Specifically, the geotextile shall have the following components and properties as a minimum:

Property	Test method
Unit mass	SANS 9864, ASTM D5261
Overall thickness	SANS 9863-1:13
Tensile strength	SANS 1525:13
CBR static puncture strength	SANS 12236:13
Puncture resistance hole	SANS 13433:13
Trapezoidal tear strength	ASTM D4533
Water flow (normal to the plane)	SANS 11058
Opening pore size O90	SANS 12956

Other tests may include:

- ASTM D4632 Test Method for Grab Breaking Load and Elongation of Geotextiles;
- ASTM D5035 Test Method for Breaking Strength and Elongation of Textile Fabrics (2" Strip Method);

- ASTM D6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe; and
- GRI-GT12(a): Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

Geotextile materials conformance

Prior to installation the of geotextile materials, material specifications will be supplied to the **CQA Monitor** for review and approval.

As a minimum the material shall comply with GRI Test Method GT12(a) (Rev 2, March 2016)

-Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

As and where required, the following ASTM standards will be used for various practices and test methods although no test work is anticipated for geotextiles at this stage:

- ASTM D4354 Practice for Sampling of Geosynthetics for Testing;
- ASTM D4355 Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus);
- ASTM D4439 Terminology for Geosynthetics;
- ASTM D4533 Test Method for Trapezoidal Tearing Strength of Geotextiles;
- ASTM D4632 Test Method for Grab Breaking Load and Elongation of Geotextiles;
- ASTM D4759 Practice for Determining the Specification Conformance of Geosynthetics;
- ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products;
- ASTM D4873 Guide for Identification, Storage and Handling of Geosynthetics;
- ASTM D5261 Test Method for Measuring Mass per Unit Area of Geotextiles;
- ASTM D5494 Test Method for the Determination of Pyramid Puncture Resistance of Unprotected and Protected Geomembranes; and
- ASTM D6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Products Using a 50-mm Probe.

Packaging, Labelling, Transportation, Unloading and Storage

The geotextiles shall be packaged, transported, unloaded and stored in accordance with the **Manufacturer's** instructions or ASTM D4873 whichever is directed by **Engineer** or **CQA Monitor**.

The following shall be ensured by the **Installer** and shall be verified by the **CQA Monitor**:

- The rolls of geotextile shall be packaged to protect them from mechanical damage during transportation and handling. The geotextile rolls must be delivered to the working area of the site in their original UV stabilised packaging. Immediately prior to deployment, the packaging is to be carefully removed without damaging the product;
- Geotextile rolls shall each be labelled on the surface of the package. Labels should be resistant to fading and moisture degradation such that they are legible at the time of installation. Labelling should include the Manufacturer's name, product identification, roll number, batch/lot number, roll dimensions and weight of the roll;
- Before off-loading on site, the Installer must ensure that the off-loading equipment is

adequate for handling the geotextile rolls without any risk of damaging them. The area where the geotextile rolls are to be off-loaded and stored must have a smooth well- drained surface, free of rocks or any other protrusions which may damage the product;

- After off-loading, the Installer shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Installer shall inform the CQA Monitor and the Manufacturer of any defects or damages. Repairs shall be made subject to approval by the CQA Monitor; otherwise damaged rolls shall be replaced at the Installer's cost; and
- A designated storage area shall be established in a relevant location such that on-site transportation and handling are minimised. The storage area should be prepared as specified above protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined. If relocation of geotextile rolls is necessary, the area should also be prepared in the same manner as mentioned above. The geotextile rolls shall be stored lying flat and continuously supported above ground. The geotextile rolls must be covered to protect them from ultraviolet exposure until they are installed.

Deployment and installation

The **CQA Monitor** shall verify that the intended layout as approved, including orientation, overlaps and joints are as intended. He shall also verify that the subgrade or geomembrane is free of deleterious materials prior to deployment, anchoring is achieved as specified, specified methods are used to minimize wrinkles and protect underlying layers during cuttingof materials, and deployment procedures are performed in compliance with the project scopeof work.

The **Installer** shall submit a detailed proposal on the methods he proposes to use for installation of the geotextile products. These methods shall be reviewed and accepted beforeany deployment and installation will commence. Some of the aspects to be ensured by the **Installer** and verified by the **CQA Monitor**, include:

- Placement of the geotextiles on slopes and basins without disturbance or damage to underlying layers;
- Equipment and procedures used to place the geotextiles;
- Placing of geomembrane, protection to the overall barrier system in accordance with the Designs, on top of the protection geotextiles without damaging or disturbing the geotextile;
- Rate of installation; and
- Relevant workforce certification.

When the geotextile is to be placed directly beneath a geomembrane as a protection layer, the subgrade surface to receive the geotextile shall meet the requirements for geomembrane installation as outlined in section 6.3.2.3. Immediately prior to installation of the geotextile the underlying surface or geomembrane shall be inspected by the **CQA Monitor**, **Installer** and **Contractor**, to confirm that it is in a condition to safely accept the geotextile on top of it. The **CQA Monitor**, **Installer** and **Contractor** shall sign acceptance of the surface condition of the underlaying layer.

The **Installer** shall ensure and the **CQA Monitor** shall verify that field panels are placed one at a time, and each field panel is seamed (heat bonded or single thread chain stitched) immediately after placement to the adjoining panel (in order to minimise the number of unseamed panels). Installation and seaming shall not take place in wet weather or in the presence of blowing dust,

or strong winds.

During installation, the **Installer** shall ensure and the **CQA Monitor** shall verify the following:

- Any equipment used shall not damage any of the liner components by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means;
- Any subgrade immediately underlying the protection geotextile is clean and free of debris;
- All personnel working on the geomembrane or geotextile shall not smoke, wear damaging shoes, or engage in any activities which could damage any of the geosynthetic components;
- The method used to unroll the panels must not cause folds in the geotextile and must not damage the underlying subgrade;
- The method used to place the panels shall minimise wrinkles (especially differential wrinkles between adjacent panels);
- Adequate temporary loading and/or anchoring (e.g., closed UV stabilised sandbags (containing no material exceeding 3mm) (SANS 10409), tyres (ASTM D6270-17)), which will not damage the geotextile, must be placed to prevent uplift by wind;
- When geotextile is being installed, adequate care should be taken to ensure no unwanted objects are found underneath the lining system; and
- It should be ensured that trimming of the geotextile is done by an upward pointing cutting hook blade or similar approved by the Engineer or CQA Monitor.

Each geomembrane and geotextile layer shall be inspected by the **CQA Monitor**, **Installer** and **Contractor**, for damage after placement, prior to seaming. Damaged areas shall be marked, removed and repaired in accordance with the specifications. The locations of repaired sections shall be recorded in the quality control documentation.

Rolls shall be laid flat, on the subgrade without folds or wrinkles, with a minimum overlap of 150 mm in both longitudinal and transverse directions.

No vehicular traffic shall be allowed on the installed geotextiles and walking on the geotextilesmust be kept to an absolute minimum. Acceptable installation therefore may be accomplishedsuch that the geotextile is unrolled in front of backward moving equipment (only if the equipment does not result in a damaged surface). If the installation equipment causes ruttingof more than 25mm to the sub-grade, the sub-grade must be restored to its original acceptedcondition before placement continues.

Care must be taken to minimise the extent to which the geotextile is dragged across the subgrade in order to avoid damage to the geotextile and/or the underlying subgrade.

Seams

The **CQA Monitor** shall verify sufficient overlap, that the specified seam procedures were followed in compliance with the project specification. Seaming of field panels shall be done only under suitable conditions.

The **Installer** shall ensure and the **CQA Monitor** shall verify the following:

- Field seams should be oriented up/down the line of maximum slope. In corners and odd-shaped geometric locations, the number of seams should be minimised;
- No horizontal seams should be less than 1.5 m from the toe of the slope or areas of potential stress concentrations, unless otherwise authorised;
- When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel is cut at an angle of 45 degrees;

- Seaming of field panels shall be carried out by means of overlapping the two adjoining sheets of geotextile by a minimum of 300 mm and heat bonding or single thread chain stitching the geotextiles together;
- Prior to seaming, the seam area is to be clean and fee of moisture, dust, dirt, debris of any kind, and foreign material; and
- Seaming shall not take place in excessively high temperatures or at ambient temperatures below 0°C. In all cases, the geotextile sheets shall be dry and protected from the wind.

Repairs

Any repairs shall be in accordance with the **Manufacturer's** instructions, scope of work and subject to verification and approval by the **CQA Monitor**. Typically, geotextiles are to be repaired by applying patches, with a minimum of 300 mm overlaps in all directions around thedamaged area and heat bonded. The repair seam should be the same seam direction as damaged geotextile.

Protection

The **CQA Monitor** shall observe and document that all materials placed on top of the geosynthetics are done in such a manner as to ensure that the geosynthetics and underlying materials are not damaged.

7.2.4 Geocells

This specification covers geocells made from high density polyethylene (HDPE) strips which are joined together by the manufacturer at intervals such that when opened in the field form a honeycombed structure which is subsequently filled with soil, stone or concrete.

Specifications

The supply and installation of the geocells will be according to the following specifications and codes of practice (these specifications are available at the **Contractor's** expense from relevant companies. The **Contractor/Installer/CQA Monitor** should ensure that the newest revisions/edition is used):

- ASTM Standards
  - D 792 - Specific Gravity (Relative Density) and Density of Plastics by Displacement
  - D 1004 - Test Method for Initial Tear Resistance of Plastics Film and Sheeting
  - D 1238 - Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
  - D 1505 - Test Method for Density of Plastics by the Density-Gradient Technique
  - D 1603 - Test Method for Carbon Black in Olefin Plastics
  - D 3895 - Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
  - D 4218 - Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
  - D 4833 - Test Method for Index Puncture Resistance of Geotextiles,
  - Geomembranes and Related Products
  - D 5596 - Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
  - D 5721 - Practice for Air-Oven Aging of Polyolefin Geomembranes
  - D 5885 - Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry

- D 6693 - Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- D 7238 - Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus

- GRI Standards
  - GS13 - Guide for Geomembrane-Related Geocell Seam Strength and Its Efficiency with Respect to the Perforated Sheet Strength
  - GS14 - Test Method for Average Wall Thickness of a Geomembrane- Related Geocell by Indirect Measurement
- EPA Standards U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

Geocells materials conformance

This specification covers geocells made from high density polyethylene strips with a formulated sheet density of 0.940 g/cc, or higher. Density can be measured by ASTMD1505 or ASTM D792. If the latter, Method B is recommended.

The polyethylene resin from which the geocell is made will generally be in the densityrange of 0.932 g/ccor higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

The resin shall be virgin material with no more than 25% rework. If rework is used, it must be a similar HDPE as the parent material.4.4No post consumer resin (PCR) of any type shallbe added to the formulation.

The **CQA Monitor**, prior to installation, shall obtain samples of the relevant geocells for conformance testing to confirm that these materials meet project requirements. One set oftests will be carried out at commencement, and as directed should the materials supplierschanged.

The geocell walls, being made from HDPE strips shall conform to the test propertyrequirements prescribed in Table 3.

Table 3: Geocells made from High Density Polyethylene Strips

Test Properties	Test Method	Test value	Testing Frequency (minimum)
Wall thickness (Nominal –10%)	GRI-GS14	1.25mm	Per bundle
Density (min. ave.)	ASTM D 1505/D792	0.94 g/cc	90 000 kg
Seam Efficiency (min. ave.)	GRI-GS13	100%	9 000 kg
Tensile Properties (min. ave.) *(1)* ○ yield strength ○ break strength	ASTM D6693 Type IV	 18 kN/m 13 kN/m 12%	9 000 kg

○ yield elongation ○ break elongation		100%	
Tear resistance (min. ave.)	ASTM D1004	155N	20 000 kg
Puncture Resistance (min.ave.)	ASTM D4833	330N	20 000 kg
Direct shear friction angle (4)	ASTM D5321	30º	20 000 kg
Carbon Black Content(range) (2)	ASTM D4218	2-3%	9 000 kg
Carbon Black Dispersion (3)	ASTM D5596	Note 5	20 000 kg
Oxidative Induction Time(OIT) (min. ave.) (5) (a) Standard OIT —or — (b) High Pressure OIT	 ASTM D 3895 ASTM D5885	 100 min. 400min.	90 000 kg
Oven Aging at 85ºC (5) (a) Standard OIT (min. ave.) - % retained after 90 days —or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	 55% 80%	Per formulation
UV Resistance (6) (a) Standard OIT (min. ave.) —or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (8)	ASTM D7238 ASTM D3895 ASTM D5885	 N.R. (7) 50%	Per formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction.
- Yield elongation is calculated using a gage length of 33 mm
- Break elongation is calculated using a gage length of 50 mm
(2) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category3
(4) Actual geocell strip against well graded sand
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) The condition of the test should be 20 hr. UV cycle at 75ºC followed by 4 hr. condensation at 60ºC.
(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Packaging, Labelling, Transportation, Unloading and Storage

The factory fabricated geocell shall be bundled according to their heights using polymer strapping or sturdy rope such that damage does not occur during handling or shipment to theproject site.

Labelling of geocell bundles shall be consistent with the manufacturers quality manual but must include the product name, manufacturer, location made and specification followed.

Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

7.2.5 Cuspated Drainage Sheets

During cuspated drainage sheet installation, the **CQA Monitor** shall observe and document deployment, overlaps, field seaming, and repairs to assess that the installation is in compliance with the SCOPE OF WORK.

Specifications

The geosynthetic cuspated drainage core shall consist of a Pure High Density Polyethylene (HDPE) incorporating an evenly dispersed carbon black content as well as time proven Ultra Violet stabilisers and anti-oxidants. Reprocessed or reground materials shall not be used. Specifically, the GCDC shall have the following components and properties:

- The unit mass of the GCDC shall be approximately 700 g/m2;
- The overall core thickness (uncompressed) shall not be less than 4.3 mm;
- The thickness under 200 kPa at 10 000 hrs shall not be less than 3.5 mm;
- The compressive yield strength shall not be less than 900 kPa;
- The uncompressed cusp height shall not be less than 3.5 mm;
- The in-plane water flow at 200 kPa vertical pressure shall not be less than 0.38 l/m.s at a hydraulic gradient of 1.0; and
- Carbon black shall be between 0.8 and 2.5%.

Cuspated Drainage Sheet Materials Conformance

Not required.

Deployment

The **CQA Monitor** shall verify that the installed geomembrane is free of deleterious materialsprior to deployment of the cuspated drainage sheet, anchoring is achieved as specified, specified methods are used to minimize wrinkles and protect underlying layers during cuttingof materials, and deployment procedures are performed in compliance with the project SCOPEOF WORK. In particular, the **CQA Monitor** shall verify that the cuspated drainage sheets areinstalled with the cusps facing upwards to receive the primary HDPE geomembrane.

Seams

The **CQA Monitor** shall verify sufficient overlap and that the specified seam procedures were followed in compliance with the project SCOPE OF WORK.

Repairs

The **CQA Monitor** shall verify that all repairs are performed in compliance with the SCOPE OF WORK.

Protection

The **CQA Monitor** shall observe and document that all materials placed on top of the installed cuspated drainage sheets are done in such a manner as to ensure that the geosynthetics and underlying materials are not damaged.

7.3 HDPE Pipe And Fittings

During high-density polyethylene (HDPE) pipe installation, the **CQA Monitor** shall observe and document that the installation is in accordance with the Construction Specifications.

Placement

Observation that the handling procedures used do not damage the pipe, backfill is placed in accordance with the requirements of the Construction Specifications so as not to damage thepipe, any foreign material is removed from the interior of the pipe, and indentations on the pipeare within the allowable limits.

Joints and Connections

Monitoring of the jointing and connection operations to verify that the Installer follows the Construction Specifications and the pipe Manufacturer's recommendations, verification that the pipes are clean when installed, and that perforated sections of pipe are aligned properly prior to connection.

Non-destructive Testing

Observe any required testing of the pipe to verify accordance with the Construction Specifications.

8. DOCUMENTATION

8.1 Daily Record Keeping

The **CQA Monitor** shall keep daily records consisting of field notes, observation and testing data sheets and reporting of construction problems and resolutions.

8.2 Soils Observation and Testing Data Sheets

Soils observation and testing data sheets generally include the following information:

- Date, project name, location, and weather data;
- A reduced-scale site plan, or full-scale plots, showing work areas and test locations;
- Descriptions of ongoing construction;
- Summary of test results and samples taken, with locations and elevations;
- Off-site materials received including quarry certificates;
- Test equipment calibrations, if necessary; and

- Signature or initials of the CQA Monitor.

8.3 Geosynthetic Observation And Testing Forms

The **CQA Monitor** shall work with the CQC personnel to document geosynthetic observationsand test results on forms which include the following information:

- Date, project name, location, and weather data;
- Identification of panel or seam numbers;
- Description of ongoing construction, detailing deployment areas;
- Numbering system identifying test or sample number;
- Location and identification of repairs and date of repair;
- Length and/or thickness measurements for geomembrane panels or seams;
- Welding machine temperatures and settings;
- Welding machine and technician identifications;
- Location of tests and test results;
- Identification of testing technicians and time of tests; and
- Signature or initials of the Engineer and CQA Monitor.

8.4 Construction Problem and Resolution Documentation

Any construction problem which cannot be resolved between the **Installer**, **contractor**, and **CQA Monitor** may require a special meeting in order to resolve the problem. The problem should be discussed with the **Project Manager**, **CQA Engineer**, and **Engineer** if a design issue is involved. Specific written documentation of that problem should be prepared, if warranted, and will generally include the following information:

- Detailed description of the problem;
- Location and cause of the problem;
- How and when the situation or deficiency was identified;
- How the problem was resolved;
- Any measures taken to prevent similar problems in the future; and
- Signature of the CQA Engineer and CQA Monitor.

Copies of all Construction Problem and Resolution correspondence will be submitted to the Project Manager.

8.5 Photo Documentation

The **CQA Monitor** shall photograph all phases of construction. A log of photographs shall bekept including information such as location, time, date and name of the person taking the photograph.

8.6 Design And Specification Changes

During construction, the need to address design and specification changes, modifications, or clarifications may arise. In such cases the **CQA Monitor** shall inform the **Manager** who shall notify the **Engineer**. Design and specification changes shall only be made with written agreement from the **Engineer**.Construction Completion Report

8.7 Construction Completion Report

At the completion of the project, the **Engineer** and the **CQA Monitor** shall submit to the **Manager** and the Regulatory authority a Construction Completion Report. This report shall certify that the work has been performed in compliance with the design DRAWINGS and project scope of work and will contain the following information:

- Summary of all civil related activities;
- Summary of all liner construction activities;
- Test data sheets;
- Photographic documentation;
- Details of CQA procedures adopted;
- Summaries of all QC and CQA testing;
- Earth works QC documents;
- Concrete works
- Geosynthetic QC documents;
- Liner installation observations, such as for deployment, trial seams, defect repair, destructive testing and non-destructive testing;
- Details of defects and repairs carried out;
- Sampling, testing locations, and test results;
- Changes to the design DRAWINGS or project scope of work and the justification for these changes;
- Record drawings (eg sheet layouts); and
- A statement that the geosynthetic liner system was installed in compliance with the DRAWINGS, scope of work and agreed quality assurance and control procedures.

_____

CQA Engineer

APPENDIX G2

TECHNICAL SPECIFICATIONS



10 June 2025

Rietfontein Plant

DETAILED ENGINEERING DESIGN OF SWMP AND PCD

TECHNICAL SPECIFICATIONS

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APPENDIX A.....DETAILED LIST OF STANDARDS

1. INTRODUCTION

MineLock Environmental Engineers (Pty) Ltd (MineLock) was appointed by Rustenburg Chrome Mine (Pty) Ltd (RCM) to provide a Technical Engineering Design of the Storm Water Management Plan (SWMP) of Rietfontein Plant to support their Water Use License Application (WULA). The Technical Specifications document is developed for the submission of the Water Use License application process.

2. STANDARDS AND SPECIFICATIONS

2.1 Applicable standards for health and safety

The following standards shall form part of the Contract document even though it is not issued with this document:

- MHS Act
- OHS Act

2.2 Applicable standards

The latest versions of specific sections of the following Standard Specifications for Civil Engineering Construction shall form part of this Contract. These specifications are available from the relevant companies, at the Contractor's expense. Refer to Appendix A for detailed list of standards.

- SANS 1200 or 2001
- SANS 10409 2020 (Second Edition)
- ASTM Specifications applicable to Geomembranes and Geotextiles
- Applicable GRI-GM 19 Specifications

In addition, the following Project Particular Specifications shall apply:

- PS GM: Geomembrane Liners
- PS GT: Geotextiles
- PS GD: Cuspated Drains/Drainage Cores
- PS GC: Geocells

2.3 Variations and additions to SANS 1200

This specification document is based on the South Africa National Standards 1200 Series specification. The aim of this specification is to specify certain details and features not fully covered in and to amplify and add to the requirements of the relevant paragraphs in the SANS 1200 series. The paragraph numbering from SANS 1200 was followed in this specification. The modifications, deletions, amplifications and additions specified in this specification will supersede the requirements of the relevant paragraphs in SANS 1200.

2.3.1 PSAA: GENERAL (SMALL WORKS) (SANS1200AA)

PSAA 1: Plant (Clause 4)

PSAA 1.1: Contractor's office and stores (Subclause 4.1)

a. Facilities required

The Engineer will not require any facilities, except the use of an office with electricity, ablutions, and an office for site meetings.

b. Site Instruction books

Three carbon triplicate books shall be supplied, throughout the contract period, by the Contractor as Site Instruction books.

The Engineer will use the first book on site to write day-to-day instructions and confirm any verbal information or instructions given to the Contractor.

The Contractor's staff will use the second book to provide the Engineer with any information regarding the construction of the Works which may be requested and/or for giving notification in writing as required by any of the relevant clauses of the General Conditions of the Contract.

The Contractor shall use the third book as a daily diary and shall record weather, changes in site staff and equipment, brief description of work, critical material deliveries, visitors and any other pertinent information. The Engineer shall add any notes or comments. The Engineer and Contractor shall then sign that the information is correct.

At least one copy of each site note issued by either party shall remain in the books. The books shall be mutually accessible.

PSAA 2: Ground and access to Works (Subclause 5.5)

Notwithstanding Subclause 5.5, the Contractor shall maintain access for other parties to the site, where practicable. Other parties may include employees of the Employer or other contractors.

2.3.2 PSC: SITE CLEARANCE (SANS1200C)

PSC 1: Disposal of material (Subclause 3.1)

Material obtained from clearing and grubbing shall be stockpiled at designated areas on the site. Unless otherwise indicated on the Engineer's drawings or ordered by the Engineer in writing.

2.3.3 PSD: EARTHWORKS (SANS 1200D)

PSD 1: Classes of excavation (Subclause 3.1.2)

With regard to plant specified in subclause 3.1.2, and other plant (see subclause 4.1), the Engineer will decide on site as to the classification of materials based on its removability as described in subclause 3.1.1.

PSD 2: Selection (Subclause 3.3.1)

The Engineer shall direct, if the nature of the excavated material so requires, that certain portions of the excavated material be placed only in specific sections of the works. The Contractor will not receive additional payment for such selection.

PSD 3: Special water control (Subclause 5.1.3)

Surface water will be controlled by adequate temporary drains in and around the excavations. The Contractor shall provide these adequate temporary drains. These drains shall be self-draining or, alternatively, they shall lead to sumps equipped with pumps.

It is the responsibility of the Contractor to avoid quagmire conditions due to over trafficking. Correcting this condition would be at the Contractor's own expense.

The cost of supplying equipment for dewatering and all measures for dewatering of excavations and controlling of storm water, while construction is taking place, such as temporary sumps, pipe work, etc., will be deemed to be included in the rates for site clearance, bulk and restricted excavation for maintaining the facilities and no separate payment will be made for this work.

PSD 4: Construction

PSD 4.1: Excavation (Subclause 5.2.2)

The Engineer's approval of the suitability of the in-situ material shall be obtained, after site preparation as described in subclause 5.2.1 and before placing any fill material.

Where excavated material, which is designated as suitable fill material, becomes contaminated or is mishandled or misplaced by the Contractor, he/she shall remove the contaminated material and/or replace the shortfall with suitable material at his/her own expense.

PSD 4.2: Excavation for working space (Sub-clause 5.2.2 (b) and (c))

No concrete shall be placed against the sides of excavations, other than for the sides of strip and pad footings or where specifically authorised by the Engineer.

The Contractor shall over excavate external concrete faces below ground-level (other than concrete placed against the sides of excavations as above) to provide sufficient working space for the erection of formwork.

Tenderers shall allow in their rates for excavation for any over excavation required for working space.

No additional payment shall be made for working space. Excavation volumes for structures will be calculated as the net volume of the structure below ground level after general site excavations have been completed.

PSD 4.3: Over-excavation to sides of excavations (Sub-clause 5.2.2(3))

Where the sides of excavations are over-excavated to establish safe slopes, provide access to excavations, or for other purposes not specifically required by the Engineer, such over-excavation shall be backfilled with material as required by the Engineer and compacted to a minimum density of 93% mod AASHTO. No separate payment will be made for this work.

PSD 5: Disposal (Sub-clause 5.2.2.3)

Where material is carried to spoil or to fill low areas, filling shall be done, unless otherwise specified, generally in accordance with sub-clause 5.2.3.1 except that compaction requirements will be relaxed. In such cases, each layer of material deposited shall be compacted by spreading with earthmoving equipment and by routing construction traffic such that the whole of each layer is traversed by heavy equipment.

PSD 6: Negligence (Subclause 5.1.2.5)

The Contractor shall be liable for all damages howsoever caused to services or buildings which form part of this Contract.

PSD 7: Borrow Pits (Subclauses 5.2.2.2 and 5.2.3)

The Contractor shall make his own arrangements for the importation of material of a specified quality, when and if required, from borrow pits outside the Contract Site. Unless off-site borrow pits are shown on the Engineer's drawings or are designated by the Engineer at tender stage.

All arrangements regarding any permissions and permits required for excavating this material shall be made by the Contractor.

PSD 8: Transport for Earthworks (Subclause 5.2.5.1)

Free haul shall be regarded as all haul within a radius of 1 km from the boundary of the site of the Works.

PSD 9: Material of compaction standard not to specification (Subclause 7.3)

To ascertain compliance with the specifications, the Engineer shall have free access to the site and will undertake inspections of the work in progress. The Contractor shall be prepared at any time to demonstrate such compliance. He will be required to establish conformity to line, level, cross-section and tolerance by the use of straight-edge, tape, level, etc.

The Engineer may also require additional tests to those specified. The costs will be met by the Employer, where such additional tests prove compliance with the specification. Where such tests fail, the costs to remedy the failure and the costs of the tests shall be met by the Contractor.

PSD 10: Measurement and Payment

PSD 10.1: Restricted excavation

The volume of restricted excavation shall be calculated from the net plan dimensions and the difference between the original ground profiles, and the blinding layer levels shown on the drawings. If the Contractor decides to form terraces first and to execute restricted excavation for the relevant structure from the final formed level, no additional payment for the restricted excavation shall be done except for restricted excavation in undisturbed in situ material.

PSD 10.2: Over-excavation

No separate payment will be made for over-excavation as defined in PSD 4.2 and PSD 4.3.

2.3.4 PSGA: CONCRETE (SMALL WORKS) (SANS1200GA)

PSGA 1: Materials (Clause 3)

PSGA 1.1: Cement storage (Sub-clause 3.2.2)

Without the Engineer's permission, cement shall not be kept in storage for longer than eight weeks.

PSGA 1.2: Concrete with reactive aggregates (Sub-clause 3.2 and 3.4)

Aggregates which are reactive with Portland Cement shall not be used.

PSGA 1.3: Plums (Sub-clause 3.4.2)

The use of plums shall not be permitted.

PSGA 1.4: Admixtures

Admixtures may only be used with the prior approval of the Engineer.

PSGA 2: Construction (Clause 5)

PSGA 2.1: Cover (Sub-clause 5.1.3)

Unless stated otherwise in the drawings, the minimum cover to reinforcement shall be 50 mm.

PSGA 2.2: Spacers reinforcement

Spacers of approved design include approved plastic or other proprietary spacers, or purpose made precast mortar blocks. Where mortar blocks are used, they shall be properly shaped so as not to slip out of position. Mortar blocks shall be made of the same mix as the mortar of the concrete in which they are to be placed.

PSGA 2.3: Formwork and finishes (Sub-clause 5.2)

PSGA 2.3.1: Formwork ties

Where sleeves are used through the concrete for formwork ties, such sleeves are to be removed prior to grouting up of resulting holes.

Ties, when cast in, shall have some form of positive shear key to prevent any rotation when loosening formwork. The formwork ties and bolt holes shall be placed with regularity and precision.

PSGA 2.3.2: General

Degree II shall be the general degree of accuracy.

PSGA 2.4: Fillets and chamfers

Unless shown otherwise on the drawings, all internal and external angles in concrete works shall have 20 mm x 20 mm fillets and chamfers with the exception of the top edges of slabs that are to receive applied finishes. This edge shall not be chamfered. The cost of forming these chamfers and fillets shall be covered in the tendered formwork unit rate.

PSGA 2.5: Strength and concrete (Sub-clause 5.4.1.5.)

All concrete for the Works shall be considered to be strength concrete in terms of Sub clause 5.4.1.5. with the exception of mixes weaker than 15 MPa.

All structural concrete shall have a strength of 30 MPa. Unless otherwise specified on the drawings or in the Bill of Quantities.

PSGA 2.6: Concrete surfaces (Sub-clause 5.4.8)

PSGA 2.6.1: Wood-floated finish

The surface shall first be struck off and tamped to bring mortar to the surface, where wood floating is ordered or scheduled. After the concrete has hardened sufficiently, it shall be wood-floated, either by hand or machine, only sufficiently to produce a uniform surface free from screed marks.

PSGA 2.7: Repair of defects

As soon as possible after the formwork is removed all defects to the concrete shall be attended to, in full. The Engineer may prohibit further concreting of the element concerned until he is satisfied that this remedial work has been satisfactorily attended to.

2.4 Project particular Specifications

2.4.1 PS GM: GEOMEMBRANE LINES

PS GM: Geomembrane liners

The supply and installation of the geomembrane liners in this Specification is based on the SANS 10409:2020 Code of Practice for the Design, Selection and Installation of Geomembranes.

PS GM 1: Scope

This specification covers the work involved in the geomembrane component of the project. It covers the supply of all materials, handling, installation and testing of the liners.

PS GM 2: Supporting Specifications

The publications in Appendix A form part of this specification to the extent referenced. Where a particular publication is referred to, that publication shall, unless otherwise stated, be the edition in effect thirty (30) days prior to the date of issue of this specification. Any contradictions between publications shall be submitted to the Engineer for decision.

The specifications in Appendix A contain clauses that are generally applicable to the manufacture, supply and installation of geomembrane liners.

PS GM 3: Materials

PS GM 3.1: Geomembrane liners

The HDPE material supplied for the geomembrane liners shall comply with the minimum property specifications as contained in GRI-GM13 Table 2(b) (SI Metric Units).

The geomembrane liner is to have a nominal thickness of either 2.0 mm or 1.5 mm as specified on the drawings, and shall either be textured or smooth as specified in the drawings, with the textured having a minimum asperity height of 0.4 mm as measured per ASTM D7466.

The geomembrane liner materials shall comply with the requirements of SANS 1526 for Geomembranes. It shall consist of a Pure High Density Polyethylene (HDPE) incorporating an evenly dispersed carbon black content as well as time proven Ultra Violet stabilisers and anti-oxidants. Reprocessed or reground materials shall not be used.

PS GM 3.2: Materials certification

The material of the geomembrane shall comply with the requirements of SANS 1526, and with any deviations listed in the project specification and which have been agreed upon between the geomembrane supplier, the client and the engineer. A geomembrane with the specified properties shall be supplied and installed. Before installation of the liner, the supplier shall provide written confirmation, with supporting documentation, that the geomembrane supplied complies with the specifications. The engineer may decide to take samples of the material at the place of manufacture, or after delivery to site (or both), for independent testing purposes.

PS GM 3.3: Materials general

The physical and chemical characteristics of the geomembranes and their jointing systems must be such that the integrity of the geomembranes is maintained during construction and shall have at least a hundred-year service life. As such the geomembranes shall be resistant to degradation as a result of the temperature and chemical characteristics of stored product, sunlight, ultraviolet rays (oxidation), ozone, airborne pollution, and weathering.

The geomembrane liners are to be supplied to site in panels no less than 6.5 m wide to minimise the number of site welds required. If necessary, factory-controlled welding is to be carried out to attain the required minimum width, which should be tested according to ASTM D7982.

PS GM 4: Packaging, Transportation, Unloading and Storage

The products shall be packaged, transported, unloaded and stored in accordance with the manufacturer's instructions, or as per ASTM D7865-13, whichever is directed by Engineer.

PS GM 4.1: Labelling, packaging and transportation

The procedures for geomembrane delivery to site shall include the following:

- the delivery and storage on site shall be as in accordance with the manufacturer's recommendation and ASTM D4873;
- the geomembrane rolls shall be delivered in one of the following ways:
  - the container shall be unpacked off site and the rolls transported to site; or
  - the container shall be delivered and unpacked on site,
- due care and attention shall be given to ensuring that no mechanical damage occurs during transportation to site, protection being provided, for example, in the form of end-caps and protective layers around rolls;
- wherever possible, supervision shall be provided during all handling operations;
- the material shall be stored in a secure and protected area at all times;
- the engineer or his representative shall be present, whenever possible, to observe the material delivery and unloading on site and shall note details of any material received in a damaged state;
- verify that storage of materials ensure adequate protection against dirt, theft, fire, environmental influences, vandalism and passage of vehicles, and take corrective action as necessary;
- ensure that rolls are properly labelled and that labelling corresponds with MQC documentation; and
- record details of complete roll numbers, batch numbers, roll size and any damage on the material delivery checklist in accordance with annex B.

Upon his arrival on site, the installation contractor shall:

- verify that all equipment used on site is suitable for its purpose and does not risk damage to the geomembrane or the substrate; and
- mark rolls which appear damaged, if this has not already been done by the engineer (see 9.2.1(f) - SANS 10409:2020 Edition 2).

Geomembrane rolls shall each be labelled on the surface of the package. Labels should be resistant to fading and moisture degradation such that they are legible at the time of installation. Labelling should include the Manufacturer's name, product identification, roll number, batch/lot number, roll dimensions and weight of the roll.

All documentation (including test results), stipulated in the tender document and confirming compliance with MQC and MQA procedures shall be provided by the installation contractor to the engineer before delivery of the geomembrane to the site.

PS GM 4.2: Unloading

Before off-loading on site, the contractor must ensure that the off-loading equipment is adequate for handling the geomembrane rolls without any risk of damaging them.

The area where the geomembrane is to be off-loaded and stored must have a smooth well-drained surface, free of rocks or any other protrusions which may damage the material. After

off-loading, the contractor shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The contractor shall inform the Engineer and the manufacturer of any defects or damages. Repairs shall be made subject to approval by the Engineer, otherwise damaged rolls shall be replaced at the contractor's cost.

PS GM 4.3: Storage

A designated storage area shall be established in a relevant location such that on-site transportation and handling are minimised. The storage area should be prepared as specified in PS GM 4.2, protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined.

If relocation of liner rolls is necessary, the area should also be prepared in the same manner as PS GM 4.2. The geomembrane rolls shall be stored lying flat and continuously supported above ground.

PS GM 5: Plant

The Contractor shall provide all tools necessary to ensure a high level of workmanship.

PS GM 6: Construction

The geomembrane installation shall generally be carried out in accordance with the requirements of SANS 10409.

PS GM 6.1: Installation

A detailed proposal shall be submitted with the contractor's tender on the methods he proposes to use for installation of the geomembrane products. Some of the aspects to be covered include:

- Rate of installation.
- Relevant workforce certification.
- Equipment and procedures used to place the geomembrane.
- Placement of the geomembrane without disturbance to the layer being installed or any underlying layers.
- Placing of geomembrane should be such that no damage is incurred, by any means, to the underlying geotextile.

Immediately prior to installation of the geomembrane lining, the subgrade surface shall be inspected by the Engineer, the Contractor and the Lining Sub-Contractor, to confirm that it is in a condition to safely accept the geomembrane on top of it (as per SANS 10409:2020). The Lining Sub-Contractor shall sign acceptance of the surface condition of the subgrade.

- Signed surface acceptance shall only be valid for a specified period agreed upon by Engineer, Contractor and Sub-Contractor, before installation commences, as to maintain desired design specifications.
- The final surface layer shall be left smooth and dense and finished levels shall be correct to within + 30 mm as measured under a 3 m long straight edge.
- The area to be lined must be free of all protrusions, stones, roots, vegetation and other materials which may be detrimental to the performance of the liner. On the surface to be lined, a maximum particle size of 3 mm diameter is permissible.

- The earthworks contractor shall be responsible to protect the subgrade from storm water damage.

Field panels are to be located in a manner consistent with the specification and best suited to the design layout. A floor plan clearly showing the intended layout of the geomembrane, including orientation of panels and positions of seams should be submitted prior to installation commencing. Managing bridging or trampolining and thermal movement of the geomembrane (which can lead to stressed conditions), shall be addressed in the design and at the pre-construction meeting.

At the time of installation, each field panel or portion of a roll of geomembrane shall be given an “identification code”. Field panels are to be placed one at a time, and each field panel is to be seamed as soon as the new panel has the same surface temperature as the panels already installed. To minimise long term exposure and risk of wind uplift, the contractor should ensure that the panels laid out can be seamed within the same workday. The Lining Sub-Contractor shall record the roll number, panel number, location, panel size and date of installation of each geomembrane field panel. Exposed geomembrane should at all times be secured by means of sandbags.

Installation and seaming shall not take place in wet weather or in the presence of excessive moisture, blowing dust, strong winds and temperatures below zero.

During installation, the Lining Sub-Contractor shall ensure the following:

- Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.
- Rolls of the geomembrane shall be so positioned as to minimize the amount of handling required.
- When liner is being installed, adequate care should be taken to ensure no unwanted objects are found underneath the liner.
- The prepared surface has not deteriorated since the acceptance inspection and is still acceptable immediately prior to placement of the geomembrane.
- All personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any activities which could damage the geomembrane.
- Any equipment used shall not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means.
- The method used to place the panels shall minimise wrinkles (especially differential wrinkles between adjacent panels).
- The method used to unroll the panels must not cause folds in the geomembrane and must not damage the supporting soil surface.
- The geomembrane shall be temporarily weighted (e.g., closed UV stabilised sandbags (containing no material exceeding 3 mm) (SANS 10409:2020), tyres (ASTM D6270-17)) to prevent wind uplift from foreseeable and reasonable expected wind conditions. From deployment to full or partial handover of the geomembrane installation it shall be the responsibility of the liner contractor. Thereafter it shall be the responsibility of the client or as agreed at the pre-construction meeting.
- If sandbags are to be used, it shall be supplied and filled by the liner contractor with selected approved material made available on site by the client. Bags containing stones, or other sharp objects which might damage the membrane shall not be used. Care shall be taken with placement and movement of the weighting objects. These

shall not be dragged or dropped. The removal of sandbags shall be agreed at the preconstruction meeting and removed in such a way as not to damage the liner.

Deployment shall not be undertaken in the presence of excessive moisture, in an area of standing water, or during high winds. The following weather condition factors shall be taken into account when deploying field panels unless agreed to at the preconstruction meeting:

- Wind: Liners shall not be deployed with wind speed exceeding 20 km/h.
- Precipitation; Liners shall not be deployed during rainfall.

Each geosynthetic and geomembrane layer shall be inspected for damage after placement, prior to seaming. Damaged areas shall be marked, removed and repaired in accordance with the specifications. The locations of repaired sections shall be recorded in the quality control documentation. No vehicular traffic shall be allowed on the installed geomembranes.

PS GM 6.2: Seaming and Trial Seaming

In general, field seams should be orientated up/down the line of maximum slope. The number of seams should be minimised in corners and odd-shaped geometric locations. Unless otherwise authorised, no horizontal seams should be less than 1.5 m from the toe of the slope or areas of potential stress concentrations. When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel is cut at an angle of 45 degrees.

To produce a totally homogeneous seam, seaming of field panels shall be carried out by means of a continuous heat extrusion welding process, or an electric double wedge fusion welding process. Typically, continuous heat extrusion welding will be used for patching, T-joints and repairs, while electric double wedge fusion welding will be used for panel seaming. A seam numbering system compatible with the panel numbering system shall be established.

The extrusion welding apparatus shall be equipped with gauges giving the temperature at the nozzle and extruder barrel. The fusion welding apparatus must be automated device which produces a double seam with an enclosed space for pressure testing. The fusion welding apparatus must also be fitted with gauges giving the applicable temperatures and speed.

In excessively high temperatures where the air pressure channels begin to close, or where passing welds are unobtainable, seaming shall not take place. Similarly, in ambient temperatures below 0°C no seaming shall be attempted. In all cases, the geomembrane shall be dry and protected from the wind. Prior to seaming, the seam area is to be clean and free of moisture, dust dirt, debris of any kind, and foreign material.

Trial seams shall be made at the beginning of each seaming period (morning and afternoon) for each seaming apparatus used or if the seaming apparatus has been switched off for more than one hour. Trial seams shall be made on fragment pieces of the same geomembrane liner, that is installed, to verify that seaming conditions are adequate. The trial seam shall be approximately 1 m long by 300 mm wide, with the seam centred lengthwise. Trial seams shall be made under the same conditions as the actual seams.

Trial welds should be recorded with, but not limited to, the following information: Trial weld number, time, date, apparatus serial number, welder name, apparatus settings and ‘Pass’ or ‘Fail’. With continuous heat extrusion welding, ten specimens will be taken, of which 5 will be tested in shear and the remaining 5 will be tested in peal.With electric double wedge welding, ten specimens will be taken of which 5 will be tested in shear and the remaining 5 will be tested with peal on both sides (10 peal).

According to GRI-GM 1, all specimens shall meet the criteria for film tearing bond (FTB), i.e. the geomembrane must fail before the weld seam. Field seaming can commence only after

the Trial welds were deemed successful.

All seaming shall be performed 300 mm into the anchor trench. Field seams shall be made by overlapping adjacent sheets at least 75 mm for electric double wedge fusion welding and 30 mm for extrusion welding. Seams must be aligned with the fewest possible number of wrinkles and “fishmouths”. Where wrinkles or “fishmouths” are unavoidable, they shall be cut along the ridge of the wrinkle in order to achieve a flat overlap.

The cut wrinkles or “fishmouths” shall be seamed and any portion where the overlap is inadequate shall be patched with an oval or round patch of the same geomembrane, extending a minimum of 150 mm beyond the cut in all directions.

For electric double wedge fusion welding, a protective layer of plastic may be required to be placed directly below the overlapped membranes being seamed. Especially applicable when subgrade is damp or wet.

PS GM 6.3: Anchorage

As shown on the drawings, the outer edges of the geomembrane liners are to be anchored in the same anchor trench at the top of the slope, together with the other components of the lining system. To prevent stress concentrations on the geomembranes the front edge of the trench is to be rounded. The lining systems are to be placed in the trench such that they cover the entire trench floor, but do not extend up the rear trench wall.

The anchorage trench is to be backfilled and compacted in layers not exceeding 150 mm thick with selected material specified by the engineer or with cement stabilised soil as specified on the drawings. Care must be taken during backfilling of anchor trenches to prevent any damage to the geosynthetic lining components.

Mechanical anchoring: Due consideration shall be given to proper anchorage and sealing, where applicable, of the geomembrane to structures other than soil subgrades.

To minimise trampolining at the toe of the slope and the formation of wrinkles, backfilling of the anchor trench should be carried out during the cool of the morning or extended period of overcast skies. It is also recommended to place sand bags, or similar, on the material at the toe to decrease trampolining.

PS GM 6.4: Slope stability

All slopes shall be designed after consideration of the shear strength in accordance with ASTM D5321 and interface friction of the site specific materials to be used. A performance specification shall be provided by the engineer based on the interface test results when required.

Global and veneer slope stability analyses shall be undertaken. An analysis shall include consideration of the consequences of the geomembrane's leaking and, in certain circumstances, the effects of wave action. Established principles of design of water reservoirs shall be observed where appropriate. A suitable factor of safety shall be demonstrated.

At no time shall the geomembrane be relied upon to act as a structural component of the system unless it has been specifically designed for such an application.

The engineer shall specify the direction of construction of liner elements on the side slope.

PS GM 6.5: Compaction

The geomembrane shall not be used as a structural component (except as in (c) - SANS 10409:2020 Edition 2). It is therefore a prerequisite that all supporting surfaces be compacted

according to engineers design specification. Settlement shall be considered in the design.

Great care shall be taken when compacting around structures in, or protruding through, the supporting surface, to avoid differential settlement. Site-specific compaction requirements shall be determined by the engineer.

PS GM 6.6: Design of protection against mechanical damage

Where there is mechanical plant working in the lined area, or in the vicinity of the geomembrane, a suitable protection method for the membrane shall be specified by the engineer, for example, a sand/cement or concrete screed, suitably filled geocells or an interlocking block system may be placed on the lined area covering the embankments and the berm.

Where such a protective covering is placed on the geomembrane, it may be necessary to introduce an intermediate protective layer, such as a suitable geotextile or sand layer, before application of the top protective layers.

Where such protective covering is placed the engineer shall specify a maximum production rate for surface preparation, liner installation and covering installation.

PS GM 7: Ground water

The potential for lateral or vertical movement (or both) of ground water shall be considered. The earthworks shall be free of surface water during geomembrane installation. If ground water is likely to be present, a suitable drainage system shall be provided to ensure that flotation of the geomembrane will not occur.

PS GM 8: Prevention of gas formation, and provisions for venting

Entrapment of gases under the geomembrane shall be prevented. To this end, all vegetation in the area to be covered shall be removed and, where necessary, a suitable weed killer applied. Where this cannot be done, or where there are significant fluctuations in the ground-water table below the structure, or where the possibility of gas collection cannot be excluded for other reasons, a suitable means of collecting and managing any gas or air build-up under the geomembrane shall be incorporated in the design and installation.

PS GM 9: Dissipation of inflow energy

a) Where liquid will continuously flow onto the geomembrane, the use of suitable energy dissipaters, for example, a concrete slab or suitable sacrificial layer, shall be considered.
b) Embankment crests shall be sloped away from the lined area to ensure that rainwater drains away from it.

PS GM 10: Tolerances

The required tolerances are as per the supporting specifications listed in this document.

PS GM 11: Testing and Construction Quality Control

PS GM 11.1: Construction quality control

A Construction Quality Assurance / Control Plan shall be supplied by the Contractor with his tender, which clearly indicates documentation ensuring compliance with the necessary material specifications, and control points requiring quality control checking during construction/installation. As a minimum, the Construction Quality Control Plan shall include the following:

- Method statement for liner installation at each area/facility.
- Project Quality Plan for each area that lists every activity with its associated work instruction/procedure, records, inspection requirements and signature requirements.
- All quality inspection sheets to be used.

It is strongly recommended that the Contractor uses a digital cloud-based software program for daily uploading of all CQC information for review/approval by the Engineer and/or the Employer.

PS GM 11.2: Materials conformance tests

The Contractor shall take samples of the geomembranes for conformance testing as per ASTM 4354, when instructed by the Engineer at the commencement of the liner installation.

Six samples, each 300 mm x 300 mm, are to be taken across the entire width of a roll of each geomembrane type, (1 sample per 10 000 m2) not including the first 1.5 m. The samples are to be marked with the machine direction, roll number on the sample, and date the sample was obtained. The samples are then to be sent to an accredited Geosynthetics testing laboratory where the following conformance tests are to be performed (according to the relevant ASTM standard test method), if applicable:

- Performance strength of geomembrane ASTM D4885
- Air-Oven Aging ASTM D5721
- Test Method for the Determination of Pyramid Puncture Resistance of Unprotected and Protected Geomembranes ASTM D5494
- Test Method for Initial Tear Resistance of Plastic Film and Sheeting ASTM D1004
- Ultraviolet Fluorescent Weatherometer GRI-GM11
- Density ASTM D1505
- Thickness ASTM D5199
- Tensile strength and elongation at break ASTM D6693
- Carbon black content ASTM D4218
- Dispersion of carbon black content ASTM D5596
- Test Method for Carbon Black in Olefin Plastics ASTM D1603
- Nominal thickness of Geosynthetic ASTM D5199

  Core thickness of textured sheets ASTM D5994

- Asperity height of textured sheets ASTM D7466
- Standard Test Method for Tensile Properties of Plastics ASTM D638
- Stress Crack Resistance (SP-NCTL) ASTM D5397
- Standard Oxidative Induction Time (OIT) ASTM D3895
- High Pressure Oxidative Induction Time (HP-OIT) ASTM D5885
- Specific Gravity Mass Comparison ASTM D792
- Melt flow index ASTM D1238

As measured in accordance with ASTM D5199, the thickness of geomembrane liner shall be a minimum nominal thickness. The thickness of the liner sheet received shall be confirmed by manufacturer supplied thickness conformance data.

PS GM 11.3: Air channel test

As per GRI-GM 6 and ASTM D5820 Electric Double Wedge Welds is tested non-destructively by inflating the space between the two wedge welds and maintaining a certain pressure for a predetermined period. All double wedge welded seams are to be tested.

PS GM 11.4: Peel test

This test determines the effectiveness of the weld by peeling the weld apart at a rate of 50 mm/min on a strip 25 mm wide cut perpendicular to the joint direction. An increasing force is applied to the two strips of membrane forming the joint. If one of the strips break prior to 25% separation across the weld it is considered acceptable. It should be noted that if any percentage of the separation reaches the air channel it is considered unacceptable, as per GRI-GM 19.

PS GM 11.5: Vacuum testing

This test should be done during operations as an indicator of the performance of the extrusion weld but will be confirmed with a spark test during independent quality assurance.

Vacuum testing should be performed as per ASTM D5641.This test creates a vacuum on one side of the joint. If a vacuum of minus 75 kPa can be maintained for three minutes the joint shall be considered effective. This test must be done where three or more sheets are lapped or where patching is done on straight runs at a rate of one test per 5 linear metres of welding.

PS GM 11.6: Destructive testing

The location of the samples will be taken as prescribed by the engineer. The specimen size and testing procedure will be similar to PS GM 6.2 in accordance with GRI-GM 29. Destructive testing should be performed every 150m of the seam length and/or as specified by the engineer (GRI-GM 14).

PS GM 11.7: Spark testing

If non-destructive spark testing will be performed on the seam, a wire is embedded in the weld during the extrusion process. Spark testing shall be carried out on all extrusion welded seams in accordance with the test method specified in ASTM D6365. All extrusion welded seams are to be spark tested.

PS GM 11.8: Electrical leak location testing

Electrical leak location testing should be performed as per the ASTM methods for bare geomembranes (ASTM D7002, D7703, D7240, D7953).

PS GM 12: Measurement and Payment

PS GM 12.1: Supply Geomembrane

Supply HDPE geomembrane liner including all jointing, trimming laps, anchoring and wastage (m^2) (specify geomembrane thickness).

This item includes the cost of all plant, labour, materials, customs requirements, shipment and transport to the relevant site, off-loading and storage at the permanent storage site as indicated by the Engineer and according to specifications or as detailed on the contract drawings.

PS GM 12.2: Install Geomembrane

Install HDPE geomembrane liner including all jointing, trimming laps, anchoring and wastage (m^2) (specify geomembrane thickness).

This item includes the cost of all plant, labour and materials required for the transporting from the permanent storage area to the position of installation, panel cutting, panel deployment, seaming, testing, any repairs required and any activity forming part of the installation for the geomembrane liner as detailed on the contract drawings.

This item also includes the cost of all plant, labour and materials required for the anchorage of the geomembranes according to the contract drawing details (excavation and backfilling measured elsewhere).

2.4.2 PS GT: GEOTEXTILES

PS GT 1: Scope

This particular specification covers the supply and installation of protection geotextiles to be installed as the protection layer at various aspects of the design.

PS GT 2: Interpretations

PS GT 2.1: Supporting specifications

The publications in Appendix A form part of this specification to the extent referenced. Where a particular publication is referred to, that publication shall, unless otherwise stated, be the edition in effect 30 (thirty) days prior to the date of issue of this specification. Any contradictions between publications shall be submitted to the Engineer for decision. The specifications in Appendix A contain clauses that are generally applicable to the manufacture, supply and installation of geotextile liners.

PS GT 2.2: Application

This specification contains clauses that are generally applicable to the manufacture, supply and installation of protection geotextiles.

PS GT 3: Materials

PS GT 3.1: Material conformance tests and Properties of protection geotextiles

The geotextiles to be used, as a protection layer, shall be a nonwoven, polyester or polypropylene geotextile. Specifically, the geotextile shall have the following components:

- The CBR static puncture strength (SANS 12236:13).
- The puncture resistance hole (SANS 13433:13).
- The trapezoidal tear strength (ASTM D4533).
- The unit mass of the geotextile (SANS 9864, ASTM D5261).
- The overall thickness (SANS 9863-1:13).
- The tensile strength (SANS 1525:13).

Other tests may include:

- ASTM D6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe.
- ASTM D7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent Condensation Apparatus.
- ASTM D4632 Test Method for Grab Breaking Load and Elongation of Geotextiles.
- ASTM D5035 Test Method for Breaking Strength and Elongation of Textile Fabrics (2” Strip Method).

PS GT 3.2: Materials certification

The Contractor shall submit documented certification that the geotextile materials to be supplied comply with the aforementioned specifications. This documentation shall be submitted to the engineer and any other relevant parties prior to any shipment of any materials to site.

PS GT 3.3: General

The purpose of the protection geotextile layer is to protect the overlaying geomembrane liner from mechanical damage during and after construction. The geotextiles are to be supplied to site in panels no less than 5.0 m wide to minimise the number of site joints required. The physical and chemical characteristics of the geotextiles must be such that the integrity of the geotextile is maintained throughout the life of the mine. As such the geotextiles shall be resistant to degradation as a result of the temperature (nominal) and chemical characteristics of the seepage, sunlight, ultraviolet rays, ozone, airborne pollution and weathering (ASTM D5970, ASTM D4355, ASTM D4594).

PS GT 4: Packaging, Transportation, Unloading and Storage

The geotextiles shall be packaged, transported, unloaded and stored in accordance with the Manufacturer's instructions or ASTM D4873 whichever is directed by Engineer.

PS GT 4.1: Labelling, packaging and transportation

The rolls of geotextile shall be packaged to protect them from mechanical damage during transportation and handling. The geotextile rolls must be delivered to the working area of the site in their original UV stabilised packaging. Immediately prior to deployment, the packaging is to be carefully removed without damaging the product.

Geotextile rolls shall each be labelled on the surface of the package. Labels should be resistant to fading and moisture degradation such that they are legible at the time of installation. Labelling should include the Manufacturer's name, product identification, roll number, batch/lot number, roll dimensions and weight of the roll.

PS GT 4.2: Unloading

The Contractor must ensure that the off-loading equipment is adequate for handling the geotextile rolls without any risk of damaging them before off-loading on site. The area where the geotextile rolls are to be off-loaded and stored must have a smooth well-drained surface, free of rocks or any other protrusions which may damage the product.

After off-loading, the Contractor shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Contractor shall inform the Engineer and the manufacturer of any defects or damages. Repairs shall be made subject to approval by the Engineer; otherwise damaged rolls shall be replaced at the Contractor's cost.

PS GT 4.3: Storage

A designated storage area shall be established in a relevant location such that on-site transportation and handling are minimised. The storage area should be prepared as specified in PS GT 4.2, protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined.

If relocation of geotextile rolls is necessary, the area should also be prepared in the same manner as PS GT 4.2. The geotextile rolls shall be stored lying flat and continuously supported above ground. The geotextile rolls must be covered to protect them from ultraviolet exposure

until they are installed.

PS GT 5: Construction

PS GT 5.1: Installation

A detailed proposal on the methods he proposes to use for installation of the geotextile products shall be submitted, by the Contractor, with his tender. Some of the aspects to be covered include:

- Placing of geomembrane, protection to the overall barrier system in accordance with the Designs, on top of the protection geotextiles without damaging or disturbing the geotextile.
- Rate of installation.
- Relevant workforce certification.
- Placement of the geotextiles on slopes and basins without disturbance or damage to underlying layers.
- Equipment and procedures used to place the geotextiles.

When the geotextile is to be placed directly beneath a geomembrane as a protection layer, the subgrade surface to receive the geotextile shall meet the requirements for geomembrane installation as outlined in PS GM 6.1.

Immediately prior to installation of the geotextile the underlying surface or geomembrane shall be inspected by the Engineer, the Contractor and the Lining Sub-Contractor, to confirm that it is in a condition to safely accept the geotextile on top of it. The Lining Sub-Contractor shall sign acceptance of the surface condition of the subgrade.

Field panels are to be placed one at a time, and each field panel is to be seamed (heat bonded or single thread chain stitched) immediately after placement to the adjoining panel (in order to minimise the number of unseamed panels). Installation and seaming shall not take place in wet weather or in the presence of blowing dust, or strong winds.

During installation, the Contractor shall ensure the following:

- Any subgrade immediately underlying the protection geotextile is clean and free of debris.
- All personnel working on the geomembrane or geotextile shall not smoke, wear damaging shoes, or engage in any activities which could damage any of the geosynthetic components.
- Any equipment used shall not damage any of the liner components by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means.
- The method used to unroll the panels must not cause folds in the geotextile and must not damage the underlying subgrade.
- The method used to place the panels shall minimise wrinkles (especially differential wrinkles between adjacent panels).
- Adequate temporary loading and/or anchoring (e.g., closed UV stabilised sandbags (containing no material exceeding 3mm) (SANS 10409), tyres (ASTM D6270-17)), which will not damage the geotextile, must be placed to prevent uplift by wind.
- When geotextile is being installed, adequate care should be taken to ensure no unwanted objects are found underneath the lining system.

- It should be ensured that trimming of the geotextile is done by an upward pointing cutting hook blade or similar approved by the engineer.

Each geomembrane and geotextile layer shall be inspected for damage after placement, prior to seaming. Damaged areas shall be marked, removed and repaired in accordance with the specifications. The locations of repaired sections shall be recorded in the quality control documentation. Rolls shall be laid flat, on the subgrade without folds or wrinkles, with a minimum overlap of 300 mm in both longitudinal and transverse directions.

No vehicular traffic shall be allowed on the installed geotextiles and walking on the geotextiles must be kept to an absolute minimum. Care must be taken to minimise the extent to which the geotextile is dragged across the subgrade in order to avoid damage to the geotextile and/or the underlying subgrade. Acceptable installation therefore may be accomplished such that the geotextile is unrolled in front of backward moving equipment (only if the equipment does not result in a damaged surface). If the installation equipment causes rutting of more than 25mm to the sub-grade, the sub-grade must be restored to its original accepted condition before placement continues.

PS GT 5.2: Anchorage

As shown on the drawings, the outer edge of the protection geotextile is to be anchored in the same anchor trench at the top and/or bottom of the slope, together with the other components of the lining system.

To prevent stress concentrations on the liner components the front edge of the trench is to be rounded. The geotextile is to be placed in the trench such that it covers the entire trench floor but does not extend up the rear trench wall.

The anchorage trench is to be backfilled and compacted in layers not exceeding 150mm thick, with selected material or with cement stabilised soil as detailed on the drawings.

PS GT 5.3: Seaming

In general, field seams should be oriented up/down the line of maximum slope. In corners and odd-shaped geometric locations, the number of seams should be minimised. No horizontal seams should be less than 1.5 m from the toe of the slope or areas of potential stress concentrations, unless otherwise authorised. When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel is cut at an angle of 45 degrees. Seaming of field panels shall be carried out by means of overlapping the two adjoining sheets of geotextile by a minimum of 300 mm and heat bonding or single thread chain stitching the geotextiles together.

In all cases, the geotextile sheets shall be dry and protected from the wind. Prior to seaming, the seam area is to be clean and fee of moisture, dust, dirt, debris of any kind, and foreign material. Seaming shall not take place in excessively high temperatures or at ambient temperatures below 0°C.

PS GT 5.4: Installation around penetrations and structures

The geotextile shall be cut away to fit neatly and tightly around penetrations and structures through the liner system. No welding or sealing of the geotextile is required around penetrations and structures through the lining system, however, protection to the underlying subgrade should be maintained as far as possible.

PS GT 5.5: Damage repair

The repair seam should be the same seam direction as damaged geotextile. Any repairs shall

be in accordance with the manufacturer's instructions and subject to approval by the engineer. Typically, geotextiles are to be repaired by applying patches, with a minimum of 300 mm overlaps in all directions around the damaged area and heat bonded.

PS GT 6: Tolerances

The tolerances required in the supporting specifications shall apply.

PS GT 7: Testing

A Construction Quality Assurance/Control Plan shall be supplied by the Contractor with his tender, which clearly indicates documentation ensuring compliance with the necessary material specifications, and control points requiring quality control checking during construction/installation.

PS GT 8: Measurement and Payment

PS GT 8.1: Supply geotextile

a. Description of type

   i. (Position and area indicated) ……..Unit: m²

   ii. Etc. for other positions and areas

b. Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of lined surface. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting protection geotextile around penetrations and structures.

This item includes full compensation for procuring, custom costs, shipping, transporting material to site. The cost for materials including cutting and wasting shall be included in the tendered price.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the geotextiles.

PS GT 8.2: Install geotextile

a. Description of type

   iii. (Position and area indicated) ……..Unit: m²

   iv. Etc. for other positions and areas

b. Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of lined surface. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting protection geotextile around penetrations and structures.

This item includes full compensation for transporting material from permanent storage area to position of installation, deploying, cutting and wasting and bending up against structures over filler blocks, and preparing ends for fixing to structures and for all labour incidentals required for the installation or application of the protection and filtration geotextile, complete as per

manufacturer's specifications.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the geotextiles.

2.4.3 PS GD: CUSPATED DRAINS/DRAINAGE CORES

PS GD 1: Scope

This is a particular specification and covers the supply and installation of cuspated drains.

PS GD 2: Interpretations

PS GD 2.1: Supporting specifications

The publications in Appendix A form part of this specification to the extent referenced. Where a particular publication is referred to, that publication shall, unless otherwise stated, be the edition in effect 30 (thirty) days prior to the date of issue of this specification. Any contradictions between publications shall be submitted to the Engineer for decision. The specifications in Appendix A contain clauses that are generally applicable to the manufacture, supply and installation of Cuspated drains.

PS GD 2.2: Application

This specification contains clauses that are generally applicable to the manufacture, supply and installation of cuspated drain.

PS GD 3: Materials

PS GD 3.1: Properties of Geosynthetic Cuspated Drainage Core (GCDC)

The geosynthetic cuspated drainage core to be used as a leakage drainage layer within the geocomposite lining system for the leachate pond shall be "Hi-DRAIN 500" as supplied by Aquatan or "Leakdrain S3U Standard as supplied by ABG, or an equivalent product as approved by the Engineer. It shall consist of a High Density polyethylene (HDPE) incorporating an evenly dispersed carbon black content as well as time proven Ultra Violet stabilisers and anti-oxidants. Reprocessed or reground materials shall not be used. Specifically, the GCDC shall have the following components and properties:

- The unit mass of the GCDC (SANS 9864:13, ISO 9864).
- The overall core thickness (uncompressed) (ASTM D1777).
- The thickness under 200 kPa at 10 000 hrs
- The compressive yield strength (ASTM D1621).
- The uncompressed cusp height.
- The in-plane water flow at 200 kPa vertical pressure at a hydraulic gradient of 1.0 (ASTM D4716, GRI-GC8, EN ISO 12958).
- Carbon black (ASTM D4218).
- The cuspated drainage core shall exhibit a High Pressure Oxidative Induction Test (HPOIT) result of at least 400 minutes, or a Standard Oxidative Induction Test (OIT) result of at least 100 minutes (ASTM D3895).

PS GD 3.3: Materials certification

The Contractor shall submit documented certification that the cuspated drain materials supplied comply with the aforementioned specifications. This documentation shall be submitted to the engineer and any other relevant parties prior to any shipment of any materials

to site.

PS GD 3.4: Materials general

The cuspated drain products are to be supplied to site in panels no less than 1.2 m wide respectively to minimize the number of site joints required.

The purpose of the cuspated drain is to drain away any leakage through the primary geomembrane in the leachate pond to prevent a build-up of hydraulic head on the secondary geomembrane.

The physical and chemical characteristics of the cuspated drain products and their jointing systems must be such that the integrity of the drainage systems is maintained throughout the life of the plant and after closure. As such the cuspated drain products shall be resistant to degradation as a result of the temperature (nominal) and chemical characteristics of the seepage, sunlight, ultra violet rays, ozone, airborne pollution and weathering (ASTM D5970, ASTM D4355, ASTM D4594).

PS GD 4: Packaging, Transportation, Unloading and Storage

The cuspated drain products shall be packaged, transported, unloaded and stored in accordance with the manufacturers' instructions, or ASTM D4873 whichever is directed by Engineer.

PS GD 4.1: Labelling, packaging and transportation

The rolls of cuspated drain products shall be packaged so as to protect them from mechanical damage during transportation and handling. The product rolls must be delivered to the working area of the site in their original packaging. Immediately prior to deployment, the packaging is to be carefully removed without damaging the product.

Rolls shall each be labelled on the surface of the package. Labels should be resistant to fading and moisture degradation such that they are legible at the time of installation. Labelling should include the Manufacturer's name, product identification, roll number, batch/lot number, roll dimensions and weight of the roll.

PS GD 4.2: Unloading

Before off-loading on site, the Contractor must ensure that the off-loading equipment is adequate for handling the cuspated drain rolls without any risk of damaging them. The area where the cuspated drain products are to be off-loaded and stored must have a smooth well-drained surface, free of rocks or any other protrusions which may damage the product.

After off-loading, the Contractor shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Contractor shall inform the engineer and the manufacturer of any defects or damages. Repairs shall be made subject to approval by the Engineer, otherwise damaged rolls shall be replaced at the Contractor's cost.

PS GD 4.3: Storage

A designated storage area shall be established in a location such that on-site transportation and handling are minimised. The storage area should be protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined. The cuspated drain rolls shall be stored laying flat and continuously supported.

PS GD 5: Construction

PS GD 5.1: Installation

The Contractor shall submit with his tender a detailed proposal on the methods he proposes to use for installation of the cuspated drain products. Some of the aspects to be covered include:

- Placement of the cuspated drain without disturbance or damage to underlying layers and linings.
- Equipment and procedures used to place the cuspated drain.
- Placing of the relevant material on top of the cuspated drain in liner system without damaging or disturbing the underlying geomembrane lining.
- Rate of installation.
- Relevant workforce certification.

Field panels are to be located in a manner consistent with the specification and best suited to the design layout. Field panels are to be placed one at a time, and each field panel is to be seamed immediately after placement to the adjoining panel (in order to minimise the number of unseamed panels. The Contractor shall record the identification code, location and date of installation of each cuspated drain field panel.

Installation and seaming shall not take place in wet weather or in the presence of excessive moisture, blowing dust, or strong winds.

During installation, the Contractor shall ensure the following:

- Any equipment used shall not damage the geomembrane or cuspated drain by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means.
- The prepared surface has not deteriorated since the acceptance inspection and is still acceptable immediately prior to placement of the cuspated drain.
- Any geomembrane liner immediately underlying the cuspated drain is clean and free of debris.
- All personnel working on the cuspated drains shall not smoke, wear damaging shoes, or engage in any activities which could damage any of the geosynthetic components.
- The method used to unroll the panels must not cause folds in the cuspated drain, and must not damage the underlying geomembrane.
- The method used to place the panels shall minimise wrinkles (especially differential wrinkles between adjacent panels).
- Adequate temporary loading and/or anchoring (e.g., closed UV stabilised sandbags (containing no material exceeding 3mm), tyres (ASTM D6270-17)), which will not damage the geotextile, must be placed to prevent uplift by wind.
- When cuspated drain is being installed, adequate care should be taken to ensure no unwanted objects are found underneath the lining system.

Each geomembrane and cuspated drain layer shall be inspected for damage after placement, prior to seaming. Damaged areas shall be marked, removed and repaired in accordance with the specifications. The locations of repaired sections shall be recorded in the quality control documentation.

Rolls shall be laid flat on the installed underlying geomembrane liner without folds or wrinkles, with a standard overlap or seam as specified by the manufacturer in both longitudinal and transverse directions. The orientation of the placed cuspated drains should be such that the cusps are facing upwards.

No vehicular traffic shall be allowed on the installed lining and walking on the liners must be kept to an absolute minimum. Acceptable installation therefore may be accomplished such that the cuspated drain is rolled out by hand.

Care must be taken to minimise the extent to which the cuspated drain is dragged across the geomembrane liner in order to avoid damage to the cuspated drain and the underlying geomembrane, and to prevent the formation of folds in the underlying liner.

PS GD 5.2: Anchorage

The outer edge of the cuspated drain is to be anchored in the same anchor trench at the top (and bottom where specified) of the slope, together with the other components of the lining system, as shown on the drawings. The front edge of the trench is to be rounded, so as to prevent stress concentrations on the cuspated drain.

The anchor trench is to be backfilled and compacted in layers not exceeding 150 mm thick, with selected material or with cement stabilised soil, as specified in the Drawings.

PS GD 5.3: Seaming

In general, field seams should be oriented parallel to the line of maximum slope. In corners and odd-shaped geometric locations, the number of seams should be minimised. No horizontal seams should be less than 1.5 m from the toe of the slope or areas of potential stress concentrations, unless otherwise authorised. When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel is cut at an angle of 45 degrees.

Seaming of cuspated drain field panels shall be carried out by means of overlapping the two adjoining sheets by at least 150 mm and interlocking the cusps of the two sheets into one another. If deemed necessary by site conditions, the seams shall then be stitch-welded at 500 mm centres by means of a heat extrusion welding process. The extrusion welding apparatus shall be equipped with gauges giving the temperature at the nozzle and extruder barrel.

Prior to seaming, the seam area is to be clean and free of moisture, dust, dirt, debris of any kind, and foreign material. Seaming shall not take place in excessively high temperatures or at ambient temperatures below 0°C. In all cases, the cuspated drain sheets shall be dry and protected from the wind.

PS GD 5.4: Installation around penetrations and structures

The cuspated drain shall be cut away to fit neatly around penetrations and structures through the liner system. No welding or sealing of the cuspated drain is required around penetrations and structures through the lining system.

PS GD 5.5: Damage repair

Any repairs shall be in accordance with the manufacturer's instructions and subject to approval by the engineer.

PS GD 6: Tolerances

The tolerances required in the supporting specifications shall apply.

PS GD 7: Testing

The Contractor shall supply with his tender, a Construction Quality Assurance / Control Plan that clearly indicates documentation ensuring compliance with the necessary material specifications, and control points requiring quality control checking during construction/installation.

PS GD 8: Measurement and Payment

PS GD 8.1: Supply cuspated drain

a. Description of type

(i) (Position and area indicated)……..Unit: m2

(ii) Etc. for other positions and areas

b. Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of lined surface. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting cuspated drain around penetrations and structures.

This item includes full compensation for procuring, custom costs, shipping, transporting material to site. The cost for materials including cutting and wasting shall be included in the tendered price.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the cuspated drain in an earth trench as detailed on the contract drawing details (excavation and backfilling measured elsewhere).

PS GD 8.2: Install cuspated drain

a. Description of type

(i) (Position and area indicated)……..Unit: m2

(ii) Etc. for other positions and areas

b. Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of lined surface. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting or cuspated drain around penetrations and structures.

This item includes full compensation for transporting material from permanent storage area to position of installation, deploying, cutting and wasting and bending up against structures over filler blocks, and preparing ends for fixing to structures and for all labour incidentals required for the installation or application of the cuspated drain, complete as per manufacturer's specifications.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the cuspated drain in an earth trench as detailed on the contract drawing details (excavation and backfilling measured elsewhere).

2.4.4 PS GC: GEOCELLS

PC GC 1: Scope

This is a particular specification and covers the supply and installation of Geocells.

PC GC 2: Interpretations

PC GC 2.1: Supporting specifications

The following supporting specifications, standards and guidelines shall, inter alia, form part of the contract document together with this Particular Specification:

- GRI Standard GS-13 – Guide for Geomembrane-related Geomat Seam Strength and its Efficiency with respect to the Perforated Sheet Strength;
- GRI Standard GS-14 – Test Method for the Average Wall Thickness of a Geomembrane-related Geomat by Indirect Measurement
- ASTM D 792 – Specific Gravity (Relative Density) and Density of Plastics by Displacement
- ASTM D 1004 – Test Method for Initial Tear Resistance of Plastics Film and Sheeting
- ASTM D 1238 – Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- ASTM D 1505 – Test Method for Density of Plastics by the Density-Gradient Technique
- ASTM D 1603 – Test Method for Carbon Black in Olefin Plastics
- ASTM D 3895 – Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
- ASTM D 4218 – Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- ASTM D 4833 – Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
- ASTM D 5596 – Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- ASTM D 5721 – Practice for Air-Oven Aging of Polyolefin Geomembranes
- ASTM D 5885 – Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
- ASTM D 6693 – Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- ASTM D 7238 – Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus

PC GC 2.2: Application

Geocell, is three-dimensional compartmentalized geosynthetic structure resulting in discrete cells when opened which are subsequently filled with soil, concrete or other infill material for civil engineering applications.

PC GC 3: Materials

PC GC 3.1: Properties of Geocells

The geocell walls, being made from HDPE strips shall conform to the test property requirements prescribed. The strength of the factory joining of the geocell strips by thermal, ultrasonic or other methods, per GRI-GS13, is a new test method necessitated by the various joining methods. It is a tensile peel test and its value is compared to the perforated sheet strength of the product being evaluated. An efficiency calculated using these two results is specified accordingly.

The table calls for direct shear friction tests, per ASTM D5321, to assure that soil infill of the

individual cells will be stable and not allow the soil to be lost or the geocell to rise out of position. A checklist of conditions for the tests are as follows;

- Procedure: “B” soil to geosynthetic
- Samples materials to be tested: Geocell wall to Sand (AASHTO 2A or USCS SW)
- Orientation of Geocell: Machine direction
- Normal pressures: 14 kPa (2 psi), 38 kPa (5 psi) and 69 kPa (10 psi)
- Moisture conditions: Saturated
- Consolidation conditioning: No requirement because sand is free draining
- Shear rate: 1 mm/minute (0.04 in./min.)

The properties of the HDPE strips and their joining to form the geocell structure shall be tested at the minimum frequencies shown in Table 1. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

PC GC 3.2: Materials certification

The Contractor shall submit documented certification that the geocell materials supplied comply with the aforementioned specifications. This documentation shall be submitted prior to any installation of the products on site.

PC GC 4: Packaging, Transportation, Unloading and Storage

The geocells shall be packaged, transported, unloaded and stored in accordance with the manufacturers’ instructions.

PC GC 4.1: Labelling, packaging and transportation

The factory fabricated geocell shall be bundled according to their heights using polymer strapping or sturdy rope such that damage does not occur during handling or shipment to the project site.

Labelling of geocell bundles shall be consistent with the manufacturers quality manual but must include the product name, manufacturer, location made and specification followed.

PC GC 5: Construction

PC GC 5.1: Installation

The Contractor shall submit with his tender a detailed proposal on the methods he proposes to use for installation of the geocell layers. Some of the aspects to be covered include:

- Placement, expansion and securing the geocells without disturbance or damage to any underlying liner system or prepared trenches or surfaces;
- Equipment and procedures used to place the geocells; and
- Filling of the installed geocells with concrete or soil without damaging or disturbing the underlying geomembrane lining or prepared surface.

During installation, the Contractor shall ensure the following:

- Any equipment used shall not damage any of the liner components by handling, trafficking, excessive heat, leakage of hydrocarbons (e.g. diesel, petrol, etc.), or other means;

- Any geomembrane liner with its protection geotextile underlying the geocells must be clean and free of debris;
- All personnel working on the geomembrane, geotextile or geocells shall not smoke, wear damaging shoes, or engage in any activities which could damage any of the geosynthetic components;
- The method used to expand and deploy the geocell the panels must not cause crimps in the geocells, and must not damage the underlying geomembrane or prepared surface; and
- Adequate temporary loading and/or anchoring (e.g., sand bags, tyres), which will not damage the geocells, must be placed to prevent uplift by wind.

Geocell panels shall be opened and expanded uniformly into position over the underlying geotextile and geomembrane liner or prepared subgrade/trench. Accommodation of non-linear alignments may require non-uniform expansion of individual geocell sections in order to form tapered or curved elements.

Expanded panels shall be held in position with a temporary frame placed on top of the installed liner and held in position by means of sand bags or a similar method. Under no circumstances can pegs be driven through the liner.

Care must be taken to minimise the extent to which the geocell panels are dragged across any underlying geotextile, geomembrane liner or prepared surface in order to avoid damage and the formation of folds in the underlying liner or damage to the prepared surface.

PC GC 5.2: Installation around penetrations and structures

The geocells shall not cut through or penetrate any structure. If this occurs on site it should be communicated to the engineering representative on site.

PC GC 5.3: Damage repair

Any repairs shall be in accordance with the manufacturer's instructions and subject to approval by the engineer.

PC GC 6: Tolerances

The tolerances required in the supporting specifications shall apply.

PC GC 7: Sampling

Sampling shall be in accordance with the specific test methods listed in Table 1. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire bundle width.

The number of tests shall be in accordance with the appropriate test methods listed in Table 1.

The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are typically the minimum average values and are designated as "min. ave."

PC GC 8: Retest and Rejection

If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

PC GC 9: Measurement and Payment

PC GC 9.1: Supply geocells

a) Description of type

(i) (Position and area indicated)……..Unit: m2

(ii) Etc. for other positions and areas

b) Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of geocell installed. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting geocells around penetrations and structures.

This item includes full compensation for procuring, custom costs, shipping, transporting material to the site permanent storage. The cost for materials including cutting and wasting shall be included in the tendered price.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the geocells.

PC GC 9.2: Install geocells

a) Description of type

(i) (Position and area indicated)……..Unit: m2

(ii) Etc. for other positions and areas

b) Etc. for other types

Separate items will be scheduled for different structures or areas to be lined.

The unit of measurement will be square metres of geocells installed. No additional area shall be measured as overlaps and/or wastage. Similarly, no additional payment will be made for cutting geocells around penetrations and structures.

This item includes full compensation for transporting material from permanent storage area to position of installation, deploying, cutting and wasting and bending up against structures over filler blocks, and preparing ends for fixing to structures and for all labour incidentals required for the installation or application of the geocells, complete as per manufacturer's specifications.

This item also includes the cost of all plant, labour and materials required for the anchorage and seaming of the geocells.

3. SCHEDULE OF QUANTITIES

3.1 Preamble to the Schedule of Quantities

The general conditions of contract, the special conditions of contract, the specifications (including the project specifications), and the drawings are to be read in conjunction with the Schedule of Quantities.

(a) The Schedule comprises items covering the Contractor's profit and costs of general liabilities and of the construction of temporary and permanent works.

(b) The Contractor is at liberty to insert a rate of his own choosing for each item in the schedule and his attention is drawn to the fact that the Contractor has the right, under various circumstances, to payment for additional works carried out and that the Engineer shall base his assessment of the rates to be paid for such additional work on the rates inserted in the Schedule by the Contractor.

(c) Clause 8 of each standardised specification and the measurement and payment clause of each particular specification, read together with the relevant clauses of the project specification, set out what ancillary or associated activities are included in the rates for the operations specified.

Descriptions in the schedule of quantities are abbreviated and the schedule has been drawn up generally in accordance with the latest issues of the standardised SANS 1200 specifications.

Should any requirement (other than the unit of measurement) of the measurement and payment clause of the applicable standardised specification, or the project specification, or the particular specification conflict with the terms of the Schedule, the requirement of the standardised, project, or particular specification, as applicable, shall prevail.

Should the unit of measurement of the applicable standardised specification, or the project specification, or the particular specification conflict with the unit of measurement of the Schedule, the unit of measurement of the Schedule shall prevail.

Unless otherwise stated, items are measured nett in accordance with the drawings, and no allowance has been made for wastage. Rates entered must include for providing laps, wastage, fixing materials, etc. No provision was made for any bulking or additional quantities to comply with the OHS act. This should be included in the rate.

The prices and rates inserted in the Schedule of quantities are to be the full inclusive prices to the Employer for the work described under the several items. Such prices cover all costs, expenses, overheads and profits that are required in and for the construction of the work described, and shall cover the cost of all general risks, liabilities and obligations set forth or implied in the documents on which the tender is based.

The prices and rates inserted in the Schedule of quantities are to be exclusive of value added tax (VAT). Provision is made in the summary of the schedule of quantities for VAT. A price or rate is to be entered against each item in the Schedule, whether the quantities are stated or not. An item against which no price is entered, will be considered to be covered by the other prices or rates in the schedule.

In the event of any extended amount in the Schedule of Quantities being in disagreement with the product of the rate and the quantity, the rate shall be accepted as correct, and the extended amount will be corrected for the purpose of making payments for construction. Any errors in

addition will be similarly corrected.

The Schedule of Quantities includes, as far as can be determined, every class of operation, construction or material that the Contractor is likely to be called upon to perform or supply. It must not be assumed, however, to include and describe every detail of the works and operation but must be taken as part of the Contract as a whole. The quantities entered in the Schedule of Quantities are approximate only and the Contractor, when tendering, must take this point into consideration when fixing his rate for individual items.

The Contract price for the completed Contract shall be computed from the actual nett quantities of work and day work done in accordance with the Engineer's instructions, drawings and specifications, and valued at the unit rates and prices tendered against the respective items in the Schedule of Quantities and the Day work Schedule.

_____

Johann Le Roux
Director
Pr. Tech. Eng.

APPENDIX A

DETAILED LIST OF STANDARDS

The following **Standard Specifications** and **Test Methods** shall form part of this Contract (these documents are available at the Contractor's expense from relevant companies. TheContractor should ensure that the newest revisions/edition is used).

- SANS 1200 A - General
- SANS 1200 C - Site clearance
- SANS 1200 D – Earthworks
- SANS 1200 DB – Earthworks (Pipe Trenches)
- SANS 1200 LB – Bedding (Pipes)
- SANS 1200 GA - Concrete (Small Works)
- SANS 10409 - Design, selection and installation of geomembranes
- SANS 12236 - Static puncture test (CBR test)
- SANS 13433 - Dynamic perforation test (cone drop test)
- SANS 1525:13 - Wide-width tensile test
- SANS 1526 - Thermoplastics sheeting for use as a geomembrane
- SANS 9863-1:13 - Determination of thickness at specified pressures
- SANS 9864 - Test method for the determination of mass per unit area of geotextilesand geotextile-related products
- SANS 10318, Geosynthetics – Terms and definitions.
- GRI Standard GM6 - Practice for Pressurized Air Channel Test for Dual SeamedGeomembranes
- GRI Standard GM11 - Accelerated Weathering of Geomembranes Using aFluorescent UVA Device
- GRI Standard GM13 - Standard Specification for Test Properties, Test Frequencies and Recommended Warranties for High Density Polyethylene (HDPE) Smooth andTextured Geomembranes
- GRI Standard GM14 - Selecting variable intervals for taking geomembranedestructive seam samples using the method of attributes.
- GRI Standard GM19 - Standard Specification for Seam Strength and Relatedproperties of Thermally Bonded Polyolefin Geomembranes
- GRI Standard GM29 - Field Integrity Evaluation of Geomembrane Seams (andSheet) Using Destructive and/or Non-destructive Testing
- GRI Test Method GT12(a) - Test Methods and Properties for Nonwoven GeotextilesUsed as Protection (or Cushioning) Materials.
- ASTM D1004 - Test Method for Initial Tear Resistance of Plastic Film and Sheeting
- ASTM D1238-13 - Standard Test Method for Melt Flow Rates of Thermoplastics byExtrusion Plastometer
- ASTM D1603 - Test Method for Carbon Black in Olefin Plastics
- ASTM D1505-18 - Standard Test Method for Density of Plastics by the Density-Gradient Technique
- ASTM D3895 - Standard Test Method for Determining the Minimum OxidativeInduction Time of Geomembranes
- ASTM D4218 - 15 Standard Test Method for Determination of Carbon Black Contentin Polyethylene Compounds By the Muffle-Furnace Technique
- ASTM D4354 - Practice for Sampling of Geosynthetics for Testing
- ASTM D4355 - Standard Test Method for Deterioration of Geotextiles by Exposure

toUltraviolet Light, Moisture and Heat in a Xenon Arc-Type Apparatus

- ASTM D4437, Standard practice for non-destructive testing (NDT) for determining the integrity of seams used in joining flexible polymeric sheet geomembranes.
- ASTM D4439 - Terminology for Geosynthetics
- ASTM D4533 - Standard Test Method for Trapezoid Tearing Strength of GeotextilesDurability
- ASTM D4594 - Standard Test Method for Effects of Temperature on Stability ofGeotextiles
- ASTM D4632 - Test Method for Grab Breaking Load and Elongation of Geotextiles
- ASTM D4759 - Practice for Determining the Specification Conformance ofGeosynthetics
- ASTM D4873 - Guide for Identification, Storage and Handling of Geosynthetics
- ASTM D4885-01(2018) - Standard Test Method for Determining PerformanceStrength of Geomembranes by the Wide Strip Tensile Method
- ASTM D5035 - Test Method for Breaking Strength and Elongation of Textile Fabrics(2”Strip Method)
- ASTM D5199-98 - Standard Test Method for Measuring Nominal Thickness ofGeotextiles and Geomembranes
- ASTM D5261 - Test Method for Measuring Mass per Unit Area of Geotextiles
- ASTM D5321, Standard test method for determining the coefficient of soil-geosynthetic or geosynthetic-geosynthetic interfaces by direct shear.
- ASTM D5397-19 - Standard Test Method for Evaluation of Stress Crack Resistanceof Polyolefin Geomembranes Using Notched Constant Tensile Load Test
- ASTM D5494 - Test Method for the Determination of Pyramid Puncture Resistance ofUnprotected and Protected Geomembranes
- ASTM D5596-03 - Standard Test Method for Microscopic Evaluation of theDispersion of Carbon Black in Polyolefin Geosynthetics
- ASTM D5641/D5641M-16 - Standard Practice for Geomembrane Seam Evaluationby Vacuum Chamber
- ASTM D5721-08 - Standard Practice for Air-Oven Aging of PolyolefinGeomembranes
- ASTM D5820-95 - Standard Practice for Pressurized Air Channel Evaluation of Dual-Seamed Geomembranes
- ASTM D5885/D5885M-17 - Standard Test Method for Oxidative Induction Time ofPolyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry
- ASTM D5970 - Standard Test Method for Deterioration of Geotextiles from OutdoorExposure
- ASTM D5994/D5994M-10 - Standard Test Method for Measuring Core Thickness ofTextured Geomembranes
- ASTM D6270 - Standard Practice for Use of Scrap Tires in Civil EngineeringApplications
- ASTM D6241 - Test Method for Static Puncture Strength of Geotextiles andGeotextile Related Products Using a 50-mm Probe
- ASTM D6365-99 - Standard Practice for Nondestructive Testing of GeomembraneSeams Using the Spark Test

- ASTM D638 - Standard Test Method for Tensile Properties of Plastics
- ASTM D6392, Standard test method for determining the integrity of nonreinforced geomembrane seams produced using thermo-fusion methods.
- ASTM D6693/D6693M-04 - Standard Test Method for Determining Tensile Propertiesof Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- ASTM D7002-16 - Standard Practice for Electrical Leak Location on ExposedGeomembranes Using the Water Puddle Method
- ASTM D7238 - Test Method for Effect of Exposure of Unreinforced PolyolefinGeomembrane Using Fluorescent Condensation Apparatus
- ASTM D7240-18 - Standard Practice for Electrical Leak Location Using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layervia Electrical Capacitance Technique (Conductive-Backed Geomembrane Spark Test)
- ASTM D7466 - Standard Test Method for Measuring Asperity Height of TexturedGeomembranes
- ASTM D7703-16 - Standard Practice for Electrical Leak Location on ExposedGeomembranes Using the Water Lance Method
- ASTM D7747, Standard test method for determining integrity of seams produced using thermofusion methods for reinforced geomembranes by the strip tensile method.
- ASTM D792 - Standard Test Method for Specific Gravity and Density of Plastics byDisplacement
- ASTM D7953-14 - Standard Practice for Electrical Leak Location on ExposedGeomembranes Using the Arc Testing Method
- ASTM D7982 - Standard Practice for Testing of Factory Thermo-Fusion Seams forFabricated Geomembrane Panels
- ASTM D7865 - Standard Guide for Identification, Packaging, Handling, Storage andDeployment of Fabricated Geomembrane Panels
- ASTM D6497/D6497M-02(2015)e1 Standard Guide for Mechanical Attachmentof Geomembrane to Penetrations or Structures

APPENDIX H

GROUND WATER IMPACT STUDY REPORT

HYDROGEEK CONSULTING



REPORT

Clover Alloys
Conceptual and Numerical Model GROUNDWATER IMPACT ASSESSMENT Rietfontein Plant

Submitted to:
Andre van Rooyen
EIMS

Prepared by:
Hydrogeek Consulting (PTY) Ltd

Report number: *202501-2*

Executive Summary

Hyrogeek Consulting is pleased to provide this hydrogeological assessment and to assess the existing groundwater management, potential impacts and monitoring programme at Rietfontein Plant. A hydrocensus was conducted on the 11th to 13th of February 2024. The hydrocensus involved the measuring of static/dynamic groundwater levels, and sampling of groundwater quality in the vicinity of the Rietfontein Plant. The assessment concluded the following:

- A good correlation between groundwater level and surface elevation at Rietfontein Plant suggests that the groundwater flow in the shallow aquifer is undisturbed and mimics topography.
- The Sandspruit was identified as a potential receptor due to the proximity to the Rietfontein Plant. The Sandspruit is deemed more susceptible to contamination by surface water runoff and seepage from the shallow weathered aquifer.
- There are signs of groundwater contamination down gradient of the Rietfontein Chrome Plant towards the Sandspruit (a tributary of the Hex River). Elevated chrome was observed in borehole FH02 and elevated nitrate and sulphate concentrations observed in monitoring boreholes at RCM which is indicative of contamination caused by mining activities.
- Stormwater management infrastructure will be place through a lined PCD dam will be in place to mitigate the risk to groundwater.

The main constituents of concern identified during the analysis are listed as follows:

- **Rietfontein Chrome Plant** – Electrical Conductivity (EC), TDS and Chrome (Cr)

The numerical modelling results:

- The pollution plume migration of the current and future stockpiles is and will be contained through the current abstraction from boreholes RP01, RP02 and RP03. This needs to b77e confirmed with future monitoring boreholes of water quality, water quantity and water levels.

The following actions and recommendations are put forward for consideration:

- Monitoring monthly abstraction volumes and water levels from all boreholes that are in use on the Rietfontein Plant (preferably with automated flow meters).
- Boreholes FH01, FH02 and H/BH4 should be added to the monitoring network.
- Geophysical surveys at Rietfontein Plant Operation which consist of planned traverses around the wash plant infrastructure should be completed to determine the placement of monitoring boreholes for the detailed monitoring program/network.
- Aquifer Testing (48-72 hour) is recommended on the current abstraction boreholes to determine a sustainable yield and available volumes.
- Drilling of additional boreholes to establish a more comprehensive monitoring network as per chapter 11 Monitoring Plan.

Director: NL van Zyl (MSc. Hydrogeology)

- It is recommended to do a comprehensive quarterly analysis of all boreholes at an accredited laboratory for parameters **Physical and Aesthetic Factors**: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Total Hardness. **Macro Elements**: Total Alkalinity (MAlk), Sulphate (SO_4), Nitrate (NO_3), Chloride (Cl), Fluoride (F), Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na). **Micro Elements**: Aluminium (Al), Iron (Fe), Manganese (Mn), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Cobalt (Co), and Zinc (Zn).

The potential environmental impacts associated with the proposed new infrastructure—such as the pollution control dam (PCD), clean and dirty water separation systems, and related channels—have been reviewed in the context of the existing operations assessed under the Section 24G application. Based on the nature, location, and function of the planned infrastructure, the associated impacts are anticipated to be materially similar in type, extent, and significance to those already identified and assessed.

As such, these impacts are sufficiently addressed by the current impact assessment. Should any deviations or unique site-specific impacts arise during implementation, these will be managed under the existing environmental management framework and mitigation measures already in place

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Appendices

Appendix 1 DRASTIC

Appendix 2 Lab Quality Results

Distribution history

Name	Company
Andre van Rooyen	Environmental Impact Management Services (Pty) Ltd
Douglas Richards	Minelock Environmental Engineers

Document history

Report	Date	Version	Status
202501-02	February 2025	Conceptual 1.0	DRAFT
202501-02	March 2025	Numerical Model 2.0	DRAFT
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202501-02	May 2025	Numerical Model 4.0	FINAL
202501-02	September 2025	Impact Assessment 5.0	FINAl

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INDEMNITY AND SPECIALIST DECLARATION

The findings, results, observations, conclusions, and recommendations presented in this report are based on the author's best scientific and professional knowledge, as well as the available information. The assessment techniques employed are constrained by the information, time, and budgetary limitations relevant to the scope of the investigation. Hydrogeek Consulting reserves the right to modify aspects of the report, including recommendations, should new information emerge from ongoing research, monitoring, or further work in the field.

While Hydrogeek Consulting Ltd exercises due diligence in providing its services and preparing this document, it accepts no liability. By receiving this report, the client indemnifies Hydrogeek Consulting (Pty) Ltd against any actions, claims, demands, losses, liabilities, costs, damages, and expenses arising directly or indirectly from the services rendered or from the use of the information contained herein.

This report has been prepared in accordance with the latest requirements for specialist reports set forth by the Department of Environmental Affairs, as outlined in Government Gazette No. 40713 (24 March 2017) and Government Gazette No. 40772 (07 April 2017) under the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA).

I, NL van Zyl, hereby declare that:

- I act as the independent specialist for this application.
- I will conduct the work related to this application objectively, even if it leads to findings that are not favorable to the applicant.
- I have no circumstances that could compromise my objectivity in this work.
- I possess the necessary expertise relevant to this application, including knowledge of the Act, Regulations, and relevant guidelines.
- I will comply with all applicable legislation.
- I have not engaged, nor will I engage, in any conflicting interests related to this activity.
- I will disclose to the applicant and the competent authority any material information that could influence decisions regarding the application or the objectivity of any report or document prepared for submission.
- All information I have provided in this declaration is true and correct.

NL VAN ZYL

M.Sc Hydrogeology, Pr.Sci.Nat.

LIST OF ABBREVIATIONS

BHN	Basic Human Needs
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
CRD	Cumulative Rainfall Departure
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EARTH	Extended Model for Aquifer Recharge and Soil Moisture Transport through the Saturated Hardrock
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ET	Evapotranspiration
GMU	Groundwater Management Unit
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
ICM	Integrated Catchment Management
IFR	Instream Flow Requirements
IWRM	Integrated Water Resource Management
K	Hydraulic Conductivity
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NGDB	National Groundwater Data Base
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RU	Resource Unit
S	Storativity
T	Transmissivity
WARMS	Water Use Authorization and Registration Management System
WEM	Water Environment Management
WMA	Water Management Area
WMS	Water Management System

1 INTRODUCTION

Hydrogeek Consulting was contracted by Environmental Impact Management Services (Pty) Ltd to conduct a geohydrological impact study and report as specialist input to the section 24g rectification application and Environmental Management Program (EMP) at the Rietfontein Plant.

The focus of this investigation was centered around: -

- Determining a baseline picture of groundwater conditions on and around the Rietfontein Plant
- Determination of the historic groundwater quality and quantity impacts related to the plant activities.
- Determination of the future groundwater quality and quantity impacts related to the proposed activities.

1.1 Setting the stage

Clover Alloys SA (Pty) Ltd's Rietfontein Operation is located in the western area of the Bushveld Complex close to Rustenburg. The Rietfontein Beneficiation Plant (crushing, screening and washing) is located on Portion 23 (Portion 13 – LG 306) of the Farm Rietfontein 338 JQ within the Rustenburg Local Municipality, North West Province. The facility has a three-stage crushing and screening plant that allows it to treat any form of Run of Mine (RoM) feedstock. The washing facility concentrates on the production of specialist high grade products such as foundry and chemical grade concentrates.

Clover Alloys SA owns and operates its' own chrome fines processing and wash plant in the Rietfontein area, South Africa. The Plant supplies Chrome Sands and Concentrates, dried and wet from South Africa for foundry, specialist non-metallurgical and metallurgical applications. The plant also carries out chrome sand recovery from foundry waste from various foundries in the industrial areas, thus saving on waste dumping. The primary focus of Clover Alloys SA in the specialist high grade and nickel chromite sands and concentrates for local and global markets.

1.2 Objectives of the Investigation

The aim of the investigation is to develop a better understanding of the current hydrogeological conditions and to identify any flaws/gaps in the current groundwater management system. This investigation will also outline any potential risks to the receiving environment associated with mining activities.

2 REGULATORY FRAMEWORK

2.1 National water Act

The report is structured according to the requirements of the National Water Act, 1998 Regulations regarding the procedural requirements for water use licence applications and appeals 24 March 2017, Act No. R. 267.

2.2 Checklist for Specialist studies

This checklist is intended to assist in evaluating whether specialist studies conducted as part of an Environmental Impact Assessment (EIA), Basic Assessment, or Environmental Management Programme (EMPr) comply with the requirements of **Appendix 6 of the EIA Regulations, 2014 (as amended)**. It serves as a practical tool for both Environmental Assessment Practitioners (EAPs) and competent authorities to ensure that specialist inputs are complete, transparent, and legally compliant.

Table 1 Checklist for Specialist studies conformance with Appendix 6 of the EIA Regulations of 2014 (as amended).

Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	The relevant section in the report	Comment where not applicable.
1.(1) (a) (i) Details of the specialist who prepared the report	Page 1	
(ii) The expertise of that person to compile a specialist report including a curriculum vita	Appendix 3	
(b) A declaration that the person is independent in a form as may be specified by the competent authority	Page 2	
(c) An indication of the scope of, and the purpose for which, the report was prepared	Heading 1	
(cA) An indication of the quality and age of base data used for the specialist report	Heading 2.2	
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Heading 6	
(d) The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Heading 6.2	
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Heading 2.3	
(f) details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative;	Heading 10.1	

Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	The relevant section in the report	Comment where not applicable.
(g) An identification of any areas to be avoided, including buffers	Heading 6.2	
(h) A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Heading 10.2.4	
(i) A description of any assumptions made and any uncertainties or gaps in knowledge;	Heading 8.3	
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Heading 10.1.1 and Heading 10.1.2	
(k) Any mitigation measures for inclusion in the EMPr	Heading 10.1.2	
(l) Any conditions for inclusion in the environmental authorisation	Heading 13	
(m) Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Heading 13	
(n)(i) A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised and	Heading 12.1	
(n)(iA) A reasoned opinion regarding the acceptability of the proposed activity or activities; and		
(n)(ii) If the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Heading 13	
(o) A description of any consultation process that was undertaken during the course of carrying out the study	Heading 2.3	
(p) A summary and copies of any comments that were received during any consultation process		NA

Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	The relevant section in the report	Comment where not applicable.
(q) Any other information requested by the competent authority.		NA
(2) Where a government notice by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.		NA

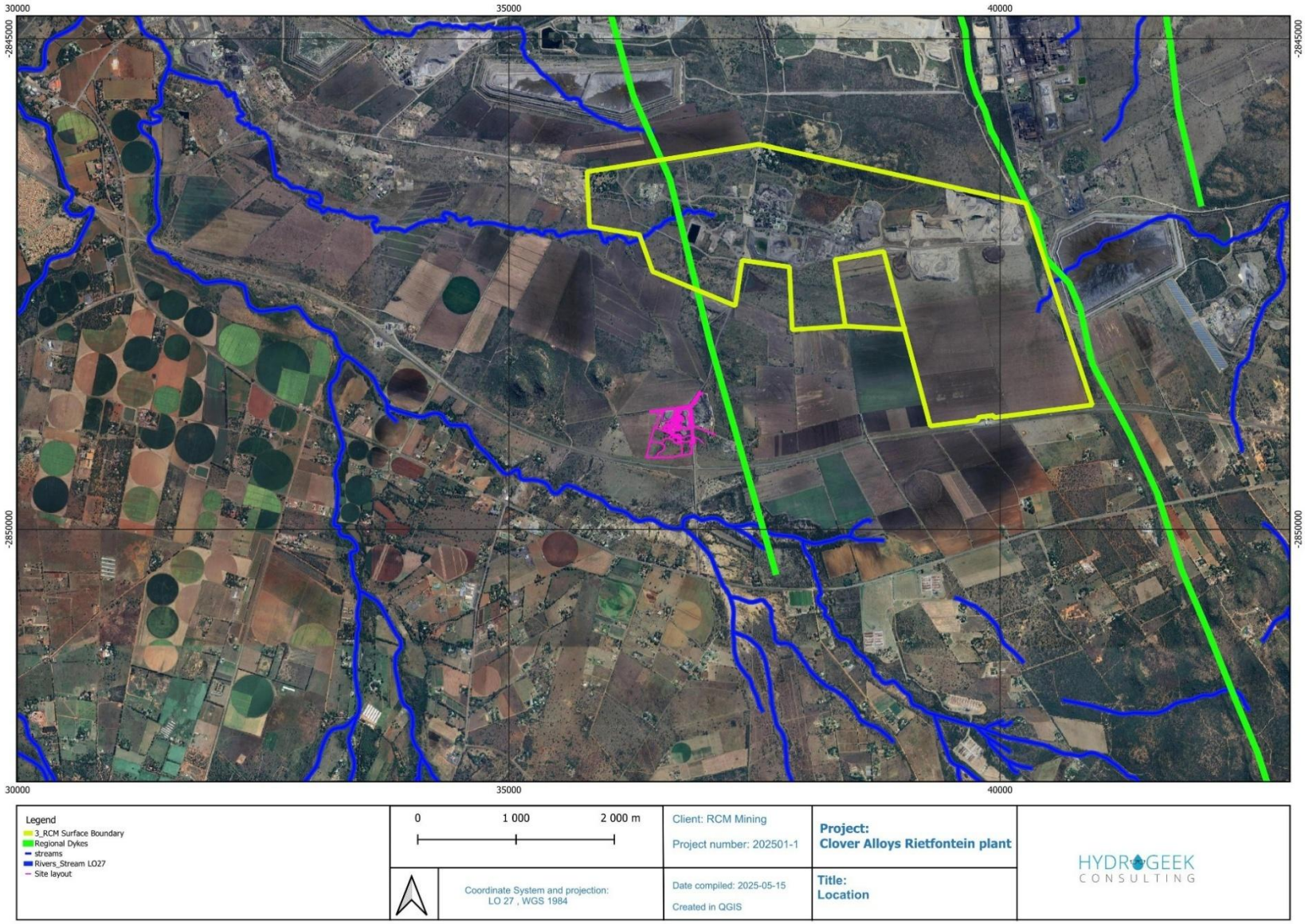


Figure 1 Location of Rietfontein plant

2.3 Reviewed Documentation

The background information used are as follows:

Table 2 Reviewed information for groundwater

Year	Company	Study
2017	GCS	Once off Water Quality Assessment - Rietfontein
2023	HK Geohydrological Services Pty Ltd	GEOHYDROLOGICAL STUDY FOR RIETFONTEIN CHROME PLANT LOCATED ON PORTION 21 OF THE FARM RIETFONTEIN 338 JQ LOCATED IN THE NORTHWEST PROVINCE
2023	MARINE MOUNTAINS ENVIRONMENTAL CONSULTANTS (PTY) LTD	GEOHYDROLOGICAL REPORT FOR CLOVER ALLOYS AT RIETFONTEIN PLANT OPERATION, RUSTENBURG LOCAL MUNICIPALITY, BOJANALA PLATINUM DISTRICT, IN NORTHWEST PROVINCE

2.4 Scope of Work

To address the objective of this assessment the following scope of services was proposed and is further detailed within this report

- Review and evaluate existing site-related data.
- Conduct a hydrocensus (1 to 2 km) to record groundwater uses in the area and groundwater levels in private user boreholes and on-site boreholes.
- Water sampling of groundwater and surface water to determine quality and to highlight any constituents of concern.
- Conduct a spatial analysis to identify any sensitive receptors in the vicinity of the existing development footprint such as rivers, streams, wetlands etc.
- Development of the conceptual model into a numerical groundwater model in FEFLOW.
- Use of a finite element groundwater modelling code, FEFLOW, that represents the hydrogeological conditions and groundwater flow conditions as well as the complexity of the hydrogeological regime.
- Steady state model calibration to simulate baseline hydrogeological conditions.
- Development of a transient model to simulate observed long-term monitoring data and increase the level of confidence in the numerical model.
- Development of a predictive model to simulate groundwater flow and mass migration.

- Impact Assessment based on existing condtions as well as future infrastructure changes will be addressed.
- Recommend monitoring and management scenarios and outcomes.

3 REGIONAL DESCRIPTION

3.1 Locality of the Study Area

Clover Alloys SA (Pty) Ltd's Rietfontein Operation is in the western area of the Bushveld Complex close to Rustenburg. The existing chrome washing plant on Portion 23 of the farm Rietfontein 338 JQ is in the North-west Province in quaternary sub-catchment A22H. Refer to Map 1. The plant will be located 14km kilometre south-east of Rustenburg and 6km southeast of Kroondal.

3.2 Regional Drainage and Surface Topography

The project area falls within the Crocodile West and Marico Water Management Area (WMA), quaternary catchment A22H.

The A22H quaternary catchment area is 579 km^2 and has a MAR of 14.07 million m^3. Runoff emanating from this quaternary catchment drains in a north–easterly direction via the Hex River. Elevations in the A22H quaternary range from 1220 meters above mean sea level (mamsl) at the highest point within the catchment and drop to 1112 mamsl at the outlet of the catchment.

The elevation of this area ranges from 1130 mamsl to 1150 mamsl. Surface drainage at the Rietfontein Chrome Plant area occurs mainly towards the South, directly into the Sandspruit as this site is situated approximately 1 km from the Sandspruit.

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.

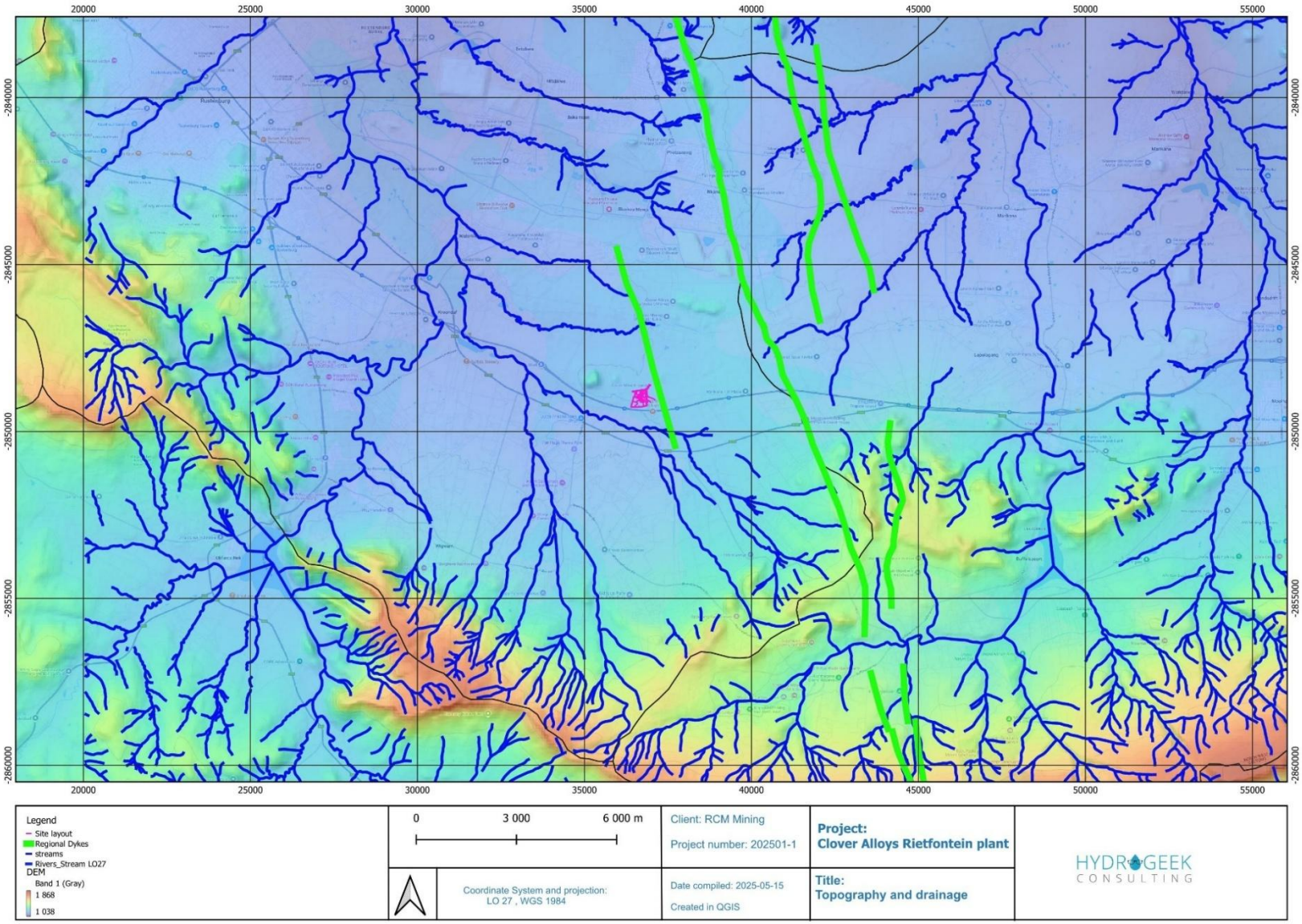


Figure 2 Regional topography and drainage

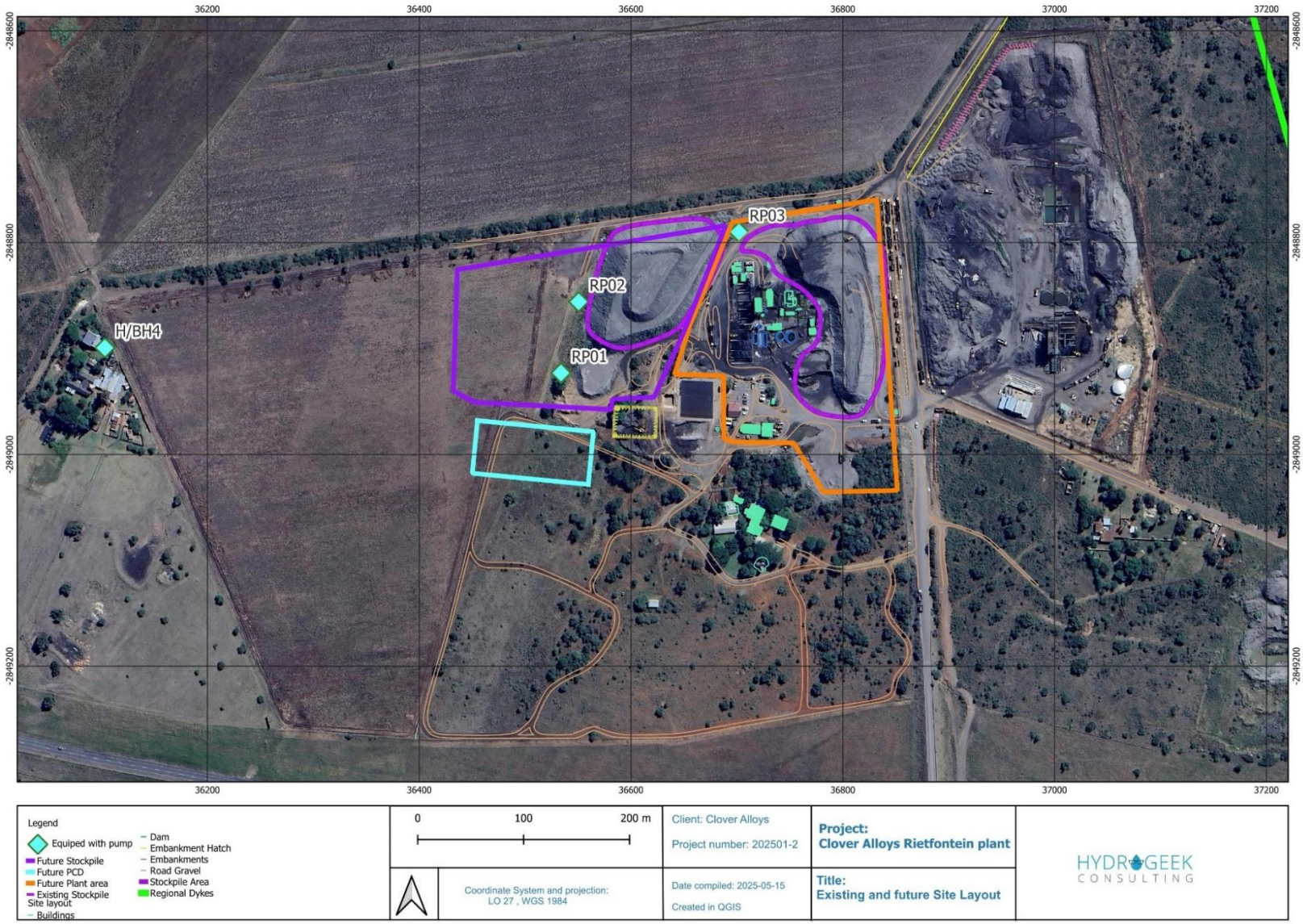


Figure 3 Plant infrastructure layout

3.3 Rainfall and Cumulative Rainfall Departure (CRD)

The area 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 peak rainfall occurring in January.

Daily rainfall data was obtained from the CCWR (Computing Centre for Water Research, Natal University) database. CCWR gauge 0511672 (Klipfontein) was used. The gauge is located 8km northwest of the plant. The records provided 73 years of recorded and patched daily data that can be representative of the rainfall that occurs on the mine (Minelock, 2022)

Table 3 Average rainfall and evaporation (Minelock, 2022)

Month	Average rainfall (mm)	Average evaporation (mm – S-Pan)
January	117	182
February	91	152
March	80	147
April	46	116
May	16	99
June	8	81
July	4	90
August	5	119
September	16	160
October	52	186
November	82	176
December	116	192
Mean annual	**633***	**1 700**

shows the average amount of rainfall per month in Kroondal (Northwest). The numbers are calculated over a 30-year period to provide a reliable average.

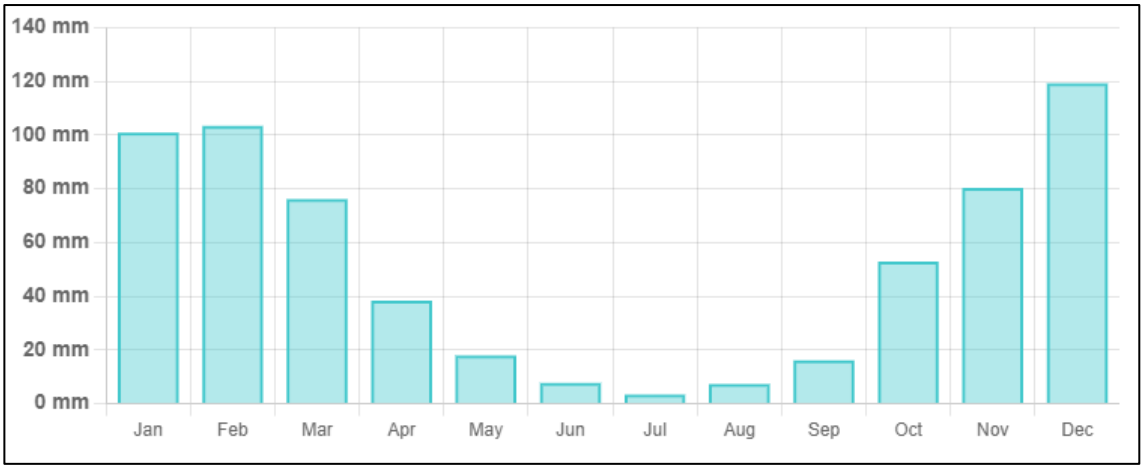


Figure 4 Climatic data representation.

The CRD is a graph that is constructed by accumulating the monthly differences between a specific monthly rainfall and the average monthly rainfall of the rainfall sequence. Increasing CRD trends are therefore indicative of consecutive above average rainfall events (probably causing groundwater recharge and therefore rising water levels) whilst decreasing CRD trends are indicative of consecutive below average rainfall events with no or very little groundwater recharge and therefore declining water levels.

3.4 Evaporation

The proposed development is in Evaporation Zone 3B. The closest Evaporation station A2E008, the Rustenburg station, is located 8km East of the proposed development, and gives a mean annual evaporation (MAE) of 1645mm for the S-Pan value and 2054mm for the A-Pan value. The evaporation measurements cover the years 1957 to 1979.

4 GEOLOGY OF THE STUDY AREA

4.1 Regional Geology

The regional geology of the area is given in Figure 6. The ore body is in the Critical zone of the Rustenburg Layered suite in the Bushveld Ingenious Complex (BIC). The area strikes east-west and dip10 degrees to the north. The chrome layers are interlayered by pyroxenites, norites and anorthosites. The black turf soil overlays the residual weathered bedrock, approximately up to 6m thick in places. The weathered zone ranges in thickness up to 40m.

The regional area is underlain by the Ruighoek pyroxenite, Mathlagame norite, Mathlagame norite anorthosite and Kroondal Norite of the Rustenburg Layered Suite, Bushveld Complex, Vaalian Era. The soil cover on the site consists of a dark brown to black, firm loamy clay with abundant vegetation roots. This soil is dispersive and expansive and forms large cracks when moisture is driven off. Locally the soil is referred to as black “turf”.

Generally, it should be noted that the geology of site has been artificially modified in areas due to mining activities surrounding the site. This artificially modification of the geology could possibly have an impact on the hydraulic properties of groundwater flow in the subsurface. A simplified description of the units underlying the project area is represented in Figure 5.

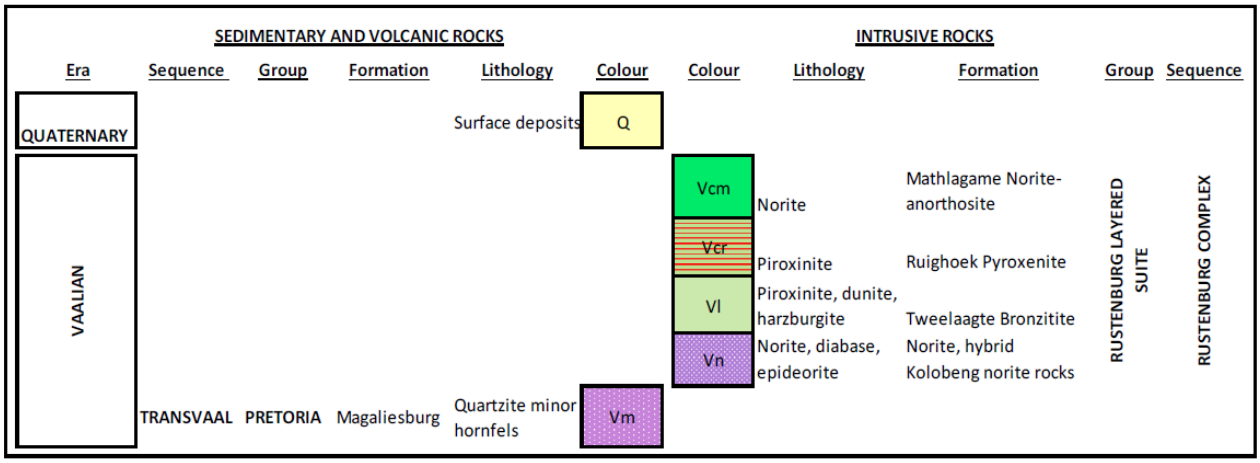


Figure 5 Geology groups present

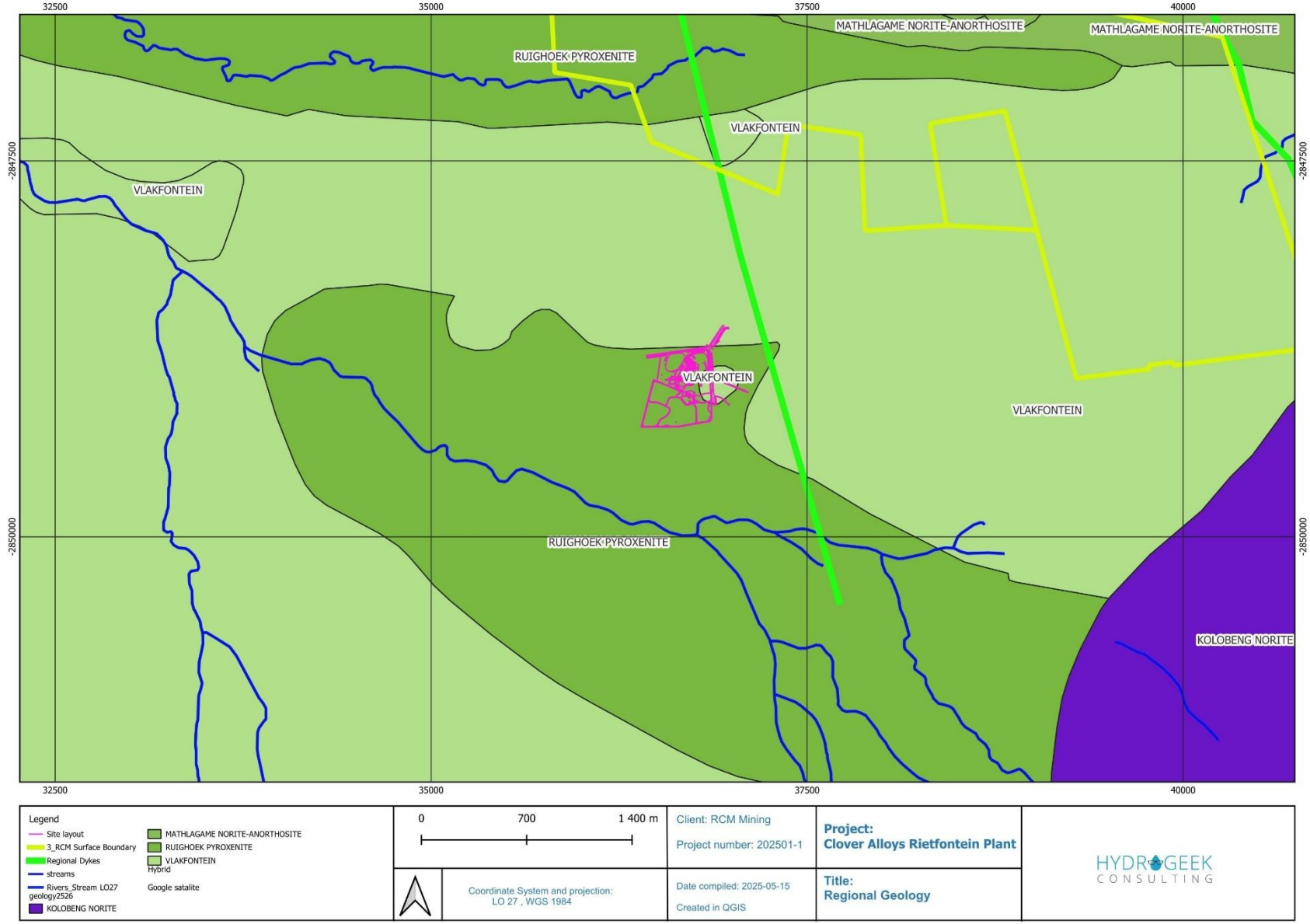


Figure 6 Regional Geology

5 HYDROGEOLOGY OF THE STUDY AREA

5.1 Aquifers and Groundwater Occurrence

The area of interest is located on a fractured and intergranular aquifer, with a successful borehole yield of between 0.5 l/s and 2.0 l/s. According to Barnard (2000), the rocks of the Rustenburg layered suite are characterized by a well-developed igneous layering. The mainly mafic rocks include norite, gabbro, magnetite gabbro anorthosite an pyroxenite. Groundwater occurrence is associated mainly with deeply weathered and fractured mafic rocks. Some of the norite zones weather more easily than other rock types. This characteristic in association with north-south striking dykes that cut through and across the norite, has formed groundwater compartments especially in the area between Rustenburg and Pretoria. The groundwater yield potential is classified as poor as the majority of the boreholes on record produce less than 2l/s. The mafic rocks weather to a clay rich soil that is represented by the well-known black turf. The very low permeability of this soil (in the order of 10-3m/d) is considered to reduce recharge to underlying aquifers. In most cases the hydraulic conductivity of the subsurface would be increased due to mining actives and this would in term mean higher yielding aquifers relating to old and current mine workings.

5.1.1 Unsaturated zone – shallow, saprolitic aquifer

The main source of recharge into the shallow aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. This aquifer may contain coarse, anorthositic sediment or turf clay sediment when underlain by anorthosite or gabbro-norite respectively. The hydraulic conductivity of this aquifer ranges between 10^{-8} and 10^{-2}m.day^{-1} and porosity ranges between 0.4 and 0.7 for turf clay sediments. The hydraulic conductivity of the coarse, anorthositic sediment can reach up to 20m/day with porosities ranging between values of 0.25 to 0.5.

5.1.2 Saturated zone – fractured bedrock aquifer

Groundwater movement is predominantly associated with secondary structures in this aquifer (fractures, faults, dykes, etc.). The average water level depth in the area ranges between 5 and 40 mbgl. Borehole yields in the Rustenburg Layered Suite fractured aquifers are generally low and can be expected to be between 0.1 and 2 l/s with regional flow resembling flow in the porous medium (i.e. obeying Darcy's law). These formations contain limited quantities of water resources due to the poor storage capacity of the igneous rock. Groundwater quality in the area is also expected to be intermediate to poor with EC values ranging from 4.4 to 120 mS/m and possibly elevated Ca, Mg, Cl, and SO4 as well as carbonate alkalinity concentrations. Both the porosity and the hydraulic conductivity of the Rustenburg Layered Suite fractured aquifers are known to be low. The commonly expected values of porosity and permeability for igneous rock types, similar to those present in the Rustenburg Layered Suite, are 0.05 (porosity) and 10-5 m.d^{-1} (hydraulic conductivity) respectively (Kruseman & de Ridder, 1994). Movement of groundwater in this aquifer will be preferential in secondary structures such as joints, faults and fractures. Dolerite intrusions in the form of dykes and sills are often encountered in this area. The dykes are found to run in a north-northeast / south-southwest direction and

can serve both as aquifers and aquifuges. Thick, unbroken dykes inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These structures thus tend to dominate the flow of groundwater. Unfortunately, their location and properties are rather unpredictable. Their influence on the flow of groundwater is incorporated by using higher than usual flow parameters for the rocks of the aquifer. According to the groundwater study done by Future Flow (2010) in the direct vicinity of the dyke the weathering depth tends to be more than that of the general valley area due to the effect of fracturing and subsequent higher groundwater recharge and flows associated with the intrusion of the dolerite dyke.

5.1.3 Water Strike Depths

Three boreholes were drilled as part of a study in 2023. The findings of the study provide some information on the water strikes and yields encountered. The water strikes ranges from 20- 34 mbgl, at blow yields of 0.1 to 1.2 l/s.

5.2 Monitoring Network

The current monitoring network consists of the existing abstraction boreholes RP01 and RP02. Currently limited groundwater monitoring exists upstream and downstream of the operations. Boreholes found in the hydrocensus (Borehole FH01 and FH02) exist down gradient of the plant and should be added to the monitoring network.

It is recommended to drill and site additional monitoring boreholes up and downgradient of the expansion of the Waste Rock Dumps and the Pollution Control Dam.

Table 4 Monitoring boreholes and location monitored.

Boreholes	Purpose
RP01 and RP02	Monitoring
RP01, RP02 and RP03	Water Supply

6 FIELD INVESTIGATION

6.1 Source Pathway Receptor Model

A part of the objective of the baseline groundwater assessment was to assess the potential impacts that the Rietfontein Plant Operation might have on the receiving groundwater environment and the sensitive receptors identified during the hydrocensus. For a risk to exist there must be a source, pathway and a receptor present.

6.1.1 Rietfontein Plant Operation

During the hydrocensus, multiple groundwater users were identified within a 2 km radius of the Rietfontein Plant Operation. The groundwater users are not expected to experience adverse impacts from the Rietfontein

Chrome Plant due to the Sandspruit non-perennial tributary of the Hex River forming a divide between the plant and majority of private groundwater users.

Hydrocensus information proved sufficient to determine groundwater quality and potential pollution down-gradient of the Rietfontein Plant. Borehole FH02 situated down gradient of the Rietfontein plant indicated an elevated Total Chrome concentration which confirms that during high-rainfall contaminated run-off contributes to groundwater contamination. Therefore, the aquifer is considered a receptor.

6.2 Hydrocensus

A hydrocensus was conducted on the 11th, 12th and 13th of February 2025. Boreholes were identified within a radius of 2 km of the Rustenburg Chrome Mine (RCM) site and a radius of 2 km around the Rietfontein Plant Operation. Information collected from the hydrocensus included verification of existing boreholes, location of private boreholes, current use, type of pump, groundwater level and the identification of any sensitive receptors.

During the hydrocensus conducted around the Rietfontein Plant Operation site, a total of 26 boreholes were included which was a combination of open/un-equipped boreholes, on-site production boreholes and privately owned water supply boreholes. The key hydrogeological information is summarised as follows:

- Of the 26 boreholes, the static water levels of 15 boreholes were measured with an average static water level of 17.24 mbgl.
- 14 of the 26 boreholes identified are privately owned water supply boreholes.
- The Rietfontein Plant Operation site is situated approximately 1 km north of the Sandspruit, which acts as a divide between the site and the private users situated to the south of the Sandspruit.

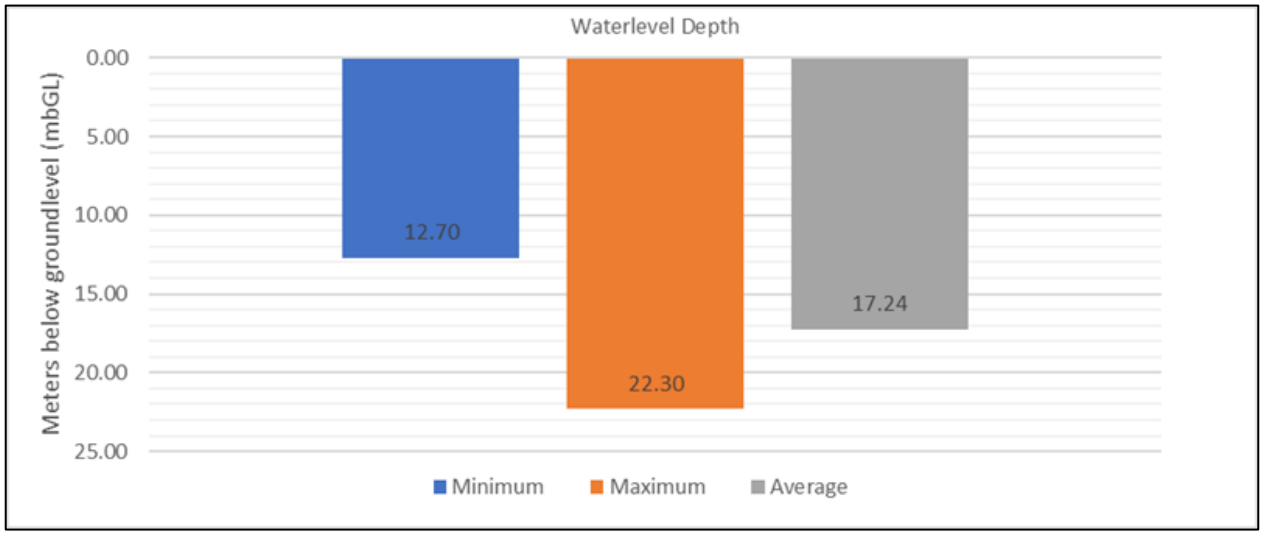


Figure 6.1: Water level statistic graph for Rietfontein Plant Operation hydrocensus

6.3 Groundwater Gradient

Groundwater will flow in response to a hydraulic gradient, typically created by difference in topographic elevation i.e. groundwater will flow from a topographic high to a topographic low. Therefore, a linear correlation generally exists between topography and groundwater level.

The hydrocensus data from the Rietfontein Plant study area is limited in spatial extent but shows a good linear relationship (R^2 = 89.94 %). Indicating that undisturbed groundwater mimics surface topography and will flow south/south-east towards the Sandspruit, a non-perennial tributary of the Hex river (Figure 6.2).

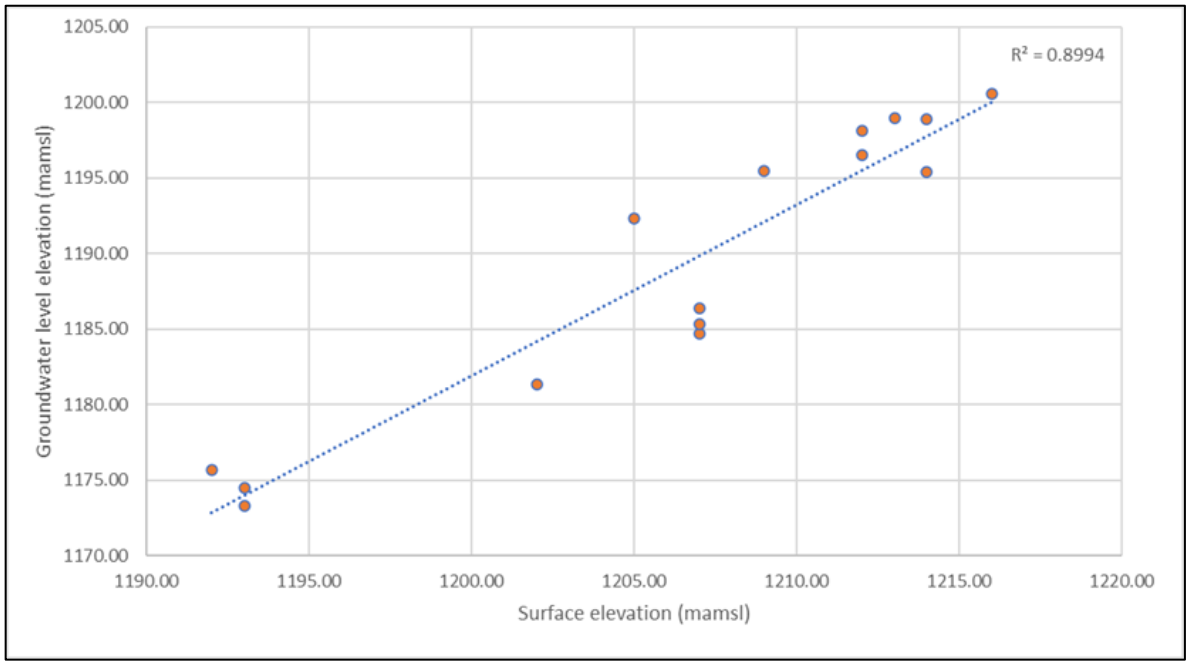


Figure 6.2: Correlation between groundwater elevation and surface elevation.

Table 5 Hydrocensus information for Rietfontein Plant Operation.

Borehole ID	Coordinates		Elevation (maMSL)	BH Type	Casing Mate-rial	Bore-hole Condi-tion	Borehole Depth (mbGL)	Equipment	Static Water Level (mbGL)	Static Water Level (maMSL)	Status		Usage				Comments
	Latitude	Longi-tude									Operational	Non-opera-tional	Domestic	Livestock	Irrigation	Other	
SC01	-25.7527	27.3721	1212.00	Production	Steel	Good	-	Submersible	13.9	1198.10	x		x		x		Yield - 0.3 l/s
SC02	-25.7529	27.3712	1209.00	Production	Steel	Good	-	Submersible	13.5	1195.50	x			x	x		Yield - 0.3 l/s
SC03	-25.7532	27.3704	1208.00	Production	Steel	Good	-	Submersible	-	-	x		x	x	x		Yield - 0.3 l/s Sealed off
SC04	-25.7531	27.3699	1208.00	Production	Steel	Good	-	Submersible	-	-	x		x	x	x		Yield - 0.3 l/s Sealed off
RN01	-25.7651	27.3651	1207.00	Production	Steel	Good	-	Submersible	22.3	1184.70	x		x		x		Yield - 1.4 l/s
RN02	-25.7654	27.3644	1207.00	Production	Steel	Good	-	Submersible	21.7	1185.30	x			x	x		Yield - 0.8 l/s
RN03	-25.7610	27.3621	1202.00	Production	Steel	Good	41	Submersible	20.7	1181.30	x		x	x	x		Yield - 2 l/s
RN04	-25.7613	27.3622	1202.00	Production	Steel	Good	-	Submersible	-	-	x			x	x		Yield - 0.8 l/s
BS01	-25.7541	27.3481	1185.00	Production	Steel	Good	-	Submersible	-	-	x		x		x		
RN06	-25.7571	27.3558	1192.00	Production	Steel	Good	-	Submersible	16.3	1175.70	x		x		x		
FH01	-25.7492	27.3659	1212.00	Open BH	Steel	Good	-	None	15.5	1196.50	x						
FH02	-25.7504	27.3651	1205.00	Open BH	Steel	Good	-	None	12.7	1192.30	x						
RP01	-25.7476	27.3641	1206.00	Production	Steel	Good	-	Submersible	-	-	x					x	Borehole buried beneath surface Water for wash plant
RP02	-25.7470	27.3643	1207.00	Production	Steel	Good	-	Submersible	20.6	1186.40	x					x	Water for wash plant
RP03	-25.7464	27.3658	1210.00	Production	Steel	Good	-	Submersible	-	-	x					x	Water for wash plant
VM01	-25.7572	27.3501	1193.00	Production	Steel	Good	-	Submersible	18.5	1174.50	x		x		x		
VM02	-25.7568	27.3489	1193.00	Production	Steel	Good	-	None	19.7	1173.30	x	x					Pump removed
BH1	-25.7467	27.3707	1214.00	Production	Steel	Good	32.6	Unkown	18.62	1195.38	x						
BH2	-25.7489	27.3707	1216.00	Production	Steel	Good	46.28	Unkown	15.42	1200.58	x						
BH3	-25.7480	27.3687	1213.00	Production	Steel	Good	30.73	Unkown	14	1199.00	x						
BH4	-25.7473	27.3695	1214.00	Production	Steel	Good	35.83	Unkown	15.11	1198.89	x						
BH5	-25.7441	27.3690	1209.00	Unknown	Steel	Good	60	None	-	-	x						
BH6	-25.7446	27.3695	1211.00	Unknown	Steel	Good	35	None	-	-	x						
BH7	-25.7444	27.3696	1211.00	Unknown	Steel	Good	35	None	-	-	x						
H/BH3	-25.7441	27.3593	1213.00	Production	Steel	Good	-	Submersible	-	-	x						

Borehole ID	Coordinates		Elevation (maMSL)	BH Type	Casing Material	Borehole Condition	Borehole Depth (mbGL)	Equipment	Static Water Level (mbGL)	Static Water Level (maMSL)	Status		Usage				Comments
	Latitude	Longitude									Operational	Non-operational	Domestic	Livestock	Irrigation	Other	
H/BH4	-25.7474	27.3598	1204.00	Production	Steel	Good	-	Submersible	-	-	x						
Minimum									12.70	1173.30							
Maximum									22.30	1200.58							
Average									17.24	1189.16							

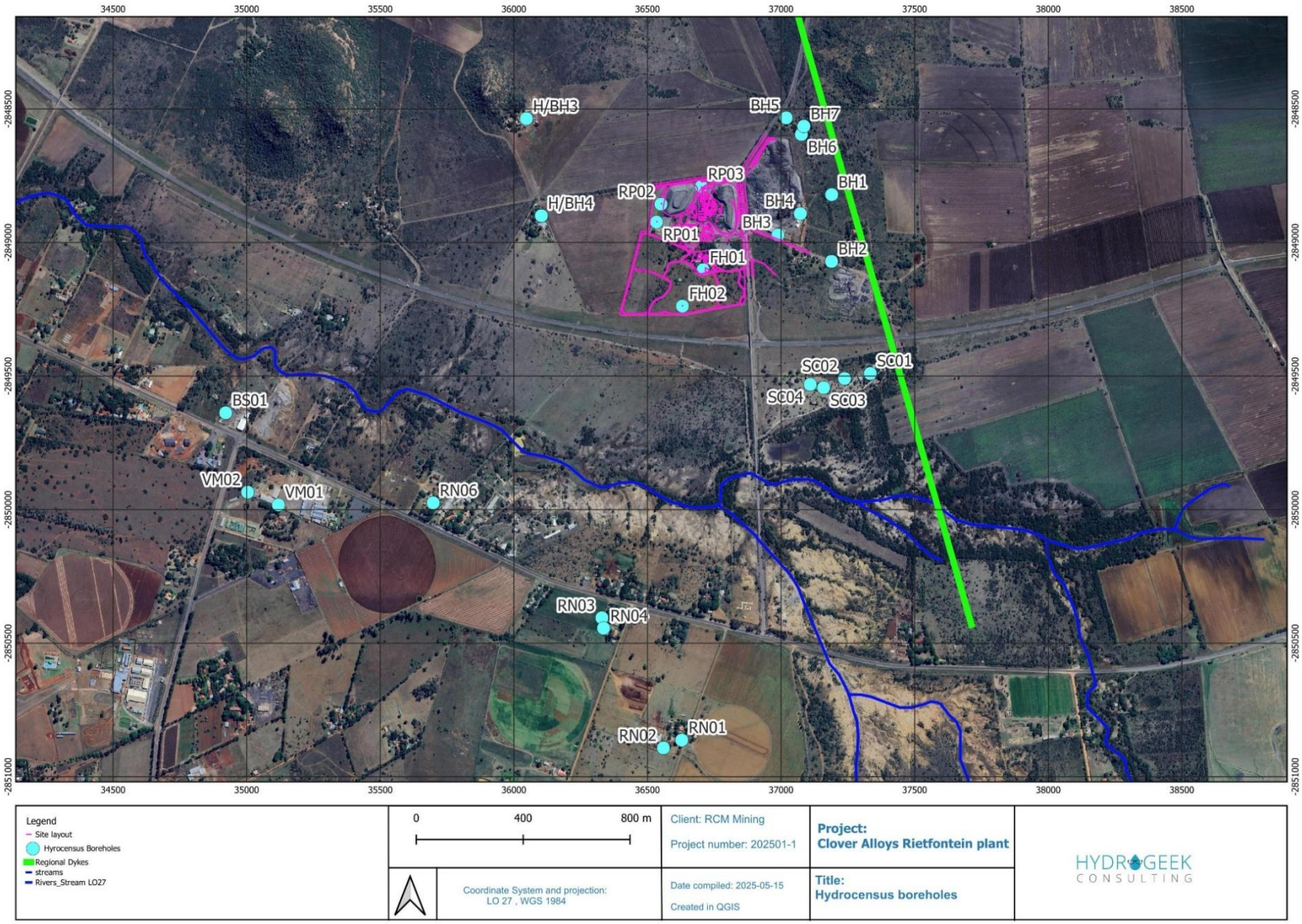


Figure 3 Hydrocensus survey

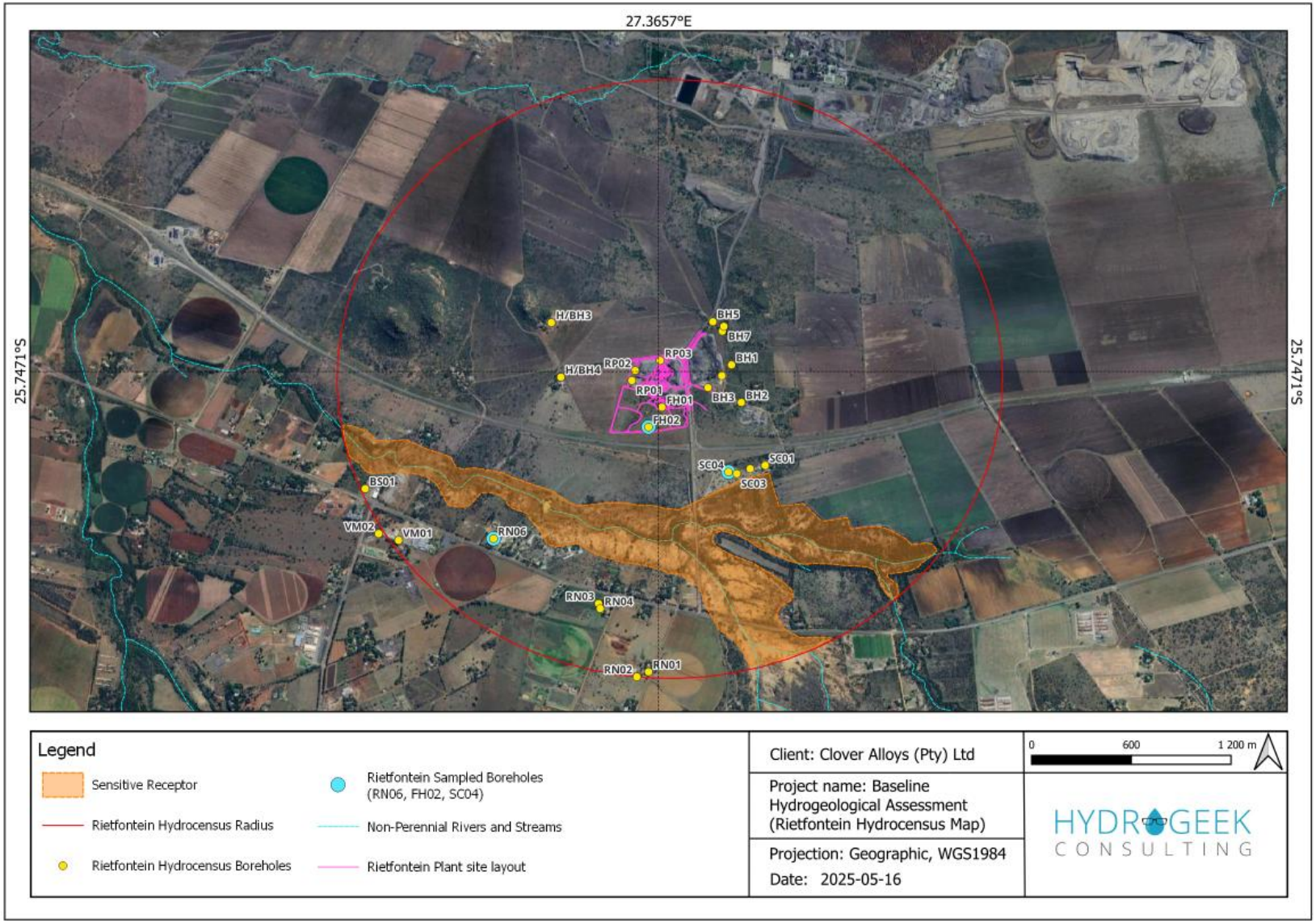


Figure 4 Hydrocensus survey boreholes sampled

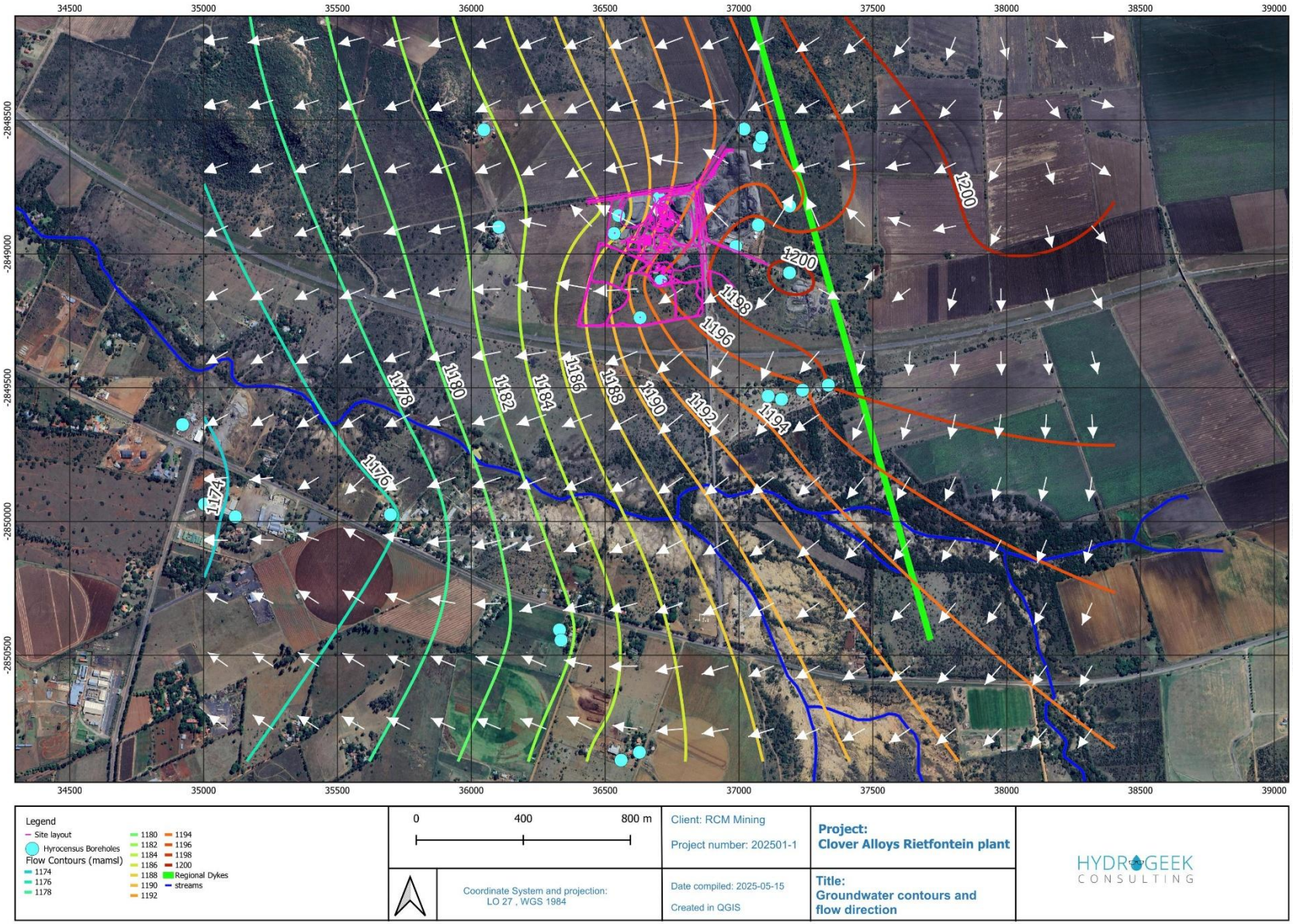


Figure 5 Groundwater flow contours (mamsl) and directions

6.4 Dewatering and Abstraction

An approved usage of 2059 m^3/a has been approved from two boreholes. Based in the hydrocensus on site, three boreholes RP01, RP02 and RP03 are used for industrial purposes. The abstraction rates are unknown and no record of monitoring was provided. These abstraction rates need to be verified with flow meters and recorded for monitoring.

Table 6 Section 21 (a) Water Use Activities approved in WUL

Description and Purpose	Volume (m^3/a)	Property Description	Co-ordinates
Taking water from Borehole 1 for industrial use	1 320	Portion 23 of the Farm Rietfontein 338 JQ	S 25.75046 E 27. 36512
Taking water from borehole 2 for domestic use	739	Portion 23 of the Farm Rietfontein 338 JQ	S 25. 74772 E 27. 38802
Total	**2 059**		

6.5 Hydraulic Conductivity and Transmissivity

The hydraulic conductivity for the site was not assessed during this study, but previous studies provide values that can be used that were obtained through aquifer testing in the area (Table 7).

Table 7 Hydraulic conductivities previously used at RCM

Study	Area	Transmissivity values (T)	Hydraulic Conductivity (k)
JMA, 2009	Wonderkop Segment		0.45 m/d and 6.7 m/d, geometric mean of 1.5 m/d
Digby Wells, 2014	Dyke that forms the catchment divide east of the project area	6.8 m^2/d and the transmissivity of the aquifer matrix is estimated at 3.5 m^2/d.	
Digby Wells, 2016	Mining area, upper 20-30m	2.41 to 4.82 m^2/d	1.4 x 10^{-6} to 2.8 x 10^{-8}

6.6 Recharge

Groundwater recharge is the process by which water moves downward from the surface to underground aquifers. It occurs through natural processes like precipitation, infiltration, and percolation, as well as through artificial recharge methods.

Pre mining conditions the Hex River would have acted as the regional drain to remove groundwater as baseflow to the river. A small portion of rainfall (approximately 1-3%) would have recharged groundwater. As mining activities started the disturbed areas have been altered. Recharge rates are expected to the higher up to 15-20% on waste areas and open-cast mining.

6.7 Stormwater Management Plan

It is understood that a stormwater management plan report is in place (Minelock, P284_Rietfointein Plant SWMP Design Report) based on the findings from the specialist studies, the Pollution Control Dam (PCD) and associated infrastructure were sized as an integrated system (). The PCD was designed according to the Best practise Guidelines and Government notice GN 704 as well as the NEMWA regulations of 2013, 2015 as amended in 2018 as applicable on mine waste.

The PCD will collect dirty water from the site footprint area via carious channels as shown in the design drawings. The PCD is designed to size the PCD for a total volume of 8000 m^3, which will results in the following approach according to the water balance study.

- Pollution control dam capacity = 8000 m^3
- Temporary product stockpile cathment size = 3.19ha
- Dust suppression = 10 m^3/d.

This stormwater management infrastructure will assist in mitigating any further contamination based on the associated infrastructure.

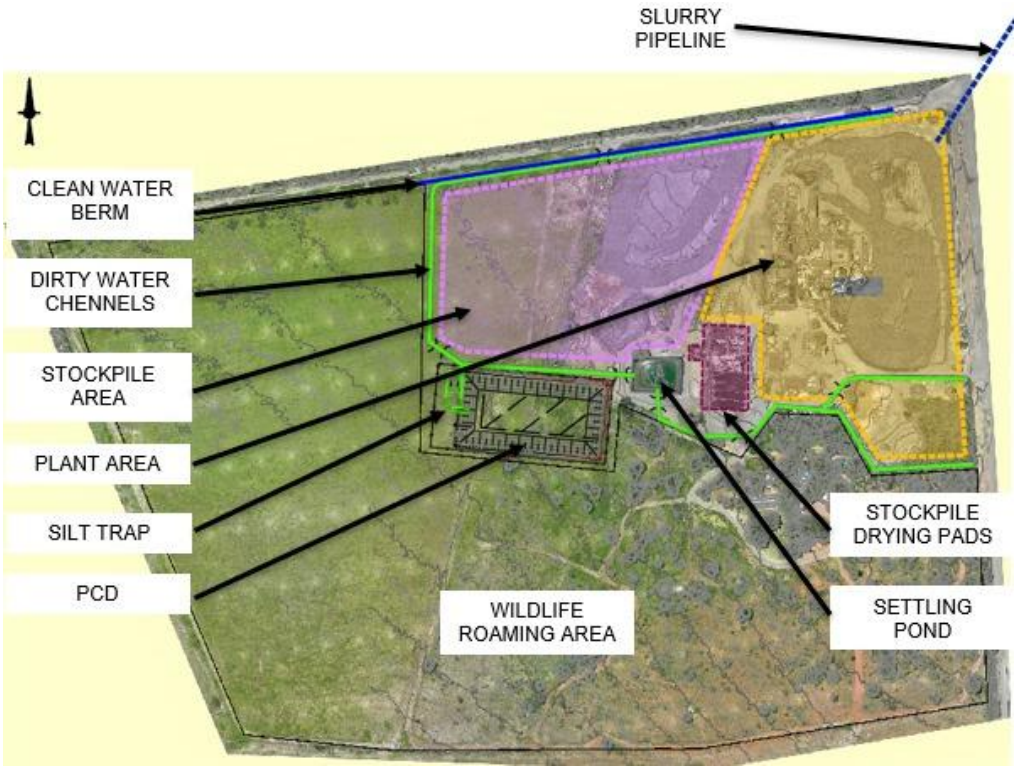


Figure 6 Stormwater infrastructure Plan

6.8 Water Quality

Based on previous work in 2017 by Digby Wells Borehole 1 indicate exceedances for magnesium, sulphate and fluoride concentrations based on the IWUL 2017. Additionally, no exceedances based on the SANS Drinking Water Standards or SAWQG for Industrial Use are seen. Potential impact on the groundwater is attributed to activities at Clover Alloys at Rietfontein. The Borehole 2 indicate exceedances for conductivity, calcium, magnesium, chloride and sulphate concentrations based on the IWUL for 2017. Additionally for conductivity, total dissolved solids, total hardness and nitrate concentrations based on either the SANS 241:2014 Drinking Water Standards or SAWQG for Industrial Use are exceeded. The exceedance indicates potential impacts associated with the activities at Clover Alloyes at Rietfontein.

The surface water localities, Sink, Settling and Cement Dam indicate exceedances for conductivity, total dissolved solids, total hardness, ammonium and nitrate concentrations based on either the SANS 241:2014 Drinking Water Standards or SAWQG for Industrial Use. The Settling and Cement Dam shows exceedances for nickel concentrations based on the SANS 241:2014 Drinking Water Standards.

The programme involves monitoring of two abstraction boreholes at the Rietfontein operations for only quality based on this report. The most recent water quality analysis results obtained from Clover Alloys Quarterly Ground Water Monitoring Report (Fourth Quarter of 2023) are summarised in Table 8 below. **No parameters exceeded the SANS guidelines, and the water quality is deemed good**.

Table 8 Water quality analysis results from the fourth quarter of 2023.

Variable	Unit	Limit	Borehole ID's	
			RT01	RT02
pH	pH units	7-9	8.01	7.91
Al	mg/l	<0.15	<0.01	<0.01
Ca	mg/l	40-60	37.4	29.9
Cl	mg/l	100	42.95	35.8502
Fe	mg/l	0.1	<0.005	<0.005
Mg	mg/l	30-40	27.38	24.48
Na	mg/l	<100	18.62	17.21
SO4	mg/l	<200	40.07	34.51
NO3	mg/l	<6	30.4	23.2F
F	mg/l	<1	0.143	0.174

6.8.1 Rietfontein Plant Operation hydrocensus

- **EC –** EC values for the two private water supply boreholes exceeded the Class 4 Limits of the DWS Drinking Water Guideline Limits.
- **Nitrate –** All Nitrate concentrations are below the acute health limit of ≤ 11 mg/L.
- **Chrome –** The Chrome concentration for borehole FH02 (0.4 mg/L) located down gradient of the Rietfontein Chrome Plant, exceeded the SANS 241:2015 Drinking Water Standards acute health limit of 0.05 mg/L. This indicates possible contamination of the groundwater regime, originating from the plant.

6.8.2 Piper Diagram

A Piper plot is a tri-linear plot where the hydro-chemical composition of water samples is evaluated determining the ratios of predominant cations and anions. The plot is divided into water facies depicting the dominant ratios.

- The calcium-magnesium-bicarbonate (left quarter) of the Piper diagram is normally characterized by recently recharged water.
- The sodium-bicarbonate (bottom quarter) is typical of flow within the aquifer, with the sodium replacing the calcium and magnesium in solution.
- The sodium-chloride dominant (right quarter) is associated with stagnant or slow-moving groundwater with little or no recharge.
- The sulphate dominant (top quarter) is typical of water impacted by the oxidation of pyrite, or other sulphate bearing sources.

The following observations are made with reference to the piper diagrams for the Rietfontein Plant study area shown in

- Boreholes FH02, SC04 and RN06 sampled during the Rietfontein Plant hydrocensus plot towards the left-hand side of the diamond which indicates magnesium-bicarbonate type groundwater. This groundwater is typically associated with recently recharged groundwater

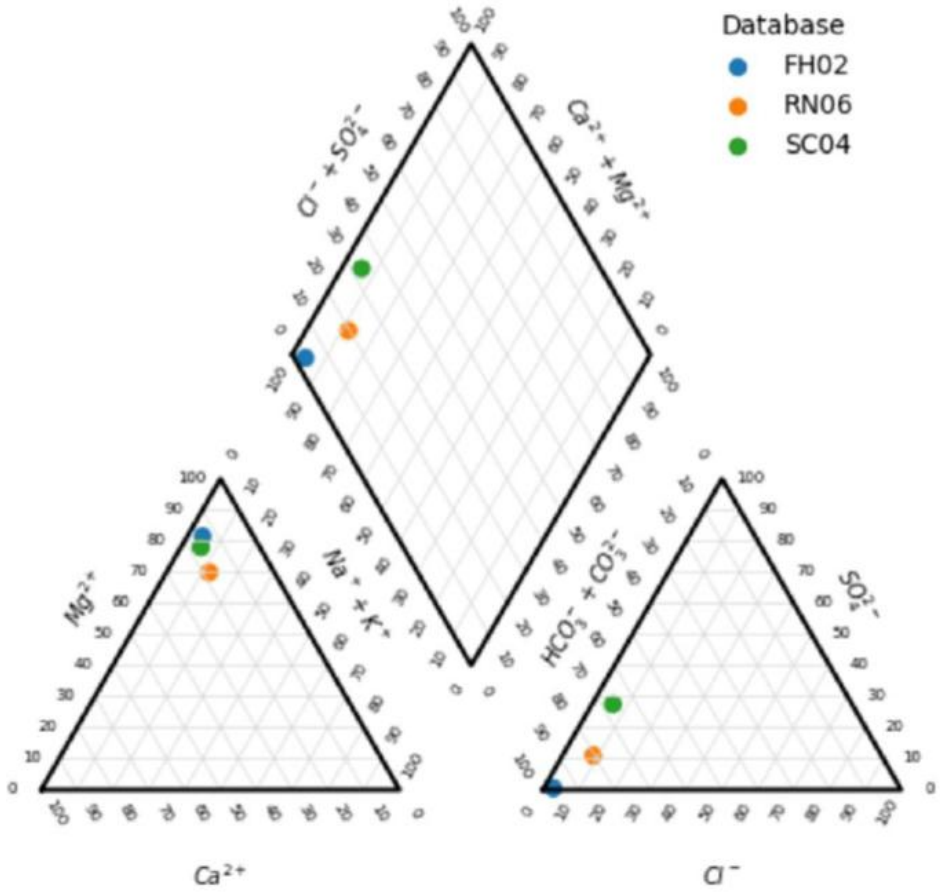


Figure 7 Piper diagram for Rietfontein Plant

Table 9 Water Quality Analysis results of boreholes tested.

	DWS Drinking Water Guideline Limits					SANS241: 2015 Drinking Water Standard Limits		RN06 (Rietfontein)	SC04 (Rietfontein)	FH02 (Rietfontein)
	Class 0	Class 1	Class 2	Class 3	Class 4	Aesthetic limits	Chronic Health Limits			
pH	5-9.5	4.5-5 or 9.5-10	4-4.5 or 10-10.5	3-4 or 10.5-11	<3 or >11	≥5 to ≤9.7		7.92	7.83	7.5
Electrical Conductivity	<70	70-150	150-370	370-520	>520	Aesthetic ≤170		914	1349	958
TDS	<450	450-1000	1000-2400	2400-3400	>3400	Aesthetic ≤1200		611	940	616
Antimony							Chronic health ≤0.02	<0.05	<0.05	<0.05
Arsenic	<0,01	0,01 - 0,05	0,05-0,2	0,2-2	>2		Chronic health ≤0,01	<0.05	<0.05	<0.05
Barium							Chronic health ≤0,7	0.12	0.14	0.07
Beryllium								<0.05	<0.05	<0.05
Boron							Chronic health ≤2,4	<0.5	<0.5	<0.5
Calcium	<80	80-150	150-300	>300				42.28	59.91	34.54
Copper	<1	1-1,3	1,3-2	2 - 15	>15		Chronic health ≤2	0.06	<0.05	0.07
Total Iron	<0,5	0,5-1	1 - 5	5 - 10	>10	Aesthetic ≤0,3	Chronic health ≤2	<0.05	<0.05	0.14
Magnesium	<70	70-100	100-200	200-400	>400			98.67	172	119.7
Manganese	<0,1	0,1-0,4	0,4-4	4 - 10	>10	Aesthetic ≤0,1	Chronic health ≤0,4	<0.05	<0.05	0.31
Molybdenum								<0.01	<0.01	<0.01
Potassium	<25	25-50	50-100	100-500	>500			2.83	3.56	3.12
Sodium	<100	100-200	200-400	400-1000	>1000	Aesthetic ≤200		30.11	21.16	9.97

	DWS Drinking Water Guideline Limits					SANS241: 2015 Drinking Water Standard Limits				RN06 (Rietfontein)		SC04 (Rietfontein)		FH02 (Rietfontein)	
	Class 0	Class 1	Class 2	Class 3	Class 4	Aesthetic limits		Chronic Health Limits							
Chloride	<100	100-200	200-600	600-1200	>1200	Aesthetic ≤300				25.5		28.65		8.39	
Fluoride	<0,7	0,7-1	1-1,5	1,5-3,5	>3,5			Chronic health ≤1,5		0.18		0.67		0.22	
Free & Saline Ammonia	0 - 1	1 - 2	2 - 10	>10		Aesthetic ≤1,5				0.11		0.12		9.44	
Nitrate	<6	6 -10	10 - 20	20-40	>40			Acute health ≤11		1.94		6.68		<0.5	
Nitrite								Acute health ≤0,9		<0.13		<0.13		<0.13	
Ortho Phosphate as P										<0.2		<0.2		0.72	
Sulphate	<200	200-400	400-600	600-1000	>1000	Aesthetic ≤250		Acute health ≤500		43.97		185.2		<2	
Cadmium								Chronic health ≤0.003		<0.05		<0.05		<0.05	
Lead								Chronic health ≤0.01		<0.05		<0.05		<0.05	
Cr(VI)*										<0.05		<0.05		<0.05	
Total Chrome	0 - 0,05		0,05 - 1	1 - 5	>5			Chronic health ≤0,05		<0.05		<0.05		0.4	
Nickel								Chronic health ≤0.07		<0.05		<0.05		<0.05	
Cobalt										<0.05		<0.05		<0.05	
Selenium								Chronic health ≤0.04		<0.1		<0.1		<0.1	
Lithium										<0.05		<0.05		<0.05	
Zinc	0 - 5	5 - 10	10 - 50	50 - 700	>700	Aesthetic ≤5				0.08		<0.05		0.21	

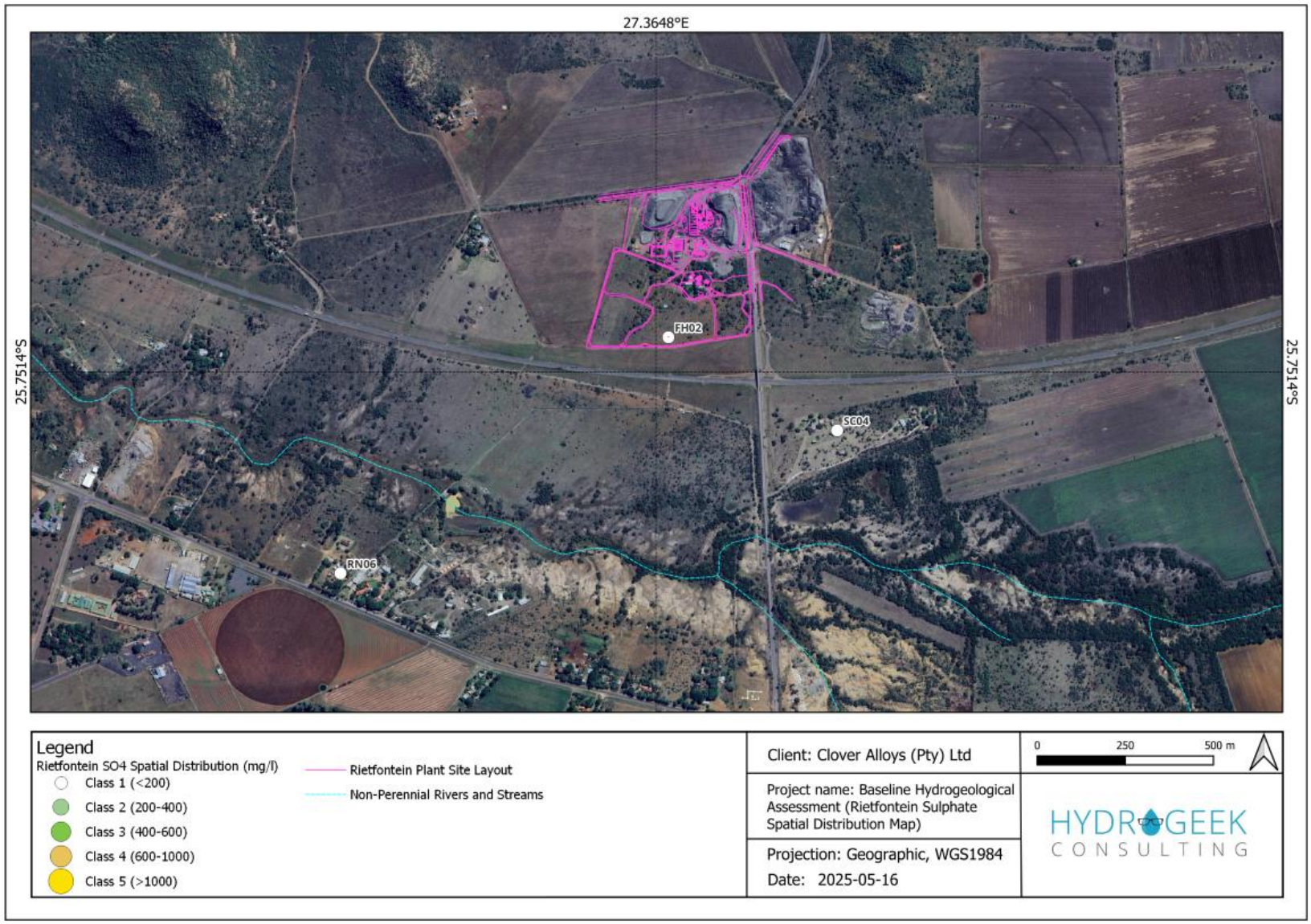


Figure 8 Spatial distribution of Sulphate (SO_4) concentrations for Rietfontein Chrome Plant

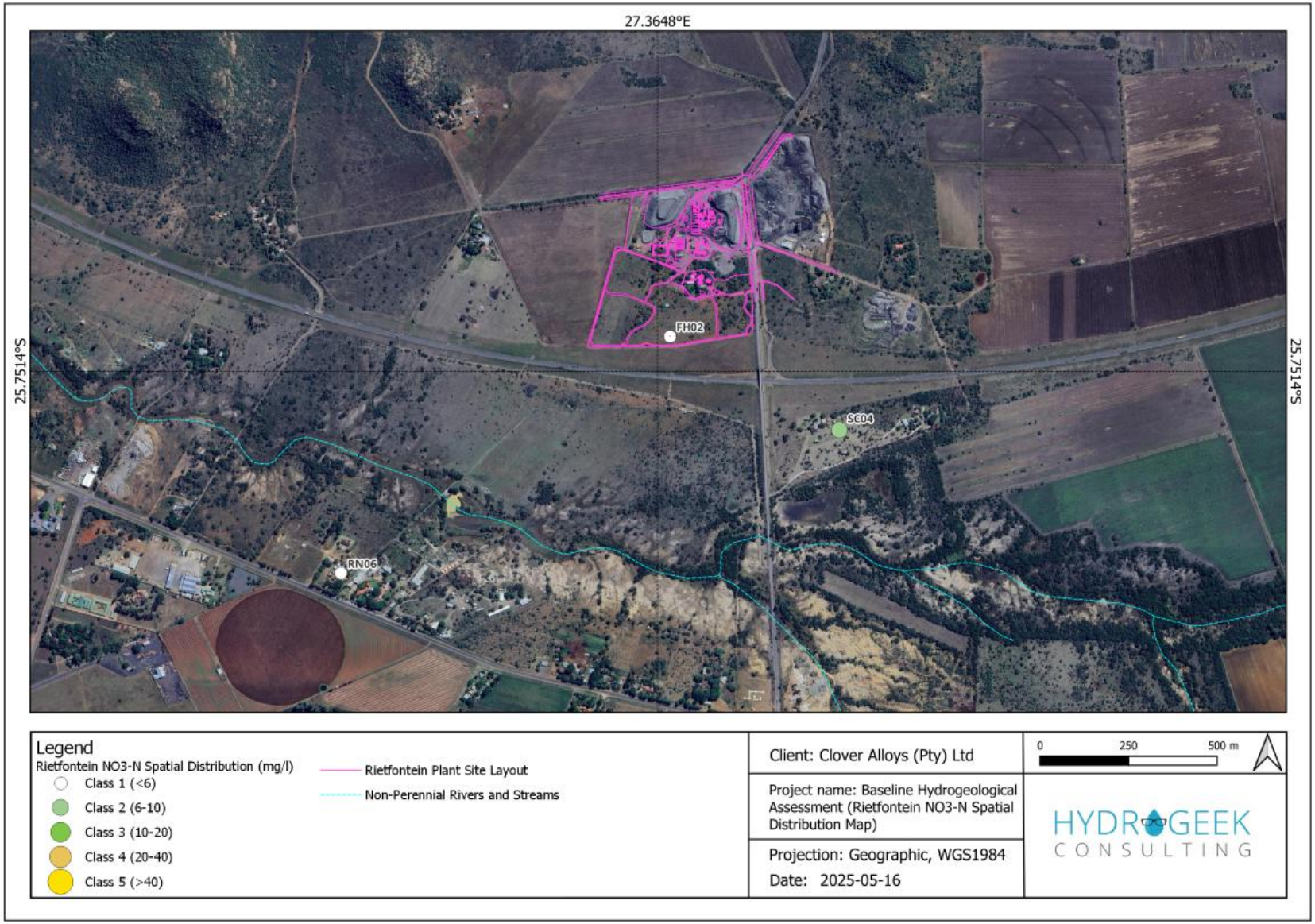


Figure 9 Spatial distribution of Nitrate (NO_3) concentrations for the Rietfontein Plant Operation

7 Conceptual Model of the Aquifer System

The geometrical characterization of hydrostratigraphic units was established through past studies and experience in these geological environments. Subsequently, interpretations were extrapolated to cover an approximate area of 10.5 x 12 km, utilizing additional data sources such as rock outcrops and surface formation maps.

- The Rietfontein area consists of an eastern and western existing Stockpile area (for reference Minelock did a waste classification on these materials), Pollution Control Dam and Plant area.
- The area exhibits varying levels of conductivity and recharge. Hydraulic conductivity ranges from 1.5 x 10-1 m/d for the Shallow weathered to 1.0 x 10-5 m/d for the intact bedrock.
- The hydrostratigraphic units within the region are delineated as follows:

    1. Turf Clay
    2. Shallow weathered zone
    6. Bedrock – Intact

- Groundwater levels are shallow ranging from 13.5 – 20.6 mbgl. Groundwater levels unaffected by production are below 15 mbgl.
- The groundwater flow direction is towards the west or south west. Localised drawdown on site is observed with a borehole level at 20.6 mbgl.
- Three abstraction boreholes (RP01, RP02 and RP03) are being used for abstraction.
- The Sandspruit was identified as a potential receptor due to the proximity to the Rietfontein Plant. The Sandspruit is deemed more susceptible to contamination by surface water runoff and seepage from the shallow weathered aquifer.
- There are signs of groundwater contamination down gradient of the Rietfontein Chrome Plant towards the Sandspruit (a tributary of the Hex River).

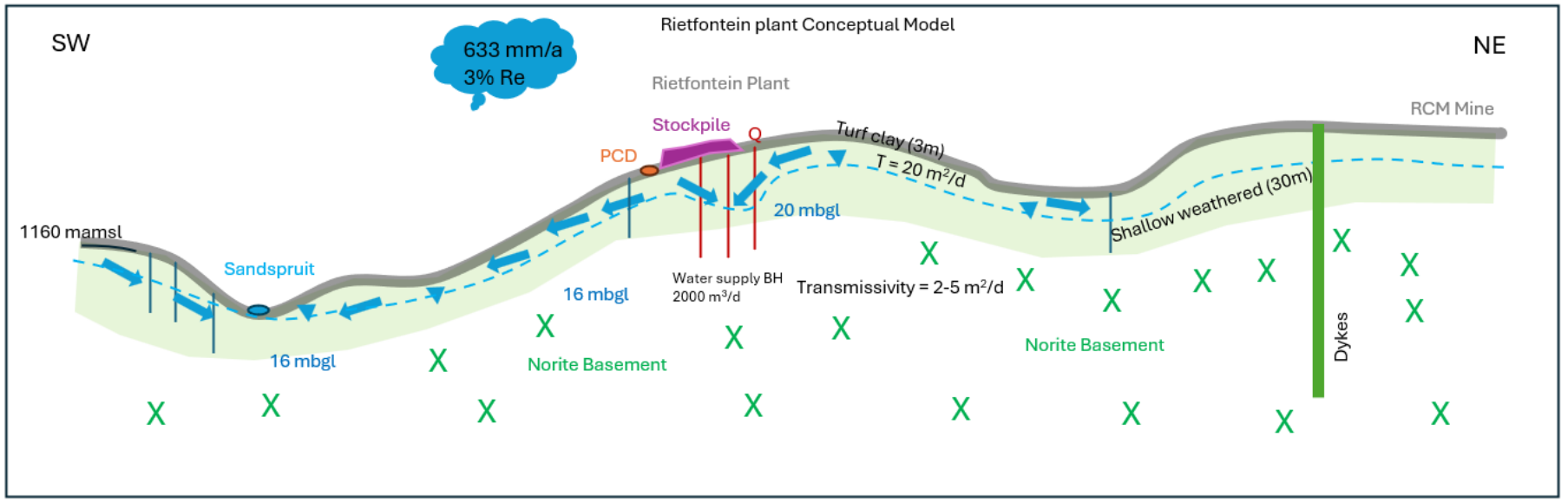


Figure 10 Conceptual model

8 GROUNDWATER FLOW MODEL DEVELOPMENT

8.1 Objectives of the Modelling

- Determination of the future groundwater quality and quantity impacts related to the proposed changes in plan activities will be modelled.

8.2 Modelling Package

FEFLOW is a powerful 3-D finite element groundwater flow and solute transport model. It can solve transient or steady-state flow, saturated and unsaturated flow, multiple free surfaces or perched water tables.

FEFLOW has a comprehensive selection of graphical tools for building the finite element mesh, assigning property zones and setting boundary conditions. The software includes state-of-the-art 3-D visualization of modelling outputs.

The main advantages of FEFLOW are its versatility in solving different flow and transport problems, flexibility in discretizing problems (representing models with elements) due to use of the finite element method, and flexibility in formulating boundary conditions (due to its use of “constrained” boundaries). This flexibility in model discretization and boundary conditions can be very useful when simulating complex flow problems (e.g. mine developments in structurally controlled bedrock and progressive excavation of open pit and underground mine excavations). FEFLOW is recommended for complex natural resource problems in which complex geometries and/or complex boundary conditions will have to be simulated.

The main disadvantage of FEFLOW is that it requires significant modelling expertise, including in-depth understanding of finite-element methods. The software’s flexibility makes it a powerful tool but can also make it difficult to use (for inexperienced users in particular). Setting up FEFLOW may also require more data that may not be readily available.

8.3 Assumptions and limitations

- The activation and concentrations of source terms were based on monitoring data and historic Google Earth images.
- The geology was based on the 1:250 000 published geological maps as well as 1:50 000 topographical maps.
- QGIS online aerial imagery was used in the layout of the various maps compiled for the current report. The imagery may well be dated and has been used for reference only.
- The model is used for decision making and should be applied accordingly. Modelled impacts may vary at any point and on-going monitoring is required to actively manage the proposed mining activities and possible impacts.
- No site characterization boreholes were drilled for this investigation; aquifer parameters and hydrostratigraphic units were assumed based on historical data and similar studies.

- The investigation utilized data from field surveys and existing monitoring as a snapshot, with further trends to be verified through ongoing monitoring as outlined in the monitoring program.
- The numerical groundwater flow model was developed using site-specific information, excluding influences from neighboring mining developments.

8.4 Model Area

The model domain has been revised to encompass the regional extents of the pits, underground workings and waste areas, ensuring a simplified yet comprehensive representation. The current model domain is considered adequate, with boundary adjustments deemed unnecessary as they would have minimal impact on the modelled outcomes. Notably, topographical highs were predominantly selected in the north and south regions. Additionally, in the western and southeastern areas, a river serves as the outer boundary of the model domain. These adjustments were made to maintain model simplicity while adequately capturing the hydrogeological dynamics of the study area.

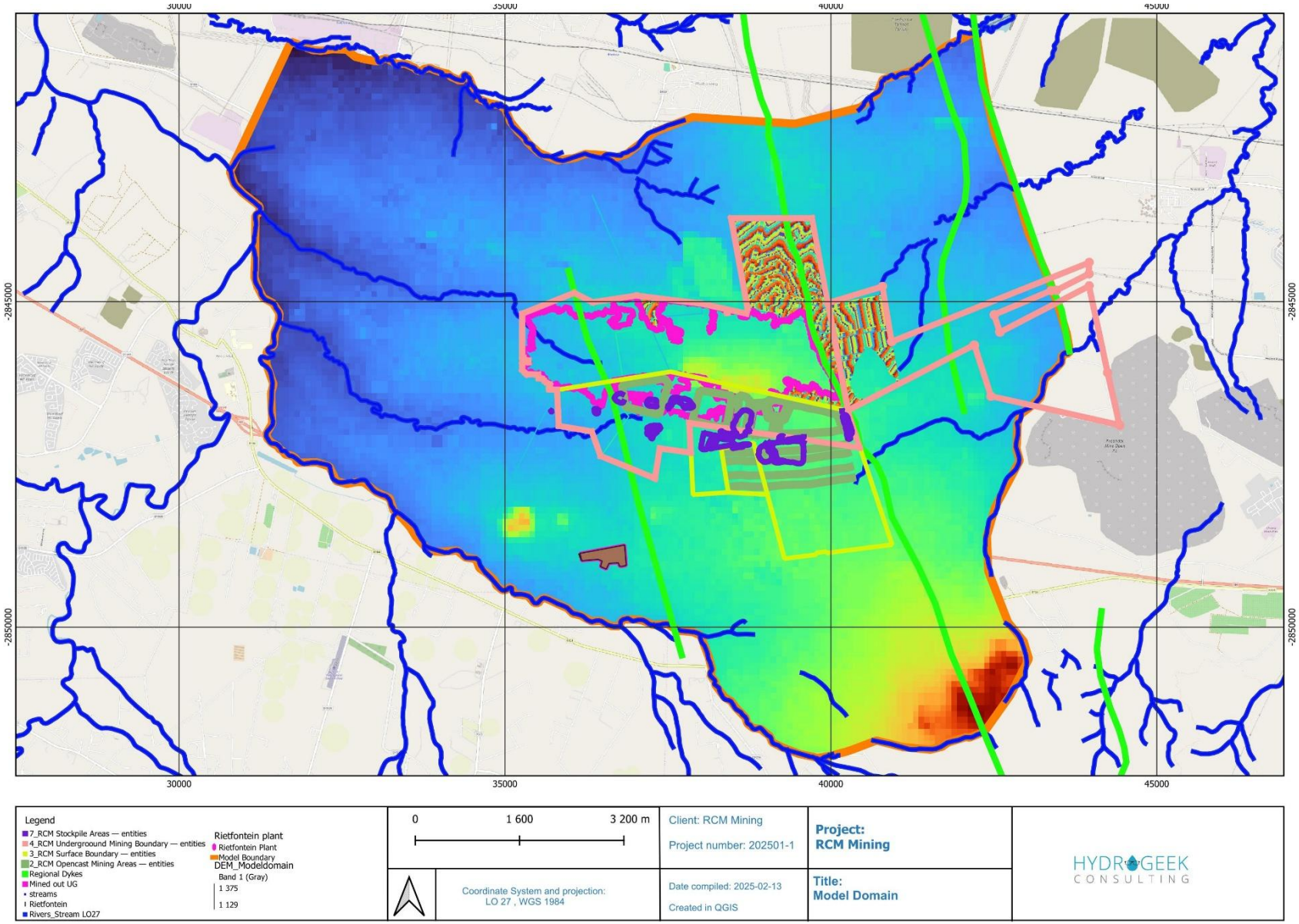


Figure 11 Model boundary

8.5 Construction of the Finite Element Grid

The numerical model encompasses the area of Rietfontein covering a total area of 170 km^2 (approximately 10 km × 17 km). A finite element network (grid) was designed to provide a high resolution of the numerical solution, while at the same time accommodating the large model area. The super element mesh contains the main important features of the conceptual model, e.g. the surface expression of the main hydro lithological aquifer units, structures, drainages and mine facilities. The finite element grid is based on a super element mesh constructed across the area

The finite element grid was compiled using the FEFLOW pre-processing software, which facilitated the construction of six-noded triangular prism elements over the area of investigation. The triangular grid consists of 81.381 elements and 41,050 nodes per slice.

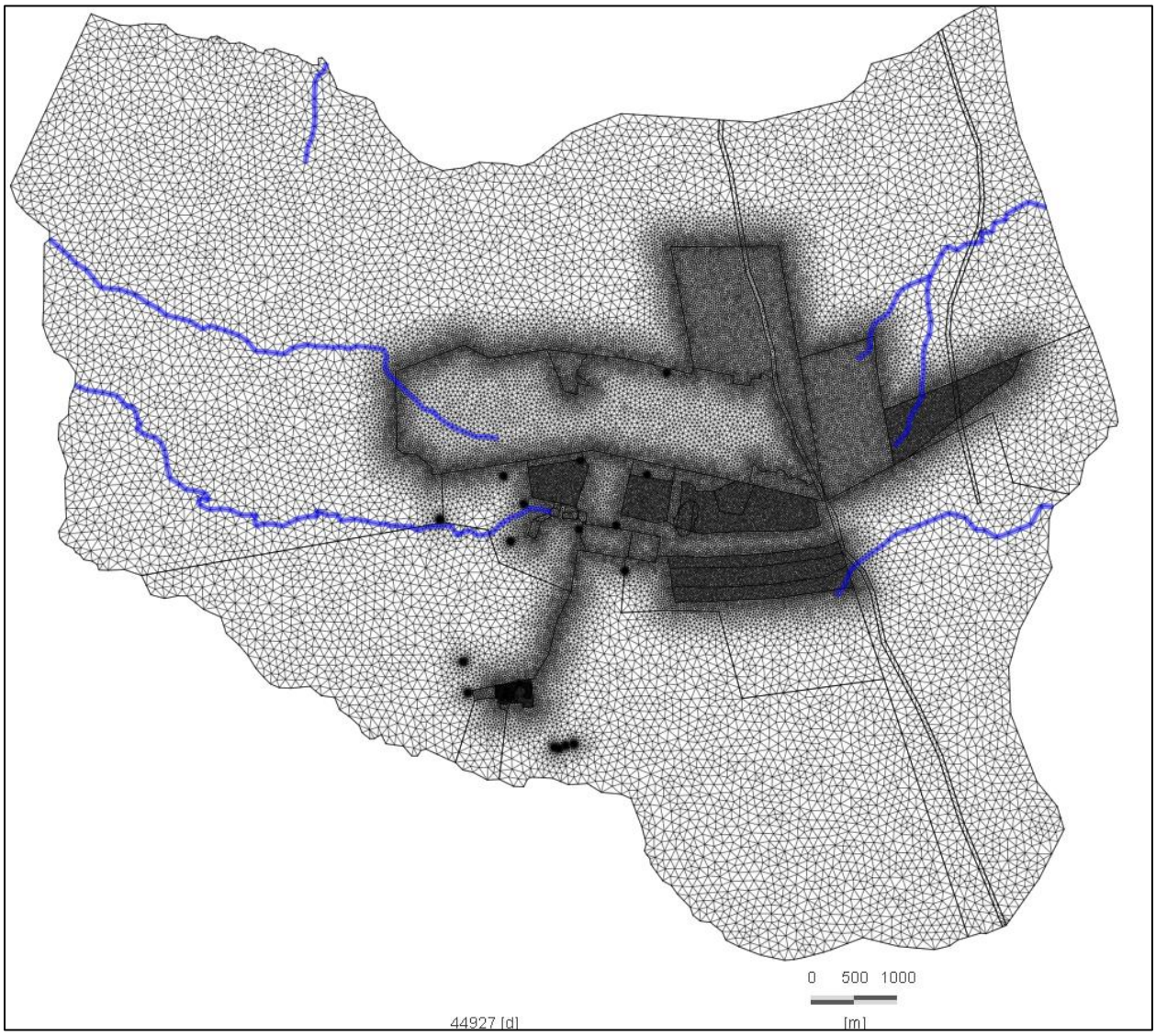


Figure 12 FEFLOW Mesh

8.6 Boundary Conditions

Boundary conditions express the way the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as piezometric head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions. Boundary conditions in a groundwater flow model can be specified either as:

- Dirichlet Type (or constant head) boundary conditions, or
- Neuman Type (or specified flux, including “no flux”) boundary conditions, or
- A mixture of the above

The model area perimeter coincides with topography as no flow boundaries. At the southern boundary a constrained head (max flow 0 m3/d) is specified equal to the water level elevation (water can only leave the model at this position).

Table 10 Boundary Conditions

Boundary	Topographical Feature	Boundary Condition
Northern Boundary	Catchment Divide	Seepage face hydraulic head
Southern Boundary	Surface Water feature	Seepage face hydraulic head
Western Boundary	Surface Water feature	Seepage face hydraulic head
Eastern Boundary	Geological Dyke	No flow boundary Condition

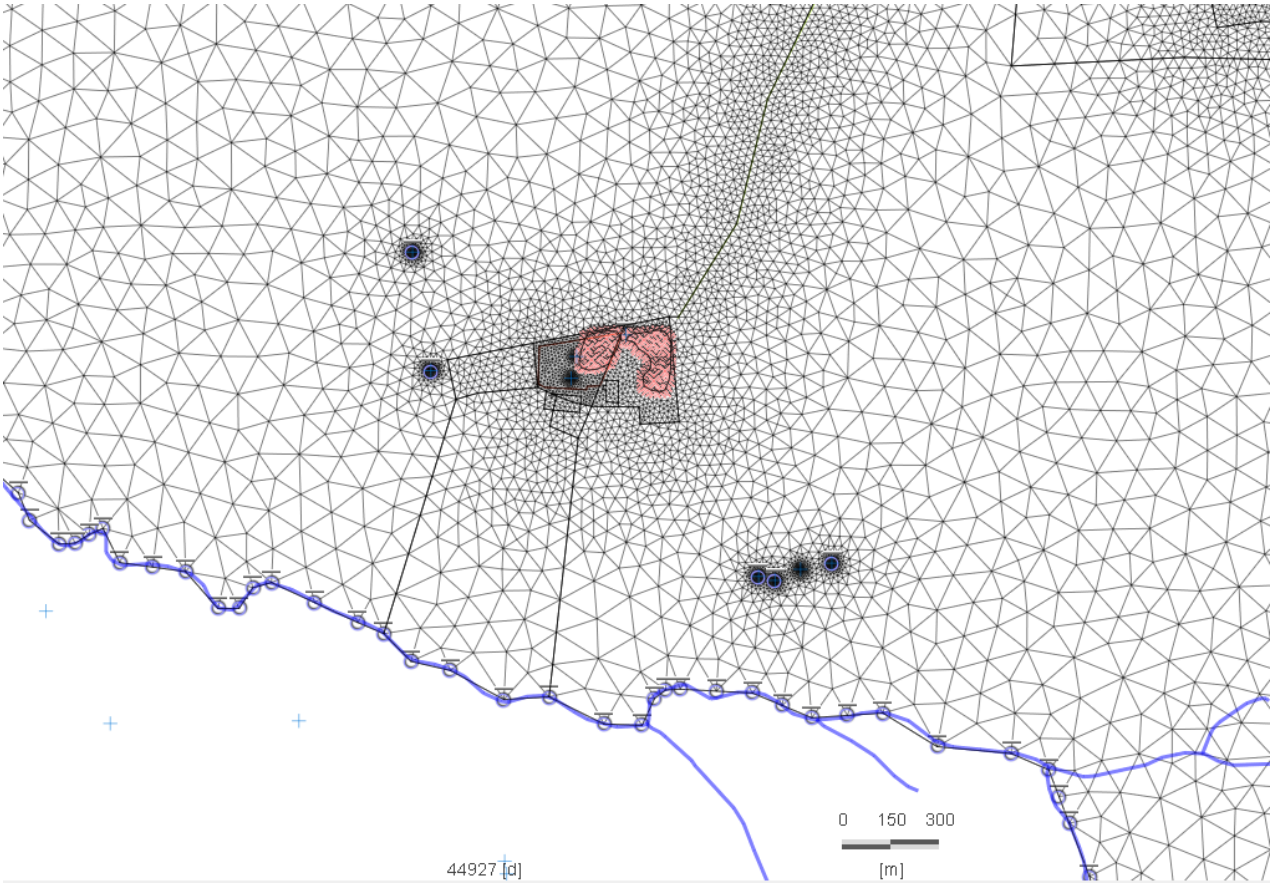


Figure 13 FEFLOW boundary conditions in Rietfontein Area

8.7 Model layers

The hydrostratigraphic units within the region have been discretized into six numerical model layers, providing a structured representation of the subsurface hydrogeological framework:

- Layer 1Turf clay
- Layer 2: Shallow Weathered
- Layer 3: Basement Bedrock

These model layers serve as the foundation for simulating groundwater flow and transport processes within the study area. Additionally, the top slice of the model corresponds to the topography of the area, ensuring accurate representation of surface features and elevations. Conversely, the bottom of the model extends below the surrounding underground mining activities providing comprehensive coverage of the subsurface environment. No mining is currently taking place at the Rietfontein plant. This vertical arrangement enables the integration of both natural and anthropogenic influences on groundwater dynamics, facilitating robust modelling and analysis.

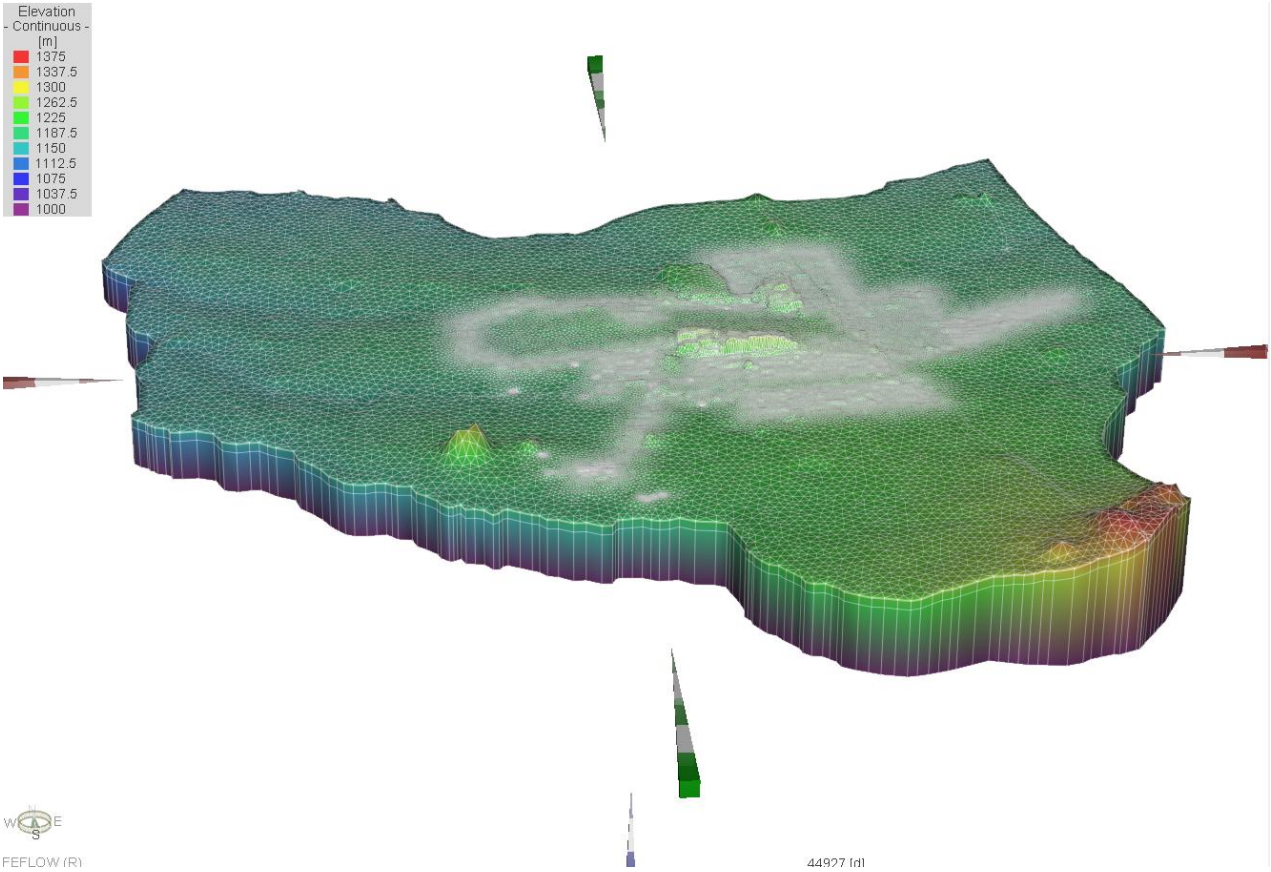


Figure 14 3D Model looking North with elevation

8.8 Aquifer Transmissivity (Hydraulic Conductivity)

The aquifer parameters calibrated in the model is based on the previous aquifer testing in the area. The model calibration refined the parameters as shown in Table 11.

Table 11 Calibrated Aquifer parameters

Hydrostratigraphic Units	Model Layer	Hydraulic Conductivity (m/d)	Anisotropy (Kx/Kz)	Drainage Porosity
Turf Clay	1	3.0×10^{-1}	10	0.15
Shallow Weathered	2	1.5×10^{-1}	10	0.03
Basement bedrock	3	1.0×10^{-5}	10	0.03

8.9 Steady State Simulation (Calibration)

Calibration is the process of identifying a suitable set of hydraulic parameters, boundary conditions, and stresses that best describe the observed hydraulic heads or fluxes within a defined catchment (Anderson and Woessner, 1992). Under steady state conditions the groundwater flow equation is reduced to exclude storativity and only transmissivity (or hydraulic conductivity) and recharge are considered in the calibration process. The model calibration was carried out by adjusting hydraulic conductivity and aquifer recharge.

During steady-state calibration, parameters defining hydraulic properties described in section 2.5.

The following model metrics are used to judge the calibration performance:

- Model convergence
- Water balance error <1%
- RMS error of < 10m
- Normalized RMS of < 10%

Simulated potentiometric surface matches the conceptual understanding of groundwater flow. The steady state results are given in Table 12.

Table 12 Steady state results

Calibration Results			
Groundwater level ID	**Observed Water Level**	**Simulated Water Level**	**Difference**
SC01	1198,1	1196,83034	1,270
SC02	1195,5	1194,5599	0,940
FH01	1196,5	1191,04727	5,453
FH02	1192,3	1190,54156	1,758
RP02	1186,4	1187,94105	-1,541
BH1	1195,38	1198,40846	-3,028
BH2	1200,58	1197,56042	3,020
BH3	1199	1195,04082	3,959
BH4	1198,89	1196,48329	2,407
Mean error (m)	**ME**		**1,582**
Root Mean Square Error	**RMSE**		**2,502**
Normalized Root Mean Square Error	**nRMSE**		**17,65%**

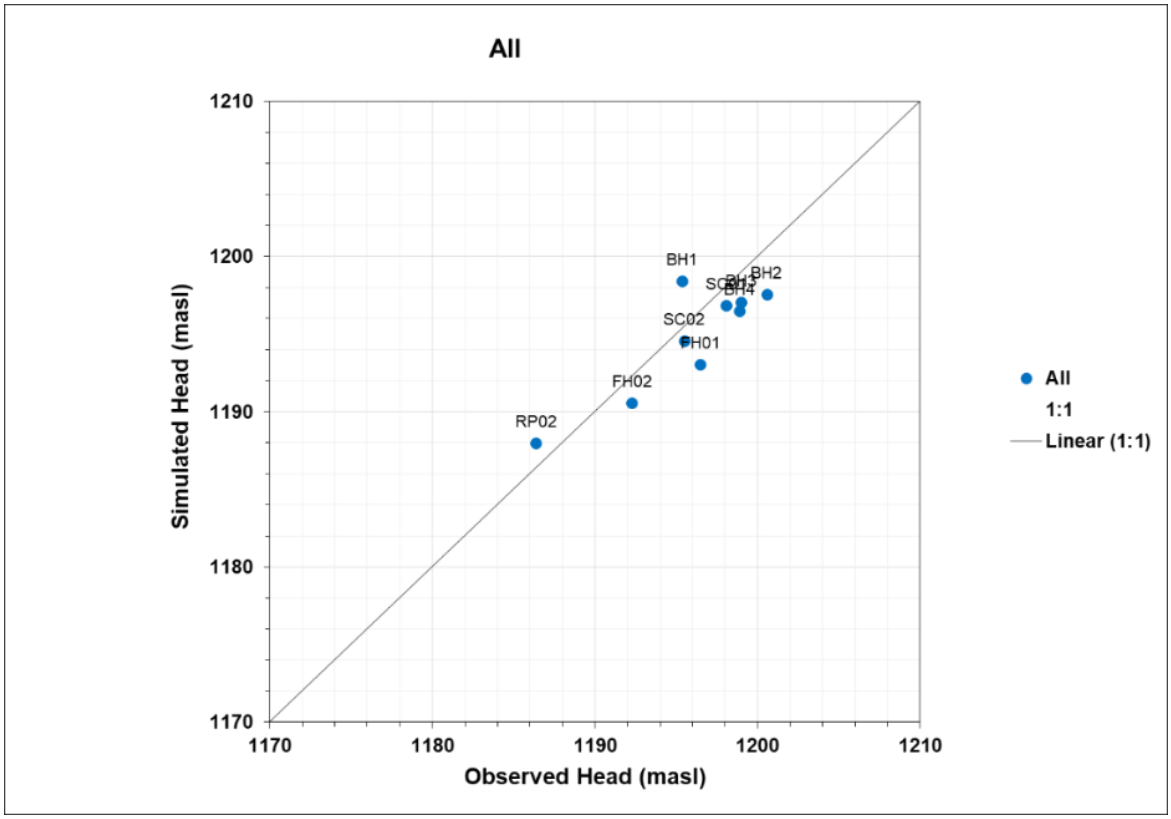


Figure 15 Scatterplot of measured vs simulated heads

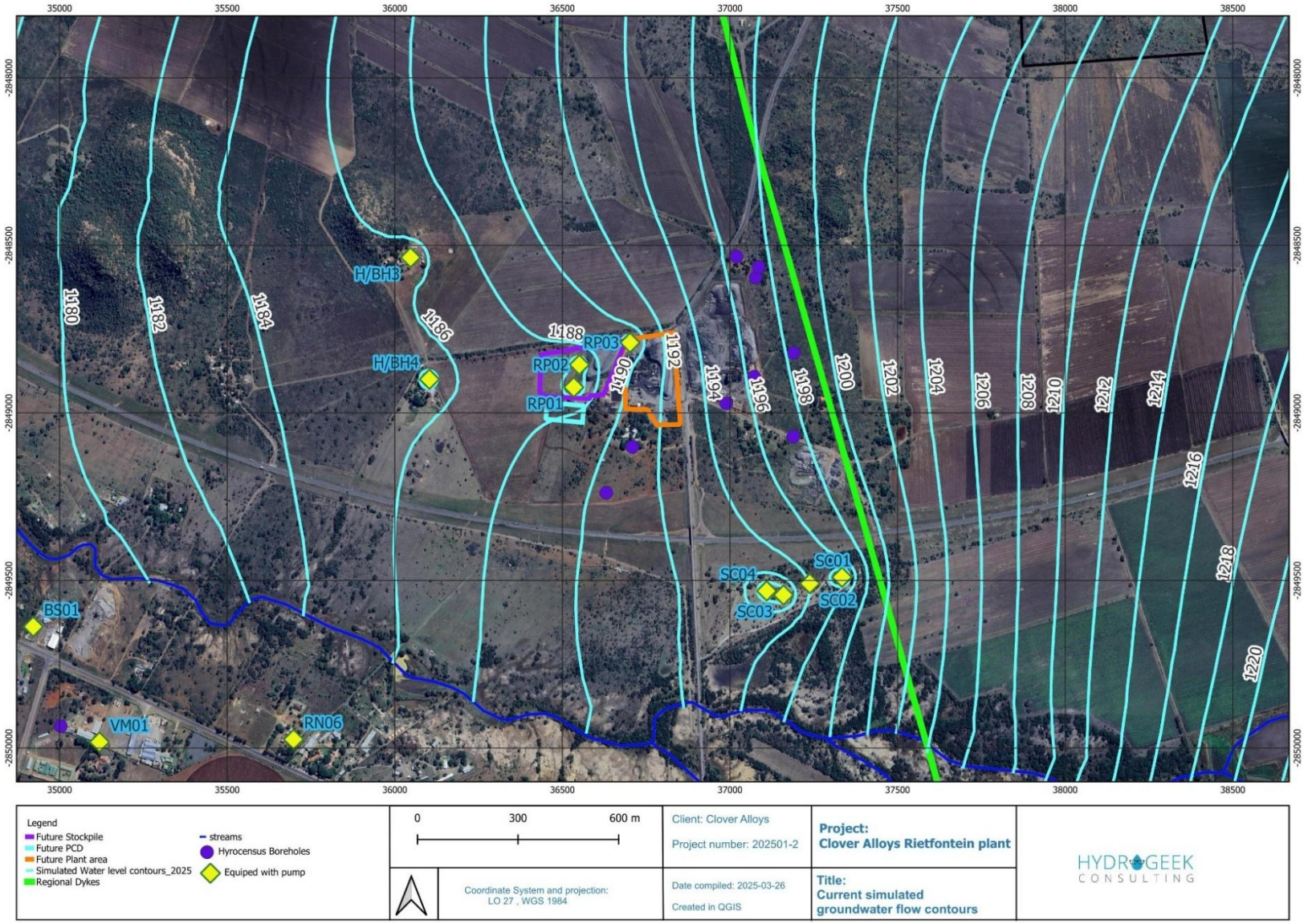


Figure 16 Piezometric surface based on current conditions

8.10 Steady State Groundwater Balance

The calibration simulation conducted represents the current groundwater flow conditions as observed in Feb 2025. Figure 21 depicts the interpreted piezometry of the model, representing shallow weathered zone

It can be observed that the abstraction borehole has impacted the groundwater flow. Continuing with the simulations, the model captures the interactions between the abstraction wells and waste facilities impact on groundwater levels. The results provide insights into the flow dynamics and potential changes induced by the plant operations. It's crucial to interpret these findings in conjunction with the calibrated model and acknowledge the limitations and uncertainties inherent in numerical simulations.

Table 13 Water Balance for current conditions

	Inflow (m^3/d)	Outflow (m^3/d)	Balance (m^3/d)
Effective Recharge	2606	0	2606
Water losses from drainages		2427,96	178,04
Water losses from abstraction boreholes		184,54	-6,5
Seepage losses from facilities	6,5		0
Total	**2612,5**	**2612,5**	**0**
Balance error (%)			**0**

9 DEVELOPMENT OF THE CONTAMINANT TRANSPORT MODEL

9.1 Introduction

A numerical model of solute transport, coupled with the groundwater flow model, was developed to simulate the effect of the establishment of new location of waste rock piles on groundwater quality. The following paragraphs present the methodology used, the simulations performed, and the results obtained

9.2 Processes Controlling Contaminant Transport

Transport through a porous medium is mainly controlled by the following two processes:

- Advection; and
- Hydrodynamic dispersion.

For clarity these processes will be discussed briefly.

9.2.1 Advection

Advection is the component of contaminant movement described by Darcy's Law. If uniform flow at a velocity (V) takes place in the aquifer, Darcy's law calculates the distance (x) over which a labelled water particle migrates over a time period (t) as x = Vt.

9.2.2 Hydrodynamic Dispersion

- Mechanical dispersion; and
- Molecular diffusion.

Mechanical dispersion is the process whereby the initially close group of labelled particles is spread in a longitudinal as well as in a transverse direction. This is caused by the velocity distribution (as a result of varying microscopic streamlines) that develops at the microscopic level of flow around the grain particles of the porous medium. Although this spreading is both in the longitudinal and transversal direction of flow, it is primarily in the former direction. Very little spreading can be caused in the transversal direction by velocity variations alone.

Molecular diffusion mainly causes transversal spreading, by the random movement of the molecules in the fluid from higher contaminant concentrations to lower ones. It is thus clear that if V = 0, the contaminant is transported by molecular diffusion only, or in other words the higher the velocity of the groundwater, the less the relative effect of molecular diffusion on the transportation of a labelled particle.

In addition to advection, mechanical dispersion and molecular diffusion, several other phenomena may affect the concentration distribution of a contaminant as it moves through a porous medium. The contaminant may interact with the solid surface of the porous matrix in the form of adsorption of contaminant particles on the solid surface, deposition, solution of the solid matrix and ion exchange. All these phenomena cause changes in the concentration of a contaminant in a flowing fluid.

9.3 Mass Balance Equation

The mass balance equation (Bear and Verruijt, 1992) (equation of hydrodynamic dispersion or the advection-dispersion equation) of a pollutant (contaminant) is expressed as:

$$\frac{\delta nc}{\delta t} = -\Delta \bullet q\, c, \text{total} - f + n\rho I' - Pc + Rc \qquad (3)$$

Where:

nc	= mass of pollutant per unit volume of porous medium;
n	= porosity of saturated zone;
c	= concentration of pollutant (mass of pollutant per unit volume of liquid (water));
$\Delta \bullet$ q c, total	= excess of inflow of a considered pollutant over outflow, per unit volume of porous medium, per unit time;
f	= quantity of pollutant leaving the water (through adsorption, ion exchange etc.);
$n\rho I'$	= mass of pollutant added to the water (or leaving it) as a result of chemical interactions among species inside the water, or by various decay phenomena;

Γ'	=rate at which the mass of a pollutant is added to the water per unit mass of fluid;
p	= density of pollutant;
Pc time;	= total quantity of pollutant withdrawn (pumped) per unit volume of porous medium per unit
Rc unit time.	= total quantity of pollutant added (artificial recharge) per unit volume of porous medium per

9.4 Kinematic Porosity Values

Definition of kinematic porosity: "From the point of view of fluid displacement, the adhesive water may be viewed as part of the solid. The empty volume, where the water can circulate, is smaller than the total porosity: it defines the kinematic or effective porosity of a saturated medium".

A Kinematic porosity of 3% was applied.

9.5 Longitudinal and Transversal Dispersivities

A longitudinal dispersivity value of 10 m was calibrated for the simulations (Spitz and Moreno, 1996). Bear and Verruijt (1992) estimated the average transversal dispersivity to be 10 to 20 times smaller than the longitudinal dispersivity. An average value of 1 m was selected for this parameter during the simulations.

9.6 Source Term

A fluid flux and a mass flux boundary condition were implemented as input parameters into the numerical model. This boundary condition facilitates the introduction of a mass load (expressed in g/m^2/d) into the model, derived from the product of the seepage rate (in m/d) and the concentration (in mg/l) of the contaminant. For instance, arsenic concentrations of 0.27 mg/l were utilized in the model calculations to determine the corresponding mass load introduced at the specified boundary. The rate modelled for the PCD dam is 172 l /day.

Table 14 Source terms

Area	Seepage rate mm/a	Seepage rate m/d	TDS mg/l	mass load g/m2/d
Pollution Control Dam (lined)	-10	-0.000026	1000	-0.026
Existing Waste Stockpiles	-90	-0.00024657	1000	-0.24657
Future Waste Stockpiles	-90	-0.00024657	1000	-0.24657

leakage calculations below used by Minelock correlated well with what was used in the plume modelling.

- Primary Leakage drainage system ALR (1 m depth) 2 847 ℓ/ha/day
- Primary Leakage drainage system ALR (2.7 m depth) 4 678 ℓ/ha/day

- Primary Leakage drainage system capacity 4 704 ℓ/ha/day
- Primary Leakage drainage system ALR (2.7 m depth) 3 483 ℓ/PCD/day

For the secondary liner, the estimated leakage rate would be **150 ℓ/PCD/day**

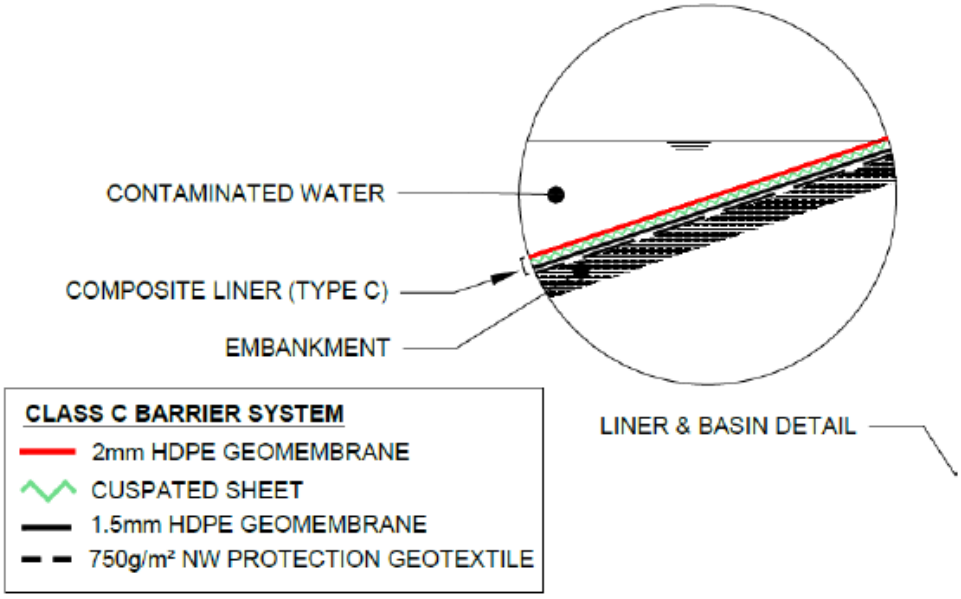


Figure 17 Liner design

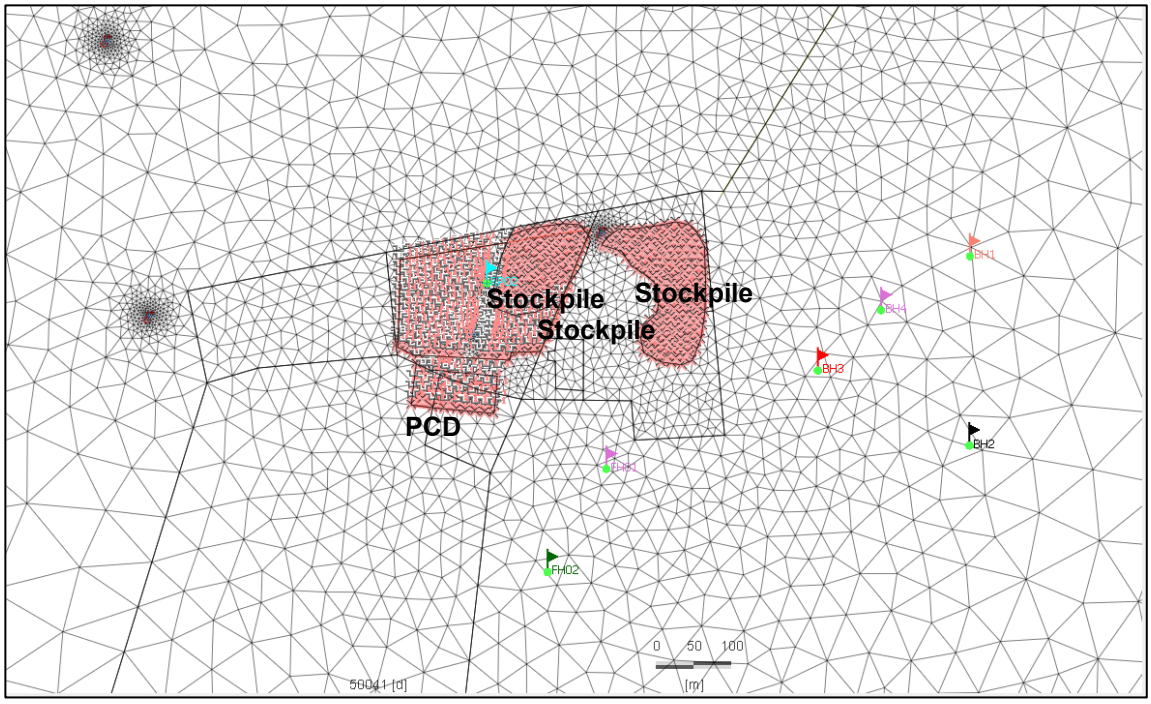


Figure 18 Source term included in model as fluid flux.

9.7 Mass Transport Transient Simulations

9.7.1 Scenario 1: Current Impact from existing Stockpiles 2023-2025

The progression of TDS concentrations in groundwater within the unweathered zone (layer 2 of the model) in the absence of sealing measures. The Stockpiles are situated on site close to the abstraction boreholes and started in 2023 in the model, resulting in a reduced impact, as the cone of depression captures the plume. The findings suggest that a dissolved plume would form and have already reached the abstraction boreholes. The source concentration exceeds the standard criterion of 450 mg/l, with a background value of 100 mg/l. The existing plume spreads towards the east but remains within the boundaries of Rietfontein.

9.7.2 Scenario 2: Future Impact from existing and future Waste Rock Dumps LOM 2025-2036

In this scenario the additional stockpile area started in 2026. The progression of TDS concentrations in groundwater within the unweathered zone (layer 2 of the model) in the absence of sealing measures. The lined PCD was also simulated as part of this study and shows negligible impact in terms of the quality. The Stockpiles are situated on site close to the abstraction boreholes and started in 2023 in the model, resulting in a reduced impact, as the cone of depression captures the plume. The findings suggest that a dissolved plume would form and have already reached the abstraction boreholes. The source concentration exceeds the standard criterion of 450 mg/l, with a background value of 100 mg/l. The existing plume spreads towards the east but remains within the boundaries of Rietfontein.

The future plume spreads over a distance of 100m towards the east but is retarded/captured by the abstraction boreholes.

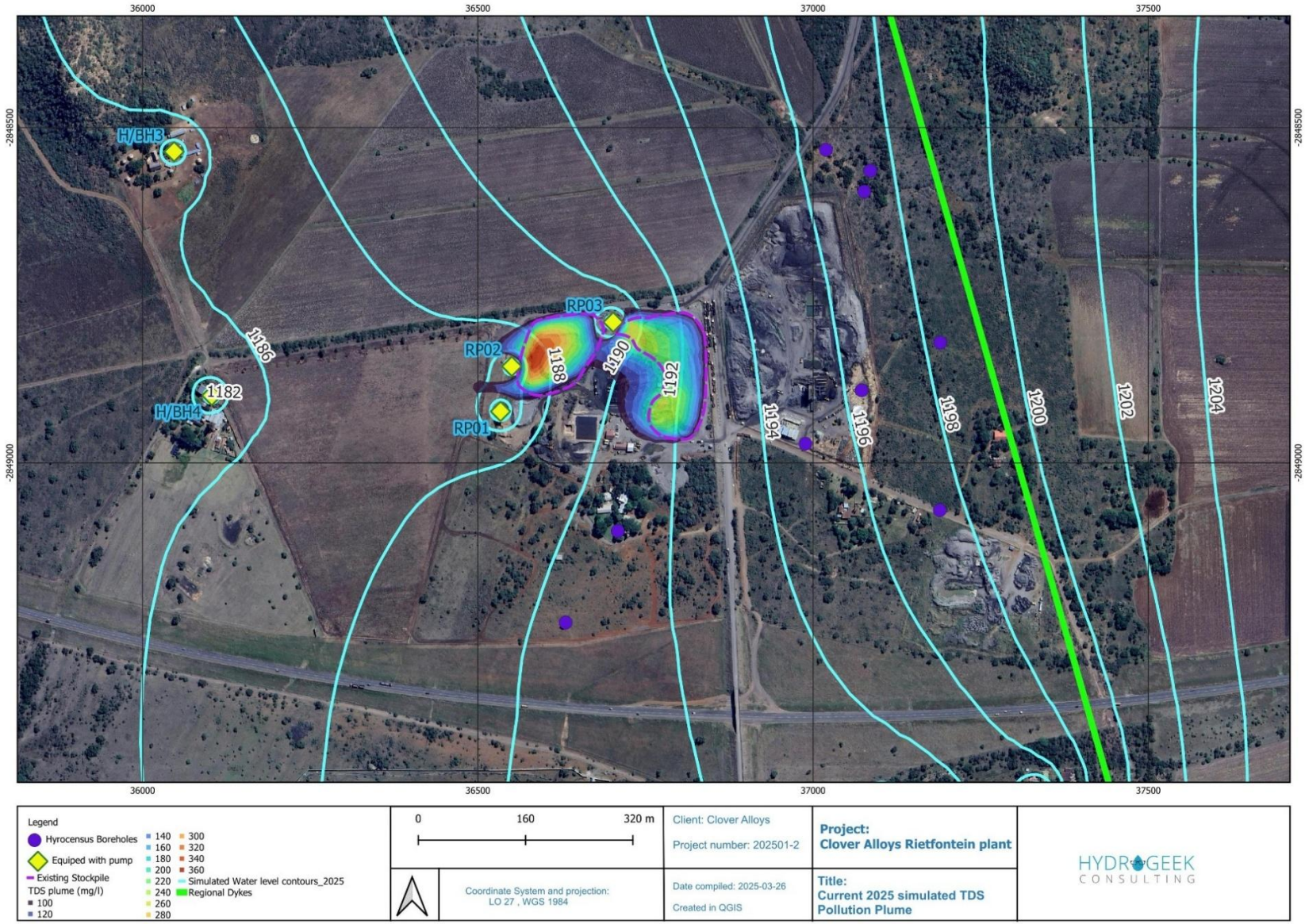


Figure 19 Pollution Plume current conditions

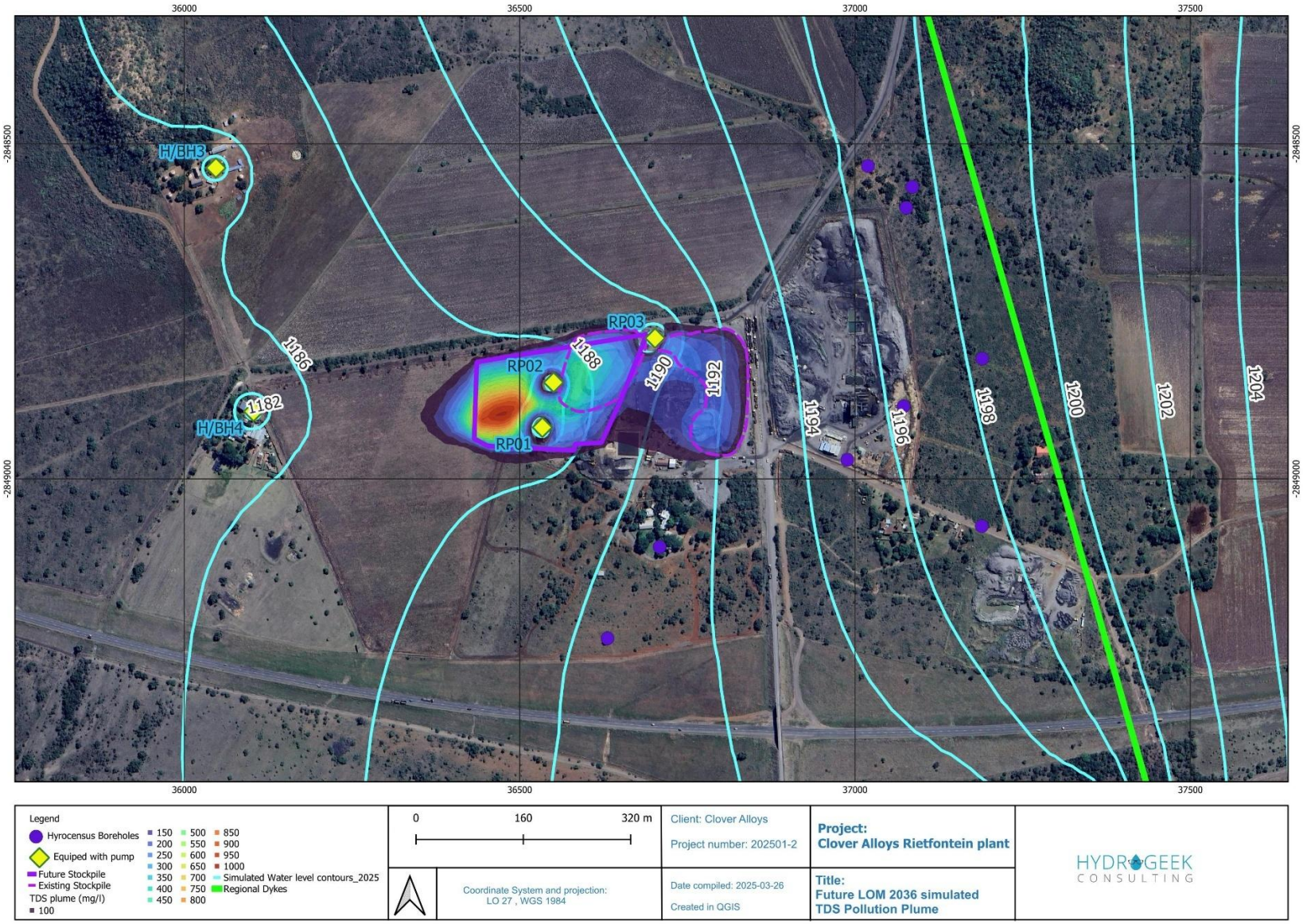


Figure 20 Pollution Plume at 2036 current LOM

10 HYDROGEOLOGICAL RISK ASSESSMENT AND ENVIRONMENTAL MANAGEMENT PROGRAMME

The aim of this section is to assess the likely hydrogeological impacts that the Rietfontein Plant might have on the receiving environment and sensitive receptors. The groundwater risk assessment methodology is based on defining and understanding the three basic components of the risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is therefore aimed at describing and defining the relationship between cause and effect. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist.

The current impacts from the infrastructure were assessed to have already impacted the groundwater environment is terms of quality and quantity. The additional infrastructure will not have higher impact on the current groundwater environment; therefore the current and future impacts can be contained through the proposed mitigation.

10.1 Rietfontein Plant Operation

Statement on Impact Differentiation

The potential environmental impacts associated with the proposed new infrastructure—such as the pollution control dam (PCD), clean and dirty water separation systems, and related channels—have been reviewed in the context of the existing operations assessed under the Section 24G application. Based on the nature, location, and function of the planned infrastructure, the associated impacts are anticipated to be materially similar in type, extent, and significance to those already identified and assessed.

As such, these impacts are considered to be sufficiently addressed by the current impact assessment. Should any deviations or unique site-specific impacts arise during implementation, these will be managed under the existing environmental management framework and mitigation measures already in place."

10.1.1 Future and current impacts of the Chrome wash plant on the hydrogeological regime.

- There is currently evidence of groundwater contamination as seen by the elevated Chrome concentration in borehole FH02, unlikely from the plant operations.
- Abstraction at water supply boreholes can lead to a decline in the groundwater levels and potentially affect private groundwater users located approximately 400 – 600m to the northwest of the plant.
- Abstraction at water supply boreholes can lead to a decline in groundwater levels and potentially capture contamination from the Stockpiles.
- Poor storm water management in the past and runoff during heavy rains can increase the seepage of Chrome into groundwater
- Storage and handling of hydrocarbons and hydrocarbon spillage at plant and generators.

10.1.2 Mitigation and management measures.

- Currently there are no groundwater monitoring boreholes at the Rietfontein Chrome Plant. Geophysical surveys need to be conducted on site and around the facility to determine the placement of monitoring boreholes in an upgradient position, on-site and down gradient position of the stockpiles, pollution control dam and plant.
- Monitoring of abstraction boreholes water quality to ensure water quality is to standard required by plant.
- 48–72-hour aquifer testing of the three boreholes (RP01, RP02 and RP03) to determine a sustainable yield for the aquifer and the effect on each other.
- Monitoring of abstraction volumes and monitoring boreholes water levels to ensure abstraction rates are sustainable and managed.
- Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.

10.2 Risk Assessment Criteria

10.2.1 Procedure

The impact significance rating methodology, as presented herein and utilised for all EIMS Impact Assessment Projects, is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The approach may be altered or substituted on a case by case basis if the specific aspect being assessed requires such-such instances require prior EIMS Project Manager approval. The broad approach to the significance rating methodology is to determine the significance (S) of an environmental risk or impact by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relating this to the probability/ likelihood (P) of the impact occurring. The S is determined for the pre- and post-mitigation scenario. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the S to determine the overall final significance rating (FS). The impact assessment will be applied to all identified alternatives.

10.2.2 Determination of Significance

The final significance (FS) of an impact or risk is determined by applying a prioritisation factor (PF) to the post-mitigation environmental significance. The significance is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and Reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$\boldsymbol{C = \frac{(E + D + M + R) * N}{4}}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 15 below.

Table 15 Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. Highly localised, limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property or site boundary, or the area within a few hundred meters of the site)
	3	Local (i.e. beyond the site boundary within the Local administrative boundary (e.g. Local Municipality) or within consistent local geographical features, or the area within 5 km of the site)
	4	Regional (i.e. Far beyond the site boundary, beyond the Local administrative boundaries within the Regional administrative boundaries (e.g. District Municipality), or extends into different distinct geographical features, or extends between 5 and 50 km from the site).
	5	Provincial / National / International (i.e. extends into numerous distinct geographical features, or extends beyond 50 km from the site).
Duration	1	Immediate (<1 year, quickly reversible)
	2	Short term (1-5 years, less than project lifespan)
	3	Medium term (6-15 years)
	4	Long term (15-65 years, the impact will cease after the operational life span of the project)
	5	Permanent (>65 years, no mitigation measure of natural process will reduce the impact after construction/ operation/ decommissioning).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected, or affected environmental components are already degraded)
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; moderate improvement for +ve impacts; or where change affects area of potential conservation or other value, or use of resources).

	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease; high improvement for +ve impacts; or where change affects high conservation value areas or species of conservation concern)
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease, substantial improvement for +ve impacts; or disturbance to pristine areas of critical conservation value or critically endangered species)
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring very high time and cost.
	5	Irreversible Impact.

Once the C has been determined, the significance is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/ scored as per Table 16.

It is noted that both environmental risks as well as environmental impacts should be identified and assessed. Environmental Risk can be regarded as the potential for something harmful to happen to the environment, and in many instances is not regarded as something that is expected to occur during normal operations or events (e.g. unplanned fuel or oil spills at a construction site). Probability and likelihood are key determinants or variables of environmental risk. Environmental Impact can be regarded as the actual effect or change that happens to the environment because of an activity and is typically an effect that is expected from normal operations or events (e.g. vegetation clearance from site development results in loss of species of concern). Typically the probability of an unmitigated environmental impact is regarded as highly likely or certain (management and mitigation measures would ideally aim to reduce this likelihood where possible). In summary, environmental risk is about what could happen, while environmental impact is about what does happen.

Table 16: Probability/ Likelihood Scoring

Probability	1	Improbable (Rare, the event may occur only in exceptional circumstances, the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <5% chance).
	2	Low probability (Unlikely, impact could occur but not realistically expected; >5% and <20% chance).
	3	Medium probability (Possible, the impact may occur; >20% and <50% chance).
	4	High probability (Likely, it is most probable that the impact will occur- > 50 and <90% chance).
	5	Definite (Almost certain, the impact is expected to, or will, occur, >90% chance).

The result is a qualitative representation of relative significance associated with the impact. Significance is therefore calculated as follows:

$$S = C \, x \, P$$

Table 17 Determination of Significance

Consequence	5- Very High	**5**	10	15	20	25
	4- High	4	8	12	16	20
	3- Medium	3	6	9	12	15
	2- Low	2	4	6	8	10
	1- Very low	1	2	3	4	5
		1- Improba-ble	2- Low	3- Medium/ Possible	4- High/ Probable	5- Highly likely/ Defi-nite
	Probability					

The outcome of the significance assessment will result in a range of scores, ranging from 1 through to 25. These significance scores are then grouped into respective classes as described in Table 18

Table 18 Significance Scores

S Score	Description
≤4.25	Low (i.e. where this impact is unlikely to be a significant environmental risk/ reward).
>4,25, ≤8.5	Low-Medium (i.e. where the impact could have a significant environmental risk/ reward).
>8.5, ≤13.75	High-Medium (i.e. where the impact could have a significant environmental risk/ reward).
>13.75	High (i.e. where the impact will have a significant environmental risk/ reward).

The impact significance will be determined for each impact without relevant management and mitigation measures (pre-mitigation significance), as well as post implementation of relevant management and mitigation measures (post-mitigation significance). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Table 19 Risk Assessment Rating Consequence

Impacts without Mitigation	Phase	Extent	Duration	Magnitude	Reversibility	Nature	Consequence	Probability	Significance		Mitigation measure
Impacts on water quality by plant operations (Current and future Waste rock dumps)	Construction and operational	2	4	3	3	-1	-3	3	-9	High-Medium	
Impacts on water quantity by abstraction boreholes. (Pumping from production boreholes)	Construction and operational	2	4	3	3	-1	-3	3	-9	High-Medium	
Impacts with Mitigation	**Phase**	**Extent**	**Duration**	**Magnitude**	**Reversibility**	**Nature**	**Consequence**	**Probability**	**Significance**		
Impacts on water quality by plant operations (Waste rock dumps seepage and spills from plant operations)	Construction and operational	1	4	2	3	-1	-2.5	2	-5	Low-Medium	Currently there are no groundwater monitoring boreholes at the Rietfontein Chrome Plant. Geophysical surveys need to be conducted on site and around the facility to determine the placement of monitoring boreholes in an upgradient position, on-site and down gradient position of the stockpiles, pollution control dam and plant. Monitoring of abstraction boreholes water quality to ensure

											water quality is to standard required by plant. Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.
Impacts on water quantity by abstraction boreholes. (Pumping from production boreholes)	Construction and operational	1	4	2	3	-1	-2.5	2	-5	Low-Medium	48–72-hour aquifer testing of the three boreholes (RP01, RP02 and RP03) to determine a sustainable yield for the aquifer and the effect on each other. Monitoring of abstraction volumes and monitoring boreholes water levels to ensure abstraction rates are sustainable and managed. Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.

10.2.3 Impact Prioritization

Further to the assessment criteria presented in the section above, it is necessary to consider each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impacts' post-mitigation significance (post-mitigation). This prioritisation factor does not aim to detract from the significance ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the post-mitigation significance based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 20: Criteria for Determining Prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable Loss of Resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 20. The impact priority is therefore determined as follows:

$$\boldsymbol{Priority = CI + LR}$$

The result is a priority score which ranges from 2 to 6 and a consequent PF ranging from 1 to 1.5 (Refer to Table 21).

Table 21: Determination of Prioritisation Factor

Priority	Prioritisation Factor
2	1
3	1.125
4	1.25
5	1.375
6	1.5

In order to determine the final impact significance (FS), the PF is multiplied by the post-mitigation significance scoring. The ultimate aim of the PF is an attempt to increase the post mitigation environmental risk rating by a factor of 0.5, if all the priority attributes are high (i.e. if an impact comes out with a high medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a higher significance).

Table 22: Final Environmental Significance Rating

Significance Rating	Description
<-25	Very High (Impacts in this class are extremely significant and pose a very high environmental risk. In certain instances these may represent a fatal flaw. They are likely to have a major influence on the decision and may be difficult or impossible to mitigate. Offset's may be necessary.
<-13.75 to -25	High negative (These impacts are significant and must be carefully considered in the decision-making process. They have a high environmental risk or impact and require extensive mitigation measures).
-8.5 to -13.75	Medium-High negative (i.e. Impacts in this class are more substantial and could have a significant environmental risk. They may influence the decision to develop in the area and require more robust mitigation measures).
<-4.25 to <-8.5	Medium- Low negative (i.e. These impacts are slightly more significant than low impacts but still do not pose a major environmental risk. They might require some mitigation measures but are generally manageable).
-1 to -4.25	Low negative (i.e. Impacts in this class are minor and unlikely to have a significant environmental risk. They do not influence the decision to develop in the area and are typically easily mitigated.
0	No impact

Significance Rating	Description
1 to 4.25	Low positive
>4.25 to <8.5	Medium-Low positive
8.5 to 13.75	Medium-High positive
>13.75	High positive

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

10.2.4 Cumulative impact

The cumulative impact on both the water levels and quality, with the infrastructure is plotted on Figure 21. The impacts can be seen based on the plant activities with the sensitive receptor the Sandpruit. The activities include the abstraction of production boreholes and the seepage of the two existing and future waste rock Dumps.

10.3 EMPR inclusion

See attached Table 24

Table 23 Risk Assessment Rating Final Environmental Significance

Impacts	Cumulative Impact (CI)	Loss of Resources (LR)	Priority (P)	Priority factor (PF)	Post mitigation Significance	Final Significance (FS)		Mitigation measure
Impacts on water quality by plant operations (Current and Future Waste rock dumps seepage)	2	2	4	1.25	-5	-6.25	Medium-Low negative	Currently there are no groundwater monitoring boreholes at the Rietfontein Chrome Plant. Geophysical surveys need to be conducted on site and around the facility to determine the placement of monitoring boreholes in an upgradient position, on-site and down gradient position of the stockpiles, pollution control dam and plant. Monitoring of abstraction boreholes water quality to ensure water quality is to standard required by plant. Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.
Impacts on water quantity by abstraction boreholes. (Pumping from production boreholes)	2	2	4	1.25	-5	-6.25	Medium-Low negative	48–72-hour aquifer testing of the three boreholes (RP01, RP02 and RP03) to determine a sustainable yield for the aquifer and the effect on each other. Monitoring of abstraction volumes and monitoring boreholes water levels to ensure abstraction rates are sustainable and managed. Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.

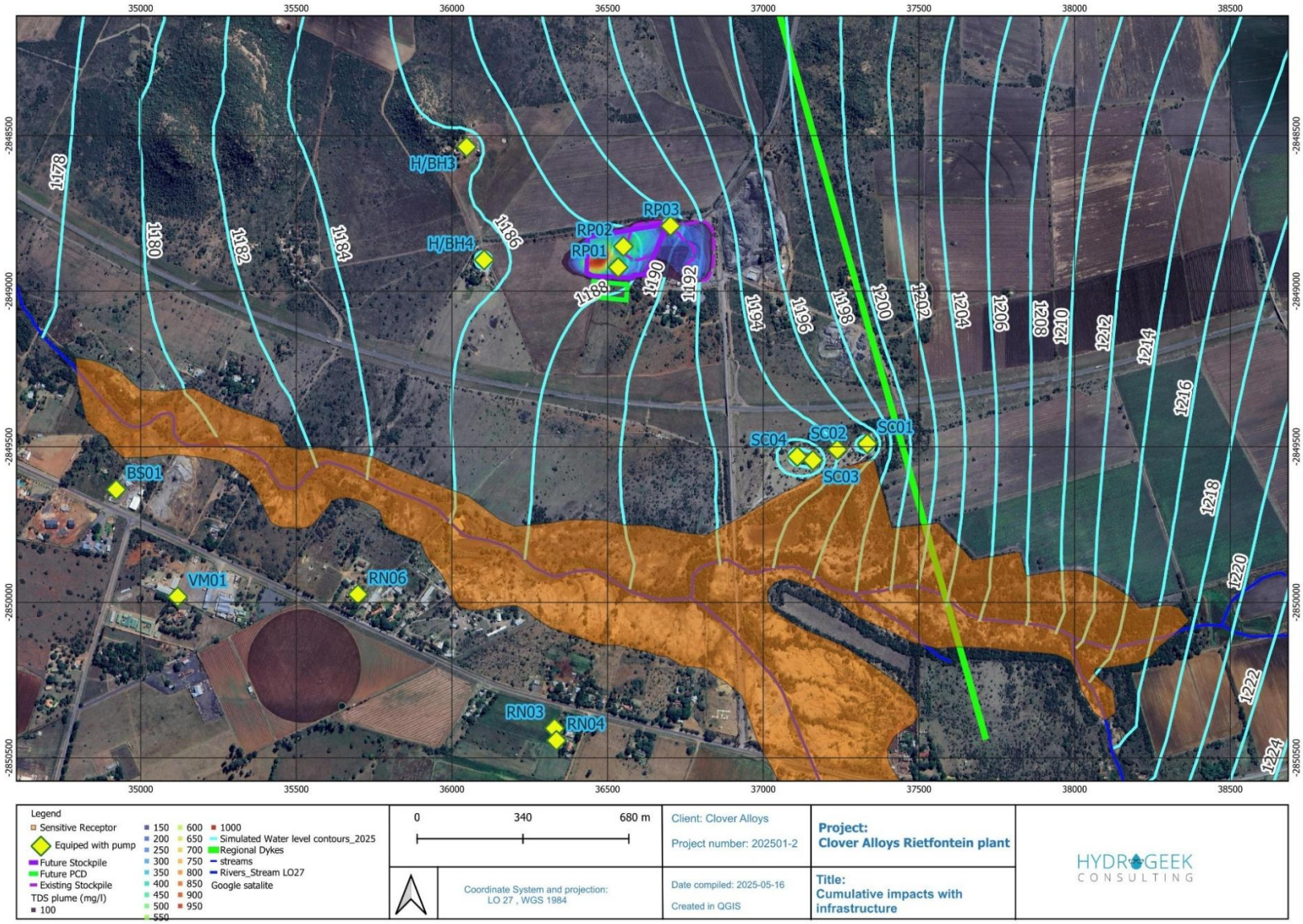


Figure 21 Cumulative impacts and sensitive receptors

Table 24 EMPr Inclusion

Mitigation Measures	Phase	Timeframe	Responsible Party for Implementation	Monitoring Party (Frequency)	Target	Performance Indicators (Monitoring Tool)
Currently there are no groundwater monitoring boreholes at the Rietfontein Chrome Plant. Geophysical surveys need to be conducted on site and around the facility to determine the placement of monitoring boreholes in an upgradient position, on-site and down gradient position of the stockpiles, pollution control dam and plant.	Construction Operation	Prior to construction and ongoing throughout lifespan of mine	Applicant	Monthly water levels and quarterly groundwater quality samples	Ensure compliance with relevant legislation	No legal directives Legal compliance audit scores
Monitoring of abstraction boreholes water quality to ensure water quality is to standard required by plant.	Construction Operation	Prior to construction and ongoing throughout lifespan of mine	Applicant	Monthly water levels and quarterly groundwater quality samples	Ensure compliance with relevant legislation	No legal directives Legal compliance audit scores
48–72-hour aquifer testing of the three boreholes (RP01, RP02 and RP03) to determine a sustainable yield for the aquifer and the effect on each other.	Construction Operation	Prior to construction and ongoing	Applicant	One off	Ensure compliance with relevant legislation	No legal directives Legal compliance audit scores

		throughout lifespan of mine				
Monitoring of abstraction volumes and monitoring boreholes water levels to ensure abstraction rates are sustainable and managed.	Construction Operation	Prior to construction and ongoing throughout lifespan of mine	Applicant	Daily measurement of abstractions rates through flow meter on abstraction boreholes	Ensure compliance with relevant legislation	No legal directives Legal compliance audit scores
Stormwater management infrastructure through a lined PCD dam will be in place to mitigate the risk to groundwater.	Construction Operation	Prior to construction and ongoing throughout lifespan of mine	Applicant	One off	Ensure compliance with relevant legislation	

11 Monitoring Plan

Groundwater monitoring boreholes must be evaluated for various chemical constituents, including:

- **Physical and Aesthetic Factors**: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Total Hardness.
- **Macro Elements**: Total Alkalinity (MAlk), Sulphate (SO_4), Nitrate (NO_3), Chloride (Cl), Fluoride (F), Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na).
- **Micro Elements**: Aluminium (Al), Iron (Fe), Manganese (Mn), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Cobalt (Co), and Zinc (Zn).

- Monthly assessments of water levels are required, with water quality monitoring conducted quarterly. Detailed reports summarizing the monitoring outcomes must be submitted to the Regional Head of the Department within the timelines set forth in the Water Use License (WUL) conditions. Existing Boreholes FH01, FH02 and H/BH4 should be added to the monitoring network.
- Monitor boreholes RP01, RP02, RP03, FH01, FH02 and H/BH4
- Additional boreholes to be drilled RP05-RP09 as monitoring boreholes.

Table 25 Proposed monitoring network

Borehole	Area monitored	Use	Status
RP01	Existing Stockpile	Abstraction borehole	Current
RP02	Existing Stockpile	Abstraction borehole	Current
RP03	North of Plant	Abstraction borehole	Current
RP04	North-west Background	Monitoring	To be drilled
RP05	West of Stockpiles	Monitoring	To be drilled
RP06	South of PCD	Monitoring	To be drilled
RP07	West of PCD	Monitoring	To be drilled
RP08	West Background	Monitoring	To be drilled
RP09	Plant Area	Monitoring	To be drilled
FH01	South of Plant	Monitoring	Existing not used
FH02	South of Plant	Monitoring	Existing not used

H/BH4	Far West	Monitoring	Existing not used

Additionally, calibrated mechanical or electronic flow meters should be installed at all abstraction points to accurately measure and record water abstraction volumes. These figures must be included in the monitoring reports and utilized for updates to the groundwater flow model.

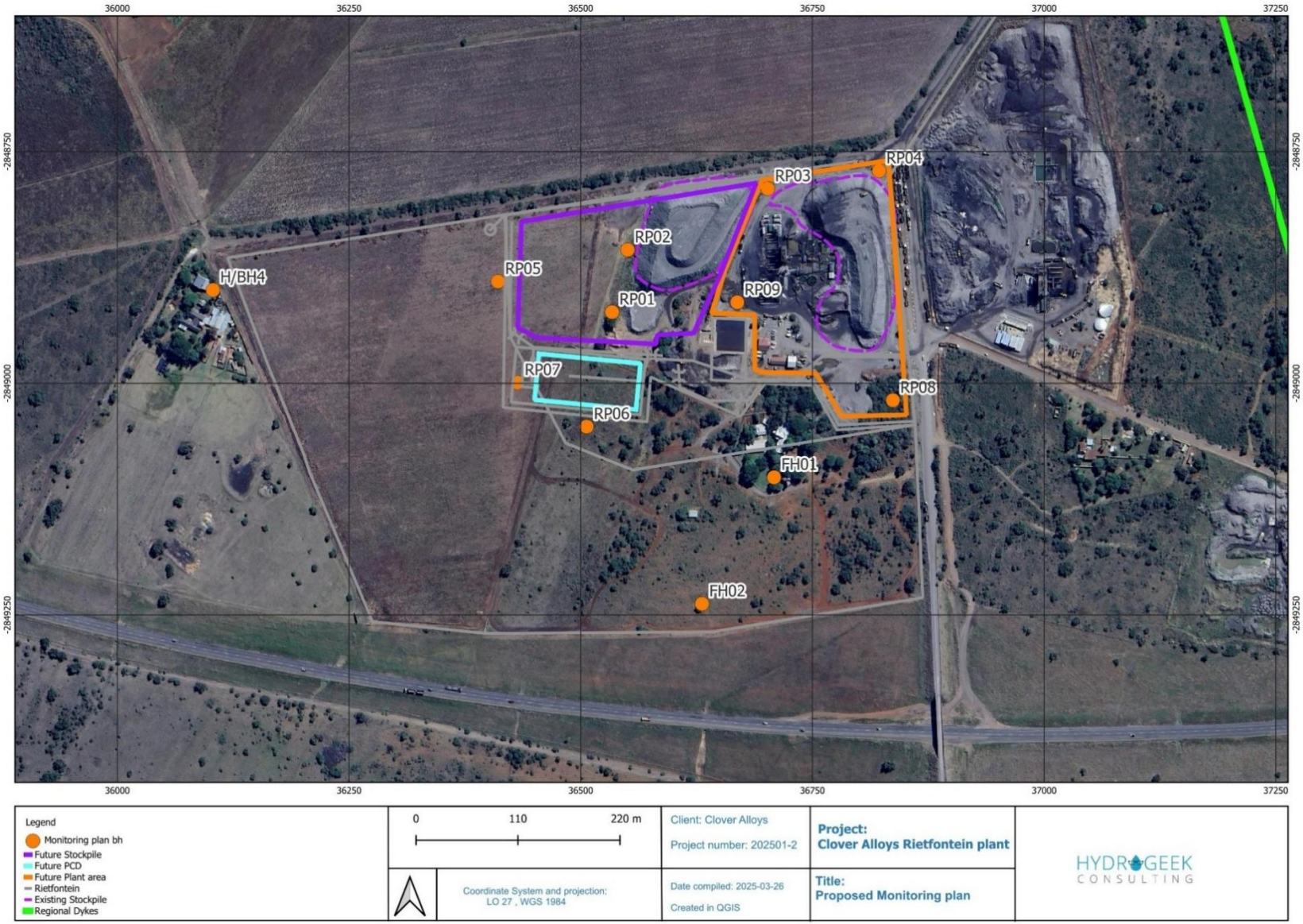


Figure 22 Proposed groundwater monitoring plan

12 CONCLUSIONS AND RECOMMENDATIONS

- A hydrocensus was conducted on the 11th, 12th and 13th of February 2025 to obtain the latest hydro-geological data of the surrounding area, location of sensitive receptors relative to the study areas, current state of private user and on-site monitoring boreholes. The groundwater levels varied between a minimum of 12.7 mbgl and a maximum of 22.3 mbgl for the Rietfontein Chrome Plant study area
- Also based on the hydrocensus, it can be concluded that the Sandspruit is a sensitive receptor due to the proximity of the wetland/spruit to the Rietfontein Plant Operation. The Sandspruit is more susceptible to contamination by surface water runoff and seepage from the shallow weathered aquifer.
- A total of 13 boreholes were sampled of which 8 were submitted (2 private water supply boreholes, 1 unequipped borehole, and 5 monitoring boreholes) for analysis of basic inorganic parameters and the results were compared to the 241:2015 'Drinking Water Standards' (SANS, 2015), as well as the DWS South African Water Quality Guidelines - Domestic Use (DWS and WRC, 2000). The main constituents of concern identified during the analysis are listed as follows:
- Rietfontein Chrome Plant – Electrical Conductivity (EC) and Chrome
- There are signs of groundwater contamination down gradient of the Rietfontein Chrome Plant towards the Sandspruit (a tributary of the Hex river). This is indicated by the elevated Chrome concentration measured in borehole FH02.
- The weak correlation between groundwater elevation and surface elevation observed at Rietfontein suggests localised dewatering of the aquifer either due to abstraction by dewatering and water supply boreholes or due to open cast mining.
- The application of the DRASTIC method resulted in a vulnerability rating of 114, which classified the aquifer as having **a medium vulnerability**. Based on geological analysis and hydrocensus data it can be concluded that the aquifer system in the study area can be classified as a **Minor Aquifer System.**
- There is a major shortfall in up-gradient, on site and down gradient monitoring borehole reference points to measure the extent and intensity of contaminant migration through the groundwater. Montoring boreholes are required to monitor the stockpiles, pollution control dam and plant area. The temporal groundwater level drawdown should also be measured monthly.
- The modelling results indicate contamination is contained within the plant site. Abstraction boreholes causes a decline in groundwater levels and captures and contains the migration of the plume towards the west.
- Stormwater management infrastructure will be place through a lined PCD dam will be in place to mitigate the risk to groundwater.

13 RECOMMENDATIONS

The following recommendations are put forward for consideration:

- Monitoring monthly abstraction volumes and water levels from all boreholes that are in use on the Rietfontein Plant (preferably with automated flow meters).
- Boreholes FH01, FH02 and H/BH4 should be added to the monitoring network.
- Geophysical surveys at Rietfontein Plant Operation which consist of planned traverses around the wash plant infrastructure should be completed to determine the placement of monitoring boreholes for the detailed monitoring program/network.
- Aquifer Testing (48-72 hour) is recommended on the current abstraction boreholes to determine a sustainable yield and available volumes.
- Drilling of additional boreholes to establish a more comprehensive monitoring network as per chapter 11 Monitoring Plan.
- It is recommended to do a comprehensive quarterly analysis of all boreholes at an accredited laboratory for parameters **Physical and Aesthetic Factors**: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Total Hardness. **Macro Elements**: Total Alkalinity (MAlk), Sulphate (SO_4), Nitrate (NO_3), Chloride (Cl), Fluoride (F), Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na). **Micro Elements**: Aluminium (Al), Iron (Fe), Manganese (Mn), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Cobalt (Co), and Zinc (Zn).

13.1 Specialist opinion:

The potential environmental impacts associated with the proposed new infrastructure—such as the pollution control dam (PCD), clean and dirty water separation systems, and related channels—have been reviewed in the context of the existing operations assessed under the Section 24G application. Based on the nature, location, and function of the planned infrastructure, the associated impacts are anticipated to be materially similar in type, extent, and significance to those already identified and assessed.

As such, these impacts are considered to be sufficiently addressed by the current impact assessment. Should any deviations or unique site-specific impacts arise during implementation, these will be managed under the existing environmental management framework and mitigation measures already in place.

The project is considered viable from a groundwater perspective, provided that the recommended mitigation measures and supporting studies are implemented to better define water availability and quality on site. The associated risks can be effectively managed through regular monitoring of groundwater quality, water levels, and abstraction volumes from the aquifer.

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Signature Page

Hydrogeek Consulting PTY Ltd

Authorization		
Name	**Signature**	**Date**
NL van Zyl Hydrogeologist		May 2025

Reg.No. 2019/327216/07

Directors: NL van Zyl

Appendix 1 DRASTIC

DRASTIC parameters	Range	Rating (r)	Weight (w)
Water table depth (m)	0.0–1.5	10	5
	1.5–4.6	9	
	4.6–9.1	7	
	9.1–15.2	5	
	15.2–22.9	3	
	22.9–30.5	2	
	> 30.5	1	
Net recharge	11–13	10	4
	9–11	8	
	7–9	5	
	5–7	3	
	3–5	1	
Aquifer media	Rubble and sand	0	3
	Gravel and sand	7	
	Gravel, sand, clay, and silt	5	
	Sand and clay	4	
	Sand, clay, and silt	3	
Soil media	Rubble, sand, clay, and silt	9	2
	Gravel and sand	7	
	Gravel, sand, clay, and silt	6	
	Sand	5	
	Sand, clay, and silt	3	
	Clay and silt	2	
Topography or slope (%)	0–2	10	1
	2–6	9	
	6–12	5	
	12–18	3	
	> 18	1	
The impact of the vadose zone	Rubble, sand, clay, and silt	9	5
	Gravel and sand	7	
	Gravel, sand, clay, and silt	5	
	Sand, clay, and silt	3	
Hydraulic conductivity ($m\,d^{-1}$)	0–4.1	1	3
	4.1–12.2	2	
	12.2–28.5	4	
	28.5–40.7	6	
	40.7–81.5	8	

Appendix 2 Water Quality Lab Results

EPL
ENVIRONMENTAL POLLUTION LABORATORY

sanas
Testing Laboratory

TEST REPORT
56313A

Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

				Date Received:	2025/02/14
Sample ID:	**BH16A**	**Matrix:**	Water	**Date Analysed:**	2025/02/17
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Issued:**	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	3.91	**Na**	38.22	**Zn**	<0.05
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.09	**Cr**	<0.05	**Mn**	0.46	**Pb**	<0.05		
Be	<0.05	**Cu**	<0.05	**Mg**	65.02	**Sb**	<0.05		
Ca	31.15	**Fe**	3.50	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	45.42	**NO2 as N**	<0.13	**SO4**	126.50
F	0.26	**NO3 as N**	<0.5	**PO4 as P**	0.41

Other Parameters

pH	7.49
EC (µs/cm)	730
NH4*	0.21
TDS	570
Cr(VI)*	<0.05

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6) Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.
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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

				Date Received:	2025/02/14
Sample ID:	**BH17**	**Matrix:**	Water	**Date Analysed:**	2025/02/17
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Issued:**	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	0.85	**Na**	18.80	**Zn**	1.09
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.07	**Cr**	<0.05	**Mn**	<0.05	**Pb**	<0.05		
Be	<0.05	**Cu**	<0.05	**Mg**	145.00	**Sb**	<0.05		
Ca	72.00	**Fe**	0.08	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	14.04	**NO2 as N**	<0.13	**SO4**	232.50
F	0.22	**NO3 as N**	29.91	**PO4 as P**	0.22

Other Parameters

pH	7.57
EC (µs/cm)	1278
NH4*	0.11
TDS	997
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

Sample ID:	FH02	**Matrix:**	Water	**Date Received:**	2025/02/14
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Analysed:**	2025/02/17
				Date Issued:	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	3.12	**Na**	9.97	**Zn**	0.21
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.07	**Cr**	0.40	**Mn**	0.31	**Pb**	<0.05		
Be	<0.05	**Cu**	0.07	**Mg**	119.70	**Sb**	<0.05		
Ca	34.54	**Fe**	0.14	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	8.39	**NO2 as N**	<0.13	**SO4**	<2
F	0.22	**NO3 as N**	<0.5	**PO4 as P**	0.72

Other Parameters

pH	7.50
EC (µs/cm)	958
NH4*	9.44
TDS	616
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue Gauteng 0081	**Attention:** **Tel:** **Email:**	Stephan Botha (084) 625-5483 stephan.botha@noa8.co.za	**Project number:** **Project name:**	N/A N/A

Sample Information

Sample ID:	**LANBH13**	**Matrix:**	Water	**Date Received:**	2025/02/14
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Analysed:**	2025/02/17
				Date Issued:	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	1.54	**Na**	30.23	**Zn**	0.08
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.14	**Cr**	<0.05	**Mn**	<0.05	**Pb**	<0.05		
Be	<0.05	**Cu**	0.11	**Mg**	175.20	**Sb**	<0.05		
Ca	50.18	**Fe**	0.55	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	73.21	**NO2 as N**	<0.13	**SO4**	305.20
F	0.24	**NO3 as N**	29.63	**PO4 as P**	<0.2

Other Parameters

pH	7.70
EC (µs/cm)	1441
NH4*	0.07
TDS	1233
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

				Date Received:	2025/02/14
Sample ID:	**LANBH6**	**Matrix:**	Water	**Date Analysed:**	2025/02/17
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Issued:**	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	1.28	**Na**	78.78	**Zn**	0.44
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.15	**Cr**	<0.05	**Mn**	0.06	**Pb**	<0.05		
Be	<0.05	**Cu**	0.29	**Mg**	160.90	**Sb**	<0.05		
Ca	43.02	**Fe**	32.99	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	217.90	**NO2 as N**	<0.13	**SO4**	358.30
F	0.16	**NO3 as N**	19.80	**PO4 as P**	<0.2

Other Parameters

pH	7.57
EC (µs/cm)	1514
NH4*	0.11
TDS	1124
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(064) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

Sample ID:	LANBH9	**Matrix:**	Water	**Date Received:**	2025/02/14
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Analysed:**	2025/02/17
				Date Issued:	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	2.90	**Na**	121.70	**Zn**	0.59
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.11	**Cr**	<0.05	**Mn**	<0.05	**Pb**	<0.05		
Be	<0.05	**Cu**	0.05	**Mg**	124.20	**Sb**	<0.05		
Ca	37.48	**Fe**	<0.05	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	98.72	**NO2 as N**	<0.13	**SO4**	294.30
F	0.11	**NO3 as N**	10.85	**PO4 as P**	0.51

Other Parameters

pH	7.57
EC (µs/cm)	1450
NH4*	0.08
TDS	1045
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

				Date Received:	2025/02/14
Sample ID:	**RN06**	**Matrix:**	Water	**Date Analysed:**	2025/02/17
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Issued:**	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	2.83	**Na**	30.11	**Zn**	0.08
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.12	**Cr**	<0.05	**Mn**	<0.05	**Pb**	<0.05		
Be	<0.05	**Cu**	0.06	**Mg**	98.67	**Sb**	<0.05		
Ca	42.28	**Fe**	<0.05	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	25.25	**NO2 as N**	<0.13	**SO4**	43.97
F	0.18	**NO3 as N**	1.94	**PO4 as P**	<0.2

Other Parameters

pH	7.92
EC (µs/cm)	914
NH4*	0.11
TDS	611
Cr(VI)*	<0.05

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Client and Project Information

Client:	NOA8 (Pty) Ltd				
Address:	Oberon Avenue	**Attention:**	Stephan Botha	**Project number:**	N/A
	Gauteng	**Tel:**	(084) 625-5483	**Project name:**	N/A
	0081	**Email:**	stephan.botha@noa8.co.za		

Sample Information

Sample ID:	SC04	**Matrix:**	Water	**Date Received:**	2025/02/14
Units:	mg/l [ppm] (unless stated elsewhere)	**Container:**	Plastic	**Date Analysed:**	2025/02/17
				Date Issued:	2025/02/24

Cations and Metals

As	<0.05	**Cd**	<0.05	**K**	3.56	**Na**	21.16	**Zn**	<0.05
B	<0.5	**Co**	<0.05	**Li***	<0.05	**Ni**	<0.05		
Ba	0.14	**Cr**	<0.05	**Mn**	<0.05	**Pb**	<0.05		
Be	<0.05	**Cu**	<0.05	**Mg**	172.00	**Sb**	<0.05		
Ca	59.91	**Fe**	<0.05	**Mo**	<0.1	**Se**	<0.1		

Anions (Discrete Analyser)

Cl	28.65	**NO2 as N**	<0.13	**SO4**	185.20
F	0.67	**NO3 as N**	6.68	**PO4 as P**	<0.2

Other Parameters

pH	7.83
EC (µs/cm)	1349
NH4*	0.12
TDS	940
Cr(VI)*	<0.05

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Appendix 3 Curriculum Vita



Curriculum vitae NICO VAN ZYL

Contact Details: nico@hydrogeekconsulting.com
+27718773744 (Mobile)
www.linkedin.com/in/nico-van-zyl-00b33a51 (LinkedIn)
hydrogeekconsulting.com (Company)

Education

M.Sc. Hydrogeology, University of the Free State, Bloemfontein, SA, 2011

Honours. Hydrogeology, University of the Free State, Bloemfontein, SA, 2009

B.Sc. Geology, University of the Free State, Bloemfontein, SA, 2009

Certifications

Collaboration for Success BHP Billiton - Bayside Aluminium, 5 December 2014

Languages

Afrikaans – Fluent

English – Fluent

Hydrogeek Consulting (Pty.) Ltd. – Johannesburg

Hydrogeologist/Groundwater Modeller

Nico is passionate about the field of Hydrogeology and have a special interest in Groundwater modelling (FEFLOW) as a tool to provide cost effective solutions to clients. We are moving more to decision support modelling , through uncertainty analysis using programs that PEST tools. There is so much uncertainty to groundwater modelling it is time we accept it and let allow the flow of information to reach the right places. We are committed to the Bayesian way of thinking, that we start with uncertainty and end with uncertainty. Information reduces uncertainty.

Our experience ranges from Interpretation of groundwater data to form Conceptual Hydrogeological Models and Numerical Groundwater Models for underground and open pit mines.
In the past few years we have been busy in different regions around the world, developing Numerical Groundwater Models. Regions and countries include , USA, Australia (Pilbara region), Argentina, UAE, Germany, Peru, South Africa , African countries Zambia, DRC, Mozambique, Ghana and Guinea. The focus is on helping clients with planning and management decisions in terms of groundwater solutions (pore pressures, water supply, dewatering , cone of depressions and quality impacts from mining activities). Sectors we have worked in include mining (gold, platinum, coal and diamond) , manufacturing and government.

HG aim to solve complex issues by being well-informed on what the data is telling us. Our service will provide you with interpreted data to inform your Conceptual model and Uncertainty associated. HG consulting will always be based on cost effective solutions for your Groundwater models. HG believe in under promising and over delivering as we hold our client's long-term satisfaction in the highest regards.

Why us?
With good experience in FEFLOW a modelling software package, we are confident we can provide a service that yields trustworthy and professional results

Employment History

Hydrogeek Consulting (Pty) Ltd – Johannesburg

Director – (2019 to Present)

Golder Associates – Johannesburg

Hydrogeologist/Groundwater Modeller and Modelling team leader (2014 to 2019)

AGES – Potchefstroom

Hydrogeologist (2012 to 2014)

University of the Free State

Researcher (2011)

PROJECT EXPERIENCE – HYDROGEOLOGY

South32: Bayside Groundwater Management Plan Kwa-Zulu Natal, South Africa	This Groundwater Management Plan for Bayside was developed using a detailed Source-Pathway-Receptor (SPR) assessment and simulations to assess the effectiveness of the different scenarios that Bayside are considering.
Development of a post closure Water Management Plan -Phase 2 Decant Study Gauteng, South Africa	The decant study needed to investigate the potential for the South Deep underground workings to decant on surface based on conservative assumptions. In this report the available hydrogeological data is assessed in more detail as the results and findings are critical to the understanding of the post closure flow system at South Deep.
Western Hub Dewatering and Water Supply Project Pilbara, Australia	Groundwater Model developed in FEFLOW package. The simulations of dewatering boreholes together with water supply scenarios to meet the demand of the mine. The mine dewatering was done with de-

	watering boreholes. The project also involved the impact assessment and the recovery of pit water levels post closure.
Middelburg Ferrochrome – Groundwater Modelling as part of the Contaminated Land team, Middelburg, South Africa. Mpumalanga, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW). Data was interpreted and used to update the conceptual model of the site. Remediation scenarios was simulated from trenches to capture contamination downstream.
Amandelbult Groundwater Model for dewatering of the underground, Thabazimbi, South Africa. Limpopo, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations was used. Dewatering of two underground mines was simulated and the post closure water management scenarios were also done as part of closure, different scenarios was simulated for the TSF's.
Platreef DFS Groundwater Model, Mokopane, Limpopo Province, South Africa. Limpopo, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) for EIA purposes.
Jindal Groundwater Modelling Open Pit dewatering- KwaZulu-Natal, South Africa Kwa-Zulu Natal, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations will be used.

KCC Hydrogeological Services Kolwezi, DRC	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations in a Dolomitic karst environment.
Lonmin Marikana Groundwater Model Marikana, South Africa	Developing of a Groundwater Flow Model with Contaminant Transport.
UMK Mine Groundwater Model Hotazel, South Africa	Developing of a Groundwater Flow Model with Contaminant Transport. For closure purposes
Maamba Colliery HSESMP Hydrogeological Baseline and Groundwater Model Study Maamba, Zambia	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations will be used.
WASSA Golden Star Dewatering Model underground and opencast mine WASSA, Ghana	The groundwater specialist study was completed to fulfil the objectives as required by the EIA, WUL and rehabilitation and closure strategy. Works included construction of a conceptual hydrogeological model and numerical groundwater model to assess the potential impacts on groundwater quantity and quality.
Klipspruit Colliery Mpumalanga, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations will be used.

Khutala Colliery Mpumalanga, South Africa	This task involved numerical flow and solute transport modelling, developing a new groundwater model using, a highly sophisticated and powerful 3D finite element modelling package (FEFLOW) designed to cope with complex hydrogeological situations will be used.
Two Rivers Mine South Opencast Pit Steelpoort, South Africa	Groundwater inputs to the overall EIA and EMPR, including, geophysical surveying, drilling, testing, groundwater quantity and quality impacts, modelling, reporting of the Two Rivers Mine South Opencast Pit.
Majuba Underground Coal Gasification Amersfoort, South Africa	Project focussed on characterizing the hydrogeology and groundwater, including pore water pressure monitoring. The development of a conceptual hydrogeological model and numerical model to identify potential impacts on the groundwater system as result of UCG operations.
Townlands Underground Mine Project North-West, South Africa	The groundwater specialist study was completed to fulfil the objectives as required by the water management strategy, EIA, WUL and rehabilitation and closure strategy. Works included construction of a conceptual hydrogeological model and numerical groundwater model to assess the potential impacts on groundwater quantity and quality.
Bayside Aluminium Kwazulu-Natal, South Africa	The potential impacts from these identified sources on the groundwater system and migration of contaminant plumes from these sources were evaluated through the groundwater modelling.
KCM Nchanga SPR Model Study Groundwater Flow and Contaminat Transport Modelling	Developing of a Groundwater Flow Model with Contaminant Transport.

Nchanga, Zambia	
Mopani Nkana Mine Dewatering Groundwater Model Ndola, Zambia	Developing of a Groundwater Flow Model to determine dewatering rates and pore pressures.
Mopani Mufulira Mine Dewatering Groundwater Model Mufulira, Zambia	Developing of a Groundwater Flow Model to determine dewatering rates and pore pressures.
Kinsevere Mine Dewatering and Post Closure Groundwater Model Lubumbashi, DRC	Developing of a Groundwater Flow Model to determine dewatering rates and impact. Post closure study to determine Pit Lake conditions.
Reminex Mines TriK Dewatering Modelling Study, Guinea 2023	Details to follow
Waterval Smelter Numerical Model , Rustenburg, North Wes 2022	Details to follow
Talon Metals Hydrogeology and Modelling Review, Minnesota, US 2022	Details to follow
Bel Air Alufer Well field design DFS Groundwater Model, Bel Air, Guinea 2022	
Numerical Modelling EÜ Magdeburg Concepts for dewatering of systems, Magdeburg, Germany	Details to follow

Modelo 3D Waste Dump Las Bambas, Peru , South America	Details to follow
Barberton Mines Geohydrological Study and Groundwater Model, Barberton, South Africa	Details to follow
Bunker Hill Mine Conceptual Understanding , Kellogg, IDAHO, USA	Details to follow
Groundwater flow and solute transport model, San Lorenzo, Argentina	Details to follow
Ardmore Graphite Open Pit Stage 3 Dewatering Model, Queensland, Australia	Details to follow
Casa Berardi Mine Principle Open Pit dewatering, Quebec, Canada	Details to follow
Sunnyside Diamonds Hydrogeological Conceptual Model, Northern Cape, South Africa	Details to follow

Training

FEFLOW 7 Groundwater Modelling for Mine Sites

DHI WASY, 21-23 September 2016

FEFLOW Groundwater Modelling for Mine Sites

DHI WASY, 24 August - 26 August 2015

Advanced FEFLOW Groundwater modelling

DHI WASY, 30 October 2012- 2 November 2012

Symple School of Hydrogeological Modelling ,

Milan Italy (18 months)

SUPPLEMENTAL SKILLS

Leapfrog Hydro

Hydrogeological Modelling

Data interpretation

Surfer, GRAPHER

Maps

QGIS, Global Mapper

Groundwater Modelling

FEFLOW 8.0 and FEPEST

Python Coding

Past Statistics

PROFESSIONAL AFFILIATIONS Pr.Sci.Nat 400165/14

PUBLICATIONS

Conference Proceedings

Love*, David, Vanessa Aphane, Gerhard van der Linde and Nico van Zyl. 2015. *Innovative approaches to predicting, mitigating and remediating groundwater pollution in UCG*. SAUCGA Workshop, September. Muldersdrift, South Africa.


HYDROGEEK
CONSULTING

APPENDIX I

HIGH LEVEL COST ESTIMATION

MineLock
Environmental Engineers

Rietfontein Plant - Storm Water Management Infrastructure
High Level Cost Estimation

SUMMARY	
POLLUTION CONTROL DAM	R5 692 376.26
PRODUCT STOCKPILE AREA	R853 325.00
SILT TRAP	R1 936 951.11
DIRTY WATER CHANNELS	R1 947 367.74
PIPELINE RIVER CROSSING	R816 026.29
SUBTOTAL A	**R11 246 046.39**
10% P's and G's	**R1 124 604.64**
SUBTOTAL B	**R12 370 651.03**
10% Contingencies	**R1 237 065.10**
TOTAL (VAT ECLUDED)	**R13 607 716.13**

* Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors
*Note: All material quantities excludes wastage

Rietfontein - Pollution Control Dam						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
1	SANS 1200A, PSA	**SECTION 1 : PRELIMINARY AND GENERAL**				
1.1	8.3	**FIXED CHARGE AND VALUE-RELATED ITEMS**				
1.1.1	8.3.1	**Contractual Requirements**	Sum	1.0		-
	8.3.2	**Establish facilities on site**				
1.1.2	8.3.2.1	Facilities for Engineer				
1.1.2.1		a) Furnished office (refer PSAB1)	Sum	1.0		-
1.1.2.2		b) Cellular phone and modem	Sum	1.0		-
1.1.2.3		c) Name Boards (1 no)	Sum	1.0		-
1.1.2.4		d) Carports (1 vehicles)	Sum	1.0		-
1.1.2.5		e) Sanitary facilities	Sum	1.0		-
SILT TRAP 2		f) Survey equipment	Sum	1.0		-
1.1.3	8.3.2.2	Facilities for Contractor				
1.1.3.1		a) Offices and storage sheds	Sum	1.0		-
1.1.3.2		b) Workshops	Sum	1.0		-
1.1.3.3		c) Laboratories	Sum	1.0		-
1.1.3.4		d) Living accommodation	Sum	1.0		-
1.1.3.5		e) Ablution and latrine facilities	Sum	1.0		-
1.1.3.6		f) Tools and equipment	Sum	1.0		-
1.1.3.7		g) Water supplies, electric power and communications	Sum	1.0		-
SEWAGE PLAN		h) Dealing with water	Sum	1.0		-
DEMOLISH CROCODILE A		i) Access	Sum	1.0		-
WEST SHAFT SUMP		j) Plant (To be specified by Tenderer)	Sum	-		
SUPERVISION (Assuming S		i) Grader		1.0		-
		ii) Roller		1.0		-
		iii) Truck		1.0		-
		iv) Truck		1.0		-
		v) Excavator		1.0		-
1.1.3.11		k) Occupational Health & Safety (POHAS 3.6)	Sum	1.0		-
1.1.4	8.3.3	**Other fixed charge obligations**	Sum	1.0		-
1.1.5	8.3.4	**Removal of site establishment**	Sum	1.0		-
1.1.6		**Additional tests as requried by the Enigneer (as described in Specification Document)**	Prov Sum	1.0		-
1.2	8.4	**TIME RELATED ITEMS**				
1.2.1	8.4.1	**Contractual requirements**	Month			-
	8.4.2	**Operations and maintenance of facilities on site**				
1.2.2	8.4.2.1	Facilities for Engineer				
1.2.2.1		a) Furnished office as per PSAB1	Month			-
1.2.2.2		b) Cellular phone as per PSAB2	Month			-
1.2.2.3		c) Name Boards (1 no)	Month			-
1.2.2.4		d) Carports (1 vehicles)	Month			-
1.2.2.5		e) Sanitary facilities	Month			-
1.2.2.6		f) Survey equipment	Month			-

Rietfontein - Pollution Control Dam						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
1.2.3	8.4.2.2	Facilities for Contractor				
1.2.3.1		a) Offices and storage sheds	Month			-
1.2.3.2		b) Workshops	Month			-
1.2.3.3		c) Laboratories	Month			-
1.2.3.4		d) Living accommodation	Month			-
1.2.3.5		e) Ablution and latrine facilities	Month			-
1.2.3.6		f) Tools and equipment	Month			-
1.2.3.7		g) Water supplies, electric power & communications	Month			-
1.2.3.8		h) Dealing with water	Month			-
1.2.3.9		i) Access	Month			-
1.2.3.10		j) Plant	Month			-
		i)				
		ii)				
1.2.3.11		k) Occupational Health & Safety (POHAS 3.6)	Month			-
1.2.4	8.4.3	**Supervision for duration of the construction**	Month			-
1.2.5	8.4.4	**Contract**	Month			-
1.2.6	8.4.5	**Other time related obligations (contractor to specify)**				
		i)	Month			-
		ii)	Month			-
		ii)	Month			-
1.3	8.5	**SUMS STATED PROVISIONALLY BY THE ENGINEER**				
						-
1.3.1		**Contingencies**	Sum			
1.3.2		**Contract Price Adjustment**	Sum			-
		Total Section 1				-
2		**SECTION 2 : EARTHWORKS, DRAINAGE AND INFRASTRUCTURE**				
2.1	SANS 1200C, PSC	**SITE CLEARANCE**				
	8.2.1	**Clear and grub of site and remove all obstructions (spoil to be spread neatly within 1 km freehaul as directed by Engineer) at:**				
2.1.1		Pollution Control Dam Boundary	m²	8 470.0	R2.00	16 940.00
2.2	SANS 1200D, PSD	**EARTHWORKS**				
	8.3.2	**Bulk excavation in all material. Stockpile, sort (selected material to be used for Pollution Control Dam embankments) or disposed of as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul and stockpiling of materials):**				
2.2.1		Pollution Control Dam	m^3	17 765.0	R25.00	444 125.00
2.2.2		Restricted excavation of manhole / drainage collector sump	m^3	600.0	R40.00	24 000.00
	8.3.2(b)	Extra-over item 2.2.1 to 2.3.6 for excavation in:				
2.2.3		Hard Rock material from +- 1m below	m^3	10 224.5	R30.00	306 735.00

Rietfontein - Pollution Control Dam						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
		Import selected fill material for uneven subgrade conditions: Rip to at least 100 mm deep and re-compacted to at least 93% of Mod. AASHTO MDD				
2.2.4		Pollution Control Dam basin	m^3	330.0	R40.00	13 200.00
2.2.5		Spillway for PCD	m^3	3.3	R40.00	132.00
	8.3.2	**Construct compacted embankment walls with selected and approved material (free issue) from excavations or stockpiles and compact to required specification or Engineers approval (placed volumes excludes bulking and compaction factors. Rate to include excavations, compaction, load, haul [free haul 1 km], spread, level, trim, tie-in, form side slopes etc) to form:**				
2.2.6		Pollution Control Dam: Fill embankments constructed with residual norite soils of at least G7 quality and compacted in maximum 150 mm thick layers to at least 93% of Mod. AASHTO MDD	m^3	696.0	R40.00	27 840.00
2.2.7		Fill PCD berm rip and recompact insitu layer of 150mm to 93% MOD AASHTO ± 2% OMC, construct channel berm @ 93% MOD AASHTO within ± 2% OMC in 150mm thick layers	m^3	328.9	R40.00	13 156.00
	8.3.4	**Importing of materials:**				
2.2.8		Extra over items for 2.2.4 for importation of materials from stockpile	m^3	Rate only	R14.39	
	8.3.6	**Overhaul**				
2.2.9		Limited overhaul	m^3	Rate only	R14.11	
2.2.10		Long overhaul	m^3 - km	Rate only	R8.47	
2.3	SANS 1200DB PSDB	**GENERAL EARTHWORKS**				
		TRENCHES FOR SUBSOIL DRAINAGE AND SPILLWAY				
	8.3.2	**Restricted excavation in all material for pipe trenches, backfill, compact and dispose of surplus material as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul, place, shoring, cutting back, dewatering etc.):**				
2.3.1		Restricted excavation for collector drain and interception subsoil drain pipeline system. Load and lay outlet underdrain system before and during construction of embankments. (Rate to include base compaction to around 93% MOD AASHTO Density at +- 2% OMC)	m^3	66.5	R40.00	2 661.12
2.3.2		Restricted excavation of leakage detection sump	m^3	13.8	R40.00	550.00
2.3.3		Restricted excavation of Spillway for PCD, max vertical excavation of 0,8 m, (should a boxcut be required, the material below the side walls should be replaced in 150 mm layers and compact to 95% MOD AASHTO density)	m^3	42.9	R40.00	1 716.00
	8.3.2	**Backfill in all materials:**				
2.3.4		Backfilling manhole: Load, haul and place and compact in 150mm layers, with each layer compacted to around 93% MOD AASHTO Density at +- 2% OMC	m^3	594.6	R40.00	23 784.00
		ANCHOR TRENCHES				

Rietfontein - Pollution Control Dam						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
	8.3.2	**Restricted excavation in all material for trenches, backfill, compact and dispose of surplus material as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul, place, shoring, max vertical excavation 0.5 m, cutting back, dewatering etc.):**				
2.3.5		Pollution Control Dam liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	105.0	R40.00	4 200.00
	8.3.2	**Extra over item (volumes indicated are material to be stabilised): Supply, mix, place and compact of cement stabilized material. Dry mix to be compacted to 93% MOD AASHTO**				
2.3.6		PCD anchor trench backfill 2% stabilized material	m^3	105.0	R203.20	21 336.00
		PIPE TRENCHES				
	8.3.2	**Restricted excavation in all material for trenches, backfill, compact and dispose of surplus material as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul, place, shoring, max vertical excavation 0.5 m, cutting back, dewatering etc.):**				
2.3.7		For leakage drainage (Pipe 1) solid 160mm HDPE pipe line, embedded in embankment to a depth of 0.16m	m	20.0	R158.67	3 173.40
2.3.8		For PCD drainage pipe to pump (Pipe 1) solid 160mm HDPE pipe line, embedded in embankment to a depth of 0.16m	m	20.0	R158.67	3 173.40
	8.3.10	**Importing and placement of topsoil from stockpile**				
2.3.9		PCD Berm	m^3	46.8	R25.00	1 170.00
2.4	SANS 1200LB, PSLB	**BEDDING AND BLANKET (PIPES)**				
		BEDDING AND BLAKET FOR SUBSOIL DRAIN SYSTEM				
	8.2.1	**Supply only of bedding and blanket by importation from commercial sources:**				
2.4.1		Selected granular material (crushed stones larger than 19mm) as blanket for pipeline	m^3	66.8	R490.36	32 756.05
	8.3.4	**Importing of materials:**				
2.4.2		Extra over items for 2.3.1 to 2.3.13 for importation of materials from stockpile	m^3	Rate only	R14.39	
	8.3.6	**Overhaul**				
2.4.3		Limited overhaul	m^3	Rate only	R14.11	
2.4.4		Long overhaul	m^3 - km	Rate only	R8.47	
2.5	SANS 10409	**PRE-LINER INSTALLATION PREPARATION**				
		PREPARATION AND INSPECTION OF EMBANKMENTS AND BASIN BEFORE COMMENCEMENT OF INSTALLATION OF LINER SYSTEM				
2.5.1		Chicken Run to eliminate all penetrations from surface larger than 3mm from the surface	m^2	8 760.0	R1.00	8 760.00
		Compaction to 95% MOD AASHTO				

Rietfontein - Pollution Control Dam

ITEM	PAYMENT	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
2.5.2		Smooth drum compaction against slopes	m^2	5 760.0	R8.00	46 080.00
2.5.3		Pneumatic compaction for basin	m^2	3 000.0	R8.00	24 000.00
2.6		**GEOSYNTHETICS**				
	PS GT	**Supply and install non-woven protection geotextile (750 g/m^2 Bidim or similar) for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.6.1		Leakage detection sump (ontop and below)	m^2	90.0	R65.00	5 850.00
2.6.2		Pollution Control Dam	m^2	10 512.0	R65.00	683 280.00
	PS GM	**Supply and install 1.5 mm HDPE geomembrane layer to Project Specification (rate to include cutting, strapping, wastage & seaming) at:**				
2.6.3		Pollution Control dam	m^2	10 512.0	R85.00	893 520.00
	PS GT	**Supply and install cuspated sheet for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.6.4		Pollution Control dam	m^2	10 512.0	R90.00	946 080.00
	PS GT	**Supply and install 2 mm HDPE geomembrane layer to Project Specification (rate to include cutting, strapping, wastage & seaming) at:**				
2.6.5		Pollution Control dam	m^2	10 512.0	R120.00	1 261 440.00
	PS GT	**Supply and install non-woven protection geotextile (210 g/m^2 Bidim or similar) for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.6.6		Collector and Interception Subsoil drains	m^2	580.8	R25.00	14 520.00
	PS GT	**Supply and install 150mm geocells for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.6.7		Settling Pond	m^2	1 350.90	55.00	74 299.50
		Cement stabilized material for geocells (PCD Area)				
2.6,8		Supply, mix, place and compact of 5% cement stabilised material, 150mm filled geocells. Dry mix to be compacted to 93% MOD AASHTO	m^3	202.64	350.00	70 922.25
2.7	SABS 1200LE	**STORM WATER DRAINAGE**				
	8.2.10	**Drainage Collector Sump cover including frames:**				
2.7.1		Panzer borehile lid at Leakage detection borehole from Interlock Systems	No	1.0	R5 500.00	5 500.00
	8.2.14	**Supply, lay and bed, complete with couplings HDPE SDR 13,6 PN 10 160mm pipes from leakage detection sump complete with couplings as detailed:**				
2.7.2		Gasket clamps	No	6.0	R2 760.00	16 560.00
2.7.3		Pipe boot and steel straps	No	3.0	R1 620.00	4 860.00
	8.2.1	**Supply and install subsoil drain system pipes:**				

Rietfontein - Pollution Control Dam

ITEM	PAYMENT	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
2.7.4		Drainex DN110 HDPE perforated pipe (or similar) as interception underdrain pipeline. Rate to include connections and junctions	m	165.6	R45.00	7 452.00
2.7.5		Drainex DN160 HDPE perforated pipe (or similar) as collector underdrain pipeline. Rate to include connections and junctions	m	124.8	R70.00	8 736.00
2.7.6		Solid DN160 HDPE pipe (or similar). Rate to include connections and junctions	m	60.0	R70.00	4 200.00
		Supply and delivery of submersible pump:				
2.7.7		Float switch pump	No	1.0	R150 000.00	150 000.00
		Installation of submersible pump:				
2.7.8		Float switch pump installation	No	1.0	R20 000.00	20 000.00
2.8	SABS 1200GA	**CONCRETE STRUCTURAL**				
		SPILLWAY				
	8.4.3	**Strength Concrete: 30MPa/19mm**				
2.8.1		Spillway	m³	15.18	R1 600.00	24 288.00
	8.2	**Formwork**				
	8.2.2	**Smooth vertical plane to:**				
2.8.2		Spillway - Walls	m²	42.9	R748.66	32 117.51
	8.3	**Reinforcement**				
2.8.3		Spillway, Mesh ref no.395, minimum lap length of 400mm, 50mm cover required	/sheet	6	R1 824.00	10 488.00
	8.4.4	**Unformed Surface Finishes**				
2.8.4		Spillway	m²	30	R56.96	1 708.80
		SCHEDULED CONCRETE ITEMS				
	8.4.2	**Blinding layer in 15MPa/19mm Concrete**				
2.8.5		Manhole sump - 50mm minimum thickness	m²	27.5	R120.00	3 300.00
	8.4.2	**Strenght concrete class 30MPa/19 mm no fines concrete in:**				
2.8.6		Leakage detection sump	m³	2.8	R2 358.92	6 487.03
2.9		**FENCING**				
		Supply and erection of new fencing material:				
2.9.1		Fence around Pollution control dam. Fence to be fully galvanised. Installation as per manufacturers guidelines. Rate to include excavations, concrete works, backfilling, compacting and finsishes.	m	462.0	R298.10	137 722.20
		Supply and install double leaf gate:				
2.9.2		1800mm high diamond mesh double leaf gate, 4800mm wide, with lock	No	1.0	R6 457.00	6 457.00
2.10		**MISCELLANEOUS**				

Rietfontein - Pollution Control Dam						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2.10.1		Supply and attach signage to Pollution Control dam Fence. Sign faces with painted/galvanized background, with painted symbols, characters, legends and borders	Prov Sum	1.0	R5 000.00	5 000.00
2.10.2		Supply and install cargo/crawl net, mesh size 200mm, rope size 12mm (15m wide, 14m long)	No	6.0	R7 500.00	45 000.00
2.10.3		Supply and install Life Bouy as specified on drawings (rate to include gum pole and approved life bouy)	No	6.0	R3 850.00	23 100.00
2.10.4		Supply and install manhole rings for drainage collector sumps (4 x 1250 x 1000 mm chamber rings), including starter ring. Rate to include concrete base, ladder entrance, 'Denso' sealed joints and precast heavy duty concrete lids	No	4.0	R45 000.00	180 000.00
2.10.5		Supply and install manhole rings for drainage collector sumps (1 x 1250 x 500 mm chamber rings), including starter ring. Rate to include concrete base, ladder entrance, 'Denso' sealed joints and precast heavy duty concrete lids	No	1.0	R30 000.00	30 000.00
** Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors *Note: All material quantities excludes wastage*						
		Total Section 2 (Pollution Control Dam)				5 692 376.26

Rietfontein - Product Stockpile Area						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2		**SECTION 2 : EARTHWORKS, DRAINAGE AND INFRASTRUCTURE**				
2.1	SANS 1200C, PSC	**SITE CLEARANCE**				
	8.2.1	**Clear and grub of site and remove all obstructions (spoil to be spread neatly within 1 km freehaul as directed by Engineer) at:**				
2.1.1		Product Stockpile Area	m²	31 900.0	R2.00	63 800.00
2.2	SANS 1200D, PSD	**EARTHWORKS**				
	8.3.2	**Remove the top 150 mm of topsoil, including roots and plant matter, and stockpile it for future landscaping.**				
2.2.1		Product Stockpile Area	m^3	4 785.0	R25.00	119 625.00
	8.3.2(b)	Extra-over item 2.2.1 to 2.3.6 for excavation in:				
2.2.2		Hard Rock material from +- 1m below	m^3	-	R30.00	-
		Excavate and remove an additional 450–500 mm of black turf soils to spoil, leaving ~300 mm in place.				
2.2.3		Product Stockpile Area	m^3	15 950.0	R30.00	478 500.00
	8.3.2	**Loosen/scarify the surface of the remaining black turf layer. Compact to ≥93% of Modified AASHTO MDD.**				
2.2.4		Product Stockpile Area (Stockpiles can be founded directly on this thin, compacted soil layer, providing both groundwater protection and greater stability.)	m^3	4 785.0	R40.00	191 400.00
** Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors *Note: All material quantities excludes wastage*						
		Total Section 2 (Product Stockpile Area)				853 325.00

Rietfontein - Silt Trap						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2		**SECTION 2 : EARTHWORKS AND INFRASTRUCTURE**				
		Earthworks				
2.1	1200 C	**Site Clearance**				
2.1.1	8.2.1	Clear and grub of site and remove all obstructions (spoil to be spread neatly within 1 km freehaul as directed by Engineer) at:	m^2	430.00	2.00	860.00
2.2	1200 D	**Excavation**				
2.2.1	8.3.2	Restricted excavation in all material and dispose as directed by the engineer (All turf material to be removed)	m^3	990.00	40.00	39 600.00
2.2.2	8.3.2(b)	Extra-over item 8.3.2 for excavation in:				
		Hard Rock material	m^3	Rate only	30.00	
2.3		**Layer Works**				
2.3.1	8.3.2	Import from stockpile and place Silt trap platform, compact at 93% MOD AASHTO within ± 2% OMC in 150mm thick layers	m^3	64.50	85.00	5 482.50
2.4	1200 G	**Concrete**				
2,4,1	8.4.2	Blinding layer in 15MPa/19mm Concrete				
		50mm minimum thickness	m^2	516.00	120.00	61 920.00
2,4,2	8.4.3	Strength Concrete: **30MPa/19mm**				
		Silt Trap & Weir	m^3	147.90	1 600.00	236 632.00
2.5	8.2	**Formwork**				
2.5.1	8.2.2	Smooth vertical plane to:				
		Walls	m^2	231.00	1 500.00	346 500.00
2.6	8.3	**Reinforcement**				
2.6.1	8.3.1	Mild steel bars	t	0.01	-	-
2.6.2	8.3.1	High-tensile steel bars	t	2.45	30 000.00	73 590.00
2.6.3	8.3.2	High-tensile Welded Mesh	t	Rate only	18 000.00	
2.6.4	8.3.2	Mesh REF NO. 617 with minimum 50mm cover Sheet size 2,4 x 6m	/sheet	53	1 600.00	84 116.67
2.6.5	8.3.2	Mesh REF NO. 888 with minimum 50mm cover Sheet size 2,4 x 6m	/sheet	369	2 300.00	848 720.96
2.7	8.4.4	Unformed Surface Finnishes				
2.7.1		Wood-floated finnish	m^2	397.05	56.96	22 615.97

Rietfontein - Silt Trap						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2.8	8.5	**Joints**				
2.8.1		Construction Joints	m	Rate only		
2.8.2		External Wall Joints (Waterstops)	m	115.20	515.79	59 419.01
2.9	8.8	**Cast in Steel work**				
2.9.1		Rails with Fishtail lugs				
		15kg/m Rails	t	3.24	21 600.00	69 984.00
2.9.2		Angles with Fishtail lugs				
		100 x 100 x 10 Angles	t	1.50	21 600.00	32 400.00
2,10	1200 HA	**Structural Steel - Sundry Items**				
2.10.1	8.3.2	Hand Rails	m	100.20	550.00	55 110.00
** Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors *Note: All material quantities excludes wastage*						
		Total Section 2 (Silt Trap)				1 936 951.11

Rietfontein - Dirty Water Channels						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2		**SECTION 2 : EARTHWORKS, DRAINAGE AND INFRASTRUCTURE**				
2.1	SANS 1200C, PSC	**SITE CLEARANCE**				
	8.2.1	**Clear and grub of site and remove all obstructions (spoil to be spread neatly within 1 km freehaul as directed by Engineer) at:**				
2.1.1		Dirty water channel 1 and Culvert	m²	785.4	R2.00	1 570.80
2.1.2		Dirty water channel 2 and Culvert	m²	897.6	R2.00	1 795.20
2.1.3		Dirty water channel 3A and Culverts	m²	924.0	R2.00	1 848.00
2.1.3		Dirty water channel 3B	m²	669.9	R2.00	1 339.80
2.1.4		Dirty water channel 4 and Culvert	m²	643.5	R2.00	1 287.00
2.1.5		Dirty water channel 5 and Culverts	m²	2 131.8	R2.00	4 263.60
2.2	SANS 1200DB PSDB	**GENERAL EARTHWORKS**				
	8.3.2	**Cut and fill in all materials:**				
2.2.1		Cut Dirty water channel 1, rip and recompact to 93% MOD AASHTO ± 2% OMC	m^3	549.8	R25.00	13 744.50
2.2.2		Cut Dirty water channel 2, rip and recompact to 93% MOD AASHTO ± 2% OMC	m^3	628.3	R25.00	15 708.00
2.2.3		Cut Dirty water channel 3A, rip and recompact to 93% MOD AASHTO ± 2% OMC	m^3	554.4	R25.00	13 860.00
2.2.4		Cut Dirty water channel 3B, rip and recompact to 93% MOD AASHTO ± 2% OMC	m^3	268.0	R25.00	6 699.00
2.2.5		Cut Dirty water channel 4, rip and recompact to 93% MOD AASHTO ± 2% OMC	m^3	321.8	R25.00	8 043.75
2.2.6		Cut Dirty water channel 5, rip and recompact to 93% MOD AASHTO ± 2% OMC, construct channel berm @ 93% MOD AASHTO within ± 2% OMC in 150mm thick layers	m^3	1 492.3	R25.00	37 306.50
2.2.7		Fill Dirty water berm of channel 5, rip and recompact insitu layer of 150mm to 93% MOD AASHTO ± 2% OMC, construct channel berm @ 93% MOD AASHTO within ± 2% OMC in 150mm thick layers	m^3	1 492.3	R25.00	37 306.50
		ANCHOR TRENCHES				
	8.3.2	**Excavation in all material for trenches, backfill, compact and dispose of surplus material as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul, place, shoring, max vertical excavation 0.5 m, cutting back, dewatering etc.):**				
2.2.8		Dirty water channel 1 liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	38.5	R25.00	962.50

Rietfontein - Dirty Water Channels						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2.2.9		Dirty water channel 2 liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	44.0	R25.00	1 100.00
2.2.10		Dirty water channel 3A liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	48.1	R25.00	1 203.13
2.2.11		Dirty water channel 3B liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	39.9	R25.00	996.88
2.2.12		Dirty water channel 4 liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	35.8	R25.00	893.75
2.2.13		Dirty water channel 5 liner anchor trench 0.5 m wide and for depths up to 0.5 m	m^3	104.5	R25.00	2 612.50
	8.3.2	**Extra over item for 2.3.5 to 2.3.6 above (volumes indicated are material to be stabilised):**				
2.2.14		Backfill stabilized with 5% cement Dirty water channel 1 anchor trench	m^3	38.5	R40.00	1 540.00
2.2.15		Backfill stabilized with 5% cement Dirty water channel 2 anchor trench	m^3	44.0	R40.00	1 760.00
2.2.16		Backfill stabilized with 5% cement Dirty water channel 3A anchor trench	m^3	48.1	R40.00	1 925.00
2.2.17		Backfill stabilized with 5% cement Dirty water channel 3B anchor trench	m^3	39.9	R40.00	1 595.00
2.2.18		Backfill stabilized with 5% cement Dirty water channel 4 anchor trench	m^3	35.8	R40.00	1 430.00
2.2.19		Backfill stabilized with 5% cement Dirty water channel 5 anchor trench	m^3	104.5	R40.00	4 180.00
		TRENCHES FOR CULVERTS				
	8.3.2	**Excavation in all material for road culverts, rip and recompact to 93% MOD AASHTO ± 2% OMC, backfill, compact and dispose of surplus material as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul, place, shoring, max vertical excavation 1 m, cutting back, dewatering etc.):**				
2.2.20		Culvert 1	m^3	6.8	R25.00	168.75
2.2.21		Culvert 2	m^3	6.8	R25.00	168.75
2.2.22		Culvert 3	m^3	5.4	R25.00	135.00
2.2.23		Culvert 4	m^3	5.4	R25.00	135.00
2.2.24		Culvert 5	m^3	4.1	R25.00	101.25
2.2.25		Culvert 6	m^3	6.8	R25.00	168.75
2.2.26		Culvert 7	m^3	6.8	R25.00	168.75
	8.3.2(b)	Extra-over item 2.2.1 to 2.2.22 for excavation in:				
2.2.27		Hard Rock material	m^3	Rate Only		
	8.3.4	**Importing of materials:**				
2.2.28		Extra over items for 2.2.1 to 2.2.22 for importation of materials from stockpile	m^3	Rate only		
	8.3.6	**Overhaul**				
2.2.29		Limited overhaul	m^3	Rate only		
2.2.30		Long overhaul	m^3 - km	Rate only		
	8.3.10	**Importing and placement of topsoil from stockpile**				
2.2.31		Berm Channel 5	m^3	212.0	R25.00	5 301.00
2.3	SABS 1200LE	**STORM WATER DRAINAGE**				

Rietfontein - Dirty Water Channels						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
	8.2.2	**Supply rectangular portal concrete culverts with foundation base :**				
2.3.1		Rocla rectangular Dirty water Culvert (structure1) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 666.56	16 665.55
2.3.2		Rocla rectangular RP Culvert base dirty water (structure1) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.3		Rocla rectangular Culvert (structure2) 750x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 666.56	16 665.55
2.3.4		Rocla rectangular RP Culvert base (structure2) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.5		Rocla rectangular Dirty water Culvert (structure3) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 376.77	13 767.71
2.3.6		Rocla rectangular RP Culvert base dirty water (structure3) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.7		Rocla rectangular Culvert (structure4) 600x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 376.77	13 767.71
2.3.8		Rocla rectangular RP Culvert base (structure4) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.9		Rocla rectangular Culvert (structure5) 450x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 191.84	11 918.39
2.3.10		Rocla rectangular RP Culvert base (structure5) 450x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.11		Rocla rectangular Dirty water Culvert (structure6) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 666.56	16 665.55
2.3.12		Rocla rectangular RP Culvert base dirty water (structure6) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
2.3.13		Rocla rectangular Culvert (structure7) 750x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 666.56	16 665.55
2.3.14		Rocla rectangular RP Culvert base (structure7) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R850.87	8 508.72
	8.2.2	**Install rectangular portal concrete culverts with foundation base :**				
2.3.9		Rocla rectangular Dirty water Culvert (structure1) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.10		Rocla rectangular RP Culvert base dirty water (structure1) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.11		Rocla rectangular Culvert (structure2) 750x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.12		Rocla rectangular RP Culvert base (structure2) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.13		Rocla rectangular Dirty water Culvert (structure3) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.14		Rocla rectangular RP Culvert base dirty water (structure3) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.15		Rocla rectangular Culvert (structure4) 600x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.16		Rocla rectangular RP Culvert base (structure4) 600x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.17		Rocla rectangular Culvert (structure5) 450x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.18		Rocla rectangular RP Culvert base (structure5) 450x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.19		Rocla rectangular Dirty water Culvert (structure6) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.20		Rocla rectangular RP Culvert base dirty water (structure6) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00

Rietfontein - Dirty Water Channels						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2.3.21		Rocla rectangular Culvert (structure7) 750x750 class 175s or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
2.3.22		Rocla rectangular RP Culvert base (structure7) 750x750 or similar approved to SANS 677-1986 specification	m	10.0	R1 500.00	15 000.00
	8.2.7	**Supply precast concrete inlets and outlets to culverts:**				
2.3.23		Dirty Water Culvert structure 1 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R12 989.35	25 978.70
2.3.24		Dirty Water Culvert structure 2 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R12 989.35	25 978.70
2.3.25		Dirty Water Culvert structure 3 Rocla D1 series (300 - 600 series) for portal rectangular culverts 600x750 or similar pre-cast head wall	No	2.0	R8 315.15	16 630.31
2.3.26		Dirty Water Culvert structure 4 Rocla D1 series (300 - 600 series) for portal rectangular culverts 600x750 or similar pre-cast head wall	No	2.0	R8 315.15	16 630.31
2.3.27		Dirty Water Culvert structure 5 Rocla D1 series (300 - 600 series) for portal rectangular culverts 450x750 or similar pre-cast head wall	No	2.0	R8 814.66	17 629.33
2.3.28		Dirty Water Culvert structure 6 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R12 989.35	25 978.70
2.3.29		Dirty Water Culvert structure 7 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R12 989.35	25 978.70
	8.2.7	**Install precast concrete inlets and outlets to culverts:**				
2.3.30		Dirty Water Culvert structure 1 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.31		Dirty Water Culvert structure 2 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.32		Dirty Water Culvert structure 3 Rocla D1 series (300 - 600 series) for portal rectangular culverts 600x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.33		Dirty Water Culvert structure 4 Rocla D1 series (300 - 600 series) for portal rectangular culverts 600x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.34		Dirty Water Culvert structure 5 Rocla D1 series (300 - 600 series) for portal rectangular culverts 450x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.35		Dirty Water Culvert structure 6 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.3.36		Dirty Water Culvert structure 7 Rocla S2 series (675 - 900 series) for portal rectangular culverts 750x750 or similar pre-cast head wall	No	2.0	R1 500.00	3 000.00
2.4	SANS 10409	**PRE-LINER INSTALLATION PREPARATION**				
		PREPARATION AND INSPECTION OF ALL TRAPEZOIDAL CHANNEL SURFACES BEFORE COMMENCEMENT OF INSTALLATION OF LINER SYSTEM				
2.4.1		Chicken Run to eliminate all penetrations from surface larger than 3mm from the surface	m^2	6 052.2	R3.00	18 156.60
2.5		**GEOSYNTHETICS**				
	PS GT	**Supply non-woven protection geotextile (750 g/m^2 protection geotextile or similar) for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.5.1		Dirty water channel 1	m^2	850.7	R59.00	50 190.03
2.5.2		Dirty water channel 2	m^2	972.2	R59.00	57 360.03
2.5.3		Dirty water channel 3A	m^2	993.9	R59.00	58 642.53

Rietfontein - Dirty Water Channels						
ITEM	**PAYMENT**	**DESCRIPTION**	**UNIT**	**QUANTITY**	**RATE**	**AMOUNT**
2.5.4		Dirty water channel 3B	m^2	708.5	R59.00	41 803.52
2.5.5		Dirty water channel 4	m^2	686.8	R59.00	40 521.02
2.5.6		Dirty water channel 5	m^2	2 309.0	R59.00	136 230.07
	PS GT	**Install non-woven protection geotextile (750 g/m2 protection geotextile or similar) for barrier system to Project Specification (rate to include cutting, strapping, wastage & seaming at:**				
2.5.7		Dirty water channel 1	m^2	850.7	R6.00	5 104.07
2.5.8		Dirty water channel 2	m^2	972.2	R6.00	5 833.22
2.5.9		Dirty water channel 3A	m^2	993.9	R6.00	5 963.65
2.5.10		Dirty water channel 3B	m^2	708.5	R6.00	4 251.21
2.5.11		Dirty water channel 4	m^2	686.8	R6.00	4 120.78
2.5.12		Dirty water channel 5	m^2	2 309.0	R6.00	13 853.91
	PS GT	**Supply 2 mm HDPE geomembrane layer to Project Specification (rate to include cutting, strapping, wastage & seaming) at:**				
2.5.13		Dirty water channel 1	m^2	850.7	R110.00	93 574.63
2.5.14		Dirty water channel 2	m^2	972.2	R110.00	106 942.43
2.5.15		Dirty water channel 3A	m^2	993.9	R110.00	109 333.53
2.5.16		Dirty water channel 3B	m^2	708.5	R110.00	77 938.76
2.5.17		Dirty water channel 4	m^2	686.8	R110.00	75 547.66
2.5.18		Dirty water channel 5	m^2	2 309.0	R110.00	253 988.27
	PS GT	**Install 2 mm HDPE geomembrane layer to Project Specification (rate to include cutting, strapping, wastage & seaming) at:**				
2.5.19		Dirty water channel 1	m^2	850.7	R10.00	8 506.78
2.5.20		Dirty water channel 2	m^2	972.2	R10.00	9 722.04
2.5.21		Dirty water channel 3A	m^2	993.9	R10.00	9 939.41
2.5.22		Dirty water channel 3B	m^2	708.5	R10.00	7 085.34
2.5.23		Dirty water channel 4	m^2	686.8	R10.00	6 867.97
2.5.24		Dirty water channel 5	m^2	2 309.0	R10.00	23 089.84
** Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors *Note: All material quantities excludes wastage*						
		Total Section 2 (Dirty Water Channels)				1 947 367.74

Rietfontein - Pipeline River Crossing

ITEM	PAYMENT	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
2		**SECTION 2 : EARTHWORKS, DRAINAGE AND INFRASTRUCTURE**				
2.1	SANS 1200C, PSC	**SITE CLEARANCE**				
	8.2.1	**Clear and grub of site and remove all obstructions (spoil to be spread neatly within 1 km freehaul as directed by Engineer) at:**				
2.1.1		Clear and grub within 500m wetland buffers	m²	4 500.0	R2.00	9 000.00
2.2	SANS 1200D, PSD	**EARTHWORKS WITHIN FLOODLINES**				
	8.3.2	**Bulk excavation in all material. Stockpile, sort or disposed of as directed by the Engineer within 1 km freehaul. (Rate to allow for load, haul and stockpiling of materials):**				
2.2.1		Excavate and disposal of black turf materail removed under all sleepers (576 Sleepers)	m^3	199.6	R25.00	4 989.60
2.2.2		Excavate and disposal of black turf materail removed under all footings (54 footings/plinths)	m^3	13.4	R25.00	334.13
	8.3.2(b)	Extra-over item 2.2.1 to 2.3.6 for excavation in:				
2.2.3		Hard Rock material from +- 1m below	m^3	-	R30.00	-
		Import selected fill material for foundations, 2x150mm min. Compact to 93% MOD AASHTO				
2.2.4		Load, haul and place G7 fill material for sleeper foundations	m^3	199.6	R40.00	7 983.36
2.2.5		Load, haul and place G7 fill material for footing foundations	m^3	13.4	R40.00	534.60
2.3	SABS 1200GA	**CONCRETE STRUCTURAL**				
		CONCRETE SLEEPERS				
2.3.1		Procurement of concrete sleepers (10% contingency)	No	576.0	R620.00	357 120.00
2.3.2		Delivery and offloading of concrete sleepers	Sum	1.0	30 000.0	30 000.00
2.3.3		Load, haul and placement of concrete sleepers	Sum	1.0	288 000.0	288 000.00
	8.4.3	**Strength Concrete: 25MPa/19mm**				
2.3.4		25MPa reinforced concrete foundation	m³	17.16	R2 200.00	37 752.00
2.3.5		25MPa reinforced concrete stub columns	m³	12.375	R2 200.00	27 225.00
	8.3	**Reinforcement**				
2.3.6	8.3.1	High-tensile steel bars	t	1.646	R23 000.00	37 848.80
2.3.7		Brackets (50mmx6mm thick steel brackets)	kg	197.52	R65.00	12 838.80
2.3.8		Bolts	No	480	R5.00	2 400.00
** Note: All items are Re-Measurable *Note: Placed volumes excludes bulking and compaction factors *Note: All material quantities excludes wastage*						
		Total Section 2 (Pipeline River Crossing)				816 026.29