Prepared for
AngloGold Ashanti
AngloGold Ashanti Limited
PO Box 8044
Western Levels
Gauteng
2501

Prepared by
Knight Piésold (Pty) Ltd.
4 De la Rey Road,
Rivonia,
Johannesburg, 2128

Project Number
301-00204/13

KAREERAND TSF EXTENSION PROJECT

FEASIBILITY STUDY FOR KAREERAND TSF EXTENSION PROJECT

Rev	Description	Date
0	Issued in PDF	April 24, 2019
1	Issued in PDF	October 2, 2019

Knight Piésold
CONSULTING

EXECUTIVE SUMMARY

Knight Piesold (KP) was appointed for the pre-feasibility followed by a feasibility design of the proposed Kareerand Tailings Storage Facility (TSF) extension at Stilfontein, in Northwest Province in October 2017. (Reference Purchase Order No. 4501135914).

The Kareerand TSF is located in North-West Province, approximately 6 km off the N12 and 15 km south east of the Klerksdorp town.

KP entered into an agreement with Worley Parsons Pty Ltd (WP) to provide the full Scope of Services required for this feasibility level of design. KP is the lead consultant for the Civil Engineering scope of work, while WP is responsible for the Mechanical and Process Engineering scope.

The pre-feasibility report was submitted to AGA in 2017. This was accepted and was used as a basis for the feasibility level design. The purpose of this feasibility study was to develop a design and prepare tender drawings, a project specification and this feasibility design report including AGA risk assessment.

The report covers the optimisation of cost and mitigation of environmental impacts as far as possible on the feasibility design of the Kareerand TSF, return water dams (RWD) and associated infrastructures.

Geotechnical Investigation Summary

A geotechnical investigation was done to determine the nature and extent of the underlying soils and bedrock at specific structure locations, and to provide recommendations for the TSF basin and penstock foundations.

According to the published 1:250 000 scale geological map (2626 Wes-Rand) the site is underlain by andesite, quartzite and shale of the Pretoria Group with several dolerite dykes and sills present. Dolomite from the Chuniespoort Group are present approximately 1 km north-west of the site.

The TSF extension site is covered by transported soils and underlain by residual andesite, shale or residual dolerite that transitions to highly weathered bedrock at depth. The summary of the specific geology of the site is:

a) The TSF extension footprint is mostly covered by colluvium to depths of between 0.5 m and 1 m and occasionally to 2 m.
b) The north-eastern part of the site is covered by alluvium to more than 3 m depths.
c) The transported soils are underlain by fine grained residual andesite and residual Shale to depths of between 2.5 m and more than 3.4 m with bedrock at shallow depths.
d) Residual Shale and residual Dolerite occur below the transported soils to depths of between 2.2 m and 4 m on the southern east of the extension.
e) No groundwater seepage was encountered during the excavation of the test pits at the TSF extension, presumably due to them excavated during the dry months. Groundwater seepage was encountered at various test pits at the return water dam and along the diversion channel.
f) The in-situ permeability tests conducted on the residual andesite yielded coefficient of permeability (k-values) of between 1 x10^{-7} m/s – 8 x10^{-7} m/s. This material has an average thickness between 0.7 – 1.8 m.

g) The alluvium measured a coefficient of permeability of 5×10^{-8} m/s which was less permeable than the residual andesite.

h) No permeability readings could be obtained in the colluvium due to the highly pervious nature of the material, resulting in a high seepage rate. This material can be used as wall building.

The following were concluded on the geotechnical investigation:

a) A soil/rock mattress will need to be done for the penstock intake and outfall pipe.

b) Material from the TSF basin and RWD excavations can be used to form starter wall embankments.

c) Further geotechnical investigation was also done for details design which included 41 additional test pits in the TSF basin.

Capacity Assessment

The maximum allowable rate of rise (RoR) for the existing tailings dam (cyclone operated) is 6 m/yr. This RoR wil be breach in the year 2021 at the current tonnage projection provided by the MWS, which implies that the new facility needs to be commissioned in the beginning of year 2021.

The extension dam has a footprint of 320 Ha and will close at 169 Ha. The RoR at closure will be 4.1m/yr at production rate of 2.4 million tons per month and the total volume stored will be 485 million tonnes with the total height of 122m. The tonnages will be split between the two dams to manage RoR.

Slurry will be deposited using three additional pipelines located at the toe of the facility. Two take-off pipelines will be connected to each delivery line and the distribution pipeline at the top of the facility.

Stability Assessment

The services of Prof. A Kijko of University of Pretoria Natural Hazard Centre were acquired to undertake a deterministic seismic hazard analysis (DSHA) in November 2017 for the Kareerand TSF complex. The analysis was based on seismic events (earthquake) of magnitude greater than Mw ≥ 3.0 located within a radius of 50 km of Kareerand TSF. The predicted largest horizontal peak ground acceleration for Kareerand is **0.152 ± 0.098.** Vick (1990) proposed that k values of the order of 2/3*PGA could be applicable under certain severe circumstances for un-compacted TSFs. A seismic loading coefficient of **0.167g** and a limit equilibrium FoS of 1.15 for pseudo-static seismic design criteria was used for the Kareerand TSF extension.

The limit equilibrium slope stability software package, Rocscience Slide Version 7 was used to determine the Factor of Safety (FoS) against slope failure for pseudo-static and static conditions for the TSF downstream and RWD upstream and downstream slopes.

The non-circular path-search failure surface was used to generate 20 000 slip surfaces uniformly distributed along the slope section. The slope stability was done using the following methods of analyses: Bishop simplified, Janbu simplified and Janbu corrected. The FoS for 1v:6h for static and pseudo-static analysis were 2.1 & 1.2 respectively at pool distance of 500m away from the outer wall.

Water Balance & Hydrological Assessment

A monthly water balance was modelled for different climate seasons to outline the changes and impacts of the available water resource. Various input parameters, amongst others, including the meteorological data applicable to the site, the topography of the TSF extension and RWD sites, tailings production rate, the tailings material properties and the physical dimensions applicable to the TSF and the RWD were used for the water balance. The following were concluded:

a) Approximately 64% and 60% of the water deposited onto the TSF is returned to the plant between 2018 – 2021 and 2022 – 2014 respectively.

b) On average about 40 000 – 55 000 m^3/d of make –up water will be required. The variance will depend on the wet and dry seasons respectively.

c) The estimated losses are as follows:

  - interstitial storage 31%,
  - evaporation 2.8 - 17% and
  - seepage 6.6 - 19%.

d) The total RWD volumes are 820 000m^3

A storm water diversion channel is designed north of the TSF to separate and divert the clean water from the TSF. This has a 2m topsoil bund wall as protection from any burst pipes.

Safety and Environmental Classification as per SANS 10286

The classification is based on the anticipated configuration of the residue deposit at the end of its life. To classify an impoundment or residue deposit, an evaluation of its “zone of influence” according to guidelines set out in the section 7.4.2.2 of SANS 10286 must be determined.

There are residents in the zone of influence and are estimated to be greater than 10 with the estimated value of third-party property within the zone of influence greater than R 20m. The number of workers in the zone of influence is also estimated to be greater than 10. There are underground workings. The Kareerand TSF complex therefore classifies as a **High Hazard dam**. The classification confirmed with the classification at pre-feasibility study level.

The tailings chemical properties and the potential level of risk with respect to the four levels of thresholds for leachable and total concentrations, resultant in the waste classification of Type 3 waste. The minimum barrier requirement accordingly to Regulation 634 is a Class C liner (1.5mm HDPE geomembrane, with a minimum of 300mm thick compacted clay liner).

In terms of SANS 10286:1998, clause 7.4.6, a risk analysis is required to be done on the TSF with high hazard.

Conclusions of Study

The following conclusions were made:

a) The design of the TSF extension was for the site west of the existing facility and can accommodate the proposed tonnages for life of mine of 394 million tons and the total deposited tonnage on both facilities will be 851 million tons.

b) The TSF extension will be a constructed by an upstream construction method using cyclone underflow for the outer wedge, with overall slope of 1v:6h.

c) A 18 m high starter wall be constructed on the southern side with another containment wall on the northern side.

d) The achieved factors of safety were 2.1 and 1.2 for static and earthquake loadings respectively.

e) Tailings will be hydraulically deposited on the tailings storage facility by means of the cyclones method of deposition using six (6) banks and spigotting in between the two dams to manage the pool.

f) The new TSF extension will be commissioned in 2022, and the two will be operated as two facilities until closure.

g) The life of the facilities will be for a period of approximately 20 years.

h) The overall height of the tailings dam is 122 m

i) The tailings material has been classified as Type 3 waste requiring a Class C barrier system

If the project is moved to the next stage of detail design and construction, it is recommended that:

a) The design criteria to be confirmed.

b) The life of mine production rates for the tailings is confirmed.

c) Detailed seepage and stability assessments be carried out with a view of optimising the under-drainage systems and seepage control measures.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

AGA	AngloGold Ashanti Pty Ltd
MWS	Mine Waste Solutions
KP	Knight Piesold Pty Ltd
WP	Worley Parsons
PFS	Pre-feasibility Study
FS	Feasibility Study
BD	Buffer Dam
TSF	Tailings Storage Facility
CCL	Compacted Clay Liner
EIS	environmental impact statement
EPCM	engineering, procurement and construction management
LoM	Life of Mine
MAP	mean annual precipitation
RoR	rate of rise
FoS	factor of safety
PFS	pre-feasibility study
FS	feasibility study
RWD	Return Water Dam
SDF	Standard Design Flood
Tc	Time of concentration
tpm	tons per month
HDPE	high-density polyethylene
DWS	Department of Water and Sanitation
Mamsl	meters above mean sea level

1.0 INTRODUCTION

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AGA further requested KP to revise feasibility study to include the design of geomembrane for the foundation of the TSF to mitigate against seepage and ground water pollution and this is included in this revision of the report.

1.1 BACKGROUND

KP was appointed by AGA to do a pre-feasibility study which was concluded in 2017, refer to Report 301-00204/12-001 Rev 0. KP has had a thorough understanding and knowledge of the Kareerand (TSF), having undertaken the Pre-Feasibility Study for the Extension Project, being involved with the operation and maintenance of the TSF and planning for its future development and ultimate closure since early in 2014.

The existing Kareerand TSF was commissioned in 2011 with a design life of 14 years to 2025 at a tailings throughput rate of 1.9 million tonnes per month (Mtpm). The total original design capacity was 352 million tonnes. Since commissioning, Mine Waste Solutions (MWS), a subsidiary of Anglo Gold Ashanti (AGA), has increased the production and has targeted a total tailings throughput rate of 2.5 Mtpm (including 170ktpm from Buffels Plant till 2030) until 2042 which resulted in a decrease in the design life of the existing TSF. The increased tonnage throughput necessitated the need for additional airspace; hence the extension project was initiated to split the tonnages between the two facilities. The original available footprint for the extension was 530 Ha which reduced to 340 Ha. The reasons for the reduction of the footprint was environmental impact on the surrounding area and land ownership issues. The feasibility study is based on 340 Ha.

The feasibility study report was submitted in April 2019, this was followed by introduction meeting with Department of Water and Sanitation (DWS) on May 2019.

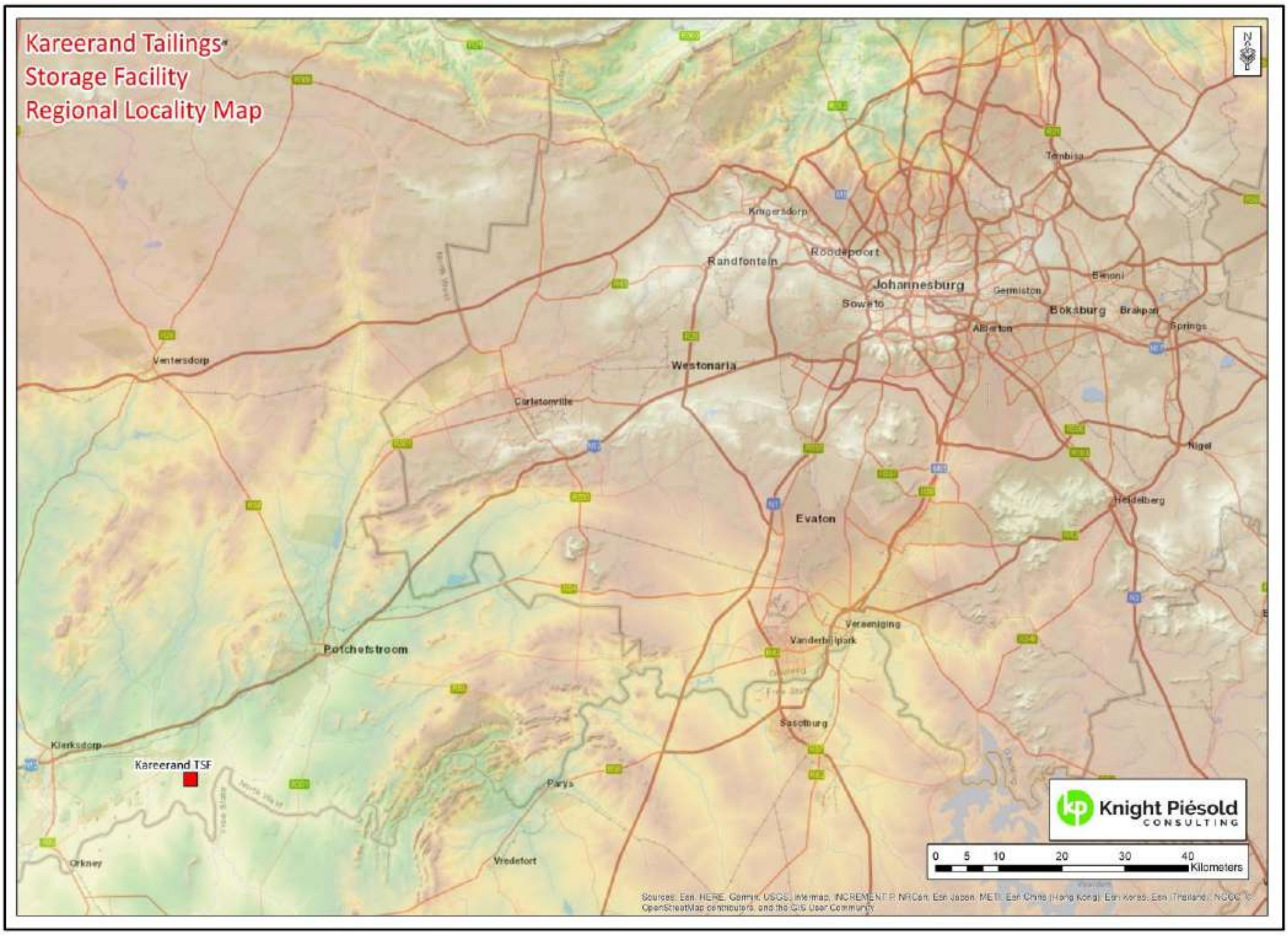


Figure 1.1 Locality Map of the TSF Extension Project

1.2 TERMS OF REFERENCE

AGA requested KP to submit a proposal to undertake a feasibility study for the extension of the existing TSF at the revised deposition rate of 2.47 Mtpm. The report sets out the proposed scope of works and cost estimates for the extension of Kareerand TSF.

1.3 SCOPE OF WORK

1.3.1 CIVIL ENGINEERING SCOPE OF WORK

The agreed Civil Engineering (tailings, geotechnical, hydrology and hydraulics engineering) scope of work for the feasibility study is outlined below:

a) Project initiation and management including progress reporting and attendance at fortnightly progress meetings with Mine Waste Solutions (MWS),
b) Review of the Pre-Feasibility Study (PFS),
c) Site visits as appropriate,
d) Refinement of design criteria developed for the PFS,
e) Review of the PFS capacity analysis and optimisation of the footprint of the proposed extension of the Kareerand TSF,
f) Review of the PFS Geotechnical Investigation Report and identification of additional geotechnical investigations required to advance the design,
g) Additional geotechnical investigations, including test pitting, rotary core drilling for core sampling and percussion drilling at specific targeted locations,
h) Review of Geohydrological Investigation Reports pertaining to both the existing and extension of the Kareerand TSF. AGA's Geohydrological Consultant (GCS) was consulted at all stages to ensure that work undertaken is aligned,
i) Review of the PFS hydrological analysis including diversion channels,
j) Review and refinement of the Water Balance for the TSF,
k) Deposition methodology,
l) Slurry Distribution pipework,
m) Decant System,
n) Storm water management,
o) Design of the Return Water Dam(s),
p) Seepage and Stability Analysis,
q) Design reports and drawings,
r) Risk assessment,
s) Closure design (Concurrent and Final Closure), and
t) Dust suppression system.

1.3.2 MECHANICL AND PROCESSING ENGINEERING SCOPE

The agreed scope of work for both mechanical and process engineering included the following activities:

a) Audit the current installed equipment, and design any additional equipment for the expansion of the current TSF, including structural components such as pump plinths, etc,
b) Evaluate the current installed piping systems and design any additional pipelines for the expansion of the current TSF,
c) Electrical design to cover all aspects of the electrical equipment required for the project,
d) The C&I input into the detail design study will be a detailed DesSoft design,
e) Final process design criteria,
f) Final process flow diagrams,

g) Final mass and water balance,
h) Process sizing calculations,
i) Final piping and instrumentation diagrams,
j) Final control philosophy,
k) Input Into facility cost estimate, and
l) Input into detail design report.

1.3.3 GENERAL SCOPE OF WORK

The following general scope of work was also agreed and included in the feasibility study scope:

a) Designing of pre-works around the existing TSF to accommodate the extension,
b) Review of schedule of quantities compiled by others,
c) Feasibility design report and
d) Technical specification.

1.3.4 SCOPE OF WORK EXCLUDED AFTER CONTRACT AWARD

The following scope of work activities were removed from the overall scope of work:

a) Electrical design to cover all aspects of the electrical equipment required for the project.
b) The C&I input into the detail design study will be a detailed DesSoft design.

1.4 BATTERY LIMITS AND EXCLUSION

1.4.1 CIVIL ENGINEERING BATTERY LIMITS

The following battery limits are applicable to the civil engineering aspects of the study:

a) Upstream battery limit to be the incoming slurry flanges on the delivery pipes from the gold plant upstream of the surge tank at the Booster Pump Station, slurry booster pump station valves flanges and the selected access point to the site from either the provincial road or other access road if controlled by AGA.
b) Downstream battery limit at the discharge of the new return water pump flange at the buffer dam.

1.4.2 MECHANICAL AND PROCESS ENGINEERING BATTERY LIMITS

a) The Battery limit for return water will be the flange on the discharge of the existing return water pumps pumping out of the new return water dams (including the necessary connections to the existing system).
b) The downstream battery limit will be the inlet at the Midway Dam.

c) The Battery limit for the incoming slurry will be the flange on the delivery pipes from the gold plant streams upstream of the surge tank.

2.0 AVAILABLE INFORMATION

2.1 TOPOGRAPHICAL SURVEY

KP received, a topographical (Lidar) survey of the proposed site, the existing TSF and the surrounding area from AGA.

2.2 PRE-FEASIBILITY STUDY REPORT

KP used the pre-feasibility study as the basis for the feasibility with optimization of the layout, and other design components.

2.3 LIFE OF MINE

KP received a business plan for 2019 from MWS which outlined the production plan from 2018 to 2042 at the following rate as shown in Table **2-1.**

Table 2-1 Mine Waste Solution Life of Mine Plan Including Buffles Plant Tonnages

Year	Average monthly Production Rate
2018 (Actual)	2 406 853
2019 - 2021	2 471 000
2022 - 2030	2 471 000
2031 - 2042	2 301 000

The above production rates were used to determine the required capacity of the TSF extension, the footprint area and to develop the stage capacity curves for the TSF.

3.0 DESIGN CRITERIA FOR THE PROPOSED TSF EXTENSION, RWD & ASSOCIATED INFRASTRUCTURE

The design criteria for the proposed TSF extension, RWD and related infrastructure were agreed by AGA/MWS and KP in 2018. **Table 3-1** below shows the agreed design criteria:

Table 3-1 Feasibility Design Criteria

Item	Design Criteria	Source/ Comments
1.0 GENERAL		
Commissioning date of existing TSF	2011	Design Report Ref FA/BR/025/2009, By Fraser Alexander
Design life of existing TSF	14 yr	Design Report Ref FA/BR/025/2009, by Fraser Alexander
TSF Extension commissioning	2022	MWS
Required Life of TSF Extension	20 yr	MWS
2.0 HYDROLOGY		
Stormwater management	Separate clean and dirty water	As per legislation (GN 704) and best practice
1:20 year – 24 hr	117 mm	
1:50 year – 24 hrs	147 mm	
1:100-year – 24 hrs	173 mm	
1:200-year – 24 hrs	202 mm	
7 days event	216 mm	
3.0 TSF DESIGN		
Seismic loading (PGA)	0,152 ± 0,098 g	Report 2016-17/2 (Rev 2,0) (A Kijko)
Average tailings (Mtpm)	2 471 Mtpm	MWS BP 2019
Specific gravity	2,7	Concept design FA-019
Grading - Underflow-wall	<2 mm and GM = 0.68	MEP-JvT/KHH2159/3010020402/Rev.0
Grading - Overflow-beach	<0.425 mm and GM =0.59	MEP-JvT/KHH2159/3010020402/Rev.1
Cyclone U/F split (mass)	26 %	
Slurry density:		
Feed	1 387	
Underflow	1 857	
Overflow	1 323	
Percentage solids by mass:		
Feed	41.5 %	
Underflow	70.4 %	
Overflow	37.3 %	
Final dam elevation	1 432 mamsl	

Item	Design Criteria	Source/ Comments
	(122 m height)	
Overall outer side slope angle	1v:6h	
Intermediate slope angle	1v:4h	
Maximum slope distance	25 m	
Bench vertical spacing	12 m	
Bench width	23 m	
Tailings dam footprint area	362 Ha 520 Ha 882 Ha	Extension Existing Total
Hazard Rating	High Hazard	
Dam Safety Category	Category 3	
Deposition Methodology	On-wall Cylones	
Barrier system	Class C	Refer to report No. 1306001 by GCS
Wall construction method		To consider Upstream/Downstream/Centreline
Decanting System		To consider gravity, and/or siphon
Stormwater management - RWD	1:100 year storm event	Regulation 704, of the water Act 1998
Minimum Factor of Safety Static	1.5	Industry norms & Standards
Minimum Factor of Safety Seismic	1.1	Industry norms & Standards

The southern African national standards were used.

4.0 RESIDUE ANALYSIS

4.1 TAILINGS CHARACTERISATION

The residue is gold tailings originating from reclamation of existing old tailings dam and underground mining and with particle sizes less than 2 mm for underflows and 425 microns for overflow. Piezocone testing was undertaken at the existing TSF and laboratory tests for the tailings were used to determine the in-situ tailings design parameters. These were also compared with estimated parameters from USCS soil classification and experience with gold tailings. The tailings design parameters used are presented in **Table 4-1**:

Table 4-1 Tailings Parameters used for Feasibility Study

Parameter	Units	Laboratory Result	Design Parameters
In-situ density (underflow)	kN/m³	15.2	15.2
In-situ density (overflow)	kN/m³	14.2	14.2
Internal friction angel (underflows)	Deg (º)	29.7	29.7
Internal friction angel (overflow)	Deg (º)	25	25
Cohesion	kPa	0	0
Coefficient of permeability – Underflow	m/s	5×10^{-7}	5×10^{-7}
Coefficient of permeability - Overflow	m/s	5×10^{-8}	5×10^{-8}

4.2 GEOCHEMICAL CHARACTERIZATION

In terms of the National Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R635 of 23 August 2013), the potential level of risk associated with disposal of waste products must be assessed against four levels of thresholds for leachable and total concentrations, which determine the waste type and associated barrier design / liner requirements.

During a pre-feasibility study, a separate study was undertaken to determine the Geochemical Characterisation of MWS's Tailings. The tailings were classified as **Type 3** waste, which meant that a barrier system of a **Class C** liner is required store the tailings. Refer to report No. 1306001 by GCS for environmental geochemical assessment of Kareerand TSF compiled in 2013.

5.0 PRE-FEASIBILITY REVIEW

5.1 GENERAL

5.1.1 GEOTECHNICAL INVESTIGATION

The Pre-feasibility study outcome:

“The area of the TSF Extension is underlain by colluvium overlying andesite, shale, quartzite, dolerite and hardpan ferricrete. The foundation conditions under the starter wall can be divided into two geotechnical zones, namely Zone 1 where the fill layers can be placed on residual soils and zone 2 where the fill layers are placed on shallow hard rock conditions.

The TSF floor is covered by the typical soil profile as described above for the TSF starter wall. It is recommended that 200 mm topsoil be stripped and stockpiled. The colluvium and nodular ferricrete must be used as a borrow material for the fill layers on the starter wall and water return dams. The borrow area must be planned in such a way that the basin and upstream starter walls are covered by a continuous clay/low permeability layer. It is recommended that the borrow area should be a zone adjacent the starter wall perimeter.”

Feasibility Study Review:

A further geotechnical investigation was undertaken to further classify the material and get a good understanding of the foundation material. The final geotechnical report was not available at the time of this report.

5.1.2 GEOHYDROLOGICAL INVESTIGATION

Pre-feasibility study outcome:

“Seepage modelling carried out as part of the Geotechnical Investigation has demonstrated that the seepage plume from the TSF will eventually reach the Vaal River, despite installation of an extensive groundwater extraction/interception system and irrespective of whether a geosynthetic liner is installed under the TSF extension. A preliminary assessment indicates that the inclusion of a grout curtain downgradient of the TSF may mitigate this. This must be further investigated in the full Feasibility Study/Design Phase for the TSF.”

Feasibility Study Review:

A geohydrological model is being done separately from the feasibility study and the outcomes will be discussed in the relevant reports by others. A critical review should be done to evaluate why the installation of the geomembrane/ geosynthetic liners will not mitigate the plume generation. The residual Andesite and Alluvium layers under the footprint will mitigate this to certain extend however, there are areas of high permeability which should be designed for in the detail design.

The grout curtain downgradient was not investigated further in the feasibility study, however, the geohydrologist recommended an extraction boreholes and tree system to mitigate the plume.

A further investigation is being undertaken by other to evaluate how best to manage the plume migration.

5.1.3 SEISMICITY

Pre-feasibility study outcome:

A Deterministic Seismic Hazard Analysis evaluated all known seismic events within a 50 km radius of the site, and predicted that the largest horizontal Peak Gravitational Acceleration (PGA) at the Kareerand Tailings Dam site is 0.17 ± 0.08 g.

Feasibility Study Review:

It is recommended that a seismograph is installed at the side to determine the earthquake experienced at the site. This will assist in assigning the correct seismic loading during the development of the facility. AGA has commenced with the installation and has appointed University of Pretoria to for the review of the seismograph data.

As recommendation by Seed 1979 and Melo et al 2004, the seismic coefficient should be in the range of k = 0.1 – 0.15 for increasing seismic hazard areas for Richter scale 6 to 8.5 respectively and factors of safety above 1.15 should be considered for detail design.

Furthermore, its is recommended that a seismic loading for evaluation of the stability of the TSF should be in the order of 2/3 x PGA as suggested by Vick 1990.

5.1.4 GEOCHEMISTRY

Pre-feasibility study outcome:

“Geochemical Characterisation of MWS’s Tailings has determined that the Tailings have been classified as Type 3 waste, implying that a Class C liner will be required under the TSF unless it can be shown that alternative seepage mitigation measures will be equally or more effective at preventing seepage into the groundwater”

Feasibility Study Review:

According to Regulation 636 of August 2013, a Type 3 waste requires a minimum of Class C barrier system. An amendment to the regulation, was gazetted in September 2018, which indicated that a risk-based approach can be conducted by a competent person to determine and recommend the pollution control measures that are site specific.

A geohydrological model will determine the plume migration and assist the competent person to determine the mitigation measure for Kareerand TSF extension. This information pertaining to the geochemistry is included in the Geohydrology report No. 17-0109 by GCS Pty Ltd.

5.1.5 CAPACITY

Pre-feasibility study outcome:

“At a consistent tailings production rate of 2.6 Mt/month over the life of the TSF, it was determined that the facility will be able to store 503 Mt on the extension and a total of 449 Mt on the existing footprint at a deposition split of 40 % to the existing footprint and 60 % to the extension. This translates into a life of facility of 24 years for the existing footprint and 27 years for the extension.

For an alternative production scenario that was analysed, in which throughput gradually reduced over time, the life of the facility increases to 29 years for the existing footprint and 33 years for the extension.”

Feasibility Study Review:

A capacity assessment review has been done based on the latest MWS business plan (life of mine plan). The proposed mine tonnage through put can be stored on the extension footprint.

5.1.6 SLOPE STABILITY

Pre-feasibility study outcome:

"A slope stability analysis was undertaken for both static and seismic conditions assuming firstly that the underdrainage system was dysfunctional, and the phreatic surface was therefore abnormally high (conservative assessment), and secondly with a functioning underdrainage system.

Under normal (static) conditions with a deficient drainage system, the factor of safety against circular slope failure is above the minimum legislated factor of safety of 1.5. During the maximum seismic conditions (0.25g) the sections analysed returned a factor of safety of below the minimum prescribed 1.1, with all falling below 1.0.

When the phreatic surface was lowered to the estimated level for the case where all drainage systems are operating satisfactorily the factor of safety was just above the minimum of 1.1.

It is therefore extremely important that the designed drainage system should be installed correctly and constantly monitored and maintained during the operation of the facility."

Feasibility Study Review:

A review of the Slope stability assessment should be done in the feasibility study where the drainage system and the overall design slopes are designed to ensure conformance to industry norms and standards for both static and pseudo-static (seismic) conditions.

This has been done in the feasibility study and the drainage system designed to mitigate the pre-feasibility outcomes. It is further recommended that the detail design under take a sensitivity analysis to determine the sensitivity of the system on the overall factors affecting stability.

5.1.7 DEPOSITION METHODOLOGY

Pre-feasibility study outcome:

"Tailings will be deposited through the single cyclone system using eight banks of forty 250 Ø cyclones evenly spaced around the perimeter of the TSF. On average, sixty (60) units will be used simultaneously, 20 cyclones being operational on each of 3 banks.

Each bank of forty cyclones will be fed from a header pipe on the crest, which in turn is connected to one of three main distribution lines located at the toe of the facility. Alternate banks will be used to spread the deposition around the perimeter and so control the pond position.

It is intended to develop the outer TSF profile with 23 m wide benches at 12 m vertical intervals."

Feasibility Study Review:

The deposition strategy is adopted in the feasibility study.

5.1.8 BOOSTER PUMP STATION UPGRADE

Pre-feasibility study outcome:

"It is required to increase the pumping capacity of the cyclone feed booster pumps by adding five additional pumps."

Feasibility Study Review:

The need for an additional pump train was evaluated and designed in this study. This was followed by a cost benefits analysis done by MWS. It was concluded that the additional pump train will be put on hold and MWS will rather add a fifth pump on each of the four existing pump trains

5.1.9 DECANT SYSTEM

Pre-feasibility study outcome:

"On commencement of deposition in the Extension a pool of supernatant water will accumulate at the lowest point, which is at the southern extremity of the interface between the existing and new facilities. The pool will migrate northwards as the beach develops from deposition off the southern wall of the Extension.

A series of three temporary penstocks (900 mm ID) constructed over an outfall pipe consisting of 750 NB spigot and socket concrete pipes encased in reinforced concrete will decant process and storm runoff from the facility as the pool migrates northward.

Once the pool reaches its permanent position, decanting will be changed to either a siphon system or barge mounted pumps."

Feasibility Study Review:

The pre-feasibility decant system design has to be optimized based on the height and time from intermediate intake to the permanent intake. It is proposed that the permanent intake will be utilised for a maximum height of 20 m and it should be sleeved during the development of the dam. The intake will further be sealed off and a barge / siphon system will be used. It also recommended that the sealing of the penstock be designed by a competent person and to be constructed/implemented by a competent contractor.

5.1.10 WATER BALANCE

Pre-feasibility study outcome:

"The Water Balance was set-up for initial conditions (Year 0) and end of life conditions (Year 25). The Water Balance has shown that the current operating level of the Buffer dam (BD) is too high to cater for storm events. The operating level should be lowered from 70% to 50%. The main driver for the size of the BD and the new Return Water Dam (RWD) is the side slope run-off and the rate at which water can be returned to the Midway Pump Station. A new RWD of 300,000 m^3 will be required initially, but the size will need to be increased to 1,200,00 m^3 towards the end of life. Various rainfall, decanting and pumping scenarios were analysed, but the analysis must be refined during the Detail Design Phase."

Feasibility Study Review:

A water balance model should be developed to ensure the following legislative requirements are met:

a) Clean storm water run-off must be diverted away from the TSF and that the dirty water emanating from the TSF and plant area must be contained and reused.

b) The TSF and RWD freeboards are determined against Regulation 704 of the Water Act (Act 36 of 1998) of South Africa and requires a minimum freeboard of the 1:50 year storm plus 800mm above the mean operating level of the pool.

c) **Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years**.

5.1.11 HAZARD RATING AND RISK ASSESSMENT

Pre-feasibility study outcome:

"In terms of the South African code SANS 10286 Section 7.4.1 the safety classification for the TSF at Kareerand is "High Hazard", since the Zone of Influence encompasses several homesteads on the North bank of the Vaal River, as well as farmsteads and agricultural infrastructure east of the TSF, on the north bank of the river. The number of residents exposed to risk is likely to be between 11 and 100, and the value of third-party property is likely to be between 5 and 50 million Rand.

A spreadsheet-based risk analysis of failure mode versus consequence has been carried out for the TSF. The analysis identified seepage into groundwater as the highest risk followed by runoff from the outer slopes of the TSF and insufficient return water pumping capacity. All other risk events considered in the analysis are in the "Green" zone.

The environmental risks associated with the tailings pipelines are "Category 3 – High Risks"

Feasibility Study Review:

The hazard rating and risk assessment was adopted in the feasibility study.

5.1.12 DWS DAM SAFETY CLASSIFICATION

Pre-feasibility study outcome:

"The existing TSF is classified as a category 3 dam. The expanded facility will also be classified as a category 3 dam."

Feasibility Study Review:

The pre-feasibility dam classification is adopted for the feasibility study and the following should be adopted:

a) An approved professional person (APP) should be appointed for the extension,

b) The APP should apply to the DWS for

    i. dam classification,

    ii. license to construct, and

    iii. license to impound.

6.0 SUMMARY OF GEOTECHNICAL INVESTIGATION

6.1 INTRODUCTION

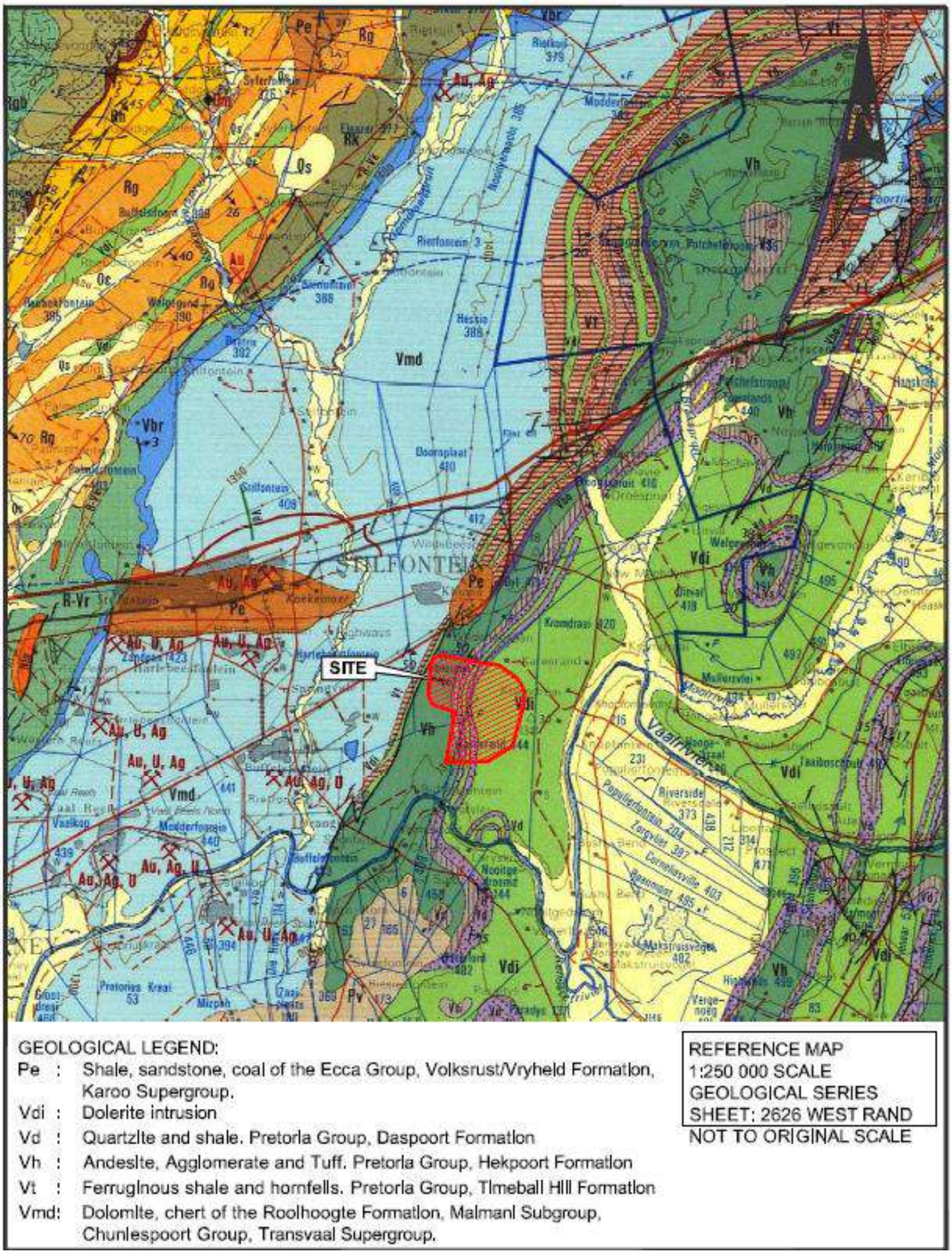
The purpose of the detailed geotechnical investigation was to determine the nature and extent of the underlying soils and bedrock at specific structure locations, and to provide recommendations for the construction of the foundations. This section provides the summary of the geotechnical investigation report attached to this report in **Appendix B.**

6.2 SITE REGIONAL GEOLOGY

According to the published 1:250 000 scale geological map (2626 Wes-Rand) the site is underlain by andesite, quartzite and shale of the Pretoria Group with several dolerite dykes and sills present. Dolomite from the Chuniespoort Group are present approximately 1 km north-west of the site. According to the geological map, the dolomite dips approximately 50° towards the site in a south-easterly direction. No suitable outcrops could be found during the investigation to confirm the dip angle. The western boundary of the site was specifically investigated during the feasibility geotechnical investigations to ensure that it does not occur on dolomite ground (>100 m non-dolomitic overburden). Refer to Figure **6.1** providing an abstract of the geological map.

Pedogenic soil in the form of nodular to honeycomb ferricrete occurs in the residual soil horizons. Ferricrete form when iron and manganese are introduced into the soil, generally in dissolved state and precipitates during water evaporation. The iron and manganese cements over time binding soil particles together, which could, under favourable conditions, grow into a hardpan horizon.

According to Weinert’s climatic N-value the site falls in an area where the N-value is less than 5, indicating that the area is associated with humid/wet environments and chemical weathering is the dominant rock weathering mode. The products of chemical weathering (decomposition) are commonly finer grained silty and clayey residual materials which may exhibit expansive properties. Residual soil layers generally comprise deeper soil profiles.



GEOLOGICAL LEGEND:

Pe :	Shale, sandstone, coal of the Ecca Group, Volksrust/Vryheid Formation, Karoo Supergroup.
Vdi :	Dolerite intrusion
Vd :	Quartzite and shale. Pretoria Group, Daspoort Formation
Vh :	Andesite, Agglomerate and Tuff. Pretoria Group, Hekpoort Formation
Vt :	Ferruginous shale and hornfels. Pretoria Group, Timeball Hill Formation
Vmd:	Dolomite, chert of the Roolhoogte Formation, Malmani Subgroup, Chuniespoort Group, Transvaal Supergroup.

REFERENCE MAP
1:250 000 SCALE
GEOLOGICAL SERIES
SHEET: 2626 WEST RAND
NOT TO ORIGINAL SCALE

Figure 6.1 Regional Geological Map

6.3 METHOD OF INVESTIGATION

A total of sixty-four (64) test pits were excavated on site during the pre-feasibility and feasibility study level investigations, phased in accordance with the structures as listed below.

Table 6-1: Investigation Sequence

Area	Date	No. of Test Pits	Test Pit ID	Excavation Equipment
TSF Extension	9 -15th May 2017	29	TP1 to TP29	TLB
Return Water Dam	4 – 6th Sept. 2018	18	TP2-01 to TP2-18	Excavator 20T
Diversion Canal	20 – 23rd Nov. 2018	17	TP3-01 to TP3-17	TLB
TSF Extension (revised layout)	3 – 10th April 2019	41	NTP1 – NTP41	TLB

The test pits were excavated to maximum reach or excavation refusal of the machine(s) and logged in-situ by an engineering geologist according to standard practice. The soil profile logs are provided in the detail Geotechnical Investigation Report in **Appendix B.**

In addition to the test pitting, four rotary cored boreholes were drilled along the proposed penstock alignment and logged by an engineering geologist according to current standards. Drilling was carried out from 3 to 9 October 2018 and representative rock samples were submitted to Rocklab in Pretoria for UCS testing.

An additional twenty-two inspection points were carried out along the topsoil bund wall along the existing TSF embankment.

Representative soil samples were collected from soil horizons during the investigation and were submitted to SGS Matrolab in Pretoria for laboratory testing.

The following tests were conducted:

a) Foundation indictor (grading, hydrometer and Atterberg limits)
b) Standard Proctor compaction
c) Modified AASHTO compaction
d) California Bearing Ratio (CBR)
e) Consolidated undrained triaxial
f) Shear box
g) Flexible wall permeability
h) Soil corrosivity (pH and conductivity)
i) Chemical dispersivity
j) Consolidation

Nine in-situ falling head permeability tests were conducted but only five tests were successful.

6.4 SUMMARY OF SITE-SPECIFIC GEOLOGY

The TSF extension site is covered by transported soils and underlain by residual andesite, shale or residual dolerite that transitions to highly weathered bedrock at depth. The typical expected andesite characteristics are plastic, clayey and silty soils which may potentially expansive. It is expected that the plasticity index of the residual soils will be significantly high. This means that the material is likely to exhibit low permeabilities which is favorable for the basin of the TSF.

The typical soil profiles are discussed in the following paragraphs and the detail profiles are presented in the Geotechnical Investigation report in **Appendix B**. The location and profile of the basin at pre -feasibility is shown on **Figure 6.2** & **6.3** below

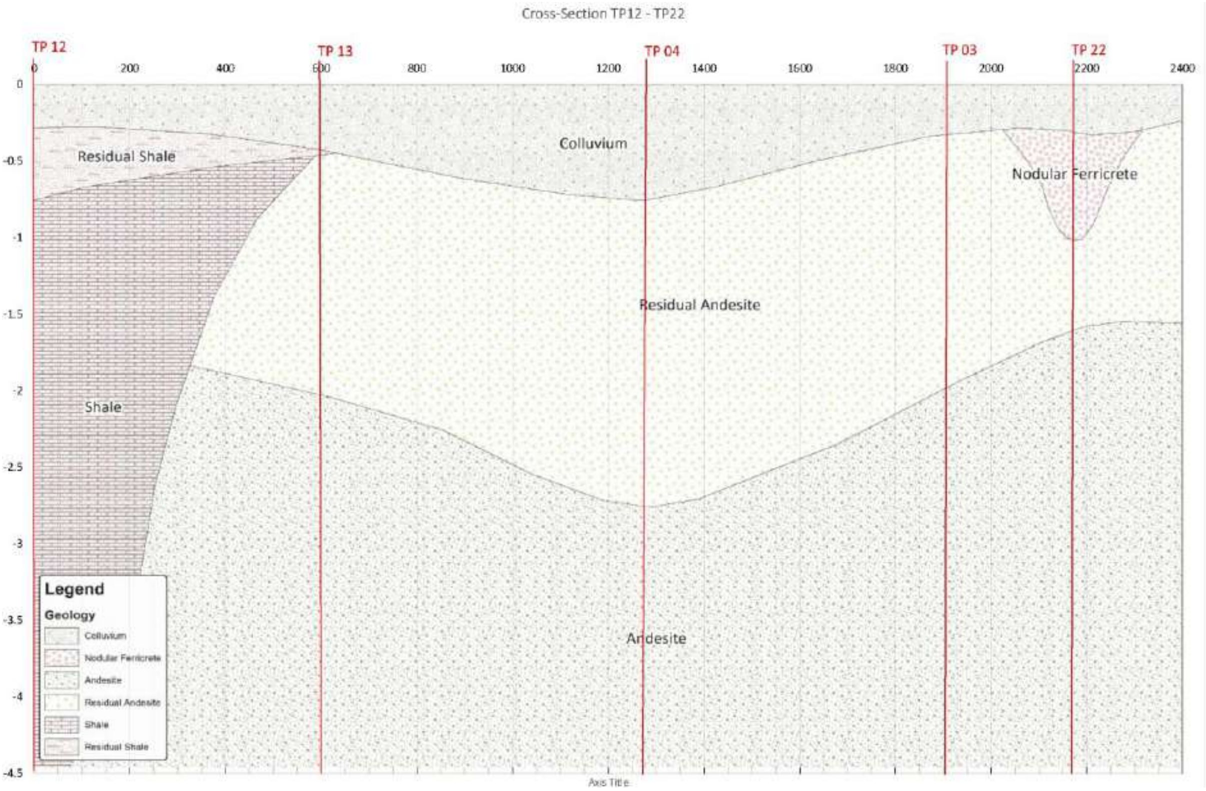


Figure 6.2 **Basin Geological Profile from West to East at Pre-Feasibility Level Investigation**

6.5 GEOTECHNICAL EVALUATION

6.5.1 SITE SPECIFIC GEOLOGY

Below is a description of the general site-specific geology.

a) **Transported Material:** The transported soil (alluvium) comprises generally sandy silty clay with a soft consistency that transitions to firm with depth. The soil structure is often slickensided to intact with depth the alluvium often becomes coarse grained and consist of sandy gravel to gravelly sand with abundant sub-rounded to rounded gravel. The thickness of the alluvium is mostly more than 3m but is thinner along the edge of the drainage areas. See **Figure 6.3** shows the deep alluvium in the swamp zone adjacent to the existing TSF. The alluvial clays can however be a problem, as they could exhibit settlement or expansive behaviour.

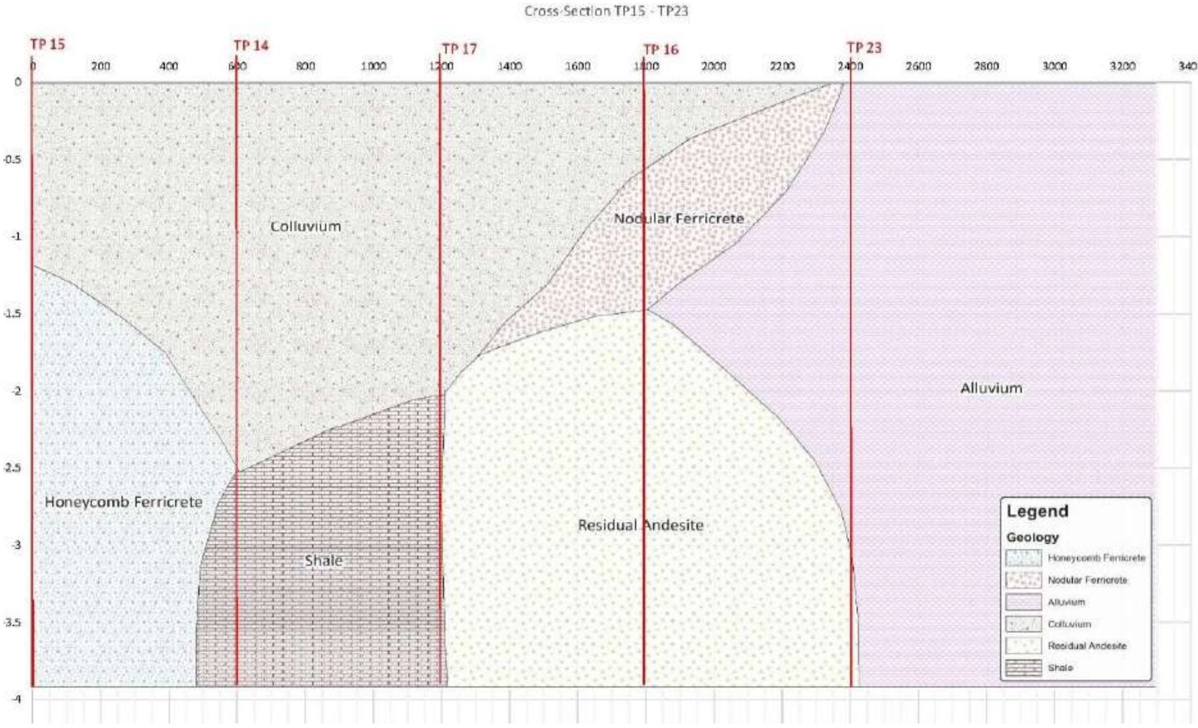


Figure 6.3 Alluvium in the Drainage layer next to existing TSF

b) **Transported Material:** The remainder of the site is covered by colluvium that generally comprises a matrix supported silty sand and sandy silt with abundant medium to coarse gravel and cobbles and with a consistency that is generally medium dense. The colluvium varies in thickness of between 0.4 m and 2.8 m but has an average thickness of 0.9 m. A pebble marker was occasionally intersected at the bottom of the layer that is described as silty sandy gravel with scattered cobbles.

c) **Padogenic Material:** Nodular ferricrete and occasional honeycomb ferricrete occur at several test pits across the site and generally comprise medium dense to dense ferricrete nodules in a silty sand matrix. The horizon has a typical thickness of between 0.4 m and 1.0 m. Excavation refusal occurred mostly on the honeycomb ferricrete.

d) **Residual Material:**

   i. **Residual shale** occurs mostly at the return water dams and some parts of the TSF extension as shown on Figure **6.4.** The material can be classified as sandy silty clay with minor gravel and has a firm to stiff consistency with depth. The gravel content increases towards bedrock. The residual shale gradually transitions to very soft rock bedrock with depth.

   ii. **Residual dolerite** occurs sporadically as medium dense silty sand with minor gravel. It occurs mostly at depth below the alluvium in the drainage areas. It is presumed that two dolerite dyke intrusions occur across the site, while it is known that the eastern portion of the existing TSF is underlain by a dolerite sill.

   iii. Andesite Bedrock occurs at depth generally as highly weathered very soft rock andesite or shale. The very soft rock transitions quickly to a soft rock with depth is mostly excavated as a gravel. The TLB encountered excavation refusal on the soft rock, while the excavator could continue until it reached medium hard rock but was generally halted in the soft rock material. Excavation refusal was also encountered on the medium hard rock quartzite located in limited areas in the TSF extension area.

e) Ground Water: Groundwater seepage was encountered at various test pits at the return water dam and along the diversion channel. No groundwater seepage was encountered during the excavation of the test pits at the TSF extension, presumably due to them excavated during the dry months.

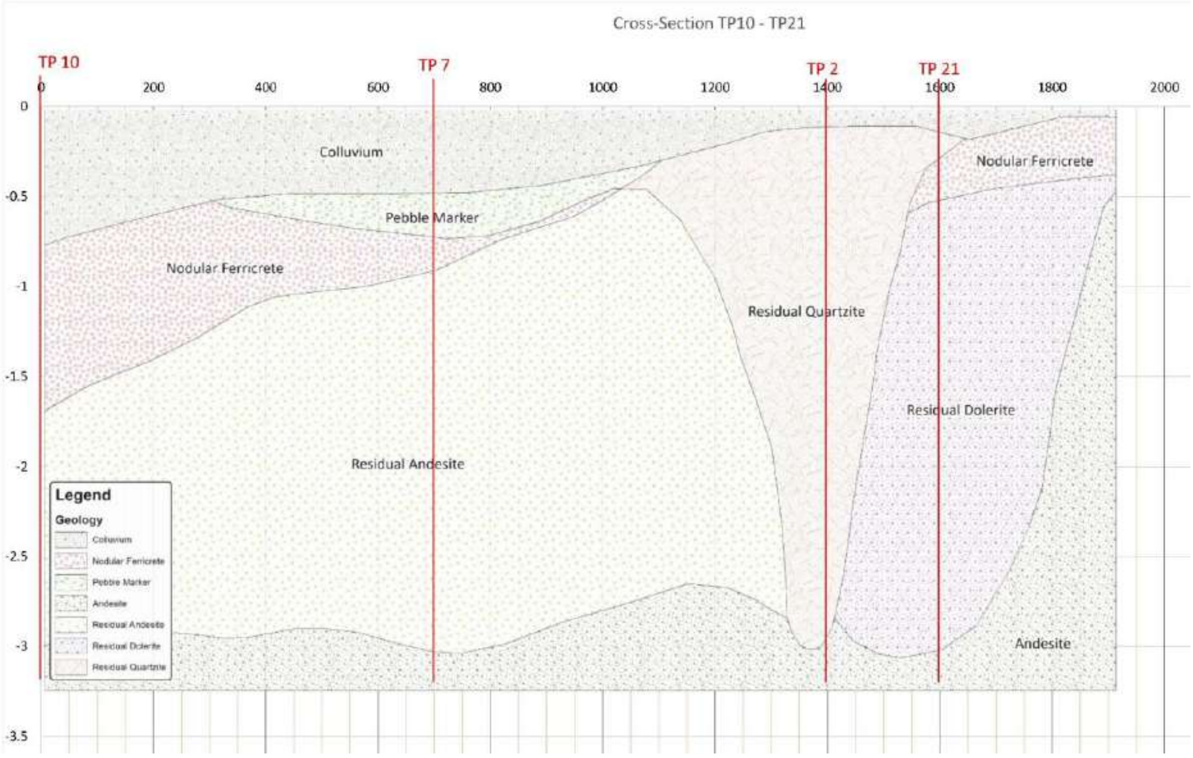


Figure 6.4 Variety of Residual Material with andesite

Below the potential fill material in the basin (colluvium, pebble marker and nodular ferricrete) the majority of the TSF footprint is underlain by a very low permeable clayey sand layer with a stiff consistency. It is recommended to remove the colluvium, pebble marker and nodular ferricrete for use of embankment fill material. The encountered material is shown on the map in Figure **6.5**.

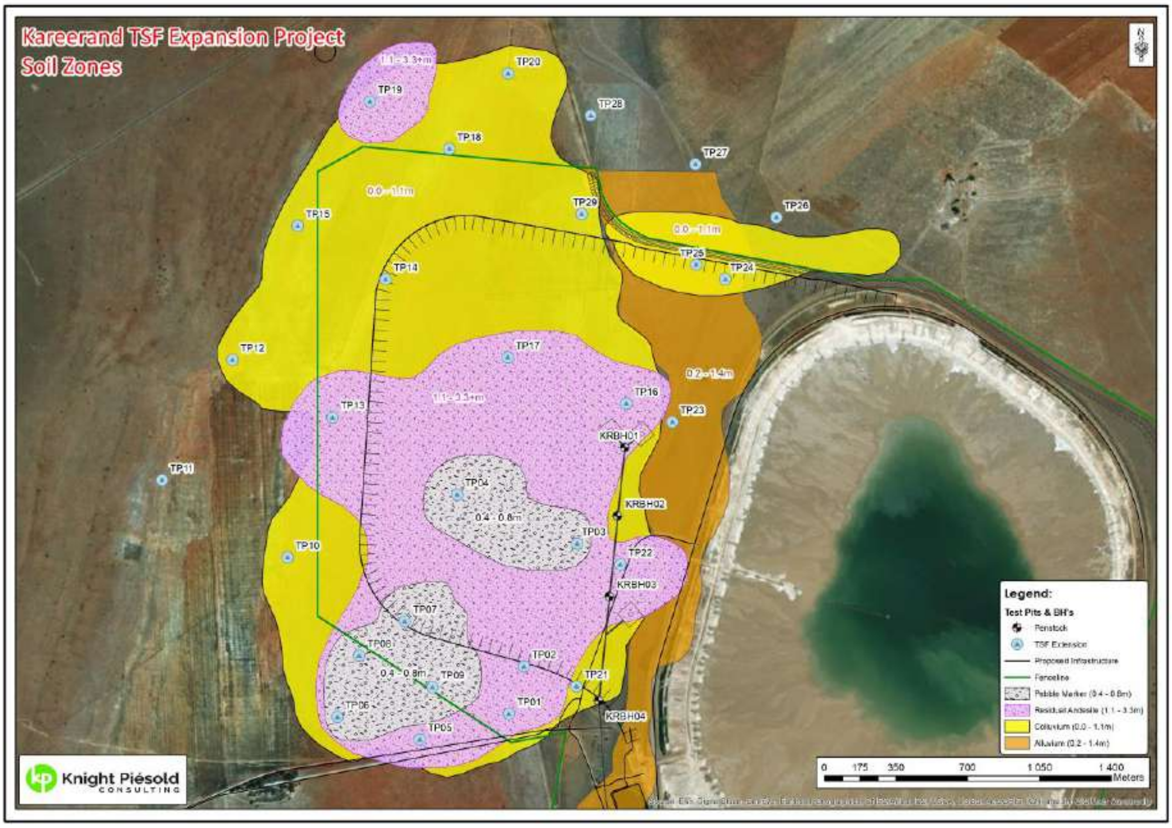


Figure 6.5 **Geological Mapping of the Proposed TSF Extension**

6.5.2 PROPOSED TSF EXTENSION AND RWD

i) The TSF extension footprint is mostly covered by colluvium to depths of between 0.5 m and 1 m and occasionally to 2 m.

j) The north-eastern part of the site is covered by alluvium to more than 3 m depths. (The areas along the drainage channel is covered by alluvium to depths of between 2.5 m and more than 3 m).

k) The transported soils are underlain by fine grained residual andesite and residual Shale to depths of between 2.5 m and more than 3.4 m. with bedrock at shallow depths.

l) Residual Shale and residual Dolerite occur below the transported soils to depths of between 2.2 m and 4 m on the southern east of the extension.

6.5.3 IN-SITU PERMEABILITY

Five (5) in-situ falling head permeability tests were conducted on the TSF extension footprint during the feasibility phase investigation. Three (3) tests were conducted on the residual andesite, one on the alluvium and one on the colluvium.

Table 6-2 Summary of In-situ Permeabilities Test Results

TP No.	Depth of Tested Layer (m)	In-situ Coefficient of Permeability (k = m/s)	Material Description
TP13	1.1 – 2.3	8.2 x 10^{-7}	Residual andesite
TP16	1.5 – 3.3	3.2 x 10^{-7}	Residual andesite
TP12	1.2 -1.9	3.8 x 10^{-7}	Residual andesite
TP16	0.3 – 1.4	4.8 x 10^{-8}	Alluvium
TP16	0.2 – 1.0	Highly permeable	Colluvium

The in-situ permeability tests conducted on the residual andesite yielded coefficient of permeability (k-values) of between 3 x10^{-7} m/s – 8 x10^{-7} m/s. This material has an average thickness between 0.7 – 1.8 m.

The alluvium measured a coefficient of permeability of 5×10^{-8} m/s which was less permeable than the residual andesite.

No permeability readings could be obtained in the colluvium due to the highly pervious nature of the material, resulting in a high seepage rate. This material can be used as wall building.

6.5.4 GROUND WATER

There was not ground water encountered on the test pits under the TSF extension footprint, however seepage ground water was encountered on the proposed return water dam footprint area which down stream the existing RWD.

6.5.5 PENSTOCK INTAKE STRUCTURE AND OUTFALL PIPELINE

The temporary penstock structures are positioned on the contact between the dolerite sill/dyke and the andesite / shale formations and hence the soil profiles are deeply weathered and extend with depth.

It is generally recommended for heavy loaded structures to be placed on bedrock. However, according to the boreholes the highly weathered very soft rock dolerite occurs at depths of between 4 m (BH03) and 8 m (BH02). Since the structure is only temporary the following foundation option is recommended:

a) Excavate the footprint positions to a depth of at least 2.5 m on dense or stiff residual dolerite.

b) Backfill the foundation with either imported rockfill or imported G5 quality material to create a raft type of foundation. The thickness and extent of the raft should be determined by a geotechnical engineer to accommodate the required loads of at least 300 kPa.

c) Backfilling by rockfill should comprise a large vibratory roller (>10T) to compact the material to the optimal density. The optimal density of the rockfill should be obtained by doing test runs on the material to determine the number of passes required for optimal compaction.

d) Backfilling by G5 quality material should include the placement of layers limited to 200 mm in thickness, compacted to at least 98 % of Mod AASHTO density at optimum moisture content.

6.6 CONSTRUCTIOIN MATERIAL

The topsoil will be stripped and the potential fill material in the basin (colluvium and nodular ferricrete) underlaying the topsoil will be used as fill material. The very low permeable clayey sand layer with a stiff consistency, residual andesite material will be use as the barrier material under the TSF extension footprint. It is recommended to remove the colluvium, pebble marker and nodular ferricrete for use of embankment fill material.

The alluvium has a medium to high potential expansiveness, and the residual andesite has low to medium potential expansiveness. The fine-grained soils can be obtained within the TSF extension area as well as the return water dam area by over excavating the foundations to reach bedrock. This material will be replaced with competent material under the starter wall.

6.7 GEOTECHNICAL CONCLUSIONS

The following conclusion were made:

d) The site is overlain by transported material, Colluvium and Alluvium. The colluvium is predominant on the site, while the alluvium is confined in the drainage layer next to the existing TSF. The Colluvium varies in depth while the alluvium is approximately 3 m and more.

e) The transported material is overlain by residual andesite and shale. This andesite has low permeability characteristic which can be used a compacted clay liner (CCL).

f) A soil/rock mattress will need to be done for the penstock intake and outfall pipe.

g) Material from the TSF basin and RWD excavations can be used to form starter wall embankments.

h) It is recommended that further investigation be done on the TSF extension footprint to ascertain the geotechnical parameters particularly the permeability and shear strength.

7.0 CAPACITY ASSESSMENT

7.1 EXISTING TAILINGS DAM

The maximum allowable rate of rise (RoR) for the existing tailings dam (cyclone operated) is 6 m/yr. The RoR for the projected tonnages of the MWS business plan (LoM) will breach the above rates of rise in the year 2020, if the current deposition rate is maintained beyond 2020. These high RoR have negative impacts to the development of the dam which are;

i. accessibility during development of the dam,
ii. not enough time for consolidation,
iii. high phreatic surface, thus high excess pore pressure.

This high RoR will lead to the overall instability of the TSF.

The capacity of the existing TSF till 2022 is illustrated in **Figure 7.2** below.

7.2 TAILINGS DAM EXTENTION

The tailings dam extension capacity assessment was done for the tonnage profile received for the MWS business plan 2019. A 3D capacity assessment has been undertaken to evaluate the capacity using overall outer slopes of 1V:6H. A 3D Model is shown in **Figure 7.1**

The stage capacity curves have been developed using areas in 1.0 m increments obtained in the 3D model and can be seen in **Figure 7.2.** These graphs show that the rate of rise above the starter wall will be 5.4 m/yr on the extension and will reduce on the existing facility to about 2 m/yr.

The capacity assessment for the extension and the existing TSF was based on the following aspects;

a) Production rate of (MWS) business plan - 2 471 000 tpm
b) Hydraulically placed in-situ dry density - 1.4 t/m^3
c) Current area of the existing TSF (elevation 1348mamsl) - 340 Ha
d) Area for the TSF extension - 320 Ha
e) Top area of existing TSF at closure - 85 Ha
f) Top area of extension TSF at closure - 169 Ha
g) Total additional volume of tailings (extension & existing) - 485.7 x 10^6 m^3
h) Height of tailings dam at closure - 122 m
i) Rate of rise – extension – over starter wall - 5.4 m/yr
j) Consolidation of the two facilities - N/A
k) Rate of rise at closure (existing & extension) - (1.8 & 4.1 m/yr)
l) Overall side slope for existing & extension 1v:6

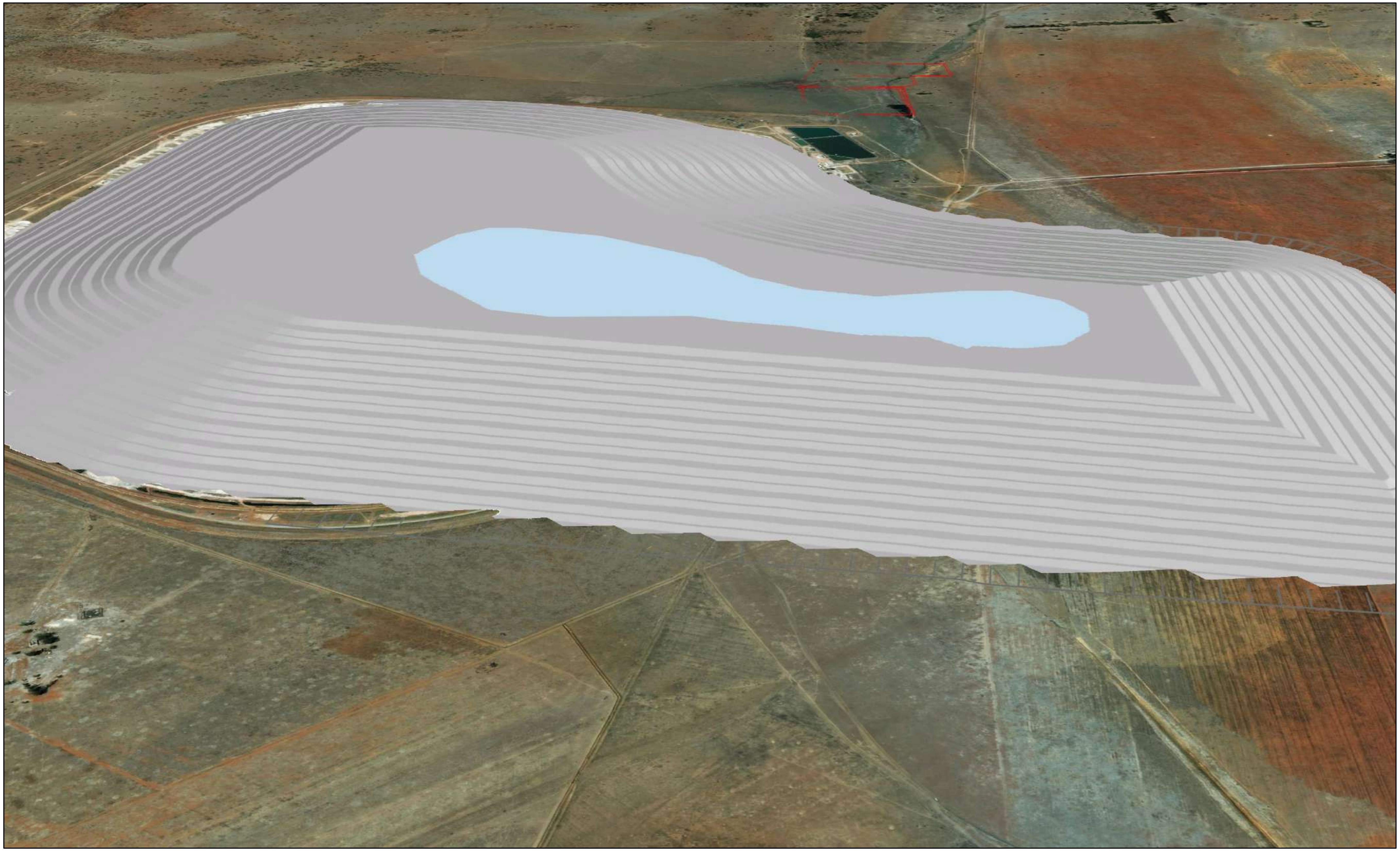


Figure 7.1 3D Capacity Model

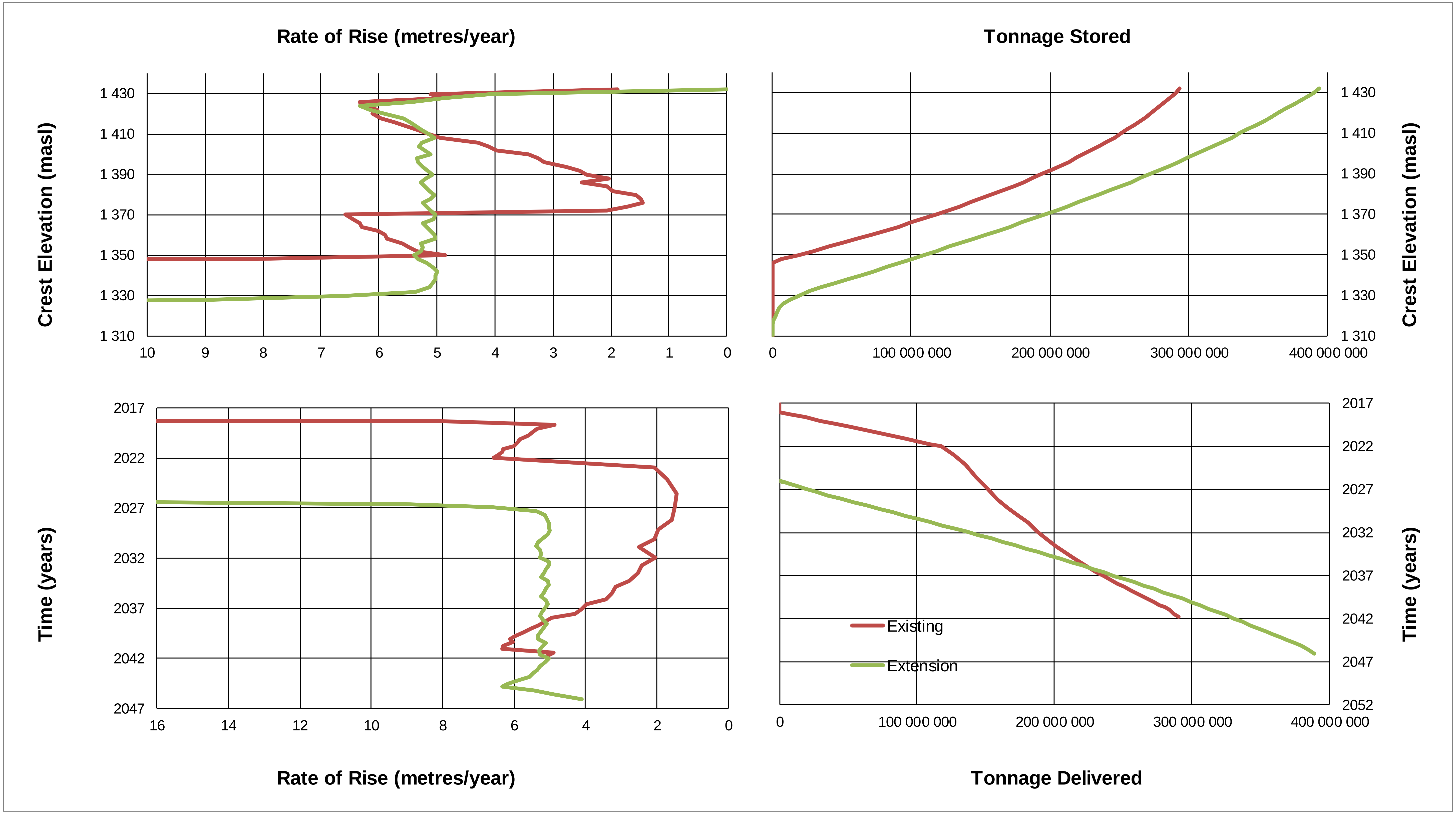


Figure 7.2 Stage Capacity Curves for Extension and Existing TSF

7.3 TONNAGE SPLITS

The tonnages will be split between the two facility as shown on in **Table 7-1** below. It should be noted most of the tonnage should be deposited on the new extension to ensure that the two facilities can converge at closure.

Table 7-1: Tonnage Splits

Year of operation of Extension			Percentage Split	
	Actual years	No. of years	Existing TSF	TSF Extension
0 - 1	2022 - 2023	1	30	70
1 - 6	2023 - 2027	5	20	80
6 - 8	2028 - 2029	2	25	75
8 - 9	2030 - 2030	1	30	70
9 - 10	2031 - 2031	1	25	75
10 - 12	2032 - 2033	2	30	70
12 - 14	2034 - 2035	2	35	65
14 - 16	2036 - 2037	2	40	60
16 - 19	2038 - 2041	3	45	55
19 - 20	2042	1	40	60

8.0 SLURRY DEPOSITION STRATEGY

Tailings will be deposited onto the extension of tailings dam by means of a cyclone method of deposition. The TSFs' will be operated as two independent tailings dams. The variance will be the deposition tonnages at a given time to ensure that a maximum rate of rise is not breached in either of the facilities. The deposition splits will be part of the operations and as illustrated in **Table 7-1** in Section 7 above. The aim will be to consolidate the two dams at closure and operate a single central pool. The three additional tailings delivery pipeline are located around the perimeter of the tailings dam between the access road and the solution trench with cyclone off-takes at station 1, 2, 3, 4, 5, & 6 respective from the three delivery pipelines. See drawings 301-00204/200 in **Appendix F**.

9.0 OUTER WALL DEVELOPMENT

9.1 BARRIER DESIGN

9.1.1 METHOD OF ANALYSIS

The barrier system design was based on the performance approach design such that the ultimate design performs similar to the minimum legislated requirements are met. In simple terms, the aim was to compare the seepage rate through different material combinations. This was achieved analytically by using (Darcy's Law) to estimate the seepage through the tailings and the barrier system. The method used is described in the book: Planning, Design, and Analysis of Tailings Dams (1990) by Steven G. Vick. A few barrier systems were compared to the performance of the Class C barrier system as legislated. For the Extension of the TSF, there were seven different barrier system designs that were investigated,

a) Case 1: The tailings are placed directly on the in-situ dolerite material (this is a zone within the footprint),

b) Case 2: Tailings are placed directly on the in-situ andesite material (this zone is the predominant material within the footprint),

c) Case 3: The tailings are placed on top of a 300 mm compacted clay layer plus a 1.2 m thick in-situ clay (andesite).

d) Case 3a: The tailings are placed on a 1.5 mm HDPE geomembrane, overlaying a 300 mm ripped and recompacted clay layer and 1.2 m in-situ clay,

e) Case 3b: The tailings are placed on 1.5 mm HDPE geomembrane, overlaying a 300 mm compacted clay layer and in-situ dolerite,

f) Case 4: The tailings are placed on top of a 300 mm compacted clay layer and 1.2 m in-situ dolerite,

g) Case 5: The tailings are placed on 300 – 500 mm thick layer of tailings mixed with bentonite, on top of a 1.5 mm HDPE geomembrane, plus the 200 mm thick ripped and compacted in-situ material together with 1.2 m in-situ clay below.

h) Case 6: The tailings are placed on top of a 1.5 mm HDPE geomembrane, a geosynthetic clay layer (GCL), ripped and recompacted in-situ clay to a depth of 300 mm and 1.2 m deep in-situ clay.

Table 9.1 below shows the permeabilities used for the different materials. The performance of the barrier system is a combination of the performance of different materials as per the cases evaluated above.

Table 9-1: Permeability Values Used in the Model

Material	Permeability, k	
	(m/s)	(m/yr)
Tailings (overflow)	6.60 x 10^{-8}	2.08
Compacted Clay	1.00 x 10^{-9}	0.03
Tailings/Bentonite	1.00 x 10^{-9}	0.03
HDPE Liner (1.5mm)	1.00 x 10^{-11}	0.0003
Geosynthetic Clay Liner	1.00 x 10^{-11}	0.0003
Rip & Recompacted Clay (CCL)	1.00 x 10^{-9}	0.03
In-situ-Clay Area (Andesite)	3.00 x 10^{-8}	0.94
Dolerite Area	3.00 x 10^{-7}	9.4

9.1.2 RESULTS OF THE ANALYSIS

The materials above were combined in different combinations to evaluate the seepage performance of the system. The results are shown in **Figure 9.1** below.

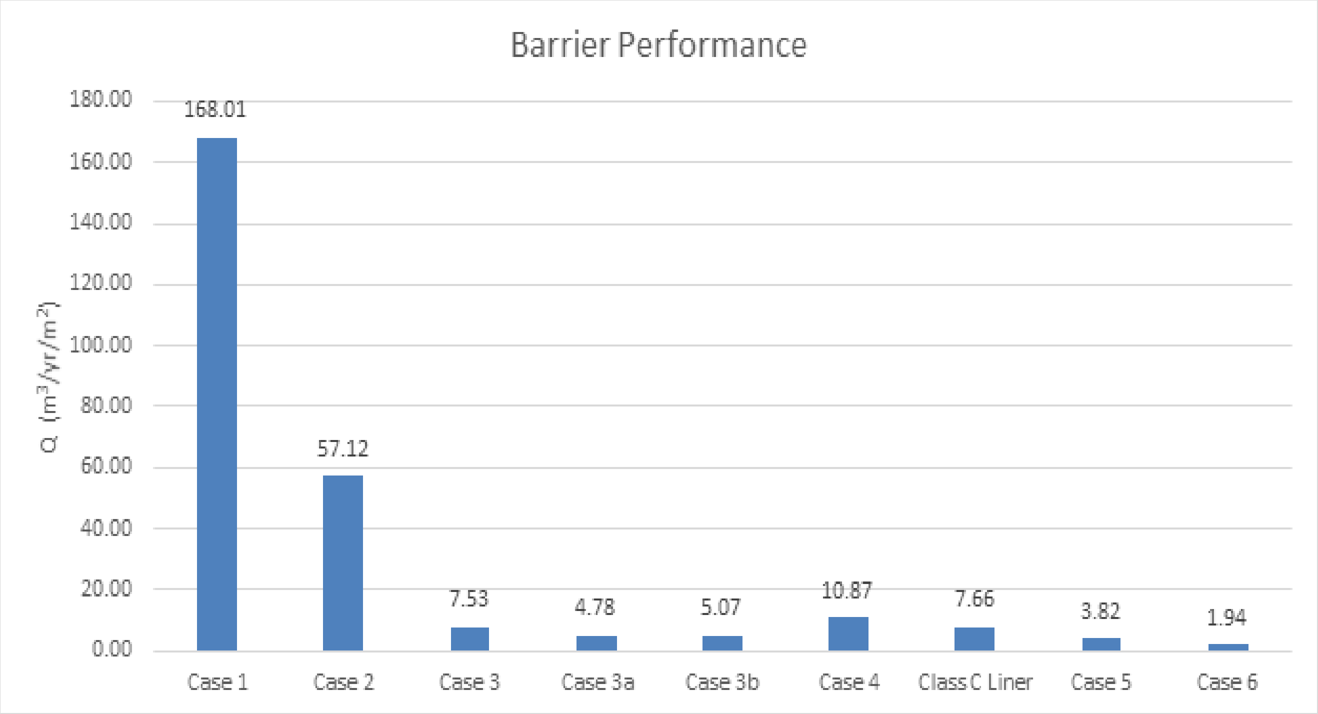


Figure 9.1 Different Barrier System Performances

The above analysis shows that the best performing barrier system is Case 3, 3a, 3b & 5. It should be noted that Case 3a is assuming a consistent 1.2m of residual in-situ clay (Andesite). The proposed Extension site has different material zones as illustrated in **Figure 9.1** below. To simulate the existing condition on the proposed site, a Case 3 & 4 were grouped. The grouping of Case 3 & 4 can therefore be concluded as a representative of the existing condition on site. This grouping does not meet the required barrier performance of Class C Liner barrier system.

a) The most cost effective and practical barrier system is **Case 3a** which is **"***the tailings are placed on a 1.5 mm HDPE geomembrane, overlaying a 300 mm ripped and recompacted clay layer and 1.2 m in-situ clay"*. This will be developed in the detail design for construction if approved by AGA.

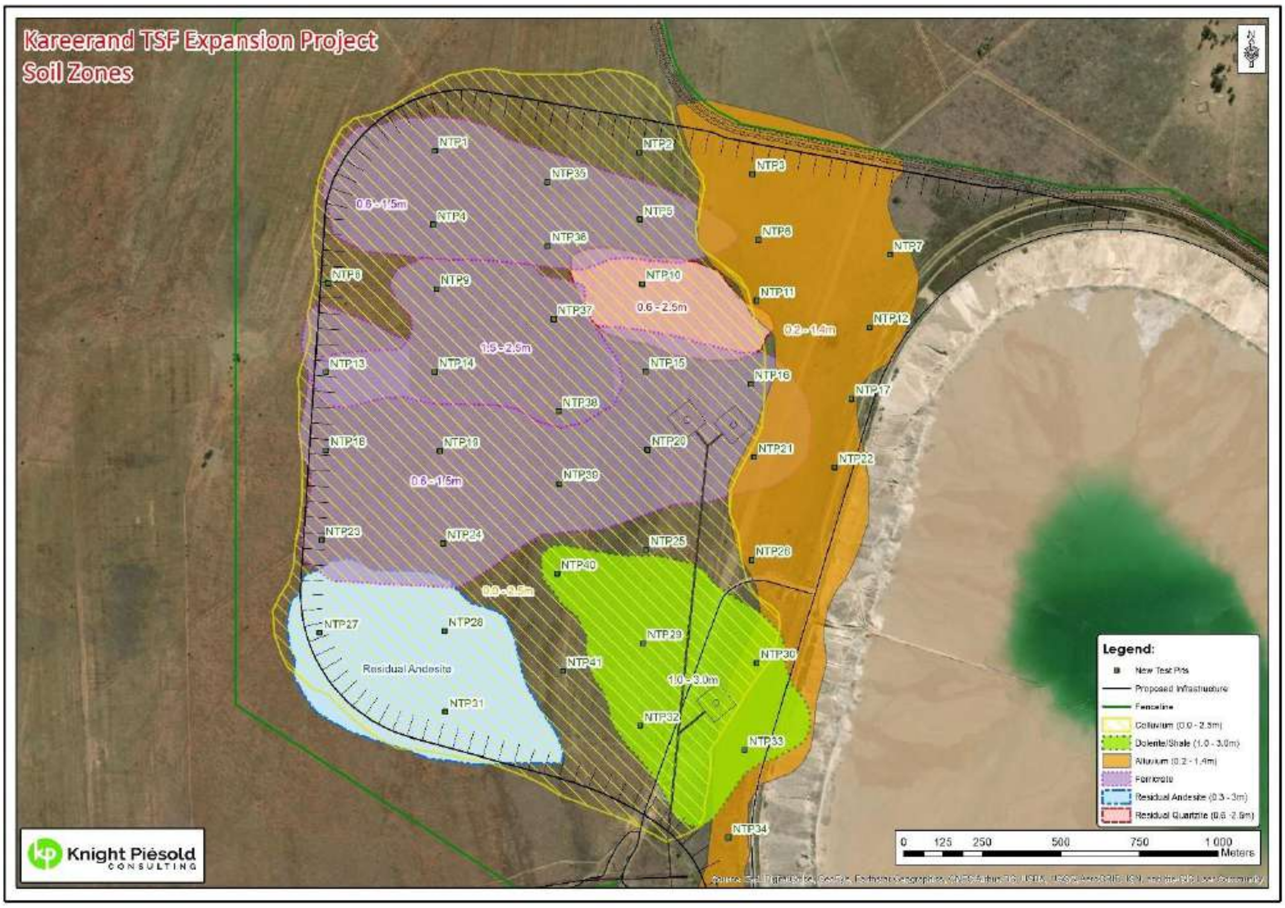


Figure 9.2 Material Zone on the Proposed Extension

9.2 SEEPAGE MODEL

9.2.1 DRAINAGE PIPES

The limit equilibrium slope stability software package, Rocscience Slide Version 7, groundwater modelling was used. A seepage analysis was used to determine the size of the toe drains and the discharge volume from the TSF to design the solution trench. The assessment was carried out for a single pipe and double pipe toe drains. The seepage volume results are in **Table 9-2** and the output file from the seepage assessment are in **Appendix D**.

Table 9-2: Seepage assessment results

Scenario	Seepage Volume ($m^3/s/m$)
Single pipe	1.00×10^{-8}
Double pipe	5.00×10^{-8}

The toe drain capacity was calculated to assess the FoS for the drain.

$$\text{FoS (drain)} = \frac{\text{Allowable volume (pipe)}}{\text{Volume discharged (dam)}}$$

Volume discharged (Q_d) = q x w

Allowable volume (Q_{all}) = $(1/n)*(A^{5/3})/(P^{2/3})*\ (S_o^{1/2})$

The seepage volume used in the design was taken as one order of magnitude more to account for in-situ conditions. The seepage discharge from the TSF is $7.7 \times 10^{-8} m^3/s/m$. The factor of safety for the outlet pipe is as follows,

Q_p (pipe) = 10 ℓ/s (allowable)

$Q_d = 7.70 \times 10^{-8}\ m^3/s/m \times 100m = 7.7 \times 10^{-6} m^3/s = 0.0077$ ℓ/s,

$FoS = Q_{all} / Q_d = 129$

Where:

Q_{all} - allowable capacity of designed channel using manning’s equation.

Q_d - expected volume to be discharged to the solution trench.

n - pipe roughness coefficient

A - cross sectional area

P - the wetted perimeter

S_o - the slope of the pipe

W - the discharge width of the tailing’s material (spacing).

q - the discharge volume from the seepage analysis.

As rule of thumb, the FoS for the drain should be 10 or greater. The factor of safety for the outlet pipe is 129 and this is greater than 10, therefore this shows that the toe drains and the pipes will convey the water safely.

9.2.2 SEEPAGE ASSESSMENT

A seepage model was developed where the site monitoring data was used and compared with predicted phreatic surface development within the TSF as the pool location varies. The outcomes of the phreatic surface with respect to the pool movement are shown in **Table 9-3**. The outcome of the model is shown below, and the results were used in the slope stability for TSF final height. The phreatic levels are shown in the slope stability output files in **Appendix D.**

Table 9-3 Phreatic Level with Respect to Pool Location

Pool Location from Outer Wall	Top of TSF @ (m)	Mid Way of the Slope (m)
100	18	14
250	28	38
400	35	48
Piezocone testing (on existing facility)	20 - 30	6.8 -16.8

9.3 STABILITY ASSESSMENT

9.3.1 SEISMIC ASSESSMENT

The services of Prof. A Kijko of University of Pretoria Natural Hazard Centre were acquired to under take a deterministic seismic hazard analysis (DSHA) in November 2017 for the Kareerand TSF complex, refer to the detail report in **Appendix C**. The analysis was based on seismic events (earthquake) of magnitude greater than Mw ≥ 3.0 located within a radius of 50 km of Kareerand TSF.

The DSHA for the Kareerand TSF comprised of the following extract from DSHA report:

a) *"Compilation of a seismic events catalogue and selection of seismic event within a 50 km radius of the dam.*

b) *Identification of seismic event capable of producing significant ground motion (peak ground acceleration) at the site of the dam.*

c) *Assessment of the annual probability of exceeding the specified value of seismic event magnitude and its return period. At the same time the analysis provides assessment of the worst-case scenario, i.e. occurrence of seismic event with the maximum possible magnitude in vicinity of the dam.*

d) *A selection of the controlling seismic event, i.e. the event that is expected to generate the strongest level of shaking, in our case, expressed in terms of PGA. The controlling event is described in terms of its magnitude and distance from the dam site. In this report the controlling event is determined as event of MW magnitude 5.63 ± 0.11 located at the epicenter of 9th March 2005 Stilfontein event. The MW = 5.63 ± 0.11 is considered as maximum possible, mine related seismic event magnitude, characteristic to the area.*

e) *Selection of most adequate Modified Mercalli intensity (MMI) prediction equation (IPE). "*

The predicted largest horizontal peak ground acceleration for Kareerand is **0.152 ± 0.098**

9.3.1.1 SEISMIC COEFFICIENT FOR DESIGN

The design value adopted for Kareerand was 0.152g ± 0.098.

Seismic coefficient is defined as the proportion of gravity which is applied as a horizontal load in a pseudo-static stability analysis. Seed (1979) suggested that the seismic coefficient should be in the range k = 0.1 to 0.15 for increasing seismic hazard areas for Richter scale 6 and 8.5 respectively and the factor of safety (FoS) should be greater than 1.15. (Melo & Sharma, 2004).

Vick (1990) suggested that k values of the order of 2/3*PGA could be applicable under certain severe circumstances for un-compacted TSFs.

A seismic loading coefficient of 0.167g and a limit equilibrium FoS of 1.15 for pseudo-static seismic design criteria was used. The horizontal seismic factor for slope stability design used was **0.167**.

It is recommended that AGA installs a seismograph as the site to measure the ground acceleration during the life of the facility. This date can be used during the development of the dump to assess or review the seismic loading which can lead to revision of the outer slopes.

9.3.2 GENERAL

A stability assessment is the computation of a factor of safety (FOS). The factor of safety in static equilibrium of a soil mass is the ratio of the resisting forces (shear resistance) to the driving forces (weight of the soil mass over the critical failure surface and pore water pressures). In the tailings industry, a recommended long-term factor of safety for tailings facilities is 1.5.

The design stability of the TSF and RWD was determined using critical sections. The critical sections at the highest point of the TSF, and a typical section is shown in Error! Reference source not found. d am development. The starter wall was designed to contain the slurry during the early development of the dump. The highest section, which is located on the deep alluvium, has a boxcut of 1.0 – 1.5 m with side slopes of 1v:2h and a 10 m wide crest.

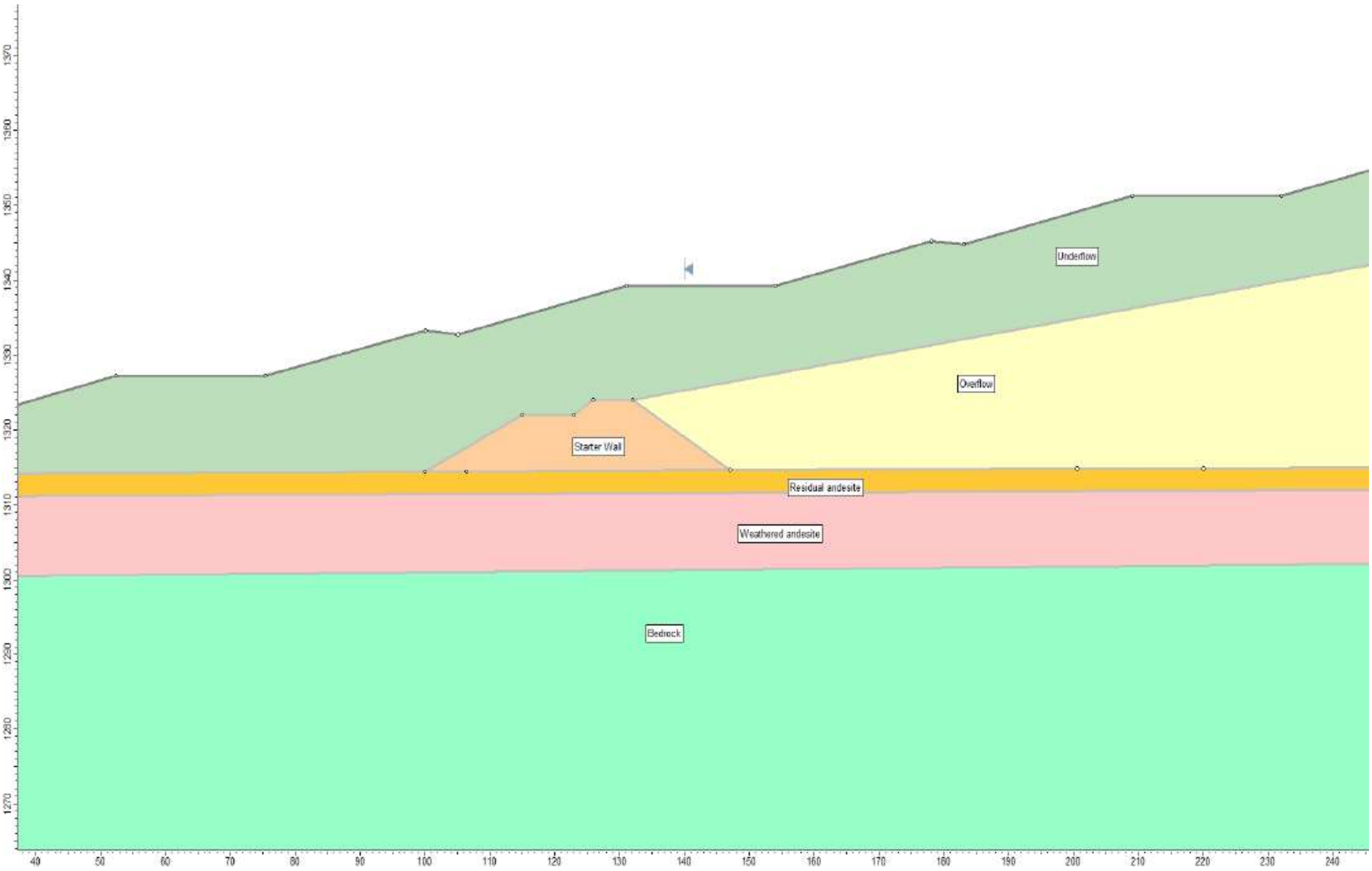


Figure 9.3 Typical section for Stability Analysis

9.3.3 METHOD OF ANALYSIS

The limit equilibrium slope stability software package, Rocscience Slide Version 7 was used to determine the Factor of Safety (FoS) against slope failure for pseudo-static and static conditions for the TSF downstream and RWD upstream and downstream slopes. The slopes of the dam walls were analysed for different wall material strength. The average strength parameter (i.e. friction angle) used for the underflow and overflow were 29 ° and 25 ° respectively.

The applicable analyses were carried out for each of the scenarios stated above utilising the material strength parameters summarised in **The** initial stability analyses were done to check the suitability of raising the existing TSF by an additional 40 metres with and without a liner. The top surface of the existing facility will have a bentonite/tailings layer to reduce the water flow from the additional tailings that will be placed above it. The Extension was checked for stability as it will be placed on a lining system.

A minimum FoS of 1.5 is required for static conditions (NEM – Waste Act, 2008 Reg 632 of 2015; Chamber of Mines Guidelines, 1996) and 1.1 is required for seismic conditions (ANCOLD, 2012). The results are summarized in **Table 3.**

Table 9-4.

The non-circular path-search failure surface was used to generate 20 000 slip surfaces uniformly distributed along the slope section.

The slope stability was done using the following methods of analyses:

a) Bishop simplified

b) Janbu simplified

c) Janbu corrected

The initial stability analyses were done to check the suitability of raising the existing TSF by an additional 40 metres with and without a liner. The top surface of the existing facility will have a bentonite/tailings layer to reduce the water flow from the additional tailings that will be placed above it. The Extension was checked for stability as it will be placed on a lining system.

A minimum FoS of 1.5 is required for static conditions (NEM – Waste Act, 2008 Reg 632 of 2015; Chamber of Mines Guidelines, 1996) and 1.1 is required for seismic conditions (ANCOLD, 2012). The results are summarized in **Table 3.**

Table 9-4: Summary of Material Strength Parameters

Method	Unit Weight (kN/m3)	Cohesion (kPa)	Friction Angle (degrees)	
Overflow	14	0	25(±1)	1 x 10^{-7}
Underflow	14.7	0	29(±1)	5 x 10^{-7}
Starter wall	18	0	30(±1)	1 x 10^{-7}
Alluvium (Transported material)	18	0	28(±2)	1 x 10^{-9}
Andesite	17	0	15	1 x 10^{-9}
Residual Diabase	22	0	30	1 x 10^{-7}
Reworked Residual andesite	19	0	25	1 x 10^{-9}
Barrier system	12	14	0	1 x 10^{-11}
Hard rock	22	50	35	1 x 10^{-8}

9.3.4 STATIC ASSESSMENT RESULTS

The various Factor of Safety (FoS) values for the side slopes of 1:6 were computed and the results obtained for the static assessment are shown in **Table 9-5**, the phreatic used in the assessment was developed from the seepage model with the pool distance being 400 m away from the outer wall. The FoS values are well above the required 1.5 value. The output files for the slope stability are **Appendix C**.

Table 9-5: Static Assessment Results at Final TSF Height

Method	FOS	
Slope	**1:6**	**1:5**
Bishop Simplified	2.3	2.2
Janbu Simplified	2.2	2.1
Janbu Corrected	2.3	2.2

9.3.5 SEISMIC ASSESMENT RESULTS

The various Factor of Safety (FoS) values for each condition were computed and the results obtained for the Seismic assessment are shown in **Table 9-6,** the phreatic surface used in the assessment was with a pool distance of 400 m from the outer wall.

The FoS values are above the required 1.1 for a circular slip failure. On analysing the range of identified seismic accelerations, was found that the FoS value improved to 1.1 with a decreased acceleration and a lowered phreatic surface as was shown during the pre-feasibility stage. This further indicated that during operation, pool control and general good practice is of the utmost importance.

Table 9-6: Seismic Assessment Results at Final TSF Height

Slope	1: 6	1:5
Method	FOS (Seismic acceleration 0.166g)	FOS (Seismic acceleration 0.166g)
Bishop Simplified	1.41	1.04
Morgenstern-price (over barrier system)	1.10	1.00
Janbu Corrected	1.41	1.04

9.4 RISK ASSESSMENT

9.4.1 GENERAL

The risk of failure of the TSF extension was assessed using a qualitative risk analysis model from AGA. It is however, recommended that a probabilistic risk analysis be done to determine the sensitive operational aspects of the facility. The risk assessment identifies the areas to which the risk of failure is most sensitive, providing a list of areas which should receive more attention during design, operation and/or closure. The following were identified as the primary risk:

a) Overtopping
b) Slope failure, and
c) Piping failure

The overall probability of failure based on the secondary or tertiary fault should be determined and compared to acceptable probability of failure of the facilities.

9.4.2 ANGLOGOLD ASHANTI STD

AGA group risk management process aims to ensure that all material risks are identified and managed and the decisions can be made with confidence. The AGA risk process comprises of identifying and analysing risks that could potentially have an impact on the operation of the TSF achieving its objectives. KP has prepared a risk management plan for the feasibility design stage of the Kareerand TSF and the overview is shown in **Figure 9.4.**

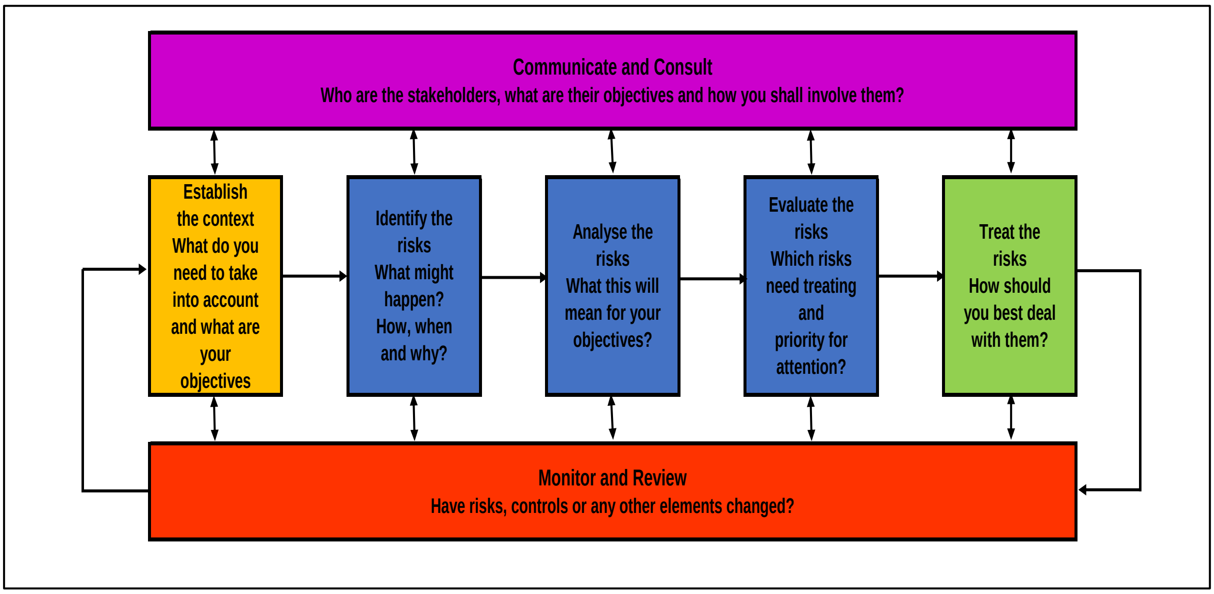


Figure 9.4 Risk Management Process as Outlined in ISO31000:2009

The role of the risk management process developed by Knight Piésold Consulting is to,

a) Set the framework by:

b) Identifying threats,

c) Minimum required actions per post-treatment risk classification index;

d) Identifying external and internal factors that could have an effect on Kareerand project achieving its project objectives,

e) Identifying significant risk exposures (uncertainties) that they believe Kareerand project are exposed to considering the key elements identified;

f) Listing the high-level controls to manage these risk issues;

g) Assigning ratings based on Anglo Gold Ashanti's risk control effectiveness guide, consequence and likelihood criteria; and

h) Identifying those individuals who are responsible for the specific risks and controls as identified.

The uncertainties identified comprised a good spread of risks covering both internally and externally focused risks. The risks identified represent all currently (at the time of the assessment) known uncertainties that could affect the Kareerand TSF project from achieving its project objectives.

The risk assessment process identified a total of 30 project level risks that could have a material impact on the project objectives, considering all aspects of the proposed development. The risk assessment is attached in **Appendix H**.

10.0 HYDROLOGICAL ASSESSMENT

The Water Balance is based on the production schedule, stage capacity curves and layout of the TSF Expansion. The balance model was done in excel as provided. The detail water balance report is presented in **Appendix E**.

10.1 CLIMATIC INFORMATION

The Kareerand TSF of the AngloGold Vaal River Operation is situated adjacent to the south of the Orkney Potchefstroom road (R502), in the North-West Province. The climate is classified as BSk by the Köppen-Geiger system. Cold semi-arid climates (type "BSk") tend to be located in temperate zones. Typically found in continental interiors some distance from large bodies of water. Cold semi-arid climates tend to have dry winters and wetter summers. The Kareerand TSF is in the C24B quaternary catchment and the Middle Vaal Water Management Area (WMA).

10.2 RAINFALL AND EVAPORATION

A long record of rainfall is required to reliably assess statistical characteristics of the site's local rainfall. The rainfall depths were extracted from the closest weather station to the study site, obtained from the WR2012 database (details given in **Table 10-1**) (WRC, 2012). The selection of the Bushy Bend Station (436747) is since this is the closest station to the study area with a reliable record.

Table 10-1: Details for rainfall Bushy Bend Station (436747)

Name of rainfall station	Rainfall station number	Distance (km)	Latitude (°)(')	Longitude (°)(')	Record (Years)	MAP(mm)
Bushy Bend	436747	7.0	26° 57'	26° 55'	55	592

The Mean Annual Precipitation (MAP) in the vicinity of the site was calculated to be 592 mm, based on the Bushy Bend Station dataset; the average monthly rainfall depths are shown in **Figure 10.1** below. About 83% of the annual rainfall falls in summer (October to March), with the maximum amount of precipitation falling in January.

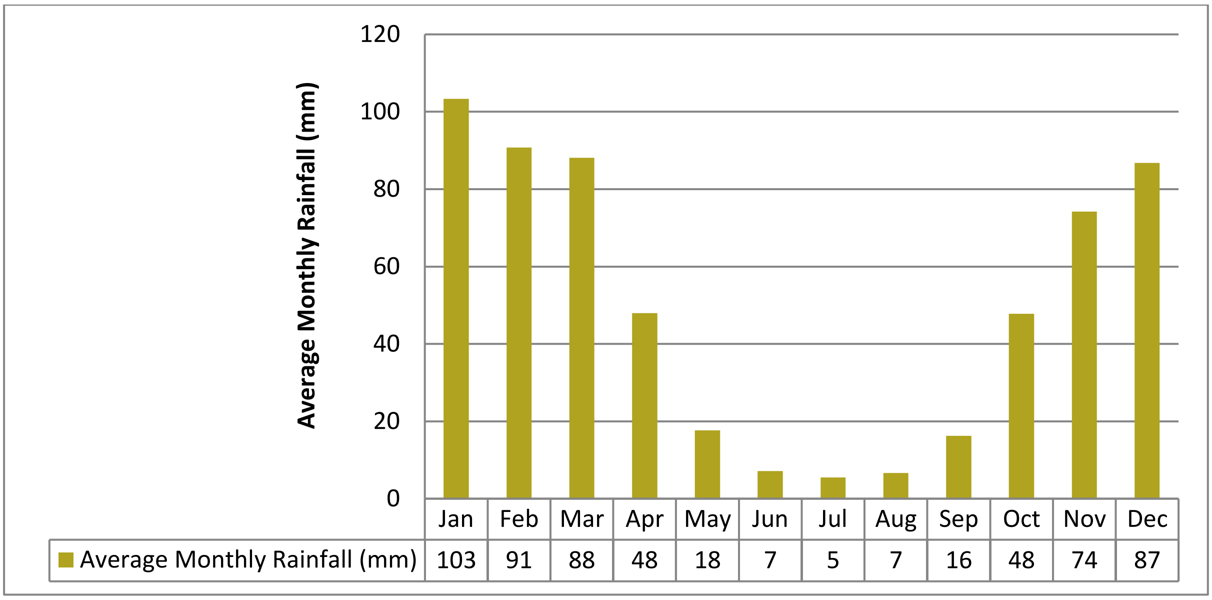


Figure 10.1 Average Monthly Rainfall

TR102 report on South African Storm Rainfall (Department of Environment Affairs, 1983) was also reviewed to obtain the storm rainfall depths for the recurrence intervals. The data is shown in **Table 10-2** for the Bushy Bend Station (436747); the data was obtained statistically using the 55 years of data. The maximum observed rainfall was obtained from Figure 3.22 of the SANDRAL Drainage Manual, which is a function of the veld type region. The maximum observed rainfall was found to be approximately 216 mm for a 7-day duration event.

Table 10-2: Storm rainfall depths (mm) for the various recurrence intervals

			Recurrence Interval (Years)						
Duration	Minimum Annual Maximum Recorded (mm)	Maximum Annual Maximum Recorded (mm)	2	5	10	20	50	100	200
1 Day	22	120	55	78	96	117	147	173	202
2 Day	26	172	69	100	124	150	189	223	260
3 Day	28	175	77	110	137	165	208	244	284
7 Day	49	216	95	133	162	192	236	272	311

10.3 WATER MANAGEMENT AND FREEBOARD REQUIRMETNS

10.3.1 GENERAL

The management of water at the TSF is an important aspect in calculating the sizes of the decant system (penstocks) and the necessary return water dam volume. The RSA legislation states that clean storm water run-off must be diverted away from the TSF and that the dirty water emanating from the TSF and plant area must be contained and reused.

10.3.2 FREEBOARD REQUIREMENTS

The TSF and RWD freeboards are determined against Regulation 704 of the Water Act (Act 36 of 1998) of South Africa requires a freeboard of the 1:50 year storm plus 800mm above the mean operating level of the pool.

10.4 WATER BALANCE

A monthly water balance was modelled for different climate seasons to outline the changes and impacts of the available water resource. Various input parameters, amongst others, including the meteorological data applicable to the site, the topography of the TSF extension and RWD sites, tailings production rate, the tailings material properties and the physical dimensions applicable to the TSF and the RWD were used for the water balance. The water balance input parameters are presented in in **Table 10.3** below.

Table 10-3: Monthly Water Balance Information

Descriptions	Value
Footprint area of the TSF	5 600 000 m^2
Approximate Area of Pool	28%
Approximate Area of Wet Beach	30%
Approximate Area of Dry Beach	42%
Slurry Density	1.35 t/m^3
Particle SG	2.7
Tailings average monthly tonnage	2 471 000 t/ month
Seepage from the TSF	1 x 10^{-8} m/s
Evapotranspiration factor from Wet Beach	0.8
Evapotranspiration factor from Dry Beach	0.4

The following should be noted:

e) Approximately 64% and 60% of the water deposited onto the TSF is returned to the plant between 2018 – 2021 and 2022 – 2014 respectively.

f) On average about 40 000 – 55 000 m^3/d of make –up water will be required. The variance will depend on the wet and dry seasons respectively.

g) The estimated losses are as follows:

  - interstitial storage 31%,
  - evaporation 2.8 - 17% and
  - seepage 6.6 - 19%.

10.5 RWD SIZING

The RWD will be constructed downstream of the TSF and existing RWD complex. The RWD has been designed according to current South African legislation. The required capacity of the RWD has been determined based on the requirement to contain the 1:100-year storm event from the TSF surface area and the TSF side wall run-off.

The minimum required storage for the RWD has been determined and is presented in Table 10-4.

Table 10-4: Storage Requirements for the RWD (1:100yr storm)

Component	Volumes (m^3)
1:100-year Rainfall directly onto the RWD	147 608
1:100-year TSF side wall runoff to Buffer dam	121 375 – 157 519 (2022 - 2030)
1:100-year TSF side wall runoff to RWD	147 066 – 191 292 (2022 - 2030)
1:100-year TSF side wall runoff – Total	268 441 – 348 811 (2022 - 2030)
1:100-year Rainfall directly on the TSF Extension	429 399
1:100-year Rainfall directly on the TSF Existing	421 958
Average Max Monthly storage	-
Total RWD Storage (minimum)	820 000

10.5.1 SPILLWAY DESIGN FOR RWD

A trapezoidal spillway with 1:1.5 side slopes was sized to cater for the 1:100-year storm event with a 1 000 mm freeboard before the wall crest is overtopped.

10.6 STORMWATER AND STREAM DIVERSIONS

10.6.1 CATCHMENT AREA

The catchment was delineated based on 5 m contours. The delineated catchment is shown in **Figure 10.1** below**Error! Reference source not found.**. All assumed hydrological parameters are summarised in **Table 10-5.**

Table 10-5: Assumed hydrological parameters

Parameter	Value at Downstream End
Size of catchment (km^2)	19.16 (85% Rural, 15% Urban)
Longest water course length (km)	7.715
Length to catchment centroid along longest river course (km)	4
Mean Annual Rainfall (mm)	592
Average river course slope: (10-85 Method) (%)	0.7
SDF Basin No	7
Veld Type Distribution (HRU 1/72)	5

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 10.2 Catchment Area for Stormwater Diversion Channel

10.6.2 METHODOLOGY

To develop a model for a peak runoff input, five (5) methods were used to determine the design flood peaks for the delineated catchment based on their applicability to the catchment area. These methods are the Alternative Rational Method, SCS-SA Method, Standard Design Flood (SDF) Method, Empirical Method and the Probable Maximum Flood (PMF) Method.

The rainfall depths with durations corresponding to the Time of Concentration (Tc) for any sub catchment were used to calculate peak flows for the catchment. The underlying assumption is that the largest possible peak flow is obtained when the storm rainfall event has duration equal to the time required for the whole catchment to contribute runoff at the outlet.

10.6.3 FLOOD PEACK RESULTS

Peak flood flows for the 1 in 2 year, 1 in 5 year, 1 in 10 year, 1 in 20 year, 1 in 50 year, and the 1 in 100-year recurrence interval storm events and the probable maximum flood were estimated for the delineated catchment using the abovementioned methods. Calculations were based on current conditions on site.

The estimated peak flows are presented in **Table 10-6** for the 1 in 2 year, 1 in 5 year, 1 in 10 year, 1 in 20 year, 1 in 50 year, 1 in 100-year recurrence intervals and the probable maximum flood. The SDF method was selected for use in the channel sizing analysis. The PMF was used to determine the hydraulic efficiency of the channel.

Table 10-6: Summary of the peak flows (in m³/s) estimated for the study

Flood Calculation Method	Peak flows (m³/s)					
	Return Period (years)					
	2	**5**	**10**	**20**	**50**	**100**
Alternative Rational	20	35	48	61	79	95
SCS-SA	37	-	58	80	120	150
Empirical	N/A	N/A	41	48	65	84
Standard Design Flood	10	35	59	85	125	**158**
PMF	501					
Selected Peak Flow(s)	**158**					

The Utility Programs for Drainage (UPD) software was used to perform the hydraulic design and **Table 10-7** shows the summary of the hydraulic design of the channel.

Table 10-7: Summary of the peak flows (in m³/s) estimated for the study

Parameter	Value
Flood Calculation Method	SDF1:100
Flow rate (m3/s), Q	158
Flow area (m2), A	57.83
Wetted perimeter (m), P	27.87
Hydraulic radius (m), R	2.08
Top width (m), B	26.64
Critical depth (m), Sc	2.94
Critical slope (m/m), Sc	0.0106
Average velocity (m/s), v	2.70
Velocity head (m), Hv	0.37
Specific head (m), Es	4.15
Froude number (Fr)	0.58
Flow type/Flow regime	Subcritical
Normal depth (m), Yn	3.77

11.0 TSF FEATURES

Please refer to **Appendix F** of this report for the feasibility design drawings. The layout of the dam complex can be seen in Drawings 301-00204/13-003 and relevant features are described below:

11.1 FENCING

A 2.4m high game fence, same as the existing fence, will be installed around the perimeter of the TSF extension with appropriate safety signs. Signage will be positioned at strategic locations.

11.2 ACCESS ROAD

A 8m wide gravel road will be constructed around the perimeter of the TSF, RWD and pump stations. Access onto the tailings dam initially is provided by means of access ramps. The access ramps have been placed such that entry of delivery pipelines onto the dam is near an access ramp. In addition, the access ramps should be placed close to valve stations.

11.3 TOPSOIL BUND WALL

A top soil bund wall will be constructed around the TSF next to the access road. This will have a crest width of 8 m, and average height of 2 m. On the northern side the topsoil bund wall will also be used as an access road.

11.4 STORM-WATER DIVERSION CHANNEL

An unlined diversion trench will be constructed on the northern side of the TSF to divert clean storm-water run-off. The un-lined storm water channel will be trapezoidal with side slopes of 1v:3h and base width varying from 4 to 9m. The diversion is designed to accommodate the 1:200 year 24-hour storm event.

11.5 DELIVERY PIPELINE

Three (3) 500 mm diameter tailings delivery steel pipes (DN500-4000/3 flanges) will be laid around the toe of the facility for delivering slurry to the three sections of the TSF viz, the northern, western and southern side of the TSF extension.

11.6 SOLUTION TRENCH

A solution trench will be constructed around the northern, western and southern side of the TSF. This will convey seepage water from the outlet drains to the return water dam and seepage sumps. The solution trench will be a trapezoidal with side slopes of 1v:1.5h and bottom width of 1 m. The solution trench will be lined with 100 mm thick mesh reinforced concrete.

11.7 SEEPAGE COLLECTOR SUMP

A seepage collector sump will be constructed on the northern side of the TSF. The purpose of the sump is to collect seepage water from the solution trench which will be pumped back north western corner.

11.8 CATCHMENT PADDOCKS

These will be constructed around the perimeter of the facility, at the final outer wall toe location. The paddock dimensions are 50 m long x 20 m wide. These are designed to contain run-off from a 1:50 yr storm event on the paddocks and the outer wall of the dam. The paddock outer and cross walls will be constructed from material from the solution trench excavations, and material stripped in the paddock basins and will be nominally compacted. These walls will be 1 m high, crest width of 1 m and side slopes of 1v:1.5h.

11.9 STARTER WALL

A starter wall will be provided to contain the tailings during the early development of the dam.

The wall will be 18 m high at the lowest point, with a crest width of 5 m and side slopes of 1v:2h downstream and upstream 1v:1.5h. The wall will be constructed with clayey material sourced from the basin or if necessary, from other borrow areas. The parameters for the selected clayey material on the upstream section of the starter wall and outer wall are:

- percentage passing 0.075mm sieve = 65 - 85%
- Clay content = 10 - 25%
- PI = 12 - 20
- Dispersivity range = Non dispersive

11.10 DRAINAGE SYSTEM

Inner toe drains - A blanket inner toe drain will be installed along the perimeter of the starter wall and with two intermediate drains upstream of the blanket drain. The purposes of the toe drains are to maintain low phreatic surface, to reduce the pore water pressures, and to aid in consolidation of the tailings.

The toe drain will consist of 160 mm OD slotted Drainex pipe in a 300 mm thick 19 mm stone layer on top of a geotextile. The 19 mm stone will be covered by a 150 mm thick 6 mm stone layer followed by a 300 mm thick graded filter sand layer, and 300 mm thick coarse fraction of tailings as a protection layer.

Toe drains outlets – these will collect seepage water from the toe drains and convey water to the solution trench. These will be 160 mm diameter unslotted HDPE pipes.

The toe drain will be connected to the outlet drains which will be at 50 - 100m intervals. The graded filter sand envelope is shown in **Figure 11.1** below.

Existing toe drains outlet – there is a collector drain that comprises of 315 ND HDPE pipe with the existing toe drains connected to it, in a 19mm stone aggregate wrapped with a geotextile fabric. This is laid in the existing solution trench. The purpose of this is to drain the interface of the two dams, and also to monitor existing TSF toe drains.

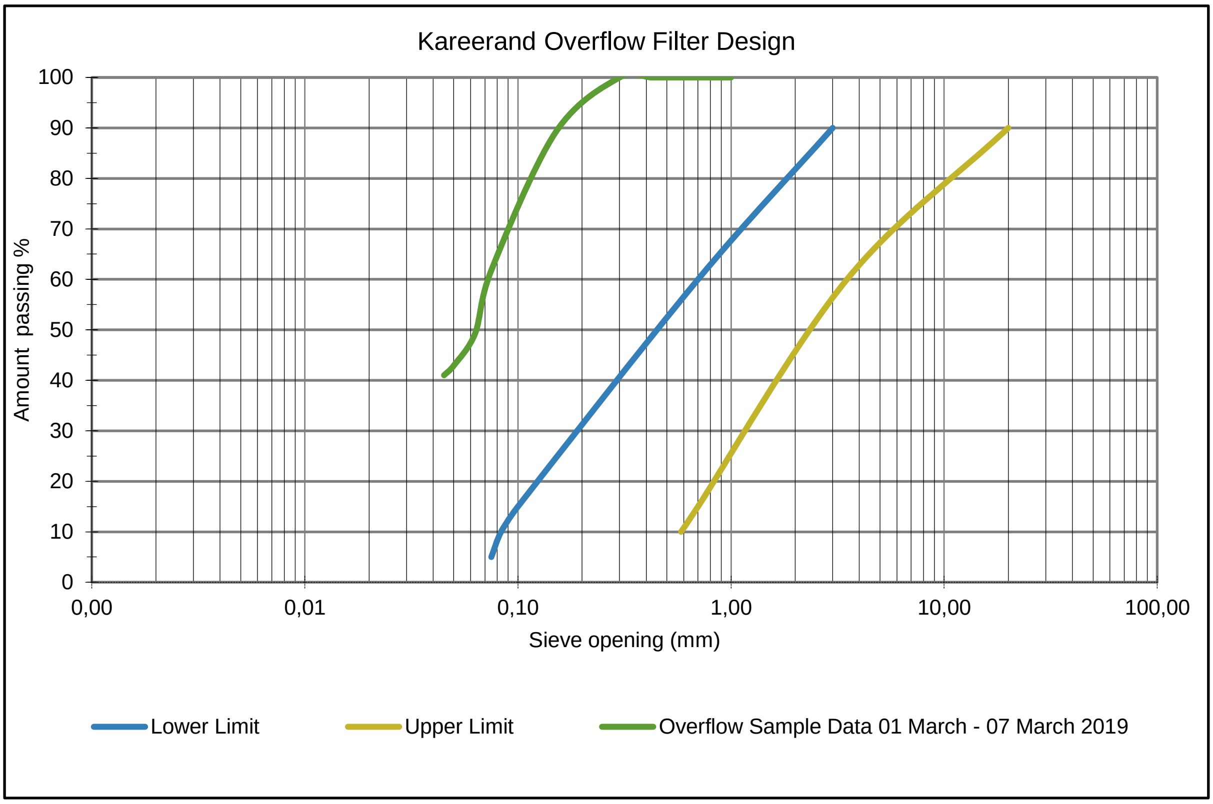


Figure 11.1 Overflow Filter Sand Envelope

Outer Toe Drain – two blanket toe drains which will be installed along the perimeter of the toe wall and central to the underflow wedge. The purposed of the outer toe drain is to lower the phreatic surface under the underflow wedge. These drains are connected to unslotted pipes which drains into the solution trench.

Central Drain – this blanket drain consists of five (5) drains pipes on the drainage zone identified during the geotechnical investigation.

Existing Toe Drain Outlet – the existing toe drain outlets will be connected to the HDPE pipe to convey the drainage water from the existing facility. The purpose of the connection is to ensure that the drains are continuously measured and monitored.

11.11 DECANT SYSTEM

An initial decant system that comprised of a penstock system which has gravity decant constructed in the centre of the TSF extension and a spigot and socket outlet pipe encased in concrete. The system is sized to decant storm water from a 1:100-year 24-hour storm event. There will be two 510 mm diameter penstock ring towers connected to a 600 mm ID Class 150D reinforced concrete spigot and socket outlet pipe. An intermediate intake structure is provided for decanting during the early development of the dam. A timber catwalk will be provided to the intermediate intake structure. This intake will be sealed once the pool reaches the final intake structure.

Intermediate penstock sealing - a 20mm thick steel plate will be lowered down the penstock ring tower and placed onto the grid supplied during the construction of the intermediate intake structure. A concrete grout plug of 1 000 mm will be poured onto the plate; care should be taken while doing this to ensure that the grout does not segregate while pouring. A second 1 m concrete plug should be poured after the first pour is set.

The sealing of the intermediate penstock needs to be designed and supervised by a qualified Engineer.

Penstock Intake Access (Pool Wall) – this will be constructed by cyclone and using underflow material. The side slopes of 1v:2h at the start of the deposition and will be progressively developed with tailings and the dam develops.

11.12 CATWALK

A timber catwalk and floating walkway structure will be constructed for access from the pool wall to the penstock intermediate and permanent intake structures respectively. The catwalk height will be raised when necessary and the floating walkway will increase with the dam pool level. The catwalk is constructed of timber supports spaced at 2.5 m centres. Three 230 x 76 mm gum pole planks (4.8 m standard lengths) will be used for the walkway. The floating walkways will be constructed from Jet floats with a 4.5mm thick aluminum chequer decking plate.

11.13 ENERGY DISSIPATER

A concrete energy dissipater box will be provided where the penstock outlet pipe daylights. The intent is to reduce the velocity of the water from the penstock before it flows into the silt trap.

11.14 SILT TRAP

A concrete silt trap will be constructed between the penstock outlet and the return water dam. This is meant to reduce the volume of suspended solids flowing into the return water dam. The silt trap will have twin compartments to facilitate de-silting.

The silt trap will be concrete lined, and sluice gates will be installed at the inlets and outlets. An outlet trench to the return water dam will also be constructed.

The silt trap is designed to settle grain of size 0.006 mm and specific gravity of 2.7. The average settling time for this particle will be 12 minutes.

11.15 RETURN WATER DAM (RWD) AND RELATED INFRASTRUCTURE

A return water dam system with 825 000 m^3 total capacity will be constructed south of the TSF and Existing RWD dam complex. The RWD will have three compartments: one for operation and the other two for storm water containment. The return water dam will be lined with a double HDPE liner system with a leakage detection system. A sump structure will also be constructed downstream of the RWD for decanting via the pump station.

The RWD wall will be 5 m at the highest point, with a crest width of 3 m and side slopes of 1v:3h downstream and upstream.

Liner – the return water dam requires a lining. The lining will be a double liner consisting of a 2 mm geomembrane, Hi-drain (leakage detection material) and a 1.5 HDPE geomembrane.

11.16 MECHANICAL AND PROCESS

The process and piping reports compiled by Worley Parsons are in **Appendix G**.

12.0 SAFETY CLASSIFICATION

The South African Code of Practice (SANS 10286:1998) was used as for the TSF safety and environmental classification. SANS 10285 requires that all mine residue deposits be classified into one or a combination of the following safety categories:

a) High hazard
b) Medium hazard
c) Low hazard

The classification is based on the anticipated configuration of the residue deposit at the end of its life. To classify an impoundment or residue deposit, an evaluation of its “zone of influence” according to guidelines set out in the section 7.4.2.2 of SANS 10286 must be determined. The safety category of the impoundment is then determined using height of the dam, anticipated flow length and a zone of influence is mapped. The height of the TSF at closure is 120 m at elevation 1 340 mamsl. The zone of influence is shown in **Figure 12.1** below. The classification then follows the code shown below in **Table 12-1.**

Figure 12.1 Zone of Influence

Table 12-1 SANS 10286: 1988 Table 2 – Safety and Environmental Classification

1	2	3	4	5
No. of Residents in Zone of Influence	**No. of Workers in Zone of Influence (1)**	**Value of Third-Party Property in Zone of Influence (2)**	**Depth to Underground Workings (3)**	**Classification**
0	<10	0 – R 2 Million	> 200 m	Low hazard
1 - 10	11 – 100	R 2 – R 20 Million	50 m – 200 m	Medium hazard
>10	>100	>R 20 Million	< 50 m	High Hazard

1. Not including workers employed solely for the purpose of operating the deposit.
2. The value of third-party property should be the replacement value in 1996 terms.
3. The potential for collapse of the residue deposit into the underground workings effectively extends the zone of influence to below ground level.

NOTES:

1. THE COSTS IN TABLE 13.1 ARE 1988 COSTS

There are residents in the zone of influence and are estimated to be greater than 10 with the estimated value of third-party property within the zone of influence greater than R 20m. The number of workers in the zone of influence is also estimated to be greater than 10. There are underground workings. The Kareerand TSF complex therefore classifies as a **High Hazard dam**. The classification confirmed with the classification at pre-feasibility study level.

In terms of SANS 10286:1998, clause 7.4.6, a risk analysis is required to be done on the TSF with high hazard.

12.1 ESTIMATED FUTURE VALUE OF PROPERTY

An assessment was done to determine the future value of property to calibrate **Table 12-2** for understanding of the cost in today's value. This assessment was based on an estimated inflation rate from 1998 to 2018 and was further projected to 2038 at an average of 6% per annum.

Table 12-2 Estimate Value of Third Party

1988	2018	2038
0 – R 2 Million	0 – R 11.4 Million	0 – R 36.5 Million
R 2 – R 20 Million	R 11.4 – R 114 Million	R 36.5– R 365 Million
>R 20 Million	>R 114 Million	>R 365m

13.0 INSTRUMENTATION

The TSF will be equipped with piezometers at strategic sections to monitor the level and behaviour of the phreatic surface regime within the dam. **Table 13-1** below shows the frequency for monitoring. This data must be forwarded to a qualified Engineer on a monthly basis. A detailed monitoring programme is included in the Operating Manual.

Table 13-1 Instrumentation Monitoring Frequency

Measured Items	Daily	Monthly	Quarterly	Annually	Once in two years
Drain flows		x			
Piezometers		x			
Slurry density	x				
Tonnage deposited	x				
Penstock height	x				
Freeboard		x			
Evaporations and rainfall	x				
Foundation indicators (grading and Atterberg limits				x	
Return water levels	x				
Cyclone splits		x			
Deposited area	x				
Siltation depth in the silt trap		x			
Piezocone testing					x

14.0 CLOSURE CONSIDERATION

The TSF complex will be constructed and operated with final closure in mind. Vegetation on all the side slopes must be established on the outer face of the final wall raise. Trials and activities related to vegetation establishment and associated irrigation systems must form part of the TSF operating cost allowances.

The closure will comply with the EMP report. The objective of establishing closure requirement during the design phase is to reduce the capital cost of closure and maintenance. This is achieved by considering flat slopes where vegetation can be established, and by establishing vegetation during operation.

It is proposed that the TSF extension including the existing TSF be developed on an ongoing basis with the closure in mind. Vegetation on all the side slopes should be provided as the TSF complex is developed. The reason for this is that experience has shown that the vegetation establishment is most effective as close as possible to the locations of deposition. A critical success factor is the management of the irrigation systems for the vegetation.

The closure objectives are to reduce ongoing maintenance to a low level or even a negligible level. The following principles must be considered for closure.

a) The ongoing side slope developed must be maintained so that the vegetation can stabilise the outer slopes. If this cannot successfully be achieved, then rock cladding must be considered.
b) The berms and/or benches must be maintained so that ongoing rain storms do not cause erosion of these structures, which will then also lead to concentrated flows down the side slopes causing additional side slope erosion.
c) The phreatic surface is likely to decrease between 1 m and 2 m per year after closure. It means that more than 20 years is likely to pass before the phreatic surface will stabilize within the TSF complex. This will also affect the drain maintenance requirements on tailings complex.
d) The upper surface of the tailings dam complex will have to be shaped and vegetated in a similar manner as the current site conditions.
e) Site water management is a critical consideration.
f) Closure of site infrastructure. The critical aspects are the penstocks and the sealing thereof once other measures have been put in place to cater for the rainstorm events.
g) The solution trenches and paddocks must be maintained until the vegetation and//or rock cladding is stable.

At closure, a closure report will need to be prepared by a Professional Engineer and according to SANS 10286:1998 must include, but not be limited to:

a) Closure objectives and criteria
b) Closure technics
c) Post closure monitoring
d) Monitoring and performance measures
e) State and stability of the outer slopes,
f) Physical and chemical stability of the TSF,
g) Hydrological consideration with respect to the top of the dam and run-off from the side of the dam,
h) State of penstocks and penstock pipeline,

i) State of the drains outlets and solution trenches,
j) Risk that the dam poses to the environment and safety.

A closure design was not part of the scope of this report and is being undertake by Agreenco Pty Ltd.

15.0 SCHEDULE OF QUANTITES

15.1 SCHEDULE OF QUANTITIES

A development of the schedule of quantities was removed as part of KP scope and it was developed by the quantity surveyors (QS Africa Pty Ltd, Report No. xxx) and it is submitted separately by others.

15.2 CONSTRUCTION SCHEDULE

The construction schedule was not part of KP scope and has been developed by others. It is envisaged that the project will be developed over three to four years as highlighted in the drawing:

a) Year one (1) -construction of the northern starter wall and associated infrastructure,

b) Year two (2) - construction the southern starter wall, penstock and associated infrastructure,

c) Year three (3) - construction of the north west starter wall and associated infrastructure.

d) Year four (4) - completion of delivery lines.

16.0 CONCLUSIONS

The following conclusions were made:

j) The design of the TSF extension was for the site west of the existing facility and can accommodate the proposed tonnages for life of mine of 394 x 10^6 tons and the total deposited tonnage on both facilities will be 851 x 10^6 tons.

k) The TSF extension will be a constructed by an upstream construction method, with overall slope of 1v:6h.

l) A 18 m high starter wall be constructed on the southern side with another containment wall on the northern side.

m) The achieved factors of safety with the old parameters were 2.2 and 1.1 for static and earthquake loadings respectively.

n) Tailings will be hydraulically deposited on the tailings storage facility by means of the cyclones method of deposition using six (6) banks and spigotting in between the two dams to manage the pool.

o) The new TSF extension will be commissioned in 2022, and the two will be operated as two facilities till closure.

p) The life of the facilities will be for a period of approximately 20 years.

q) The overall height of the tailings dam is 122 m

r) The tailings material has been classified as Type 3 waste requiring a Class C barrier system

If the project is moved to the next stage of detail design and construction, it is recommended that:

d) The design criteria to be confirmed.

e) The life of mine production rates for the tailings is confirmed.

f) Detailed seepage and stability assessments be carried out with a view of optimising the under-drainage systems and seepage control measures.

17.0 REFERENCES

Knight Piesold Pty Ltd; 2017; *Prefeasibility Study for the Kareerand Tailings Storage Facility Expansion Project*

Knight Piesold Pty Ltd; 2017; *Feasibility Geotechnical Investigation Report, for the Kareerand Tailings Storage Facility Expansion Project*

Knight Piesold Pty Ltd; 2017; *Geotechnical Investigation Details Design Phase Report, for the Kareerand Tailings Storage Facility Expansion Project.*

WorleyParsons, 2019; Piping Close Out Report

Worley Parsons, 2019: Process design philosophy.

A Kijko, 2017: Deterministic Seismic Hazard Analysis for Kareerand Tailings Dam.

18.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Ephriam Nkobani , Pr.Tech Eng
Civil Technologist

Roelanie Greyling
Civil Engineer

Albertus, du Plessis, Pr.Eng
Principal Engineer

Thabang Mokoma, Pr.Eng
Principal Engineer

Reviewed:

Duncan Grant-Stuart, Pr. Eng, APP.
Specialist

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Approval that this document adheres to Knight Piésold Quality Systems: ☐

APPENDIX A

Design Criteria

Knight Piésold
CONSULTING

DESIGN CRITERIA

MINE WASTE SOLUTIONS
ANGLOGOLD ASHANTI
KAREERAND EXTENSION FEASIBILTY STUDY

Print May/17/19 10:04:04

ITEM	DESIGN CRITERIA	SOURCE / COMMENTS
1.0 GENERAL		
Commissioning Date of Existing TSF	2011	Design Report Ref FA/BR/025/2009
Design life of Existing TSF	14 yr	Design Report Ref FA/BR/025/2009
TSF Expansion start date	2021	MWS
Required Life	20 yr	MWS
Site Co-odinates and Elevation	26°52'43.07"S, 26°52'26.08"E	
Codes and Standards	SANS 10286 - Mine Residue Code of Practice	
Units	Standard Interational (SI), South African Rand (R)	
2.0 HYDROLOGY		
Annual Rainfall	562mm, 592mm,609mm	Bushy bend WS-(Report no.: 301-000204/07), en.climate-data.org
Annual Evaporation	1750mm	Report no.: 301-000204/07
Stormwater management	Separate clean and dirty water	As per legislation (GN 704)and best practice
24hr Rainfall		
1:20 year Recurrence Interval	117mm	Report no.: 301-000204/07
1:50 year Recurrence Interval	147mm	Report no.: 301-000204/07
1:100 year Recurrence Interval	173mm	Report no.: 301-000204/07
1:200 year Recurrence Interval	202mm	Report no.: 301-000204/07
7 days event	216mm	Report no.: 301-000204/07
3.0 TSF DESIGN		
Seismic loading (PGA)	0,152 ± 0,098 g	Report 2016-17/2 (Rev 2,0) (A Kijko)
Average tailings (tpm)	2 471 000 tonnes/month	MWS BP 2019
Specific gravity	2,7	Concept design FA-019
Grading - Underflow-wall	<2mm and GM= 0.68 for wall Toe & Crest	MEP-JvT/KHH2159/3010020402/Rev.0
Grading - Overflow-beach	<0.425mm and GM=0.59	MEP-JvT/KHH2159/3010020402/Rev.1
Potential cyclone U/Fsplit (mass)	26%	Average 2018 weekly reports.
Slurry density:		
Feed	1,387	Average 2018 weekly monitoring reports
Underflow	1,857	Average 2018 weekly monitoring reports
Overflow	1,323	Average 2018 weekly monitoring reports
Percentage solids by mass:		
Feed	41,5%	Average 2018 weekly monitoring reports
Underflow	70,4%	Average 2018 weekly monitoring reports
Overflow	37,3%	Average 2018 weekly monitoring reports
Final Dam Elevation	1432 mamsl (122 m above lowest NGL)	
Overall outer side slope angle	1v:6h	
Intermediate slope angle	1v:4h	
Maximum slope distance	25m	
Bench vertical spacing	12m	
Bench width	23m	
Tailings dam footprint area	Extension: 362 Ha Total TSF 919 Ha	
Hazard Rating	High Hazard	
Dam Safety Category	Category 3	
Depostion Methodology	On-wall Cylones	
Wall construction method	Upstream/Downstream/Centreline	
Decanting System	Gravity , barge pump and/or siphon	
Stormwater management - RWD	Lined, allowed to spill once in 50yrs	Regulation 704
Minimum Factor of Safety Static	1,5	Regulation 632
Minimum Factor of Safety Seismic	1,1	Regulation 632

P:\301-00204\13\A\CALCULATIONS\SPREADSHEETS\Design Criteria\[DesignCriteria Kareerand EXT FS 2019 rev .xlsx]TSF

A					
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

APPENDIX B

Feasibiilty Geotechnical Investigation Report

KAREERAND TAILING STORAGE FACILITY

TSF EXTENSION AND ASSOCIATED STRUCTURES

GEOTECHNICAL INVESTIGATION
DETAILED DESIGN PHASE

PREPARED FOR:

ANGLOGOLD ASHANTI

76 Jeppe Street
NEWTOWN
Johannesburg
2001

PREPARED BY

Knight Piésold CONSULTING

PO Box 72292
Lynnwood Ridge
0040

Tel: +27 12 991 0557

MAY 2019

Project No:	30100204/13
Rev:	0
Report No:	KHH2493
Reference Code:	*OHV-JvT/KHH2493/Draft*

FINAL REPORT

Prepared for
Anglo Gold Ashanti
76 Jeppe Street
NEWTOWN
Johannesburg
2001

Prepared by
Knight Piésold Ltd.
The Boardwalk Office Park
Block 5
Eros Road
Faerie Glen, Pretoria
South Africa

Project Number
30100204/13

KAREERAND TAILING STORAGE FACILITY:
TSF EXTENSION AND ASSOCIATED STRUCTURES
GEOTECHNICAL INVESTIGATION
DETAILED DESIGN PHASE
FINAL REPORT

Rev	Description	Date
0	FINAL REPORT	2019-05-17

Knight Piésold
CONSULTING

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS (continued)

TABLES

FIGURES

APPENDICES

1. INTRODUCTION

Knight Piésold (KP) was appointed by Anglo Gold Ashanti Limited to perform the detailed geotechnical investigation for the extension to the Kareerand Mega Tailings Storage Facility (TSF). A feasibility level geotechnical investigation was completed by KP during 2017 and included a geohydrological investigation by Geo-Pollution Technologies (GPT Global), a sub-consultant of KP.

The Kareerand TSF was constructed to remine the old tailings storage facilities in the area and to extract additional gold and uranium, subsequently removing the old TSF structures and limiting groundwater pollution in the future. The existing Kareerand TSF has a maximum capacity of 352Mt, which will be extended to accommodate 918Mt of tailings waste material. KP has been extensively involved in the stability monitoring of the TSF structure in the past and is familiar with the project growth.

The purpose of the detailed geotechnical investigation was to determine the nature and extent of the underlying soils and bedrock at specific structure locations, and to provide recommendations for the construction of the foundations. The investigated structures are as follows:

- TSF extension area
- Return water dams
- Temporary stockpiles
- Borrow pit materials and
- Diversion channel

This report documents the results of the investigation and provides recommendations for the construction and preparations of the foundations.

2. SITE DESCRIPTION

The Kareerand TSF (from here on referred to as the “site”) is located approximately 10km south-east of Stilfontein in the North West Province. Refer to Figure 1, indicating the position of the site on the locality map. The area at the site is situated between approximate elevations of 1331m above mean sea level (amsl) and 1305amsl. The surface slopes slightly towards the south. The site next to the existing TSF is open and covered with small shrubs and grass, where and a non-perennial stream traverses the western boundary of the existing TSF towards the Vaal River.

The topography on site is generally flat and slopes gently towards the meandering, west flowing Vaal River, which passes 3km south of the site. Refer to Plate 1 in Appendix A that illustrates the TSF extension area. The proposed extension covers approximately 600ha and is situated north-west of the existing TSF.

Two 2m deep trenches have been excavated on the eastern and north eastern portions of the site. It is assumed that these trenches were excavated to control vehicle access in the area for security purposes. Refer to Plate 2.

3. AVAILABLE INFORMATION

A geotechnical investigation for the existing Kareerand TSF was conducted by Bear Geo-consultants Pty (Ltd) during May 2009 [1].

This report included:

- Work previously done by Mr K Schwartz;
- Geotechnical characteristics of the soils underlying the existing Kareerand TSF;
- Construction materials;
- Foundation recommendations

The feasibility geotechnical report (report no. KHH2396) conducted by KP, focused on the footprint of the TSF extension, dated August 2017 [2].

4. INVESTIGATION PROCEDURE

A total of 81 test pits were excavated on site during the feasibility and detailed investigations, phased in accordance with the structures as listed below.

Structure ID	Date	No. of Test Pits	Test Pit ID	Excavation Equipment
TSF Extension Feasibility	9-15 May 2017	29	TP1 to TP29	TLB
Return Water Dams	4-6 Sept. 2018	18	TP2-01 to TP2-18	Excavator 20T
Initial Diversion Channel	20-23 Nov. 2018	17	TP3-01 to TP3-17	TLB
New Diversion Channel	18-22 Feb. 2019	17	TP4-01 to TP424	Excavator and TLB

An initial diversion channel was position during the end of 2018 that was investigated but it was realigned and is referred to as the new diversion channel.

The test pits were excavated to maximum reach or excavation refusal of the machine(s) and logged in situ by an engineering geologist according to standard practice [3]. The soil profile logs are provided in Appendix B.

In addition to the test pitting, four rotary cored boreholes were drilled along the proposed penstock alignment and profiled by an engineering geologist according to current standards. Drilling was carried out from 3 to 9 October 2018 and representative rock samples were submitted to Rocklab in Pretoria for UCS testing.

The co-ordinates of the test pits and boreholes were recorded with hand-held GPS (with accuracy of 3m) and are indicated on the test pit and borehole logs in South African grid system, WGS84 datum.

An additional 22 inspection points (BTP1 to BTP22) were made along the topsoil bund wall along the existing TSF embankment. This aimed to determine if the topsoil bund could be a potential source of material for the construction of the TSF extension starter walls and return water dam embankments.

Representative soil samples were collected from soil horizons during the investigation and were submitted to SGS Matrolab in Pretoria for laboratory testing.

The following tests were conducted:

- Foundation indictor (grading, hydrometer and Atterberg limits)
- Standard Proctor compaction
- Modified AASHTO compaction
- California Bearing Ratio (CBR)
- Consolidated undrained triaxial
- Shear box
- Flexible wall permeability
- Soil corrosivity (pH and conductivity)
- Chemical dispersivity
- Consolidation

Nine in-situ falling head permeability tests were conducted but only five tests were successful.

5. GEOLOGY

According to the published 1:250 000 scale geological map (2626 Wes-Rand) the site is underlain by andesite, quartzite and shale of the Pretoria Group with several dolerite dykes and sills present. Dolomite from the Chuniespoort Group are present approximately 1km north-west of the site. According to the geological map, the dolomite dips approximately 50° towards the site in a south-easterly direction. No suitable outcrops could be found during the investigation to confirm the dip angle. The western boundary of the site was specifically investigated during the feasibility geotechnical investigations to ensure that it does not occur on dolomite ground (>100m non-dolomitic overburden). Refer to Figure 2 providing an abstract of the geological map.

Pedogenic soil in the form of nodular to honeycomb ferricrete occurs in the residual soil horizons. Ferricrete form when iron and manganese are introduced into the soil, generally in dissolved state and precipitates during water evaporation. The iron and manganese cements over time binding soil particles together, which could, under favourable conditions, grow into a hardpan horizon. These deposits have a widespread occurrence across the regional area [4].

The local geology is indicated in Figure 3, which indicates the locality of the andesite towards the western regions, the occurrence of shale in the central parts, and the sill-type contact with the dolerite that extends underneath the existing TSF. A quartzite ridge runs north to south in the central to eastern parts of the site.

According to Weinert’s climatic N-value the site falls in an area where the N-value is less than 5, indicating that the area is associated with humid/wet environments and chemical weathering is the dominant rock weathering mode. The products of chemical weathering (decomposition) are commonly finer grained silty and clayey residual materials which may exhibit expansive properties. Residual soil layers generally comprise deeper soil profiles.

6. INVESTIGATION RESULTS

6.1 TEST PIT PROFILES

Figure 3 provides a layout of the investigated structures at the TSF. In summary the site is covered by transported soils and underlain by residual andesite, shale or residual dolerite that transitions to highly weathered bedrock at depth.

Tables 1 to 4 at the end of the report provide summaries of the test pit profiles at the TSF extension, return water dams and diversion channel respectively. The positions of the test pits are provided in Figures 4A to 4D. The general soil profile is described below, while soil profile variations are further discussed for each site.

- Alluvium covers the site along the drainage areas as depicted in Figure 3 and Figures 4A to 4D. The transported soil comprises generally sandy silty clay with a soft consistency that transitions to firm with depth. The soil structure is often slickensided to intact. With depth the alluvium often becomes coarse grained and consist of sandy gravel to gravelly sand with abundant sub-rounded to rounded gravel. The thickness of the alluvium is mostly more than 4m but is thinner along the edge of the drainage areas. The maximum thickness is not known.
- The remainder of the site is covered by colluvium that generally comprises a matrix supported silty sand and sandy silt with abundant medium to coarse gravel and cobbles. Plate 3 provides a photo of soil profile. The consistency is generally medium dense. The colluvium varies in thickness of between 0,4m and 2,8m but has an average thickness of 0,9m. A pebble marker was occasionally intersected at the bottom of the layer that is described as silty sandy gravel with scattered cobbles.
- Nodular ferricrete and occasional honeycomb ferricrete occur at several test pits across the site and generally comprise medium dense to dense ferricrete nodules in a silty sand matrix. The horizon has a typical thickness of between 0,4m and 1,0m. Excavation refusal occurred mostly on the honeycomb ferricrete. Plate 4 illustrates the hardness of the ferricrete at TP10.
- The TSF extension and diversion channel area is largely underlain by residual andesite. The residual andesite can be described as reddish brown mottled black, stiff, intact, silty sand or sandy

silt. The thickness of the residual andesite is variable between 0,5m and 2,9m. Refer to Plates 5 and 6 that provides a photo of the soil profile at TP8.

- Residual shale occurs mostly at the return water dams as sandy silty clay with minor gravel and has a firm to stiff consistency with depth. The gravel content increases towards bedrock. The residual shale gradually transitions to very soft rock bedrock with depth. Plate 7 provides a typical soil profile of the residual shale at TP12.
- Residual dolerite occurs sporadically as medium dense silty sand with minor gravel. It occurs mostly at depth below the alluvium in the drainage areas and south-eastern parts of the TSF extension, and predominantly along the diversion channel. It is presumed that two dolerite dyke intrusions occur across the site, while it is known that the eastern portion of the existing TSF and diversion channel are underlain by a dolerite sill.
- Bedrock occurs at depth generally as highly weathered very soft rock andesite or shale. The very soft rock transitions abruptly to a soft rock with depth, which is mostly excavated as a gravel. The TLB encountered excavation refusal on the soft rock, while the excavator could continue until it reached medium hard rock but was generally halted in the soft rock material. Excavation refusal was also encountered on the medium hard rock quartzite located in limited areas in the TSF extension area and indicated on the regional geological zones.
- Groundwater seepage was encountered at various test pits at the return water dam and along the diversion channel and are indicated on the test pit summaries. No groundwater seepage was encountered during the excavation of the test pits at the TSF extension, presumably due to them excavated during the dry months. However, during later phases of test pit excavations it occurs widespread at relatively shallow depths.

6.1.1 TSF Extension

- The TSF extension footprint is mostly covered by colluvium to depths of between 0,5m and 1m and occasionally to 2m (TP17).
- The north-western part of the site is covered by alluvium to more than 3m depths.
- The transported soils are underlain by fine grained residual andesite and residual shale to depths of between 2,5m and more than 3,4m.
- Bedrock occurs at shallow depths at TP2, TP6 and TP9.

6.1.2 Return Water Dams and Structures

- The areas along the drainage channel is covered by alluvium to depths of between 2,5m and more than 3m.
- The alluvium thins towards the upper east and west areas and is underlain by colluvium to depths of between 1m and 2m.
- Residual shale and residual dolerite occur below the transported soils to depths of between 2,2m and 4m.

6.1.3 Initial Diversion Channel

- The initial diversion channel, excavated by TP3-01 to TP3-17, is covered by colluvium to depths of between 0,5m and 2m, while at the drainage channel alluvium is present to more than 5m depths.
- The remainder of the channel is underlain by residual andesite and residual dolerite to depths of more than 3m. No bedrock was encountered in the test pits excavated by the TLB.

6.1.4 New Diversion Channel

The alignment for the new diversion channel has the same alignment as the initial diversion channel between test pits TP3-01 and TP3-06. Therefore, the investigation for the new diversion channel included test pits TP4-07 to TP4-24 as indicated on Figure 4D.

The results indicate the following:

- The north-eastern part of the alignment is covered by thick alluvium and residual andesite soils that extends to depths of more than 5m.
- Excavation refusal was encountered at Section TP4-09 to TP4-12 on dolerite bedrock at depths of between 1,8m and 2,9m, as well as at position TP4-15 at a depth of 2,6m. Refer to Figure 5 that provides a topographical contour map of the excavation refusal encountered along the route.
- Along the alignment at TP4-16 to TP4-18 shallow excavation refusal was encountered at depths of between 1m and 1,6m on dolerite boulders, presumably close to bedrock.
- Groundwater seepage was encountered intermittently at depths of between 1,4m and 2,9m, mostly between TP4-07 and TP4-13. It is expected that shallow ground water seepage may be present along the entire route after heavy rainfall.

6.2 BOREHOLE PROFILES

A summary of the borehole profiles is provided in Table 4, with the borehole logs and core photographs contained in Appendix C. In summary it appears the boreholes are located close to the contact between the dolerite dyke/sill and the shale / andesite formations.

- The area is covered by colluvium that varies between 1m and 2,3m thick.
- Residual dolerite occurs below the colluvium to depth of between 4m and 8m.
- The residual soil appears to transition to a highly weathered extremely to very soft rock with depth that becomes very soft rock between depths of 4m and 7,5m. In BH02 the rock quality increases to moderately to slightly weathered at 7,8m, while in the other boreholes the highly weathered rock extends to more than 15m depths.

6.3 IN SITU PERMEABILITY TEST RESULTS

Five in situ falling head permeability tests were conducted on the TSF extension footprint during the feasibility phase investigation. Three tests were conducted on the residual andesite, one on the alluvium and one on the colluvium. Refer to Table 5 providing the locations, depths and results of the tests.

The in-situ permeability tests conducted on the residual andesite yielded coefficients of permeability (k-values) of between $4x10^{-5}$cm/s and $8x10^{-5}$cm/s. The same test on the alluvium measured a coefficient of permeability of 5×10^{-6}cm/s.

No permeability readings could be obtained in the colluvium due to the highly pervious nature of the material since the high clay content of the material caused shrinkage cracks upon drying, resulting in a high seepage rate. It is anticipated that during the wet season these the clay will expand and close the cracks.

6.4 LABORATORY TEST RESULTS

6.4.1 Soil Laboratory Test Results

The detailed soil laboratory test results are contained in Appendix D1 and D2 and summarised in Table 6. The results are discussed below.

Alluvium

The upper alluvium horizons generally comprise sandy silty clay, which becomes sandy gravel with depth in the thick horizons. The upper alluvium has a clay content of between 25% and 47% with a high Plasticity Index (PI) value of between 17% and 38% (average of 27%). The Grading Modulus (GM) of the upper alluvium varies between 0,37 and 0,9, while the potential expansiveness is medium to very high. The upper alluvium has a Standard Proctor Maximum Dry Density (MDD) of between 1379kg/m^3 and 1586kg/m^3 with an Optimum Moisture Content (OMC) of 17% to 23%.

The lower coarse-grained alluvium, tested at TP2/10 and TP3-03 below depths of 1,5m comprises silty gravelly sand with a clay content of 4% to 12% and a GM of 1,12 to 2.35.

Colluvium

The colluvium is relatively variable across the site. The fine-grained colluvium occurs mostly along the diversion channel areas and sandy silty clay to clayey silt. The clay content in the fine-grained colluvium varies between 15% and 47% and the GM between 0,29 to 0,63.

The coarse-grained colluvium occurs most at the TSF extension and is slightly silty and clayey sandy gravel with a GM of 1,73 to 2,35. The Modified AASHTO MDD tests yielded an MDD of between 1557kg/m^3 and 2049kg/m^3 but measured low CBR strengths and classifies as poorer than G9 quality material.

Nodular Ferricrete

The nodular ferricrete is coarse-grained at TP10, TP13 and TP3-06, but fine grained at TP16. The following results were obtained as an average of the three samples. A PI of 17% with a GM of 1,6 and a low potential expansiveness in all three samples. The average Modified AASHTO MDD is 1855kg/m^3 @ 12% OMC. The results yielded low CBR strengths and the material is generally poorer than G9 quality material.

Residual Andesite

The residual andesite is mostly a fine-grained soil but can be variable with a clay content of between 9% and 37% (average of 22%) and a GM of between 0,34 and 1,14 (average of 0,58). The soil has a low to medium potential expansiveness. Standard Proctor compaction tests yielded an MDD of between 1324kg/m^3 and 1671kg/m^3 (average of 1555kg/m^3) with OMC's of 10% to 25%.

Residual Shale

The residual shale, generally a fine-grained soil, was encountered and excavated as a sandy gravel with low fine content. Only at TP16 is the residual shale completely weathered and comprises gravelly clayey silt. The fine-grained soil has a Proctor MDD of 1590kg/m^3 with an OMC of 12%.

Residual Dolerite

The residual dolerite, sampled along the diversion channels, comprises silty gravelly sand with an average clay content of 3% and PI value of 14%. One sample at TP2-08 is fine-grained. The soil has a low potential for expansiveness. The Modified AASHTO MDD of the soil was measured between 1597kg/m^3 and 1991kg/m^3 with an OMC of between 9% and 15%.

According to COLTO, the CBR strength values classifies the coarse-grained residual dolerite soil as G7 to G8 quality material but also as poorer than G9 quality material.

Strength Test Results

Shear box tests was conducted on samples remoulded to 95% of Proctor MDD. The residual andesite yielded an internal friction angle of 34° with cohesion of 7kPa. The same tests conducted on the alluvium yielded an internal friction angle from 16° with a cohesion of 14kPa to 24° with cohesion of 4kPa. The average internal friction of the alluvium is 20°.

Consolidated, undrained tri-axial tests were conducted on remoulded residual andesite from TP3 and the alluvium in TP25. An internal friction angle of 29° and cohesion of 1kPa was measured on the residual andesite and an internal friction angle of 22° and cohesion of 2kPa was measured on the alluvium.

Permeability Test Results

The permeability tests conducted in the laboratory comprised of two methods, viz. falling head tests on remoulded samples and permeability tests on samples enclosed in a triaxial cell at a pressure of 50kPa.

The results however are very similar between the two tests methods. The results indicate that both the residual andesite and alluvium has coefficient of permeability generally between 1x10^{-6}cm/s and 8x10^{-8}cm/s. The recompacted residual shale yielded a higher coefficient of permeability of 1x10^{-5}cm/s due to the high gravel content.

Consolidation Test Results

Four undisturbed samples were taken during the investigation for consolidation testing. Potential settlement was calculated at a 200kPa load, as follows.

- Sample 1 was taken of residual andesite 1,5m below ground surface at TP22. The sample has an initial void ratio (e_0) of 0,774 and a dry density of 1538kg/m^3. It has a coefficient of volume compressibility (M_v) value of 1,98x10^{-4}m^2/kN. Settlement of 75mm can be expected below the TSF under a 200kPa load with a residual andesite layer thickness of 2m.

- Sample 2 was taken of alluvium at 0,9m below ground surface at TP27. The sample has an initial void ratio (e_0) of 0,614 and a dry density of 1663kg/m^3. It has a coefficient of volume compressibility (M_v) value of 3,05x10^{-4}m^2/kN. Settlement of 110mm can be expected under a 200kPa load with an alluvium layer thickness of 2m in the vicinity of TP27.
- Sample 3 was taken of alluvium 0,65m below ground surface at TP24. The sample has an initial void ratio (e_0) of 0,668 and a dry density of 1590kg/m^3. It has a coefficient of volume compressibility (M_v) value of 4,3x10^{-5}m^2/kN. Settlement of 30mm can be expected under a 200kPa load with an alluvium layer thickness of 3,4m in the vicinity TP24.
- Sample 4 was taken of ferruginised residual andesite 0,85m below ground surface at TP7. The test result was disregarded as the result was considered to be questionable.

6.4.2 Chemical Laboratory Test Results

PH value and conductivity tests were done on samples from TP3 and TP10 at the TSF extension. Residual andesite at TP3 has a pH value of 6,97 and a conductivity value of 0,1035s/m, indicating very corrosive conditions. Nodular ferricrete from TP10 has a pH value of 6,89 and a conductivity value of 0,0071s/m indicating none corrosive conditions.

Five chemical dispersive soil tests were conducted on the residual andesite and alluvium. The identification of dispersible soils was done according to the procedure proposed by Gerber and Harmse, 1987 [4]. Tests results indicate that the alluvium is marginally dispersive and the residual andesite is non dispersive. Refer to Table 7 providing a summary of the results as well as the results plotted on the dispersivity chart.

6.4.3 Rock Laboratory Test Results

The results of the rock laboratory test are provided in Appendix E. The laboratory tests on the rock samples were conducted from the core recovered from the boreholes along the temporary penstock structures. The test results are summarised in Table 8 and discussed below.

The highly weathered very soft to soft rock dolerite has a dry density of between 2170kg/m^3 and 2370kg/m$^{3.}$ The rock has Uniaxial Compressive Strength (UCS) values of between 0,9MPa and 1,3MPa. The deformation modulus and Poisson’s ratio could not be measured on the highly weathered rock.

The moderately to slightly weathered hard to very hard rock dolerite that occurs with depth in borehole BH02 has a dry density of 2960kg/m^3 and a UCS value of between 146MPa and 162MPa. The deformation modulus of the dolerite at a depth of 8,4m at BH2 has a deformation modulus 93,7GPa and a Poisson’s ratio of 0,22.

7. GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

7.1 TSF EXTENSION FOUNDATIONS

The tailings storage facility requires suitable foundations for the construction of its starter walls and associated infrastructure. The recommendations for the proposed infrastructure are discussed below.

7.1.1 TSF Starter Wall

It was assumed that the outside perimeter of the TSF footprint will form the starter wall footprint, as shown in Figure 3. The recommendations for the foundations of the starter wall can be divided according to the geotechnical conditions as follows.

- Central and western part of TSF Extension: This area is underlain by transported and residual soil, with a combined thickness of at least 2m, underlain by fine-grained residual soil with depth.
- Eastern drainage zone: The drainage zone is underlain by deep alluvium soils with a combined thickness of at least 3m.

Central and Western Part of TSF Extension

Most of the starter wall footprint is generally underlain by residual andesite with a stiff consistency below depths of 1,5m to 2m. It is anticipated that the stiff residual andesite / shale should have an allowable bearing capacity of at least 250kPa to 350kPa.

The following is recommended:

Remove and stockpile 300mm of topsoil. The topsoil must be used for slope rehabilitation purposes as soon as the TSF embankments reach final design levels.

Remove and separately stockpile the colluvium and nodular ferricrete. Use the colluvium and nodular ferricrete as fill material and place fill layers on the stiff residual andesite and shale horizons. The foundation floor must be in-situ densified by a large size (>10 Tons) vibratory pads foot roller to 95% Standard Proctor maximum dry density (MDD) at ±2% OMC. Any variable floor topography as well as the starter wall fill layers should be backfilled with horizontally placed fill material and compacted by a large size (>10 Tons) vibratory pad foot roller to 95% Modified Proctor MDD (MDD) at ±2% OMC.

It is essential that quality control by an engineering geologist or geotechnical engineer is conducted during the excavations to ensure the correct depths are reached for the foundations.

Eastern drainage zone

The drainage zone is underlain by a thick alluvium layer with a firm consistency. It is anticipated that the firm materials should have an allowable bearing capacity of 80kPa to 120kPa.

Two options are recommended after the 300mm of topsoil is stripped and stockpiled. Option 1 is to minimize excavations and option 2 is to maximize borrow material.

- Option 1: Remove material to a depth of 1mbngl. The foundation floor must be in-situ densified by a large size (>10 Tons) vibratory pads foot roller to 95% Standard Proctor maximum dry density

(MDD) at ±2% OMC. Starter wall construction may commence as discussed above if the limited allowable bearing capacity of 120kPa is sufficient.

- Option 2: Remove alluvium as well as residual soils up to soft rock conditions (more than 5m depth). Excavated material can be used as a low permeability embankment or blanket material. Starter wall construction may commence on the soft rock conditions as discussed above. At this depth the allowable bearing capacity is at least 350kPa.

7.1.2 TSF Floor

The TSF floor is covered by the typical soil profile as describe for the TSF starter wall footprint. It is recommended stripping 300mm topsoil and stockpile it as discussed above. The colluvium, pebble marker and nodular ferricrete can be used as a borrow material for the fill layers on the starter wall and water return dams. The borrow area must be planned in such a way that the basin and upstream starter walls are covered by a continuous clay/low permeability layer. The thickness of the potential fill material in the basin varies across the site from 0,1m at TP2 to 2m in TP17 with an average layer thickness of 1,1m across the site.

Below the potential fill material in the basin (colluvium, pebble marker and nodular ferricrete) the majority of the TSF footprint is underlain by a very low permeable clayey sand layer with a stiff consistency. It is recommended to remove the colluvium, pebble marker and nodular ferricrete for use of embankment fill material.

Rip the clayey sand to sandy clay layer (residual andesite) to a depth of 300mm and re-compact to 95% Standard Proctor MDD at ±2% OMC. Ensure that the entire footprint as well as the upstream side of the starter wall is covered with a low permeability layer to minimize seepage contamination of the ground water. A low permeability layer, with a thickness of 600mm, must be placed in areas that are not underlain by a sandy clay material i.e. the coarse-grained residual dolerite or the quartzite ridge striking north to south.

The permeability test results of the in situ residual soils compared to the same material recompacted and tested in the laboratory indicated that the coefficient of permeability is reduced during compaction from $1x10^{-5}$ cm/s to between $1x10^{-6}$ cm/s and $1x10^{-8}$ cm/s.

Should more fine-grained liner material be required can the floor of the TSF be over-excavated to source additional material. The general thickness of the residual soils varies between 1,5m and 2,5m thick.

7.1.3 Temporary Penstock Structure

The temporary penstock structures are positioned on the contact between the dolerite sill/dyke and the andesite / shale formations and hence the soil profiles are deeply weathered and extend with depth.

It is generally recommended for heavy loaded structures to be placed on bedrock. However, according to the boreholes the highly weathered very soft rock dolerite occurs at depths of between 4m (BH03) and 8m (BH02). Since the structure is only temporary the following foundation option is recommended:

- Excavate the footprint positions to a depth of at least 2,5m on dense or stiff residual dolerite.
- Backfill the foundation with either imported rockfill or imported G5 quality material to create a raft type of foundation. The thickness and extent of the raft should be determined by a geotechnical engineer to accommodate the required loads of at least 350kPa.

- Backfilling by rockfill should comprise a large vibratory roller (>10T) to compact the material to the optimal density. The optimal density of the rockfill should be obtained by doing test runs on the material to determine the number of passes required for optimal compaction.
- Backfilling by G5 quality material should include the placement of layers limited to 200mm in thickness, compacted to at least 98% of Modified MDD at optimum moisture content.

7.2 CONSTRUCTION MATERIALS

Two material types are required for the construction of the TSF embankments, viz. low permeability material to be placed as a nearly impervious liner and granular embankment fill material for the starter wall and water return dam embankments.

7.2.1 Embankment Fill

The colluvium and ferricrete material are suitable for the construction of the starter walls. The colluvium occurs generally as a 1m thick layer covering the TSF extension site, while the ferricrete material occurs generally between the upper colluvium and lower residual andesite soil horizons.

The colluvium comprises mostly a sandy gravel (>50% gravel content). The ferricrete material comprises relatively high gravel and sand content (55% to 78%) and is considered suitable for the construction of the embankment. It is anticipated that the ferricrete materials as well as a combination of the upper colluvium, residual quartzite and pebble marker can be used as a fill material.

The colluvium and ferricrete material have low CBR strengths and classifies as G7 to G8 materials but also as poorer than G9 materials. Should the material be used for foundation platform construction a cement stabiliser must be used to increase the strength properties of the materials.

7.2.2 Low Permeability Material

The alluvium as well as the residual andesite is a low permeable material that can be used as a liner material. Although the alluvium has a medium to high potential expansiveness, it is assumed that it will not influence the stability of the TSF but may crack upon prolonged exposure. The fine-grained soils can be obtained within the TSF extension area as well as the return water dam area by over excavating the foundations to reach bedrock, as indicated above.

7.2.3 Topsoil Bund Material

Twenty-two excavations were made into the Bund Wall to determine if the topsoil has low enough organic material suitable for the construction of the starter walls for the TSF extension. These positions are indicated in Figure 4C.

Samples were collected where the topsoil appeared to have low organic content. The results are contained in Appendix D2 and according to specification SANS5832 the following are prevalent:

- BTP5: Darker colour than reference solution
- BTP6: Darker colour than reference solution
- BTP8: Darker colour than reference solution

- BTP11: Same as reference solution
- BTP19 Darker colour than reference solution

The above results indicate that the organic content in most of the samples, which appeared to have the least organic content in the excavations, is still high. It is thus assumed that the material in the topsoil bund is not suitable for use in the construction of the starter walls since the organic material will degrade over time and cause the starter walls to settle.

7.3 RETURN WATER DAM

The return water dams are partly underlain by thick alluvium with firm consistencies and shallow water tables, while the remainder of the footprint is underlain by colluvium and residual shale.

Recommendations for the construction of the foundations is as follows:

- Excavate a cut-off trench upstream of the footprint of the return water dams to reduce the groundwater level in the soil horizons, especially where shallow levels are present in the central drainage area. The water should be diverted to reduce excessive seepage into the foundations and reduce the water content of the soil for in situ compaction. An additional trench may be installed downstream to accelerate this process.
- Remove the soft to firm alluvium soil in the drainage area to depths of at least 2,5m. During excavation the coarse-grained soils should be stockpiled separately from the clayey alluvium material.
- Compact the in-situ floor of the foundation with a sheep-foot roller to at least 95% of Std. Proctor density at optimum moisture content. Permitted the excavations are not flooded and the foundation material not exceeding 2% to 4% of optimum moisture content.
- Full time supervision by an engineering geologist / geotechnical engineer is required to ensure the foundations are suitable.
- Where required, backfilling may be conducted to raise the foundations by utilizing the coarse-grained soils. These coarse-grained soils generally have low quality strength but should be suitable for backfilling the foundations.
- The construction of the embankment walls and liners may follow the same procedure at noted at the TSF starter walls.

7.4 NEW DIVERSION CHANNEL

The excavations to invert level for the new diversion channel is as follows:

- A depth of generally 4,5m in the north-eastern portions of the alignment (TP3-01 to TP3-06)
- Between 5m and 7,5m in the central parts (TP4-07 to TP4-13)
- Between 8m and increasing to 13,6m towards the eastern portion of the alignment (TP4-14 to TP4-18)
- Approximately 4m for the remainder of the channel towards the Vaal River (TP4-19 to TP4-24).

With reference to the results of the test pits the following summary provides depth to excavation refusal correlated to the invert level of the diversion channel. It should be noted where excavation refusal was not encountered in the test pits the approximate depths are estimated.

Chainage (m)	Reference TP No.	Excavation Depth (m)	Invert Level Depth (m)	Thickness of Hard Excavation
0	TP3-01	4	4.5	0.5
250	TP3-02	4	4.6	0.6
500	TP3-03	5	4.2	-0.8
750	TP3-04	5	4.1	-0.9
1000	TP3-05	5	4.3	-0.7
1250	TP3-06	5	4.7	-0.3
1450	TP4-07	5	4.9	-0.1
1700	TP4-08	5	7.5	2.5
2000	TP4-09	4	6.3	2.3
2210	TP4-10	2.6	5.7	3.1
2440	TP4-11	2.9	6.1	3.2
2710	TP4-12	1.8	6.6	4.8
2980	TP4-13	5	8.5	3.5
3190	TP4-14	5	10.3	5.3
3450	TP4-15	2.6	11.1	8.5
3700	TP4-16	1.5	12.5	11
3950	TP4-17	1	13.6	12.6
4200	TP4-18	1.6	8.0	6.4
4450	TP4-19	4	6.7	2.7
4700	TP4-20	4	5.8	1.8
4940	TP4-21	4	4.3	0.3
5200	TP4-22	4	4.2	0.2
5450	TP4-23	4	4.0	0
5600	TP4-24	4	3.0	-1

The above summary indicates that soft excavation is generally possible between chainages 500 to 1500 to the required invert level depth, as well as next to the river. At the remaining areas, especially between chainages 3200 and 4250 hard excavation is required to reach the invert level in rock.

It may be possible to utilize heavy ripping where only half a metre of bedrock is required to be excavated at chainages 0 to 500 and chainages 4900 to 5300. However, blasting is required in the remainder of the alignment to reach the required invert level.

8. REFERENCES

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[3] The South African Institute of Engineering Geologists (1996). *Guidelines for Soil and Rock Logging*.

[4] Brink, A.B.A. (1983) *Engineering Geology of Southern Africa*, Volume 3, Building Publications, Pretoria.

[5] Gerber, F.A, and Harmse, H.J (1987) Proposed procedure for identification of dispersive soils by chemical testing. *The Civil Engineer in South Africa* 29: 397-399.

9. CERTIFICATION

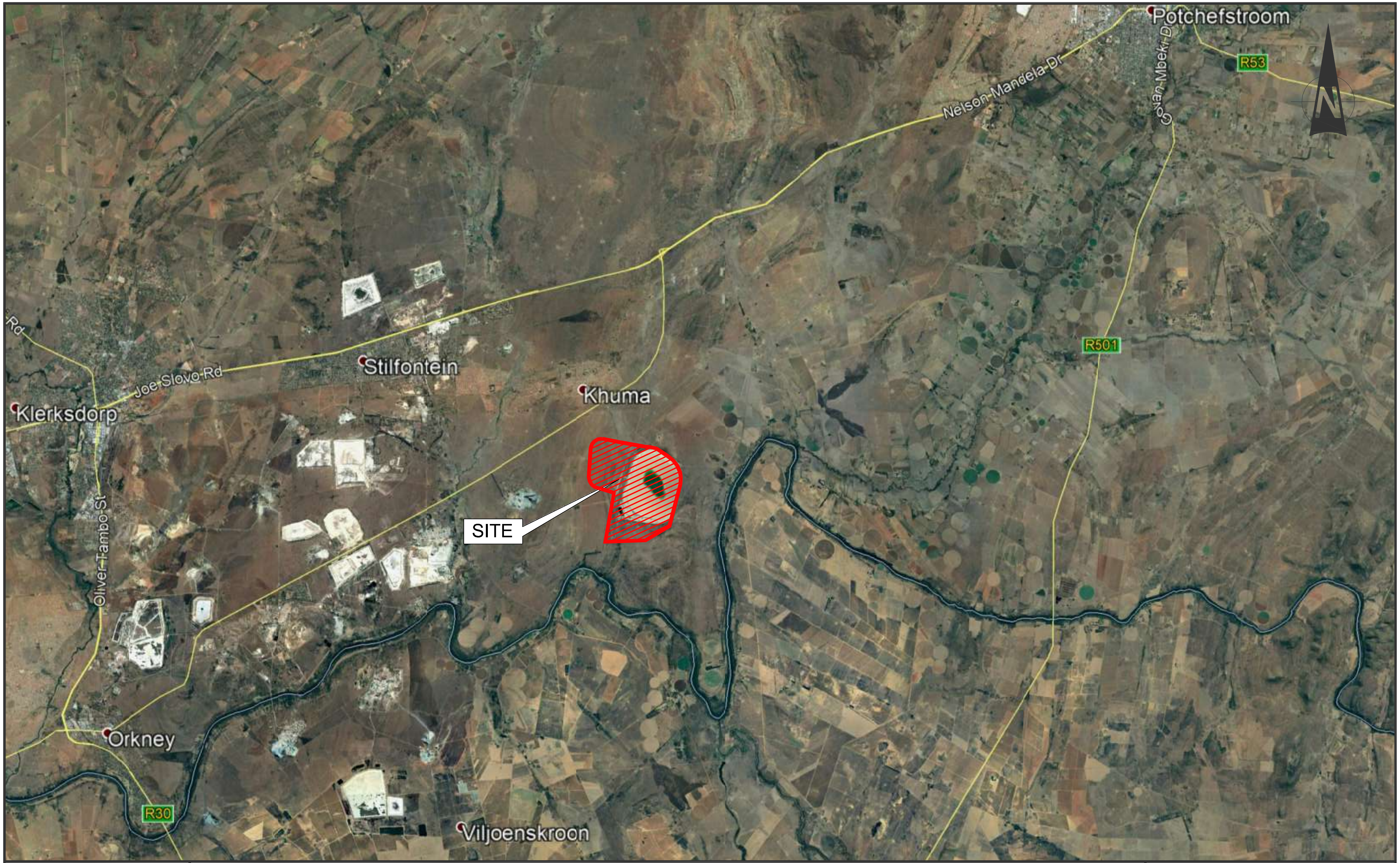
This report was prepared and reviewed by the undersigned.

Prepared: ______________________________

J VAN TONDER

Reviewed: ______________________________

J VAN TONDER



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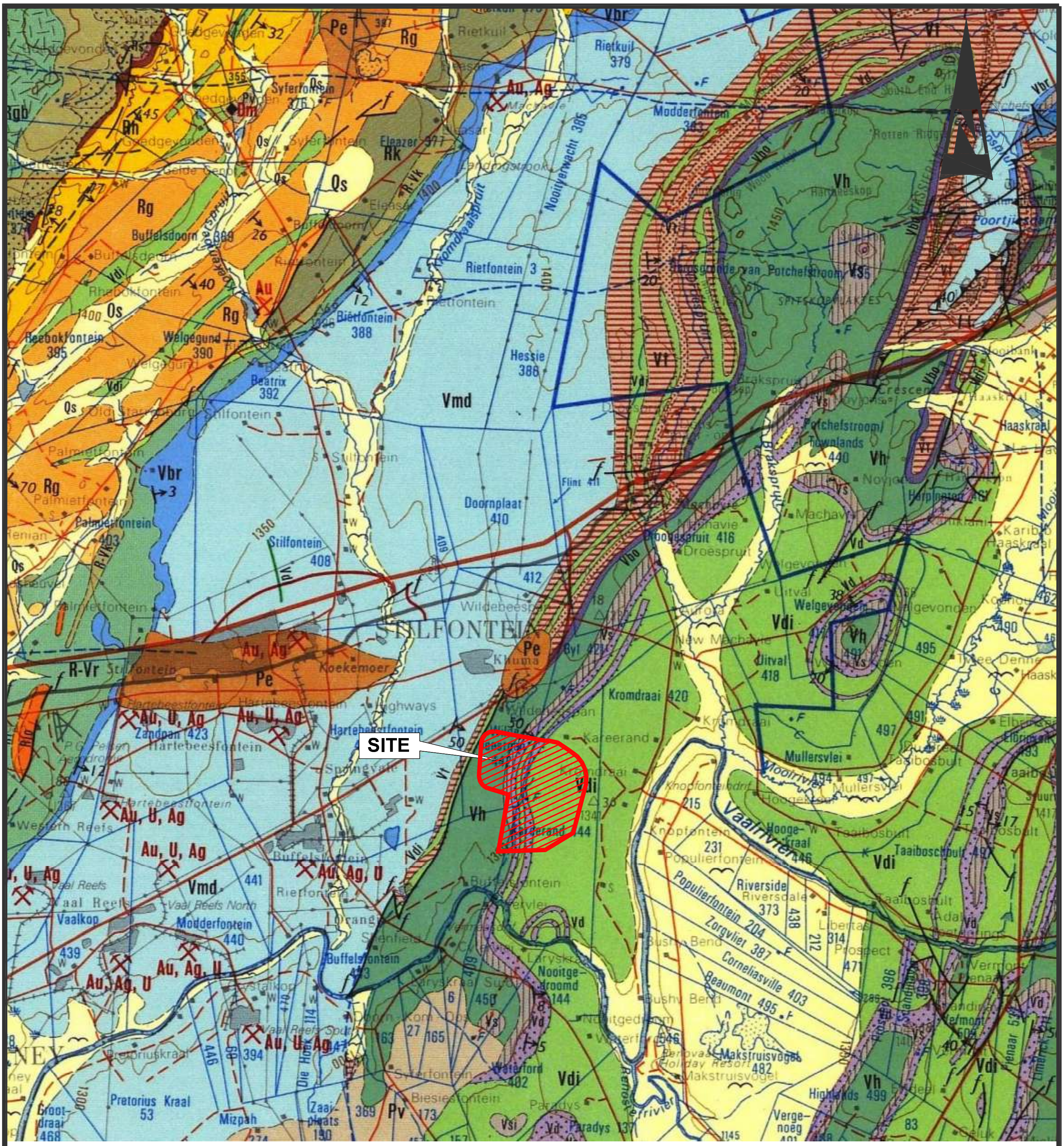
KAREERAND TAILINGS STORAGE FACILITY - TSF EXTENSION PROJECT
GEOTECHNICAL INVESTIGATION

LOCALITY PLAN

PROJECT NO: 30100204/13

FIGURE NO 1

SCALE N.T.S.



GEOLOGICAL LEGEND:

Pe : Shale, sandstone, coal of the Ecca Group, Volksrust/Vryheid Formation, Karoo Supergroup.

Vdi : Dolerite intrusion

Vd : Quartzite and shale. Pretoria Group, Daspoort Formation

Vh : Andesite, Agglomerate and Tuff. Pretoria Group, Hekpoort Formation

Vt : Ferruginous shale and hornfells. Pretoria Group, Timeball Hill Formation

Vmd: Dolomite, chert of the Rooihoogte Formation, Malmani Subgroup, Chuniespoort Group, Transvaal Supergroup.

REFERENCE MAP
1:250 000 SCALE
GEOLOGICAL SERIES
SHEET: 2626 WEST RAND
NOT TO ORIGINAL SCALE

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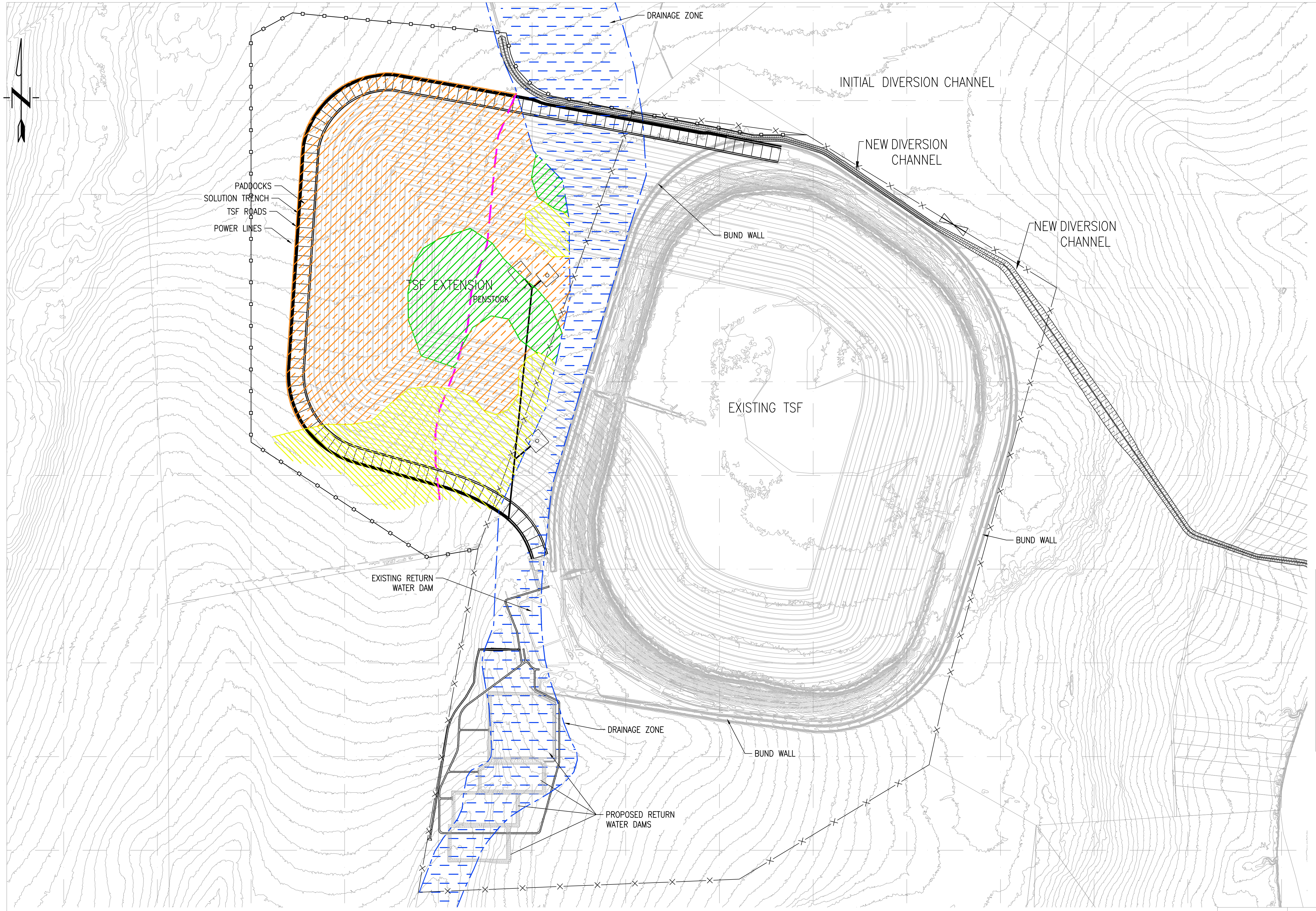
KAREERAND TAILINGS STORAGE FACILITY
TSF EXTENSION PROJECT
GEOTECHNICAL INVESTIGATION
GEOLOGY MAP

PROJECT NO: 30100204/13
FIGURE NO 2
SCALE N.T.S.

MET PROJECTSCWR1806001 MET-MWS-39-C0004 REV A



LEGEND

▤	ALLUVIUM
━ ━ ━	QUARTZITE RIDGE
▨	DOLERITE
▨	ANDESITE
▨	SHALE

SITE LEGEND

EXISTING SITE LEGEND

◌	EXISTING GRAVE SITES
—HV—	EXISTING POWER LINE
— —	EXISTING ACCESS ROADS
— · · —	EXISTING DELIVERY PIPELINES
▨	EXISTING PUMP STATION

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DESCRIPTION	DOCUMENT NUMBER	NAME	SIGNATURE	DATE
DESIGN CALCULATIONS				
RISK ASSESSMENT				

SCALE: 1:20000

TITLE	DRG. No
DIVERSION CHANNEL	FIGURE 4D
BUND WALL INSPECTION POSITIONS	FIGURE 4C
RAW WATER DAM TEST PIT POSITIONS	FIGURE 4B
TSF TEST PIT POSITIONS	FIGURE 4A

REFERENCE DRAWINGS

DETAIL	MARK	DATE	INIT	APP'D
ISSUED FOR APPROVAL	A	24.01.2019		

REVISIONS

DESIGNATION	NAME	REGISTRATION No:	SIGNATURE	DATE
DRAWN	DC			15.01.2019
CHECKED	DB			15.01.2019
SENIOR DESIGNER MET PROJECTS				
PR ENGINEER				
PR TECH				
PROJECT / MET ENGINEER	DGS			15.01.2019
MET PROJECTS MANAGER	NAME			15.01.2019

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MET PROJECTS

301-00204/13-004
REGION SOUTH AFRICA REGION – VR
BUSINESS UNIT MINE WASTE SOLUTIONS
PROJECT MINE WASTE SOLUTION–KAREERAND EXTENSION PROJECT
DRAWING TITLE SITE LAYOUT INDICATING POSITIONS OF STRUCTURES AND GEOLOGY

CWR1806001 FIGURE 3 REV A
PROJECT No: B/UNIT AREA SEQ. No: SIZE – A1

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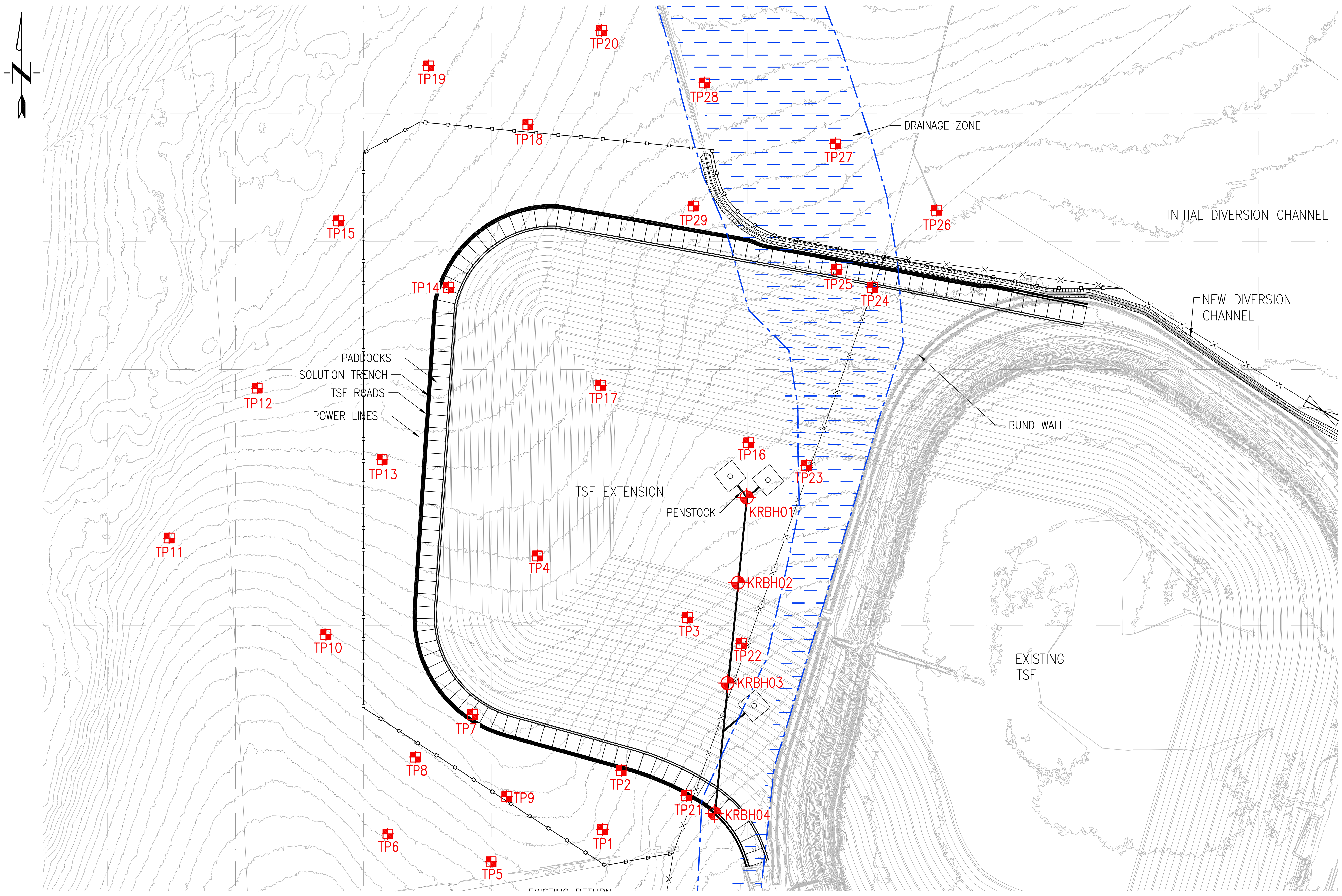
MET PROJECTSCWR1806001	MET-MWS-39-C0004	REV A



SITE LEGEND

EXISTING SITE LEGEND	
▨	EXISTING GRAVE SITES
—HV—	EXISTING POWER LINE
— — —	EXISTING ACCESS ROADS
— · · —	EXISTING DELIVERY PIPELINES
▨	EXISTING PUMP STATION

GEOTECHNICAL LEGEND

🟥	TEST PITS
⊕	BOREHOLES

Knight Piésold CONSULTING

DESCRIPTION	DOCUMENT NUMBER	NAME	SIGNATURE	DATE
DESIGN CALCULATIONS				
RISK ASSESSMENT				

SCALE: 1:12500

TITLE	DRG. No	DETAIL	MARK	DATE	INIT	APP'D
DIVERSION CHANNEL	FIGURE 4D					
BUND WALL INSPECTION POSITIONS	FIGURE 4C					
RAW WATER DAM TEST PIT POSITIONS	FIGURE 4B					
SITE LAYOUT INDICATING POSITIONS OF STRUCTURES	FIGURE 3	ISSUED FOR APPROVAL	A	24.01.2019		

REFERENCE DRAWINGS

REVISIONS

DESIGNATION	NAME	REGISTRATION No:	SIGNATURE	DATE
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CHECKED	DB			15.01.2019
SENIOR DESIGNER MET PROJECTS				
PR ENGINEER				
PR TECH				
PROJECT / MET ENGINEER	DGS			15.01.2019
MET PROJECTS MANAGER	NAME			15.01.2019

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MET PROJECTS

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REGION SOUTH AFRICA REGION – VR
BUSINESS UNIT MINE WASTE SOLUTIONS
PROJECT MINE WASTE SOLUTION–KAREERAND EXTENSION PROJECT
DRAWING TITLE TSF TEST PIT AND BOREHOLE POSITIONS

PROJECT No:	B/UNIT	AREA	SEQ. No:	SIZE – A1
CWR1806001	FIGURE 4A			REV A

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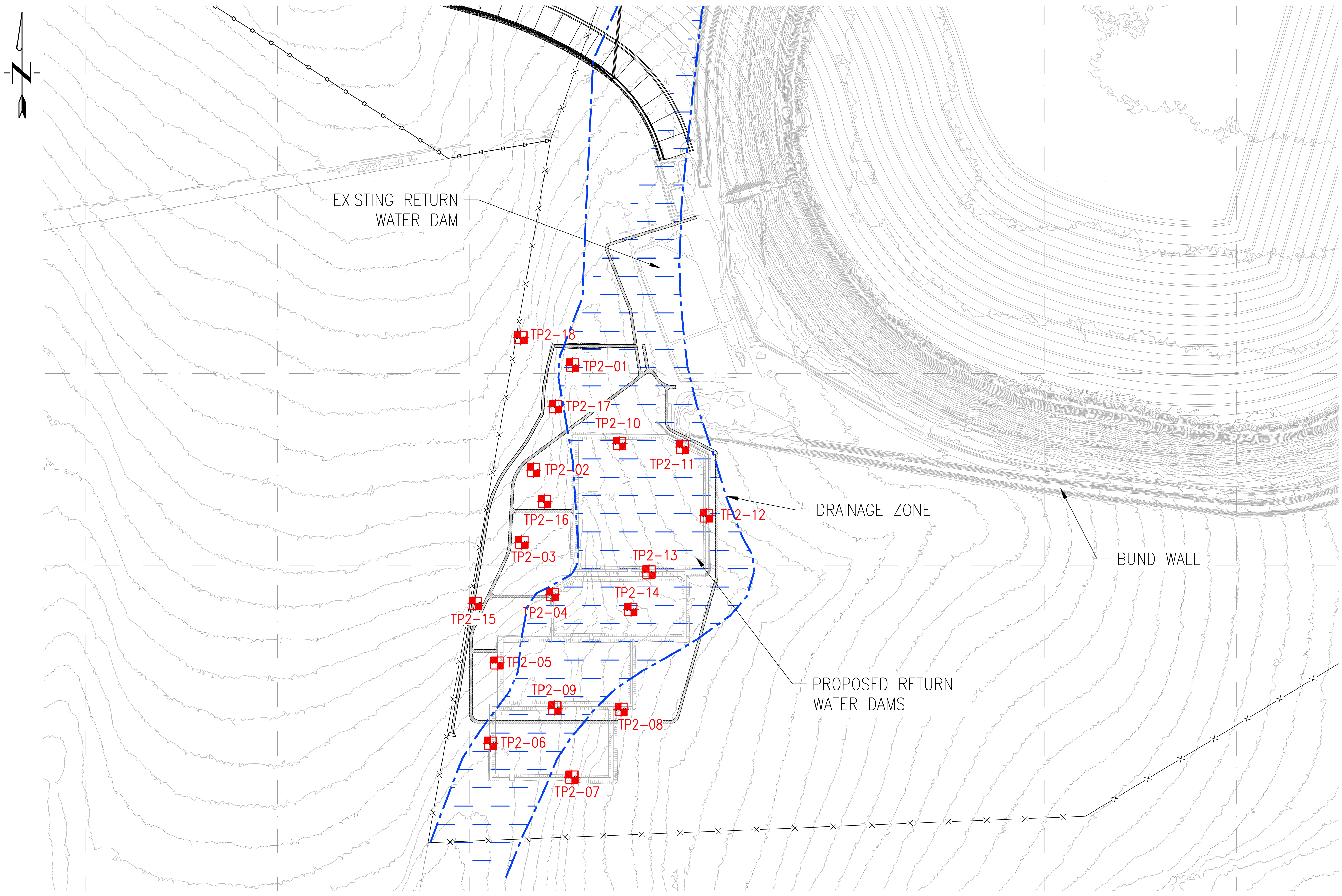

SITE LEGEND

EXISTING SITE LEGEND	
▨	EXISTING GRAVE SITES
— —HV—	EXISTING POWER LINE
— — —	EXISTING ACCESS ROADS
—— · · ——	EXISTING DELIVERY PIPELINES
▨	EXISTING PUMP STATION

GEOTECHNICAL LEGEND

🟥	TEST PITS

Knight Piésold CONSULTING

DESCRIPTION	DOCUMENT NUMBER	NAME	SIGNATURE	DATE
DESIGN CALCULATIONS				
RISK ASSESSMENT				

SCALE: 1:10000

TITLE	DRG. No
DIVERSION CHANNEL	FIGURE 4D
BUND WALL INSPECTION POSITIONS	FIGURE 4C
TSF TEST PIT POSITIONS	FIGURE 4A
SITE LAYOUT INDICATING POSITIONS OF STRUCTURES	FIGURE 3

REFERENCE DRAWINGS

DETAIL	MARK	DATE	INIT	APP'D
ISSUED FOR APPROVAL	A	24.01.2019		

REVISIONS

DESIGNATION	NAME	REGISTRATION No:	SIGNATURE	DATE
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CHECKED	DB			15.01.2019
SENIOR DESIGNER MET PROJECTS				
PR ENGINEER				
PR TECH				
PROJECT / MET ENGINEER	DGS			15.01.2019
MET PROJECTS MANAGER	NAME			15.01.2019

ANGLOGOLD ASHANTI

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MET PROJECTS

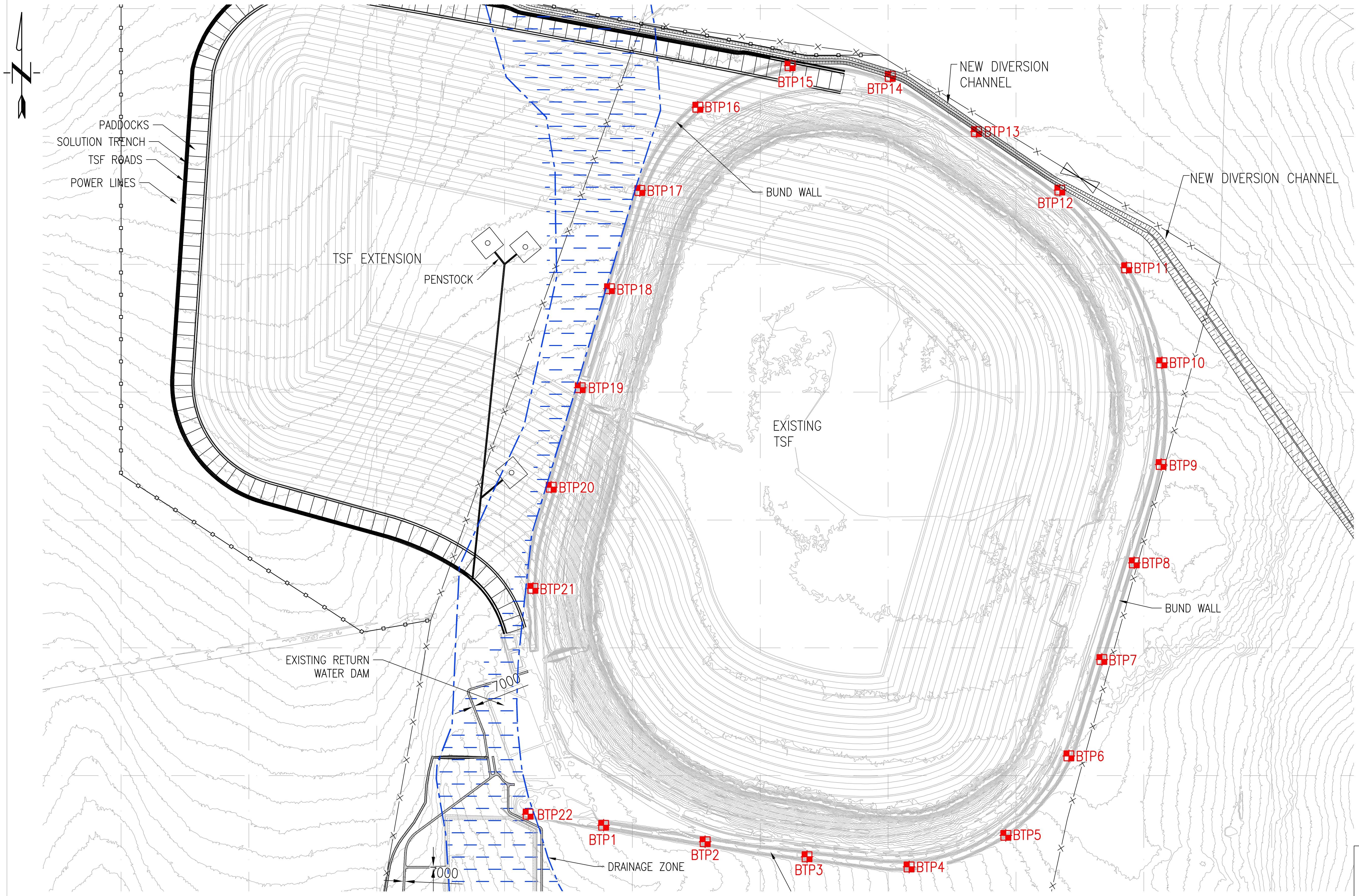
301-00204/13-004

REGION SOUTH AFRICA REGION – VR
BUSINESS UNIT MINE WASTE SOLUTIONS
PROJECT MINE WASTE SOLUTION–KAREERAND EXTENSION PROJECT
DRAWING TITLE RAW WATER DAM TEST PIT POSITIONS

PROJECT No:	B/UNIT AREA SEQ. No:	REV	SIZE
CWR1806001	FIGURE 4B	A	SIZE – A1

P:\301-00204\13\A\DATA\GEOTECHNICAL\11 DRAWINGS AND FIGURES\01 KP Drawings\2019-05-15\301-00204-13-Figures 3 To 4.dwg

MET PROJECTS | CWR1806001 | MET–MWS–39–C0004 | REV A



SITE LEGEND

EXISTING SITE LEGEND	
▨	EXISTING GRAVE SITES
— —HV—	EXISTING POWER LINE
— — —	EXISTING ACCESS ROADS
— · · —	EXISTING DELIVERY PIPELINES
▨	EXISTING PUMP STATION

GEOTECHNICAL LEGEND

🟥	TEST PITS

Knight Piésold CONSULTING

DESCRIPTION	DOCUMENT NUMBER	NAME	SIGNATURE	DATE
DESIGN CALCULATIONS				
RISK ASSESSMENT				

SCALE: 1:15000

TITLE	DRG. No
DIVERSION CHANNEL	FIGURE 4D
RAW WATER DAM TEST PIT POSITIONS	FIGURE 4B
TSF TEST PIT POSITIONS	FIGURE 4A
SITE LAYOUT INDICATING POSITIONS OF STRUCTURES	FIGURE 3

REFERENCE DRAWINGS

DETAIL	MARK	DATE	INIT	APP'D
ISSUED FOR APPROVAL	A	24.01.2019		

REVISIONS

DESIGNATION	NAME	REGISTRATION No:	SIGNATURE	DATE
DRAWN	DC			15.01.2019
CHECKED	DB			15.01.2019
SENIOR DESIGNER MET PROJECTS				
PR ENGINEER				
PR TECH				
PROJECT / MET ENGINEER	DGS			15.01.2019
MET PROJECTS MANAGER	NAME			15.01.2019

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MET PROJECTS

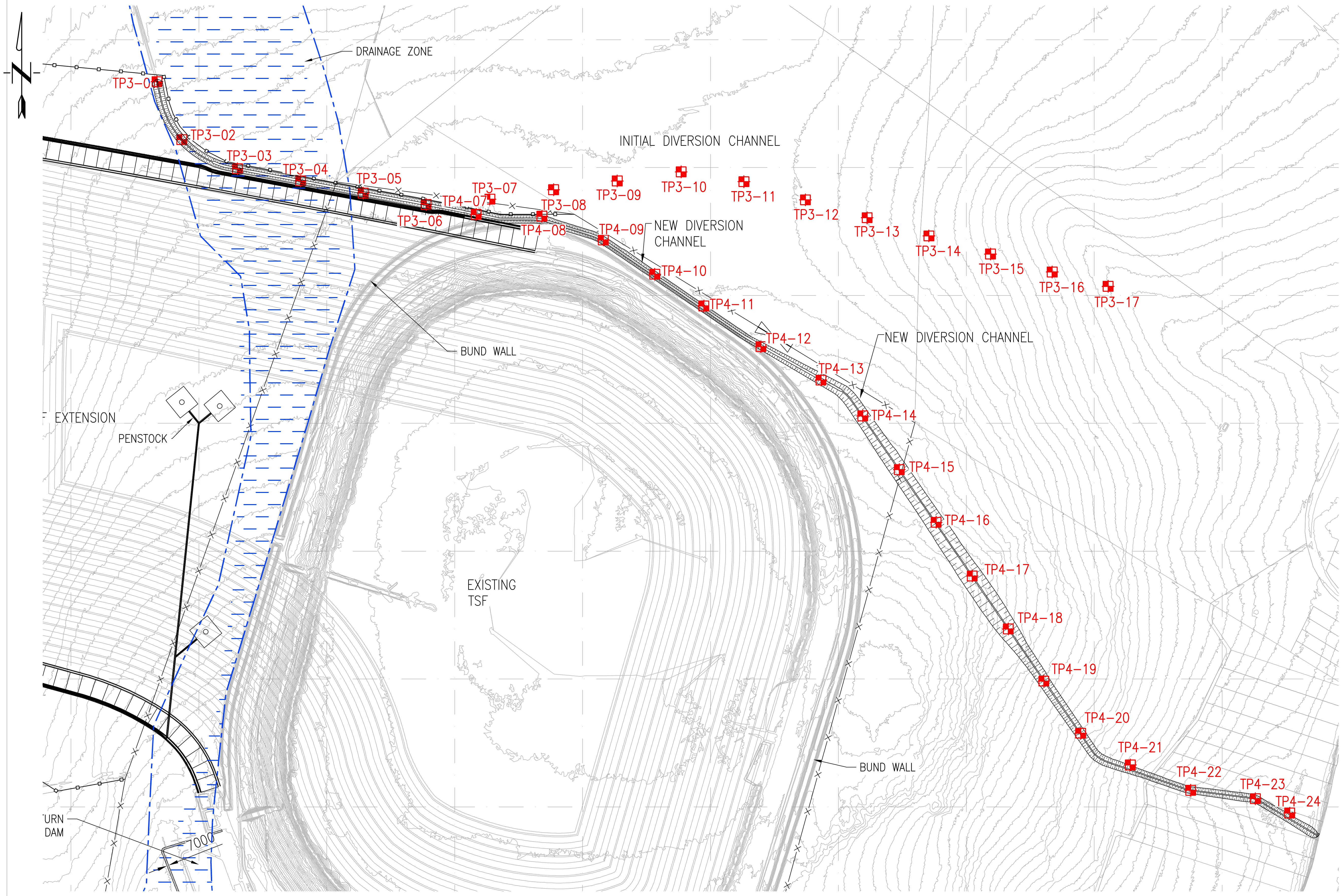
301–00204/13–004

REGION SOUTH AFRICA REGION – VR
BUSINESS UNIT MINE WASTE SOLUTIONS
PROJECT MINE WASTE SOLUTION–KAREERAND EXTENSION PROJECT
DRAWING TITLE BUND WALL INSPECTION POSITIONS

PROJECT No:	B/UNIT AREA SEQ. No:	REV
CWR1806001	FIGURE 4C	A

SIZE – A1

P:\301-00204\13\A\DATA\GEOTECHNICAL\11 DRAWINGS AND FIGURES\01 KP Drawings\2019-05-15\301-00204-13-Figures 3 To 4.dwg



SITE LEGEND

EXISTING SITE LEGEND	
◍	EXISTING GRAVE SITES
—HV—	EXISTING POWER LINE
— — —	EXISTING ACCESS ROADS
—· ·—	EXISTING DELIVERY PIPELINES
▨	EXISTING PUMP STATION

GEOTECHNICAL LEGEND

🟥	TEST PITS

Knight Piésold CONSULTING

DESCRIPTION	DOCUMENT NUMBER	NAME	SIGNATURE	DATE
DESIGN CALCULATIONS				
RISK ASSESSMENT				

SCALE: 1:15000

REFERENCE DRAWINGS

TITLE	DRG. No
BUND WALL INSPECTION POSITIONS	FIGURE 4C
RAW WATER DAM TEST PIT POSITIONS	FIGURE 4B
TSF TEST PIT POSITIONS	FIGURE 4A
SITE LAYOUT INDICATION POSITIONS OF STRUCTURES	FIGURE 3

REVISIONS

DETAIL	MARK	DATE	INIT	APP'D
ISSUED FOR APPROVAL	A	24.01.2019		

DESIGNATION	NAME	REGISTRATION No:	SIGNATURE	DATE
DRAWN	DC			15.01.2019
CHECKED	DB			15.01.2019
SENIOR DESIGNER MET PROJECTS				
PR ENGINEER				
PR TECH				
PROJECT / MET ENGINEER	DGS			15.01.2019
MET PROJECTS MANAGER	NAME			15.01.2019

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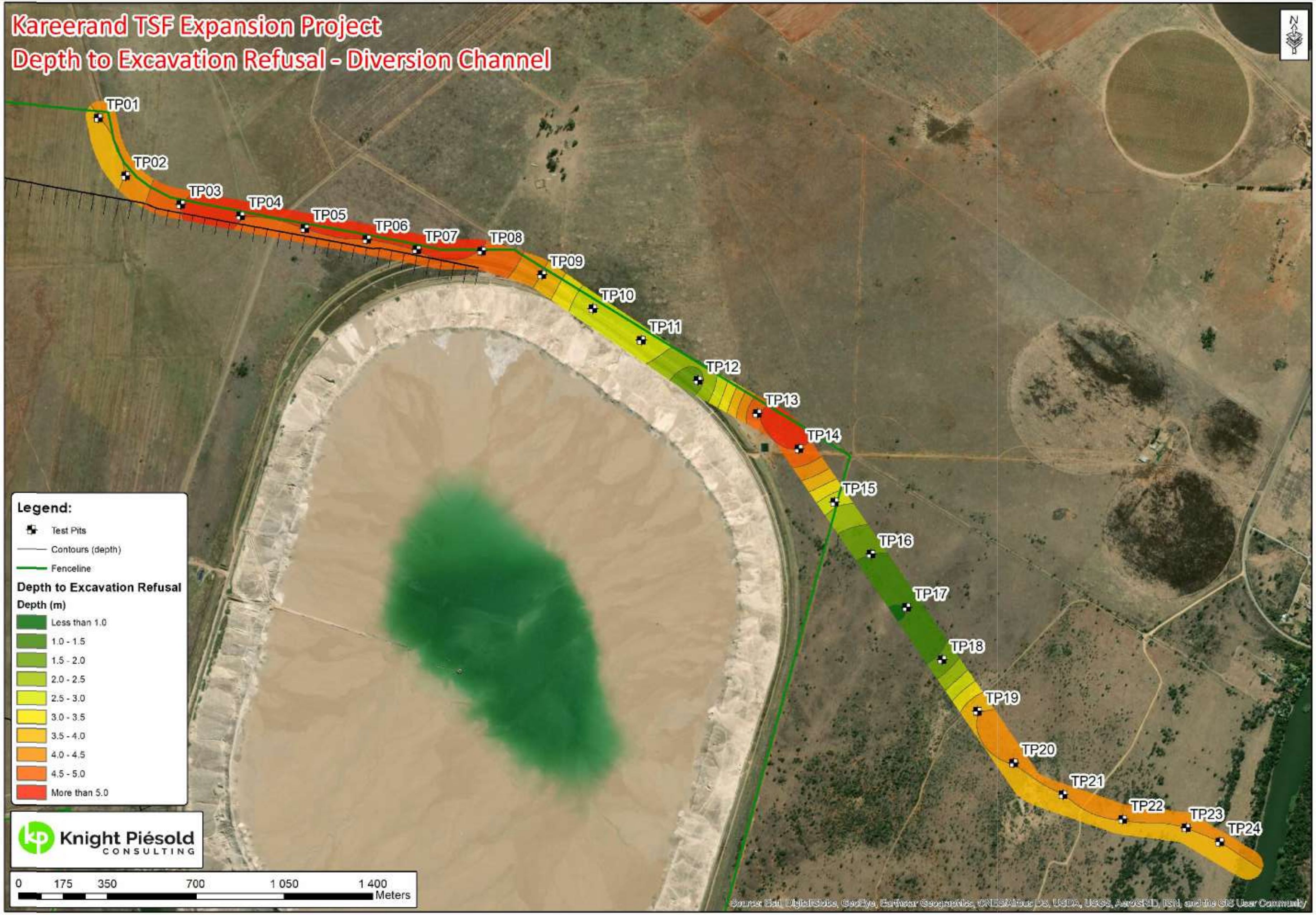
MET PROJECTS

301–00204/13–004

REGION SOUTH AFRICA REGION – VR
BUSINESS UNIT MINE WASTE SOLUTIONS
PROJECT MINE WASTE SOLUTION–KAREERAND EXTENSION PROJECT
DRAWING TITLE INITIAL AND NEW DIVERSION CHANNEL TEST PIT POSITIONS

PROJECT No:	B/UNIT AREA SEQ. No:	SIZE – A1
CWR1806001	FIGURE 4D	REV A

P:\301–00204\13\A\DATA\GEOTECHNICAL\11 DRAWINGS AND FIGURES\01 KP Drawings\2019–05–15\301–00204–13–Figures 3 To 4.dwg



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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KAREERAND TAILINGS STORAGE FACILITY - TSF EXTENSION PROJECT
GEOTECHNICAL INVESTIGATION

DEPTH TO EXCAVATION REFUSAL

PROJECT NO: 30100204/13

FIGURE NO 5

SCALE N.T.S.

APPENDIX A

SITE PHOTOGRAPHS

KAREERAND TAILING STORAGE FACILITY

SITE PHOTOGRAPHS

Plate 1: Savannah grassland covering the relatively flat site

Plate 2: View towards existing TSF

Plate 3: Dark brown to black colluvium at TP24

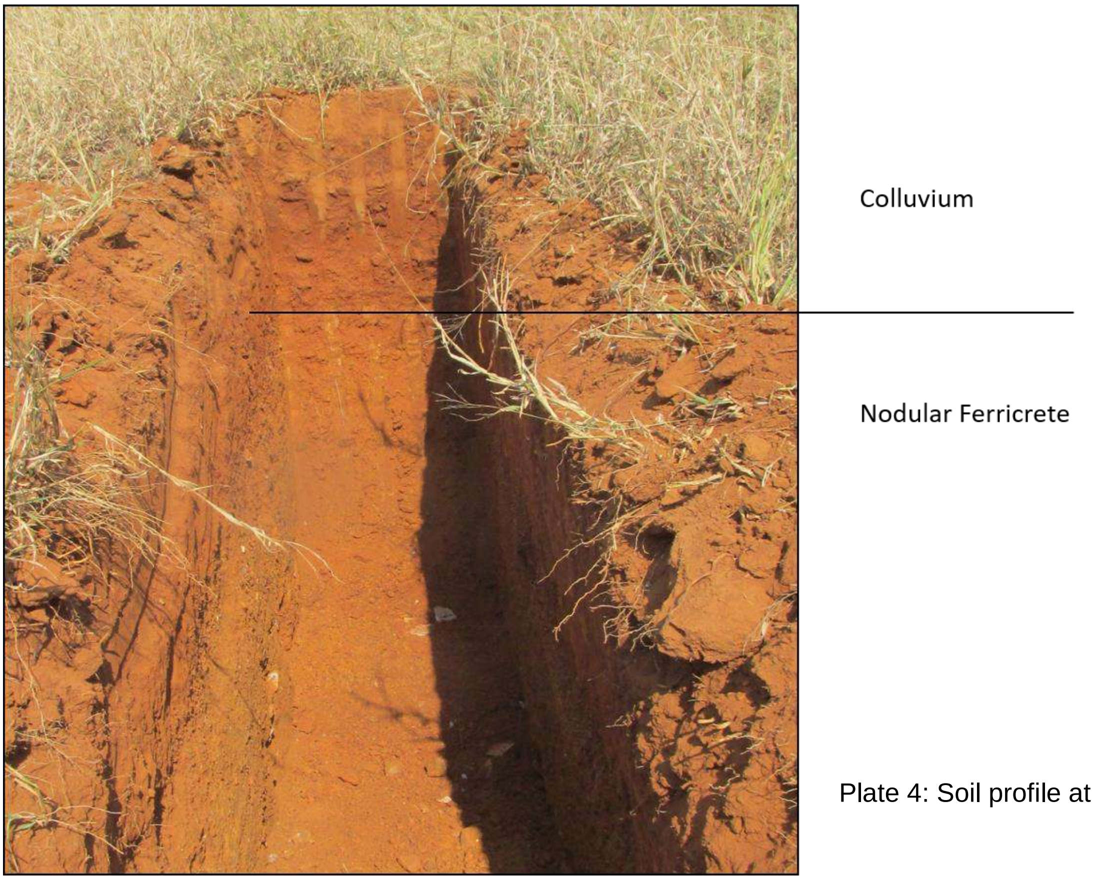

Plate 4: Soil profile at TP10

Plate 5: Upper finer reddish brown and lower yellowish brown residual andesite at TP8

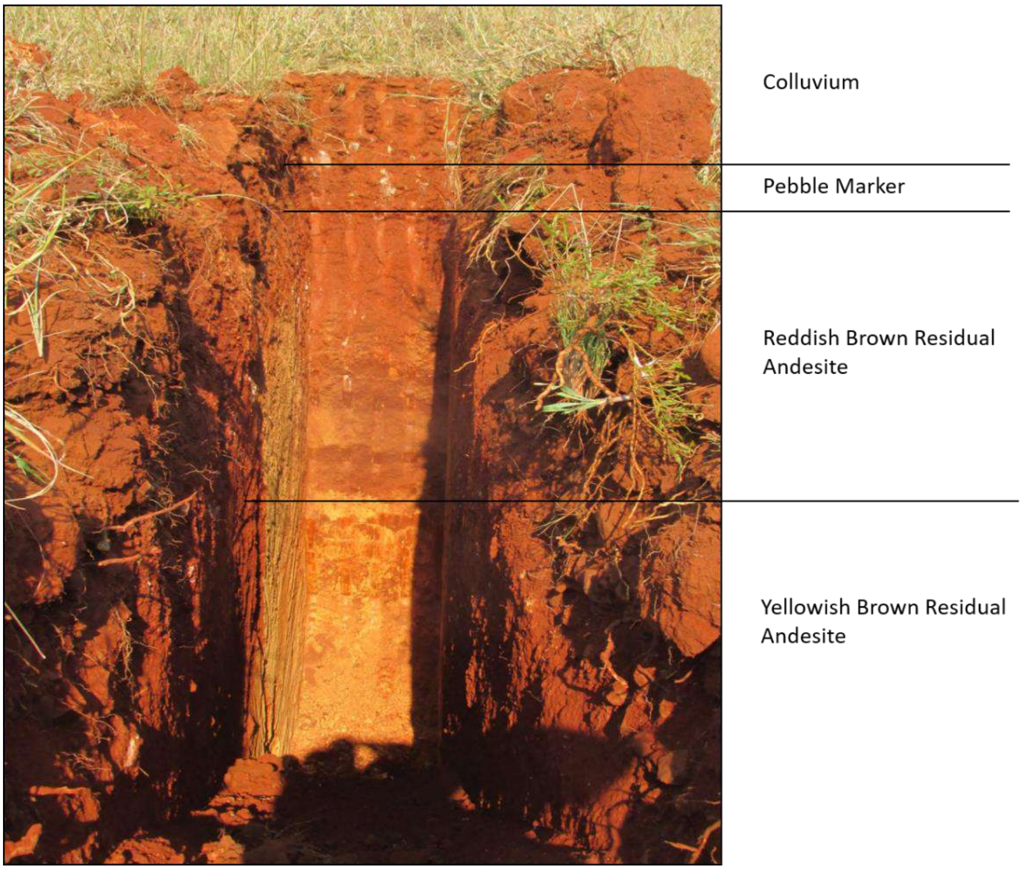

Plate 6: Soil profile at TP8

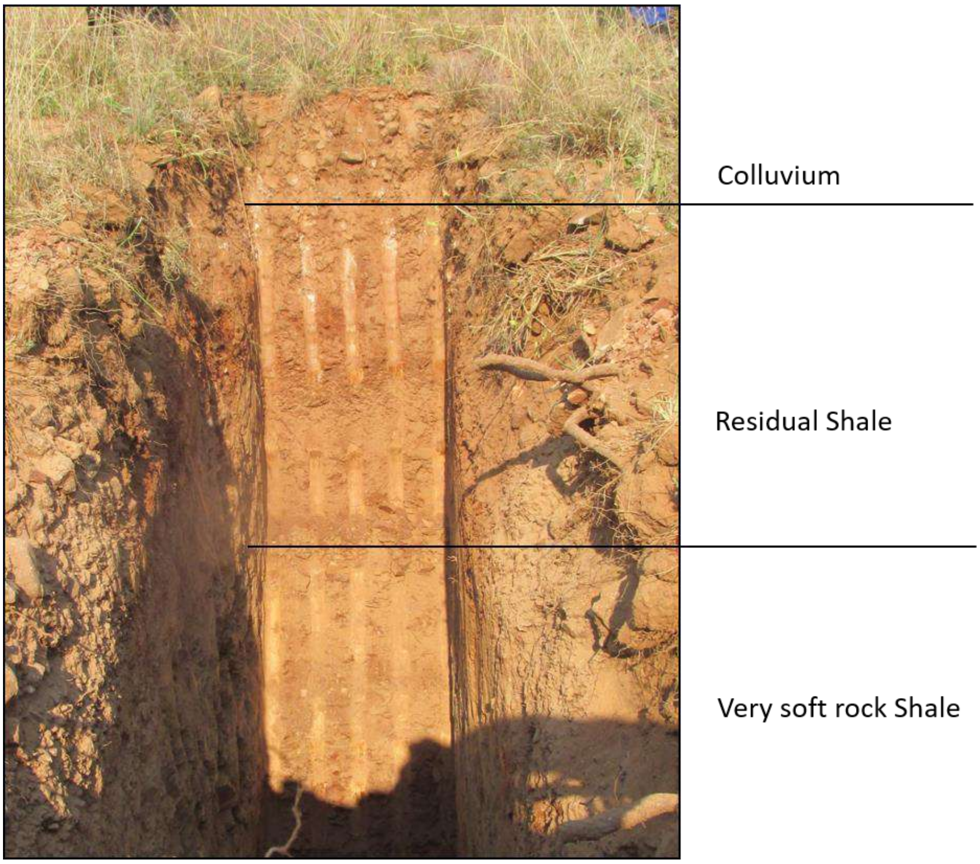

Plate 7: Soil profile at TP12

APPENDIX B

SOIL PROFILE LOGS

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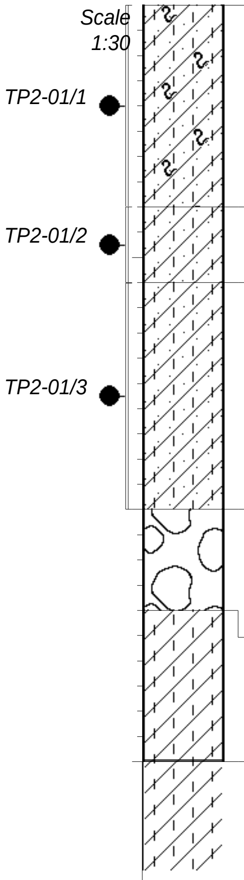
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-01
Sheet 1 of 1

JOB: 3010020413

Scale 1:30



0.00	Slightly moist to moist, dark brown, soft, intact with root voids and fine plant roots, fine silty sandy CLAY. **ALLUVIUM**.
0.80	Moist, grey brown, soft to firm, intact, sandy silty CLAY. **ALLUVIUM**.
1.10	Moist, orange brown blotched grey, soft, intact, sandy silty CLAY. **ALLUVIUM**.
2.00	Slightly moist, grey speckled white and orange, medium dense, clast supported, coarse-grained alluvium (boulder layer), with boulders up to 1,2m in length. **ALLUVIUM**.
2.40	Moist with wet zone and slow seepage from 2,6m, orange brown blotched grey, soft, silty CLAY, with trace fine sand. **ALLUVIUM**.
3.00	EOH: No refusal of excavator in material as above.

NOTES

1) No groundwater seepage encountered.

2) Small bag sample TP2-01/1 taken between 0,0m--0,8m.

3) Small bag sample TP2-01/2 taken between 0,8m--1,1m.

4) Small bag sample TP2-01/3 taken between 1,1m--2,0m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 4 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976478
Y-COORD : 12231

HOLE No: TP2-01

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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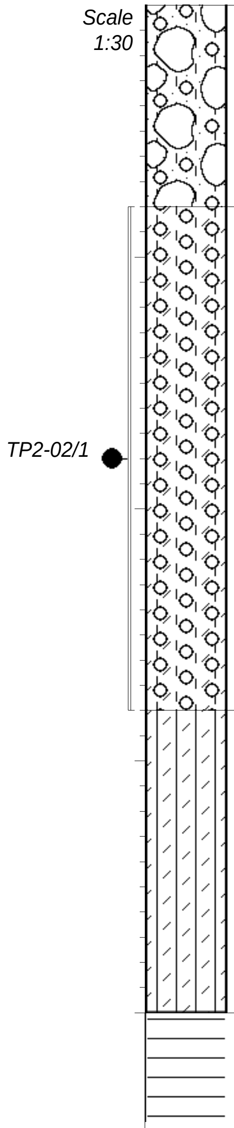
KAREERAND TSF EXTENSION
RETURN WATER DAM
PUMPSTATION

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-02
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00

Dry, brown to orange brown, <u>medium dense</u>, clast supported, fine sandy silty GRAVEL, comprising up to 800mm diameter rounded quartzite boulders. **COLLUVIUM**.

0.80

Slightly moist, reddish brown speckled black and orange, <u>stiff</u> to <u>dense,</u> shattered, ferruginous silty clayey GRAVEL, comprising angular <u>very soft</u> to <u>soft</u> rock shale. **RESIDUAL SHALE**.

2.80

Slightly moist, yellow brown, <u>stiff</u> to <u>very stiff</u>, intact and highly fractured, clayey SILT. **RESIDUAL SHALE**, becoming yellow brown stained red on joints, very closely jointed, highly to moderately weathered, <u>very soft</u> rock shale.

4.00

EOH: Slow excavation on material tending to <u>soft</u> rock SHALE.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Small bag sample TP2-02/1 taken between 0,8m--2,8m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 4 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976752
Y-COORD : 12332

HOLE No: TP2-02

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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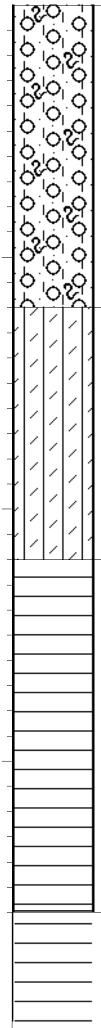
KAREERAND TSF EXTENSION
RETURN WATER DAM
PUMPSTATION

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-03
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00

Dry, brown, <u>medium dense</u>, intact with root voids and fine plant roots, silty sandy GRAVEL, comprising rounded to subrounded quartzite cobbles up to 150mm diameter in the upper 600mm, becoming ferruginous quartzite and shale gravel to 1,2m. **COLLUVIUM**.

1.20

Slightly moist, greenish yellow, <u>firm</u> gradually becoming <u>stiff</u>, intact, clayey SILT. **RESIDUAL SHALE**.

2.20

Highly weathered, light brown to yellow brown stained brown and black along joints, very fine-grained, thinly laminate and thinly bedded, very closely jointed, <u>very soft</u> rock tending to <u>soft</u> rock SHALE.

3.60

EOH: Slow excavation in material as above.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 4 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976940
Y-COORD : 12363

HOLE No: TP2-03

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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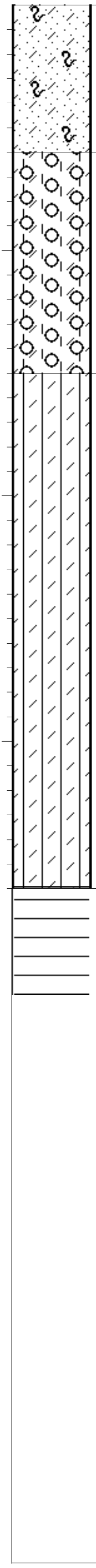
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-04
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, dark brown, medium dense, intact with root voids and fine plant roots, clayey fine SAND, with occasional subrounded quartzite cobbles up to 80mm diameter at the base. **ALLUVIUM**.
0.60	Slightly moist, orange brown speckled black and reddish brown, medium dense, clayey silty GRAVEL, comprising angular to rounded quartzite and shale, with occasional boulders up to 200mm diameter. Ferruginised **COLLUVIUM**.
1.50	Slightly moist, yellow brown, stiff, intact and relict jointed, clayey SILT. **RESIDUAL SHALE**, tending to highly weathered, yellow brown stained black and red along joints, very closely jointed, very fine-grained, very soft to soft rock shale with depth.
3.60	EOH: Slow excavation on soft rock SHALE.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977077
Y-COORD : 12283

HOLE No: TP2-04

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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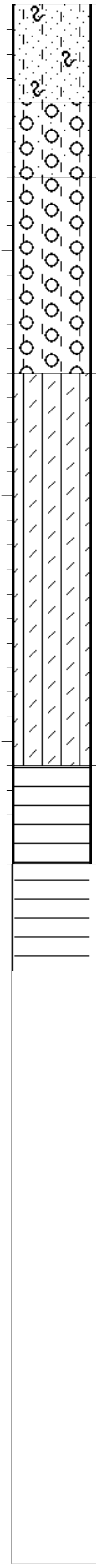
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-05
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, brown, medium dense, root and biotic voids with plant roots, silty fine SAND. **COLLUVIUM**.
0.40	Dry, brown, medium dense, clast supported, silty sandy GRAVEL, comprising rounded and subrounded quartzite pebbles up to 60mm diameter. **COLLUVIUM**.
0.70	Slightly moist, yellow brown speckled black and red brown, medium dense, ferruginous silty GRAVEL, comprising angular to sub-angular shale fragments. Ferruginous **RESIDUAL SHALE**.
1.50	Slightly moist, yellow brown stained black and red on relict joints, firm becoming stiff with depth, relict jointed, clayey SILT. **RESIDUAL SHALE**.
3.10	Highly weathered, yellow brown stained black and red along joints, very fine-grained, very closely jointed, thinly bedded and laminated, very soft rock becoming soft rock SHALE.
3.50	EOH: Slow excavation on soft rock SHALE.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Shale dips north-east.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977255
Y-COORD : 12428

HOLE No: TP2-05

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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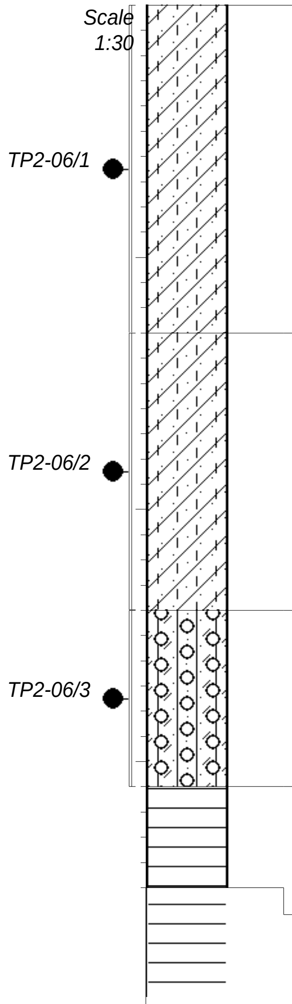
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-06
Sheet 1 of 1

JOB: 3010020413



0.00

Dry to slightly moist, dark brown, firm to soft, root voided and slight desiccation cracks, sandy silty CLAY. **ALLUVIUM**.

1.30

Slightly moist, yellow brown to reddish brown, firm becoming stiff with depth, intact, sandy silty CLAY, with sand lenses and occasional cobbles of quartzite up to 80mm diameter and prominent pebble layer at base. **ALLUVIUM**.

2.40

Slightly moist, yellow brown streaked black, firm, relict jointed, sandy clayey SILT, with abundant gravel. **RESIDUAL SHALE**, gradually becoming very soft rock shale below.

3.10

Highly weathered, yellow and red brown stained black along joints notable at depth, very closely jointed, very fine-grained, thinly bedded and laminated, very soft rock tending to soft rock SHALE.

3.50

EOH: Slow excavation on very soft tending to soft rock SHALE.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Bulk sample TP2-06/1 taken between 0,0m--1,3m.

4) Bulk sample TP2-06/2 taken between 1,3m--2,4m.

5) Bulk sample TP2-06/3 taken between 2,4m--3,1m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977464
Y-COORD : 12445

HOLE No: TP2-06

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

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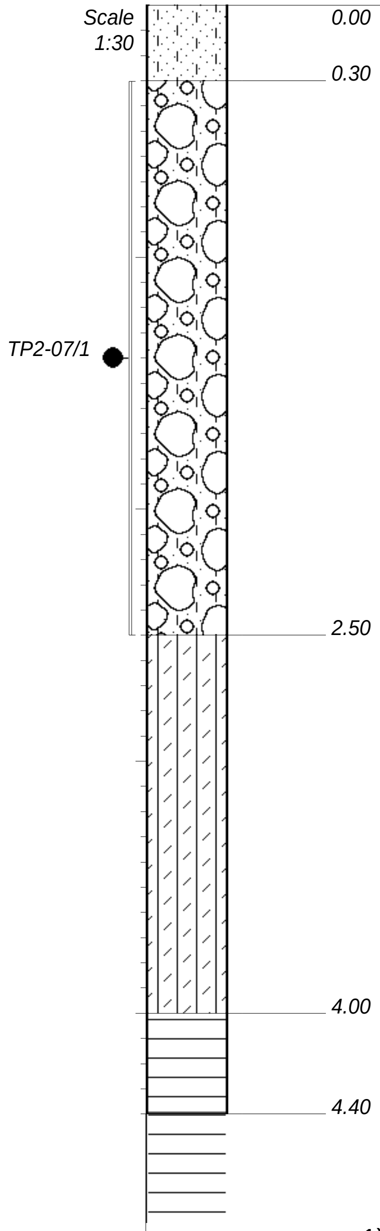
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-07
Sheet 1 of 1

JOB: 3010020413



Dry, orange brown, <u>loose</u>, root voided, silty fine SAND. **COLLUVIUM**.

Slightly moist, light brown speckled black, <u>loose</u>, root voided, silty fine sandy GRAVEL. Basal pebble marker, with large angular sandstone boulders up to 500mm diameter. Layer thickness varies to depth of 1,5m to 2,5m within test pit. Ferruginised **COLLUVIUM**.

Slightly moist becoming moist below 3,4m, grey blotched orange brown, <u>soft</u> to <u>firm</u>, slightly sandy clayey SILT. **RESIDUAL SHALE**, tending to <u>very soft</u> rock with depth.

Highly weathered, light grey to light yellow, very closely jointed, very fine-grained, thinly bedded and laminated, <u>soft</u> rock SHALE.

EOH: Slow excavation in material as above.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Small bag sample TP2-07/1 taken between 0,3m--2,5m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977552
Y-COORD : 12232

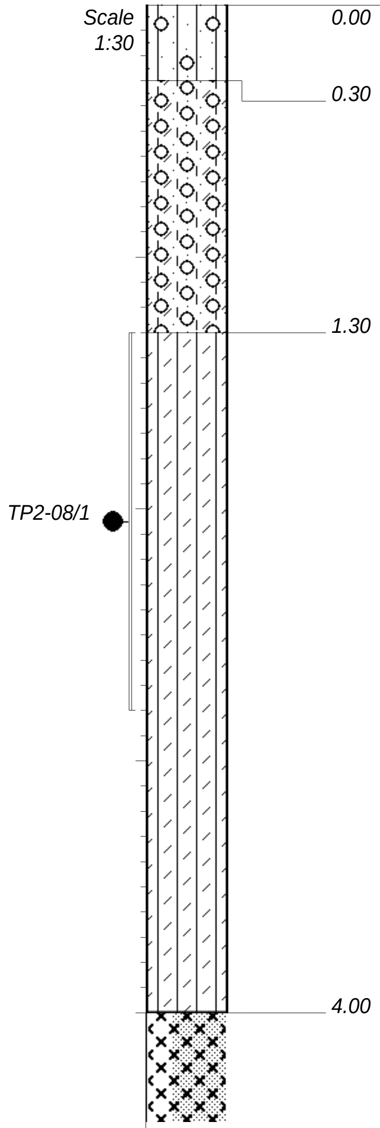
HOLE No: TP2-07

KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-08
Sheet 1 of 1

JOB: 3010020413



0.00 – 0.30: Slightly moist, brown, firm, root voided, gravelly fine sandy SILT. **COLLUVIUM**.

0.30 – 1.30: Slightly moist, reddish brown speckled black, clast supported, sandy silty clayey GRAVEL, comprising rounded quartzite up to 50mm and dolerite boulders up to 1m diameter. Overall consistency medium dense. **COLLUVIUM**.

1.30 – 4.00: Slightly moist, reddish brown becoming yellow brown speckled white and black form 2,8m, soft becoming firm, massive and relict jointed stained black, slightly fine sandy clayey SILT. **RESIDUAL DOLERITE**.
Grain size medium-grained.

EOH: No refusal of excavator on firm to stiff residual dolerite and some very soft rock dolerite zones.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Bulk sample TP2-08/1 taken between 1,3m--2,8m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977376
Y-COORD : 12104

HOLE No: TP2-08

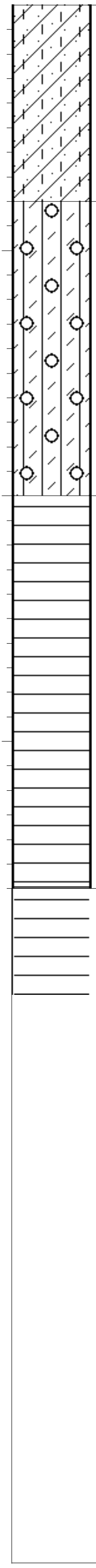
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-09
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, dark brown, stiff, slight desiccation, shattered and root voided, fine sandy silty CLAY. **ALLUVIUM**.
0.80	Slightly moist, orange brown speckled black and grey, firm, matrix supported, gravelly clayey SILT. **COLLUVIUM**. Gravel comprises up to 400mm diameter quartzite shale and scattered dolerite subrounded boulders.
2.00	Highly weathered, yellow brown stained orange and black along joints, very fine-grained, very closely jointed, thinly bedded and laminated, very soft rock SHALE, becoming soft rock shale from 2,8m.
3.60	EOH: Refusal of excavator on soft rock SHALE, tending to medium hard rock.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

3) Machine breakdown (hydraulic pipe) at 14:15. No repair same day to organise TLB/excavator for next day.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 5 September 2018

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD :
Y-COORD :

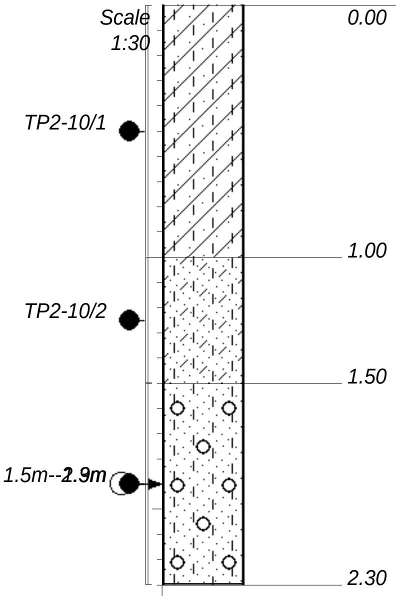
HOLE No: TP2-09

KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-10
Sheet 1 of 1

JOB: 3010020413



Slightly moist, dark brown, soft, intact with root voids, sandy silty CLAY. **ALLUVIUM**.

Slightly moist becoming moist, grey speckled green, loose, shattered, clayey silty SAND, with abundant gravel. **ALLUVIUM**.

Moist to wet, grey blotched orange speckled green, loose to dense in places, relict core stones, silty gravelly SAND, with completely weathered dolerite core stones. Ferruginous **ALLUVIUM**.

EOH: Hole terminated as excavator kept sliding (spade excavator, not teeth).

NOTES

1) Slow groundwater seepage encountered from 1,9m.

2) Small bag sample TP2-10/1 taken between 0,0m--1,0m.

3) Small bag sample TP2-10/2 taken between 1,0m--1,5m.

4) Small bag sample Tp2-10/3 taken between 1,5m--2,3m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976683
Y-COORD : 12108

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

HOLE No: TP2-10

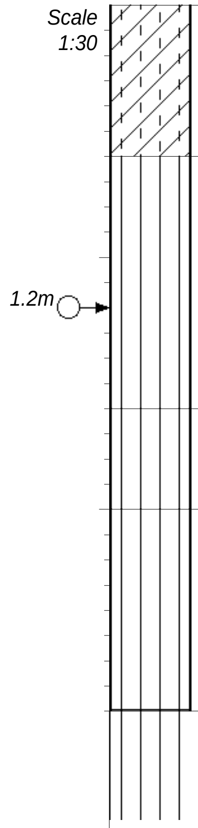
Knight Piésold CONSULTING

KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-11
Sheet 1 of 1

JOB: 3010020413



0.00	Slightly moist, dark brown, soft, intact and root voided, silty CLAY. **ALLUVIUM**.
0.60	Slightly moist to wet, grey brown occasionally speckled green, soft, shattered, slightly sandy SILT. **ALLUVIUM**.
1.60	Wet, grey blotched orange, firm to stiff, shattered, slightly sandy SILT. **ALLUVIUM**.
2.00	Wet, grey blotched orange, stiff, intact and matrix supported, slightly sandy SILT, with angular to subrounded quartzite and dolerite cobbles up to 300mm diameter. Possible pebble marker horizon. **ALLUVIUM**.
2.80	EOH: Excavation stopped due to slow progress of smooth blade excavator on material as above.

NOTES

1) Groundwater seepage encountered at 1,2m with pipe-like formation.

2) Unstable sidewalls with water profiled in situ to 1,2m. No entrance to pit after 1,2m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976692
Y-COORD : 11945

HOLE No: TP2-11

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

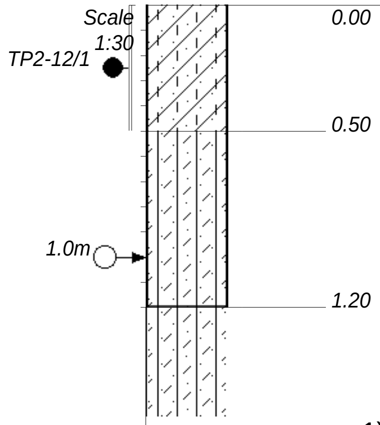
DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-12
Sheet 1 of 1

JOB: 3010020413



Slightly moist, dark brown, firm, intact with root voids, sandy silty CLAY. **ALLUVIUM**.

Slightly moist becoming moist and wet, grey, soft, slightly shattered, fine sandy clayey SILT. **ALLUVIUM**.

EOH: Excavator stopped in material as above.

NOTES

1) Strong groundwater seepage encountered at 1,0m, pipe-like seepage from side and base of test pit.

2) Unstable sidewalls.

3) No entry to pit.

4) Bulk sample TP2-12/1 taken between 0,0m--0,5m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976871
Y-COORD : 11881

HOLE No: TP2-12

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

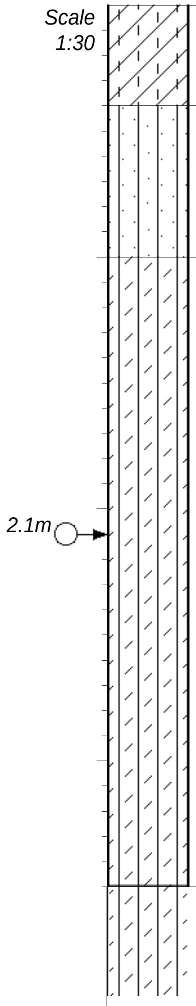
DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-13
Sheet 1 of 1

JOB: 3010020413



0.00	Slightly moist to moist, dark brown, <u>soft</u>, intact and root voided, slightly sandy silty CLAY. **ALLUVIUM**.
0.40	Moist, grey speckled black, <u>soft</u>, shattered, slightly sandy SILT. **RESIDUAL DOLERITE**.
1.00	Moist, orange speckled black and beige along joints, <u>firm</u> occasionally <u>stiff</u>, slightly sandy clayey SILT. **RESIDUAL DOLERITE**, with relict structure and core stones, becoming completely weathered dolerite from 2,3m with sub-vertical joints.
3.50	EOH: Slow refusal of flat/smooth blade excavator against large core stones.

NOTES

1) Slow groundwater seepage encountered from 2,1m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977017
Y-COORD : 12032

HOLE No: TP2-13

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C:\WP51\PROFILES\ODDBK.TXT

Knight Piésold CONSULTING

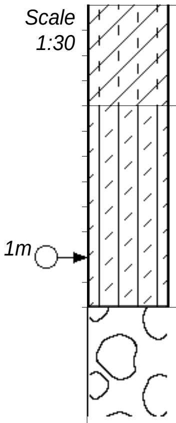
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-14
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Moist, dark brown, <u>soft</u>, slightly shattered, silty CLAY, with subrounded quartzite gravel at the base. **ALLUVIUM**.
0.40	Moist to wet, grey speckled white, <u>soft</u>, slightly sandy clayey SILT, with large rounded sandstone cobbles up to 300mm diameter. **ALLUVIUM**.
1.20	EOH: Refusal on excavator on boulder layer.

NOTES

1) Slow groundwater seepage encountered at 1m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977115
Y-COORD : 12079

HOLE No: TP2-14

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

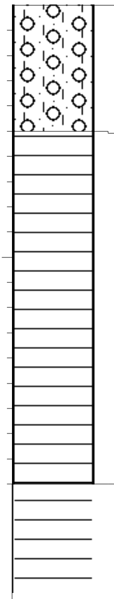
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-15
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00

Slightly moist, orange brown, loose, intact with root voids, silty sandy GRAVEL. **COLLUVIUM**. Gravel comprises subrounded quartzite gravel up to 8mm diameter.

0.50

Highly weathered, pinkish brown stained yellow brown, reddish brown and black along joints, very fine-grained, thinly bedded and laminated, very closely jointed, very soft rock SHALE, with completely weathered zones along joints.

1.90

EOH: Slow excavation on material as above.

NOTES

1) No groundwater seepage encountered.

2) Stable sidewalls.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2977100
Y-COORD : 12484

HOLE No: TP2-15

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

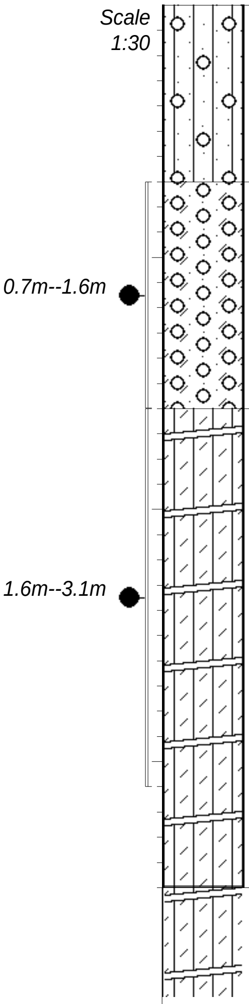
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-16
Sheet 1 of 1

JOB: 3010020413

Scale 1:30



0.00	Dry, brown, soft, intact, matrix supported, gravelly sandy SILT. **COLLUVIUM**. Gravel comprises angular to subrounded sandstone boulders up to 500mm diameter.
0.70	Slightly moist, orange brown blotched reddish brown speckled black, medium dense, intact to root channel voids, sandy clayey GRAVEL. Ferruginised **COLLUVIUM**. Gravel comprises small rounded quartzite gravel and angular shale fragments up to 25mm diameter.
1.60	Slightly moist, yellow brown, firm, relict jointed, clayey SILT. **RESIDUAL SHALE**, with very soft rock shale bands, becoming stiff with depth and becoming very soft rock shale from 3,1m.
3.50	EOH: Slow excavation on material as above.

NOTES

1) No groundwater seepage encountered.

2) Two bulk samples and one small bag sample taken between 0,7m--1,6m; 1,6m--3,1m.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

DATE : 24/01/2019 09:05
TEXT : C:\WP51\PROFILES\ODDBK.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976833
Y-COORD : 12304

HOLE No: TP2-16

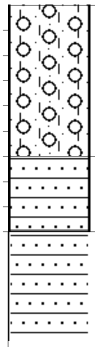
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-17
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, brown, <u>medium dense</u> to <u>loose</u>, intact and root voided, silty sandy GRAVEL. **COLLUVIUM**. Gravel comprises subrounded quartzite gravel, with scattered sandstone boulders and pockets of loose sandstone bands.
0.60	Highly weathered, light brown to pink brown stained orange and red along joints, medium-grained, very closely jointed, thinly bedded, <u>medium hard</u> rock SANDSTONE.
0.90	EOH: Refusal of excavator on <u>medium hard</u> rock SANDSTONE.

NOTES
1) No groundwater seepage encountered.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976586
Y-COORD : 12276

HOLE No: TP2-17

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

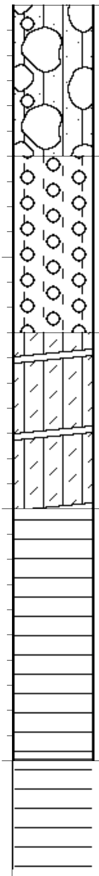
KAREERAND TSF EXTENSION
RETURN WATER DAM

GEOTECHNICAL INVESTIGATION

HOLE No: TP2-18
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, brown, <u>soft</u>, intact, gravelly sandy SILT. **COLLUVIUM**. Gravel comprises angular to subrounded sandstone boulders up to 20mm diameter.
0.60	Slightly moist, orange brown blotched reddish brown speckled black, <u>medium dense</u>, intact with root voids, silty GRAVEL. Ferruginous **COLLUVIUM**, comprising shale fragments and subrounded quartzite.
1.30	Slightly moist, yellow brown, <u>firm</u>, relict jointed, clayey SILT, with <u>very soft</u> rock shale bands. **RESIDUAL SHALE**.
2.00	Highly weathered, yellow brown stained black and red along joints, very fine-grained, thinly bedded and laminated, <u>very soft</u> rock SHALE.
3.00	EOH: Slow excavation on <u>very soft</u> rock SHALE, tending to <u>soft</u> rock.

NOTES

1) No groundwater seepage encountered.

2) Shale dips east-northeast.

CONTRACTOR : Shomene
MACHINE : Excavator 20 Ton
DRILLED BY : Joseph & Victor
PROFILED BY : BK

INCLINATION :
DIAM :
DATE :
DATE : 6 September 2018

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2976407
Y-COORD : 12366

HOLE No: TP2-18

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

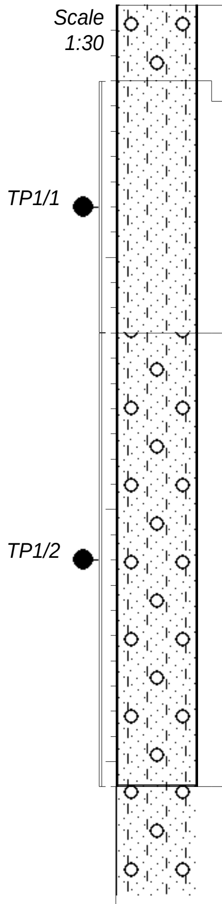
DATE : 24/01/2019 09:05
TEXT : C\WP51\PROFILES\ODDBK.TXT

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-01
Sheet 1 of 1

JOB: 3010020413



0.00	Dry, orange brown, medium dense, intact, silty fine SAND, with scattered gravel. **TOPSOIL**.
0.30	Dry, orange brown, dense, pinhole voided, silty fine SAND. **COLLUVIUM**.
1.30	Dry, brown mottled black, very dense, intact, gravelly silty SAND, with minor ferricrete nodules. Ferruginised **COLLUVIUM**.
3.10	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Small bag sample TP1/1 taken between 0,3m--1,3m.

3) Small bag sample TP1/2 taken between 1,3m--3,1m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973164
Y-COORD : 12164

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

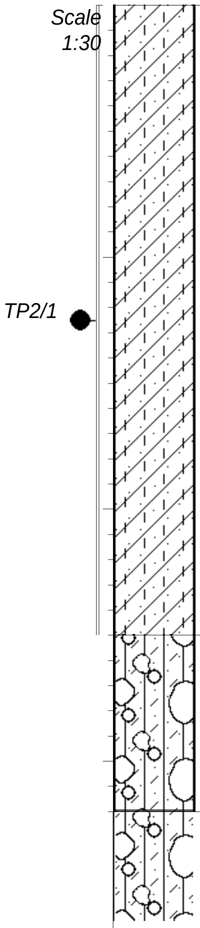
HOLE No: TP3-01

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-02
Sheet 1 of 1

JOB: 3010020413



0.00

Dry, dark brown black, stiff, shattered, sandy silty CLAY. **ALLUVIUM**.

2.50

Slightly moist, grey mottled orange brown and black, firm, intact, sandy clayey SILT, with scattered subrounded gravel and cobbles. **ALLUVIUM**.

3.20

EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Bulk sample TP2/1 taken between 0,0m--2,5m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973390
Y-COORD : 12067

HOLE No: TP3-02

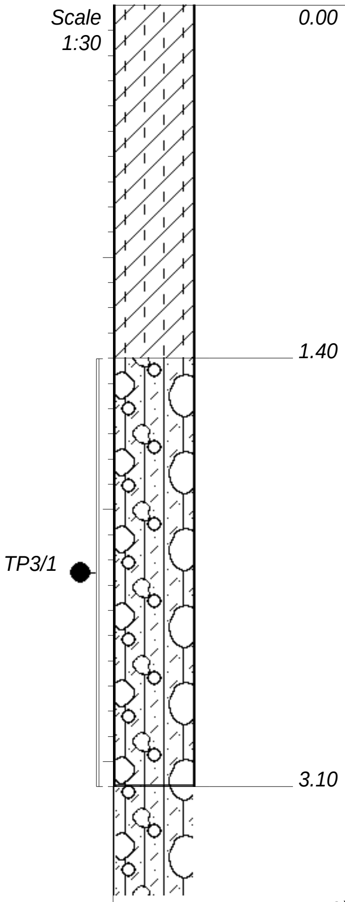
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-03
Sheet 1 of 1

JOB: 3010020413

Scale 1:30



Dry, dark brown, stiff, shattered, silty CLAY. **ALLUVIUM**.

Dry, grey mottled orange and greyish white, stiff, intact, sandy clayey SILT, with scattered subrounded and sub-angular gravel and cobbles. **ALLUVIUM**.

EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Bulk sample TP3/1 taken between 1,4m--3,1m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973504
Y-COORD : 11849

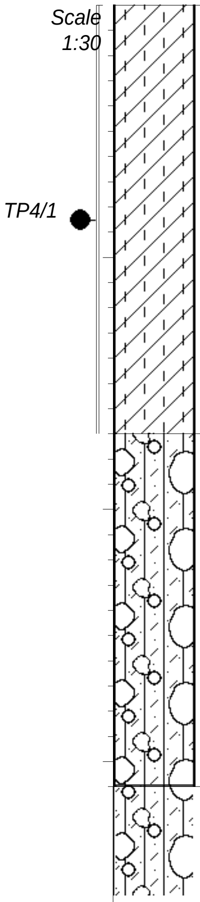
HOLE No: TP3-03

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-04
Sheet 1 of 1

JOB: 3010020413



0.00

Dry, dark brown, stiff, shattered, silty CLAY. **ALLUVIUM**.

1.70

Dry, grey, firm, intact, sandy clayey SILT, with scattered gravel and sub-angular and subrounded cobbles. **ALLUVIUM**.

3.10

EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Small bag sample TP4/1 taken between 0,0m--1,7m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973552
Y-COORD : 11602

HOLE No: TP3-04

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

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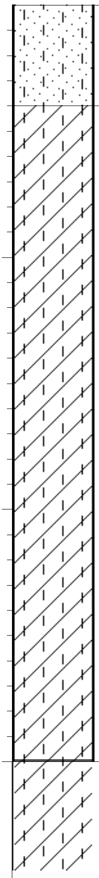
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-05
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, brown, medium dense occasionally dense, intact, silty fine SAND, with minor fine roots. **COLLUVIUM**.
0.40	Dry becoming slightly moist below 1m, orange brown mottled black, stiff, slightly slickensided, silty CLAY. Ferruginised **RESIDUAL ANDESITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973600
Y-COORD : 11358

HOLE No: TP3-05

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

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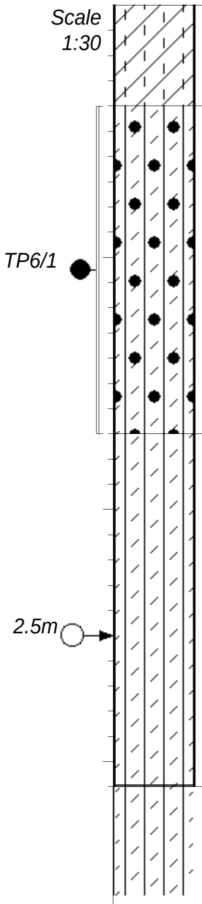
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-06
Sheet 1 of 1

JOB: 3010020413



0.00	Slightly moist, reddish brown, <u>firm</u>, intact, silty CLAY. **COLLUVIUM**.
0.40	Moist, reddish brown mottled black and yellow, <u>dense</u> occasionally <u>medium dense</u>, intact, clayey SILT, with abundant ferricrete nodules. **NODULAR FERRICRETE**.
1.70	Very moist with wet zones, yellowish brown and reddish brown above 2,5m, <u>soft</u>, intact, clayey SILT. **RESIDUAL ANDESITE.**
3.10	EOH: Maximum reach of TLB in material as above.

NOTES

1) Very slight groundwater seepage encountered below 2,5m.

2) Small bag sample TP6/1 taken between 0,4m--1,7m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973644
Y-COORD : 11111

HOLE No: TP3-06

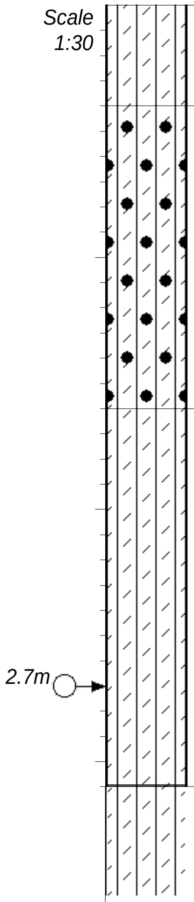
Knight Piésold CONSULTING

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-07
Sheet 1 of 1

JOB: 3010020413



0.00	Slightly moist, reddish brown, <u>firm</u>, intact, clayey SILT. **COLLUVIUM**.
0.40	Moist, reddish and yellowish brown mottled black, <u>medium dense</u>, intact, clayey SILT, with abundant ferricrete nodules. **NODULAR FERRICRETE**.
1.60	Very moist occasionally wet, yellowish and reddish brown, <u>soft</u>, intact, clayey SILT. **RSEIDUAL ANDESITE**.
3.10	EOH: Maximum reach of TLB in material as above.

NOTES

1) Very slight groundwater seepage encountered below 2,7m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973623
Y-COORD : 10862

HOLE No: TP3-07

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

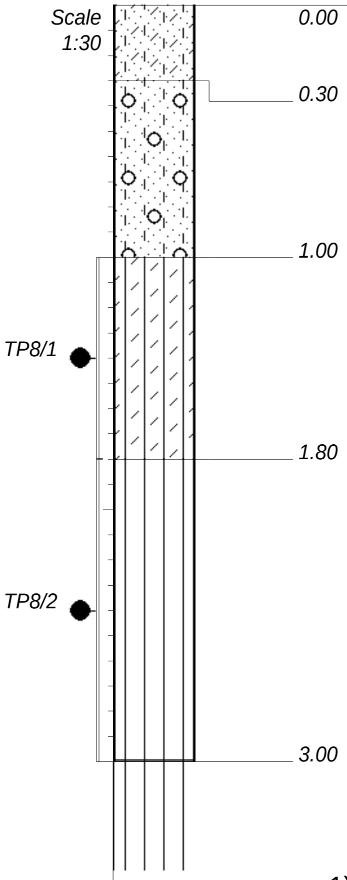
DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-08
Sheet 1 of 1

JOB: 3010020413



Dry, reddish brown, <u>medium dense</u>, intact, clayey silty SAND. **COLLUVIUM**.

Dry, reddish brown blotched black and grey, <u>dense</u>, intact, silty SAND, with abundant gravel. Ferruginised **PEBBLE MARKER**.

Slightly moist, reddish brown mottled black, <u>firm</u>, intact, clayey SILT. Ferruginous **RESIDUAL ANDESITE**.

Slightly moist, yellowish brown mottled black, <u>soft</u>, intact, slightly clayey SILT. **RESIDUAL ANDESITE**.

EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Small bag sample TP8/1 taken between 1,0m--1,8m.

3) Small bag sample TP8/2 taken between 1,8m--3,0m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973586
Y-COORD : 10613

HOLE No: TP3-08

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

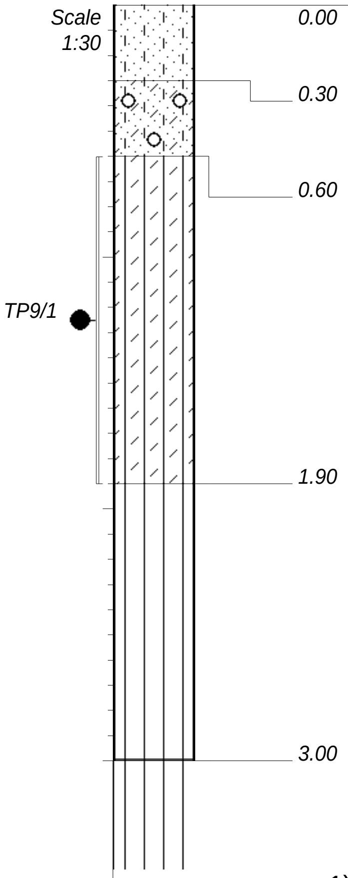
DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-09
Sheet 1 of 1

JOB: 3010020413



0.00	Dry, brown, <u>medium dense</u>, intact, silty SAND, with minor fine roots. **COLLUVIUM**.
0.30	Dry, reddish brown mottled black, <u>dense</u>, intact, clayey silty SAND, with abundant gravel. Ferruginous **PEBBLE MARKER**.
0.60	Dry, reddish brown, <u>stiff</u>, slightly pinhole voided, clayey SILT. Ferruginous **RESIDUAL ANDESITE**.
1.90	Slightly moist, yellowish brown mottled black, <u>firm</u>, intact, slightly clayey SILT. **RESIDUAL ANDESITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Bulk sample TP9/1 taken between 0,6m--1,9m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973552
Y-COORD : 10365

HOLE No: TP3-09

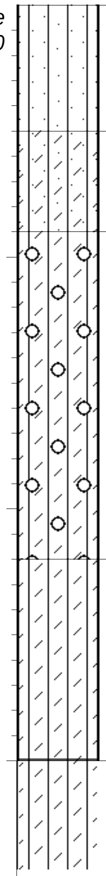
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-10
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, brown, <u>stiff</u>, intact, sandy SILT, with minor fine roots. **COLLUVIUM**.
0.50	Dry, brown mottled orange and black, <u>stiff</u>, intact, clayey sandy SILT, with minor subrounded gravel. Slightly ferruginous **ALLUVIUM**.
0.90	Dry, dark brown, <u>very stiff</u>, intact, clayey SILT, with scattered subrounded gravel. **ALLUVIUM**.
2.20	Dry, light grey mottled yellow, <u>very stiff</u>, intact, clayey SILT. **RESIDUAL ANDESITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973517
Y-COORD : 10115

HOLE No: TP3-10

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

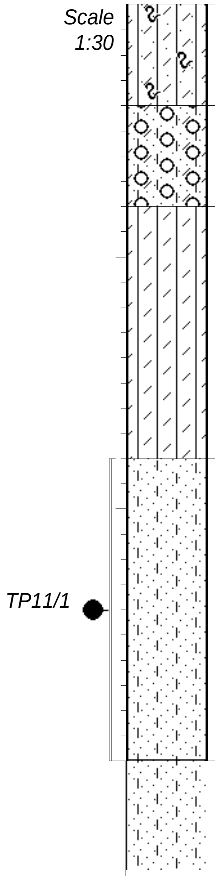
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-11
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, reddish brown, firm occasionally soft, intact, clayey sandy SILT, with fine roots. **COLLUVIUM**.
0.40	Dry, reddish brown mottled grey, dense, intact, clayey silty SAND, with abundant gravel. **PEBBLE MARKER**.
0.80	Dry, reddish brown, stiff, pinhole voided, clayey SILT. **RESIDUAL DOLERITE**.
1.80	Slightly moist, orange brown mottled black, medium dense, intact, silty SAND. **RESIDUAL DOLERITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

2) Small bag sample TP11/1 taken between 1,8m--3,0m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973555
Y-COORD : 9869

HOLE No: TP3-11

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

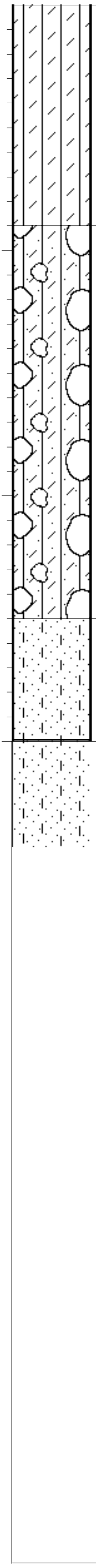
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-12
Sheet 1 of 1

JOB: 3010020413

Scale 1:30



Depth	Description
0.00	Dry, reddish brown, stiff, pinhole voided, clayey SILT. **COLLUVIUM**, with pebble marker at base.
0.90	Dry, reddish brown, stiff, intact, sandy clayey SILT, with cobbles. **RESIDUAL DOLERITE**.
2.50	Dry, orange brown, dense, intact, silty SAND. **RESIDUAL DOLERITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973626
Y-COORD : 9629

HOLE No: TP3-12

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

Knight Piésold CONSULTING

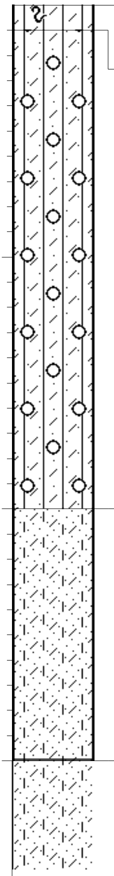
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-13
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, reddish brown, <u>firm</u>, intact, clayey SILT, with roots. **TOPSOIL**.
0.10	Dry, reddish brown, <u>stiff</u>, pinhole voided, sandy clayey SILT, with scattered subrounded gravel. **COLLUVIUM**.
2.00	Dry, orange brown and reddish brown speckled black, <u>dense</u>, intact, clayey silty SAND. **RESIDUAL DOLERITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973696
Y-COORD : 9388

HOLE No: TP3-13

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

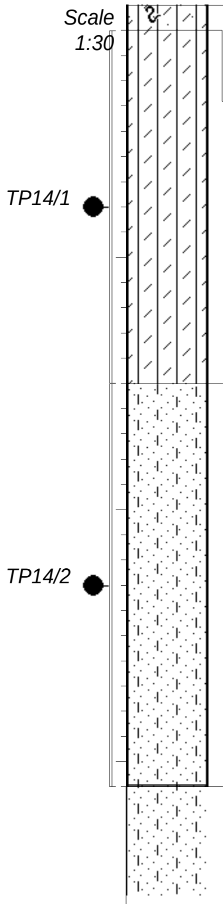
DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-14
Sheet 1 of 1

JOB: 3010020413



0.00

Dry, reddish brown, <u>firm</u>, intact, sandy clayey SILT, with fine roots. **TOPSOIL**.

0.10

Dry, reddish brown, <u>stiff</u>, pinhole voided, clayey SILT. **COLLUVIUM**.

1.50

Dry, orange brown speckled black, <u>dense</u>, intact, silty SAND. **RESIDUAL DOLERITE**.

3.10

EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.
2) Small bag sample TP14/1 taken between 0,1m--1,5m.
3) Bulk sample TP14/2 taken between 1,5m--3,1m.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM
TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018
DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973767
Y-COORD : 9146

HOLE No: TP3-14

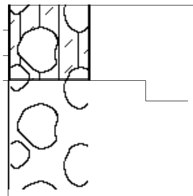
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-15
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



Dry, reddish brown, <u>firm</u>, intact, clayey SILT, with abundant subrounded and sub-angular cobbles and boulders. **COLLUVIUM**.

EOH: Refusal of TLB on COBBLES and BOULDERS.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

COORDINATE SYSTEM : WGS84
X-COORD : 2973838
Y-COORD : 8905

HOLE No: TP3-15

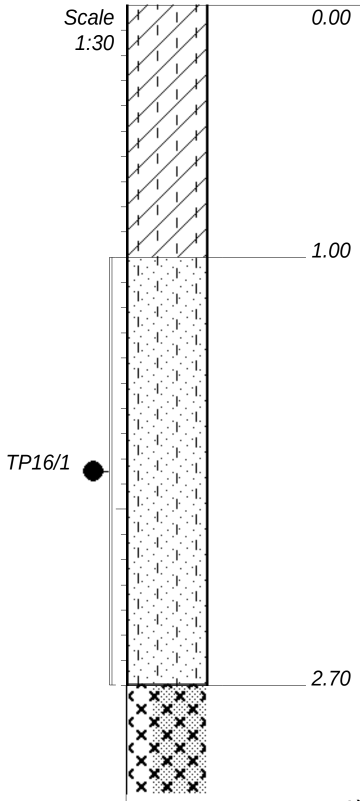
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-16
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00 – Dry, dark brown, <u>stiff</u>, microshattered, silty CLAY. **COLLUVIUM**.

1.00 – Dry, orange brown, <u>dense</u> becoming <u>very dense</u> from 2,2m, relict jointed, silty SAND. **RESIDUAL DOLERITE**.

2.70 – EOH: Refusal of TLB on highly weathered, <u>soft</u> rock DOLERITE.

NOTES

1) No groundwater seepage encountered.

2) Bulk sample TP16/1 taken between 1,0m--2,7m.

3) Logged from spoil because of puffadder in the test pit.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973908
Y-COORD : 8664

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

HOLE No: TP3-16

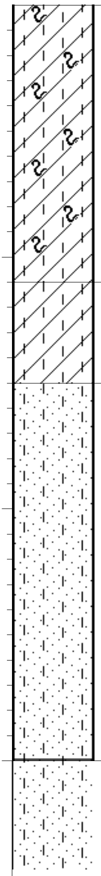
KAREERAND TSF EXTENSION
DIVERSION CANAL

GEOTECHNICAL INVESTIGATION

HOLE No: TP3-17
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Dry, dark brown, <u>stiff</u>, microshattered, silty CLAY, with roots. **COLLUVIUM**.
1.10	Dry, dark brown, <u>stiff</u>, intact, silty CLAY. **RESIDUAL DOLERITE**.
1.50	Dry, orange brown mottled black, <u>dense</u>, intact, silty SAND. **RESIDUAL DOLERITE**.
3.00	EOH: Maximum reach of TLB in material as above.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Supplied by client
MACHINE : TLB
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 20-23 November 2018

COORDINATE SYSTEM : WGS84
X-COORD : 2973964
Y-COORD : 8446

HOLE No: TP3-17

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 12:18
TEXT : C\WP51\PROFILES\OGZTP.TXT

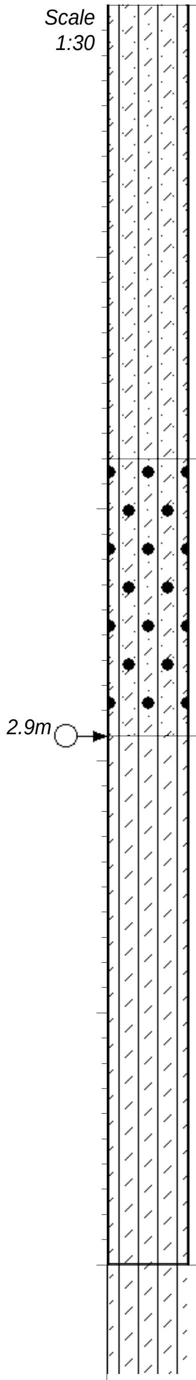
KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-07
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Moist, reddish brown, <u>soft</u>, intact, sandy clayey SILT. **COLLUVIUM**, with poorly developed pebble marker at base.
1.80	Moist, brown and grey mottled black, <u>firm</u>, intact, clayey sandy SILT, with abundant ferricrete nodules. **NODULAR FERRICRETE**.
2.90	Very moist occasionally wet, yellowish brown mottled black, <u>soft</u> becoming <u>firm</u> below 3,8m, intact, clayey SILT. **RESIDUAL ANDESITE**.
5.00	EOH: Maximum reach of excavator in material as above.

NOTES

1) Slight groundwater seepage encountered below 2,9m.

2) Collapsing sidewalls, logged from spoil.

CONTRACTOR :	Client	*INCLINATION :*		*COORDINATE SYSTEM :*	WGS84 (Lo27)
MACHINE :	Excavator	*DIAM :*		*X-COORD :*	2973683
DRILLED BY :		*DATE :*		*Y-COORD :*	10916
PROFILED BY :	MKM	*DATE :*	18-22 February 2019		
TYPE SET BY :	*EM*	*DATE :*	*17/05/2019 11:29*		
SETUP FILE :	*KPTP8.SET*	*TEXT :*	*C\WP51\PROFILES\OJFTP.TXT*		

HOLE No: TP4-07

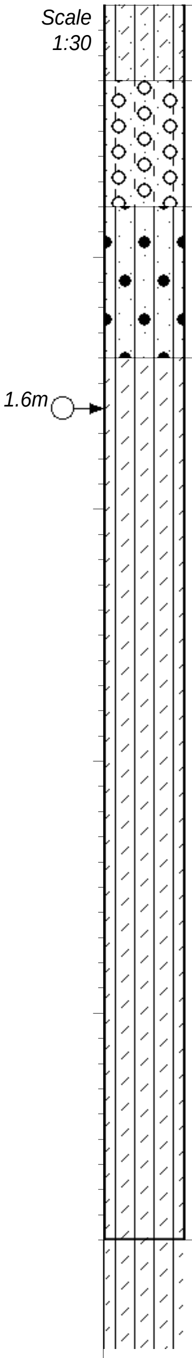
KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-08
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Moist, reddish brown, soft, intact, sandy clayey SILT. **COLLUVIUM**.
0.30	Moist, reddish brown, medium dense, intact, silty sandy GRAVEL. **PEBBLE MARKER**.
0.80	Very moist, reddish brown mottled black, firm, intact, sandy SILT, with abundant ferricrete nodules. **NODULAR FERRICRETE**.
1.40	Wet, yellowish brown, soft becoming firm below 3,9m, intact, clayey SILT, with scattered sub-angular andesite cobbles. **RESIDUAL ANDESITE**.
4.90	EOH: Maximum reach of excavator in material as above.

NOTES

1) Moderate groundwater seepage encountered below 1,6m.

2) Collapsing sidewalls, logged from spoil.

CONTRACTOR : Client
MACHINE : Excavator
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 18-22 February 2019

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2973690
Y-COORD : 10659

HOLE No: TP4-08

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

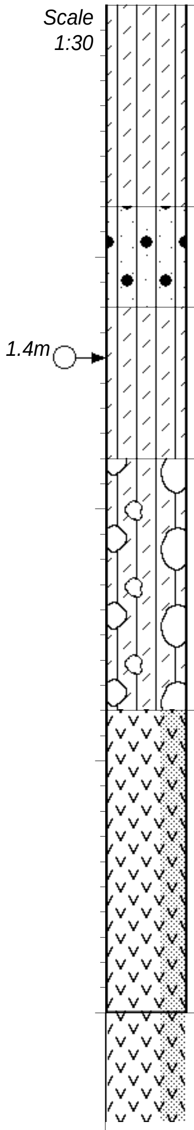
DATE : 17/05/2019 11:29
TEXT : C\WP51\PROFILES\OJFTP.TXT

KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-09
Sheet 1 of 1

JOB: 3010020413



0.00	Moist, reddish brown, soft, intact, clayey SILT. **COLLUVIUM**.
0.80	Very moist, reddish brown mottled black, firm, intact, sandy SILT, with abundant ferricrete nodules. **NODULAR FERRICRETE**.
1.20	Wet, reddish brown, soft, intact, clayey SILT. **RESIDUAL ANDESITE**.
1.80	Wet, yellowish brown, soft becoming firm below 2,5m, intact, clayey SILT, with scattered andesite cobbles. **RESIDUAL ANDESITE**.
2.80	Highly weathered, yellowish brown, soft rock ANDESITE.
4.00	EOH: Refusal of excavator on highly weathered, medium hard rock ANDESITE.

NOTES

1) Rapid groundwater seepage encountered below 1,4m.

2) Logged from spoil.

CONTRACTOR : Client
MACHINE : Excavator
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 18-22 February 2019

DATE : 17/05/2019 11:29
TEXT : C:\WP51\PROFILES\OJFTP.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2973783
Y-COORD : 10419

HOLE No: TP4-09

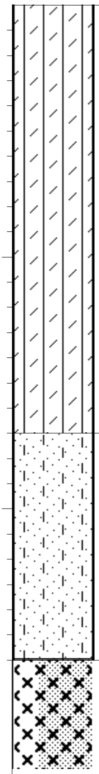
KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-10
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Wet, brown, <u>soft</u>, intact, clayey SILT. **COLLUVIUM**.
1.70	Wet, brown mottled black, <u>medium dense</u> becoming <u>very dense</u> below 2,3m, intact, silty SAND. **RESIDUAL DOLERITE**.
2.60	EOH: Gradual refusal of excavator on <u>soft</u> rock DOLERITE.

NOTES

1) Excavation stopped due to rapid groundwater seepage.

2) Collapsing sidewalls - logged from spoil.

CONTRACTOR : Client
MACHINE : Excavator
DRILLED BY :
PROFILED BY : MKM

INCLINATION :
DIAM :
DATE :
DATE : 18-22 February 2019

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2973917
Y-COORD : 10218

HOLE No: TP4-10

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

DATE : 17/05/2019 11:29
TEXT : C\WP51\PROFILES\OJFTP.TXT

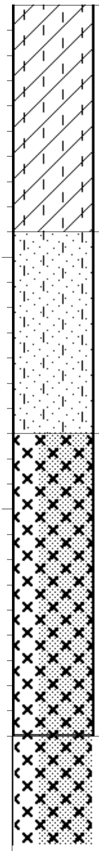
KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-11
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Very moist, reddish brown, soft, intact, silty CLAY. **COLLUVIUM**.
0.90	Very moist, brown, medium dense, intact, silty SAND. **RESIDUAL DOLERITE**.
1.70	Highly weathered, greyish brown, closely jointed, soft rock DOLERITE.
2.90	EOH: Refusal of excavator on medium hard rock DOLERITE.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Client
MACHINE : Excavator
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 18-22 February 2019

DATE : 17/05/2019 11:29
TEXT : C\WP51\PROFILES\OJFTP.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2974041
Y-COORD : 10026

HOLE No: TP4-11

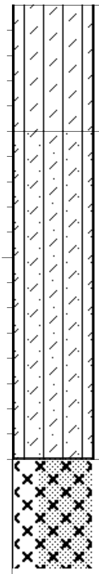
KAREERAND TAILINGS STORAGE FACILITY
NEW DIVERSION CHANNEL

GEOTECHNICAL INVESTIGATION

HOLE No: TP4-12
Sheet 1 of 1

JOB: 3010020413

Scale
1:30



0.00	Moist, dark brown, soft, intact, clayey SILT. **COLLUVIUM**.
0.50	Very moist with wet patches, yellowish grey, firm, intact, clayey sandy SILT, with minor dolerite cobbles. **RESIDUAL DOLERITE**.
1.80	EOH: Refusal of excavator on highly weathered, medium hard rock DOLERITE.

NOTES

1) No groundwater seepage encountered.

CONTRACTOR : Client
MACHINE : Excavator
DRILLED BY :
PROFILED BY : MKM

TYPE SET BY : EM
SETUP FILE : KPTP8.SET

INCLINATION :
DIAM :
DATE :
DATE : 18-22 February 2019

DATE : 17/05/2019 11:29
TEXT : C\WP51\PROFILES\OJFTP.TXT

COORDINATE SYSTEM : WGS84 (Lo27)
X-COORD : 2974200
Y-COORD : 9803

HOLE No: TP4-12