Preliminary Feasibility Study Report for the East Residue Storage Facility #6

at the Tronox Namakwa Sand EOFS Project

epoch
resources (pty) ltd

mine residue and environmental engineering consultants

PROJECT NUMBER 126-005 REPORT NO.1 EIA Rev 0 February 2021

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Prepared For

Tronox Mineral Sands (Pty) LRD

PROJECT NUMBER 126-005

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PRELIMINARY FEASIBILITY STUDY REPORT FOR THE EAST RESIDUE STORAGE FACILITY #6

AT THE TRONOX NAMAKWA SAND EOFS PROJECT

1. INTRODUCTION

Tronox Namakwa Sands (Tronox) has requested Epoch Resources (Pty) LRD (Epoch) to conduct a Feasibility Study (FS) of the East Residue Storage Facility #6 (RSF) for the Tronox East Orange Feldspathic Sands Project (Tronox EOFS Project). Tronox is an open pit mining operation, processing Heavy Metal Sands producing Zircon, Rutile, Iron and Pigment products. Mining activities are undertaken on two sites, namely the East and West mines. Two by-products are produced; a coarse sandy residue referred to as "sand tailings" and a fine silty residue referred to as "residue". This study relates to activities undertaken only on the East Mine with the RSF containing the residue stream for the 20 years Life of Mine (LoM).

A site selection study was undertaken in 2019 as part of a Pre-Feasibility Study (PFS), as documented in Epoch's report: "*Pre-feasibility study report for the EOFS Residue Storage Facility*". The preferred site for the RSF was determined to be the "Depression" site situated north-east of the plant.

The RSF is to be a full containment facility with embankment walls constructed using sand tailings material.

This document describes the design of the Residue Storage Facility for the project. The design process included:

- Confirmation of the design criteria for the facility;
- A review of the available information of the project site;
- The development of a site layout of the proposed residue storage facility;
- Characterisation of the residue based on information supplied as well as geotechnical test work;
- A geotechnical study to characterise the insitu soils beneath the RSF;
- Bankable design of the works required for the development, operation and closure of the facility;
- The compilation of a set of layout and typical detail drawings of the facility;
- The compilation of a life of mine estimate of costs associated with the development, operation and closure of the facility; and
- The collation of the work carried out into this Feasibility Design Report.

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2. UNITS AND TECHNICAL ABBREVIATIONS

Table 2-1 lists the units and abbreviations referenced in this document.

TABLE 2-1: UNITS AND ABBREVIATIONS

Unit	Description
Mt	Million Tonnes
m	Metres
ktpm	Thousand Tonnes Per Month
tpa	Tonnes Per Annum
µm	Micro Metres
mm	Millimetres
m^3	Cubic Metres
t/m^3	Tonnes per Cubic Metre
m^2	Square Metre
m.a.m.s.l	Metres above mean sea level

Abbreviation	Description
FS	Feasibility Study
FoS	Factor of Safety
FSL	Full Supply Level
HDPE	High Density Polyethylene
LoM	Life of Mine
MAP	Mean Annual Precipitation
PMA	Peak Maximum Acceleration
PSD	Particle Size Distribution
PI	Plasticity Index
SG	(Particle) Specific Gravity
SPT	Standard Penetration Tests
RD	Residue Dam
RSF	Residue Storage Facility
TP	Test Pit

3. PROJECT SETTING

The Tronox EOFS Project is located in the Matzikama Municipal District of the Western Cape Province of South Africa, as shown in Figure 3-1, approximately 71 km north-west of the town of Vredendal and 385 km north of Cape Town. The mine consists of two mining areas namely the East and West Mine with a Satellite image of the Mine depicted in Figure 3-2.

FIGURE 3-1: PROJECT LOCATION

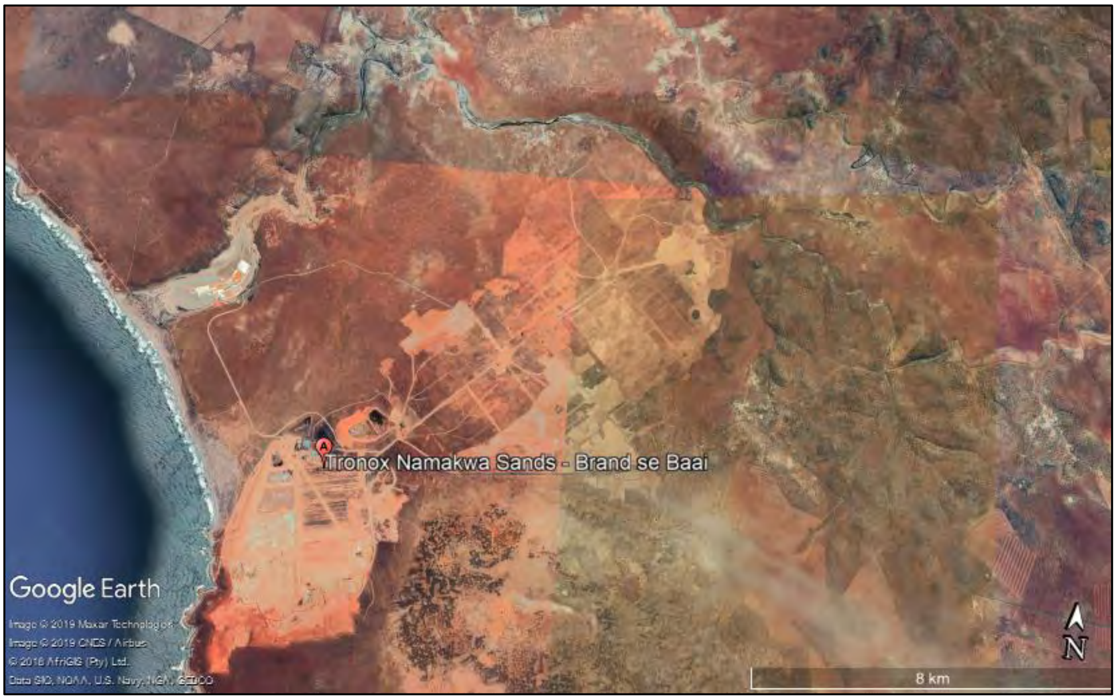

FIGURE 3-2: TRONOX NAMAKWA SANDS MINE

4. FRAMEWORK FOR THE DESIGN OF THE RESIDUE STORAGE FACILITY

4.1. TERMS OF REFERENCE

The terms of reference that Epoch were responsible for comprised:

- The design of the RSF comprising:
    - A full containment Residue Dam (RD) that accommodates 38.9 million dry tonnes of residue over a 20 year Life of Mine (LoM); and
    - The associated infrastructure for the RD (i.e. perimeter slurry deposition pipeline, pool access wall, storm water diversion, etc.);
- Estimation of the capital costs to an accuracy of +20% -15% percent, operating costs associated with the facility to an accuracy of +20% -15% percent and closure costs to an accuracy of ±30 percent; and
- Estimation of the costs over the life of the facility.

4.2. BATTERY LIMITS

The battery limits for the FS are as follows:

- The perimeter fence around the RSF;
- Downstream of the point where the slurry delivery pipeline intersects the RD wall;

- Upstream of the suction end of the of the floating pump system;
- Geotechnical site investigation and laboratory test work of the in-situ soils of the RSF site; and
- Geotechnical laboratory test work of the sand tailings and residue material.

The following are excluded from Epoch's terms of reference:

- Ground survey work;
- Site Selection process as this was undertaken in the PFS phase;
- Liaising or obtaining permission from various government authorities e.g. licences, permits, relocation of major services etc.;
- Hydrological, Geohydrological, Geochemical, Mineralogical and other environmental investigations or studies required for the EIA or for engineering design purposes. Some of the results from these studies is however required for design of the RSF and are to be conducted by others;
- Determination of flood lines along water courses;
- Stream diversions;
- Water supply studies;
- Participation and consultation with Interested and Affected Parties (I & APs);
- Equipping of the outlet manholes including pumps, motors electrics, instrumentation etc.;
- The design and costing of:
    - The RSF dewatering turret;
    - Pumps, motors, electrical components and instrumentation;
    - The slurry delivery pipeline from the process plant to the RSF; and
    - The return water pipelines from the dewatering turret to the process plant.

4.3. DESIGN CRITERIA

The life of mine production of residue will amount to 38 900 000 tonnes over 20 years. The particle Specific Gravity (SG) of the residue was determined to be 2.63, by Specialized Testing Laboratory (Pty) LRD.

The design criteria are summarised in Table 4-1.

TABLE 4-1: DESIGN CRITERIA

Item	Criteria	Value	Source
1	Ore type	Heavy mineral sands	Tronox
2	Design Life of Facility	20 years	Tronox
5	Average Residue Deposition Rate:	1.945 Mtpa	Tronox
6	Total Residue	38 900 000 tonnes	Tronox
7	Particle Specific Gravity	Residue -2.63 Sand tailings -2.615	ST Lab
8	Average Dry Density	0.6 t/m^3	ST Lab/Epoch
9	Average Particle Size Distribution	Residue -75% passing 15 μm	Patterson & Cooke ST Lab/Epoch

10	% solids to water (by mass)	Sand tailings – 75% passing 0.3mm Residue – 22% Sand tailings – 80%	Fluor/Tronox
11	Delivery Method	Hydraulically Pumped	Tronox
12	Geochemistry of residue	Inert, non-acid generating	SRK
13	Geochemistry of EOFS tailings	Inert, non-acid generating	SRK
14	Geochemistry of RAS tailings	Inert, non-acid generating	SRK
15	S-Pan to Lake Evaporation factor	0.75	Epoch

4.4. AVAILABLE INFORMATION

The following information was made available for the design of the RSF:

- A 1m interval digital terrain model of the project area;
- An aerial image of the area;
- Residue production rate over the life of the project;
- Residue characteristics based on test work conducted in the FS study.

4.5. APPLICABLE LEGISLATION

The South African legislative requirements for the design of mine Residue Storage Facilities are listed below:

- National Environmental Management: Waste Act (Act 59 of 2008).
- Environmental Conservation Act (Act 73 of 1989).
- National Water Act (Act 36 of 1998).
- National Environmental Management Act (Act 107 of 1998).

A summary list of the requirements for the design of an RSF as stipulated in the National Environmental Management Act is contained in Appendix A of this report. The corresponding reports in which the requirements have been address are also listed in this appendix.

4.6. CLIMATIC DATA

The Tronox EOFS project is located within the F60E Quaternary catchment of South Africa.

The catchment exhibits a winter rainfall pattern with most of the rainfall occurring in the months from April to September. Rainfall data collected by Tronox on the West Mine from 1994 to 2015 was used to establish the average monthly rainfall for the area.

The average S-Pan evaporation determined from the Water Resources of South Africa 2005 study (WR2005 BJ Middleton and AK Bailey) is 1 586.73 mm per annum. A coefficient of 0.75 was assumed to yield Lake Evaporation from the S-Pan depths, and equates to 1 190.05 mm. No correction has been made for a reduction in evaporation due to the salinity in the process water.

The average monthly rainfall, S-Pan and Lake evaporation are listed in Table 4-2 as well as the variance between the two, indicating that annual evaporation exceeds the annual rainfall depth by over 1000 mm (1.0 m).

TABLE 4-2: AVERAGE MONTHLY RAINFALL AND LAKE EVAPORATION VALUES FOR TRONOX

Month	Average Rainfall (mm)	Average S-Pan Evaporation (mm)	Average Lake Evaporation (mm)	Variance (Rainfall - Lake Evaporation) (mm)
January	4.85	218.02	163.52	-158.67
February	7.96	172.48	129.36	-121.40
March	7.97	147.09	110.32	-102.35
April	11.87	103.14	77.36	-65.49
May	24.19	75.85	56.89	-32.70
June	30.02	58.07	43.55	-13.53
July	32.19	62.52	46.89	-14.70
August	27.78	82.83	62.12	-34.34
September	11.93	111.23	83.42	-71.49
October	8.67	152.80	114.60	-105.93
November	8.55	185.96	139.47	-130.92
December	9.18	219.75	162.56	-123.38
Annual	**185.16**	**1586.73**	**1190.06**	**-1004.90**

The storm event depths as listed for the Doringbaai Weather Station (Station 0106408W) were used in this study. This station is the one situated closest to the project area, some 65km south of Tronox, along the western coastline with a similar elevation (88 m.a.m.s.l) and 48 years of rainfall records.

In a study undertaken in 2017 by SRK on the West mine, SRK estimated the storm event depths for the West Mine using the Pearson Type III distribution based on the mine's 23 years of rainfall data. This study is documented in SRK Report "*Namakwa Sands West Mine Slimes Dam 6 Report – Rev 2*" of 2017. The 24hr design flood depths for the Doringbaai Weather station and the SRK study are depicted in Table 4-3.

In order to accurately predict storm event depth, data is typically collected for over a 30 year period. The mine only has 23 years of records, as such the Doringbaai storm event depths were used in calculating the required storage capacity. It should however be noted that the SRK study results correlated well with the Doringbaai data for the greater return period events, i.e. 50 and 100 year events, which are considered in this design.

TABLE 4-3: DESIGN STORM RAINFALL DEPTHS FOR TRONOX

Station	Rainfall Depth (mm) for each Recurrence Interval						
	2 Years	5 Years	10 Years	20 Years	50 Years	100 Years	200 Years
Doringbaai	30	41	49	58	69	78	87
SRK	8	15	28	41	60	76	92

5. SCOPE OF WORK

The scope of work for the FS of the RSF was as follows:

- Stage capacity characteristic curves (area-volume-height curves) for the RSF;
- A geotechnical investigation of the preferred site and laboratory testing of samples to characterise the insitu soils properties;
- Geotechnical laboratory tests on the residue products to define their geotechnical properties;
- Seepage analyses for the RSF;
- Slope stability analyses of the RSF;
- A monthly water balance of the RSF to determine typical return water volumes;
- The design of the RSF and the associated infrastructure (i.e.pool access wall, storm water diversion, etc.).
- Site layout and typical drawings of the RSF;
- Estimation of the capital costs to an accuracy of +20%-15% percent and operating costs associated with the RSF to an accuracy of +20%-15% percent;
- Estimation of closure, rehabilitation and aftercare costs to an accuracy of 30%; and
- Estimation of the costs over the life of the facility.

6. SITE SELECTION STUDY

A site selection study was undertaken in 2019 as part of a Pre-Feasibility Study (PFS), as documented in Epoch's report: "*Pre-feasibility study report for the EOFS Residue Storage Facility*", contained in Appendix B of this report.

The required capacity for the study was for 26.8 million tonnes. The study investigated 4 sites for the placement of the RSF are depicted in Figure 6-1.The preferred site for the RSF was determined to be the "Depression" site situated north-east of the plant. It ranked first on the weighted site selection rankings as a result of its ratings for safety and public health and proximity to the plant. The Depression site also yielded the lowest LoM costs based on the high-level cost comparison of the sites considered and also provided the ability for future expansion.

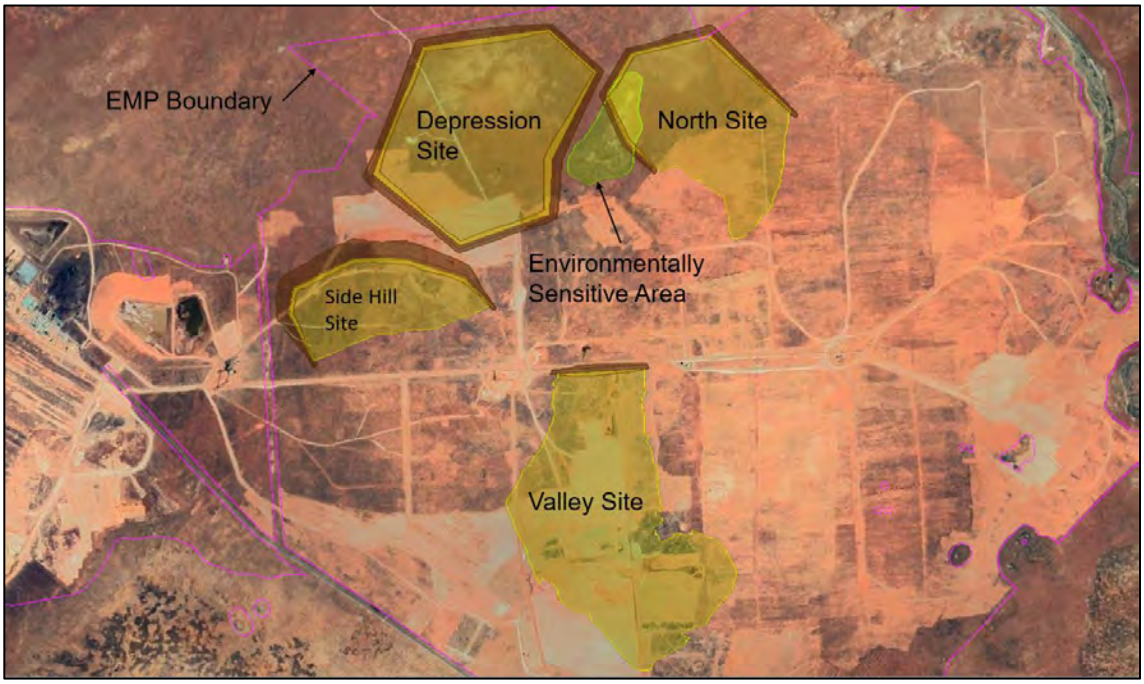

FIGURE 6-1: SITES IDENTIFIED FOR THE RSF

7. CHARACTERIZATION OF THE RESIDUE

7.1. PHYSICAL CHARACTERISATION OF THE RESIDUE

The physical characteristics of the residue product is described in terms of its particle specific gravity (PSG) and particle size distribution (PSD). These characteristics are significant in that they will influence the in-situ dry density of the placed residue as well as the behaviour of the material during deposition. Four samples of residue were received for testing. The samples were created from various section of the ore body which if blended would form a representative sample of the residue.

The following tests were conducted on all four samples:

- Foundation Indicator/Atterberg Limit tests;
- Relative density of the residue (Specific Gravity);
- Sieve analysis mass grading;

The results of these test are summarised below:

- The average particle specific gravity of the residue samples tested was 2.63;
- The PSDs of the samples are shown in Figure 7-1. The figure shows that the 75% passes 15 µm;
- Two samples tested have a medium Plasticity Index (PI) of 9, classifying these samples as CH according to the Unified Soil Classification System;
- The other two residue samples tested with a high plasticity index of 27 and 36, classifying these samples as MH/OH according to the Unified Soil Classification System.

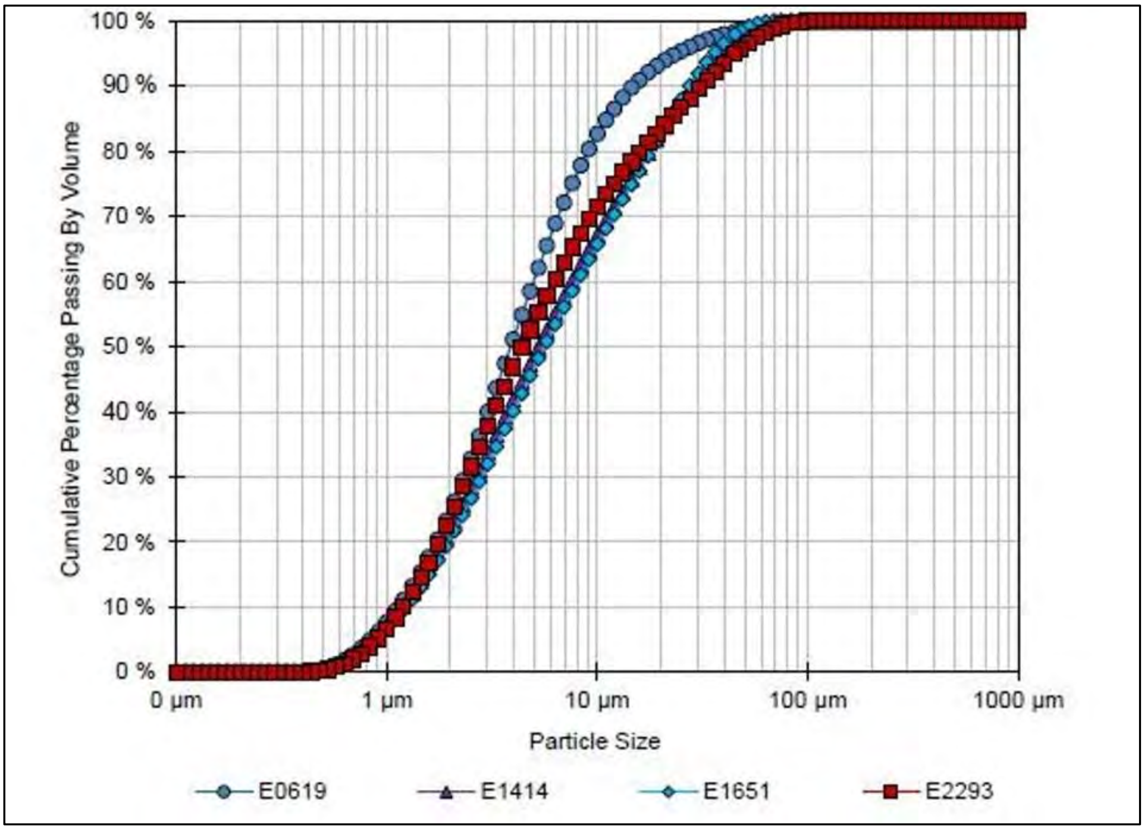

FIGURE 7-1: **PARTICLE SIZE DISTRIBUTION OF THE RESIDUE SAMPLE TESTED**

The plasticity index is the size of the range of water content in which the soil exhibits plastic properties. Given the difference in plasticity indexes in the tested samples, there is a potential for significant variability in the setting properties of the material, ultimately impacting the placed dry density of the residue and subsequently impacting capacity requirements.

The following additional tests were conducted on two samples of the residue, namely E1414 -45micron with a PI of 9 and E0619 -45 micron with a PI of 36:

- Settling and evaporation tests;
- Triaxial consolidated undrained;
- Volumetric consolidation in triaxial cell; and
- Permeability - flexible wall.

7.1.1. ESTIMATED PLACED RESIDUE DRY DENSITY

The estimated placed dry density of the residue was determined using the particle Specific Gravity (*SG*) and laboratory test results of the residue. Three tests were carried out on the two residue samples with the results listed below. Each test simulates the different conditions associated with the deposition of residue from the perimeter of the RD in order to ascertain the residue placed dry density under each condition.

- The undrained settling test simulates conditions below the pool at the centre of the RD. A dry density of 0.558t/m^3 was achieved for the E1414 residue sample and 0.271 t/m^3 for the E0619 sample;
- The bottom-drained test simulates beach conditions where water drains through the bottom of a layer. A dry density of 0.905 t/m^3 and 0.487 t/m^3 was achieved for E1414 and E0619 respectively.

- The evaporation test simulates the outer beach conditions with evaporation. A dry density of 1.054 was achieved at a moisture content of 10.6% for the E1414 and 1.075 t/m^3 at a moisture content of 41.6% for the E0619 sample.

The overall weighted dry density of the residue is expected to be in the region of 0.6 and 0.7 t/m^3. Given that the volume of residue being produced from the various regions of the mine is unknown and each sample tested is not a representative of the final residue product reporting to the RSF, as well as the average dry density based on historic mass balances of existing RSFs at Tronox equals 0.61t/m^3, the FS design of the EOFS RSF6 will be based on a placed dry density of 0.6t/m^3.

The laboratory test results can be found in Appendix C.

7.2. GEOCHEMICAL CHARACTERISATION

SRK Consulting undertook the geochemical characterisation of the tailings and residue. The EOFS tailings material is non-acid generating, inert and classified as a Type 4 waste requiring disposal on a Class D liner system. The EOFS residue material is non-acid generating, inert and classified as a Type 3 waste due to elevated leachate concentrations of Cl, RDS and B. Therefore, the RSF must be sited on a Type C liner system.

However, the Geochemical Abundance Index (GAI) which compared the global median soil values for the tailings, fines and background soil, indicated that chromium, boron and zinc are slight increased in the residue but not considered significant.

8. GEOTECHNICAL INVESTIGATION

A geotechnical investigation of the proposed site was undertaken by Inroads, and the results of the near-surface investigation were published in their report: "*Report on Geotechnical Investigation for the proposed Residue Storage Facility, Stormwater Dam & Overburden Facility fo rthe Tronox Namakwa Sands EOFS Project in Brand-se Baai, Wester Cape" February 2021.* This report is contained in Appendix D.

The focus of the investigation was to determine the geotechnical parameters and depths of the in-situ soil horizons in the vicinity of the RSF for seepage and stability analyses, as well as to identify any problem soils which could affect stability or soil permeability.

8.1. SOIL PROFILE

Inroads undertook to investigate and provide typical soil profiles of 82 Test Pits (TPs) and 6 rotary core drills drilled to 20m within the area of the RSF as depicted in Figure 8-1. During the geotechnical investigation, soil profiling was undertaken to determine the individual layers, or horizons, of the underlying soils and are summarised in Table 8-1 below.

The subsoil conditions within the RSF site are characterised by dune sand, in the unmined area, and sand tailings fill in the rehabilitated area that was previously mined along the southern boundary of the RSF. These soils are almost identical and of very loose consistency.

In most of the largely unmined area very loose dune sand overlies silty sand of aeolian origin at an average depth of 2,0 m ranging from 0,9 to 3,3 m below the present ground surface. The aeolian comprises mainly medium dense to dense and in places loose silty sand with scattered friable weakly cemented pockets.

The aeolian sand extends to the bottom of most of the holes at depths of about 3,0 m and, in places, the TLB partially refused on very dense aeolian sand and very occasional very soft rock hardpan dorbank. Boreholes NRSF01, NRSF06 to NRSF08 drilled within the unmined area show the aeolian horizon to extend to depths mostly in excess of 20,0 m. The Standard Penetration Tests (*SPT*) carried out on the subsoils to depths of up to between about 2,0 to 3,5 m yielded N values of 20 to 32, which suggests that their consistency is medium dense. Below these depths, the SPT N value recorded mainly above 50 or refused, indicating that the soils are very dense and comprise cemented sand and very soft rock in places.

Borehole NRSF06, at a depth of 17,7 to 20,1 m, encountered a soil horizon resembling the residual schist comprising a clayey silt with very stiff to very soft rock. In the rehabilitated area, very loose fill covers the site to a depth of between 1,1 to 3,2 m where it generally extends to the bottom of the pits or is underlain by loose aeolian and very occasionally moderately cemented very dense sand and very soft rock gneiss.

Boreholes NRSF02 and NRSF05 drilled along the southern wall of the RSF and within the rehabilitated area, show the fill, together with the underlying aeolian sand, to extend to depths of between 4,5 and 12 m where they are underlain by either very soft rock dorbank or completely weathered granite gneiss.

The SPT carried out in soils within the rehabilitated area to depths of up to 3,5m yielded N values of 9 to 17 which suggests that their consistency is loose to medium dense. At a depth of about 4,5 m, the SPT in borehole NRSF02 refused, signifying the presence of very dense or very stiff to very soft rock horizons below this depth and extending to 20,0 m. These comprise very soft to soft rock dorbank overlying very stiff to very soft rock completely to highly weathered limestone at about 10,0 m.

In borehole NRSF05, the aeolian becomes dense and very dense below depths of 7,5 m and 9,0 m with N values of 39 and 69 to 75 respectively. Below a depth of 12,0 m and extending to the bottom of the hole at 20,0 m, completely weathered granite gneiss occurs. It comprises very dense to very soft rock and relict jointed silty sand with clayey sandy silt below 16,5 m.

TABLE 8-1: SUMMARY OF SOIL HORIZON PROFILES

Material	Typical Depths (m-m) (where prominent)	In-situ Moisture Condition	Colour	Consistency	Soil Classification
Aeolian/Dune	0-2.0	Moist	Light brown	Very loose	Silty SAND
Aeolian	1.0 – 3.3 (TLB Refusal)	Moist	Yellow Brown/ Reddish Brown	Loose/ medium dense to dense	SILTY SAND
Weekly cemented Aeolian	1.6 - 20	Slightly moist to moist	Reddish brown	Dense	SILTY SAND
Fill	0 - 3.2	Moist to very moist	Light brown	Very loose	SAND
Residual Gneiss	0.2-refusal	Moist	Speckled grey and orange	Very dense	SILTY Coarse SAND

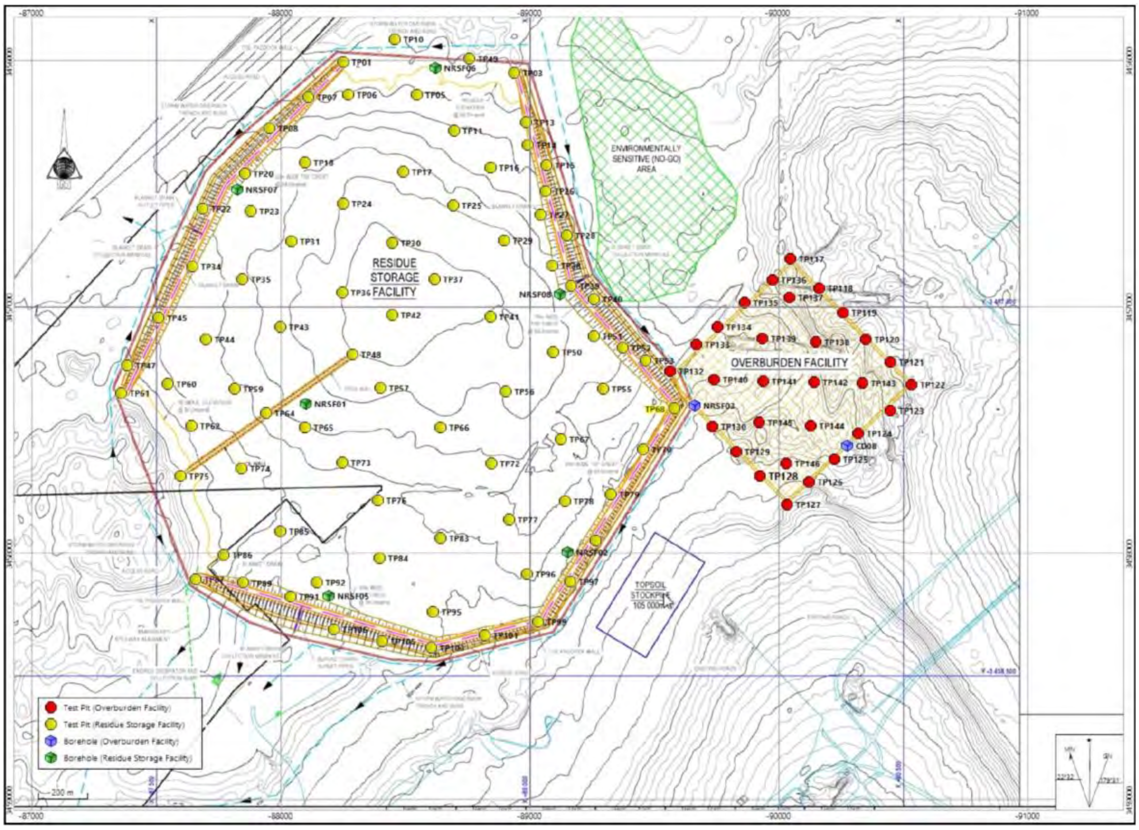

FIGURE 8-1: RSF TEST PIT AND CORE DRILL LOCATIONS

8.2. GROUNDWATER

No groundwater was encountered within any of the test pits excavated on site.

8.3. MATERIAL STRENGTH PARAMETERS AND HYDRAULIC CONDUCTIVITY

Representative disturbed and undisturbed soil samples were collected during the site investigation. Particle size distributions and Atterberg limit determinations were carried out in order to determine the Unified System Classification of Soils (*USCS*) of the soils. Slow drained shear box and flexible wall triaxial cell permeability tests were carried out on undisturbed and remoulded samples of the soils. Collapse potential and consolidation test were carried out on undisturbed samples of the Aeolian soils. The tests were undertaken to determine the geotechnical parameters required for the design of the RSF.

The hydraulic conductivity values were then utilized in the seepage analyses of the RSF. The strength parameters were used in the analysis of the slope stabilities in conjunction with the results of the seepage analyses. Table 8-2 presents the geotechnical parameters of the insitu soils.

TABLE 8-2: GEOTECHNICAL PARAMETERS OF MATERIALS CLASSIFIED IN TEST PITS

Material	Typical Depths (m)	Unified Classification	Average Bulk Density (kN/m^3)	Friction Angle (degrees)	Cohesive Strength (kPa)	Hydraulic Conductivity (m/s)
Fill & Dune (uncompacted)	0 – 2	SP	14	28	0	10^{-4}
Fill & Dune* (compacted)	0 – 2	SP	16	35	0	10^{-5}
Aeolian (uncompacted)	2 – 3.5	SP / SP-SM	16	32	0	10^{-6}
Aeolian* (compacted)	2 – 3.5	SP / SP-SM	18	37	0	10^{-5}
Weakly cemented aeolian, residual, weak dorbank (Very dense to very soft rock)	15	SP / SP-SM	19	40	0	10^{-7}

*Notes: * Disturbed samples remoulded to 98% Modified AASHTO density.*

The walls of the RSF will be built from sand tailings trucked from the PCP East Plant and no conventional compaction will be undertaken during construction of the wall. Compaction will only take place under traffic loading during construction, and under the self-weight of the sand as the wall height increases. Under such conditions where the consistency of the soil may improve slightly a friction angle of 30 degrees and dry density of 1600 kg/m^3 is considered appropriate to be used as the design parameters for the wall fill material.

Inroads recommended that before constructing the wall, the in-situ material beneath the RSF wall be compacted using an impact roller able to compact to depths of up to 2-3 m. This is not deemed necessary as the Dune sands (which comprise the top 2 to 3m of insitu soils) throughout the RSF footprint area will be mined (and hence removed) prior to the construction of the RSF. Any fill material under the RSF walls will also be removed prior to the construction of the walls, so as to allow for the excavation of the box cut into competent material and the installation of the blanket drains.

8.4. GEOTECHNICAL TESTING OF TAILINGS SAMPLES

Geotechnical testing was conducted on samples of the sand tailings products. The summary results of these tests are listed below:

- Friction Angle – 30°;
- Cohesion – 2 kPa;
- Unit weight – 16.6 kN/m^3; and
- Hydraulic conductivity – 2.3 x 10^{-5} m.s^{-1}.

8.5. GEOTECHNICAL TESTING OF RESIDUE SAMPLES

Geotechnical testing was undertaken on two different samples of the residue product. The summary result of these tests are listed below:

- Friction Angle – 33°;
- Cohesion – 0 kPa;
- Unit weight – 15 kN/m^3; and

- Hydraulic conductivity – 4 x 10^{-7} m.s^{-1}

9. SEEPAGE ANALYSES

Seepage analyses were undertaken to model the development of a phreatic surface within the RSF under varying operating conditions as detailed in the report contained in Appendix E. An increase in pore-water pressure brought on by the onset of seepage can result in the reduction in the stability of an earth structure's slope and has other adverse secondary effects such as:

- Piping (erosive loss of material);
- Loss of effective strength of the material;
- Increase in the liquefaction potential of soils; and
- Increase in the collapse potential of sensitive soils.

It is therefore imperative not only for the designer to take cognisance of the above but also the construction of the facility to be as per design and for the operator of the RSF to ensure that best-operating practices are adhered to at all times.

9.1. METHODOLOGY

Seepage analyses of the RSF were carried out using the finite element program Seep/W to assess the location of the phreatic surface that would develop during various conditions during the operational and closure phases, such as:

- Normal operating conditions including:
    - Functional drains; and
    - Normal operating pool
- Abnormal operating conditions including:
    - Failed drains; and
    - Flooded conditions were the pool will be located 100 m from the upstream face of the containment wall.

9.1.1. INPUT PARAMETERS TO SEEPAGE MODEL

The soil USCS classifications and hydraulic conductivities used are listed in Table 9-1.

TABLE 9-1: LIST OF HYDRAULIC PARAMETERS

Material	Anisotropy Ky'/Kx' Ratio	Saturated Hydraulic Conductivity (m.s^{-1})	Saturated/Unsaturated Condition
Residue	0.5	4.03 x 10^{-8}	Saturated only
Embankment (Tailings)	1	1.00 x 10^{-5}	Saturated/Unsaturated
Drains	1	1.00 x 10^{-3}	Saturated only
Aeolian (Silt)	1	1.00 x 10^{-6}	Saturated/Unsaturated

Aeolian (Slightly Cemented)	1	1.00×10^{-7}	Saturated/Unsaturated

9.1.2. CONFIGURATION OF SEEPAGE MODELS

Once all the required input parameters have been allocated as necessary, it is possible to compute the steady-state condition by determining the location of the water table (phreatic surface, or zero pore water pressure) under the given criteria and conditions. The Critical Section of the RD used for the Seepage and Stability analyses are illustrated in Figure 9-1. The typical model setup for the RD along the Critical Section is illustrated in Figure 9-2 to Figure 9-4. The RSF was assessed with a centre banket drain, upstream toe blanket drain and no drains, respectively, with both a normal operating pool and a storm pool. The construction of the facility will be a two-phase process. During the initial phase, the facility will be constructed with 1V:2.5H side slopes for both the upstream and downstream slopes and a 30 m crest to allow adequate space for construction vehicles to end tip and spread the RAS material. During the second phase, the slope of the embankments downstream face will be flattened to a 1V:5H slope by reshaping the existing material. Subsequently, the crest width will be reduced to 15 meters.

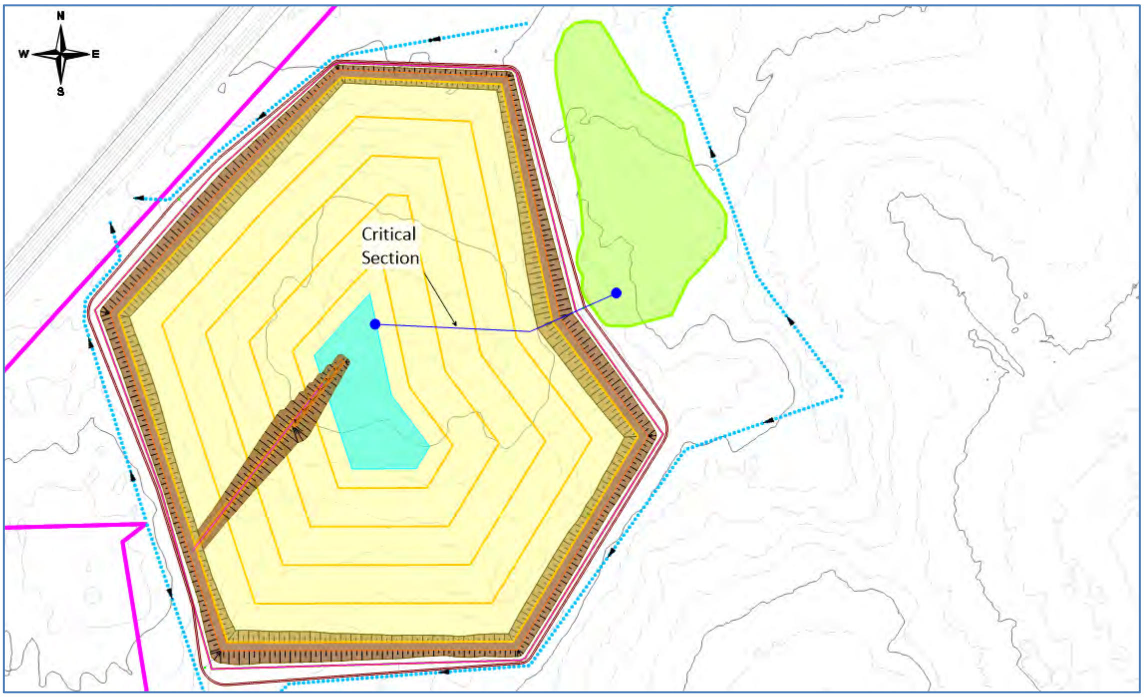

FIGURE 9-1: **CRITICAL SECTIONS ACROSS THE RSF**

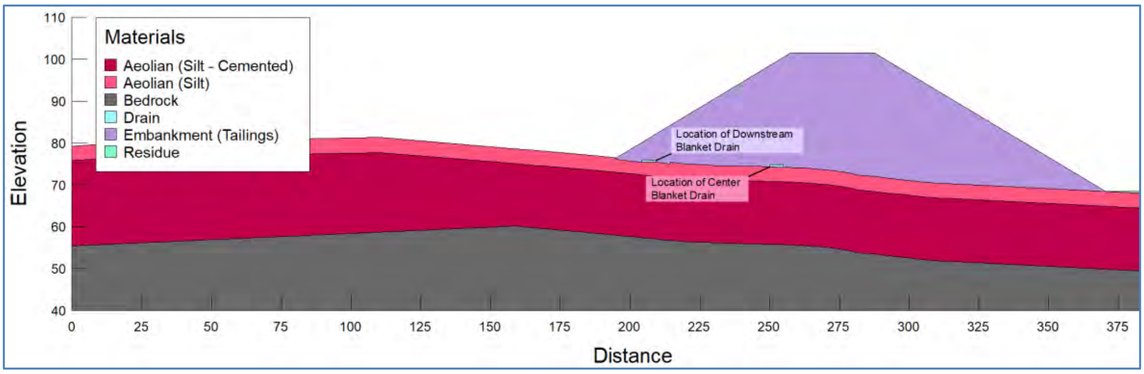

FIGURE 9-2: OPERATIONAL PHASE - INITIAL

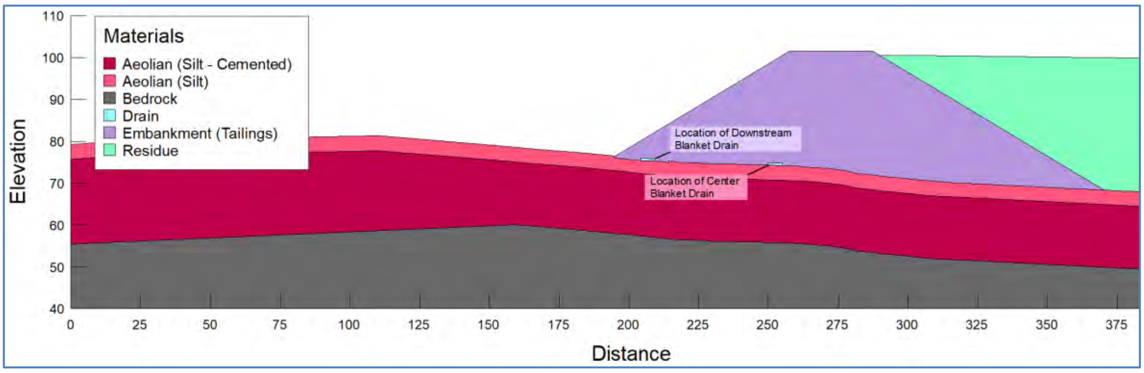

FIGURE 9-3: OPERATIONAL PHASE – RESIDUE AT MAXIMUM CAPACITY

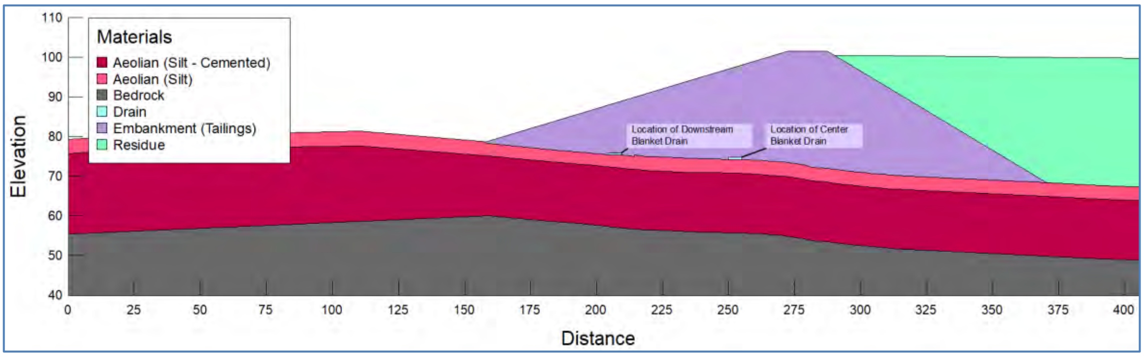

FIGURE 9-4: CLOSURE PHASE

9.2. RESULTS OF ANALYSES

A series of seepage analyses were conducted under varying operating conditions to determine the generation of pore water pressures within the RSF. The seepage assessments were also carried out to determine the effect of drainage infrastructure in reducing the generation of pore water pressures that may have adverse effects on the safety and stability of the RSF.

Each scenario was modelled with both a storm pool and an operational pool. The storm pool was taken as the resulting pool with a perimeter a distance of 100 m away from the inside face of the facility. This is a worst-case scenario that is highly unlikely to occur as the volume of water required to reach such a pool volume equates to 1 800 000m^3, exceeding by sixfold the 300 000m^3 of water expected to report to the RSF during the 1 in 200-year return period storm event (including the operational pool). Furthermore, the pool would need to be maintained at this volume in excess of 3 years to allow for the phreatic surface to rise to this level. The use of such a large pool volume is meant to showcase the robustness of the RSF design.

The operational pool was taken as the maximum estimate pool volume that would result from daily deposition as well as the estimated precipitation and evaporation cycle. A water balance conducted by Epoch titled "*Water Balance Study for the Tronox EOFS Residue Storage Facility*", revealed that the pool volume would not exceed 43 328 m^3 at any given point, during the operational life of the facility.

9.2.1. SEEPAGE ANALYSIS RESULT OF INITIAL OPERATIONAL PHASE

The model presented in Figure 9-5 illustrates a typical cross-section along the Critical Section during the initial portion of deposition when the residue material starts encroaching on the upstream toe of the facility. This scenario is seen as the worst-case as the deposited material could lead to the saturation of the upstream toe should a significant storm event occur. Further analysis showed that increasing the residue level resulted in an increased FoS.

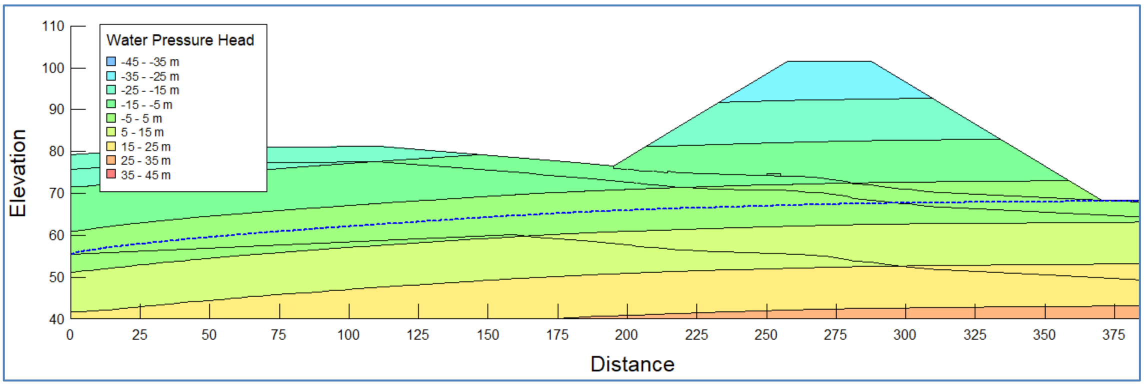

FIGURE 9-5: **INITIAL OPERATIONAL PHASE, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN**

The embankment illustrated in Figure 9-5 consists of upstream and downstream slopes equal to 1V:2.5H and a 5 m wide centre blanket drain. No further models were included for this scenario as it is shown that the phreatic surface remains below the blanket drain thus indicating that excluding the drains from the analysis would have no significant impact on the phreatic surface within the embankment.

9.2.2. SEEPAGE ANALYSIS RESULTS OF OPERATIONAL PHASE AT CAPACITY

Figure 9-6 to Figure 9-8 illustrates the effect a blanket drain would have on the phreatic surface within the embankment. It is shown that, due to the topography, a centre blanket drain is the most effective means by which to decrease the phreatic surface (Figure 9-6). However, similarly due to the topography, significantly deep manholes will need to be excavated in order to reach the blanket drain outlets. Therefore, it is believed that a downstream blanket drain is the most feasible means by which to prevent saturation of the downstream toe.

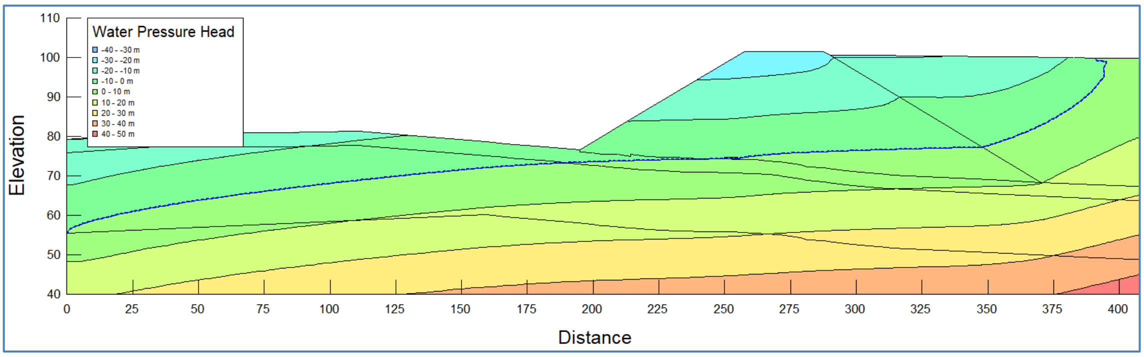

FIGURE 9-6: **OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN**

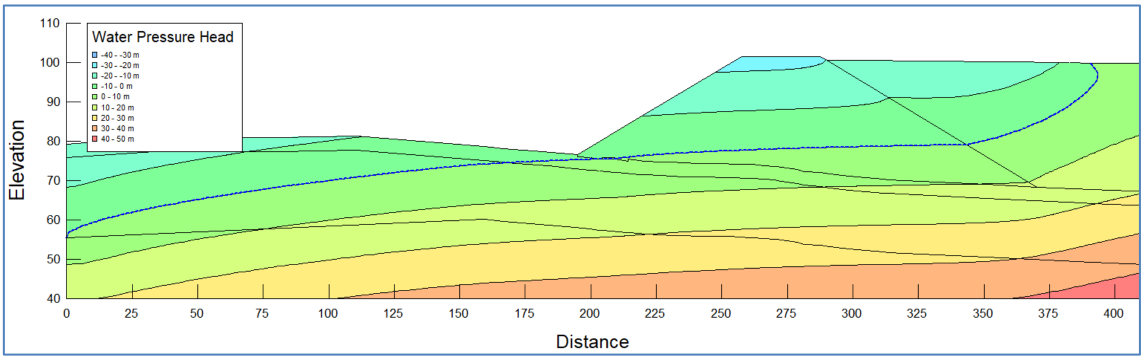

FIGURE 9-7: OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

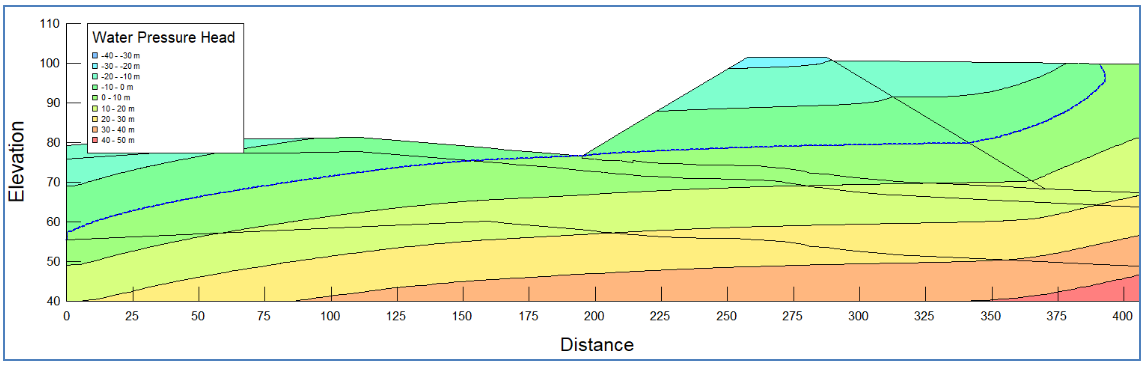

FIGURE 9-8: OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH NO ACTIVE DRAINS

9.2.3. SEEPAGE ANALYSIS RESULTS AT CLOSURE PHASE AT CAPACITY

The closure phase of the facility is depicted in Figure 9-9 to Figure 9-11. It is shown that, as during the operational phase, the downstream blanket drain is an effective means by which the phreatic surface can be decreased within the embankment. The inclined slope of the topography on which the embankment is to be built further improves the separation between the phreatic surface and downstream toe as downstream slopes are reshaped from a 1V:2.5H slope to a 1V:5H. This will decrease the likelihood that the downstream toe will become saturated, preventing piping as well as a decrease in the effective strength of the material as it becomes saturated.

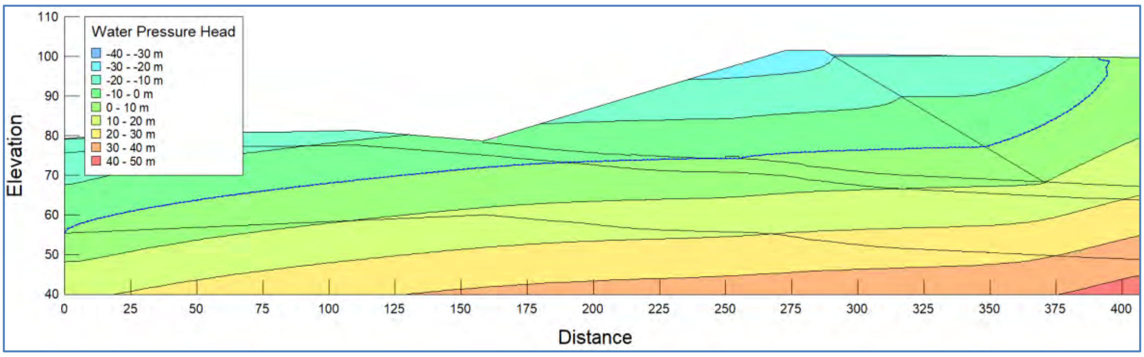

FIGURE 9-9: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN

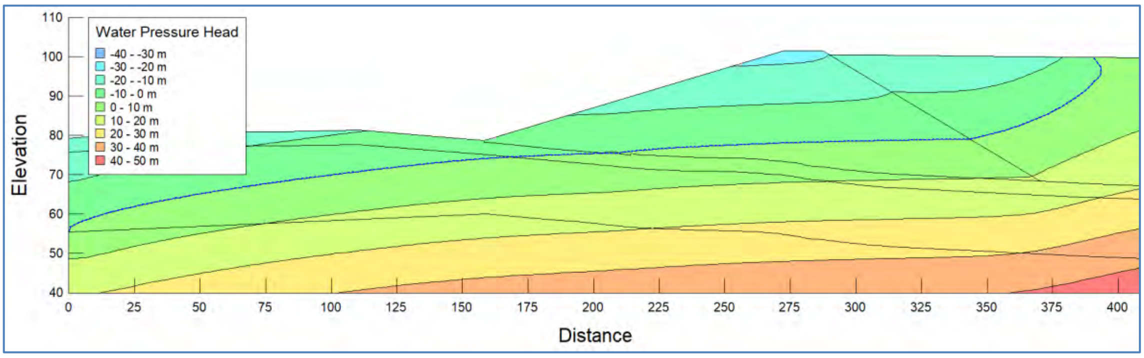

FIGURE 9-10: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

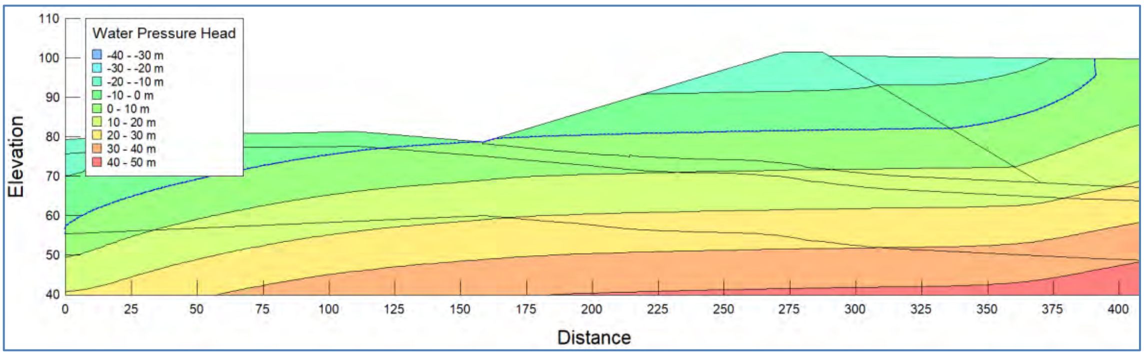

FIGURE 9-11: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH NO ACTIVE DRAINS

9.3. DISCUSSION OF RESULTS

It is evident that the addition of drains to the containment walls reduces the build-up of pore water pressures through the containment walls. While it is a fair assessment that the high permeability of the embankment material, compared to that of the residue material, results in the phreatic surface decreasing rapidly within the containment wall, it should be noted that the topography and underlying soil profile does not allow water to daylight a distance downstream of the facility. Instead, water seeps from the toe of the facility if no drains are included. This would result in the build-up of pore water pressure as the phreatic surface intersects the downstream toe, causing the material to perform undrained, reducing the effective strength of the material while also increasing the potential for erosion in the form of piping to occur. It is thus recommended that a blanket drain be included in the wall.

Piezometers will be installed in the RSF walls to monitor the phreatic surface within the walls. These are to be installed prior to the commissioning of the facility.

9.4. BASIN SEEPAGE ANALYSIS

An analysis of the expected seepage within the basin was conducted through the use of Seep/W along the critical section. The resulting seepage from a scenario with no drains as well as a scenario where the downstream toe blanket drain is active was investigated. In order to account for both the storm and operational pool scenarios, a water total head boundary condition representative of an operation pool with 150 000 m^3 was used to model the supernatant pool.

9.4.1. BASIN SEEPAGE ANALYSIS RESULTS

The results of the analysis can be seen in Figure 9-12 and Figure 9-13 for the scenario with no active drains and the scenario with a downstream blanket drain, respectively. It is shown that seepage results within the basin remain relatively unchanged for both analyses with the major difference occurring beneath the wall where the drains are located. As expected, it can be seen the point where the maximum seepage occurs moves from the downstream toe of the facility to the area where the blanket drains is located once the drain is active. An additional spike in the water flux values occurs at the intersection of the fine tailings and the upstream toe of the embankment as the waters flow transitions from the low permeability tailings to high permeability RAS material.

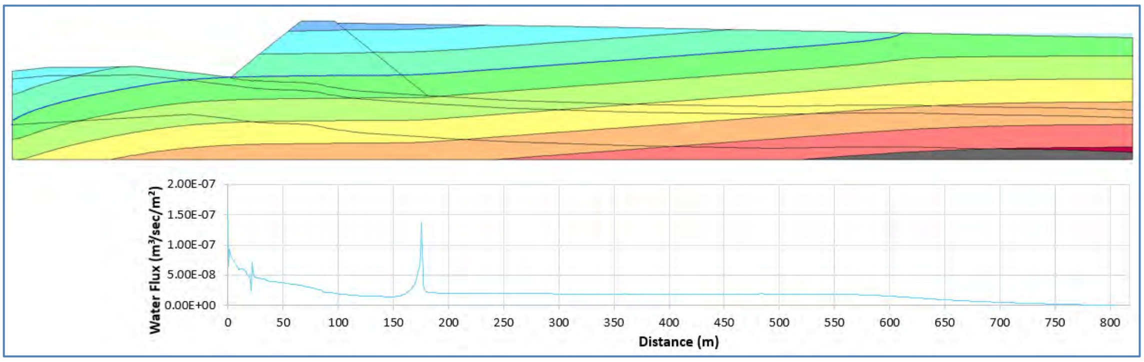

FIGURE 9-12: SEEPAGE ASSESSMENT OF THE TD BASIN WITH NO ACTIVE DRAIN

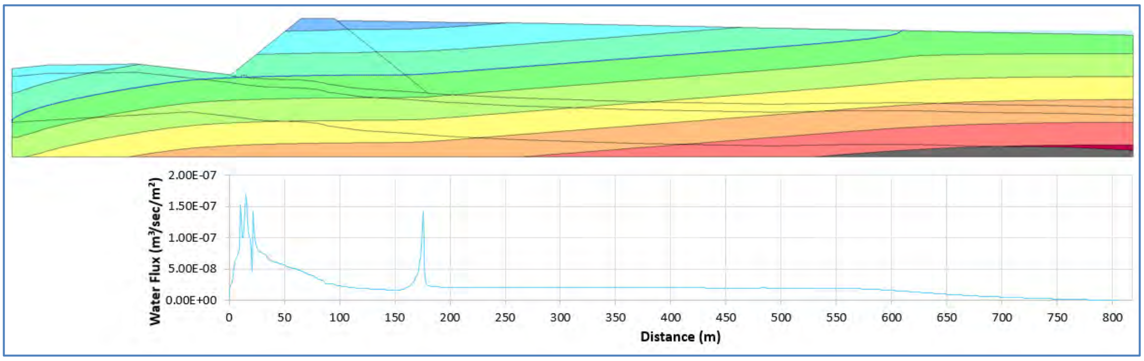

FIGURE 9-13: SEEPAGE ASSESSMENT OF THE TD BASIN WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

An average of the results was determined for 3 regions within the footprint of the facility (Figure 9-14). The first region represents the area beneath the embankment where seepage is high compared to the rest of the basin area due to presence of the blanket drain and the potential seepage interface placed on the downstream face of the embankment. The second region corresponds to the relatively constant flux value shown in Figure 9-12 and Figure 9-13, between approximately 200 m and 550 m. The third region represents the final section of the cross-section where the seepage decreases as the cross-section draws closer to the centre of the facility. The average flux values for each region are listed in Table 9-2.

TABLE 9-2: **BASIN SEEPAGE ASSESSMENT RESULTS**

Drainage Condition	Seepage (m³/sec/m²)		
	Region 1	Region 2	Region 3
No Drains	3.26E-08	1.93E-08	8.20E-09
Downstream Blanket Drain	4.22E-08	2.02E-08	8.60E-09

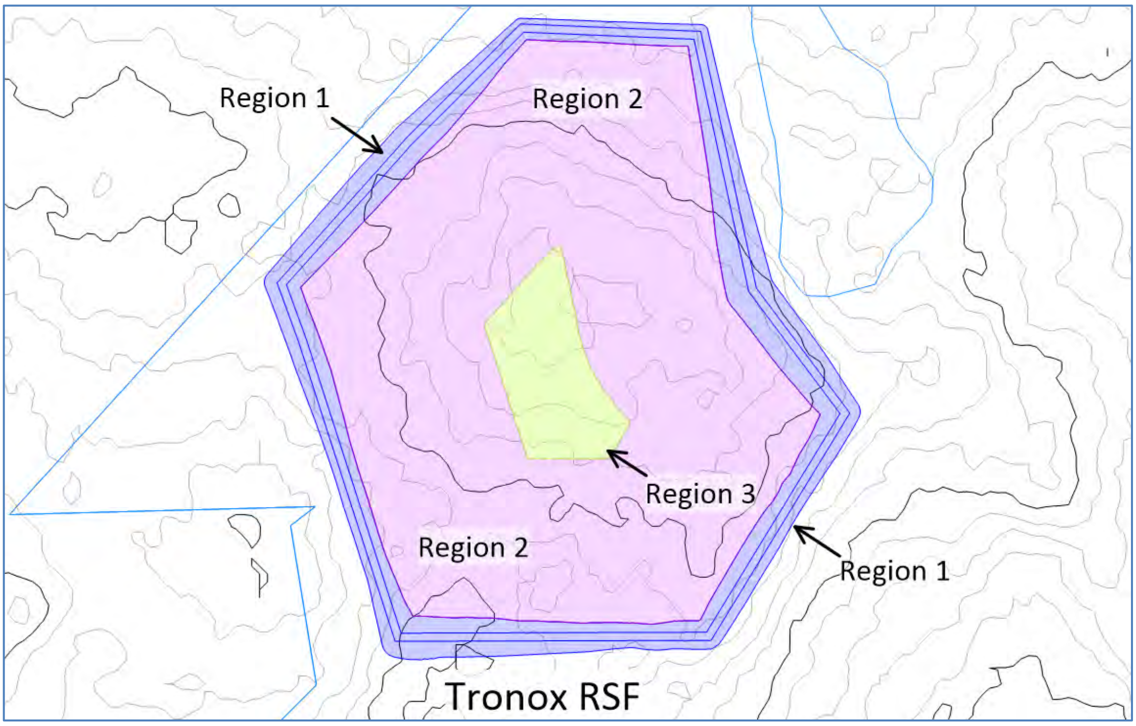

FIGURE 9-14: SEEPAGE REGIONS WITHIN THE TD FOOTPRINT

Additionally, due to the topography of the chosen site and the and the difference in permeability between the underlying soil profiles, the phreatic surface within the depression increases as deposition takes place until either a drain or the downstream toe of the facility is encountered. At this point water is removed from the system and the phreatic surface ceases to increase. It was determined that the model configuration shown in Figure 9-13 results in a water rate of 2.463E-07 m^3/s generated by the supernatant pool while the downstream blanket drain was able to intercept 1.334E-07 m^3/s. This indicates that a downstream blanket drain could reduce the amount of seepage migration beyond the embankment of the facility by up to 54 %.

10. SLOPE STABILITY ANALYSIS

A slope stability analysis was completed to assess the safety of the slopes of the RD under varying conditions. The following sections describe the process by which the analysis was completed.

10.1. METHODOLOGY

To analyse the stability of a slope requires that the Factor of Safety against the failure of the slope to be determined as well as the associated Probabilities of Failure and the Reliability Index of the analysis. The level of uncertainty associated with the long-term stability of a slope is a function of the level of uncertainty associated with:

- The shear strength parameters of the materials comprising the slope and its foundation as expressed in terms of their friction angle and cohesion; and
- The location of the phreatic surface within the slope.

The risk level, or Probability of Failure that may be tolerated for a given slope, depends on:

- The level of risk to the stakeholders (including downstream property owners, authorities, the mine owner and consultants) are willing to accept;

- The level and extent of quality control and quality assurance undertaken during construction;
- Whether the facility is in the operational raise or post-closure raise; and
- Whether or not the side slopes are monitored.

10.1.1. FACTOR OF SAFETY

The Factor of Safety *(FoS)* against the failure of a slope is a ratio between opposing forces: the forces causing failure (gravity forces of the material weight) and the forces preventing failure (shear strength of the soils).

South African legislation as documented in the NEMWA Act No. 59 of 2008 and Regulation 632 (24 July 2015) Chapter 2, 7 (4)(d), says:

"Other design considerations, as appropriate to the particular type of residue stockpile and residue deposit that must be incorporated include:

(d) keeping the pool away at least 50 meters from the walls and a factor of safety not less than 1,5; where there are valid technical reasons for deviating from this, adequate motivation must be provided, and the design must be reviewed by a competent person".

Therefore, the RD has been designed in order to achieve this factor of safety of 1.5 during the operational and closure phase.

10.1.2. PROBABILISTIC ANALYSIS

To allow for variability in the input parameters, a probabilistic analysis is conducted. The software is provided with the probabilistic distribution of the design parameters which includes:

- Type of distribution i.e. Normal distribution, Log-normal distribution etc.;
- The mean; and
- The standard deviation.

A finite number of Monte Carlo trials are conducted which selects, at random, combinations of new parameters within the defined probabilistic distribution. These randomly selected parameters are applied to the critical slip surface which is determined by the deterministic analysis. The FoS from each of the Monte Carlo simulations is recorded as it converges to an overall solution from which a *Reliability Index (RI)* and *Probability of Failure (PoF)* is determined.

The PoF is defined as the number of Monte Carlo trials that resulted in a FoS less than one represented as a percentage of the total number of trials conducted. For long term slopes, a PoF less than 0.0007% (<1:143 000) is widely accepted. Recommended PoFs for short- and medium-term slopes should not exceed 0.07% (1:1 430) and 0,007% (1:14 300) respectively (Cole, 1993).

The RI is defined as the number of standard deviations separating the defined failure FoS of 1.0 from mean FoS that the Monte Carlo simulation converged towards. A Reliability Index of 4.83 correlates to the minimum acceptable PoF, thus values greater than (>) 4.83 is considered acceptable for a long term, or permanent slope.

10.1.3. SEISMICITY

The horizontal force imposed on the structure when undertaking a pseudo-static analysis is derived from the Peak Ground Acceleration (PGA) parameter. PGA values are based on prior earthquakes and fault studies and are measured as factors of the earth's gravitational acceleration (i.e. 1g is equivalent to 9.81 m.s^{-2}).

The minimum allowable Factor of Safety for side slopes, according to NEMWA, is 1.5. Deviations from the prescribed minimum FoS must be substantiated by the designer.

The Peak Ground Acceleration (PGA) for Namakwa will be about 0.04g, based on a 10% probability of exceedance in 50 years from the Global Seismic Hazard Assessment Program (GSHAP) study (Figure 3-1) and between 0.02g and 0.03g (10% probability of exceedance in 50 years) based on the PGA map produced by the Council of Geoscience for South Africa, as depicted in Figure 10-1 below.

A value of 0.03g was used in the stability assessments for the RSF.

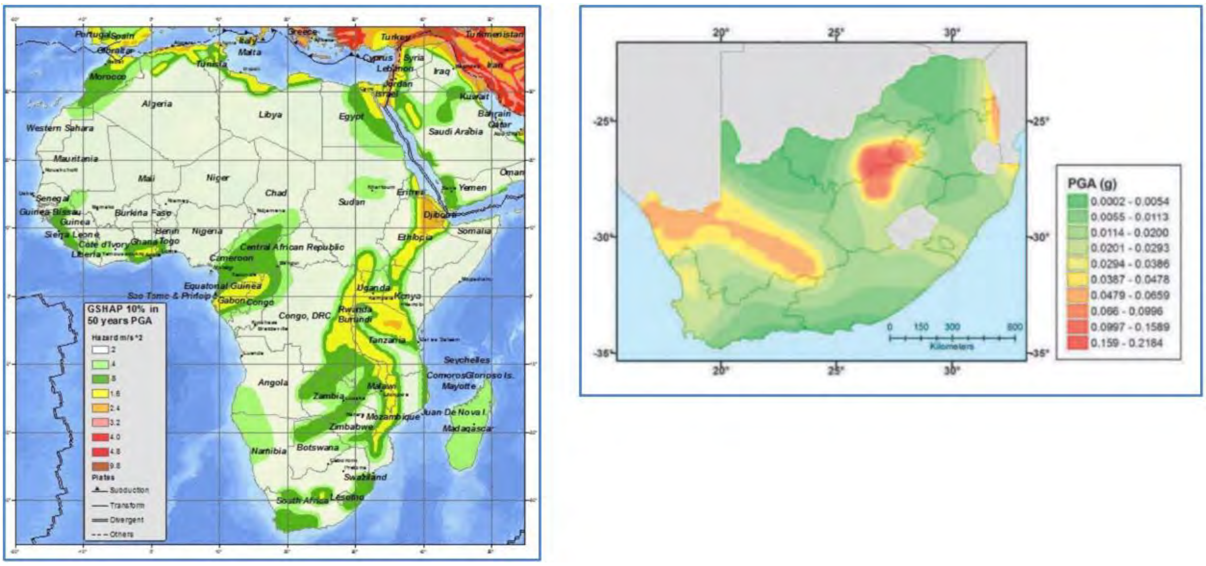

FIGURE 10-1: **PEAK GROUND ACCELERATION (GHSAP (LEFT) AND COUNCIL OF GEOSCIENCE (RIGHT).**

10.2. INPUT PARAMETERS TO THE SLOPE STABILITY MODELS

The slope stability model was defined in terms of the physical configuration of the structure and its foundations as well as the geotechnical properties of the tailings material, and the foundation material. Two types of slope stability analyses are conducted:

- Static analyses which determine the FoS without the addition of PGA (i.e. an earthquake event); and
- Pseudo-static analysis which incorporates the PGA into the assessment to determine FoS during a seismic event.

10.2.1. CONFIGURATION OF THE STABILITY MODELS

The configuration of the slope stability model and its foundations is comprised of the following:

- The same geometry that was used in the associated seepage analysis;
- The phreatic surface determined by the associated seepage analysis;
- In-situ soils modelled with engineering properties obtained from laboratory testing;

- Pseudo-static analysis performed with a PGA of 0.03 g for the RSF;
- It is envisaged that the RD will be constructed in 2 phases as is illustrated in Figure 10-2 and Figure 10-3.

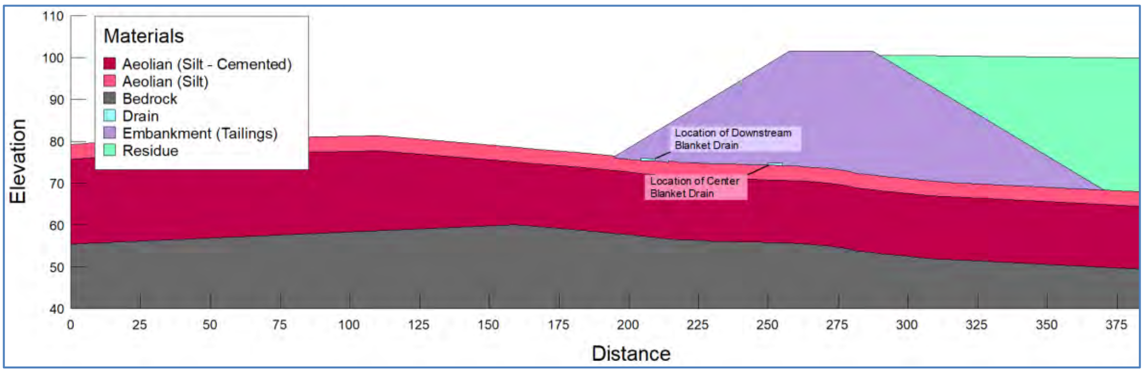

FIGURE 10-2: **OPERATIONAL PHASE AT CAPACITY**

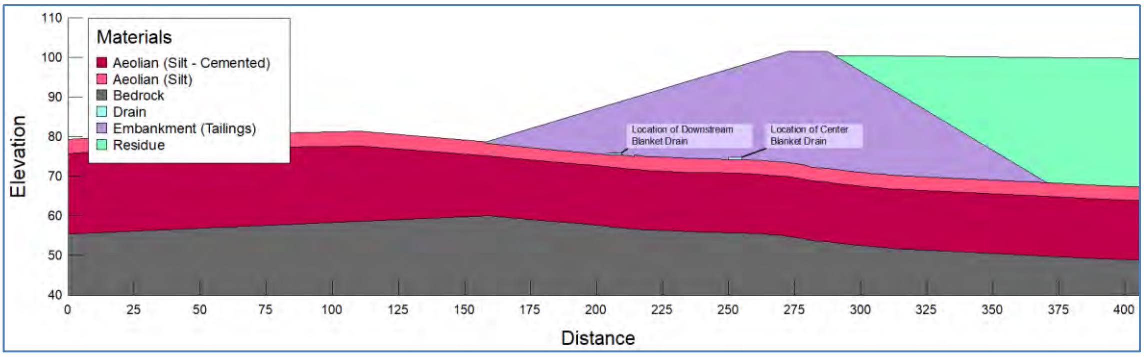

FIGURE 10-3: **CLOSURE PHASE AT CAPACITY**

The geometry used to analyse the operational and closure phase of the RD cross-section along the Critical section is listed in Table 10-1.

TABLE 10-1: SUMMARY OF RSF GEOMETRY FOR STABILITY ASSESSMENT

Feature	Operational Phase	Closure Phase
Crest Elevation (m.a.m.s.l.)	101.5	101.5
Minimum Toe Elevation (m.a.m.s.l.)	74.26	74.41
Maximum Wall Height (m)	27.24	27.09
Crest Width (m)	30	15
Upstream Slope	1V:2.5H	1V:2.5H
Downstream Slope	1V:2.5H	1V:5H

10.2.2. MATERIAL PROPERTIES

The input geotechnical parameters used in the slope stability analysis of the RD is summarised in Table 10-2. It was assumed that RAS or EOFS tailings would be used to construct the containment wall of the facility. It was also assumed that the layer of dune sand that covers the area will be removed and sent to the mines processing plant. The remaining predominant soil profile consists of silty Aeolian sand that becomes weakly cemented with depth. It was assumed that a 3.5 m deep layer of Aeolian material overlays a 15 m deep layer of weakly cemented material before encountering bedrock in the form of very soft rock dorbank.

TABLE 10-2: GEOTECHNICAL PARAMETERS ASSOCIATED WITH THE RELEVANT MATERIALS FOR SLOPE STABILITY ANALYSIS

Region	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Residue	15.0	33	0
Embankment (Sand tailings)	16.0	30	2
Aeolian (Silt)	16.0	32	0
Aeolian (weakly cemented)	19.0	40	0

10.3. RSF STABILITY RESULTS

A detailed list of the results obtained from the slope stability assessment of the RD are published in Epoch's Stability report contained in Appendix E, along with the critical slip surface generated for each model.

The results of the slope stability assessment have been separated into three sections. The first section considers results from the analysis of the upstream face of the embankment with the residue encroaching on the toe of the wall. The second section investigates the stability of the downstream face of the operation phase of the facility once the maximum deposition capacity of the RD has been reached. The last section discusses the FoS against a failure of the downstream face of the closure phase.

10.4. DISCUSSION OF RESULTS

The results of the slope stability assessment indicate that the facility is stable under static loads for the short, medium and long-term slopes under all scenarios considered. A blanket drain, however, is required to achieve FoS above the minimum required value of 1.5 for the downstream slope of the operational phase in the event of pseudo-static conditions. Additionally, it is advised to include the drain as a means to prevent water seeping through the downstream toe of the embankment. The flow of water through the toe could potentially lead to the piping of material which may cause instability of the downstream face.

Similarly, to the downstream face, the upstream face of the embankment yielded FoS greater than 1.5 for static conditions. However, all pseudo-static loading conditions resulted in FoS below 1.5 with a minimum of 1.427. It is argued that the upstream slope will be buttressed with residue as residue deposition takes place, and the resultant slip surface does not compromise the majority of the wall. As such FoS greater than 1.4 are considered acceptable for the upstream short term slope under pseudo-static conditions.

11. SITE DEVELOPMENT PLAN AND STAGE CAPACITY CALCULATIONS

The stage capacity curve for the RSF, reflecting the relationship between residue elevation, rate of rise, storage volume, footprint area, cumulative tonnage, elevation and time is included in Appendix F.

The stage capacity relationship of the RSF was calculated using the survey information supplied by the mine and the residue production rate of the Process Plant. The RSF was designed to accept residue at an average rate of 162 083 tonnes per month (tpm) from the Process Plant with a maximum capacity of 38 900 000 t. The placed dry density for tailing used in the curves is 0.6 t/m^3.

In a conventional self-raising residue dam, the rate of rise of the dam must be at such a rate as to allow for the residue to drain and consolidate to be able to harvest residue material in order to raise the “containment walls”. As the RSF is a full containment facility the stability of the RSF is not dependent on the Rate of Rise. Tronox have indicated that they would like to construct the walls to final elevation prior to commissioning the dam. Should this not be possible, the depression site offers 12 months capacity in the basin prior to the residue reaching the upstream toe of the walls. This will allow the mine with additional time to complete the walls and will also ensure that the minimum required freeboard of 1m will always be maintained.

12. RESIDUE OPERATIONAL METHODOLOGY

The depositional technique selected for this project will be a full containment, hydraulically deposited, spigot facility. The containment wall will be constructed using sand tailings material from the plant and the fine residue will be deposited behind the wall. This design is a common construction technique used in residue storage facilities.

The residue will be discharged from the top of the dam crest creating a beach with the resulting supernatant pool developing as far away from the wall as possible. Where the residue properties are suitable, natural segregation of the material occurs where the coarse material settles closest to the spigot and the fines furthest away.

As the residue is expected to be ultra-fine, more water is expected to be locked up between the residue particles, resulting in lower densities and strength. Another consequence of ultra-fine residue is very flat beaches are expected to form, which could make pool control difficult and will require careful management by the operator.

For the selected depositional methodology, residue is deposited into the RSF basin via an open-end pipeline located on the inner crest of the perimeter wall as shown in FIGURE 12-1. During commisioning, deposition of the residue behind the containment wall is directed to the base of the inner toe of the containment wall by flexible hoses. Deposition during this stage is to be carefully controlled, monitored, and intensely managed to ensure that the walls are not eroded by the residue stream.

FIGURE 12-1: RESIDUE DEPOSITION FROM MULTIPLE OPEN ENDS

13. WATER BALANCE

Water from the supernatant pool will be returned directly to the plant. As the RSF is a full containment facility and capable of storing storm events, no return water facility has been provided for in the design of the RSF. All excess water arising from storm events, will need to be stored on the RSF and slowly returned to the plant. This is discussed further in Section 13.4 below.

A water balance study has been undertaken for the Tronox RSF in order to assess the expected range of daily returns to the plant as well as the volume of excess water to be stored on the facility. This section summaries the findings of the study. The full report can be found in Appendix G.

A deterministic approach was followed during the assessment of the inflow and outflow relationship associated with the proposed RSF. The model makes use of daily rainfall values from the Nuwerus weather, situated 43 km east of the Tronox RSF location, as well as the natural topography associated with the site and deposition data determined from stage capacity calculations. An illustration of the RSF and its associated infrastructure, estimated beach slopes and catchment area can be seen in Figure 13-1.

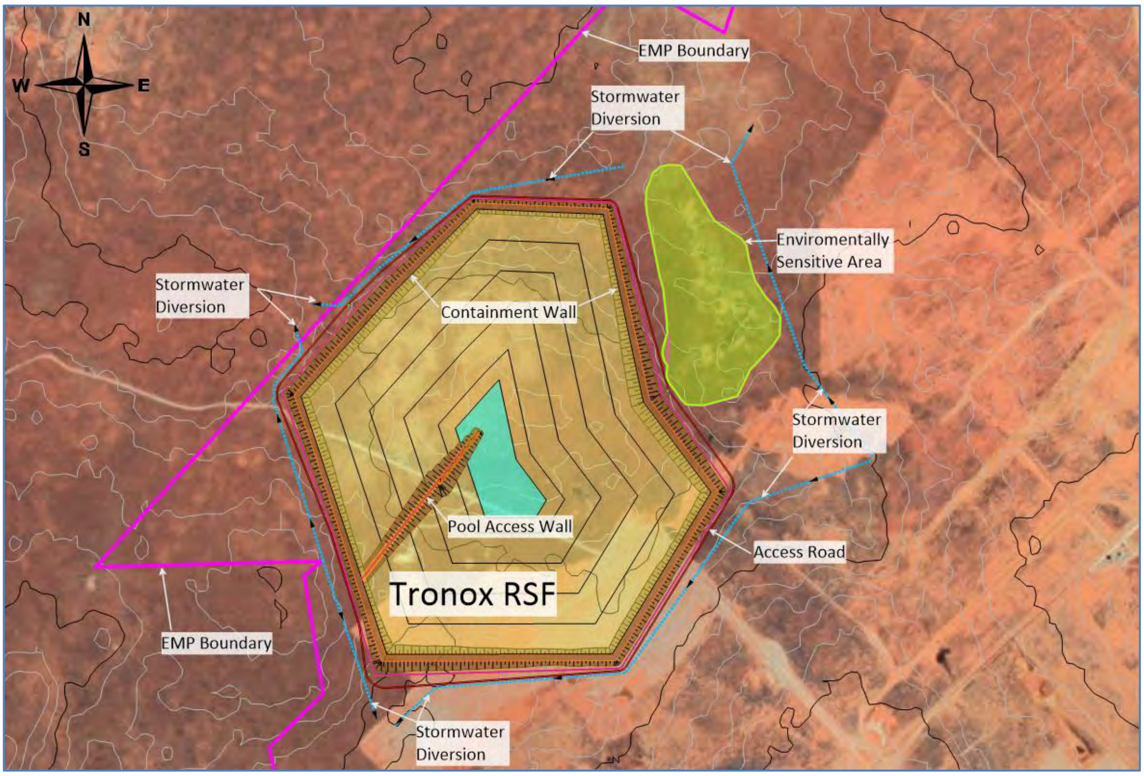

FIGURE 13-1: **TRONOX RSF AT FULL CAPACITY**

The water balance model assesses the volume of water that will be reporting to the RSF pool. The model quantifies the inflows and outflows of water that would affect the volumetric fluctuation of the pool.

Inflows into the RSF include:

- Rainfall run-off from the catchment area of 311 Ha, consisting of the deposition beach, pool surface area and natural topography downstream of the Stormwater Diversion trenches and berm. Clean water run-off emanating from the remainder of the upstream catchment area, illustrated in Figure 13-1, is assumed to be diverted away from the RSF and will not contribute to the water balance; and
- Residue delivery water;

Outflows from the RSF include:

- Evaporation;
- Return water (via pumps);
- Interstitial lock-up between residue particles; and
- Seepage (which is assumed to be minimal due to the low permeability of the residue deposited within the basin).

The various inflows are calculated for each day based on the pool size, deposition tonnage and related deposition area as well as the remaining catchment area outside of the current deposition area. The daily outflows are subtracted from the daily inflows and the remainder is added to the pool volume of the previous day to determine the current day's pool volume. The area of the pool is then used in the next day's calculations to determine the run-off from rainfall, seepage and evaporation.

13.1. PLANT RETURNS

A summary of the expected daily plant returns is listed in Table 13-1. The results show that an average annual return of 58.9 % of the residue water reporting to the RSF can be expected during an average rainfall year. During periods of high rainfall, it may be required to return up to 100 % of the residue water reporting to the RSF. The simulation also indicated that a pump with a decanting capacity of 860 m^3/hr would be active for an average of 11.03 hours per day. Periods of peak activity (24 hr active pumping hours) followed days of substantial rainfall due to the increase in available return water.

TABLE 13-1: EXPECTED DAILY RETURN VOLUMES FOR AN AVERAGE YEARLY RAINFALL

Descriptor	Unit	Values
Wet Season Average Daily Return (May to Aug)	m^3	10,867.6
	%	64.2
Dry Season Average Daily Return (Sep to Nov)	m^3	10,135.4
	%	59.0
Average Daily Return per Yearly	m^3	10,440.5
	%	61.2
Minimum Daily Return	m^3	2,640.9
	%	53.2
Maximum Daily Return	m^3	21,732.6
	%	100.0
Minimum Monthly Return	m^3	84,271.9
	%	54.8
Maximum Monthly Return	m^3	438,276.1
	%	66.9

13.2. FREEBOARD

The total freeboard of a dam is defined as the vertical distance between the normal Full Supply Level (*FSL*) and the nominal Non-Overspill Crest (*NOC*) of the dam. Freeboard is divided into two components namely the flood surcharge rise above the FSL, the primary component, and a secondary component allowing for wind, wave and surge effects (SANCOLD, 2011). In the case of a RSF, the beach freeboard developed by the deposition of the residue provides additional storage of water within the basin. The different freeboard components are illustrated in Figure 13-2.

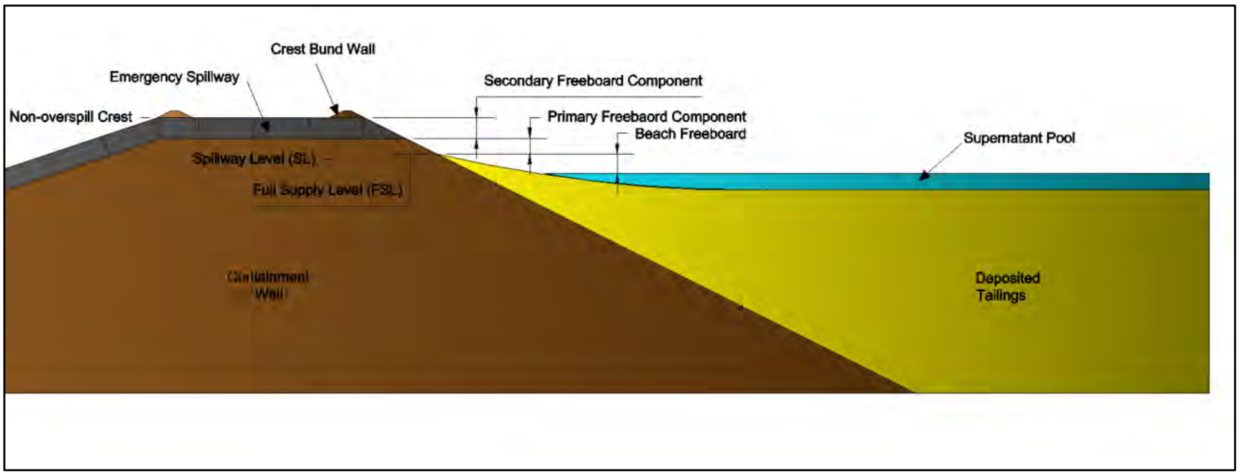

FIGURE 13-2: **TYPICAL PROVISION OF FREEBOARD ON A FULL CONTAINMENT RSF**

Pool water on a RSF needs to be adequately managed taking cognisance of the hydraulic requirement as well as the South African regulations and guidelines or best practices where no regulation or guideline is specified. Based on the regulation GN704 of the National Water Act, the required minimum freeboard for the Tronox RSF is 0.8 m, over and above the storage of the 1 in 50-year design flood (primary freeboard).

The walls of the facility will be constructed within the first years of operations to final elevation resulting in a substantial freeboard that slowly decreases as residue is deposited within the basin of the RSF. Geometric modelling of the RSF indicates that the minimum available freeboard between the surface of the maximum operating pool and the none overflow crest of the facility is estimated to be 2.61 m, with a beach freeboard of 1.67m and a primary freeboard of 1m. Thus, adequate freeboard is available to accommodate the 1:50 year storm event as well as its accompanying wave action.

13.3. SUPERNATANT POOL MANAGEMENT

The large catchment area of the RSF combined with instances of high rainfall result in a substantial increase in the supernatant pool volume during the wet season. Careful monitoring during this period is required to ensure that the maximum pool volume is not exceeded.

The dry season of the project typically experiences a notable net negative inflow of run-off water as evaporation exceed the volume of recharge received by rainfall. It would be expected that an overall decrease in the supernatant pool volume will occur in the dry seasons. The risk of beaching the decanting system is increased if the supernatant pool volume decreases too rapidly. It is thus essential to manage the returns from the RSF such that the minimum permissible storage volume is maintained to prevent the damage or loss of the decant equipment. It is assumed that a minimum dead storage volume of 20 000 m^3 must be maintained on the Tronox RSF to mitigate the risk of damage or loss of the decanting infrastructure.

A gradual drawdown approach is proposed that balances the water returns from the RSF such that the minimum dead storage is not depleted by the end of the dry season.

13.4. STORM WATER MANAGEMENT

Section 123(1) of the National Water Act, 1998 (Act No. 36 of 1998) defines a “dam with a safety risk” as a dam storing more than 50 000 m^3 and a wall of vertical height more than 5 m. Based on the daily water balance, the RSF supernatant pool volume pool would not exceed 43 328 m^3 at any given point under normal operating conditions, thus not exceeding the 50 000 m^3 requirement.

During storm events, the volume of water reporting to the RSF will increase and need to be decanted as Process Plant make-up water over a short period of time. A high-level overall Plant water balance was conducted, taking into account all plant outputs and returns in order to estimate the time over which storm water can be bled off the RSF back to the Process Plant.

Process Plant outflows considered were:

- Thickener underflow water (to RSF);
- Concentrate water; and
- Sand Tailings water.

Process Plant returns considered were:

- RSF return water;
- Sand tailings return water; and
- ROM water.

Based on these calculations the average time taken to decant the storm water from the RSF for a given 24hr storm event is depicted in Table 13-2.

TABLE 13-2: TIME TAKEN TO DECANT A STORM EVENT

Storm Return Period (years)	Storm Event (mm)	Volume of storage (m^3)	Time taken to bleed of storm event (days)
2	30	93 195	10.6
5	41	127 367	14.5
10	49	152 219	17.3
20	58	180 177	20.5
50	69	214 349	24.4
100	78	242 307	27.5
200	87	270 299	30.7

With the RSF being a full containment facility, it is capable of storing any of the above storm events for the listed period of time, without compromising the stability of the RSF as detailed in Section 9.2 and 10.4 above. Furthermore, given that the RSF will be returned to normal operating conditions within a short period of time, the facility is not considered a dam with a risk classification and as such no Storm Water Dam is required for the RSF.

14. RESIDUE STORAGE FACILITY DESIGN

The RSF comprises:

- A Residue Dam; and

- Associated infrastructure (i.e. slurry deposition pipeline, pool access wall, storm water diversion, etc.)

14.1. RESIDUE DAM DESIGN

The location and footprint area of the RD was influenced by the following factors:

- The required capacity for the residue;
- The topography (rivers, ground slopes);
- Climatic conditions;
- The receiving environment in the area of the facility;
- Acceptance of level of risk by Mine owner for long term environmental liability;
- The average in-situ placed density of the residue;
- Type of facility required (self-raising versus full containment); and
- The overall outer slopes of the facility.

The overall operational layout of the RSF is shown in Figure 14-1. Table 14-1 summarises the key layout parameters of the RD.

TABLE 14-1: KEY PARAMETERS ASSOCIATED WITH THE TRONOX RD

Item	RD Parameter Description	
1	Total Footprint Area of RD	350 Ha
2	RD Wall Elevation	101.5 mamsl
3	Final Residue Elevation	101.5 mamsl
4	Maximum Height of RD wall	27 m
5	Wall Length	6 617 m
6	Upstream Side Slopes	1V:2.5H
7	Downstream Operational Side Slopes	1V:2.5H
8	Downstream Closure Side Slopes	1V:5H
9	Time Period for Residue to reach Design Capacity	20 years

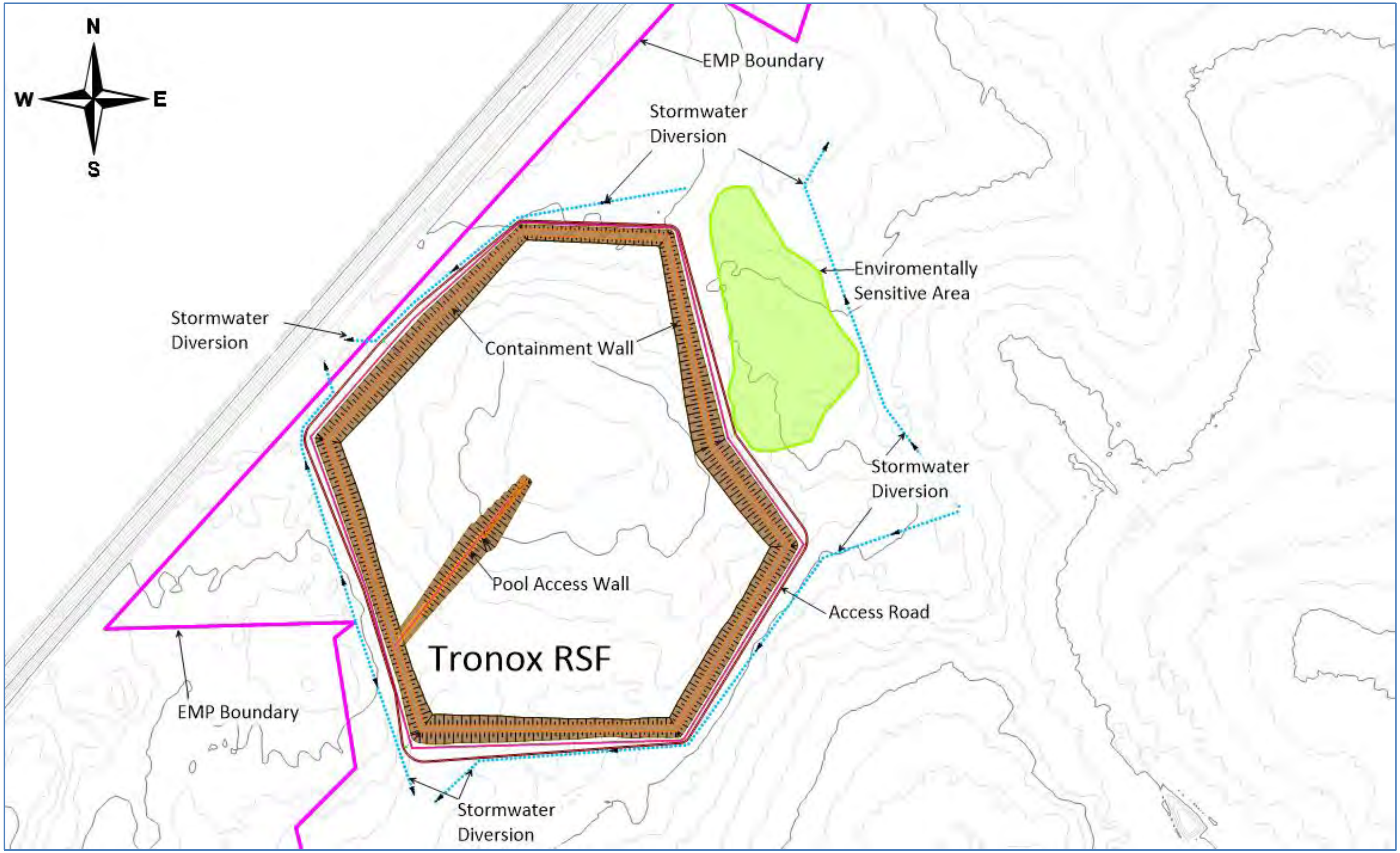

FIGURE 14-1: **RSF LAYOUT**

14.1.1. CONTAINMENT WALL DESIGN

Containment wall:

The mine will endeavour to contract the containment walls to final elevation prior to the commissioning of the facility prior to the residue braking ground in the basin. The wall will be constructed on two phases, the operational and closure phase. The operational wall will be 27 m high (101.5 mamsl) from the lowest downstream point. It will have a crest width of 30 m, with upstream and downstream slopes of 1V:2.5H. A 0.5 m high safety bund will be provided on either side of the crest of the wall.

The wall will be constructed using coarse sand tailings material sourced from the plant. The material will be trucked to the RD and tipped. No formal compaction of the material is to be undertaken. Once in position the material will be dozed to create the required side slopes.

The volume of the operational phase wall is 9 443 703 $m^{3.}$ The closure phase of the facility will require the downstream slope of the RD to be flattened to 1V:5H by reducing the crest width to 15m and introducing some additional 692 574 m^3 of sand tailings into the wall. The volume of the wall at the closure phase will be 10 136 277 m^3.

Containment wall foundations:

The geotechnical investigation indicated that the top 2 to 3 m of insitu material is either very loose dune sand of very loose fill material, and recommended that this material be compacted prior to the construction of the RD walls. As the dune sands are to be mined from the RSF footprint prior to the construction of the RSF (i.e., removed from the RSF footprint area), compaction of this material will not be necessary.

The loose fill material, located in the south east corner of the RSF footprint area, is to be removed from beneath the RSF walls.

Pool access wall:

The pool access wall will comprise a 10 m wide, embankment running from the crest of the wall into the basin of the RD. Seven benches, each 5m high, have been incorporated at the end of the pool wall to allow for the placement of the turret decant pump. An access ramp leading to each bench will allow for the pump to be towed up to the following bench as the residue level increases in the RD, always allowing access to the pumps and turret. The wall will be constructed with a sand tailings core, cladded with a geofabric and compacted selected borrow material. The material will be compacted at least 98% standard proctor density within 1.5% to 2% wet of optimal moisture content.

14.1.2. LINER DISCUSSION

The National Environmental Management: Waste Act (NEMWA) of 2008 GN.R.634 to R.636 provides the legislation pertinent to the waste classification of the residue stream, and the requirement for lining the RSF thereof. The regulations allow for a risk-based approach to design (i.e. design and management measures, including containment, should be commensurate with the level of risk posed to the environment).

In the absence of a risk-based motivation to design as prescribed by GN R632 a Type 3 wastes (residue) typically require a disposal facility that is designed to the prescribed standards of a Class C liner, and a Type 4 wastes (tailings) typically require a disposal facility that is designed to the prescribed standards of a Class D lliner.

A Class-C liner typically consists of:

- 1.5 mm HDPE geomembrane;
- 300 mm compacted clay layer;
- Leakage Detection systems; and
- A protection layer (fill material, or geotextile).

A typical cross-section of a Class-C liner is illustrated in Figure 14-2.

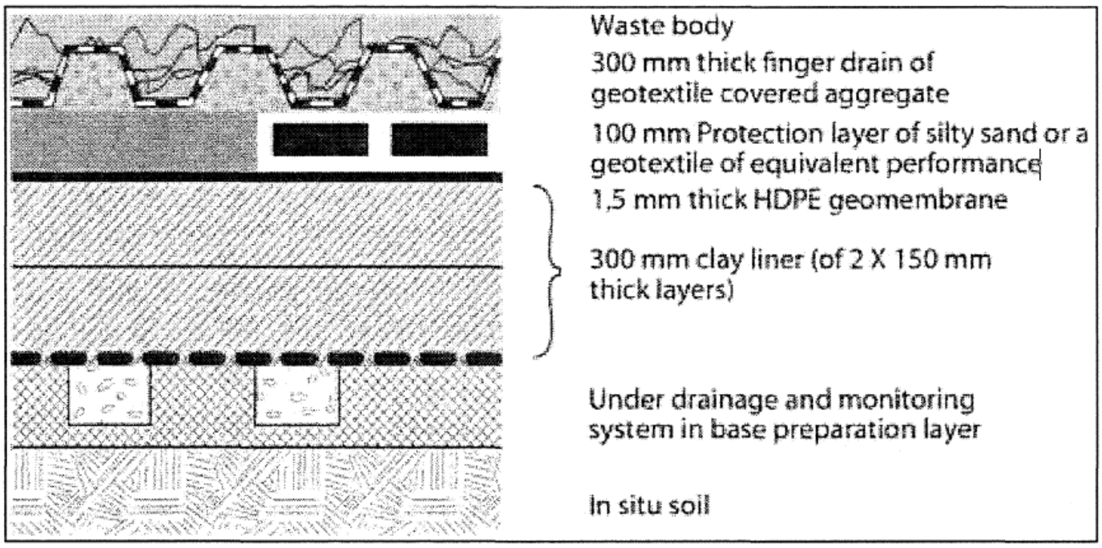

FIGURE 14-2: CLASS-C LINER SYSTEM AS PER NEMWA GN. R636

The permeability of the composite Class C liner was determined using the method by Rowe et al. (2012). A 1.5mm HDPE liner is to be placed over a Compacted Clay Liner (CCL). Two cases were analysed, namely a “Reasonable” case and an “Excellent” case, depending on the level of quality assurance implemented. Table 14-2 below shows the parameters used to determine the permeability of each case, using the method by Rowe et al.

TABLE 14-2: ROWE ET AL – LINER PERMEABILITY PARAMETERS

		Reasonable	Excellent
Wrinkle Length	m	350	20
Permeability of Clay	m/s	1.00E-09	1.00E-09
Half width of wrinkle	m	0.014	0.014
Thickness of clay	m	0.3	0.3
Wrinkles per hectare		10	5
Leakage	m/s	5.13E-09	1.47E-10

In order to achieve these permeabilities, the liner must be installed such that continuous wrinkles are minimised and do not exceed the numbers listed above. A 300mm sandy cover layer is to be placed over the liner before wrinkles form (in the morning hours or immediately after liner installation). This would be further described in a CQA Plan document.

In the event that holes do form in the liner, it is expected that particles from the residue will pass through, thus essentially blocking or reducing further flow of water through the liner, however this effect is difficult to predict without experimental test work.

A typical cross section of a class D liner as per the regulations is depicted in Figure 14-3 below.

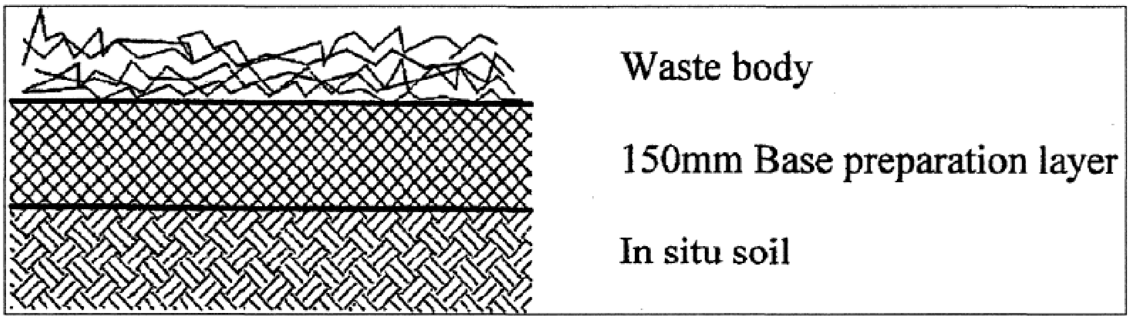

FIGURE 14-3: CLASS-D LINER SYSTEM AS PER NEMWA GN. R636

A Class D liner requires that the top 150mm of insitu soil be ripped and recompacted so as to improve the material's permeability. As the loose dune sands are to be mined from the RSF footprint, the RSF is to be sited on the Aeolian soil. As detailed in Section 8.3, the undisturbed Aeolian soils have a permeability in the order of 1x10-^{6} m/s. The disturbed samples, after compaction, yielded an increased permeability of 1x10^{-5} m/s. This can be attributed to the fact that the natural soils are in a slightly cemented state and disturbing them breaks down the cemented properties. It is thus argued that the installation of a Class D liner in the basin of the RSF will result in a higher permeability base than the natural conditions, and as such the insitu soils should not be disturbed. The insitu material can thus be considered to perform as well (or even better) than a typical Class D liner

The seepage analysis as discussed in Section 9.4 of this report indicate that the rate of seepage into the receiving environment is driven by the permeability of the residue material which is in the order of 4 x 10^{-8} m/s and not by that of the insitu soils. Furthermore, the inclusion of a blanket drain in the design of the RSF creates a preferential flow path resulting in 54% of the seepage being captured by the drains and reducing the net inflow into the receiving environment.

As discussed in Section 7.2 the Tronox EOFS residue and tailings material are non-acid generating, inert and with the GAI indicating no significant enrichment relative to the global soil median concentrations.

The RSF is a potential groundwater contaminant source of the EOFS Project. SRK undertook a geohydrological study to determine the impact the RSF would have on groundwater as detailed in their report "*East OFS Project Residue Disposal Plan, Groundwater Specialist Study*", Dec 2020. To assess the impact the RSF would have on the groundwater, three scenarios were considered with regards to the RSF base layer:

- Scenario 1 (Sc1): "as is"/no base preparation: This scenario assumes that no base preparation is required for the RSF, thus the base layer is set to the same permeability as the residue material itself (1 x 10^{-8} m/s);
- Scenario 2 (Sc2) – engineered base preparation. This scenario assumes there is base preparation for the RSF. Although considered as an option, this scenario was not numerically modelled as the permeability for the engineered base preparation (Sc2) is higher than the residue material

deposited in the RSF (as modelled in Sc1), thus it was not deemed necessary to model as the impact would be greater than that of Sc1.

- Scenario 3 - liner. This scenario assumes a Class C type liner with two different ‘equivalent K’ values for the 0.3 m composite base, as follows:
  - Scenario 3a (Sc3a): A “reasonable” Class C (HDPE and CCL) installation, represented by an equivalent 0.3 m thickness with permeability of 5.13 x 10^{-9} m/s; and
  - Scenario 3b (Sc3b): An “excellent” Class C (HDPE and CCL) installation, represented by an equivalent 0.3 m thickness with a permeability of 1.47 x 10^{-10} m/s.

The modelled results show that the contaminant footprint areas and concentrations are very similar for Sc1 and Sc3 (a and b): i.e. there is little difference/impact between the various RSF base preparation design options and can be summarised as follows:

- Average groundwater concentrations in 2051 in the local area directly underlying the RSF decrease by c.7% and c.13% for Sc3a (lined – moderate) and Sc3b (lined-excellent) respectively, in comparison to Sc1, whereas concentrations more than 200m beyond the RSF footprint are very similar across scenarios;
- The contaminant footprint areas and concentrations are very similar between Sc1 and Sc3(a&b), thus there is little difference between the various RSF base preparation design options. The contaminant plume does not migrate further than 200 m from the facility;.
- There is little difference (<5 m) between the modelled scenarios in terms of the water level increases for the various RSF base preparation design options.

Based on the above risk-based approach the inclusion of any type of liner system would not yield any significant environmental benefit. With the inclusion of the blanket drain (not considered in the geohydrological models), the impact of seepage from the RSF on the receiving environment is further reduced (by up to 54%). As such no liner/ base preparation has been included in the design of the EOFS RSF6.

14.2. WATER MANAGEMENT DESIGN

Water management requires careful consideration for any RSF, due to the non-cohesive nature of residue and its propensity to flow freely when over saturated. For RSFs, water management implies the removal of supernatant water from the RD, preventing large quantities of rainwater from reaching and being stored on the RD and reducing the seepage through the downstream toe.

The RSF requires the following water management systems:

- A floating pump system for removing supernatant water from the RD;
- Storm water diversion berms to prevent/reduce surface run-off reaching the RD;
- Emergency Spillways;

14.2.1. DECANT SYSTEM

The RSF has been designed as a full containment dam, which provides certain advantages with regards to the storage of water on the RSF. The containment walls are constructed from competent material providing increased strength, thus increasing the stability of the facility, even in the event of a raised phreatic surface. This means that some water can be stored on the RSF, therefore allowing a floating barge system and pump to be utilised, as opposed to a conventional penstock decant system.

A penstock dewatering system typically consist of a vertical decant tower, leading to a below ground outlet pipeline, gravity feeding the supernatant water to the return water facility at the toe of the RSF. As the natural topography of the site does not allow for the supernatant water to be gravity fed to a return water facility without excessive excavation, the use of a penstock was not considered in this study.

Supernatant water on the RD accumulates in a pool as a result of beaching and deposition control. This supernatant water, derived from the process plant and from rainfall, will be decanted from the surface of the RD for the following reasons:

- To prevent accumulation and eventually overtopping;
- To allow drying and consolidation of the residue; and
- To reduce the potential development of pore water pressures with potential stability issues.

Supernatant water from the RSF will be decanted and released by means of a floating pump system. The system is specially designed to operate in shallow water and cause minimal agitation of the settled residue. The system incorporates an external pump, which is positioned on the pool access ramp. The external pump is moved up the ramp as the residue level and supernatant pond level raises. The system has a floating inlet structure, known as the Turret (illustrated in Figure 14-4), which is placed in the supernatant pond and allows water to be extracted through the suction end without agitating or collecting the settled residue below the pond. Figure 14-5 illustrates how the turret extracts water from the pond. The manufacturer states that a single Turret can operate at flows up to 1 000 m³/hour, and is operable in ponds with depths not less than 400 mm. Based on this a minimum pool volume of 20 000m^3 must be maintained on the RD at all times.

FIGURE 14-4: **TURRET SYSTEM POSITIONED IN THE SUPERNATANT WATER CONNECTED TO AN EXTERNAL PUMP**

The pool access wall will be constructed to allow vehicles to drive along it in order to gain access to the pumping system. The floating pump conveys the supernatant water directly back to the plant.

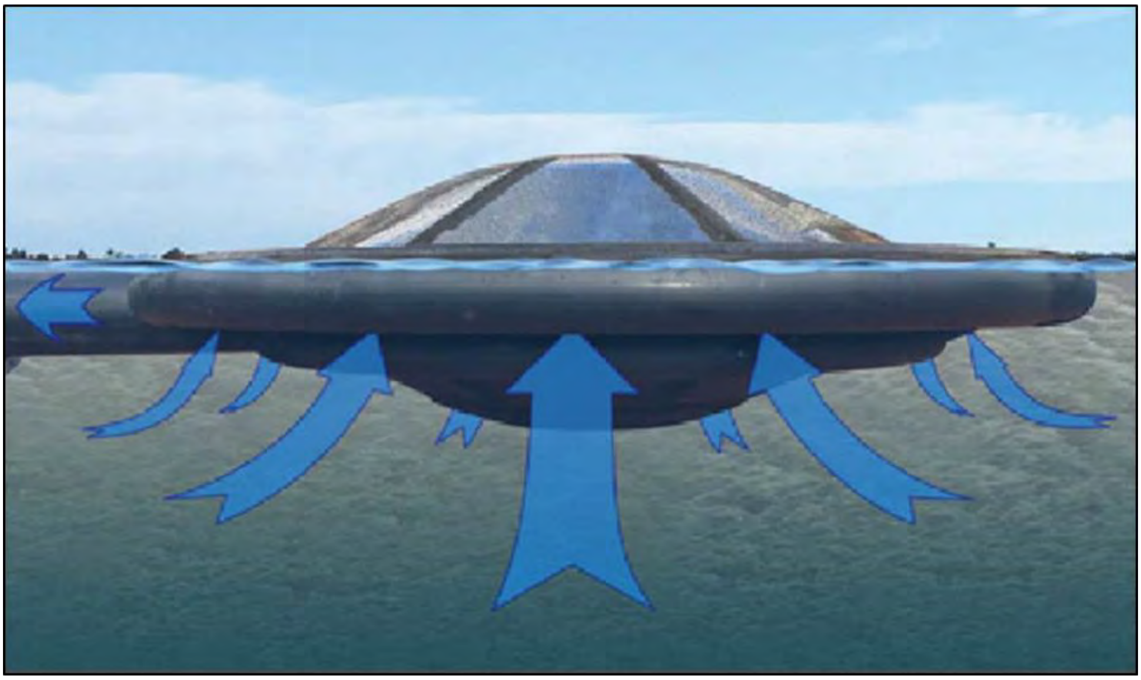

FIGURE 14-5: DESIGN FUNCTIONALITY OF THE TURRET SYSTEM

14.2.2. STORM WATER DIVERSION

Storm water diversions are required to divert clean run-off around the RSF. Storm water diversion bunds has been provided to divert the 1 in 100-year storm event from the catchment around the RSF (catchment diversions), as well as inside the RD basin (raise 1 diversions).

14.2.3. EMERGENCY SPILLWAYS

An emergency spillway has been included in the RD so as to decant excess storm water from the facility for rainfalls exceeding the 1 in 100 year storm event and to prevent overtopping of the dam. The spillway feeds into a spillway chute conveying and releasing water to the environment downstream of the RSF.

15. RSF PREPARATORY WORKS

The preparatory works associated with the RSF are discussed below. General Arrangement and typical section drawings are contained in Appendix H.

15.1. CONTAINMENT WALL BOX-CUT

As discussed in Section 14.1.1, the containment wall will be founded on Aeolian soils after the removal of the loose dune and fill sands. For the preparatory works, a box cut 500 mm deep box-cut will be excavated beneath the outer 20m of the wall footprint area to allow for the construction of the blanket drains. The box cut will then be backfilled with the RAS tailings material.

15.2. CONTAINMENT WALL

The containment wall will be constructed using sand tailings material which is to be trucked and tipped. It is to be constructed with upstream and downstream side slopes of 1V:2.5H. The operational phase wall will be constructed to 101.5 m.a.m.s.l with a maximum height of 27 m and a 30m crest width.

The closure phase will require the crest of the wall be reduced to 15 m and the side slopes to be flattened to 1V:5H. The wall elevation will remain at 101.5 m.a.m.s.l.

15.3. STORM WATER DIVERSION BUND

The storm water diversions will comprise of a minimum of a 1.5 m high, 1 m wide crest bund, constructed from insitu material nominally compacted. The bunds must be maintained on an ongoing basis during operations to ensure they are maintained at their minimum dimensions.

15.4. POOL ACCESS WALL

The pool access wall (10m wide) will be constructed with a sand tailings core and cladded with a geofabric and selected material compacted to 98% standard proctor density within 1.5% to 2% wet of optimal moisture content.

15.5. EMERGENCY SPILLWAY

An emergency spillway will be constructed in the crest of the containment wall to convey water safely from the RD in the event that the RD becomes flooded. The spillway will be 1 m deep (below the wall crest) and 5m wide. The spillways will feed into a 5m wide chute discharging water to the downstream environment.

15.6. BLANKET DRAINS

A blanket drains will be constructed in the containment wall, located 10 m from the downstream toe of the wall. The blanket drain will be 5m width and comprise of geofabirc, slotted HDPE pipes, 6 mm stone and 19 mm stone.

15.7. CATCHMENT PADDOCKS

Catchment paddocks are to be constructed along the downstream toe of the containment walls. These will have an average height of 1m and will serve the purpose of catching and storing rainfall runoff from the side slope of the walls. During the initial stages of operation, these paddocks will also catch and contain the water seeping from the RAS tailings, as it is understood that the tailings will be placed with a 20% moisture content. Water contained in these paddocks will be allowed to evaporate and not be pumped back to the plant.

16. CLOSURE, REHABILITATION AND AFTERCARE REQUIREMENTS

The proposed rehabilitation, closure and aftercare measures for the RSF are described below.

The rehabilitation, closure and aftercare plan are based on the assumption that the objective of the process is to rehabilitate, as far as possible, the area disturbed during the establishment and operation phases of the project.

16.1. KEY ENVIRONMENTAL ISSUES

The key environmental risk issues related to the rehabilitation, closure and aftercare of the RSF include:

- The potential contamination of surface water and soils due to uncontrolled run-off from the facility;
- The potential for the erosion of exposed tailings and residue and / or cover soils which can lead to silts entering the surface water;
- The potential contamination of groundwater resources in the vicinity of the RSF due to excessive infiltration of rainfall into the facility and subsequent groundwater recharge; and
- The potential aesthetic impact of the facility on its surroundings.

16.2. CLOSURE ACTIVITIES AT CESSATION OF OPERATIONS

At the cessation of operation of the RSF, the focus will be on the cover and vegetation of the top surface of the facility, the decommissioning of facilities associated with the RSF and the construction of storm water control measures as required. Specific activities that will be carried out will include:

- The dismantling and removal from site of all pipes and supports associated with the residue delivery and return water systems;
- Flattening the downstream side slopes of the RD to 1V:5H by reducing the wall crest width to 15 m and dozing the existing material down to the required slope. An additional 692 574 m^3 of RAS material will be required to achieve the required slopes. Given the large volume of RAS Tailings available during the construction phase of the containment walls, it is recommended that these walls be constructed to closure requirements side slopes of 1V:5H from the onset. This will negate the costs of double handling of material and will allow for the cladding and vegetating of the side slopes of the RSF during the operational life of the mine. This would also assist in reducing the dust originating from the side walls of the RSF during the operation of the facility.
- Capping of the top surface area of the RD with a layer of coarse tailings. The residue is an extremely slow settling and consolidating material with correlating low placed dry density of 0,6t/m^3, the time required for the residue to fully consolidate is expected to exceed 500 years. As such 1m layer of tailings is too be introduced onto the top surface of the RD on a progressive front basis. A layer of material will be placed the traversable area of the RD (adjacent to the RD containment wall). Once the region adjacent area to the capped layer has consolidated sufficiently to allow it to be traversed, a capping layer will be applied to it, and so on. The capping of the top surface is to be done in such a manner so as to allow for the collection of all storm water to report to a central point on the RD

and allow for the water to evaporate and/or infiltrate into the facility. An alternative would be to cap the RD in a “whale-back” manner which would allow for all runoff to flow off the facility. Given the low rate of consolidation of the residue and the volume of material required to achieve this (estimated at 9.3 Mm^3), this is not considered a feasible option;

- Construction of evaporation dam. With the application of the capping layer, lock-up water contained in the Residue would be released and should be removed from the RSF surface so as to further assist with consolidation. As the Process Plant will be de-commissioned at the end of LoM of 20 years, this water cannot be returned to the plant. It is thus recommended that a facility be constructed that will provide sufficient storage of both storm water and released lock-up water to be stored and allow this water to evaporate over time. This evaporation facility would be decommissioned once the RD is fully cladded and the decant barge and return water pipelines can be removed from the RD;
- The upgrading of the overflow spillway;
- The placement of a mixture of soils and selected waste materials to the outer slopes of the walls and cladded top surface of the RD in preparation for the establishment of vegetation;
- The planting/seeding of vegetation to the outer slopes of impoundment wall and top of the RD to assist in the prevention of erosion;
- The aftercare and maintenance of the cover layers and vegetation; and
- Minor earthworks to drains, roads, silt trap, trenches, etc.

The duration of the final closure process may be affected by the length of time required for the basin of the facility to dry sufficiently to enable the placement of cover material in preparation for the vegetation establishment.

The soils placed on the outer slopes of the RSF need to be protected against erosion. This will be done by a combination of mixing with selected waste material and the establishment of vegetation to the cover. The mixing of soil with material of a gravel/rocky nature has been found to be effective in improving the erosion resistance of cover layers to sloped areas. The establishment of vegetation to the side slopes of the facility could be done by hand planting, seeding or hydro-seeding and should comprise a mixture of grass and shrubs. The vegetation used in the establishment of the vegetative cover will all be indigenous and should not require irrigation.

16.3. AFTERCARE AND MAINTENANCE REQUIREMENTS

On completion of the final rehabilitation and closure works, an aftercare and maintenance program will be required to assist in ensuring that the closure measures are robust, have performed adequately and that no further liabilities arise. The aftercare period is normally not less than 5 years but can extend into decades depending on the physical and chemical characteristics of the facility. The aftercare and maintenance program for the Tronox RSF is expected to include:

- Periodic inspection of the cover and vegetation for signs of erosion damage and failures of the vegetation establishment process;
- Repairs and amendments to the closure works as necessary;
- Re-planting of areas of vegetation where required;

- Periodic inspection and monitoring to confirm the effectiveness of the closure works in achieving the stated closure objectives, including:
    - Collection and analysis of ground and surface water samples;
    - Measuring of phreatic surfaces within the RD and assessment of the overall structural stability of the facility; and
    - Inspections of spillway for signs of damage.

No allowance has been made for the treatment of water that will need to be discharged into the environment from the RSF after closure, as any discharge post closure is considered as clean water. This will however need to be confirmed during closure.

The maintenance requirements for the facility should decrease with time and should be confined to minor earthworks to repair erosion damage and upgrade facilities as required, as well as re-planting of areas of vegetation damaged due to erosion.

17. LIFE OF MINE COST ESTIMATE

An estimate of the Life of Mine (*LoM*) costs associated with the construction, operation and rehabilitation and closure of the RSF will be compiled based on schedules of quantities to be priced by prospective contractors. These costs are envisaged to be available in May 2021 and will be included in the final submission of this report. SRK have however included a closure cost for the RSF in their overall closure cost assessment for the EIR application.

18. RSF RISK IDENTIFICATION

Residue Storage Facilities pose a significant hazard to people and property around them as well as significant costs to the client. Specifically, they pose a risk to:

- Health and safety of workers, contractors and visitors to the mine;
- The environment (animals, plants, eco systems, habitats, wetlands etc.);
- The economic sustainability of the mining operation (business economics), and;
- The mine’s reputation and relationship with the community (public, authorities, NGO’s, neighbouring community).

The size and degree of the potential hazard depends on the location and size of the RSF, site specific characteristics, method of construction, residue material characteristics, construction materials, method of RSF development, operational control, closure planning and monitoring, and overall management.

18.1. SAFETY CLASSIFICATION

The RSF was classified according to the South African National Standards, Code of Practice for Mine Tailings (SANS 0286:1998). This classification provides the bases for the implementation of safety management practices for specified stages of the life cycle of a Tailings Dam. The code prescribes the aims, principles and minimum requirements that apply to the classification procedure. The classification in turn gives rise to minimum requirements for investigation, design, construction, operation and decommissioning.

The safety classification serves to differentiate between high, medium and low hazard on the basis of their potential to cause harm to life or property.

The zone of influence, as shown in Figure 18-1, may be described as the extent of the area around the RSF that may be affected with time, taking into consideration the possible impacts that may arise from the RSF e.g. flow slide, surface and groundwater contamination, sterilisation of arable land etc.

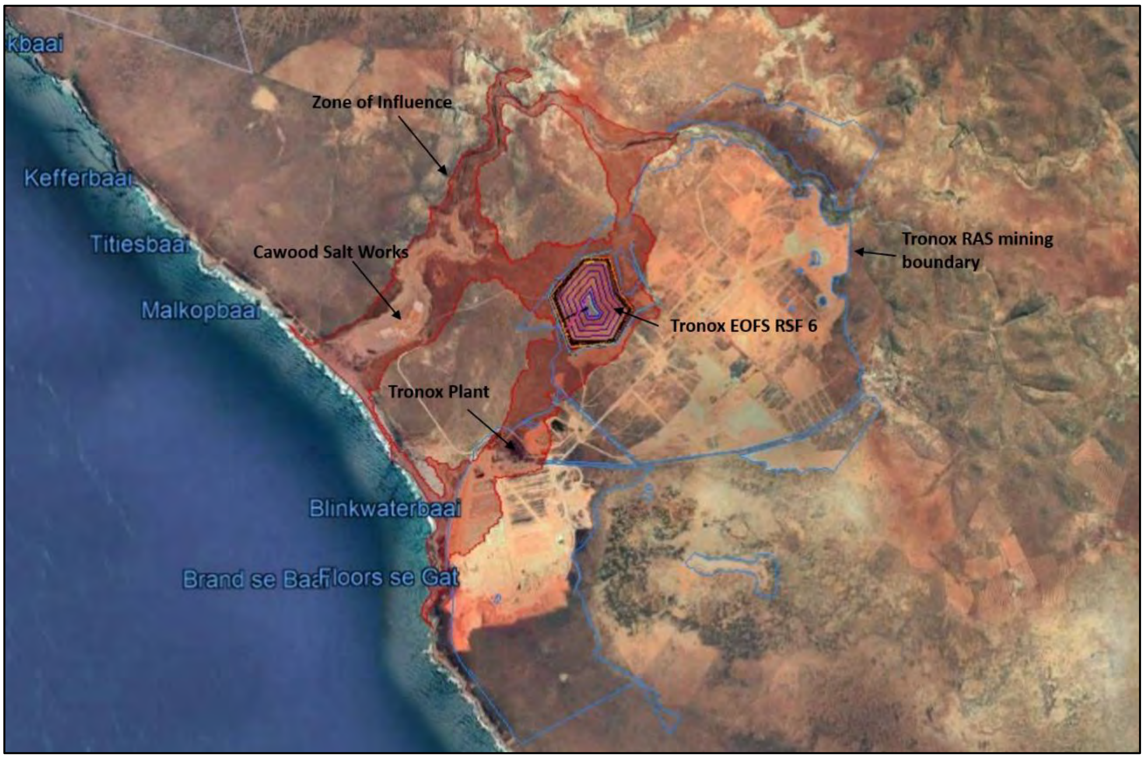

FIGURE 18-1: **ZONE OF INFLUENCE FOR THE RSF**

The safety classification of the RSF under each criteria is listed below in Table 18-1.

TABLE 18-1: **DAM SAFETY CLASSIFICATION**

Criteria	Comment	Safety Classification
Number of residences in the zone of influence	Zero, based on Google Earth images	Low Hazard
Number of workers in the zone of influence	Probably more than 100, as the plant of the mine is within the zone of influence.	High Hazard
Value of third party property in the zone of influence (replacement value in 1996 terms)	The neighbouring Cawood Salt Works Mine is in the zone of influence; therefore the costs will exceed 20 million ZAR	High Hazard
Depth to underground mine workings	No underground mining within the zone of influence.	Low Hazard

Based on the safety classification criteria detailed in the code of practice, the RSF has been classified as a High hazard dam as two of the criteria fall under the high hazard rating.

The minimum requirements associated with a high hazard dam are listed in Table 18-2.

TABLE 18-2: SUMMARY OF MINIMUM REQUIREMENTS ASSOCIATED WITH HIGH HAZARD SAFETY CLASSIFICATION

Planning Stage	Design Stage	Operation/ Commissioning Stage	Decommissioning Stage
Conceptualisation by owner with the assistance of a Professional Engineer	Geotechnical report required	Risk analysis by suitably qualified person	Professional Engineer appointed to monitor
Preliminary site selection by appropriate specialist	Residue characterisation by laboratory analyses	Suitably qualified person responsible for operation	Professional Engineer to audit annually
Geotechnical investigation by suitable qualified person	Design by Professional Engineer	Professional Engineer appointed to monitor	
	Risk analysis by suitably qualified person	Professional Engineer to audit annually	
	Construction supervision by Professional Engineer		

18.2. RISKS ASSOCIATED WITH THE RSF DURING CONSTRUCTION

The risk issues associated with construction are summarised as follows:

- The preferred site lies adjacent to an environmentally sensitive area. Care must be taken to not impact this area during the construction of the RSF;
- The liner requirements for the basin of the RD have not been finalised. Approval must be obtained from authorities. Lining the entire basin would result in significant increased capital cost as well as lengthened construction time;
- Large earthmoving vehicles will be on site during construction and staff must be made aware of the dangers involved with working near these large machines. Health and Safety procedures must be adhered to.

18.3. RISKS ASSOCIATED WITH THE RSF DURING OPERATIONS

The risk issues associated with operation and mitigated in the design are summarised as follows:

- The RSF failing and causing a flow slide is a key risk. This must be managed through an intense QA / QC system, construction management/supervision during the construction of the facility and competent operational management so as to reduce the risk of failure. More specific issues and mitigation measures are identified including:
    - Piezometer be installed in the RD wall to monitor the phreatic surface within the wall;
    - The entire perimeter of the RD must be inspected on a daily basis to ensure any defects are noted as early as possible. Such as: sloughing, slips, ratholing, seepage, etc.;
- The RD it expected to have water on the dam, as well as very soft Residue, such that if a person falls in they could drown. Emergency measures must be provided for such cases (e.g. safety ropes,

lifesavers, etc.). Residue personnel should be aware of the dangers of falling in the RD, however the local population would not be. It is suggested that sufficient signage, warning people of the dangers, be provided. It is also recommended that the dangers of the RD is clearly explained to people living near the mine;

- The water levels on the RD must be monitored to ensure that sufficient water is pumped off the RD, to provide sufficient storage for the design storm event. Similarly the minimum pool operating level must be maintained so as to not run the risk of beaching the decant turret.

18.4. RISK ASSOCIATED WITH THE RSF DURING AND AFTER CLOSURE

The risks associated with the RSF during closure and post closure are not as extreme as those during the construction and operation raise, however for closure some design work is required to design the storm water management system and to mitigate against soil erosion, as this can result in extensive damage downstream if not controlled.

Key risks to closure are:

- Time taken to clad the top surface area is dependant on the rate of consolidation of the residue. This may result in a lengthy closure period;
- It will be difficult to predict the long term effectiveness of the re -vegetation of side slopes and crest or the RSF; and
- There is a risk for potential for post-closure water treatment.

19. CONCLUSIONS

The following conclusions were deduced from the studies documented in this report:

- The RSF has been designed to store a total of 38.9 million dry tonnes of residue over a period of 20 years and comprises:
    - A RD, with a footprint area of 350 Ha and a maximum height of 27 m from the lowest contour;
    - Associated Infrastructure (i.e. storm water diversion, catchment paddocks etc.).
- From the seepage and slope stability analysis for the RD, it was found that based on the parameters determined from the test work and the geometry of the RD, the facility should be stable, with a factor of safety above 1.5 under static conditions and above 1.4 for pseudo-static;
- The water balance model indicated that on average 9 490 m^3 may be returned to the process plant circuit per day;

20. RECOMMENDATIONS

The following recommendations are provided for the Detailed Design Phase of the project:

- Confirm design criteria;
- Confirm with the authorities the liner requirements for the basin of the RSF;

- Confirmation of survey data accuracy. It is recommended to undertake survey points of the site to confirm elevation.

Report Author	Reviewer	Project Manager
Georgia Wills-Vagis	**Kyle Liesker**	**Andrew Savvas**

epoch resources (pty) lRD

Appendix A NEMWA REQUIREMENTS SUMMARY

Summary of requirements out of National Environmental Management Waste Act, 59 of 2008 - Regulations Regarding the Planning and Management of Residue stockpiles and Residue Deposits, 2015 (GNR632 amended by GN990)

Reg no	Requirement	REPORT	Section in applicable REPORT
3	**Assessment of impacts and analyses of risks relating to the management of residue deposits**		
(1)	Identify and assess environmental impacts arising from residue deposits as part of the EIA conducted in terms of NEMA.	EIA Report	6
(3)	A risk analysis based on characterisation and classification (below) to determine the appropriate mitigation measures	RSF6 BFS Design Report	14.1.2
(5)	A competent person must recommend the pollution control measures suitable for a specific residue deposit on the basis of a risk analysis as contemplated below (characterisation and classification (below))	Waste Classification RSF BFS Design Report	5.5 & 6 9, 14
4	**Characterisation of residue stockpiles and residue deposits** Characterise residue deposit to identify the potential risk to S&H and impact on environment associated with the residue when stockpiled/deposited. By a competent person Must be characterised in terms of:		
	a) physical characteristics: size distribution, permeability, void rations, consolidation, strength, specific gravity, water content (in life phases), change in above properties over time .	RSF6 BFS Design Report	4.3, 7, 9.1 & 10.2
	b) chemical characteristics toxicity, propensity to oxidise and decompose, pH & chem comp of water separated from solids, stability and reactivity (and rate thereof), acid generating and neutralising potential, concentration of volatile organic compounds.	Waste classification	5
	c) mineral content to identify any potential risk to health or safety hazard and environmental impact that may be associated with the residue when deposited.	Waste classification	5
5	**Classification of residue deposit** Risk analysis on residue deposits conducted and documented on all facilities to be established. By a competent person Classify residue deposit on the basis of:		
	a) characteristics of the residue .	RSF BFS Design Report	7
	b) location and dimensions of the deposit (height , surface area).	RSF BFS Design Report	14
	e) pollution control measured determined as a result of the risk analysis contemplated in characterisation and classification	RSF BFS Design Report	14.1.2

6	**Investigation and site selection for residue stockpiling and deposit** By a competent person		
(1)-(4)	(a) identify sufficient number of candidate sites	RSF BFS Design Report	Appendix B
	(b) qualitative evaluation and ranking of all sites	RSF BFS Design Report	
	(c) qualitative investigation of the top ranking site as in 2	RSF BFS Design Report	
	(d) Conduct a feasibility study on the highest ranking sites in terms of: i) a health and safety classification.	RSF BFS Design Report	
	ii) an environmental classification.	EIA	3.8.1.1
	iii) geotechnical investigations: - characterisation of the soil and rock profiles over footprint (and infrastructure) to define spatial extent and depth of diff soil horizons. - relevant engineering properties of foundational soil and assessment of strength and drainage characteristics.	RSF BFS Design Report	8
	iv) hydrological investigations: - potential rate of seepage and quality of seepage	RSF BFS Design Report	9.4
(5)	Conduct further investigations on the preferred site in terms of: a) land use.	EIA	All within mining areas
	b) topography and surface drainage.	EIA	3.8.1.1
	c) infrastructure and man-made features.	EIA	3.8.1.1
	d) climate.	N/A	All in similar area
	e) flora and fauna.	N/A	All in disturbed areas
	f) soils.	N/A	All in similar area
	g) ground water morphology, flow, quality and usage.	EIA	3.8.1.1
	h) surface water.	EIA	3.8.1.1
(6)	Investigation, laboratory test work, data interpretation and recommendation for the identification and selection of the most suitable site	Waste classification	5

7	**Design of the residue stockpile and residue deposit** By a Prof civil or mining engineer registered under Engineering Profession of SA Act 1990		
(2)	Consider the soil profile in the design of the residue deposit.	RSF BFS Design Report	8.1, 9, 10
(3)	Take into account all phases of the life cycle of the residue stockpile and residue deposit, from construction through to post closure, and must include the:	RSF BFS Design Report	Throughout
	a) characteristics of the residue in the design of the residue deposit.	RSF BFS Design Report	7
	b) characteristics of the site and the receiving environment in the design of the residue deposit.	RSF BFS Design Report	9, 10
	c) general layout of the residue stockpile or residue deposit, whether it is a natural valley, ring dyke, impoundment or a combination thereof and its three-dimensional geometry at appropriate intervals throughout the planned incremental growth of the residue deposit in the design .	RSF BFS Design Report	Appendix E and H
	d) type of deposition method used in the design of the residue deposit .	RSF BFS Design Report	12
	e) rate of rise of the stockpile or deposit in the design of the residue deposit.	RSF BFS Design Report	Appendix F
	f) design of the pollution control barrier system in the design of the residue deposit.	RSF BFS Design Report	14.1.2
(4)	Other design considerations as appropriate to the type of stockpile		
	a) control of storm water on and around the residue deposit in the design of the residue deposit.	RSF BFS Design Report	13.4, 14.2 and 15.3
	b) capping layer in the design of the residue deposit to prevent mobilisation of contaminants of concern.	RSF BFS Design Report	16
	c) provision, throughout the clean and dirty water systems making up the control measures, of a freeboard of at least 0.5 m above the expected maximum water level to prevent overtopping in the design of the residue deposit.	RSF BFS Design Report	13.2
	d) keeping the pool at least 50m from the walls and a factor of safety not less than 1.5, where there is a valid technical motivation for deviating, this must be motivated.	RSF BFS Design Report	10
	e)control of decanting of excess water under normal and storm conditions in the design of the residue deposit: -retention of polluted water (GN991); - design of aspects such as penstock, outfall pipe, under-system & return water dams; - height of phreatic surface, slope angles, method of construction of outer walls and effect on shear stability; - erosion of slopes- wind, water- and control by veg / berms / paddocks - potential pollution	RSF BFS Design Report	13.4
(5)	Include an operating manual in the design of the residue deposit, signed off by registered professional civil or mining engineer.	Operating manual to be completed at Detailed design phase	

8	**Impact Management**		
	Must manage impacts in the following manner:		
	(a) Identify residue material and management practices with a potential to contaminate water	Groundwater specialist study Waste Classification RSF BFS Design Report	5, 6 5 9, 13
	(b) conduct statistical defensible and representative characterisation programme of relevant materials	Groundwater specialist study Waste Classification RSF BFS Design Report	5, 6 5 9, 10 & 14
	(c) Conduct an impact prediction study to assess potential impacts on water recourses for the full life cycle of the mining operation and include: - monitoring programme - evaluate effect of mitigatory measured to demonstrate acceptable levels of impact.	Groundwater specialist study	5, 6
9	**Monitoring & reporting system**		
	Monitoring system must be "designed" and must consider:		
	- baseline conditions of air, surface and ground water quality	EMPr	Within mitigation measures: Section 5
	- objectives for air, surface and groundwater quality		
	- residue characteristics		
	- receiving environment- climate, local geology, hydrogeology, geochemical conditions		
	- migration pathways		
	- location of monitoring points and protocols		
	- reporting and frequency and procedure		

Appendix B SITE SELECTION REPORT

Site Selection Report - Tronox East Orange Feldspathic Sands Residue Storage Facility

epoch resources (pty) ltd

mine residue and environmental engineering consultants

PROJECT NUMBER 126-003 | Final | May 2019

Site Selection Report - Tronox East Orange Feldspathic Sands Residue Storage Facility

Prepared For

Tronox (Pty) Ltd - Namakwa Sands

PROJECT NUMBER 126-003

Final

May 2019

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SITE SELECTION REPORT - TRONOX EAST ORANGE FELDSPATHIC SANDS RESIDUE STORAGE FACILITY

1. INTRODUCTION

Epoch Resources (Pty) Ltd (*Epoch*) have been requested by Fluor (Pty) Ltd (*Fluor*) on behalf of Tronox (Pty) Ltd (*Tronox*) to undertake a Pre-Feasibility Study (*PFS*) for the East Orange Feldspathic Sands (*EOFS*) Residue Storage Facility (*RSF*) situated at Tronox's Namakwa Sands Northern Operation. In this report a site selection study is undertaken as part of the PFS. The study aims to deliver a position for the RSF which is most suitable based on the following considerations:

- Required storage capacity;
- Topography;
- Other mine infrastructure;
- Distance from the mine infrastructure (Process Plant, Open pits etc);
- Surrounding ore bodies;
- Geological anomalies;
- Environmental and social; and
- A risk-based analysis.

A total of four sites were identified. From these four sites, five options/combinations were investigated and classified according to predetermined design criteria and the risks/hazards associated with each option. As part of the study, a high-level cost estimate of each option was undertaken. Through this process it was possible to draw conclusions and recommendations for the most feasible site(s) for the construction of the RSF.

2. SCOPE OF WORK

A trade off based on a risk assessment was undertaken to ascertain the most suitable site. The assessment was conducted with the following Risk Categories for each site:

- Safety;
- Public health;
- Environmental;
- Mining proximity;
- Financial issues;
- Other issues which include: visual impact, complexity of construction, geological anomalies; and
- Potential for expansion.

The site selection process undertaken in this report as part of the PFS, is of a conceptual nature. The objective of this report was to identify the most suitable RSF site(s). Once the preferred site(s) is finalised, a more detailed assessment with regard to environmental, social and financial impacts needs to be undertaken.

3. DESIGN CRITERIA AND ASSUMPTIONS

3.1. DESIGN CRITERIA

The design criteria of the Fine Residue used in the trade-off of the Residue Storage Facility are shown in Table 3-1.

TABLE 3-1: DESIGN CRITERIA OF THE FINE RESIDUE

DESCRIPTION	VALUE	UNIT
Particle Specific Gravity	2.79	-
Particle Size Distribution	75% passing the 10 µm	-
Placement Dry Density	0.6	t/m^3
Tailings Production Rate	1 240 000	tpa
Life of Mine	20	years
Total Tonnes of fine residue	29	Million tonnes

3.2. ASSUMPTIONS

The following assumptions were used in the study:

- The type of storage facility was assumed to be a full containment facility, due to the expected fineness of the residue and the low solids content of the slurry;

- The embankment wall will be constructed from the coarse residue reporting from the plant. The coarse residue will be trucked to the RSF and constructed using a spreaders and dozers;
- It has been assumed that the facility will not be lined;
- No water dams were included, as it was assumed that water would be stored on the RSF and pumped to the plant via a floating pump/barge on the RSF.

4. TRONOX RESIDUE STORAGE FACILITY SITE SELECTION

Residue Storage Facilities are generally large structures that can pose a significant hazard to health, safety and the environment, depending on their location, site-specific characteristics, method of construction, operation, and level of management and operational control. In addition, the RSF construction, operation and closure can be costly and impact dramatically on the financial viability of any mining operation. It is therefore considered essential that the planning of any mine requires a rigorous RSF site selection exercise in which the trade-offs of reliability and affordability can be assessed for alternative sites and methods of construction.

Several approaches can be adopted for RSF site selection, these range from informal “gut feel” approaches, to formal quantified assessments in which considerable effort and calculations are undertaken.

Important issues regarding any site selection process are as follows:

- The need to have a formal approach;
- Maintaining as far as possible objectivity (although any qualified selection process involves some degree of subjectivity);
- The need to consider all the impacts; and
- To provide an approach that’s is defensible and open to review.

RSF sites suggested by Tronox and Epoch were selected based on:

- Suitable topography for the RSF;
- Distance from the process plant;
- The nature and sensitivity of the surrounding environment, i.e. the receiving environment
- The sites being located within the Mine Lease Area. Tronox has indicated that if a site’s footprint slightly extends past the mine lease area this would not pose an issue;
- Avoiding the following:
    - Planned mine infrastructure;
    - Existing mine infrastructure;

- Surrounding ore bodies; and
- Environmentally sensitive area.

The four potential sites identified for the storage of the fine residue are as follows and shown in the Figure 4-1 below:

- Depression site
- Valley site
- Northern site
- Side Hill site

4.1. DEPRESSION SITE

The depression site is situated North of the process plant. The natural topography of the site allows for a large majority of the tailings tonnages to be contained by the natural depression with the remainder accommodated by constructing walls around the perimeter of the depression. Key features of the site include:

- No infrastructure, communities and/or agricultural activities are located downstream of the facility;
- Walls may not be required at start-up due to the natural depression at the site;
- The site is in close proximity to an environmentally sensitive area situated on the North Eastern side;

4.2. VALLEY SITE

The valley site is situated in a North Easterly direction from the process plant. A small natural valley situated on the northern side of the site allows for the construction of a wall across the valley. Key features of the site include:

- The site is situated upstream of the dual carriage conveyor;
- The site is situated over an ore body. Concurrent mining and deposition of residue is required. Careful planning is required to ensure production is not hindered;
- No communities and/or agricultural activities are located downstream of the facility; and
- The southern extents of the site are situated approximately 1km from a provincial road.

4.3. NORTH SITE

The North site is situated in a North-Easterly direction from the process plant. The site cannot feasibly contain all the residue over the LoM therefore, an additional site would need to be commissioned for the remainder of the residue. Key features of the North site include:

- An environmentally sensitive area is situated on the South Westerly extent of the RSF; and
- The North site is the furthest distance from the process plant.

4.4. SIDE HILL

The Side Hill site is situated North East of the plant. The wall would be built on the downstream side of the slope, containing residue between the wall and side of the slope. The site cannot feasibly contain all the residue over the LoM therefore, an additional site would need to be commissioned for the remainder of the residue. Key features of the site include:

- Steep topography; and
- Close proximity to the plant.

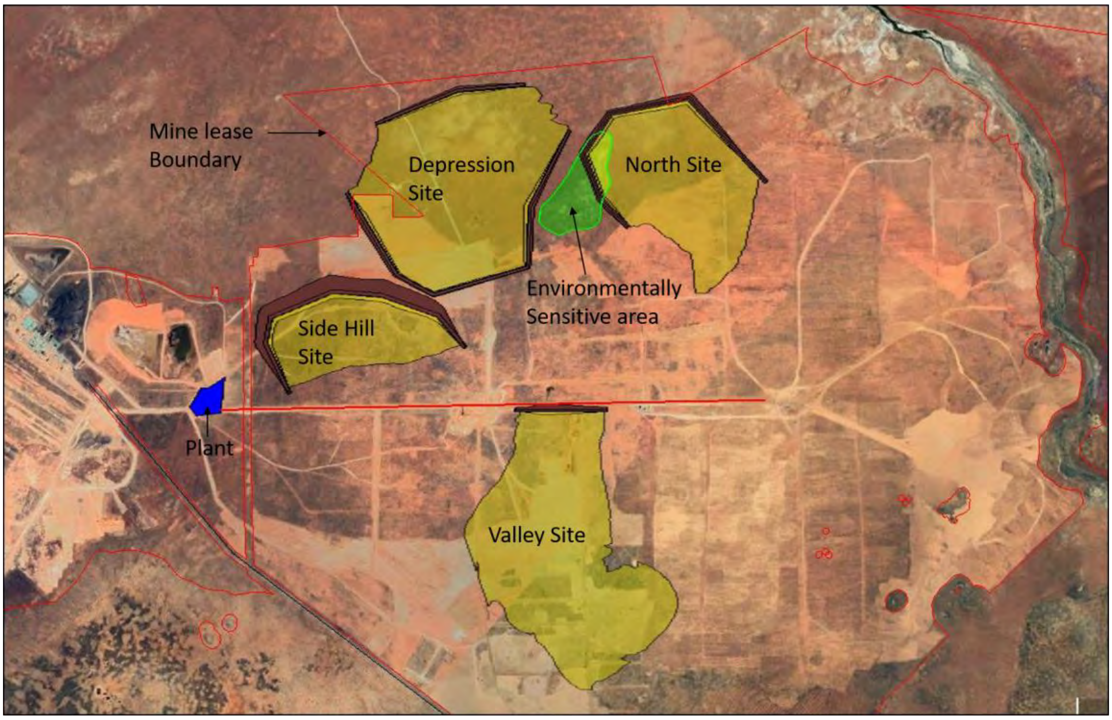


FIGURE 4-1: RSF SITE LOCALITY

5. RESIDUE STORAGE FACILITY OPTIONS

Of the four sites identified, only the Depression and Valley sites have enough capacity to store the full residue over the proposed LoM.

Five options, each capable of storing the full LoM Residue, were thus identified for investigation in this study:

- The Depression site only;
- The Valley Site only;
- A combination of Depression and Valley sites;
- A combination of the Depression and North sites;
- A combination of the Depression and Side Hill sites.

A summary of the five options can be seen in Table 5-1.

TABLE 5-1: OPTIONS STORAGE CAPABILITIES

	Depression	Valley	Depression & Valley	Depression & North	Depression & Side Hill
Wall Volume	3 000 000	1 000 000	1 195 000 + 650 000	1 195 000 + 2 857 000	1 195 000 + 6 862 000
Footprint area	3 500 000	4 000 000	2 400 000 + 3 100 000	2 400 000 + 2 000 000	2 400 000 + 1 500 000
Piping Distance to Plant	4.3	3.1		7.0 (North)	0.8 (Side Hill)
Comments	Walls are not required at start-up due to the natural depression at the site. A single site may be easier to acquire permission from the authorities. Permission to extend rights of a portion of the site will be required.	Concurrent mining and deposition of residue is required. Careful planning is required to ensure production is not hindered. Safety will be an issue. A single site may be easier to acquire permission from the authorities. This site is visible from the main road.	Two sites may not be preferable to the authorities as two areas would be considered disturbed. The Depression site would be built first while the valley site is mined.	Two sites may not be preferable to the authorities as two areas would be considered disturbed. The north site will require permission to use the environmentally sensitive area.	Two sites may not be preferable to the authorities as two areas would be considered disturbed.

The use of two sites may have the following impacts on the mine:

- Permitting and licensing for two facilities may be more difficult to obtain as opposed to one facility;
- Closure can occur independently at one facility while operations continue at the other;
- With wind speeds between 28 – 40 km/hr the probability of dust fall out from the facilities will be high. This may be more challenging to manage between two facilities.

5.1. SUMMARY OF RSF SITES

TABLE 5-2: SUMMARY OF RSF SITE OPTIONS

	UNITS	DEPRESSION	VALLEY	DEPRESSION + VALLEY	DEPRESSION + NORTH	DEPRESSION + SIDE HILL
Method of Construction	-	Fine residue pumped and coarse residue conveyed				
Footprint Area	ha	350	400	550 (Combined)	440 (Combined)	390 (Combined)
Containment Wall Height	m	23	21	10 & 12	10 & 25	15 & 25
Future Expansion	-	Yes	No	Yes at Depression	Yes	Yes
Distance from Plant	km	4.3	3.1	4.3 & 3.1	4.3 & 7.0	4.3 & 1.0

6. RISK BASED METHOD – SITE SELECTION ROCESS

In order to understand the risk-based approach to site selection it is necessary to provide some background information and to supply some definitions.

6.1. DEFINITIONS

Hazard - A hazard is the potential of a structure/equipment/plant etc. to cause harm and/or damage in the event of a failure or shortfall in performance. In the case of a RSF the hazards include the potential of the RSF to cause death (safety), illness (health), and damage to the environment (environment). The hazard could manifest itself or become a reality through a number of mechanisms e.g. in the case of the catastrophic failure of a RSF, the events which could occur resulting in the failure are typically side slope failure, overtopping failure, penstock pipe failure. The probability of the hazard becoming reality is therefore an assessment of the likelihood of the facility failing as a result of one or more of these events occurring leading to a flow slide.

Consequence - A consequence is the end result, or outcome, arising given that a hazard has become reality i.e. it actually happens. For example, should a RSF fail catastrophically, and should people be living or working within the downstream failure zone, the consequence could be death or injury to a certain number of people. The level or severity of the consequence is related to the extent, position and number of people within the failure zone.

6.2. TYPES OF HAZARDS

The types of hazards generated by a RSF are as follows:

- Catastrophic failure resulting in a flow slide from the RSF;
- Release of contaminated surface water/effluent from the top of the RSF basin as a result of direct spillage;
- Release of contaminated seepage water from the base of the facility into the groundwater and/or manifesting itself as a downstream surface seep;
- Release of contaminated residue (silt/tailings) from the RSF as a result of erosion due to rain runoff, spillage etc.;
- Release of contaminated residue (dust) from the RSF as a result of surface drying and strong winds;
- Positioning of the RSF resulting in the loss of housing, agriculture, relocation and compensation to varying degrees;
- Positioning of the RSF resulting in visual intrusion; and
- The release of possible toxic/irritating gases emitted from the RSF has been ignored as this is considered to be of insignificant importance.

6.3. TYPES OF CONSEQUENCES

The various types of consequences associated with the types of hazards mentioned above that relate to the Tronox Project mine lease footprint and its surrounding area are as follows:

- Loss of life to people in the area surrounding the RSF sites;
- Loss of property (houses, dwellings, infrastructure);
- Illness and sickness to people in the vicinity of the RSF sites;
- Environmental damage which includes damage to cultivated areas, natural flora and fauna and destruction of aquatic systems;
- Community concern giving rise to delays/objections to, or cessation of, the project arising from the relocation of people, houses, loss of cultivated land and compensation costs;
- Visual intrusion;
- Mining operations are affected; and
- Financial impacts.

6.4. RISK - A COMBINATION OF THE HAZARDS AND CONSEQUENCES

Risk is defined as the probability of an event occurring (or a hazard becoming reality) and its consequences. Put more simplistically, risk is the probability that a hazard generates a consequence. For example the risk of people being fatally injured as a result of a RSF failure is the probability that the RSF fails catastrophically combined with the presence of people being located within the zone of failure. As an extreme example, if no people are present then the probability of a person being fatally injured is remotely small, even if the RSF does fail.

The hazards listed above are combined with the one, or possibly more, of the listed consequences to give a number of risk related aspects e.g. the probability of the RSF failing causing environmental damage, or loss of property, or loss of life. The “risk aspects” are categorised according to public safety, public health, environmental, financial and other issues (which includes social, political and mining related issues).

6.5. TRANSLATION OF HAZARDS AND CONSEQUENCES TO A RISK RATING

The translation of the various hazards and their associated consequences to a “risk rating” is undertaken in the following manner:

- The probability, or likelihood, of the hazard becoming reality is assessed based on:
  - ➢ The site specifics (facility location, climate, topography, ground conditions, hydrogeology etc.), type of facility development, method of construction and operation, level of management etc.; and
  - ➢ The designers experience (subjective input).

The qualified statement of the probability of a hazard becoming reality (e.g. very high, high, medium, low, very low; or highly likely, likely, moderate, unlikely, rare) is transformed to a value between 1 and 5 using the probability descriptor versus rating number shown in Table 6-1. For example, if the catastrophic failure of a RSF is considered to be “possible” (or “moderate”, or “medium”) a value of 3 is applied. It must be noted that the lowest value of 1 indicates a very high or highly likely event, while the highest value of 5 denotes a very low probability or rare chance of something happening.

TABLE 6-1: EXAMPLES OF PROBABILITY DESCRIPTORS

RATING	EXAMPLES OF PROBABILITY DESCRIPTORS			
1	Very High	Very Probable	Highly Likely	“It Happens Often”
2	High	Probable	Likely	“It Has Happened”
3	Medium	Possible	Moderate	“I’ve Heard of It Happening Elsewhere”
4	Low	Unlikely	Unlikely	“Never Heard of It”
5	Very Low	Very Unlikely	Rare	“Practically Impossible”

The consequence of an occurrence is assessed based on:

- ➢ The severity of the consequence from a knowledge of the area, and the location and extent of associated activities undertaken in the area; and

- The experience of the designer (subjective input).

The qualified statement of the degree of severity of a consequence is translated into a value between 1 and 5 depending on the aspect under consideration using the consequence descriptors shown in Table 6-2. It must be noted that low consequence rating numbers are indicative of severe/very high levels of consequence/concern, while higher consequence rating numbers relate to low or insignificant levels of consequence/concern.

TABLE 6-2: EXAMPLES OF CONSEQUENCE DESCRIPTORS

RATING	EXAMPLES OF CONSEQUENCE DESCRIPTORS					
	Mortality	**Health**	**Environment**	**Cost**	**Production**	**Community Concern**
1	Many	Lethal	Very Extensive	Very High	Several Months	Very Severe
2	A Few	Toxic	Extensive	High	Several Weeks	Severe
3	One	Temporary Illness	Localised	Moderate	A Week	Moderately Severe
4	Severe Injury	Irritation	Low	Low	A Few Days	Low
5	Injury	Mild Irritation	Insignificant	Insignificant	One Day	Insignificant

Each area of risk (or risk aspect) now has a probability hazard value and a consequence value. One method of combining probability and consequence is through a “risk ranking” (or “risk rating”) as shown Table 6-3 that has been adapted from ALARA (1997).

TABLE 6-3: RISK RATING/RANKING NUMBERS BASED ON PROBABILITY AND CONSEQUENCE

			Probability Rating				
			Very High				Very Low
			1	2	3	4	5
Consequence Rating	Very High	1	1	2	4	7	11
		2	3	5	8	12	16
		3	6	9	13	17	20
		4	10	14	18	21	23
	Very Low	5	15	19	22	24	25

As an example, if the probability of a hazard occurring is 2 (high) and the consequence arising from the hazard is 4 (low), then the risk rating is 14.

6.6. SITE RANKING

Once all the risk rating values are applied to the various risk aspects the following analyses can be undertaken:

- Individual risk ratings of 6 or less are considered to be serious and require some form of action to reduce the risk level (i.e. increase the risk rating value). These actions could typically include applying additional engineering measures (e.g. plastic lining or flattening side slopes, enlarged compacted starter wall), changing the method of disposal (e.g. from sub-aerial to sub aqueous, upstream construction using tailings to downstream construction using compacted earth), relocating people to another area etc. If risk ratings cannot be increased above 6 by design upgrades or application of mitigating factors, consideration must be given to dismissing the site due to a fatal flaw;
- The sites can be ranked on each of the specific risk aspects e.g. under the environmental category the release of contaminated surface water resulting in environmental damage;
- The sites can be compared on each of the individual risk categories of public safety, public health, environmental, financial and other (social, political, mining etc.) i.e. the risk ratings in each of the categories can be added up to provide an indicator of how the sites are ranked purely on that individual category. For example, the comparison of the health category can indicate which sites show less overall risk as far as public health is concerned; and

- The risk ratings for all of the aspects can be added up. This is an “un-weighted” number which considers all risk aspects to have the same degree severity/impact. The sites can be rated on this un-weighted summed number. Higher numbers being more favourable site(s) and the lowest numbers being the less favoured site(s).
- Weighting factors can then be applied to each risk category and sub-category. The purpose of the weighting factor is to place more emphasis, or importance, on certain parameters of the site selection to provide a more objective ranking of the selected sites. These weighted factors can them be summed up for each site and the sites ranked . Higher numbers being more favourable site(s) and the lowest numbers being the less favoured site(s).

7. RISK ANALYSIS OF RESIDUE STORAGE FACILITIES

Five options were included in the risk analysis. For the analysis, the RSFs were considered at full capacity.

7.1. RISK CATEGORIES

The risks categories and sub-categories investigated are shown in Table 7-1. The risks encompass the possible effects the RSF can have on safety, public health, the environment, financial implications, further expansion and other issues. There may be other issues not investigated in this report, however these risks are sufficient to illustrate which RSF will be the safest option and most economical.

7.2. RISK RATING FOR EACH SITE

The various risk categories and sub-catagories considered are shown in Table 7-1 below. For all sites the hazards and consequences under each risk category were assigned a risk rating score based on Table 6-3. The final scores for each site were computed by adding all the combined scores, for the different risk categories providing an un-weighted risk rating for the sites. A summary of the Un-Weighted risk ratings for each site is shown in Table 7-2.

TABLE 7-1: RISKS CATEGORIES AND SUB-CATEGORIES CONSIDERED

Safety
RSF failure leading to loss of life
RSF failure leading to loss of property and infrastructure
Public Health
Release of contaminated surface water leading to illness
Release of contaminated seepage water leading to illness and/or contamination of water resources
Release of contaminated dust
Environmental
RSF failure results in a flow slide and environmental damage
Release of contaminated surface water leading to environmental damage
Release of contaminated seepage water leading to environmental damage
Release of contaminated silt (Tailings) by erosion leading to environmental damage
Release of tailings or slurry water from delivery pipeline and effluent from return water pipeline resulting in environmental damage
Positioning of RSF results in damage/loss of pristine/rare plant and animal species
Mining Proximity
Implications of proximity to open pits
Implications of constructing RSF in area that will result in sterilisation of ore
Financial Issues
Location of RSF relative to the plant and the cost thereof. i.e. pumping head, slimes pipeline length, infrastructure etc.
Footprint size of the RSF and its cost implications to RSF in terms of drains, solution trenches, storm diversion, access roads etc.
Cost implications of coarse residue impoundment walls / Excavations
Other Issues (Social, Political, etc.)
Degree of visual impact of RSF in relation to its surrounding environment/public
Complexity
Possibility of geological faults within the RSF footprint
Possibility of lining the RSF
Future Expansion
Possible future expansion and the effect on cost and the environment

TABLE 7-2: SITE SELECTION COMPARISON BASED ON UN- WEIGHTED RISK RATING

Weighted Risk Rating *(Risk Rating Un-Weighed)*					
Category	**Depression**	**Valley**	**Depression + Valley**	**Depression + North**	**Depression + Side Hill**
Safety	641	592	592	641	592
Public Health	283	185	173	283	201
Environment	229	245	236	133	148
Mining Proximity	245	60	60	245	245
Financial Issues	84	92	92	43	38
Other Issues	292	301	309	282	273
Further Capacity	63	42	54	63	63
TOTAL	**1837**	**1517**	**1516**	**1690**	**1560**
	1	**4**	**5**	**2**	**3**

Weighting factors were then applied to each risk category and sub-category. Weighting factors applied to the subcategories can be seen in the Appendix in the “Weighted Tailings Site Selection Comparison” table. The purpose of the weighting factor is to place more emphasis, or importance, on certain parameters of the site selection to provide a more objective ranking of the selected sites. The weighting factor for each category is based on literature, engineering judgement, and client preference. Table 7-3 summarizes the weighted risk ratings in accordance with the proposed plant location. The risk assessment tables for each site is provided in the Appendix.

TABLE 7-3: SITE SELECTION COMPARISON BASED ON A WEIGHTED RISK RATING

		Weighted Risk Rating **(Risk Rating x Weighting Factor)**				
Category	**Weighting Factor**	**Depression**	**Valley**	**Depression + Valley**	**Depression + North**	**Depression + Side Hill**
Safety	37	39	32	32	39	32
Public Health	14	61	47	44	61	48
Environment	14	102	106	96	81	84
Mining Proximity	10	49	12	12	49	49
Financial Issues	12	22	23	22	10	10
Other Issues	10	73	64	68	67	64
Further Capacity	3	21	14	18	21	21
TOTAL	**100**	**366**	**298**	**292**	**328**	**308**
	Ranking	**1**	**4**	**5**	**2**	**3**

Each RSF site has its own advantages and disadvantages. The purpose of this report is to identify and list them as objectively as possible and rank them accordingly. The following is a summary of the main characteristics of each site:

- The **Depression** site only, ranked first on the weighted site selection rankings as a result of its ratings for safety and public health and proximity to the plant.
- The **Valley** site only, ranked fourth due to scoring poorly in its rating for proximity to mining activities, as concurrent mining and deposition on the site would be required resulting in higher risk of sterilisation of resources and risk to mining staff. The site is also situated upstream of a dual conveyor.
- The combination of the **Depression and Valley** sites, ranked last in the weighted site selection rankings, due to its safety and environmental rating as a result of its close proximity to mining activities and for public health. The Valley site is limited in terms of further expansion due to the surrounding ore body.
- The combination of the **Depression and North** sites ranked second, however, the North site is partially situated over an environmentally sensitive area that would require environmental authorisation. The North site is situated the furthest from the process plant.
- The combination of the **Depression and Side Hill** sites scored third on the ranking due its low score in the safety and financial categories. The side hill site has safety and public health concerns as it is situated less than 1 km from the process plant. The site will be one of the more expensive options to construct as a result of the steep topography present.

8. HIGH LEVEL COST ESTIMATE

A high-level cost estimate has been undertaken to determine the comparative cost of the RSF options. The main objective for this was to determine if there was a significant increase in cost if two sites were selected rather than a single site. Table 8-1 shows the costs for each option analysed.

The Depression site on its own was determined to be the lowest cost option in Capital Costs (CapEx), Operational Costs (OpEx) and Closure Costs. In terms of initial start-up costs the selection of an option with two smaller footprint areas would result in a lower upfront cost, however it may be possible to phase the single site option which should be considered in the PFS.

TABLE 8-1: LOM OPTIONS COST COMPARISON

				One Site (Option 1)		One Site (Option 2)		Two Sites (Option 3)				Total	Two Sites (Option 4)				Total	Two Sites (Option 5)				Total
				20 Years LoM Depression		20 Years LoM Valley		10 Years LoM Valley		10 Years LoM Depression			10 Years LoM North		10 Years LoM Depression			5 Years LoM Side Hill		15Years LoM Depression		
		Unit	Rate (Rands)	Qty	Cost (SA Rand)	Qty	Cost (SA Rand)	Qty	Cost (SA Rand)	Qty	Cost (SA Rand)		Qty	Cost (SA Rand)	Qty	Cost (SA Rand)		Qty	Cost (SA Rand)	Qty	Cost (SA Rand)	
CAPEX	Indirect Costs																					
	Mob/De-mob, Engineering and Contingency	LS	4,104,896	1	11,126,819	1	8,502,495	1	3,007,114	1	6,046,050	9,053,164	1	11,767,350	1	6,046,050	17,813,400	1	19,417,500	1	10,221,354	29,638,854
	Earthworks																					
	Clear and Grub	Ha	20,000	15	307,160	27	534,000	13	256,912	22	440,000	696,912	30	600,000	22	440,000	1,040,000	58	1,164,000	12	240,000	1,404,000
	Top-soil strip	m3	18.5	15,000	277,500	26,700	493,950	25,700	475,450	44,000	814,000	1,289,450	60,000	1,110,000	44,000	814,000	1,924,000	58,000	1,073,000	11,250	208,125	1,281,125
	Base Prep (Rip and Re-compact)	m2	11.1	153,580	1,704,738	267,000	2,963,700	128,500	1,426,350	220,000	2,442,000	3,868,350	300,000	3,330,000	220,000	2,442,000	5,772,000	580,000	6,438,000	115,185	1,278,554	7,716,554
	Embankment Fill (Tailings Sand)	m3	8.5	3,000,000	25,500,000	1,700,000	14,450,000	650,000	5,525,000	1,195,000	10,157,500	15,682,500	2,857,000	24,284,500	1,195,000	10,157,500	34,442,000	5,500,000	46,750,000	2,985,000	25,372,500	72,122,500
	Wall drain + Solution Trench	m	3,000	3,100	9,300,000	3,300	9,900,000	780	2,340,000	2,100	6,300,000	8,640,000	3,300	9,900,000	2,100	6,300,000	16,200,000	3,100	9,300,000	2,324	6,972,000	16,272,000
	Return water																					
	Supernatant return pipe	m	901	5,000	4,505,000	6,000	5,406,000	6,000	5,406,000	5,000	4,505,000	9,911,000	7,300	6,577,300	5,000	4,505,000	11,082,300	800	720,800	3,745	3,374,245	4,095,045
	Floating walkway and floating barge system for wall mounted pumps	Sum	1,221,238	1	1,221,238	1	1,221,238	1	1,221,238	1	1,221,238	2,442,476	1	1,221,238	1	1,221,238	2,442,476	1	1,221,238	1	1,221,238	2,442,476
	Slimes Distribution Piping																					
	400mm Ring Main Pipe	m	1,722	7,500	12,915,000	10,000	17,220,000	4,700	8,093,400	3,000	5,166,000	13,259,400	3,050	5,252,100	4,700	8,093,400	13,345,500	4,900	8,437,800	5,620	9,677,640	18,115,440
	400mm T-pieces	ea	10,353	151	1,563,303	201	2,080,953	95	983,535	61	631,533	1,615,068	62	641,886	95	983,535	1,625,421	99	1,024,947	112	1,159,536	2,184,483
	400mm valves	ea	51,608	151	7,792,808	201	10,373,208	95	4,902,760	61	3,148,088	8,050,848	62	3,199,696	95	4,902,760	8,102,456	99	5,109,192	112	5,780,096	10,889,288
	Downpipes	m	1,500	2,265	3,397,500	3,015	4,522,500	1,425	2,137,500	3,050	4,575,000	6,712,500	930	1,395,000	1,425	2,137,500	3,532,500	1485	2,227,500	1,650	2,475,000	4,702,500
	Return Water Pump System																					
	25MG 250KW Barge Pump	ea	821,216	1	821,216	1	821,216	1	821,216		0	821,216	1	821,216		0	821,216	0	821,216	1	821,216	821,216
	25MG 250KW Skid Pump	ea	717,216	1	717,216	1	717,216	1	717,216		0	717,216	1	717,216		0	717,216	0	717,216	1	717,216	717,216
	Total CAPEX				81,149,498		79,206,476		37,313,691		45,446,409	82,760,100		70,817,502		48,042,983	118,860,485		104,422,409		69,518,719	173,941,128
OPEX	Pipe and Valve Replacements	m	698	0	2,841,300	0	3788400	0	1,780,548	0	1,136,520	2,917,068	0	1,155,462	0	1,780,548	2,936,010	0	1,856,316	0	2,129,081	3,985,397
REHAB	Cut to Fill Side Slopes	m3	2.7	221,534	598,142	161,000	434,700	100,000	270,000	159,285	430,070	700,070	427,244	1,153,559	159,285	430,070	1,583,628	1,500,000	4,050,000	167,000	450,900	4,500,900
CLOSURE	Load, Haul and place capping layer	m3	14.2	3,500,000	49,700,000	4,500,000	63,900,000	3,500,000	49,700,000	2,000,000	28,400,000	78,100,000	2,200,000	31,240,000	2,000,000	28,400,000	59,640,000	1,200,000	17,040,000	2,950,000	41,890,000	58,930,000
Cost LoM	Sub-Total:	R		134,288,940		147,329,576		89,064,239		75,412,999		164,477,237	104,366,523		78,653,601		183,020,123	127,368,725		113,988,700		241,357,425
	Total:	R		134,288,940		147,329,576		164,477,237					183,020,123					241,357,425				

9. CONCLUSIONS

It can be concluded that:

- The Depression Site ranked best and yielded the lowest LoM costs. As such it should be assessed further as the preferred site;
- Although the other options resulted in lower rankings they may be considered as 'back-up' options if a fatal flaw is discovered at the Depression site; and
- When considering the single or phased options it is evident that a single site will have a lower LoM cost. However, the level of accuracy for the cost trade-off does not warrant basing the decision of which site to choose on the cost trade-off alone.

10. RECOMENDATIONS

It is recommended that:

- The Depression site be considered for further study. The North and Valley sites are considered possible options and subsequent phases of the project should confirm the preferred site; and
- Detailed EIA study be completed to determine the environmental impacts of the Depression RSF.

Report Author	**Project Manager**
R O'Toole	**A Savvas**

epoch resources (pty) ltd

Appendix A: Risk Matrices

SUMMARY OF UNWEIGHTED RISK MATRIX

Category	Description	Depression	Valley	Depression + Valley	Depression + North	Depression + Side Hill
SAFETY						
	Total risk rating for Safety	39	32	32	39	32
PUBLIC HEALTH						
	Total risk rating for Public Health	61	47	44	61	48
ENVIRONMENTAL						
	Total risk rating for Environmental	102	106	96	81	84
MINING PROXIMITY						
	Total risk rating for Mining Proximity	49	12	12	49	49
FINANCIAL ISSUES						
	Total rating for Financial Issues	22	23	22	10	10
OTHER ISSUES (SOCIAL, POLITICAL, etc)						
	Total Risk rating for Other issues	72	*64*	*68*	*67*	*64*
FURTHER EXPANSION						
	Total Risk rating for Further Expansion	21	*14*	18	21	21
	Overall Risk rating (Sum of Risk rating numbers)	366	298	292	328	308
	Un-weighted ranking of sites	1	4	5	2	3

SUMMARY OF WEIGHTED RISK MATRIX

Category	**Description**	**Weighting Factors**	**Depression**	**Valley**	**Depression + Valley**	**Depression + North**	**Depression + Side Hill**
SAFETY							
	Total risk rating for Safety	*37*	641	592	592	641	592
PUBLIC HEALTH							
	Total risk rating for Public Health	*14*	283	185	173	283	201
ENVIRONMENTAL							
	Total risk rating for Environmental	*14*	229	245	236	133	148
MINING PROXIMITY							
	Total risk rating for Mining Proximity	10	245	60	60	245	245
FINANCIAL ISSUES							
	Total risk rating for Financial Issues	*12*	84	92	92	43	38
OTHER ISSUES (SOCIAL, POLITICAL, etc)							
	Total Risk rating for Other issues	*10*	292	301	309	282	273
FURTHER EXPANSION							
	Total Risk rating for Further Expansion	*3*	63	42	54	63	63
	Overall Risk rating (Sum of Risk rating numbers)		1837	1517	1516	1690	1560
	Weighted ranking of sites	100	1	4	5	2	3

Appendix C LABORATORY TEST RESULTS

Specialised Testing Laboratory (Pty) Ltd
Asphalt | Aggregate | Bitumen | Geotechnical
Unit 1, 13 Bloubokkie Street, Koedoespoort 0186
Roelof | 072 674 6343 | roelof@stlab.co.za
Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za
Quality | Excellence | On Time

Client Name: Epoch Resources
Project Name: Tronox Tailings
Job Number: EPO-19
Date: 2020-11-04
Method: SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable)

FOUNDATION INDICATOR

Sheet Ref: R-STL-011-Rev02

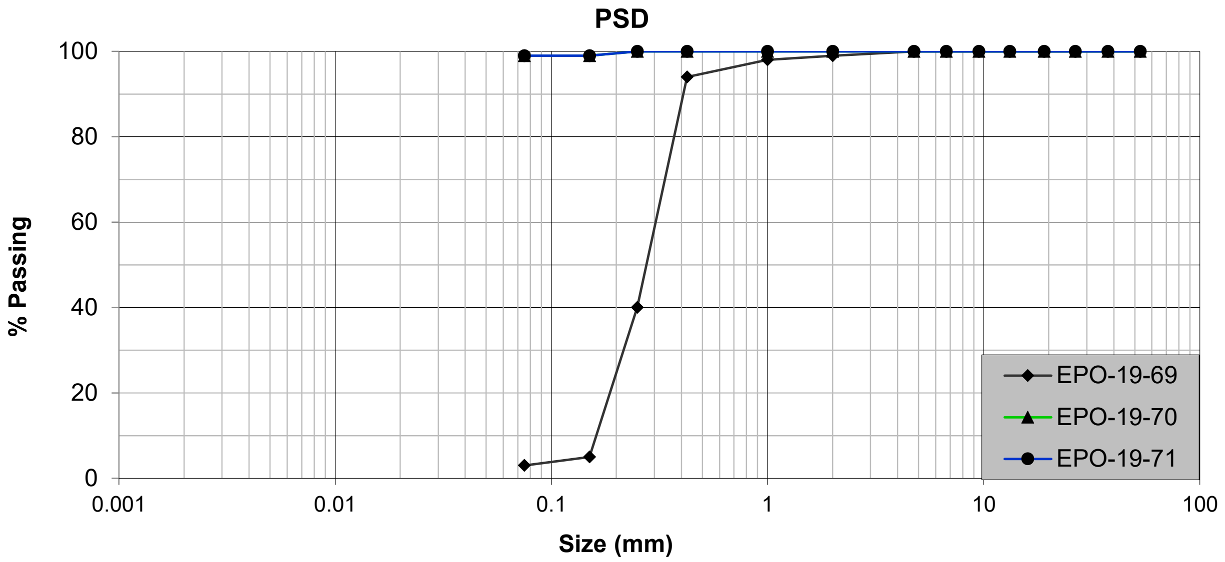
Grading & Hydrometer Analysis (Particle Size (mm) & % Passing)				**Atterberg Limits & Classification**			
Sample	RAS Coarse Tails	E1654 / -45µm	E1414 / -45µm	Sample	RAS Coarse Tails	E1654 / -45µm	E1414 / -45µm
Lab No	EPO-19-69	EPO-19-70	EPO-19-71	Lab No	EPO-19-69	EPO-19-70	EPO-19-71
53.0	**100**	**100**	**100**	Liquid Limit (%)	**-**	**53**	**54**
37.5	**100**	**100**	**100**	Plastic Limit (%)	**-**	**44**	**18**
26.5	**100**	**100**	**100**	Plasticity Index (%)	**NP**	**9**	**36**
19.0	**100**	**100**	**100**	Linear Shrinkage (%)	**0.0**	**3.0**	**1.0**
13.2	**100**	**100**	**100**	PI of whole sample	**-**	**9**	**36**
9.5	**100**	**100**	**100**				
6.7	**100**	**100**	**100**	% Gravel	**1**	**0**	**0**
4.75	**100**	**100**	**100**	% Sand	**-**	**-**	**-**
2.00	**99**	**100**	**100**	% Silt	**-**	**-**	**-**
1.00	**98**	**100**	**100**	% Clay	**-**	**-**	**-**
0.425	**94**	**100**	**100**	Activity	**-**	**-**	**-**
0.250	**40**	**100**	**100**				
0.150	**5**	**99**	**99**	% Soil Mortar	**99**	**100**	**100**
0.075	**3**	**99**	**99**				
0.060	**-**	**-**	**-**	Grading Modulus	**1.04**	**0.01**	**0.01**
0.050	**-**	**-**	**-**	Moisture Content (%)	**N / T**	**N / T**	**N / T**
0.035	**-**	**-**	**-**	Relative Density (SG)*	**2.615**	**2.65**	**2.634**
0.020	**-**	**-**	**-**				
0.006	**-**	**-**	**-**	Unified (ASTM D2487)	**-**	**-**	**-**
0.002	**-**	**-**	**-**	AASHTO (M145-91)	**A - 3**	**A - 5**	**A - 7 - 6**

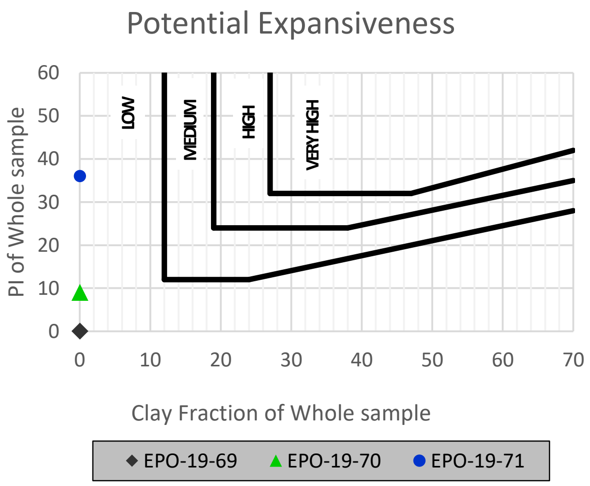
Remarks: *: Assumed
N / T: Not Tested

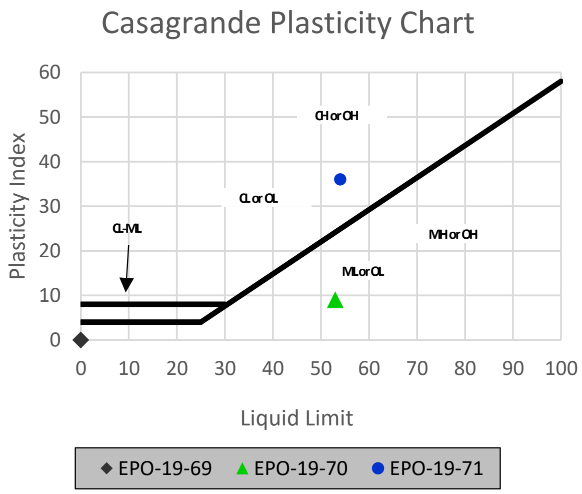
Client Name: Epoch Resources
Project Name: Tronox Tailings
Job Number: EPO-19
Date: 2020-11-04
Method: SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable)

FOUNDATION INDICATOR

Sheet Ref:
R-STL-011-Rev02







Client Name:	Epoch Resources
Project Name:	Tronox Tailings
Job Number:	EPO-19
Date:	2020-11-04
Method:	SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable)

FOUNDATION INDICATOR

Sheet Ref: R-STL-011-Rev02

Grading & Hydrometer Analysis (Particle Size (mm) & % Passing)				**Atterberg Limits & Classification**			
Sample	E2293 Fines	EOFS Fines Residue	E1654 / +45µm	Sample	E2293 Fines	EOFS Fines Residue	E1654 / +45µm
Lab No	EPO-19-72	EPO-19-73	EPO-19-74	Lab No	EPO-19-72	EPO-19-73	EPO-19-74
53.0	**100**	**100**	**100**	Liquid Limit (%)	**47**	**63**	**-**
37.5	**100**	**100**	**100**	Plastic Limit (%)	**20**	**54**	**-**
26.5	**100**	**100**	**100**	Plasticity Index (%)	**27**	**9**	**NP**
19.0	**100**	**100**	**100**	Linear Shrinkage (%)	**1.0**	**2.5**	**0.0**
13.2	**100**	**100**	**100**	PI of whole sample	**27**	**9**	**-**
9.5	**100**	**100**	**100**				
6.7	**100**	**100**	**100**	% Gravel	**0**	**0**	**1**
4.75	**100**	**100**	**100**	% Sand	**-**	**-**	**-**
2.00	**100**	**100**	**99**	% Silt	**-**	**-**	**-**
1.00	**100**	**100**	**97**	% Clay	**-**	**-**	**-**
0.425	**100**	**100**	**90**	Activity	**-**	**-**	**-**
0.250	**100**	**100**	**44**				
0.150	**99**	**100**	**18**	% Soil Mortar	**100**	**100**	**99**
0.075	**99**	**100**	**9**				
0.060	**-**	**-**	**-**	Grading Modulus	**0.01**	**0.00**	**1.02**
0.050	**-**	**-**	**-**	Moisture Content (%)	**N / T**	**N / T**	**N / T**
0.035	**-**	**-**	**-**	Relative Density (SG)*	**2.59**	**2.65**	**2.64**
0.020	**-**	**-**	**-**				
0.006	**-**	**-**	**-**	Unified (ASTM D2487)	**-**	**-**	**-**
0.002	**-**	**-**	**-**	AASHTO (M145-91)	**A - 7 - 6**	**A - 5**	**A - 3**

Remarks: *: Determined

N / T: Not Tested

Client Name:	Epoch Resources
Project Name:	Tronox Tailings
Job Number:	EPO-19
Date:	2020-11-04
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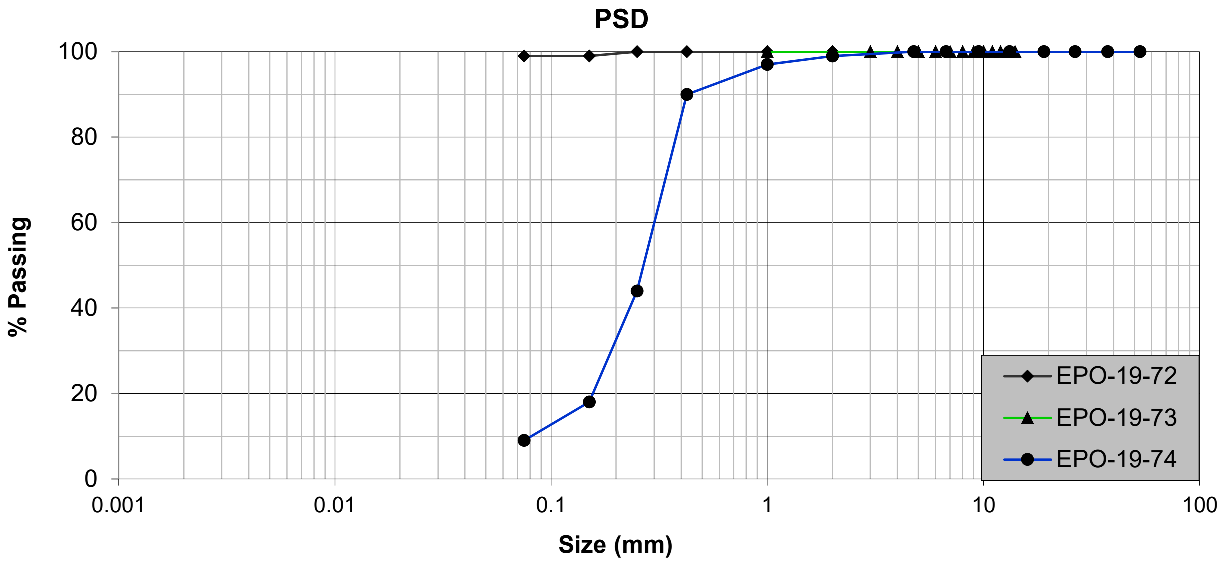
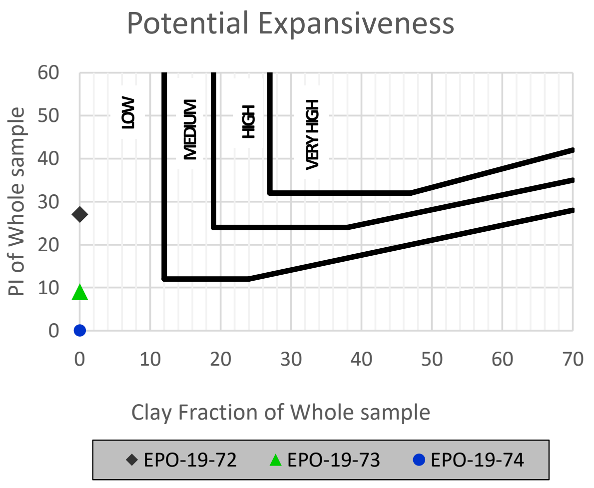
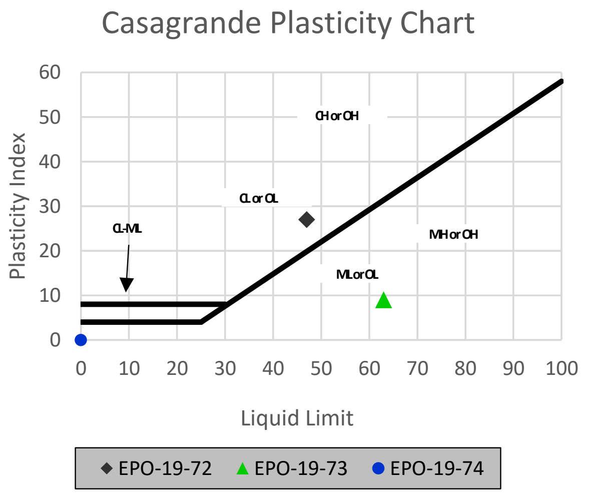
Sheet Ref:
R-STL-011-Rev02







E0619 Laser Diffraction				
Sieve Size	Percentage Passing		Sieve Size	Percentage Passing
1000.0	100.0		10.0	82.7
912.0	100.0		9.1	80.3
832.0	100.0		8.3	77.8
759.0	100.0		7.6	75.1
692.0	100.0		6.9	72.1
631.0	100.0		6.3	68.9
575.0	100.0		5.8	65.5
525.0	100.0		5.3	62.1
479.0	100.0		4.8	58.5
437.0	100.0		4.4	54.9
398.0	100.0		4.0	51.1
363.0	100.0		3.6	47.4
331.0	100.0		3.3	43.7
302.0	100.0		3.0	40.0
275.0	100.0		2.8	36.3
251.0	100.0		2.5	32.8
229.0	100.0		2.3	29.4
209.0	100.0		2.1	26.2
191.0	100.0		1.9	23.2
174.0	100.0		1.7	20.4
158.0	100.0		1.6	17.7
145.0	100.0		1.5	15.4
132.0	100.0		1.3	13.2
120.0	100.0		1.2	11.1
110.0	99.9		1.1	9.4
100.0	99.9		1.0	7.7
91.2	99.8		0.9	6.2
83.2	99.7		0.8	4.9
75.0	99.5		0.8	3.7
69.2	99.4		0.7	2.7
63.1	99.2		0.6	1.9
57.5	99.0		0.6	1.2
52.5	98.8		0.5	0.7
47.9	98.6		0.5	0.4
45.0	98.4		0.4	0.2
39.8	97.9		0.4	0.1
36.3	97.5		0.4	0.1
33.1	97.1		0.3	0.1
30.2	96.6		0.3	0.1
27.5	96.0		0.3	0.1
25.0	95.4		0.3	0.1
22.9	94.7		0.2	0.1
20.9	94.0		0.2	0.1
19.1	93.1		0.2	0.1
17.4	92.1		0.2	0.1
15.8	90.9		0.2	0.1
14.5	89.7		0.1	0.1
13.2	88.2		0.1	0.1
12.0	86.5		0.1	0.1
11.0	84.8		0.1	0.1

E1414 Laser Diffraction				
Sieve Size	Percentage Passing		Sieve Size	Percentage Passing
1000.0	100.0		10.0	67.1
912.0	100.0		9.1	64.9
832.0	100.0		8.3	62.5
759.0	100.0		7.6	60.1
692.0	100.0		6.9	57.6
631.0	100.0		6.3	55.1
575.0	100.0		5.8	52.5
525.0	100.0		5.3	49.9
479.0	100.0		4.8	47.2
437.0	100.0		4.4	44.6
398.0	100.0		4.0	41.8
363.0	100.0		3.6	39.1
331.0	100.0		3.3	36.4
302.0	100.0		3.0	33.8
275.0	100.0		2.8	31.0
251.0	100.0		2.5	28.4
229.0	100.0		2.3	25.8
209.0	100.0		2.1	23.2
191.0	100.0		1.9	20.8
174.0	100.0		1.7	18.4
158.0	100.0		1.6	16.1
145.0	100.0		1.5	14.1
132.0	100.0		1.3	12.1
120.0	100.0		1.2	10.3
110.0	100.0		1.1	8.7
100.0	100.0		1.0	7.1
91.2	100.0		0.9	5.8
83.2	100.0		0.8	4.5
75.0	99.9		0.8	3.4
69.2	99.8		0.7	2.5
63.1	99.6		0.6	1.7
57.5	99.2		0.6	1.1
52.5	98.7		0.5	0.6
47.9	98.0		0.5	0.3
45.0	97.4		0.4	0.1
39.8	96.0		0.4	0.0
36.3	94.6		0.4	0.0
33.1	93.1		0.3	0.0
30.2	91.4		0.3	0.0
27.5	89.6		0.3	0.0
25.0	87.6		0.3	0.0
22.9	85.8		0.2	0.0
20.9	83.8		0.2	0.0
19.1	81.8		0.2	0.0
17.4	79.8		0.2	0.0
15.8	77.6		0.2	0.0
14.5	75.7		0.1	0.0
13.2	73.6		0.1	0.0
12.0	71.4		0.1	0.0
11.0	69.4		0.1	0.0

E1651 Laser Diffraction				
Sieve Size	Percentage Passing		Sieve Size	Percentage Passing
1000.0	100.0		10.0	65.7
912.0	100.0		9.1	63.4
832.0	100.0		8.3	61.0
759.0	100.0		7.6	58.6
692.0	100.0		6.9	56.0
631.0	100.0		6.3	53.5
575.0	100.0		5.8	50.8
525.0	100.0		5.3	48.2
479.0	100.0		4.8	45.5
437.0	100.0		4.4	42.8
398.0	100.0		4.0	40.1
363.0	100.0		3.6	37.4
331.0	100.0		3.3	34.7
302.0	100.0		3.0	32.0
275.0	100.0		2.8	29.3
251.0	100.0		2.5	26.7
229.0	100.0		2.3	24.1
209.0	100.0		2.1	21.7
191.0	100.0		1.9	19.4
174.0	100.0		1.7	17.1
158.0	100.0		1.6	14.9
145.0	100.0		1.5	13.1
132.0	100.0		1.3	11.3
120.0	100.0		1.2	9.6
110.0	100.0		1.1	8.2
100.0	100.0		1.0	6.7
91.2	100.0		0.9	5.5
83.2	100.0		0.8	4.3
75.0	100.0		0.8	3.3
69.2	100.0		0.7	2.4
63.1	99.9		0.6	1.6
57.5	99.6		0.6	1.0
52.5	99.2		0.5	0.6
47.9	98.5		0.5	0.3
45.0	98.0		0.4	0.1
39.8	96.6		0.4	0.0
36.3	95.2		0.4	0.0
33.1	93.7		0.3	0.0
30.2	91.9		0.3	0.0
27.5	90.0		0.3	0.0
25.0	87.9		0.3	0.0
22.9	85.9		0.2	0.0
20.9	83.7		0.2	0.0
19.1	81.6		0.2	0.0
17.4	79.3		0.2	0.0
15.8	77.0		0.2	0.0
14.5	74.9		0.1	0.0
13.2	72.6		0.1	0.0
12.0	70.3		0.1	0.0
11.0	68.1		0.1	0.0

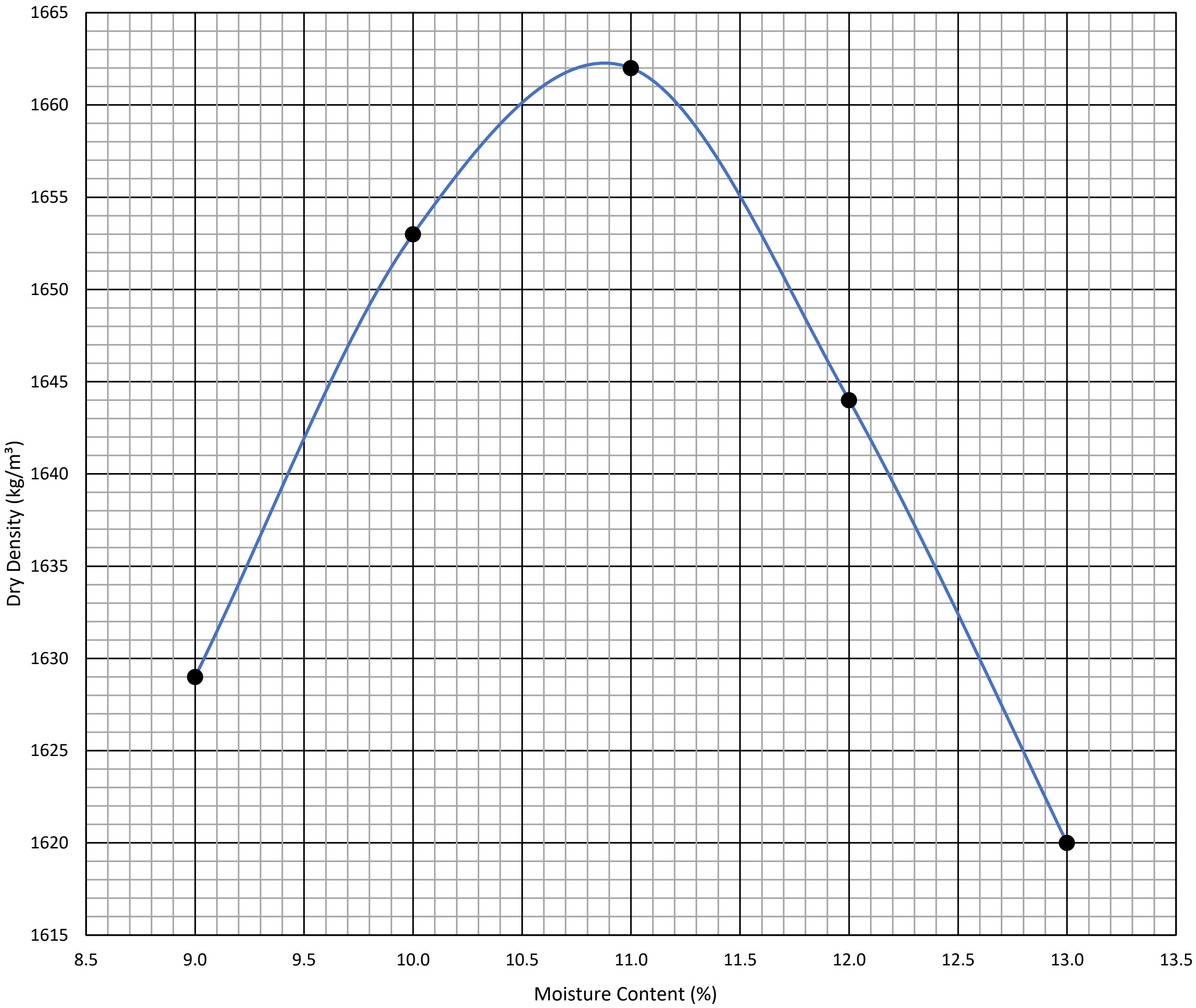
E2293 Laser Diffraction				
Sieve Size	Percentage Passing		Sieve Size	Percentage Passing
1000.0	100.0		10.0	71.5
912.0	100.0		9.1	69.5
832.0	100.0		8.3	67.4
759.0	100.0		7.6	65.2
692.0	100.0		6.9	62.9
631.0	100.0		6.3	60.4
575.0	100.0		5.8	57.9
525.0	100.0		5.3	55.3
479.0	100.0		4.8	52.6
437.0	100.0		4.4	49.8
398.0	100.0		4.0	46.9
363.0	100.0		3.6	43.9
331.0	100.0		3.3	40.9
302.0	100.0		3.0	37.8
275.0	100.0		2.8	34.7
251.0	100.0		2.5	31.5
229.0	100.0		2.3	28.4
209.0	100.0		2.1	25.4
191.0	100.0		1.9	22.5
174.0	100.0		1.7	19.7
158.0	100.0		1.6	16.9
145.0	100.0		1.5	14.5
132.0	100.0		1.3	12.2
120.0	100.0		1.2	10.1
110.0	100.0		1.1	8.4
100.0	100.0		1.0	6.6
91.2	99.9		0.9	5.2
83.2	99.7		0.8	4.0
75.0	99.3		0.8	2.9
69.2	98.8		0.7	2.0
63.1	98.2		0.6	1.3
57.5	97.5		0.6	0.8
52.5	96.7		0.5	0.4
47.9	95.7		0.5	0.2
45.0	94.9		0.4	0.1
39.8	93.4		0.4	0.0
36.3	92.1		0.4	0.0
33.1	90.8		0.3	0.0
30.2	89.5		0.3	0.0
27.5	88.1		0.3	0.0
25.0	86.7		0.3	0.0
22.9	85.4		0.2	0.0
20.9	84.0		0.2	0.0
19.1	82.7		0.2	0.0
17.4	81.2		0.2	0.0
15.8	79.7		0.2	0.0
14.5	78.3		0.1	0.0
13.2	76.7		0.1	0.0
12.0	75.0		0.1	0.0
11.0	73.4		0.1	0.0

Client Name:	Epoch Resources	**Job Number:**	EPO-19
Project Name:	Tronox Tailings	**Lab Number:**	EPO-19-69
Sample:	RAS Coarse Tails	**Method:**	SANS 3001 GR30
Depth: (m)	-	**Date:**	27-Oct-20

MDD & OMC DETERMINATION (Std. Proctor)

Maximum Dry Density: **1664** kg/m³ Optimum Moisture Content: **10.9** %

Moisture Content (%):	9.0	10.0	11.0	12.0	13.0			
Dry Density (kg/m³)	1629	1653	1662	1644	1620			



Client Name: Epoch Resources
Project Name: Tronox Tailings
Sample: E0619 / +45µm
Depth: (m) -

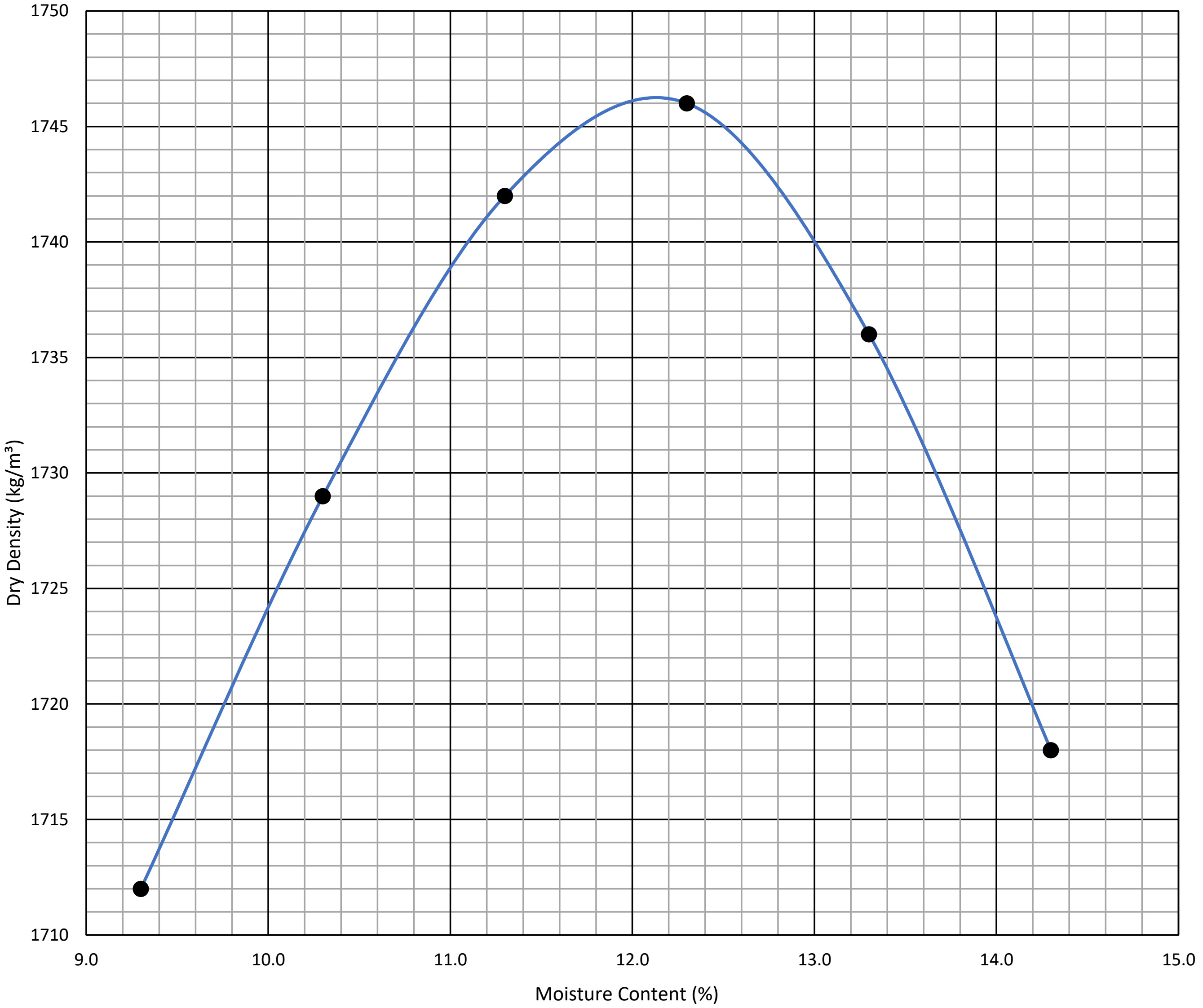
Job Number: EPO-19
Lab Number: EPO-19-77
Method: SANS 3001 GR30
Date: 04-Nov-20

MDD & OMC DETERMINATION (Std. Proctor)

Maximum Dry Density: **1748** kg/m³

Optimum Moisture Content: **12.1** %

Moisture Content (%):	9.3	10.3	11.3	12.3	13.3	14.3		
Dry Density (kg/m³)	1712	1729	1742	1746	1736	1718		



BM du Plessis
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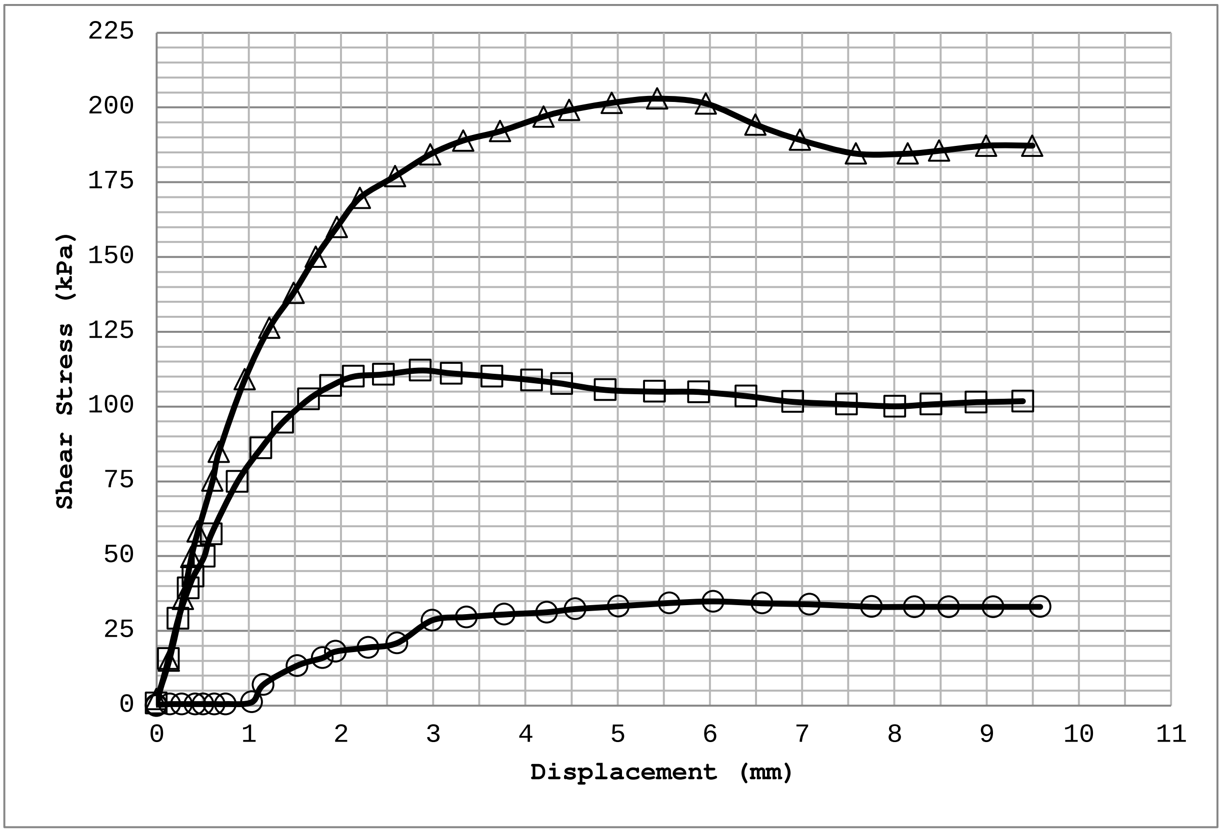
Tel/Fax 012 346 7586
Cell: 082 375 3003
bennie@geotesting.co.za

Project:	Tronox Tailings
Sample Number:	E0619/+45 micron
Sample Position:	-
Test:	DIRECT SHEAR TEST
Preparation:	Remoulded
Lab Number:	20/458
Test Date:	30-Nov-20



Normal Stress (kPa)	50.0	150.0	300.0
Shear Stress (kPa)	34.8	112.1	203.0
Displacement (mm)	6.0	2.9	5.4

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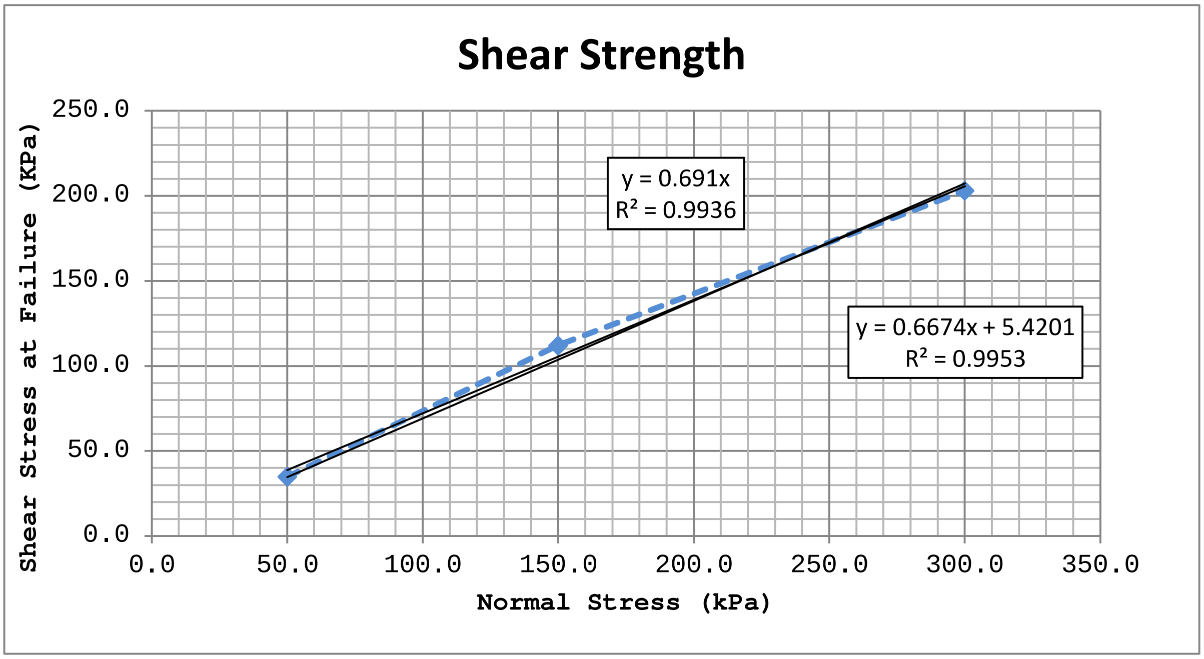
Project:	Tronox Tailings
Sample Number:	E0619/+45 micron
Sample Position:	-
Test:	DIRECT SHEAR TEST
Preparation:	Remoulded
Lab Number:	20/458
Test Date:	30-Nov-20



Linear trendline fit intersecting zero:

Apparent Cohesion Intersect : 0.0
Angle of Shear Resistance Ø : 34.6 °

Linear trendline fit intersecting 3 data points:

Apparent Cohesion Intersect : 5.4
Angle of Shear Resistance Ø : 33.7 °

Sample:	1	2	3
Initial Moisture:	12.4%	12.4%	12.6%
Initial Bulk Density (kg/m^3):	1875.1	1867.1	1877.9
Initial Dry Density(kg/m^3):	1668.7	1661.1	1667.9

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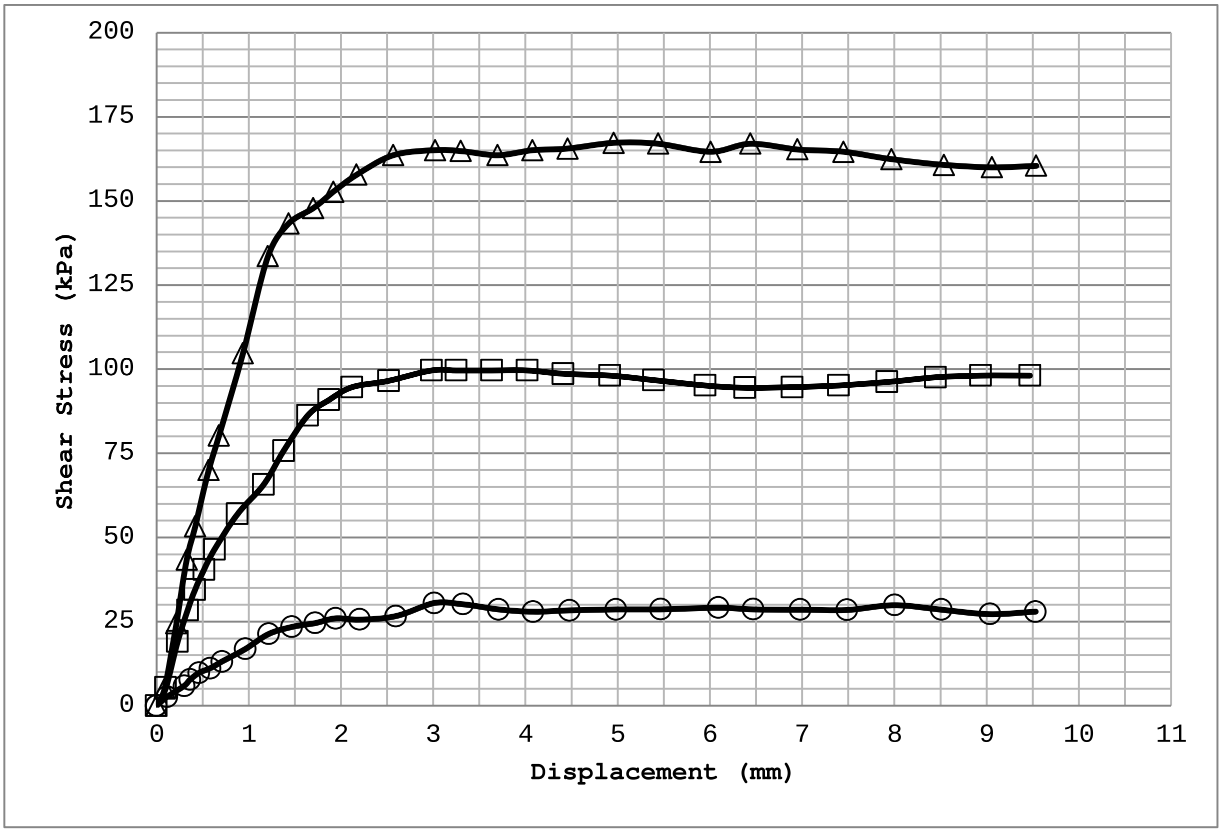
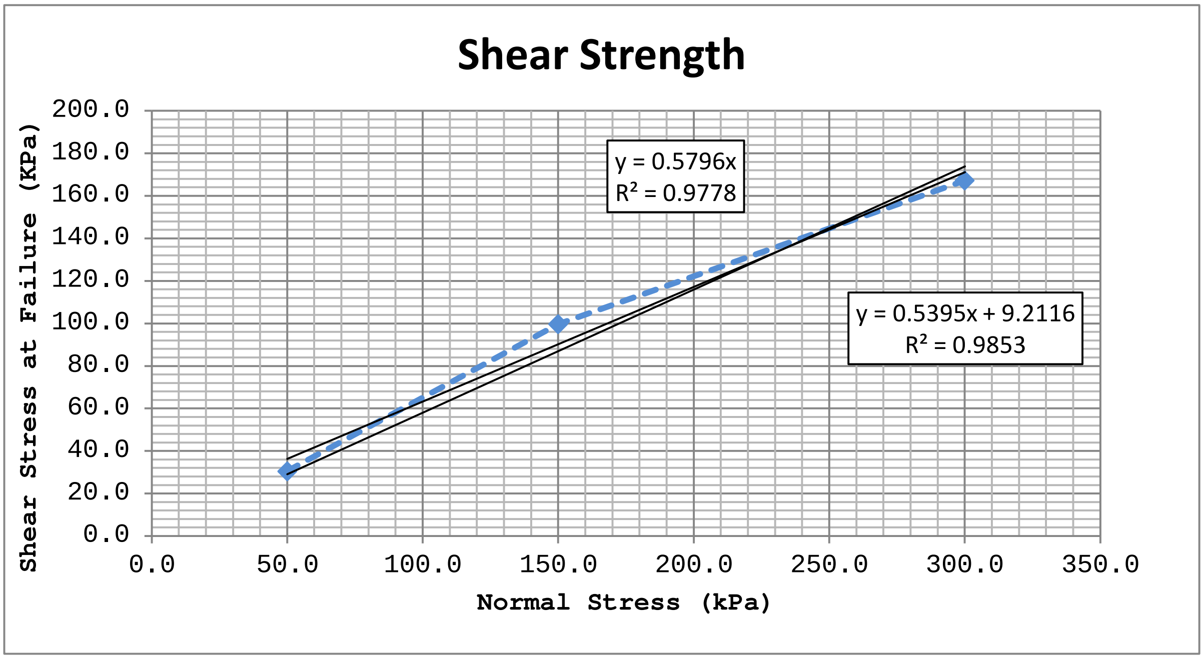
Project:	Tronox Tailings
Sample Number:	RAS Coarse Tails
Sample Position:	-
Test:	DIRECT SHEAR TEST
Preparation:	Remoulded
Lab Number:	20/455
Test Date:	27-Nov-20



Normal Stress (kPa)	50.0	150.0	300.0
Shear Stress (kPa)	30.5	99.7	167.3
Displacement (mm)	3.0	3.0	9.5

Project:	Tronox Tailings
Sample Number:	RAS Coarse Tails
Sample Position:	-
Test:	DIRECT SHEAR TEST
Preparation:	Remoulded
Lab Number:	20/455
Test Date:	27-Nov-20



Linear trendline fit intersecting zero:

Apparent Cohesion Intersect : 0.0
Angle of Shear Resistance Ø : 30.1 °

Linear trendline fit intersecting 3 data points:

Apparent Cohesion Intersect : 9.2
Angle of Shear Resistance Ø : 28.3 °

Sample:	1	2	3
Initial Moisture:	10.1%	10.6%	10.9%
Initial Bulk Density (kg/m^3):	1791.8	1772.9	1781.8
Initial Dry Density(kg/m^3):	1627.8	1602.4	1607.3

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- CIVIL ENGINEERING SERVICES -
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P.O. Box 912387 Silverton, 0127
Tel. : 012-800 1299
Fax. : 012-800 3034
Email : lizette.breiting@sgs.com

TEST RESULTS

Client:

EPOCH RESOURCES

Attention: Georgia Wills-Vagis

Project : TRONOX TAILINGS

Your Ref :

Our Ref : 40918

Date Reported : 23/11/2020

FALLING HEAD PERMEABILTY

TEST METHOD: KH HEAD Volume 2

SAMPLE	Lab No.	Depth (m)	STD. Proctor Dry Density	Compaction Effort	Dry Density	Actual Moisture Content %	Permeability (cm/s)
E0619 / +45µm	G20-0343	-	1748	95%	1669	11.57	1.72E-03
RAS COARSE TAILS	G20-0345	-	1664	95%	1584	10.71	2.36E-03

Remarks :

Form: C1 | Program ver 2.4

SHEAR TESTS: BOX SHEAR

KH Head

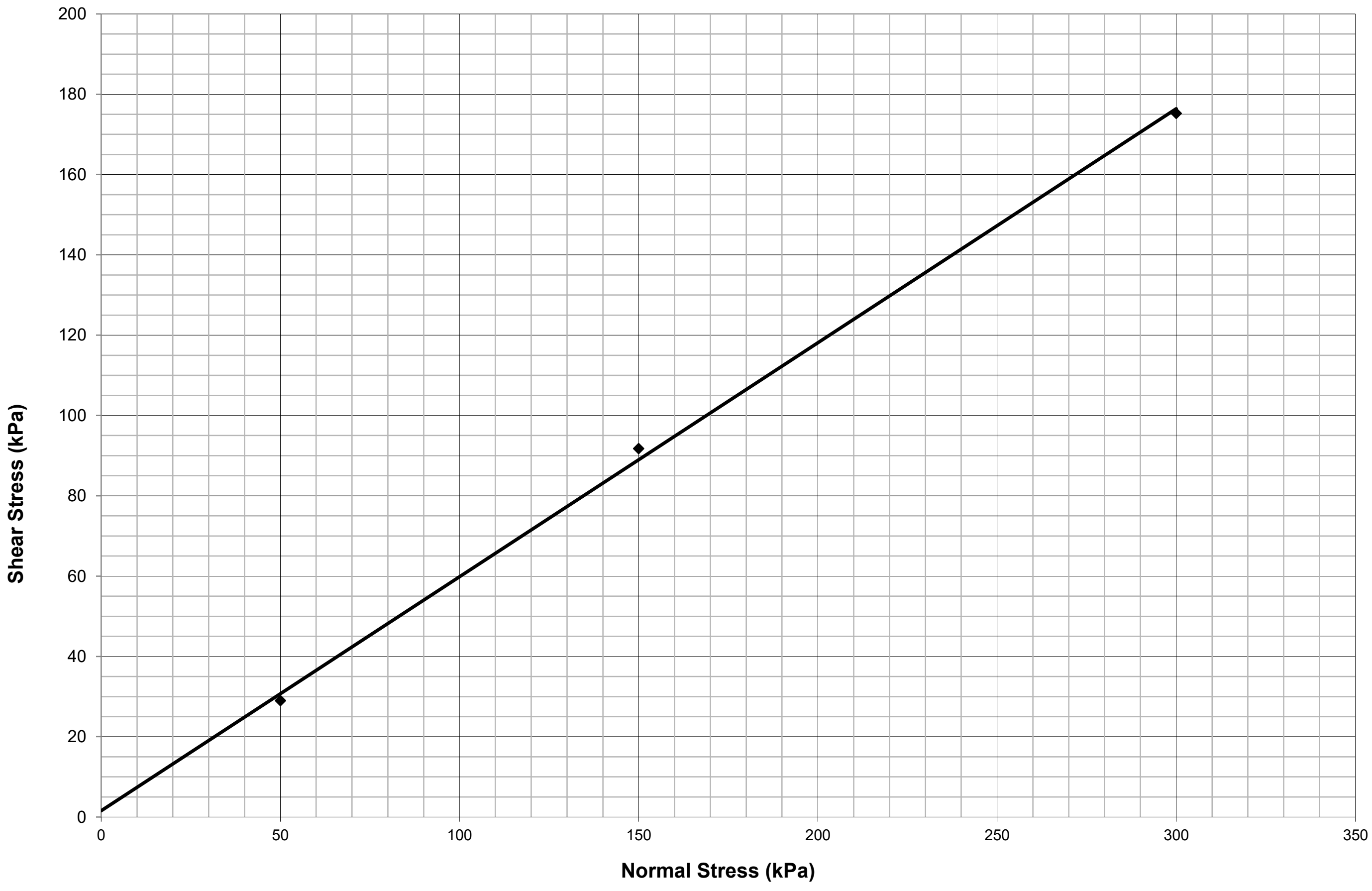
Client EPOCH RESOURCES **Project** TRONOX TAILINGS **Job no** 40918
Sample no RAS COARSE TAILS **Depth (m)** - **Date** 11/11/2020
Lab no G20-0345

Test Information		
Test Type	-	Slow Drained, SOAKED
Sample Condition	-	Remoulded by hand to 95% PROCTOR MDD
Normal Stresses	kPa	50, 150, 300
Rate of Strain	mm/min	0.0060

Initial Sample Parameters	Unit	Test 1	Test 2	Test 3	Remarks
Moisture Content	%	10.6	10.6	10.4	Complete test specimen
Dry Density	Kg/m³	1580	1582	1585	
Void Ratio	-	0.695	0.693	0.690	
Degree of Saturation	%	41.0	41.1	40.5	
Relative Density (SG)	-		2.678		Determined

Final Sample Parameters	Unit	Test 1	Test 2	Test 3	Remarks
Moisture Content	%	21.2	20.4	20.4	
Normal Stress	kPa	50	150	300	
Shear Stress	kPa	29	92	175	
Residual Stress	kPa	Not Tested	Not Tested	Not Tested	
Angle of Internal Friction	Deg.		30		Peak
Cohesion	kPa		2		Peak

Stress Plot



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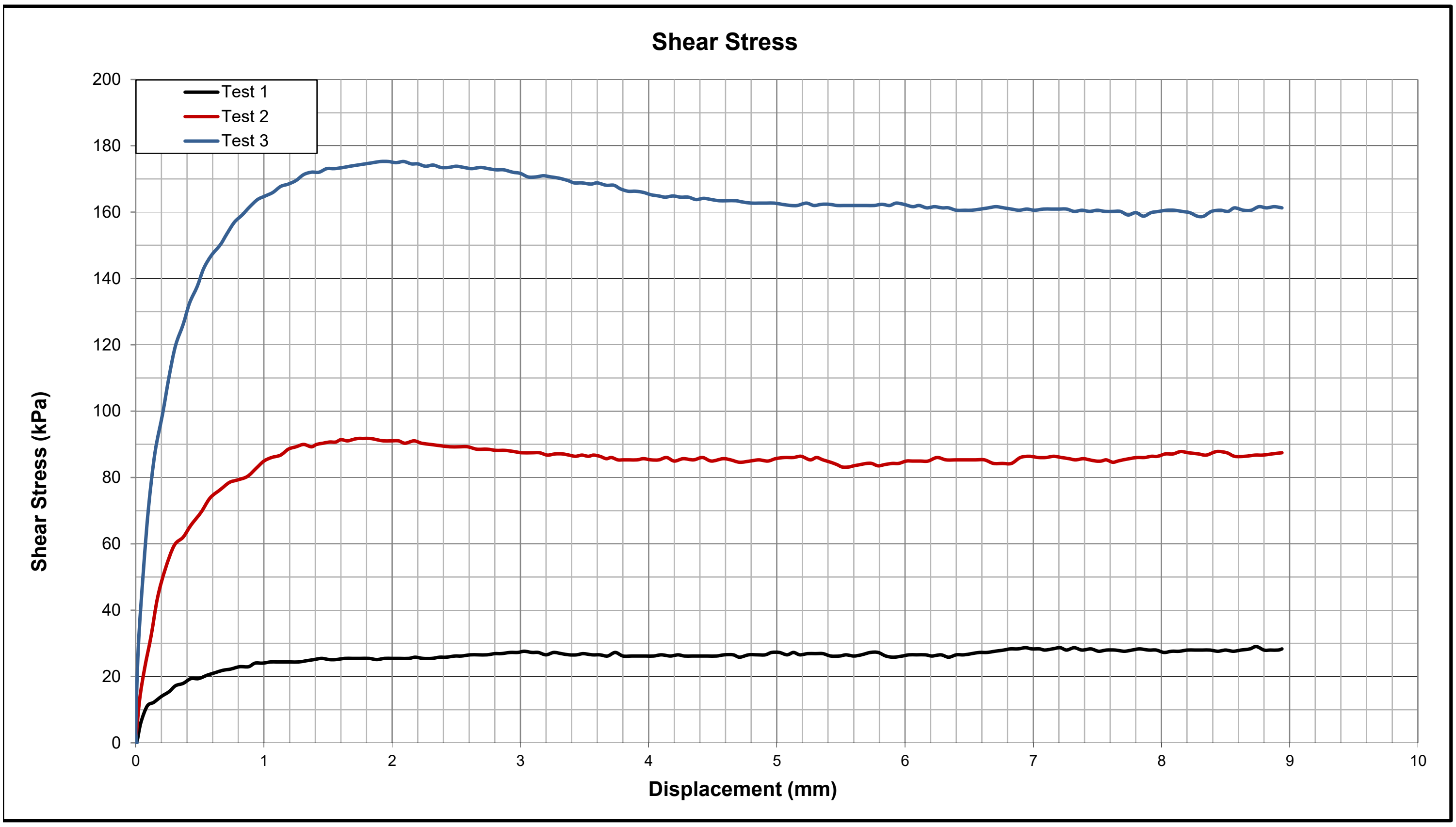
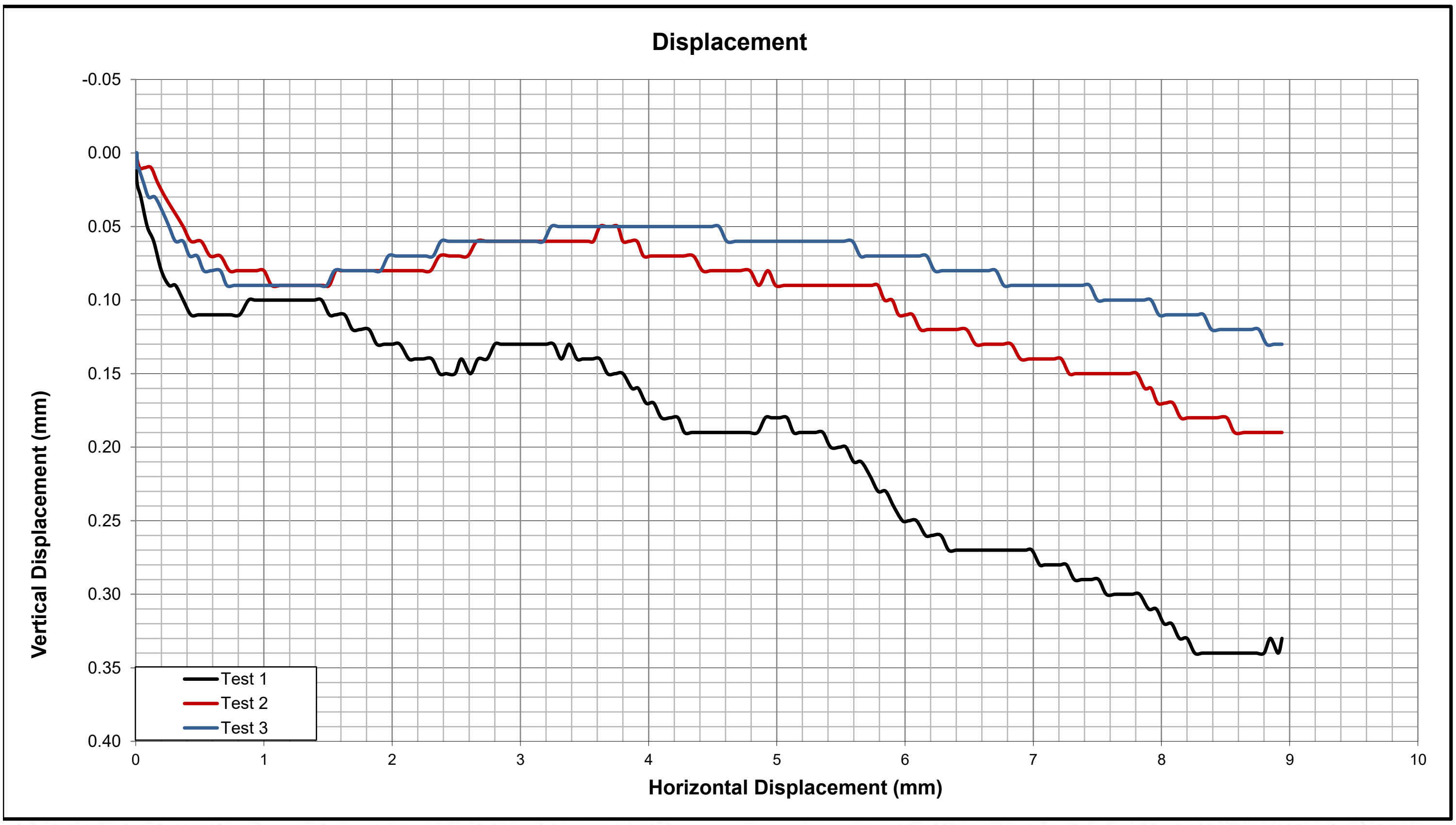
SHEAR TESTS: BOX SHEAR

KH Head

Client EPOCH RESOURCES **Project** TRONOX TAILINGS **Job no** 40918
Sample no RAS COARSE TAILS **Depth (m)** - **Date** 11/11/2020
Lab no G20-0345





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SHEAR TESTS: BOX SHEAR

KH Head

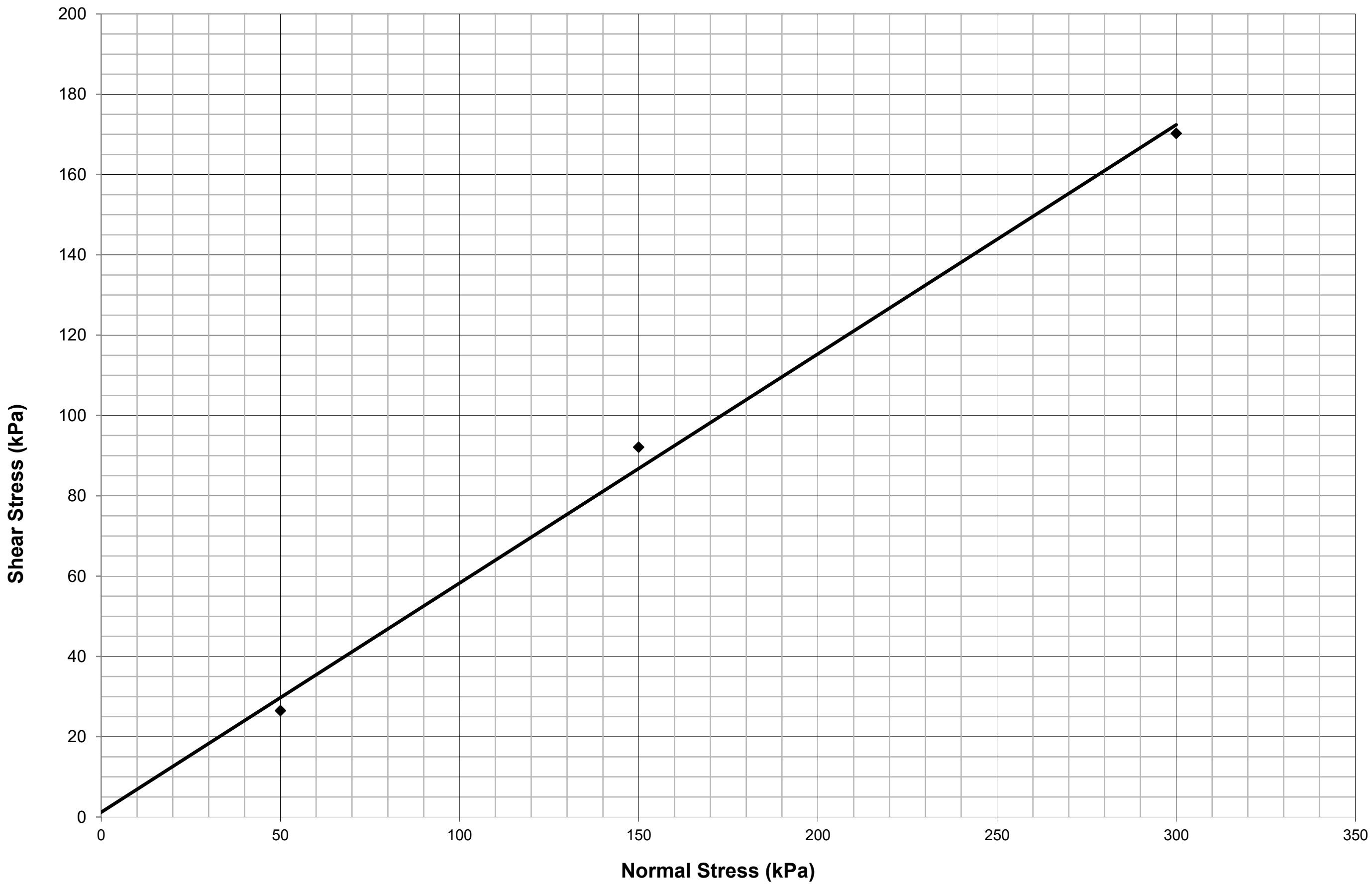
Client EPOCH RESOURCES **Project** TRONOX TAILINGS **Job no** 40918
Sample no E0619 / +45µm **Depth (m)** - **Date** 20/11/2020
Lab no G20-0343

Test Information		
Test Type	-	Slow Drained, saturated
Sample Condition	-	Remoulded by hand to estimated OMC
Normal Stresses	kPa	50, 150, 300
Rate of Strain	mm/min	0.0060

Initial Sample Parameters	Unit	Test 1	Test 2	Test 3	Remarks
Moisture Content	%	11.7	11.8	11.8	Complete test specimen
Dry Density	Kg/m³	1662	1661	1661	
Void Ratio	-	0.661	0.662	0.662	
Degree of Saturation	%	49.0	49.3	49.4	
Relative Density (SG)	-	2.761			Determined

Final Sample Parameters	Unit	Test 1	Test 2	Test 3	Remarks
Moisture Content	%	19.9	20.3	19.9	
Normal Stress	kPa	50	150	300	
Shear Stress	kPa	27	92	170	
Residual Stress	kPa	Not Tested	Not Tested	Not Tested	
Angle of Internal Friction	Deg.	30			Peak
Cohesion	kPa	1			Peak

Stress Plot



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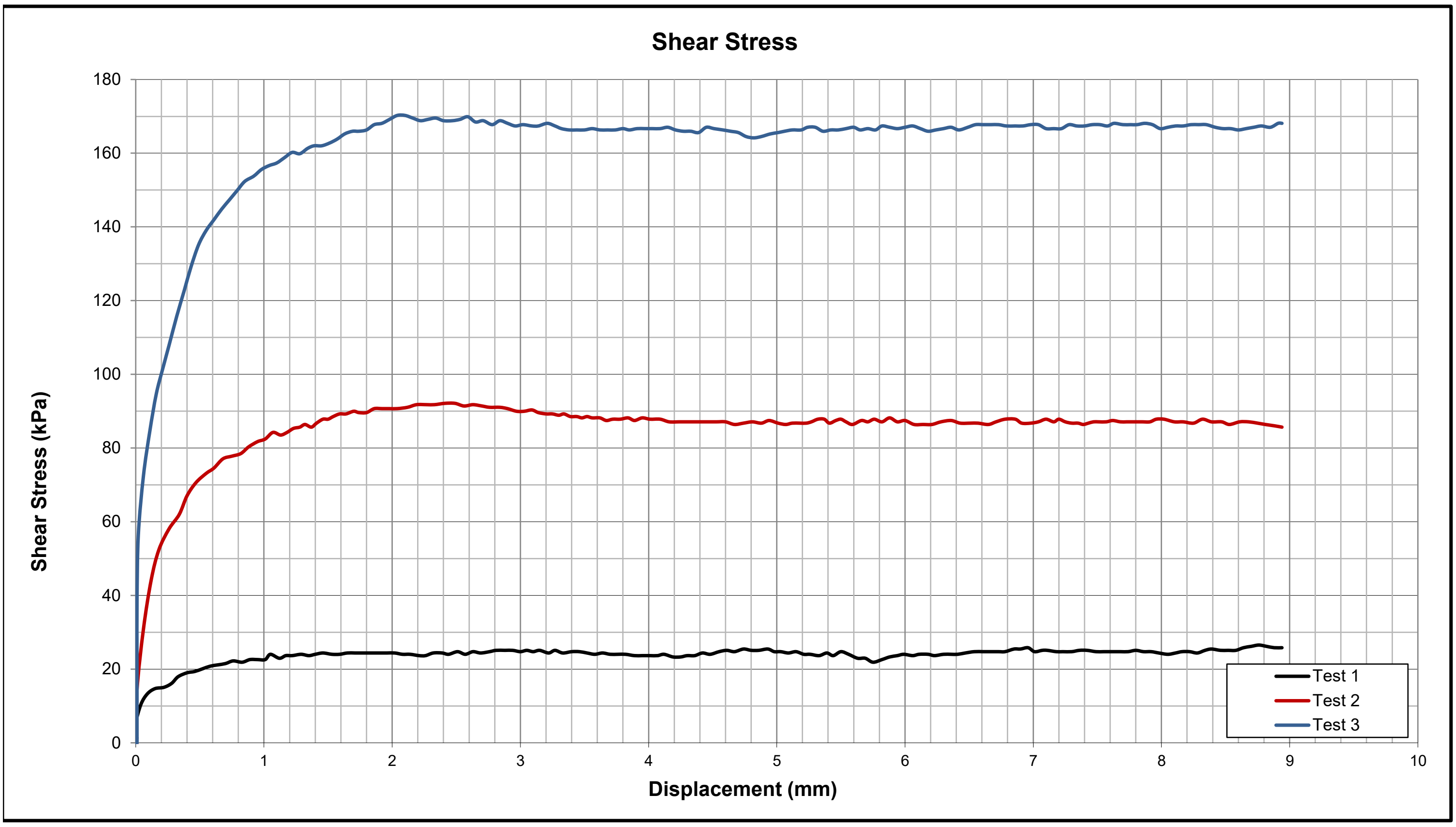
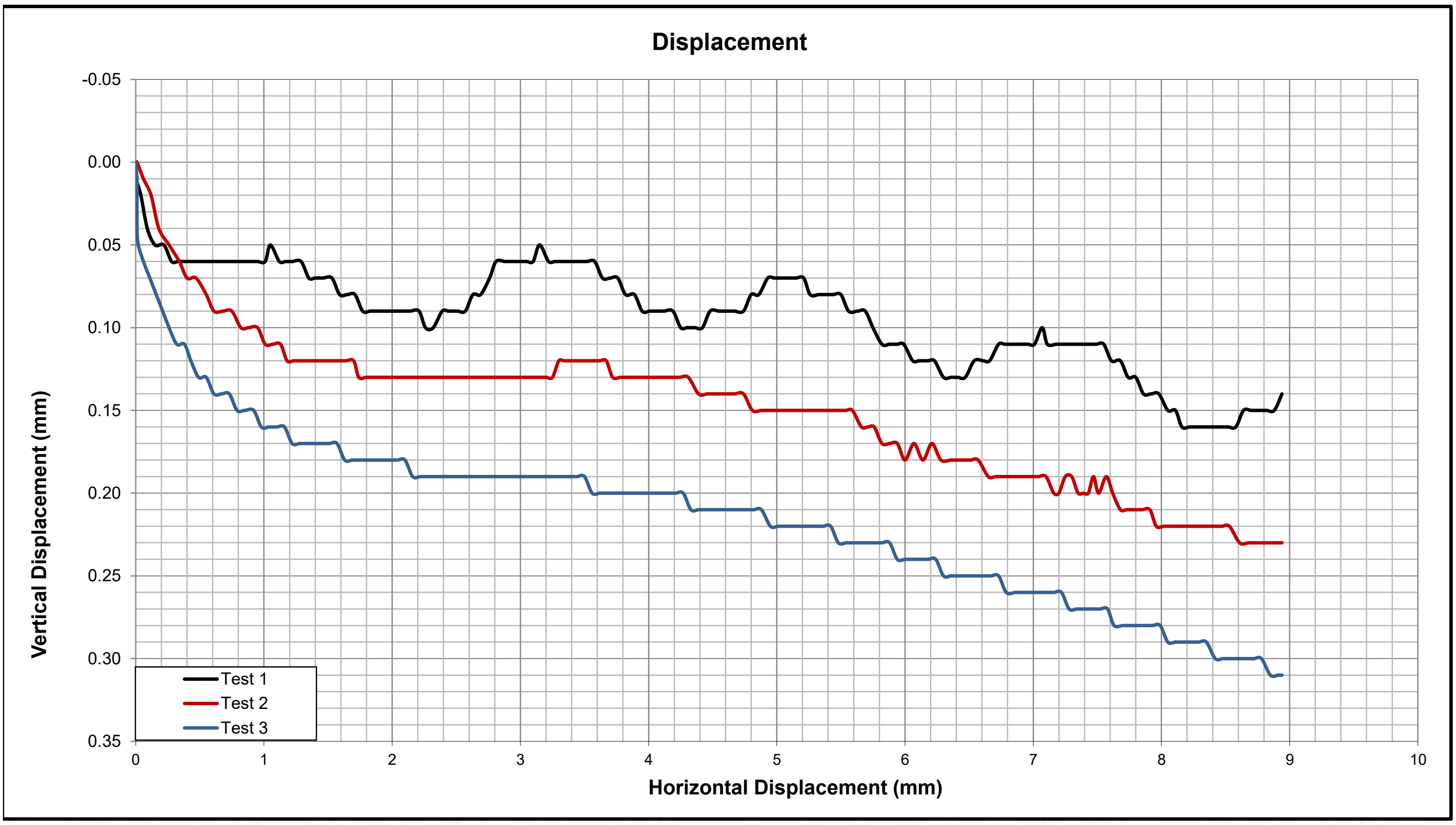
SHEAR TESTS: BOX SHEAR

KH Head

Client EPOCH RESOURCES **Project** TRONOX TAILINGS **Job no** 40918
Sample no E0619 / +45μm **Depth (m)** - **Date** 20/11/2020
Lab no G20-0343





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Project:	Tronox Tailings
Sample Number:	E1414/-45 micron
Sample Position:	-
Test:	Settling Immediately Drained & Falling Head Permeability
Sample Date:	-
Lab Number:	20/456
Test Date:	23-Nov-20

Preparation:

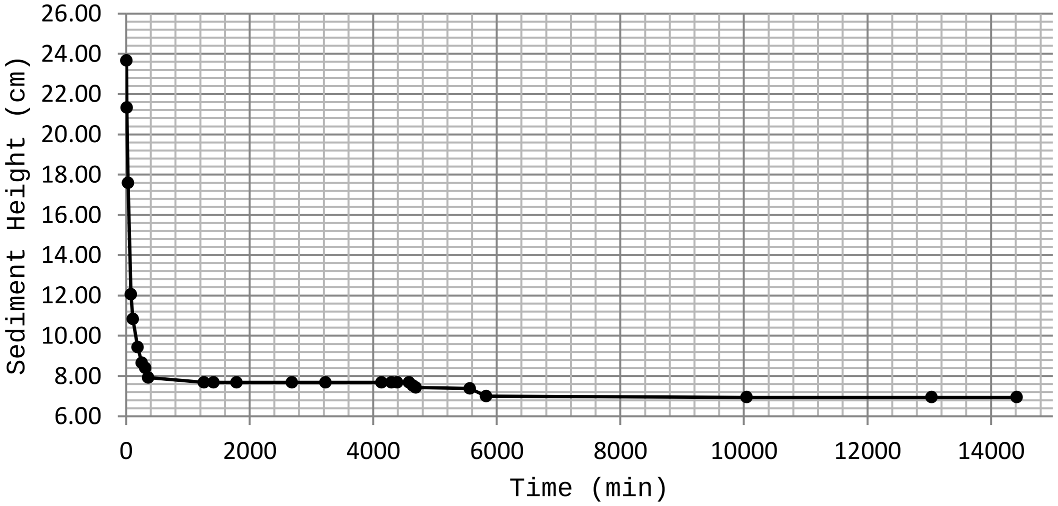
Total volume prepared (cm3):	510.0
Preparation moisture content of moist soil (%):	0.0
Target RD:	1.16
Gs:	2.63
Mass dry soil used (g):	129.9
Additional water added (g):	460.7
Total mass of solids and water (g):	590.6
Cylinder Number:	4
Cylinder Diameter (cm):	5.13

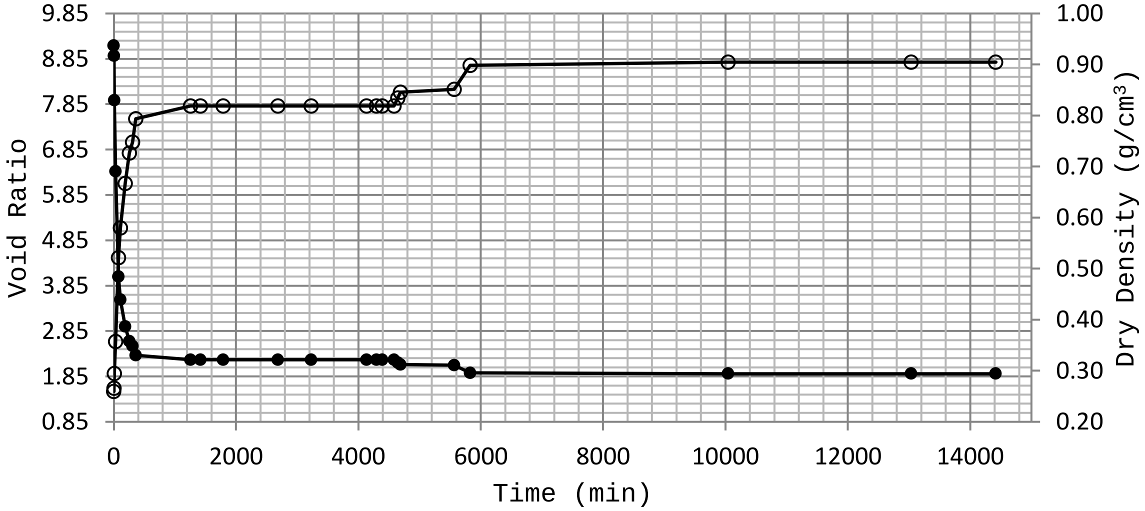
Settling during Drainage Data with Falling Head Permeability

Time (min)	Sediment Volume (cm^3)	Sediment Height (cm)	Void Ratio	Dry Density (g/cm^3)	Head (cm)	Perm. (cm/s)	Comments
0	500	24.20	9.14	0.260	24.2		
3	489	23.67	8.92	0.266	24.2	0.00E+00	Open Drain
12	441	21.33	7.94	0.295	23.7	7.22E-04	
33	364	17.59	6.37	0.357	22.7	5.84E-04	
76	249	12.05	4.05	0.522	21.9	1.73E-04	
110	224	10.84	3.54	0.580	21.4	1.19E-04	
187	195	9.43	2.95	0.667	20.8	6.11E-05	
256	179	8.65	2.62	0.727	20.2	5.94E-05	
310	174	8.41	2.52	0.748	19.8	5.04E-05	
360	164	7.92	2.32	0.794	19.6	3.26E-05	
1257	159	7.68	2.22	0.819	15.9	2.98E-05	
1417	159	7.68	2.22	0.819	15.2	3.50E-05	
1787	159	7.68	2.22	0.819	13.8	3.24E-05	
2684	159	7.68	2.22	0.819	10.6	3.82E-05	
3227	159	7.68	2.22	0.819	8.9	4.13E-05	closed
4132	159	7.68	2.22	0.819	8.9	0.00E+00	open
4292	159	7.68	2.22	0.819	8.4	4.50E-05	
4387	159	7.68	2.22	0.819	8.2	3.95E-05	
4582	159	7.68	2.22	0.819	7.7	4.03E-05	Interfaced
4642	156	7.53	2.16	0.835			
4687	154	7.43	2.12	0.846			closed
5566	153	7.38	2.09	0.851			open
5827	145	7.00	1.93	0.898			
10042	144	6.95	1.91	0.905			
13037	144	6.95	1.91	0.905			Final MC:
14417	144	6.95	1.91	0.905			91.43%

Project:	Tronox Tailings
Sample Number:	E1414/-45 micron
Sample Position:	-
Test:	Settling Immediately Drained & Falling Head Permeability
Sample Date:	-
Lab Number:	20/456
Test Date:	23-Nov-20

Settling during Drainage: Graphs





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Project:	Tronox Tailings
Sample Number:	E1414/-45 micron
Sample Position:	
Test:	Sedimentation Settling Test
Sample Date:	-
Lab Number:	20/456
Test Date:	23-Nov-20

Preparation:

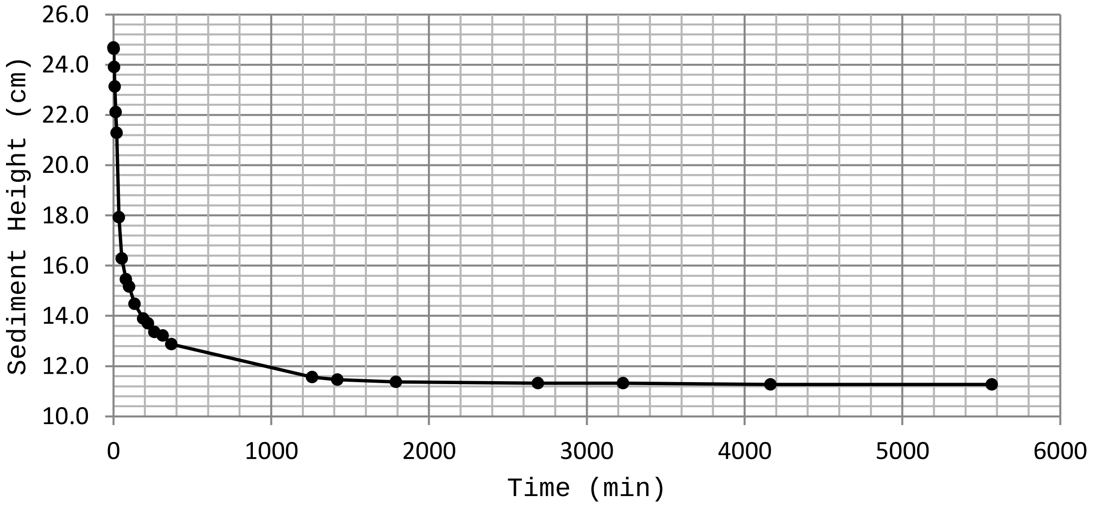
Total volume prepared (cm3):	510.0
Preparation moisture content of moist soil (%):	0.0
Target RD:	1.16
Gs:	2.63
Mass dry soil used (g):	129.9
Additional water added (g):	460.7
Total mass of solids and water (g):	590.6
Cylinder Number:	3
Cylinder Diameter (cm):	5.13

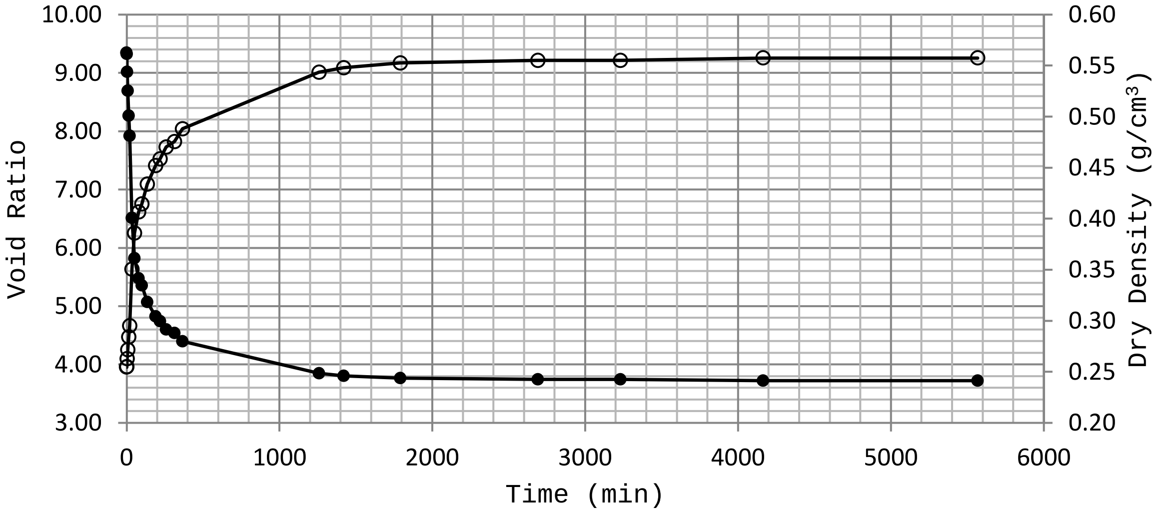
Sedimentation Test: Data

Time (min)	Sediment volume (cm^3)	Sediment height (cm)	Void ratio	Dry density (g/cm^3)	Comments
0	510	24.7	9.35	0.255	
3	509	24.6	9.33	0.255	
5	494	23.9	9.02	0.263	
9	478	23.1	8.69	0.272	
15	457	22.1	8.27	0.284	
20	440	21.3	7.92	0.295	
36	371	17.9	6.51	0.351	
53	336	16.3	5.82	0.386	
80	319	15.5	5.48	0.407	
100	313	15.2	5.35	0.415	
135	299	14.5	5.07	0.434	
190	287	13.9	4.82	0.452	
220	283	13.7	4.74	0.459	
260	276	13.4	4.60	0.470	
313	273	13.2	4.54	0.476	
367	266	12.9	4.40	0.488	
1260	239	11.6	3.85	0.543	
1420	237	11.5	3.81	0.548	
1790	235	11.4	3.77	0.553	
2690	234	11.3	3.74	0.555	
3230	234	11.3	3.74	0.555	
4163	233	11.3	3.72	0.558	
5567	233	11.3	3.72	0.558	Settling Complete

Project:	Tronox Tailings
Sample Number:	E1414/-45 micron
Sample Position:	0
Test:	Sedimentation Settling Test
Sample Date:	-
Lab Number:	20/456
Test Date:	23-Nov-20

Sedimentation Test: Graphs





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Project: Tronox Tailings
Sample Number: EOFS Fines Residue
Sample Position: -
Test: Settling Immediately Drained & Falling Head Permeability
Sample Date: -
Lab Number: 20/457
Test Date: 2-Dec-20

Preparation:

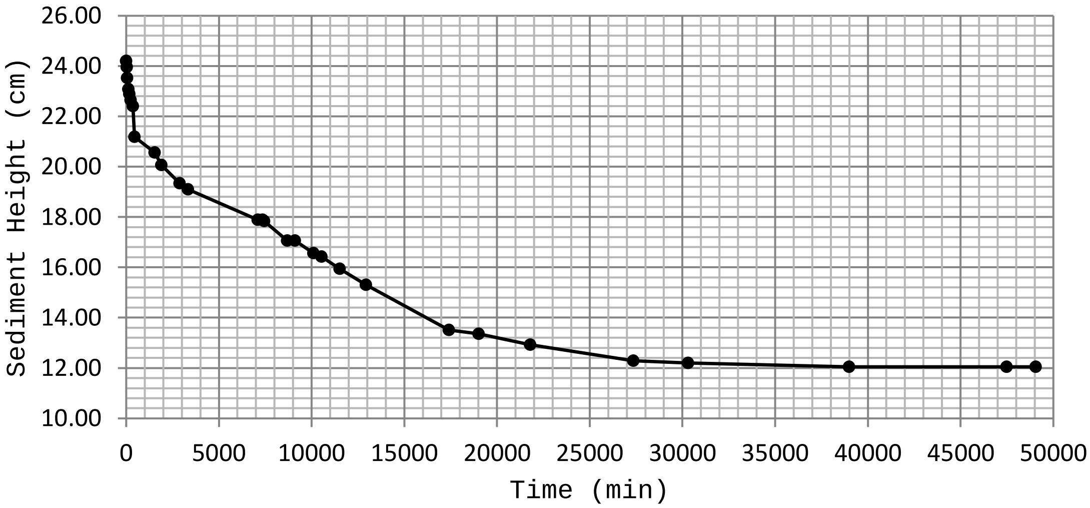
Total volume prepared (cm3): 510.0
Preparation moisture content of moist soil (%): 0.0
Target RD: 1.16
Gs: 2.65
Mass dry soil used (g): 130.2
Additional water added (g): 460.9
Total mass of solids and water (g): 591.1
Cylinder Number: 2
Cylinder Diameter (cm): 5.13

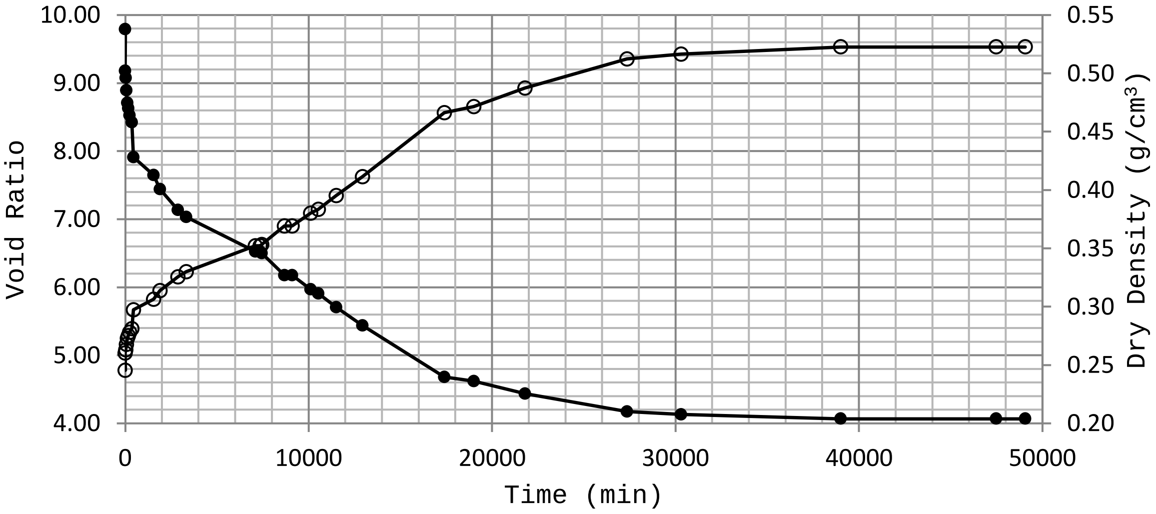
Settling during Drainage Data with Falling Head Permeability

Time (min)	Sediment Volume (cm^3)	Sediment Height (cm)	Void Ratio	Dry Density (g/cm^3)	Head (cm)	Perm. (cm/s)	Comments
0	530	25.66	9.79	0.246	25.7		Foamed
1	500	24.20	9.18	0.260	24.2	0.00E+00	Open Drain
30	495	23.96	9.08	0.263	24.0	1.37E-04	
60	486	23.52	8.89	0.268	23.9	5.31E-05	
120	477	23.08	8.71	0.273	23.5	1.05E-04	
180	473	22.89	8.63	0.275	23.4	2.64E-05	
240	468	22.64	8.53	0.278	23.2	3.94E-05	
360	463	22.40	8.42	0.281	23.0	2.62E-05	
450	438	21.19	7.91	0.297	22.9	2.49E-05	
1545	425	20.56	7.65	0.306	21.5	1.92E-05	
1895	415	20.07	7.44	0.314	21.3	1.09E-05	
2883	400	19.34	7.14	0.326	20.7	9.07E-06	
3335	395	19.10	7.03	0.330	20.3	1.34E-05	
7095	370	17.88	6.52	0.352	18.1	9.03E-06	
7360	370	17.88	6.52	0.352	17.9	1.52E-05	Interfaced
7450	369	17.83	6.50	0.353			
8680	353	17.06	6.18	0.369			
9095	353	17.06	6.18	0.369			
10105	342	16.57	5.97	0.380			
10535	339	16.42	5.91	0.384			
11515	329	15.94	5.70	0.395			
12935	316	15.31	5.44	0.412			
17406	279	13.51	4.68	0.466			
19005	276	13.36	4.62	0.471			
21800	267	12.92	4.44	0.487			
27355	254	12.29	4.17	0.512			
30305	252	12.20	4.13	0.517			
38995	249	12.05	4.07	0.523			
47485	249	12.05	4.07	0.523			Final MC:
49055	249	12.05	4.07	0.523			Pending

Project:	Tronox Tailings
Sample Number:	EOFS Fines Residue
Sample Position:	-
Test:	Settling Immediately Drained & Falling Head Permeability
Sample Date:	-
Lab Number:	20/457
Test Date:	2-Dec-20

Settling during Drainage: Graphs





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Project: Tronox Tailings
Sample Number: EOFS Fines Residue
Sample Position:
Test: Sedimentation Settling Test
Sample Date: -
Lab Number: 20/457
Test Date: 2-Dec-20

Preparation:

Total volume prepared (cm3): 510.0
Preparation moisture content of moist soil (%): 0.0
Target RD: 1.16
Gs: 2.65
Mass dry soil used (g): 130.2
Additional water added (g): 460.9
Total mass of solids and water (g): 491.1
Cylinder Number: 1
Cylinder Diameter (cm): 5.12

Sedimentation Test: Data

Time (min)	Sediment volume (cm^3)	Sediment height (cm)	Void ratio	Dry density (g/cm^3)	Comments
0	521	25.3	9.60	0.250	
60	519	25.2	9.56	0.251	
120	518	25.2	9.54	0.251	
180	517	25.1	9.52	0.252	
240	517	25.1	9.52	0.252	
300	516	25.1	9.50	0.252	
420	515	25.0	9.48	0.253	
480	515	25.0	9.48	0.253	
1575	513	24.9	9.43	0.254	
1925	512	24.9	9.41	0.254	
2912	508	24.6	9.33	0.257	
3365	508	24.6	9.33	0.257	
7180	500	24.3	9.18	0.260	
8710	496	24.1	9.10	0.262	
9125	495	24.0	9.08	0.263	
10135	494	24.0	9.06	0.264	
10565	494	24.0	9.06	0.264	
11545	492	23.9	9.01	0.265	
12965	490	23.8	8.97	0.266	
17500	485	23.5	8.87	0.269	
19155	483	23.4	8.82	0.270	
21830	480	23.3	8.76	0.271	Water evaporated
27385	478	23.2	8.72	0.273	Water evaporated
30335	476	23.1	8.70	0.273	Water evaporated
39025	473	23.0	8.64	0.275	Water evaporated
47515	471	22.9	8.59	0.276	Water evaporated
49085	471	22.9	8.59	0.276	Water evaporated

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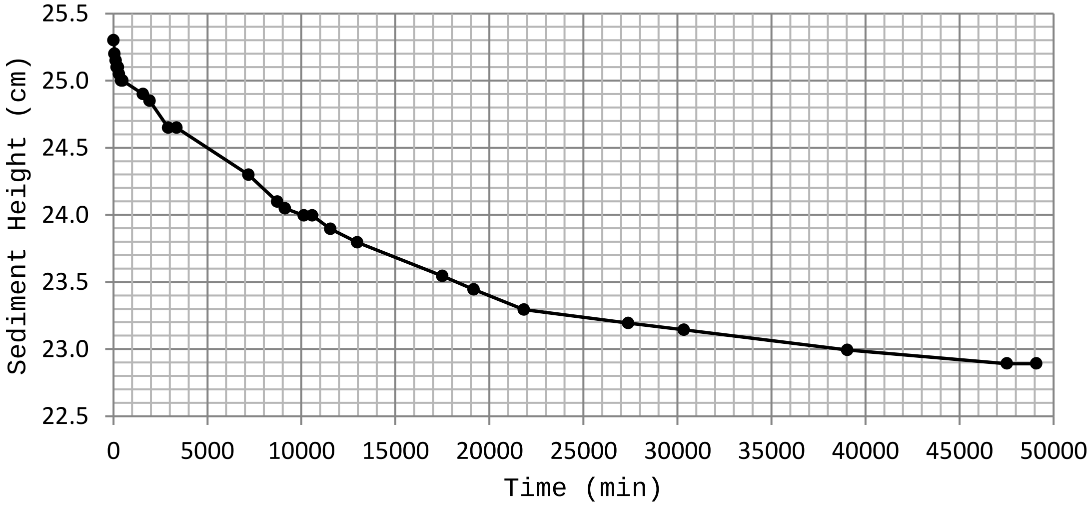
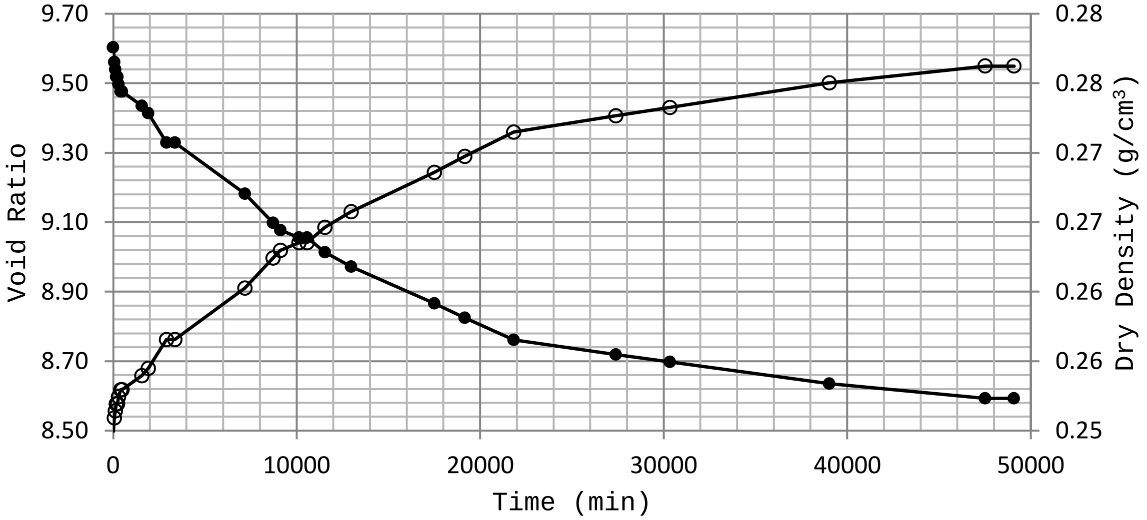
Project: Tronox Tailings
Sample Number: EOFS Fines Residue
Sample Position: 0
Test: Sedimentation Settling Test
Sample Date: -
Lab Number: 20/437
Test Date: 2-Dec-20

Sedimentation Test: Graphs





Project: Tronox Tailings

Client Sample Number: E1414-45mic_EPO-19-17

Lab Number: 20/456

Test: Ambient Slurry Drying Out

Test Start Date: 23-Nov-20

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Date Time	Temp. (˚C)	Humidity (%)	Sample Moist weight (g)	Sample Dry Weight (g)	Water & Soil Bulk Density (kg/m3)	Crack Width (Circular) (mm)	Soil Only Material Volume (cm3)	Soil Only Bulk Density (kg/m3)	Soil Level Void Ratio (Vv/Vs)	Sample Moisture (g)	Sample Moisture Content (%)	Degree of Saturation (%) (Vw/Vv)	Water & Soil Dry Density (kg/m3)	Soil Level Dry Density (kg/m3)	Comments
11/23/20 10:20	21.1	62	5923	1286	1117	0.0	5305	*1117*	9.8	4637	360.5%	96.3%	243	242	
11/23/20 11:30	24.1	52	5915	1286	1117	0.0	2361	*2506*	3.8	4629	359.9%	247.3%	243	545	
11/23/20 13:51	26.8	62	5896	1286	1124	0.0	2137	*2759*	3.4	4610	358.4%	279.7%	245	602	
11/23/20 15:21	34.9	22	5858	1286	1122	0.0	2094	*2798*	3.3	4572	355.5%	284.9%	246	614	
11/24/20 8:52	23.5	55	5779	1286	1126	0.0	2006	*2881*	3.1	4493	349.3%	296.1%	251	641	Decant
11/24/20 8:59	23.9	55	2630	1286	1287	0.0	2006	*1311*	3.1	1344	104.5%	88.6%	629	641	Bleed water
11/24/20 14:54	27.9	52	2584	1286	1299	0.0	2006	*1288*	3.1	1298	100.9%	85.6%	646	641	Bleed water
11/25/20 8:31	23.4	52	2543	1286	1319	0.0	2006	*1268*	3.1	1257	97.7%	82.8%	667	641	Interfaced
11/25/20 15:35	26.1	39	2470	1286	-	0.0	1930	*1280*	2.9	1184	92.1%	82.1%	-	666	
11/26/20 7:27	21.6	52	2404	1286	-	0.0	1845	*1303*	2.8	1118	86.9%	82.5%	-	697	
11/26/20 15:38	25.9	41	2337	1286	-	0.0	1764	*1325*	2.6	1051	81.7%	82.4%	-	729	
11/27/20 9:14	24.6	51	2295	1286	-	0.0	1694	*1355*	2.5	1009	78.4%	83.7%	-	759	
11/27/20 15:11	27.9	35	2234	1286	-	0.0	1657	*1348*	2.4	948	73.7%	81.2%	-	776	
11/30/20 13:14	27.5	43	2215	1286	-	0.0	1658	*1336*	2.4	929	72.2%	79.4%	-	776	Exposed to some rain
12/1/20 12:20	24.4	52	2118	1286	-	0.3	1586	*1336*	2.2	832	64.7%	75.8%	-	811	Cracking Started
12/1/20 15:45	26.3	39	2071	1286	-	1.0	1561	*1327*	2.2	785	61.0%	73.2%	-	824	
12/2/20 9:30	22.9	43	2037	1286	-	1.1	1555	*1310*	2.2	751	58.4%	70.4%	-	827	
12/3/20 9:48	21.9	47	1915	1286	-	3.7	1555	*1231*	2.2	629	48.9%	59.0%	-	827	
12/4/20 12:46	26	39	1849	1286	-	8.1	1554	*1190*	2.2	563	43.8%	52.8%	-	828	
12/7/20 8:14	20.9	54	1673	1286	-	29.0	1264	*1323*	1.6	387	30.1%	49.9%	-	1017	
12/8/20 9:30	21.9	49	1607	1286	-	31.9	1249	*1286*	1.6	321	25.0%	42.2%	-	1029	
12/9/20 13:18	23.9	44	1555	1286	-	31.5	1247	*1248*	1.5	269	20.9%	35.5%	-	1032	
12/10/20 12:20	27.4	34	1502	1286	-	31.3	1239	*1213*	1.5	216	16.8%	28.8%	-	1038	
12/11/20 15:13	27.4	37	1435	1286	-	32.0	1223	*1173*	1.5	149	11.6%	20.3%	-	1051	
12/14/20 15:43	22.9	53	1430	1286	-	32.0	1220	*1172*	1.5	144	11.2%	19.7%	-	1054	
12/17/20 15:00	22.6	51	1423	1286	-	32.0	1220	*1167*	1.5	137	10.6%	18.7%	-	1054	

Project: Tronox Tailings

Client Sample Number: EOFS_Fines Residue_EPO-19-73

Lab Number: 20/457

Test: Ambient Slurry Drying Out

Test Start Date: 23-Nov-20

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Date Time	Temp. (˚C)	Humidity (%)	Sample Moist weight (g)	Sample Dry Weight (g)	Water & Soil Bulk Density (kg/m3)	Crack Width (Circular) (mm)	Soil Only Material Volume (cm3)	Soil Only Bulk Density (kg/m3)	Soil Level Void Ratio (Vv/Vs)	Sample Moisture (g)	Sample Moisture Content (%)	Degree of Saturation (%) (Vw/Vv)	Water & Soil Dry Density (kg/m3)	Soil Level Dry Density (kg/m3)	Comments
11/23/20 10:20	21.1	62	5843	1290	1109	0.0	5267	*1109*	9.8	4553	353.0%	95.2%	245	245	
11/23/20 11:30	24.1	52	5838	1290	1111	0.0	3822	*1527*	6.9	4548	352.6%	136.3%	245	337	
11/23/20 13:51	26.8	62	5820	1290	1116	0.0	3432	*1695*	6.1	4530	351.2%	153.8%	247	376	
11/23/20 15:21	34.9	22	5791	1290	1117	0.0	3253	*1780*	5.7	4501	349.0%	162.7%	249	396	
11/24/20 8:52	23.5	55	5718	1290	1123	0.0	2716	*2105*	4.6	4428	343.3%	198.7%	253	475	
11/24/20 8:59	23.9	55	3287	1290	1194	0.0	2754	*1194*	4.7	1997	154.8%	88.1%	468	468	Decanted
11/24/20 14:54	27.9	52	3247	1290	1204	0.0	2537	*1280*	4.2	1957	151.7%	95.4%	478	508	Bleed water
11/25/20 8:31	23.4	52	3201	1290	1222	0.0	2430	*1317*	4.0	1911	148.2%	98.3%	493	531	Bleed water
11/25/20 15:35	26.1	39	3139	1290	1174	0.0	2400	*1308*	3.9	1849	143.3%	96.6%	482	537	Bleed water
11/26/20 7:27	21.6	52	3063	1290	1208	0.0	2365	*1295*	3.9	1773	137.5%	94.4%	509	545	Bleed water
11/26/20 15:38	25.9	41	3006	1290	1207	0.0	2345	*1282*	3.8	1716	133.0%	92.4%	518	550	Bleed water
11/27/20 9:14	24.6	51	2956	1290	1249	0.0	2331	*1268*	3.8	1666	129.2%	90.3%	545	553	Interfaced
11/27/20 15:11	27.9	35	2905	1290	-	0.0	2319	*1253*	3.8	1615	125.2%	88.1%	-	556	
11/30/20 13:14	27.5	43	2869	1290	-	0.0	2304	*1245*	3.7	1579	122.4%	86.9%	-	560	Exposed to some rain
12/1/20 12:20	24.4	52	2774	1290	-	0.0	2176	*1274*	3.5	1484	115.0%	87.8%	-	593	
12/1/20 15:45	26.3	39	2732	1290	-	0.0	2063	*1324*	3.2	1442	111.8%	91.5%	-	625	
12/2/20 9:30	22.9	43	2692	1290	-	0.0	2054	*1311*	3.2	1402	108.7%	89.5%	-	628	
12/3/20 9:48	21.9	47	2569	1290	-	0.0	1959	*1311*	3.0	1279	99.2%	86.8%	-	658	
12/4/20 12:46	26	39	2506	1290	-	0.0	1854	*1352*	2.8	1216	94.3%	88.9%	-	696	
12/7/20 8:14	20.9	54	2318	1290	-	0.0	1658	*1398*	2.4	1028	79.7%	87.7%	-	778	
12/8/20 9:30	21.9	49	2237	1290	-	7.2	1462	*1529*	2.0	947	73.4%	97.0%	-	882	Cracking Started
12/9/20 13:18	23.9	44	2169	1290	-	8.8	1406	*1542*	1.9	879	68.1%	95.6%	-	917	
12/10/20 12:20	27.4	34	2088	1290	-	11.0	1354	*1541*	1.8	798	61.9%	92.0%	-	952	
12/11/20 15:13	27.4	37	1959	1290	-	13.0	1226	*1598*	1.5	669	51.9%	90.5%	-	1052	
12/14/20 15:43	22.9	53	1874	1290	-	13.2	1200	*1562*	1.5	584	45.3%	81.9%	-	1075	
12/17/20 15:00	22.6	51	1827	1290	-	13.2	1200	*1522*	1.5	537	41.6%	75.3%	-	1075	

Appendix D GEOTECHNICAL INVESTIGATION UNDERTAKEN BY INROADS

Reference No: 2027/g

REPORT ON A GEOTECHNICAL INVESTIGATION FOR THE PROPOSED RESIDUE STORAGE FACILITY & OVERBURDEN FACILITY FOR THE TRONOX NAMAKWA SANDS EOFS PROJECT IN BRAND-SE-BAAI, WESTERN CAPE

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1. INTRODUCTION

1.1 Background

Tronox Limited is an American worldwide chemical company involved in the titanium products industry and has operations in Brand-Se-Baai on the West Coast of South Africa, named Namakwa Sands. It mines heavy minerals using the open-cast strip-mining method at its West and East Mines.

Mining at the East Mine is fairly shallow and involves the mining of a very loose surface sand horizon referred to as the Red Aeolian Sand (RAS). Tronox intends to mine the deeper Orange Felspathic Sands (OFS) resource underlying the RAS material at the East Mine (known as the EOFS Project). For the EOFS Project to proceed, a residue disposal strategy has been developed and entails the design and construction of a Residue Storage Facility (RSF) to accommodate the fine residue from the project. Other associated infrastructure includes a RAS tailings overburden stockpile facility, which is understood is an interim measure to store the tailings and will be used until portions of the mined-out pit become available to receive tailings overburden, at which stage disposal at it will cease.

The Namakwa Sands Mine is located about 390 km north of Cape Town and is accessible via the N7 National Route, R27, R362 and R363 roads.

This report presents the results of a geotechnical investigation carried out within the sites identified for the construction of the RSF and overburden facility.

1.2 The Development

The development is to comprise the design and construction of an RSF, an overburden facility and the upgrading of the existing Primary Concentration Plant (PCP) East to process EOFS ore.

The RSF will typically comprise an impoundment for residue (fines) disposal covering an area of about 376,3 hectares and having a 7,4 km long and up to 27 m high starter wall. Walls of the facility will have a crest width of approximately 30 m and will be built from sand tailings transported from the PCP East.

The stockpile facility located immediately east of the RSF will be of an approximate height of up to 6.0 m and cover a footprint of about 50 ha.

2. TERMS OF REFERENCE

Inroads Consulting was requested by Epoch Resources (Pty) Ltd on behalf of Tronox to offer a proposal for undertaking a geotechnical investigation at the sites of the RSF and overburden facility.

The geotechnical investigation was to be undertaken with the following primary objectives:

- To establish the stratigraphy and engineering characteristics of the subsoils underlying the structures;
- To determine shear strength and permeability properties of the underlying soil or rock
- To establish the excavatability of the underlying soils to appropriate depths and their suitability for the construction of the RSF.

The proposal was subsequently prepared by Inroads Consulting cc and submitted to Epoch on 29 July 2020 and was accepted by them on 04 August 2020.

3. SCOPE OF ACTIVITIES

3.1 Literature Review

Before undertaking the fieldwork, discussed below, a literature survey was carried out in which all information pertaining to the engineering geological and geotechnical conditions was obtained and reviewed. This included the 1:250 000 scale Geological Map(1) and Volume 4 of the series Engineering Geology of Southern Africa(2).

Details of these publications are presented in the References attached to this Report as Appendix A.

3.2 Fieldwork

The fieldwork was undertaken between 21st August and 3rd September 2020 and entailed setting out and excavating a total of 111 test pits within the RSF and overburden sites. Initially, there were 106 test pits identified for the RSF and 30 test pits planned for the overburden facility, however, due to time constraints some of the pits were omitted and 82 and 29 were excavated within the aforementioned sites respectively.

The test pits were put down within the site employing a Volvo BL71B Tractor Loader Backhoe (TLB) to depths ranging between 0,2 m to 3,5 m, averaging 2,9 m below the present ground surface. Each of the test pits within the RSF were set out by a land surveyor and the remaining pit positions within the overburden facility were coordinated using a hand-held Garmin GPS device. The sidewall of the exposed soil in each test pits was also photographed.

A total of six rotary cored boreholes were drilled to 20 m within the RSF and two holes were drilled in the overburden site on 10 to 19 December 2020 and 7 to 13 January 2021.

The pits and boreholes were profiled following the standard methods and procedures prescribed in the document *Guidelines for Soil and Rock Logging in South Africa (2002)(3)* and their positions are presented in the site plan attached as Appendix B.

Samples were recovered from certain of the soil horizons and sent to Roadlab (Pty) Ltd. an ISO accredited civil engineering testing laboratory in Belville, Cape Town, South Africa.

3.3 Preliminary Report

A preliminary report for the RSF was submitted on 12 September 2020 in which the findings of the fieldwork were presented, specifically the subsoil conditions, together with a summary of the test pit profiles and estimates of soil engineering parameters.

A more comprehensive preliminary report, which included the laboratory tests, was submitted on 26 October 2020.

4. SITE DESCRIPTION

The area for the RSF and overburden facility is located about 2,0 km north of the existing Primary Concentration Plant East Complex. The natural ground surface over most of the areas is covered mainly by shrubs. In previously mined areas, the surface cover comprises loose backfilled sand stabilized by windbreaks, and in places, the areas have been revegetated.

The landscape within the overburden facility has been significantly modified by the current mining activities, and it is understood that it will be rehabilitated to its original condition in accordance with an Environmental Management Plan once mining has ended.

Photographs of the sites are presented in Appendix C of this report.

5. GEOLOGY

According to the 1:250 000 geological series map, the area is largely underlain by red aeolian sand of the Koekenaap Formation. The eastern corner of the overburden facility, however, is shown to be underlain by pale red and red dune sands of the Hardevlei Formation.

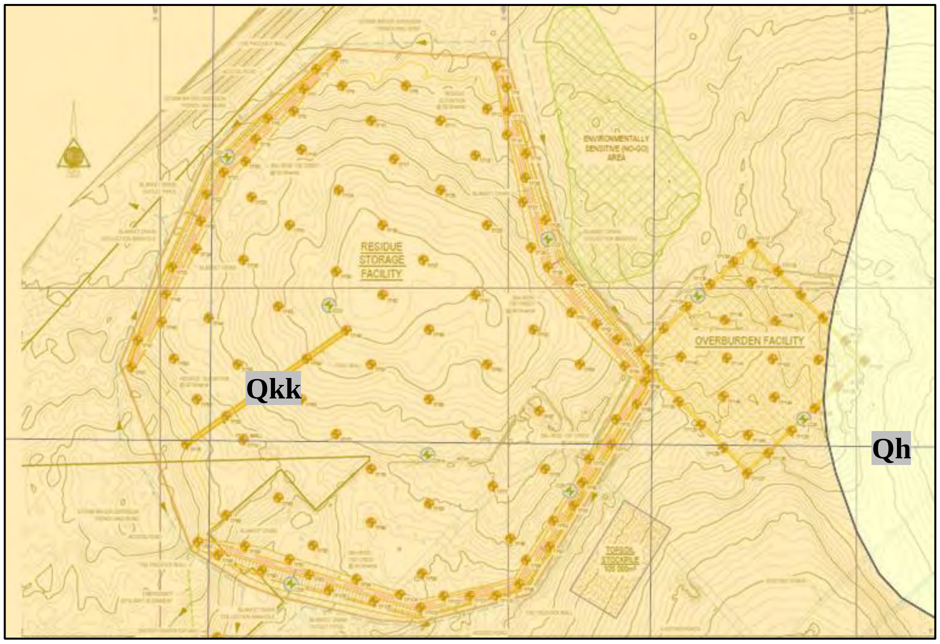

Figure 5.1: Surface geology in the region (from 1:250 000 Geological series).
Qkk = Koekenaap Formation, Qh = Hardevlei Formation

6. GROUND CONDITIONS

6.1 Subsoils

The subsoil conditions within each of the sites are described below and are characterized by very loose dune sand and sand tailings fill, overlying a relatively dense silty sand of aeolian provenance to an average depth of about 2,0 m in the range of 0,2 to 3,5 m. Most of the pits were profiled from the surface as both the dune sand and the sand tailings are very loose and sidewalls of most of the pits collapsed. The detailed soil profiles are attached to this report as Appendix D and summaries of the test pit profiles for each site are also attached with these. The photographs of the pits are contained in Appendix E.

The boreholes drilled within the sites show the aeolian horizon to extend to depths mostly in excess of 20,0 m. Borehole logs and photographs are contained in Appendix F and G respectively.

6.1.1 RSF

The subsoil conditions within the RSF site are represented by 82 test pits excavated along its wall and within its basin. They are characterised by dune sand, in the unmined area, and sand tailings fill in the rehabilitated area that was previously mined along the southern boundary of the RSF. These soils are almost identical and of very loose consistency.

In most of the largely unmined area very loose dune sand overlies silty sand of aeolian origin at an average depth of 2,0 m ranging from 0,9 to 3,3 m below the present ground surface. The aeolian comprises mainly medium dense to dense and in places loose silty sand with scattered friable weakly cemented pockets. The aeolian sand extends to the bottom of most of the holes at depths of about 3,0 m and, in places, the TLB partially refused on very dense aeolian sand and very occasional very soft rock hardpan dorbank.

Boreholes NRSF01, NRSF06 to NRSF08 drilled within the unmined area show the aeolian horizon to extend to depths mostly in excess of 20,0 m. The Standard Penetration Tests (SPT) carried out on the subsoils to depths of up to between about 2,0 to 3,5 m yielded N values of 20 to 32, which suggests that their consistency is medium dense. Below these depths, the SPT N value recorded mainly above 50 or refused, indicating that the soils are very dense and comprise cemented sand and very soft rock in places.

Borehole NRSF06, at a depth of 17,7 to 20,1 m, encountered a soil horizon resembling the residual schist comprising a clayey silt with very stiff to very soft rock.

In the rehabilitated area, very loose fill covers the site to a depth of between 1,1 to 3,2 m where it generally extends to the bottom of the pits or is underlain by loose aeolian and very occasionally moderately cemented very dense sand and very soft rock gneiss.

Boreholes NRSF02 and NRSF05 drilled along the southern wall of the RSF and within the rehabilitated area, show the fill, together with the underlying aeolian sand, to extend to depths of between 4,5 and 12 m where they are underlain by either very soft rock dorbank or completely weathered granite gneiss.

The Standard Penetration Tests (SPT) carried out in soils within the rehabilitated area to depths of up to 3,5 m yielded N values of 9 to 17 which suggests that their consistency is loose to medium dense.

At a depth of about 4,5 m, the SPT in borehole NRSF02 refused, signifying the presence of very dense or very stiff to very soft rock horizons below this depth and extending to 20,0 m. These comprise very soft to soft rock dorbank overlying very stiff to very soft rock completely to highly weathered limestone at about 10,0 m.

In borehole NRSF05, the aeolian becomes dense and very dense below depths of 7,5 m and 9,0 m with N values of 39 and 69 to 75 respectively.
Below a depth of 12,0 m and extending to the bottom of the hole at 20,0 m, completely weathered granite gneiss occurs. It comprises very dense to very soft rock and relict jointed silty sand with clayey sandy silt below 16,5 m.

6.1.2 Overburden facility

The area of the overburden facility is currently being mined and as a result, the subsoil conditions are variable where materials such as fill, dune sand and the exposed aeolian and granular and hardpan dorbank are encountered on the surface and extend to variable depths.

Dorbank hardpan with dorbank cobbles, small boulders and gravel occur in places within most of the areas where the dune sand has been mined, it is at least dense in consistency and, mostly along the north-eastern boundary of the site, it comprises very soft rock on which the TLB refused at shallow depths of 0,4 m.

Boreholes NRSF03 and CD-08 drilled within the area also show the aeolian horizon to extend to depths in excess of 20,0 m. The Standard Penetration Tests (SPT) carried out in the fill or dune sand which covers the site yielded N values of 3 to 16 to depths of up to 3,5 m. This suggests that the consistency of the soil is loose to medium dense. Below this depth, the SPT N values recorded mainly above 20 and 50 in borehole NRSF03 and CD-08, indicating that the soil is medium dense and very dense to very soft rock respectively.

6.2 Groundwater

No groundwater was encountered in any of the pits excavated within the sites. Piezometers were installed in some of the boreholes and to date, the water levels have not been measured in them. It is, however, expected that the groundwater levels be significantly deeper than 10 m, based on the drilling water levels dropping in the boreholes after each drilling shift, as indicated in the driller’s report.

7. LABORATORY TESTING

Disturbed and undisturbed samples were recovered from the underlying soil horizons and a range of tests were carried out on them to assess their engineering characteristics. The tests were undertaken to TMH, SANS and ASTM specifications and the results are presented in Appendix H and discussed in more detail below.

7.1 Indicator Tests

To more accurately identify and classify the soil horizons encountered, particle size distribution analysis and Atterberg limit determinations were carried out on the samples of the dune sand, aeolian and tailings fill which covers the sites.

Except for the aeolian encountered in TP146 at the overburden facility, it is evident from the test results that the fill, dune sand and aeolian underlying the RSF and Overburden Facility are uniformly non-plastic or slightly plastic, denoted as “NP” or “SP” respectively. The aeolian in test pit TP146 has a weighted plasticity index of 4, which also suggest that it is of low expansive potential according to the method of Van der Merwe(4)

All of the soils tested comprises predominantly of sand fraction, which comprises 87 to 99 % of the total sample mass, with the balance made up of silt and clay fractions. Their grading moduli of about 1,0 is indicative of a fine to medium-grained soil.

According to the AASHTO classification system(5), the fill and dune sand belong to the A-3 soil group, which is described as fine sand. The Unified Soil Classification System(USCS)(6) groups them as “SP” which is poorly graded sand.

The underlying aeolian sand classifies as an A-3 and occasionally as an A-2-4 soil type these being fine sand and silty sand respectively. The USCS classify it as an SP, SP-SM and occasional SM soil types, these being poorly graded sand, poorly graded sand with silt and silty sand respectively.

A soil sample was also taken from a borrow pit located within the basin of the RSF. This is a potential source of borrow material within the basin of the RSF which can be used to construct the starter walls. The soil classifies as A-4 and SM soil types which are silty soil or silty sand in accordance with the AASHTO and USCS classifications respectively.

Table 7.1: Summary of indicator tests

Test pit no.	Depth (m)	Soil Description	LL	PI	PI$_{ws}$	LS	GM	MIT Size Fraction - %				Classification	
								Gravel	Sand	Silt	Clay	AASHTO	USCS
Residue Storage Facility (RSF)													
TP20	1.4 - 1.8	Aeolian - Silty sand		NP		0	1.1	0	99	0	1	A3	SP
TP27	1.2 - 1.5	Aeolian - Silty sand		SP		1.2	1.0	0	99	0	1	A3	SP
TP45	1.3 - 1.8	Aeolian - Silty sand		SP		1.1	1.1	0	99	0	1	A3	SP
TP56	1.8 - 3.0	Aeolian - Silty sand		NP		0	1.0	0	92	2	6	A3	SP-SM
TP57	0.3 - 1.8	Dune/Aeolian - Sand		NP		0	1.0	0	98	0	2	A3	SP
TP64	1.7 - 2.0	Aeolian - Silty sand		NP		0	1.0	0	95	1	4	A3	SP-SM
TP87	1.6 - 1.85	Aeolian - Silty sand		NP		0	0.9	0	94	1	5	A3	SP-SM
TP91	0.5 - 3.0	Fill - Sand		NP		0	1.0	0	99	0	1	A3	SP
Borrow Pit		Residual granite gneiss - Cemented silty sand	27	9	7	4.6	0.9	3	62	20	15	A-4	SM
Overburden Stockpile Facility													
TP133	2.0 - 2.3	Aeolian - Silty sand		NP		0	1.0	0	98	0	2	A3	SP
TP138	1.9 - 2.2	Aeolian - Silty sand		NP		0	1.0	0	98	0	2	A3	SP
TP146	0.6 - 3.0	Aeolian - Silty sand	25	4	4	2	0.9	0	87	6	7	A-2-4	SM

LL = liquid limit; PI = plasticity index; LS = linear shrinkage; GM = grading modulus, USCS = Unified Soil Classification System, AASHTO = American Association of State Highway and Transportation Officials

Table 7.2: Summary of results of compaction tests (Standard Proctor)

Site	Test pit no.	Depth (m)	Soil Type	MDD (kg/m^3)	omc (%)
RSF	TP56	1.8 - 3.0	Aeolian - Silty sand	1837	7.8
	TP57	0.3 - 1.8	Dune/Aeolian - Sand	1667	8.7
	TP91	0.5 - 3.0	Fill - Sand	1668	8.6
	Borrow Pit		Residual granite gneiss - Cemented silty sand	1856	8.2

MDD = maximum standard Proctor dry density; omc = optimum moisture content.

Table 7.3: Summary of slow drained shear box tests

Sample Type	Site	Test pit no.	Depth (m)	Soil Description	Dry density (kg/m^3)	Moisture Content (%)	Cohesion c' (kPa)	Angle of friction φ' (degrees)
Undisturbed	RSF	TP20	1.4 - 1.8	Aeolian - Silty sand	1778	7	15	41
		TP27	1.2 - 1.5	Aeolian - Silty sand	1791	6	6	41
		TP45	1.3 - 1.8	Aeolian - Silty sand	1710	6	3	39
		TP87	1.6 - 1.85	Aeolian - Silty sand	1612	9	0	35
	Overburden Facility	TP133	2.0 - 2.3	Aeolian - Silty sand	1725	5	4	39
		TP138	1.9 - 2.2	Aeolian - Silty sand	1805	10	13	43
Remoulded	RSF	TP56	1.8 - 3.0	Aeolian - Silty sand	1819	8	12	43
		TP57	0.3 - 1.8	Dune/Aeolian - Sand	1640	8	3	40
		TP91	0.5 - 3.0	Fill - Sand	1637	9	2	43
		Borrow Pit		Residual granite gneiss - Cemented silty sand	1843	33	6	41

Figure 7.1: Shear Box Tests (all undisturbed and remoulded samples)

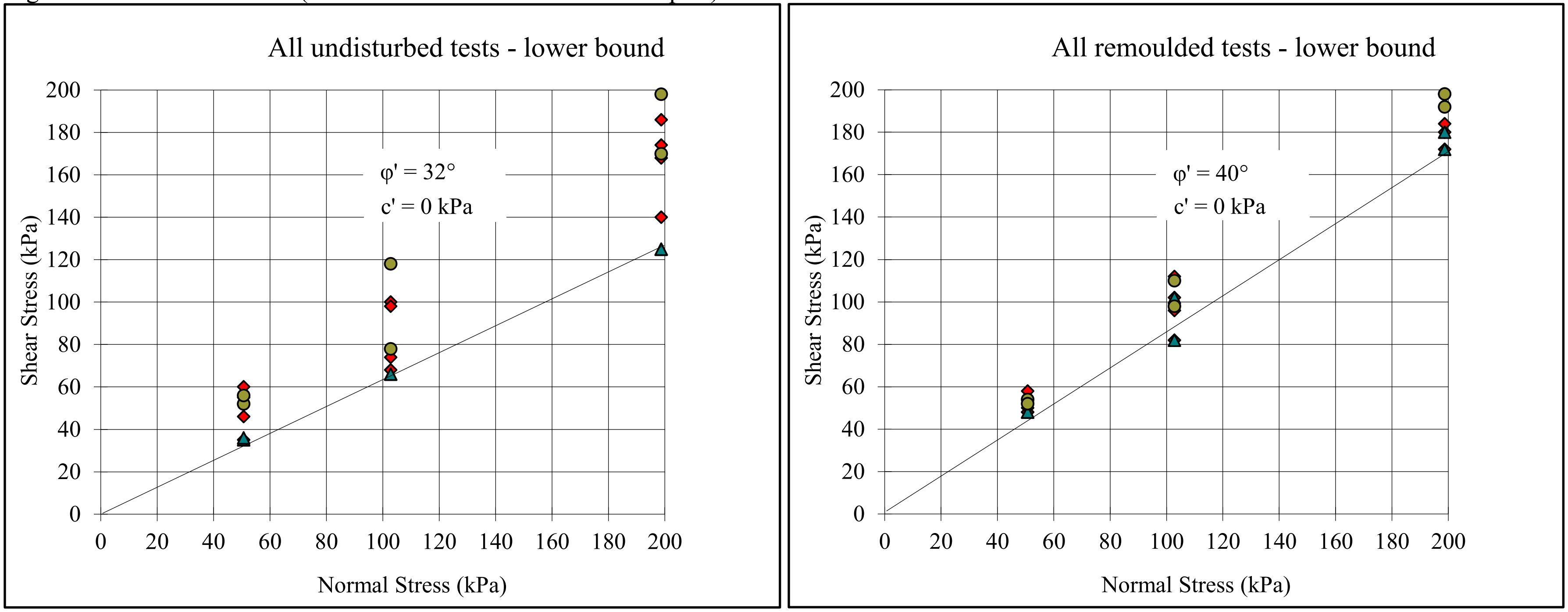

Table 7.4: Coefficient of permeability

Sample Type	Site	Test pit no.	Depth (m)	Soil Type	Moisture Content (%)	Dry Density ρ_d (kg/m^3)	Coefficient of Permeability k (m/sec)
Undisturbed	RSF	TP20	1.4 - 1.8	Aeolian - Silty sand	4.9	2007	7.99×10^{-7}
		TP27	1.2 - 1.5	Aeolian - Silty sand	6.9	1584	2.85×10^{-8}
		TP45	1.3 - 1.8	Aeolian - Silty sand	5.2	1558	5.34×10^{-6}
		TP64	1.7 - 2.0	Aeolian - Silty sand	7.3	1658	9.48×10^{-7}
		TP87	1.6 - 1.85	Aeolian - Silty sand	13.5	1613	3.03×10^{-7}
	Overburden Stockpile Facility	TP133	2.0 - 2.3	Aeolian - Silty sand	5.0	1680	3.78×10^{-7}
		TP138	1.9 - 2.2	Aeolian - Silty sand	8.2	1850	9.47×10^{-7}
Remoulded to 98% Proctor	RSF	TP56	1.8 - 3.0	Aeolian - Silty sand	7.8	1800	3.80×10^{-6}
		TP57	0.3 - 1.8	Dune/Aeolian - Sand	8.7	1634	4.65×10^{-5}
		TP91	0.5 - 3.0	Fill - Sand	8.6	1634	2.15×10^{-5}
		Borrow Pit		Residual granite gneiss - Cemented silty sand	8.2	1819	9.38×10^{-8}

Table 7.5: Summary of results of collapse tests

Sample Type	Site	Test pit no.	Depth (m)	Soil Type	ρ_d (kg/m^3)	S_r (%)	nmc %	Collapse % at 200 kPa
Undisturbed	RSF	TP45	1.3 - 1.8	Aeolian - Silty sand	1769	33	6.26	1.63
		TP87	1.6 - 1.85	Aeolian - Silty sand	1605	33	8.01	6.92

ρ_d = dry density; S_r = degree of saturation; nmc = natural moisture content;

Table 7.6: Summary of consolidation tests

Site	Test pit no.	Depth (m)	Soil description	ρ_d kg/m^3	S_r %	P_0 kN/m^2	P_c kN/m^2	C_c	C_r	M_E (MPa)	
										P_0 - 100 kPa	P_0 - 200 kPa
RSF	TP64	1.7 - 2.0	Aeolian - Silty sand	1696	28	30	70	0.056	0.007	5	7
Overburden Stockpile Facility	TP133	2.0 - 2.3	Aeolian - Silty sand	1719	29	35	50	0.033	0.007	9	12
	TP138	1.9 - 2.2	Aeolian - Silty sand	1831	62	40	100	0.045	0.007	11	14

ρ_d = dry density; Sr = degree of saturation; P_0 = overburden pressure; Pc = preconsolidation pressure; Cc = virgin compression index; Cr = recompression index; ME = constrained modulus

7.2 Compaction Tests

Proctor compaction tests were carried out on representative samples of the fill, dune sand, aeolian and residual gneiss, and the results are summarized in Table 7.2 above. The purpose of the tests was to obtain appropriate dry density estimates for remoulding samples in the triaxial and shear box apparatuses for determining permeabilities and shear strength parameters.

7.3 Shear Strength Tests

Slow drained shear box tests were carried out on undisturbed samples of the aeolian and remoulded samples of the fill, dune sand, aeolian, and residual gneiss. The latter were prepared by remoulding specimens to 98% of the Proctor maximum dry density and optimum moisture content. Normal stresses of 50, 100 and 200 kPa approximately, were applied to each of the test specimens and the results are summarised in Table 7.3 and Figure 7.1 above.

7.4 Permeability Tests

The permeability of both undisturbed and remoulded samples of the selected soil horizons was determined in the flexible wall triaxial cell. The remoulded samples were prepared to approximately 98 % of their Proctor maximum and at optimum moisture content. The results of the permeability tests are summarised in Table 7.4 above.

7.5 Collapse Potential Tests

Collapse tests were carried out on undisturbed block samples of the aeolian. The results are summarised in Table 7.5. At collapse stress of 200 kPa the corresponding strains have been estimated to be between 1,63 and 6,92 % which according to Jennings and Knight(7) is material which may exhibit “moderate problems” to “problems”, should structures be placed within it and without some form of prior treatment or precautionary measures being carried out.

7.6 Consolidation Tests

Undisturbed block samples of the aeolian were recovered from the RSF and overburden facility and saturated consolidometer tests were carried out on them. The results are summarised in Table 7.6 above. The constrained modulus for the aeolian, ranging from overburden pressure to 100 and 200 kPa measured between 5,0 MPa and 14,0 MPa. The low constrained modulus of the soil indicates that it is compressible.

8. DISCUSSION ON MATERIAL PROPERTIES

In preparing the recommendations presented below, the following assumptions and inferences have been made to estimate the soil properties required for the design of the facilities.

8.1 Strength Parameters

The sieve analyses and Atterberg limits have classified the fill and dune sand as “SP” soil type, the aeolian as “SP” and “SP-SM” soil types and residual gneiss as “SM” soil type according to the Unified Soil

Classification system. An order of magnitude of typical shear strength parameters for normally consolidated soils with these classifications, based on Kenney(8) and Navfac DM7(9) is φ' = 30 to 42 degrees and c' = 0 to 5 kPa.

With the friction angle of between φ' = 31 and 44 degrees and cohesion of 0 to 15 kPa, the results of shear box test carried out on all undisturbed and remoulded samples generally agrees with the type of material tested, however, the cohesion of up to 15 kPa is considered to be uncharacteristically high. On the other hand, friction angles at between 31 and 44 degrees are considered reasonable.

The in-situ density of the aeolian ranges from 1558 to 1805 kg/m^3 and improves to between 1752 to 1837 kg/m^3 when compacted to approximately 98 % of their Proctor maximum and at optimum moisture content.

Similar tests and comparisons could not be made for the fill and dune sand since undisturbed samples could not be taken from the sidewalls of the test pits due to their very loose nature. Their densities after remoulding specimens to 98 % of the Proctor maximum dry density and optimum moisture content ranges from 1634 to 1648 kg/m^3.

The in-situ consistency of both the fill and dune sand is very loose and typical shear strength parameters for a quick draining non-cohesive material as indicated in Table 3.3.5 of the Franki book (10) are 26 to 28 degrees for the effective friction angle and less than 1450 kg/m^3 for dry density.

8.2 Permeability

The results of the permeability tests are summarised in Table 7.4 above and record permeability coefficients of mainly 10^{-7} m/sec for the undisturbed aeolian, which agrees with the "SM" soil type. It should be noted that the in-situ permeability of the fill and dune sand, which cover the sites, was not determined, since undisturbed samples could not be taken from the sidewalls of the test pits due to their very loose nature. Using the Hazen's method(11) the in-situ permeability of these very loose soils is estimated to be of the order of 10^{-4} m/sec.

The permeability coefficient of the remoulded fill, dune sand and aeolian measured about 10^{-5} m/sec which is fairly typical of the "SP" to "SP-SM" soil type tested.

The permeability of the remoulded aeolian samples at 10^{-5} to 10^{-6} m/sec is unexpectedly higher than that of the undisturbed samples at 10^{-7} m/sec. This is probably influenced by the cemented nature of the undisturbed soil.

The permeability coefficient of the remoulded sample of the residual gneiss from the borrow pit measured 10^{-8} m/sec which is typical of an "SM" soil type.

8.3 Design Parameters

Given the above, for design purposes, the following shear strength parameters and coefficients of permeability are considered appropriate for the in-situ and remoulded soil types encountered within the sites.

Table 8.1: Soil engineering parameters for design

Soil Horizon	Layer thickness (m)	USCS	φ’ (degrees)	c’ (kN/m^2)	ρ_d (kg/m^3)	k (m/sec)
Fill & dune sand (very loose in-situ)	3.5	SP	28	0	1400	10^{-4}
As above but compacted to 98 % Proctor		SP	35	0	1600	10^{-5}
Aeolian– silty sand (medium dense and weakly cemented in places)	3.5	SP/ SP-SM	32	0	1600	10^{-6}
As above but compacted to 98 % Proctor		SP/ SP-SM	37	0	1800	10^{-5}
Weakly cemented aeolian, residual, weak dorbank (Very dense to very soft rock)	15	SP/ SP-SM	40	0	1900	10^{-7}

φ’ = effective friction angle; c’ = effective cohesion; ρ_d = dry density; k = coefficient of permeability.

9. SUMMARY AND RECOMMENDATIONS

9.1 Subsoil Conditions

The sites of the RSF and overburden facility are blanketed by dune and fill sand, aeolian silty sand and occasional dorbank cobbles and boulders and hardpan, as shown in the test pit summary in Appendix D. The majority of the boreholes show that the aeolian extends to depths of more than 20,0 m below surface, with sporadic completely to highly weathered gneiss, limestone and dorbank occurring in places below depths of between 4,5 m and 17,7 m.

9.2 Construction of RSF Walls

Walls of the RSF will be built from sand tailings transported from the PCP East by conveyors or trucks. It is understood that no conventional compaction will be undertaken during construction of the RSF wall, and will only take place under traffic loading during construction, and under the self-weight of the sand as the wall height increases. Under such conditions, where the consistency of the soil may improve slightly, a friction angle of 30 degrees and dry density of 1500 kg/m^3 is considered to be appropriate for the fill material.

The SPT tests carried on the subsoils covering the site show their consistency to be loose to medium dense and medium dense up to depths of about 3,5 and 7,0 m. Below depths of about 7,0 m, the SPT tests generally yielded N values of greater than 50 indicating the that the subsoils comprise very dense or very stiff to very soft rock material.

Based on the above, and for design purposes, the thicknesses of various soil horizons beneath the wall were determined and are summarised in Table 8.1 above.

9.3 Stockpile on Overburden Facility

A 6 m high RAS tailings will be stored at the overburden facility. No major stability or settlement issues are anticipated should the tailings be placed on the fairly competent medium dense aeolian sand or very soft rock dorbank covering the site. It is understood that the RAS horizon will be mined in this area which will expose the aeolian and dorbank on which the RAS tailings will be deposited.

9.4 Collapse Potential

The aeolian sand exhibits a collapse potential of 1,6 to 6,9 % which suggest that it may cause “moderate problems” to “problems”, should structures be placed within it and without some form of prior treatment or precautionary measures being carried out.

The dune sand horizon overlying the aeolian may also be collapsible, however, due to its very loose nature, block samples to test for collapse potential could not be taken. Should these horizons be loaded and subsequently become saturated, substantial differential settlement of the subsoils are likely. Although collapse settlement may not affect the dams themselves due to their inherent flexibility, the effects of collapse settlement should be taken into consideration in the design of structures associated with the operation of RSF. These may include pump stations and plinths and anchor blocks for tailings delivery and return water pipe columns.

9.5 Excavatability

No major difficulties in excavating within the basin and around the perimeter of the RSF are envisaged to a depth of 5,0 m, however, cognisance should be taken of refusal which may occur sporadically on very soft rock gneiss and dorbank at depths as shallow as 1,5 m below the present ground surface.

9.6 Groundwater

No groundwater was encountered in any of the pits excavated within the sites. Piezometers were installed in some of the boreholes and to date, they have not been measured. It is, however, expected that the groundwater levels be significantly deeper than 10 m based on how the drilling water levels dropped in the boreholes after every drilling shift.

Moruti Shuping B.Sc. Honours – Geotech
for Inroads Consulting cc

Brian Harrison Pr Eng
for Inroads Consulting cc

APPENDIX A

References

Ref	Title	Author	Publisher	Year
1	1:250 000 Geological Series,	The Chief Director Geological Survey	The Government Printer, Pretoria, South Africa	
2	Engineering Geology of Southern Africa. Volume 4.	Brink A. B. A.	Building Publications, South Africa.	1985
3	Guidelines for Soil and Rock Logging in South Africa.	Brink A. B. A. Bruin R. M. H.	Association of Engineering Geologists South Africa Section. South African Institution of Civil Engineers. South African Institute of Engineering Geologists.	2002
4	The Prediction of Heave from the Plasticity Index and Percentage Clay Fraction.	Van der Merwe D.H.	Trans. S.A. Ins. Civ. Eng. No. 6,	1964
5	AASHTO – Classification of Soils and Soil-Aggregate Mixtures	AASHTO	AASHTO Designation M-145	1970
6	Unified Soil Classification System for Engineering Purposes.	ASTM	ASTM Designation D-2487	1967
7	A guide to construction on or with materials exhibiting additional settlement due to collapse of grain structure.	Jennings J.E. & Knight K.	Proceedings, 6th Regional Conference for Africa SM and FE. Durban.	1975
8	Discussion.	Kenney T. C.	Proceedings, ASCE, Vol. 85, No. SM3, 67-69.	1959
9	Soil Mechanics, Foundation and Earth Structures, Design Manual DM7	NAVFAC	Naval Facilities Engineering Command, Alexandria, Va	1971
10	A Guide to Practical Geotechnical Engineering in Southern Africa, Fourth Edition	Byrne G. & Berry A.D.	Franki	2008
11	Craig's Soil Mechanics, Seventh Edition	Craig R.F.	Spon Press	2004

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APPENDIX B

Site Plan

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2041

16 Devon Place
Longmeadow Business Estate
1609

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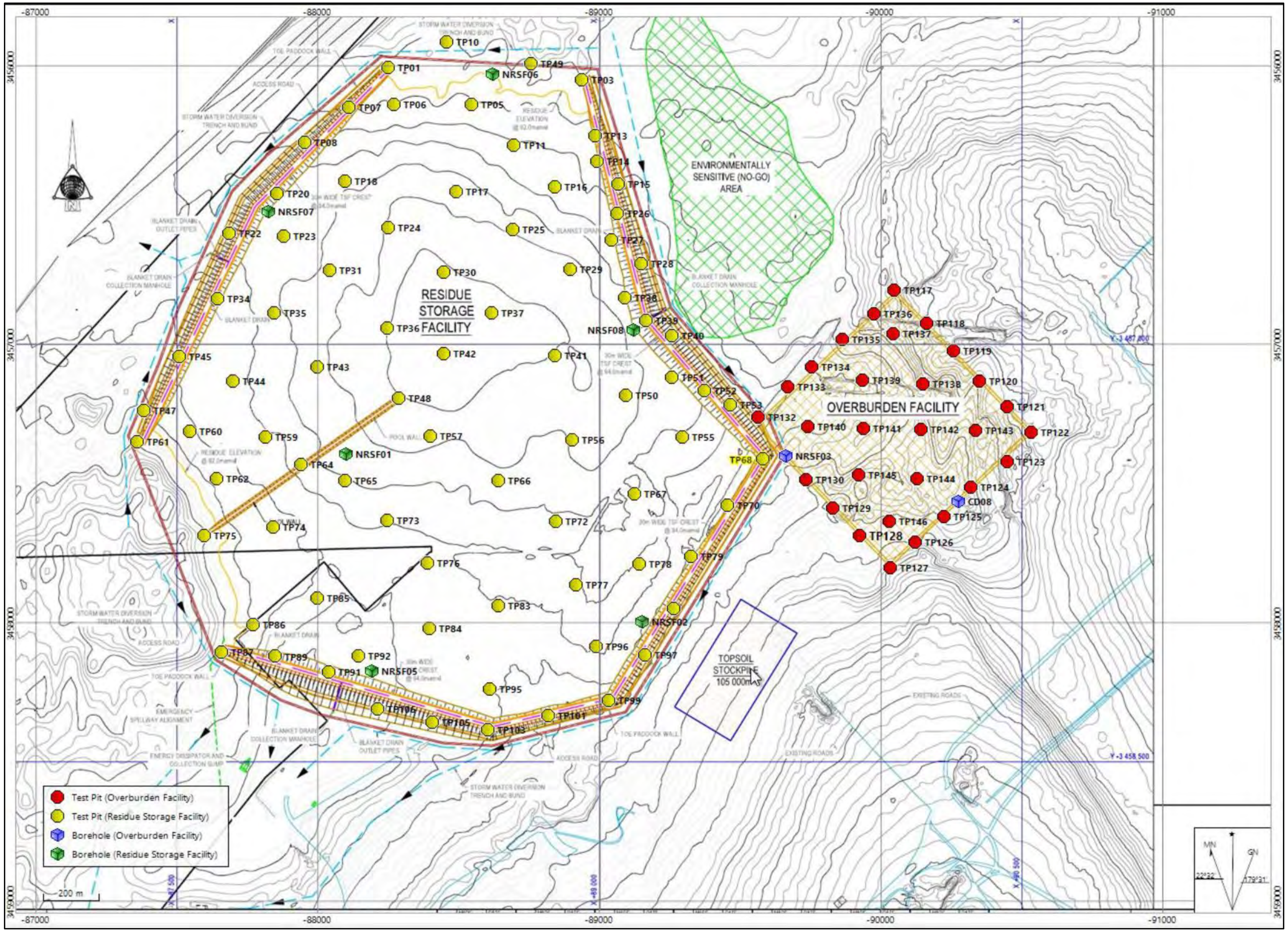

Ref: 2027 g	**EPOCH RESOURCES (PTY) LTD**	**DRAWING 1**
	NAMAKWA SANDS RSF & OVERBURDEN FACILITY	
	SITE PLAN SHOWING POSITIONS OF TEST PITS & BOREHOLES	

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APPENDIX C

Photographic Record

PHOTOGRAPHIC RECORD

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

1

Comments: View of RSF site from near TP03 looking south-west

PHOTOGRAPH

2

Comments: View of RSF site from near TP47 looking east

PHOTOGRAPHIC RECORD

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

3

Comments: Borrow pit site

PHOTOGRAPH

4

Comments: View of the rehabilitated area of RSF site from near TP103 looking north-west

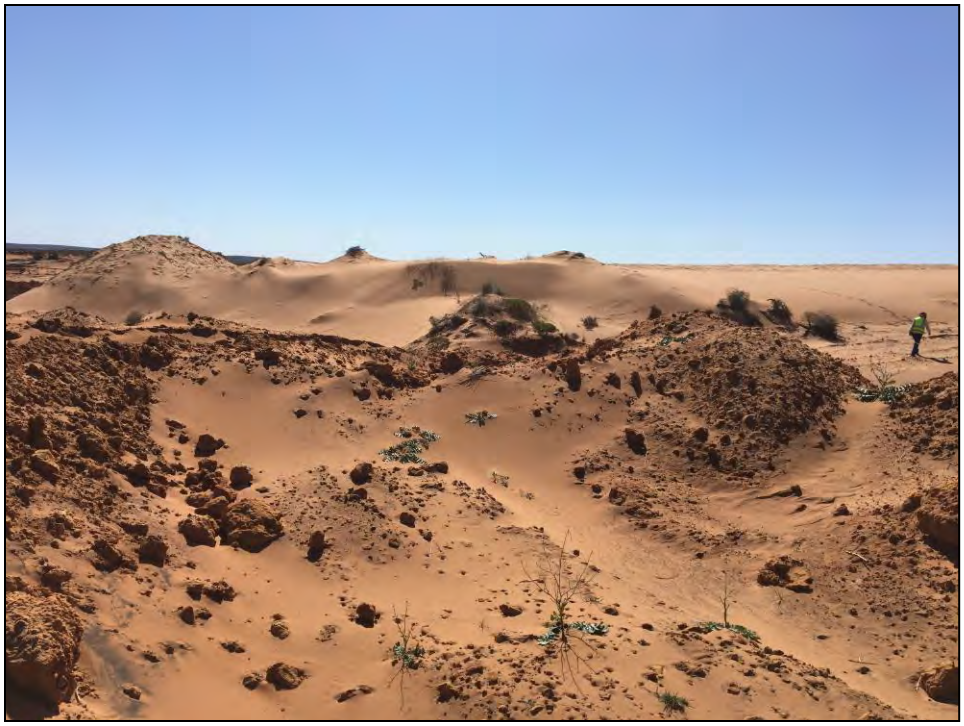
PHOTOGRAPHIC RECORD	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **5**	
Comments: View of Overburden site from TP145 looking north-east	
PHOTOGRAPH **6**	
Comments: View of Overburden site from TP141 looking south-west	

PHOTOGRAPHIC RECORD

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

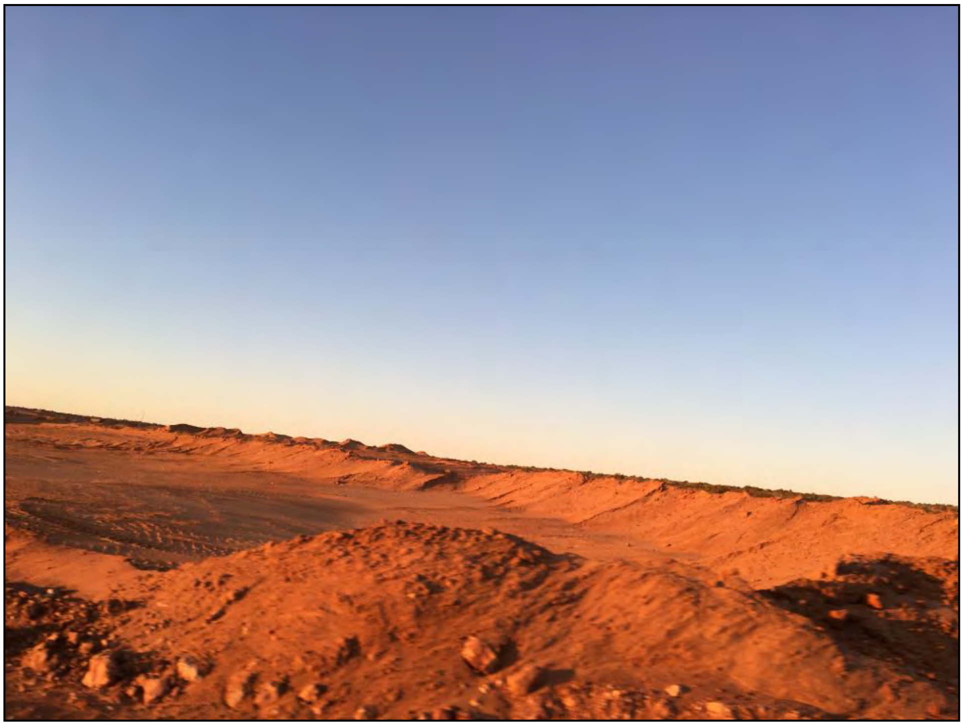
7



Comments: View of Overburden site from TP138 looking north-west

PHOTOGRAPH

8



Comments: View of Overburden site from TP125 looking north

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APPENDIX D

Soil Profiles

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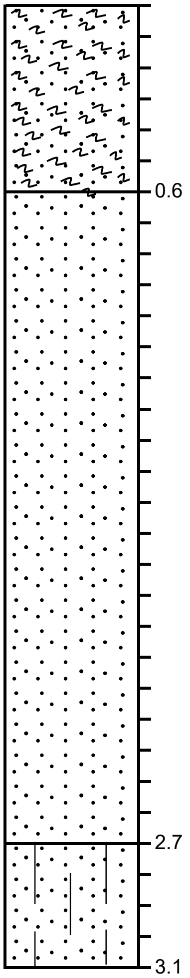
PROFILE SHEET

TP01

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456007
Y -088251



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND with scattered roots. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be medium dense, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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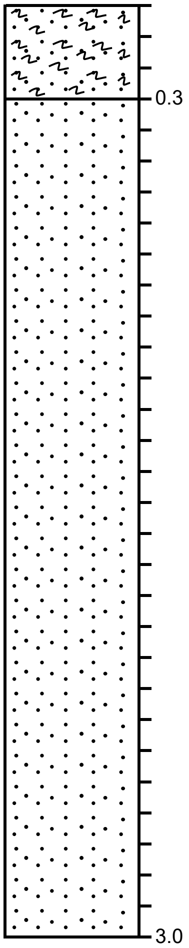
PROFILE SHEET

TP03

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456052
Y -088939



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole positioned on top of dune.
2. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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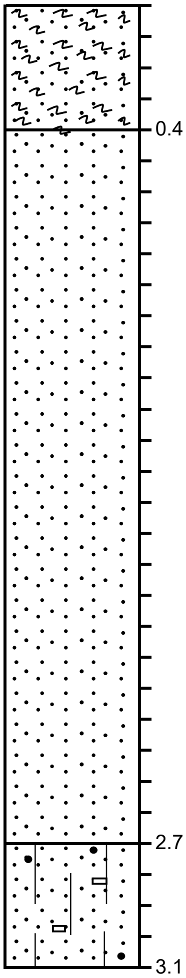
PROFILE SHEET

TP05

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456142
Y -088546



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose.</u>

Moist, yellow brown, appears to be <u>loose</u>, SILTY SAND. *Aeolian.*
Becomes <u>medium dense</u> with depth and contains friable coarse nodules.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
   Hole located on top of dune.
2. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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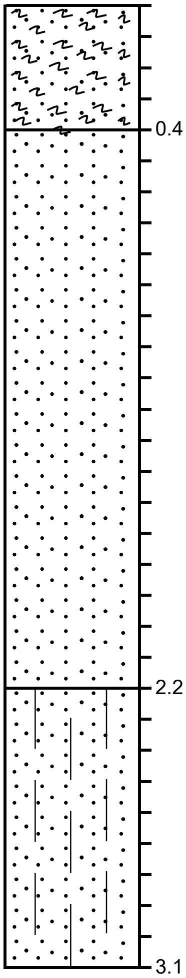
PROFILE SHEET

TP06

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456143
Y -088272



Moist, light brown, silty SAND with abundant large roots. *Aeolian/Dune.*

Appears very loose.

0.4

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

2.2

Slightly moist, yellow brown, appears to be medium dense, SILTY SAND with pockets of weakly cemented silty sand. *Aeolian.*

3.1

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal. Hole located on top of dune.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

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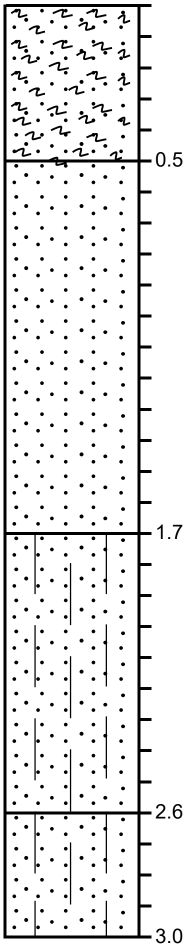
PROFILE SHEET

TP07

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456151
Y -088111



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND with scattered roots. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be medium dense, SILTY SAND. *Aeolian.*

Moist, orange brown mottled light brown, appears to be dense, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole position at top of dune.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B
Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
Ɪ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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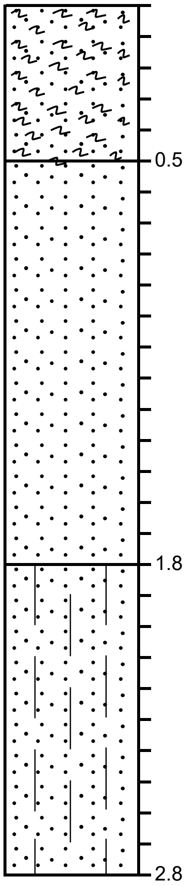
PROFILE SHEET

TP08

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456277
Y -087956



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be dense, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

Becoming very dense below 2,5 m.

NOTES:
1. Bottom of hole at 2,8 m. Partial refusal on very dense sand.
   Hole profiled from outside due to sidewall collapse.
   Hole positioned on dune slope.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	├┤ *In-situ* test

Ref: 2027/g
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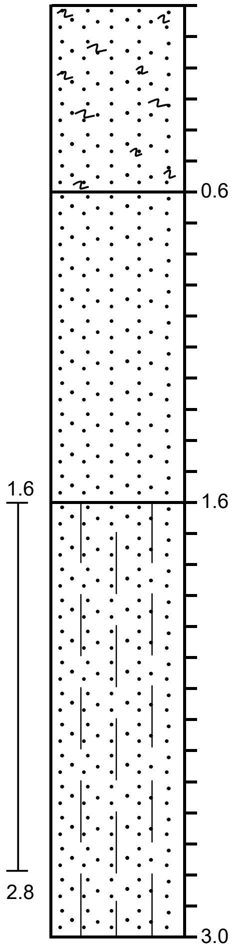
PROFILE SHEET

TP10

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3455916
Y -088459



Moist, light brown, silty SAND with few roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown mottled khaki below 2,8 m, appears dense, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,6 to 2,8 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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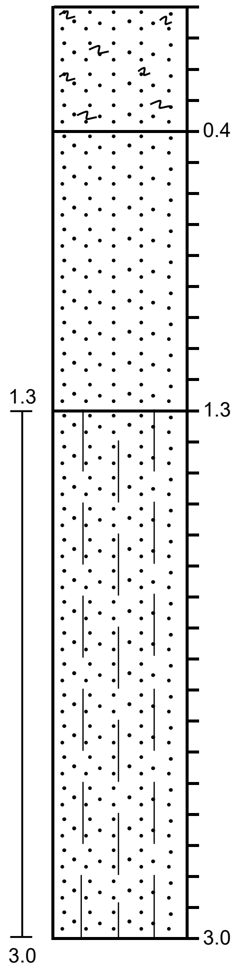
PROFILE SHEET

TP11

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456288
Y -088698



Moist, light brown, silty SAND with few roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, yellow brown, appears to be medium dense, SILTY SAND with friable nodules and pockets of weakly cemented silty sand. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,3 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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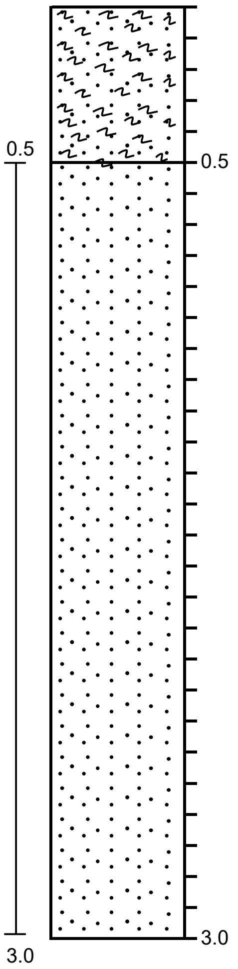
PROFILE SHEET

TP13

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456252
Y -088967



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole positioned on top of dune.
2. Bulk sample taken from 0,5 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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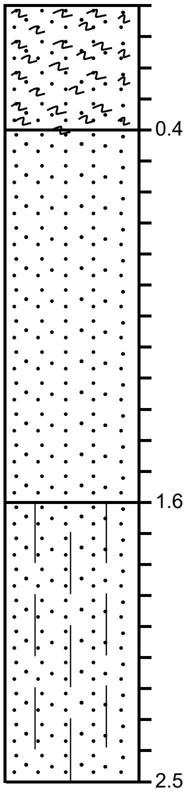
PROFILE SHEET

TP14

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456345
Y -088991



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears dense, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 2,5 m. Partial refusal on very dense sand.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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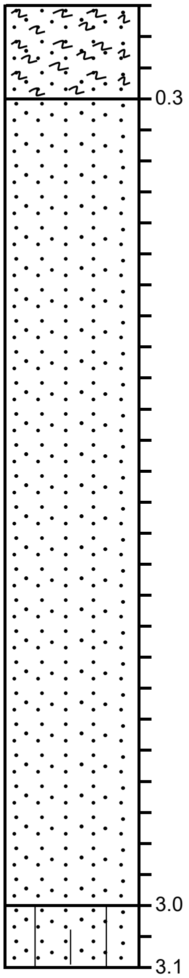
PROFILE SHEET

TP15

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456427
Y -089066



0.3 m: Moist, light brown, silty SAND with minor roots. *Aeolian/Dune.* Appears very loose.

0.3–3.0 m: Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

3.0–3.1 m: Moist, orange brown, appears dense, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,1 m. Partial refusal on very dense sand.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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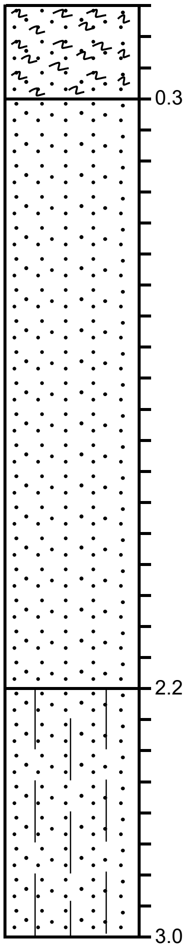
PROFILE SHEET

TP16

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456437
Y -088845



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND with scattered roots to 1,0 m. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B
Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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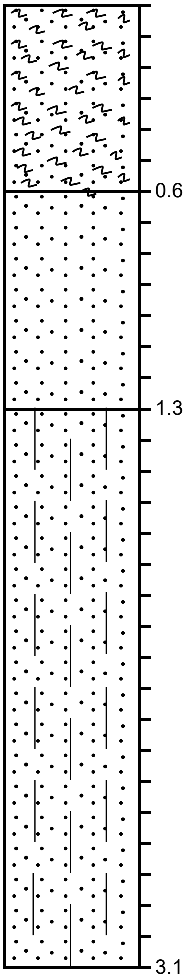
PROFILE SHEET

TP17

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456455
Y -088494



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be medium dense, SILTY SAND with scattered friable nodules. A*eolian.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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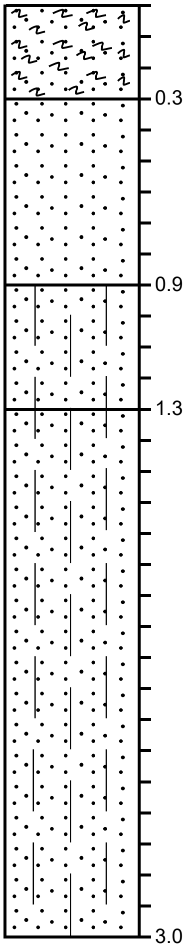
Houghton	***Fax: (011) 443 2951***
2041	***e-mail: admin@inroads-sa.co.za***

PROFILE SHEET

TP18

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456418
Y -088093



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist to very moist, dark brown, appears to be loose to medium dense, SILTY SAND. *Aeolian.*

Moist, yellow brown, appears to be medium dense, pinholed, (weakly cemented?) SILTY SAND. *Aeolian.*

Appears to become dense below 2,3 m.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	├┤ *In-situ* test

Ref: 2027/g

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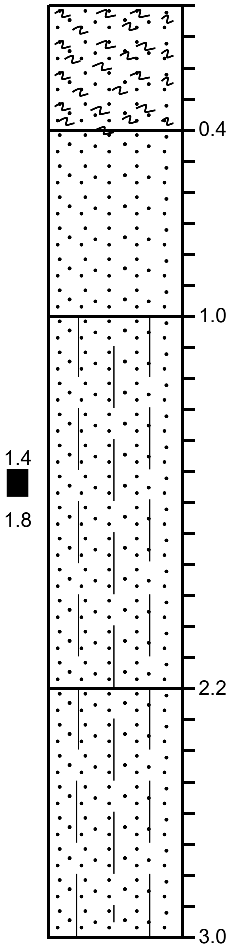
PROFILE SHEET

TP20

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456462
Y -087858



Moist, light brown, <u>very loose</u>, silty SAND with abundant roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, <u>very loose</u>, silty SAND with scattered fine roots. *Aeolian/Dune.*

Moist to moist dark brown becoming light orange brown below 1,4 m, <u>medium dense</u> becoming <u>dense</u> below 1,4 m, pinholed, very weakly cemented SILT SAND. *Aeolian.*

Moist, yellow brown, appears to be <u>dense</u>, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Partial refusal on <u>dense</u> sand.
   Hole profiled to 2,0 m. Profiled from outside below 2,0 m.
2. Undisturbed sample taken from 1,4 to 1,8 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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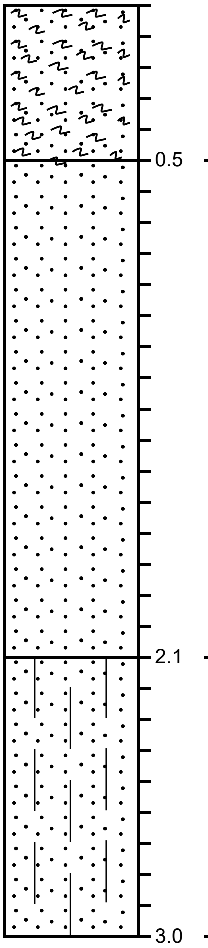
PROFILE SHEET

TP22

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456603
Y -087688



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be medium dense to dense, SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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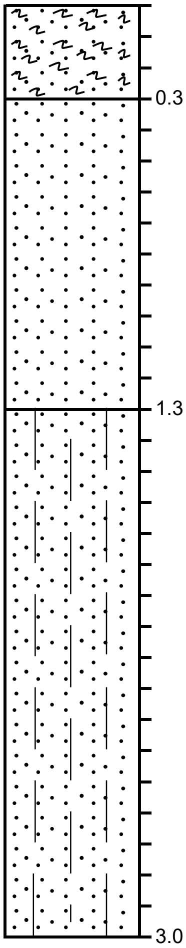
PROFILE SHEET

TP23

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456616
Y -087881



Depth (m)	Description
0.0 – 0.3	Moist, orange brown, silty SAND with abundant roots. *Aeolian/Dune.* Appears <u>very loose</u>.
0.3 – 1.3	Moist becoming slightly moist with depth, orange brown, silty SAND. *Aeolian/Dune.* Appears <u>very loose</u>.
1.3 – 3.0	Slightly moist, yellow brown mottled khaki, appears to be <u>loose to medium dense</u>, SILTY SAND with pockets of <u>dense</u> weakly cemented silty sand. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
Ⅰ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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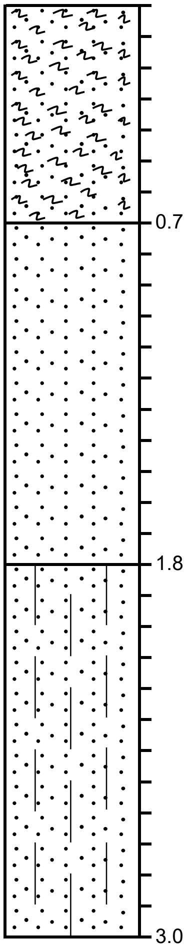
PROFILE SHEET

TP24

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456585
Y -088253



Moist, orange brown, silty SAND with abundant large roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, orange brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Very moist, reddish brown, appears to be very loose, SILTY SAND. *Aeolian.*

Appears to become medium dense below 2,7 m.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole positioned on top of dune.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

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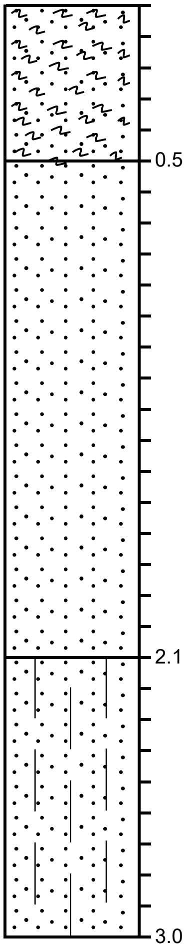
PROFILE SHEET

TP25

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456590
Y -088684



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, yellow brown, appears to be loose, SILTY SAND. *Aeolian.*

Below 2,4 m appears to be medium dense to dense.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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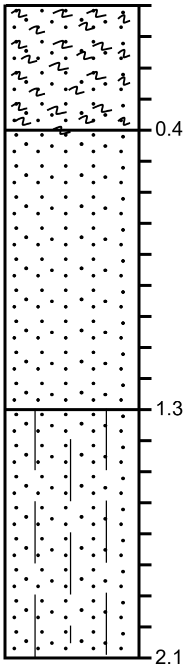
PROFILE SHEET

TP26

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456532
Y -089095



0.0 – 0.4: Moist, light brown, very loose, silty SAND with abundant roots. *Aeolian/Dune.*

0.4 – 1.3: Moist becoming slightly moist with depth, light brown, very loose, silty SAND with scattered roots. *Aeolian/Dune.*

1.3 – 2.1: Slightly moist to moist, orange brown mottled dark reddish brown, medium dense to dense becoming dense below 1,8 m, weakly cemented SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 2,1 m. Partial refusal on very dense sand.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢ *In-situ* test

Ref: 2027/g

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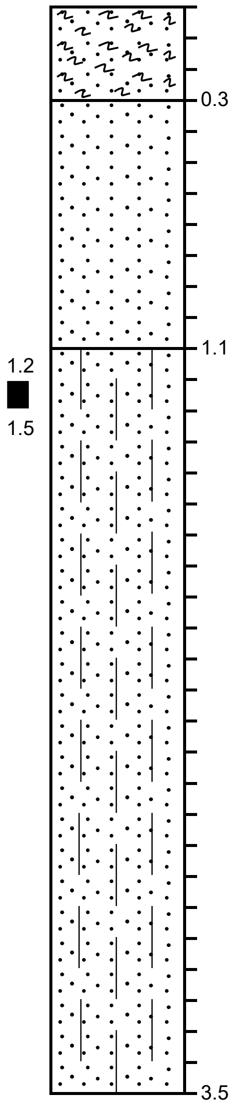
PROFILE SHEET

TP27

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456629
Y -089035



Moist, light brown, very loose, silty SAND with abundant roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, very loose, silty SAND. *Aeolian/Dune.*

Very moist at base of horizon.

Moist becoming very moist below 1,3 m, reddish brown, medium dense to dense, SILTY SAND. *Aeolian.*

Becomes mottled light brown with weakly cemented pockets.

NOTES:
1. Bottom of hole at 3,5 m. Not to refusal.
   Hole profiled to 1,5 m. Hole collapsing above 1,1 m.
2. Undisturbed sample taken from 1,2 to 1,5 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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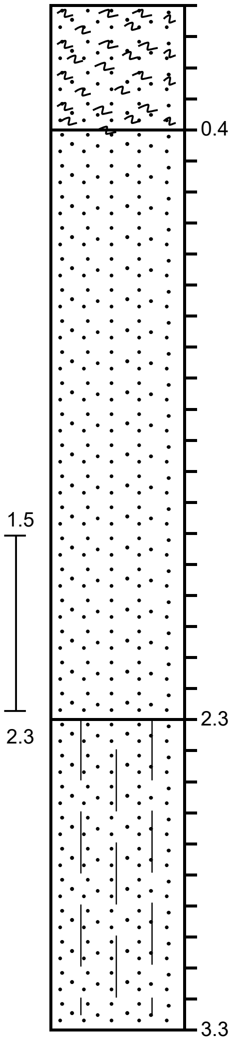
PROFILE SHEET

TP28

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456713
Y -089151



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist, reddish brown, SILTY SAND. *Aeolian.*

Becomes weakly cemented at base.

Contains friable calcareous concretions at base.

NOTES:
1. Bottom of hole at 3,3 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,5 to 2,3 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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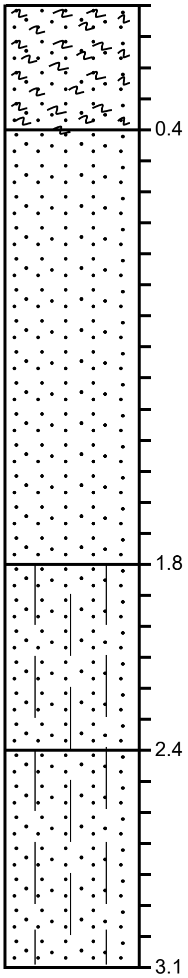
PROFILE SHEET

TP29

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456734
Y -088897



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Very moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

Moist, khaki mottled orange brown, appears to be medium dense to dense, SILTY SAND. *Aeolian?*

Becomes dense with depth and weakly cemented?

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage	■ Undisturbed sample	Ɪ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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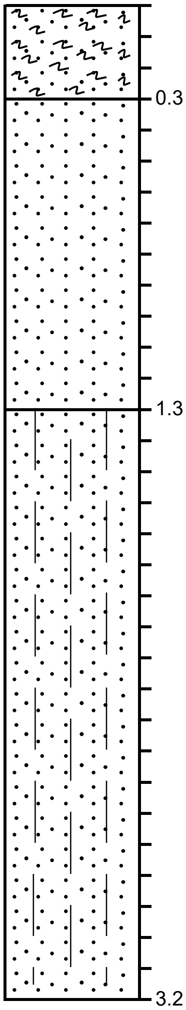
PROFILE SHEET

TP30

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456745
Y -088447



Moist, light brown, silty SAND with abundant fine and medium roots. *Aeolian/Dune.* Appears very loose.

Moist, light brown, silty SAND with scattered roots. *Aeolian/Dune.*

Appears very loose.

Slightly moist to moist, orange brown mottled light brown, appears to be medium dense to dense, SILTY SAND. *Aeolian.*

Very moist and moist above 1,5 m and appears loose..

Becomes dense below 2,5 m.

Below 2,5 m becomes mottled light brown and contains friable weakly cemented silty sand pockets.

NOTES:
1. Bottom of hole at 3,2 m. Partial refusal on dense weakly cemented silty sand. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 28-Aug-20

▽	Water seepage	■	Undisturbed sample	I	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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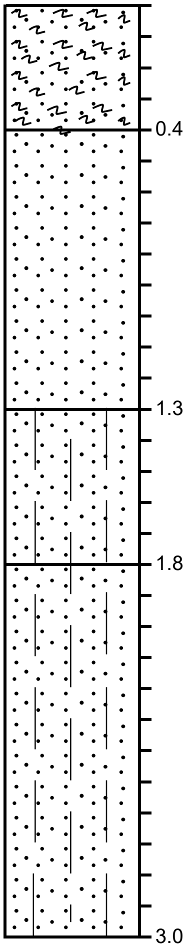
PROFILE SHEET

TP31

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456737
Y -088045



Moist, orange brown, silty SAND with abundant fine roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, orange brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, brown, appears to be loose, SILTY SAND with abundant fine to coarse nodules and scattered gravel. *Aeolian.*

Slightly moist, light yellow brown, appears to be medium dense, SILTY SAND with few friable nodules and pockets of weakly cemented silty sand. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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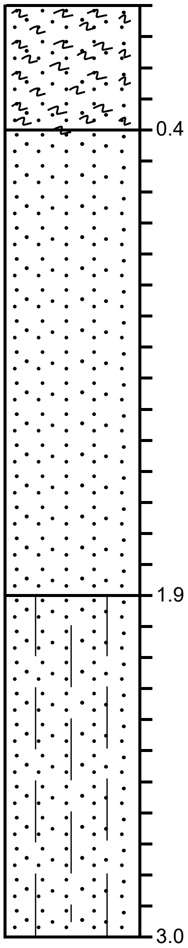
PROFILE SHEET

TP34

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456839
Y -087645



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose</u>.

Slightly moist, orange brown, appears to be <u>medium dense to dense</u>, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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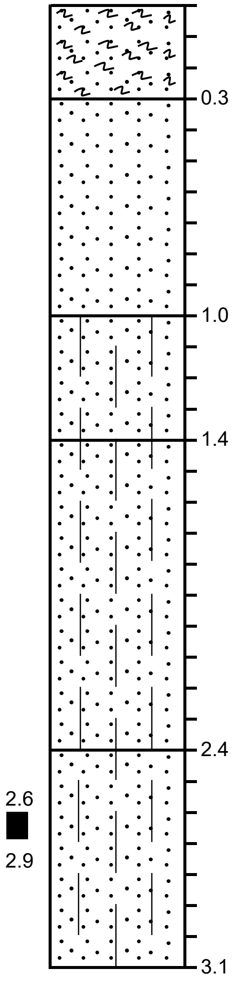
PROFILE SHEET

TP35

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456890
Y -087848



Moist, light brown, very loose, silty SAND with abundant fine roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, very loose, silty SAND. *Aeolian/Dune.*

Moist, orange brown, loose, SILTY SAND. *Aeolian.*

Moist, orange brown, dense, weakly cemented SILTY SAND with friable nodules. *Weakly cemented aeolian.*

Slightly moist, orange brown mottled khaki, medium dense to dense, pinholed, SILTY SAND with scattered friable nodules. *Aeolian.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
2. Undisturbed sample taken from 2,6 to 2,9 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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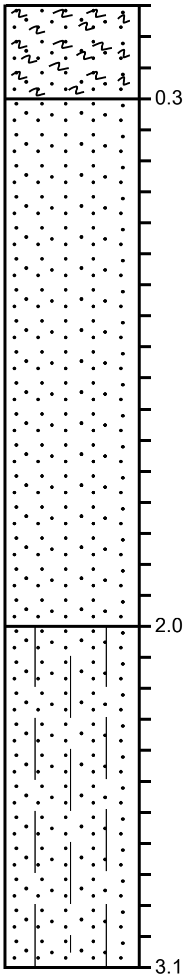
PROFILE SHEET

TP36

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456943
Y -088247



Moist, light brown, silty SAND with abundant fine and medium roots. *Aeolian/Dune.* Appears very loose.

Moist, light brown, silty SAND with scattered roots. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be medium dense to dense, SILTY SAND. *Aeolian.*

Below 2,5 m becomes mottled light brown and contains abundant friable weakly cemented pockets.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 28-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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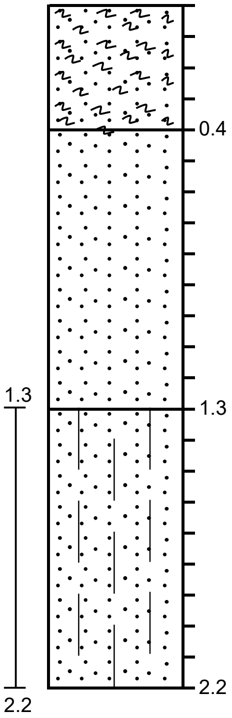
e-mail: admin@inroads-sa.co.za

PROFILE SHEET

TP37

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456890
Y -088619



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, yellow brown, appears to be dense, weakly cemented SILTY coarse SAND with miner fine and scattered coarse gravels and nodules. *Alluvium?*

NOTES:
1. Bottom of hole at 2,2 m. Partial refusal on dense sand.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,3 to 2,2 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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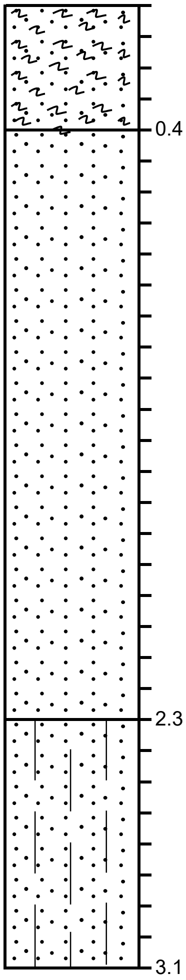
PROFILE SHEET

TP38

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456836
Y -089092



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, SILTY SAND. *Aeolian.*

Becomes weakly cemented at base.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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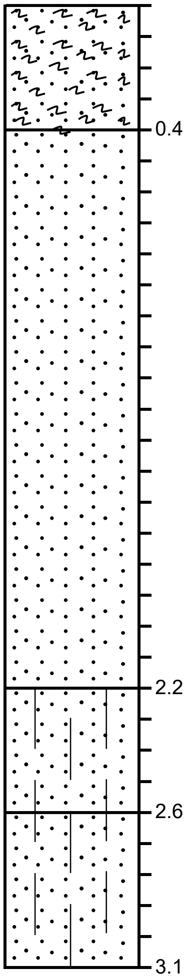
PROFILE SHEET

TP39

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456919
Y -089187



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, reddish brown, SILTY SAND. *Aeolian.*

Slightly moist to moist, reddish brown, weakly cemented SILTY SAND. *Aeolian.*

Appears to be dense.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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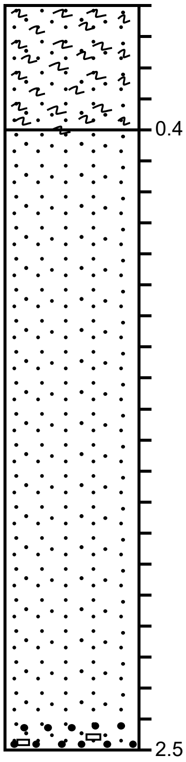
PROFILE SHEET

TP40

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3456973
Y -089298



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Contains scattered ferricrete boulders at base of horizon.

Appears <u>very loose</u>.

NOTES:
1. Bottom of hole at 2,5 m. Refusal on hardpan dorbank.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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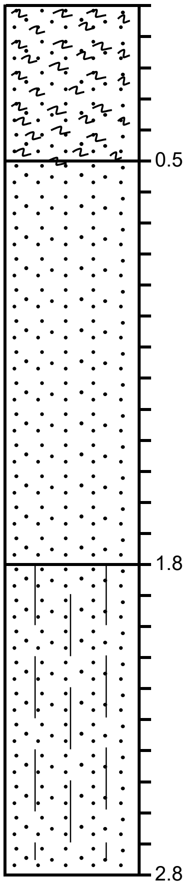
PROFILE SHEET

TP41

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457044
Y -088843



Moist, light brown, silty SAND with minor roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose</u>.

Slightly moist, light brown, appears to be <u>medium dense</u>, pinholed, SILTY SAND. *Aeolian.*

Becomes <u>dense</u> and speckled black with depth.

NOTES:
1. Bottom of hole at 2,8 m. Partial refusal on <u>dense</u> sand.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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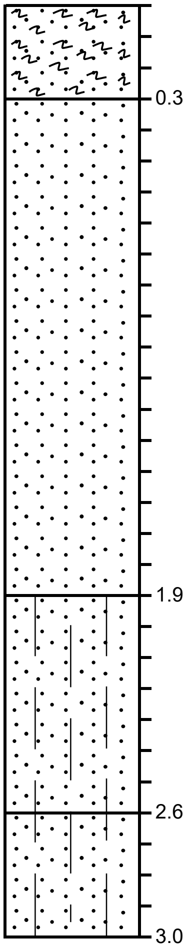
PROFILE SHEET

TP42

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457036
Y -088469



Moist, light brown, silty SAND with abundant fine roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be medium dense, SILTY SAND with abundant fine gravel and scattered coarse gravel and cobbles. *Alluvium?*

Moist, reddish brown, appears to be dense, pinholed, weakly cemented SILTY SAND with small pockets of white calcareous nodules. *Aeolian?*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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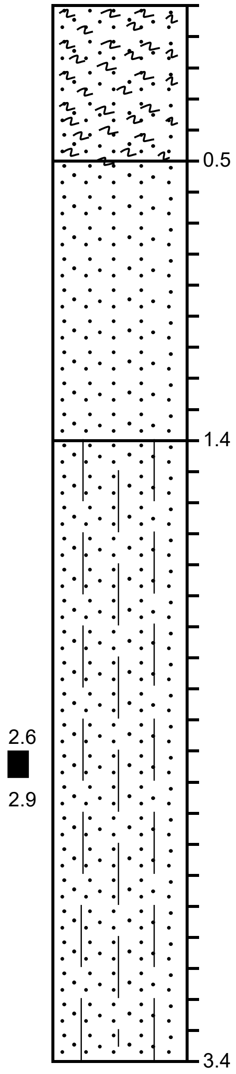
PROFILE SHEET

TP43

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457084
Y -087999



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist below 2,1 m, orange brown, medium dense becoming dense below 2,2 m, SILTY SAND with scattered friable nodules below 2,2 m. *Aeolian.*

Becomes mottled reddish brown and light brown below 2,4 m.

NOTES:
1. Bottom of hole at 3,4 m. Not to refusal.
2. Undisturbed sample taken from 2,6 to 2,9 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 28-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

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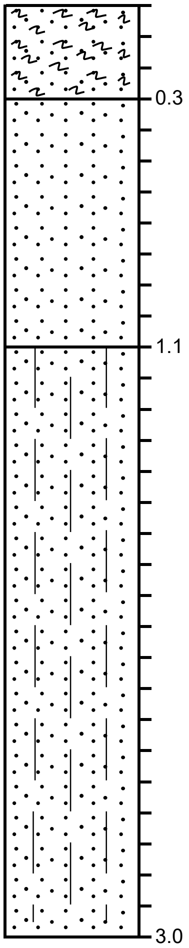
PROFILE SHEET

TP44

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457135
Y -087699



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, yellow brown, appears to be medium dense, SILTY SAND with scattered friable nodules. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 28-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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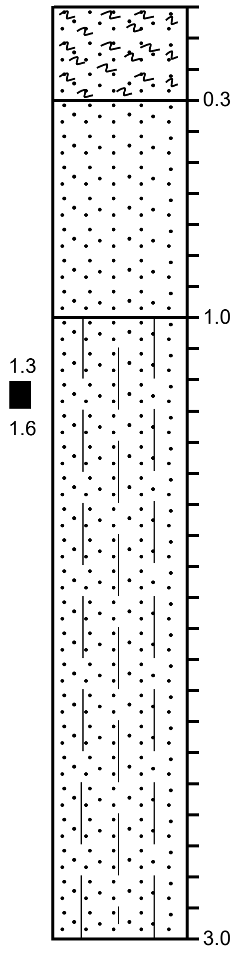
PROFILE SHEET

TP45

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457047
Y -087509



Moist, light brown, very loose, silty SAND with few roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, very loose, silty SAND . *Aeolian/Dune.*

Slightly moist, orange brown, medium dense to dense becoming dense below 1,7 m, pinholed, weakly cemented SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
2. Undisturbed sample taken from 1,3 to 1,6 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 22-Aug-20

▽	Water seepage	■	Undisturbed sample	I	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g

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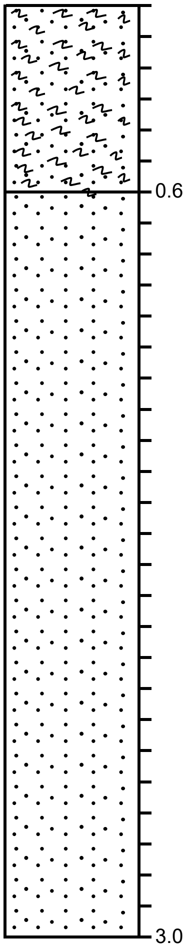
PROFILE SHEET

TP47

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457239
Y -087383



Moist, light brown, silty SAND with abundant fine roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose.</u>

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole position on slope of dune.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 24-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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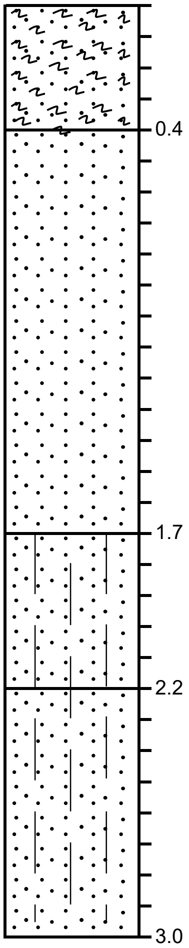
PROFILE SHEET

TP48

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457195
Y -088289



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

0.4

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

1.7

Moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

2.2

Moist, orange brown, appears to be medium dense, weakly cemented SILTY SAND.
Weakly cemented aeolian.

Appears to become dense with depth.

3.0

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 24-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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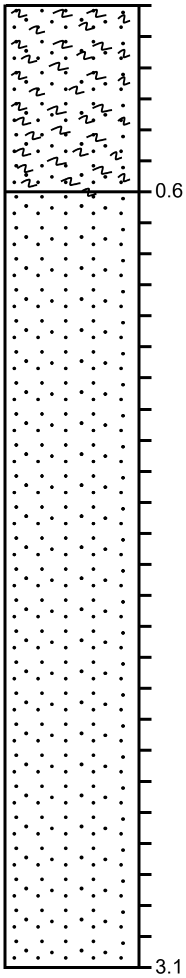
PROFILE SHEET

TP49

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3455993
Y -088759



Moist, light brown, loose, silty SAND with few roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole positioned on top of dune.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 22-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g

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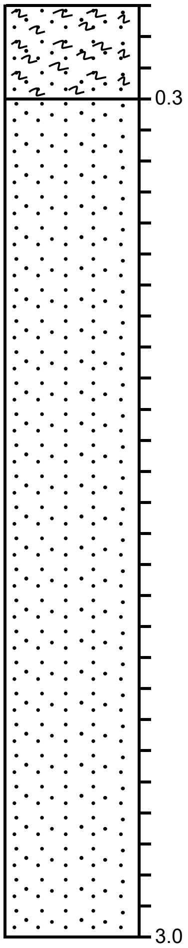
PROFILE SHEET

TP50

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457186
Y -089096



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽	Water seepage	■	Undisturbed sample	I	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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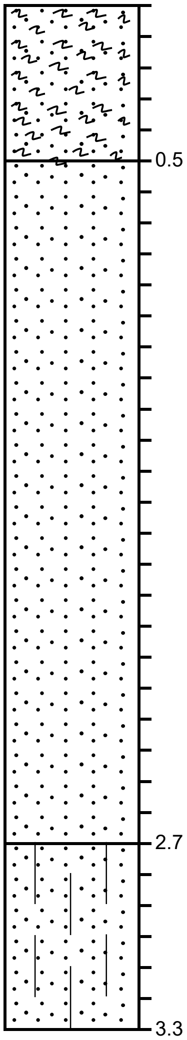
PROFILE SHEET

TP51

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457121
Y -089259



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, reddish brown, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,3 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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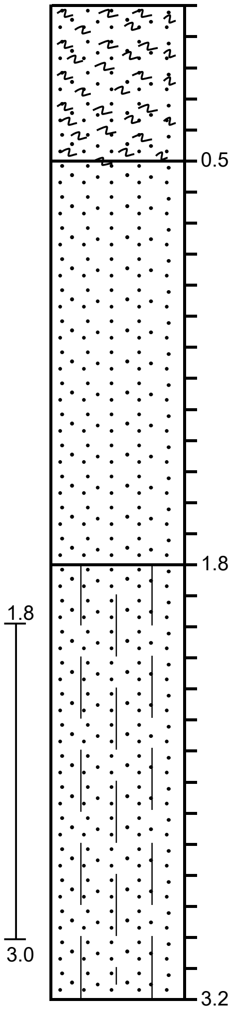
PROFILE SHEET

TP52

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457169
Y -089374



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Very moist to moist, dark reddish brown, SILTY SAND with pockets of cemented material. *Aeolian.*

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 2,0 to 3,0 m.
3. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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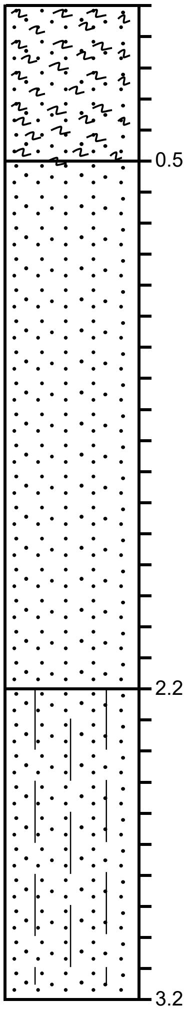
PROFILE SHEET

TP53

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457220
Y -089466



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist becoming moist below 2,9 m, reddish brown, weakly cemented SILTY SAND. *Weakly ferruginised aeolian.*

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Operator reported very dense material at base.
2. No groundwater seepage encountered.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 21-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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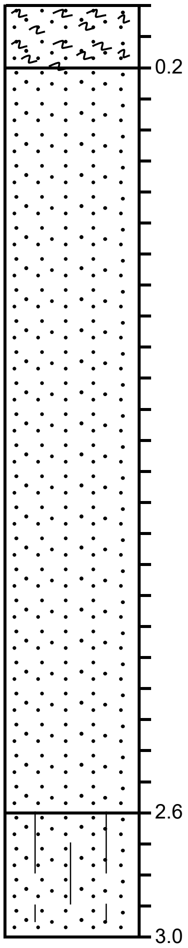
PROFILE SHEET

TP55

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457334
Y -089296



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, light yellow brown mottled reddish brown, appears to be loose, SILTY SAND.
Aeolian.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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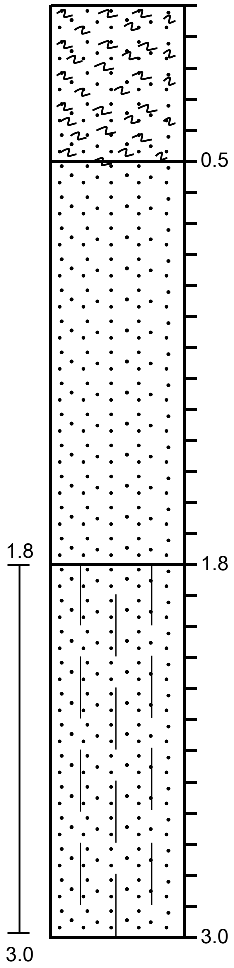
PROFILE SHEET

TP56

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457347
Y -088904



Moist, light brown, silty SAND with few fine roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose</u>.

Slightly moist, light brown , appears to be <u>dense</u>, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,8 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 26-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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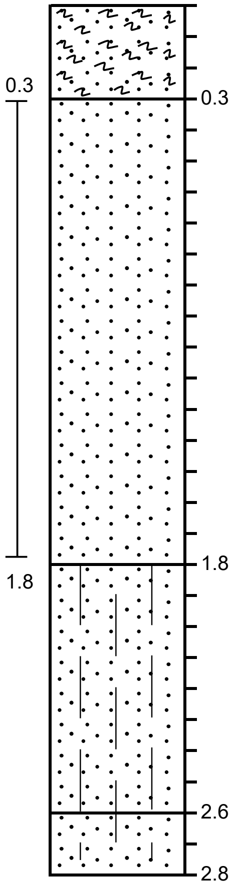
PROFILE SHEET

TP57

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457331
Y -088402



Moist, light brown, silty SAND with few fine roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, yellow brown, appears to be medium dense, pinholed, SILTY SAND. *Aeolian.*

Appears to become dense with depth.

Moist, khaki mottled yellow brown, appears to be dense, (weakly cemented) SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 2,8 m. Partial refusal on dense sand.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 0,3 to 1,8 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
Ⅰ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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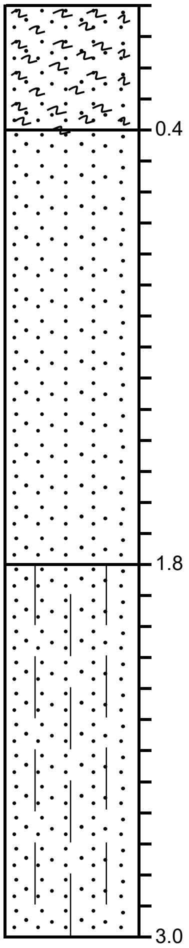
PROFILE SHEET

TP59

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457337
Y -087817



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, yellow brown, appears to be medium dense, SILTY SAND with friable nodules and pockets of weakly cemented silty sand. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 28-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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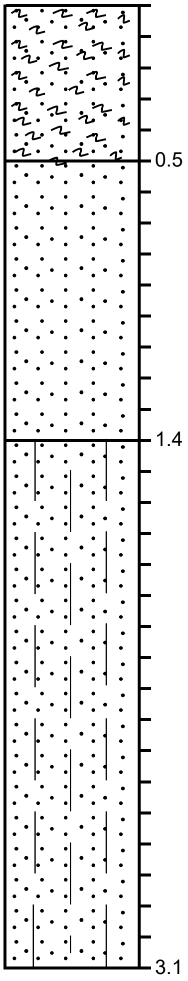
PROFILE SHEET

TP60

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457317
Y -087548



0 – 0.5: Moist, orange brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

0.5 – 1.4: Moist becoming slightly moist with depth, orange brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

1.4 – 3.1: Moist, yellow brown, appears to be loose, SILTY SAND with abundant friable nodules.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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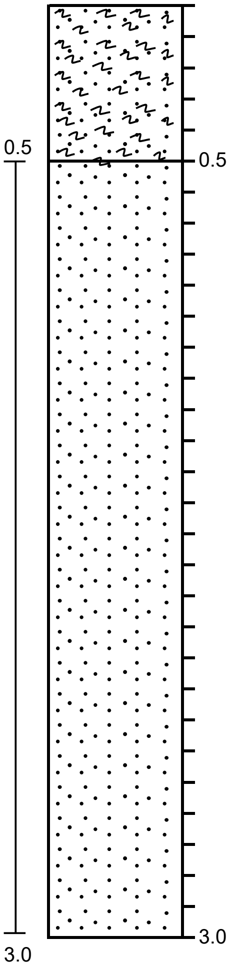
PROFILE SHEET

TP61

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457354
Y -087359



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 0,5 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 24-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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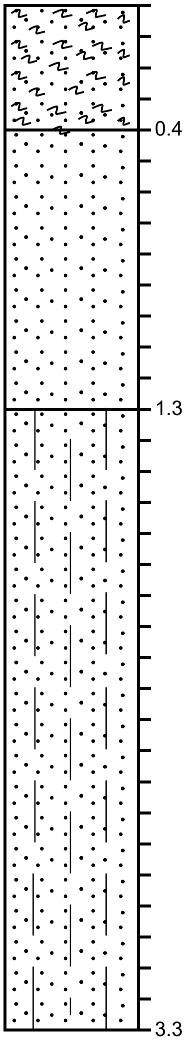
PROFILE SHEET

TP62

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457484
Y -087643



Moist, light brown, silty SAND with few fine roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be medium dense, SILTY SAND with scattered pockets of friable nodules. *Aeolian.*

NOTES:
1. Bottom of hole at 3,3 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 28-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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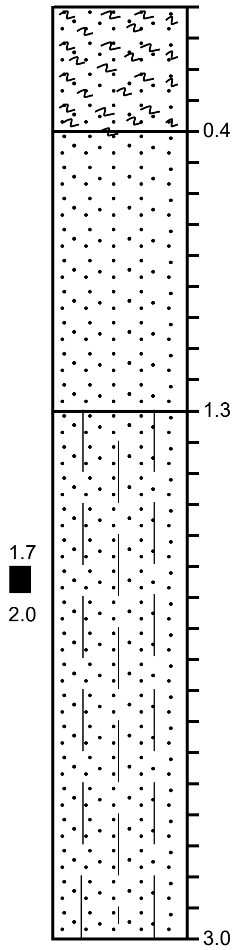
PROFILE SHEET

TP64

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457436
Y -087942



Moist, light brown, <u>very loose</u>, silty SAND with abundant roots. *Aeolian/Dune.*

Moist becoming slightly moist with depth, light brown, <u>very loose</u>, silty SAND with scattered fine roots. *Aeolian/Dune.*

Moist, orange brown, <u>loose</u>, SILTY SAND. *Aeolian.*

Below 2,0 m becomes <u>medium dense</u>.

Below 2,3 m becomes mottled light brown and <u>dense</u> with scattered friable weakly cemented pockets.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
2. Undisturbed sample taken from 1,7 to 2,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 24-Aug-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	├┤	*In-situ* test

Ref: 2027/g
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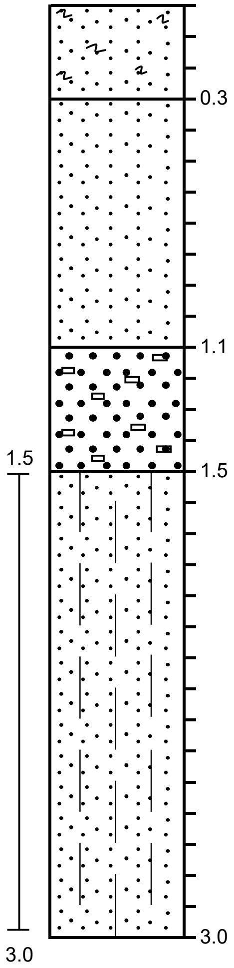
PROFILE SHEET

TP65

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457491
Y -088099



Moist, light brown, silty SAND with few roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Clast supported COBBLES and small elongated ferricrete BOULDERS in a matrix as above. *Boulder ferricrete.*

Appears dense to very dense.

Moist, orange brown, appears to be loose, SILTY SAND with friable fine to coarse nodules. *Aeolian.*

Appears to become medium dense below 1,7 m and nodules become less with depth.

Below 2,4 m becomes khaki.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,5 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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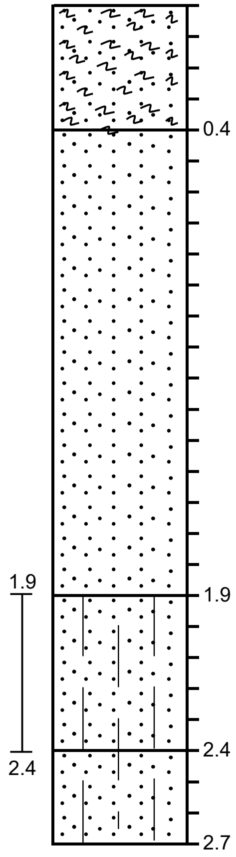
PROFILE SHEET

TP66

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457494
Y -088643



Moist, light brown, silty SAND with abundant fine roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, reddish brown, appears to be dense, weakly cemented SILTY SAND with traces of fine gravel. *Weakly cemented aeolian.*

Moist, yellow brown, appears to be dense, weakly cemented SILTY SAND with traces of fine gravel. *Aeolian.*

NOTES:
1. Bottom of hole at 2,7 m. Partial refusal on dense sand.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,9 to 2,4 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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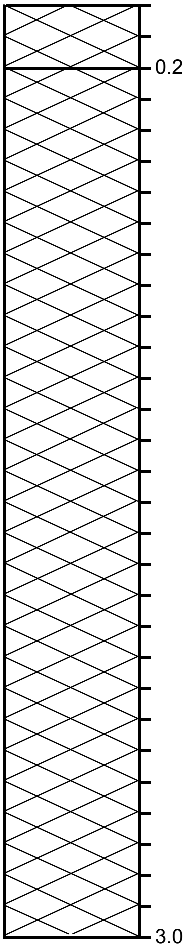
PROFILE SHEET

TP67

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457539
Y -089126



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune/Fill?*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune/Fill?*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Appears to be located in old rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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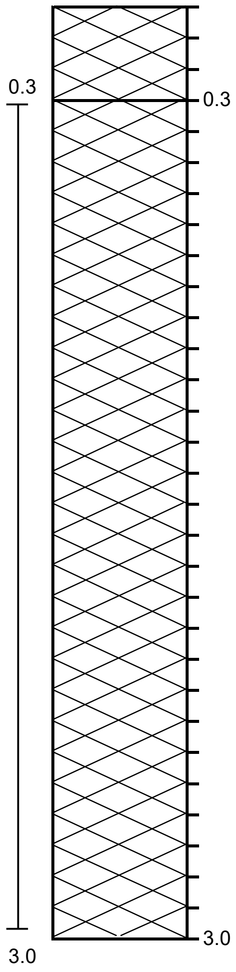
PROFILE SHEET

TP68

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457415
Y -089580



Moist, light brown, silty SAND with fine roots. *Aeolian/Dune/Fill?*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune/Fill?*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Appears to be located in old rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 0,3 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

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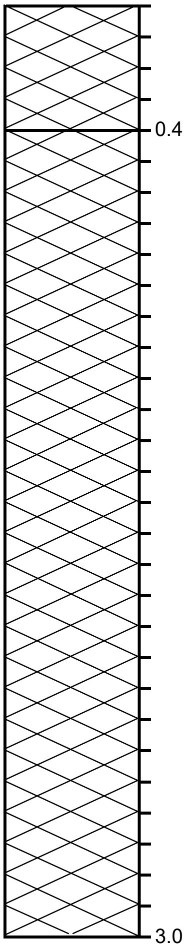
PROFILE SHEET

TP70

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457580
Y -089456



Moist, light brown, silty SAND with few fine roots. *Aeolian/Dune/Fill?*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune/Fill?*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Appears to be located in old rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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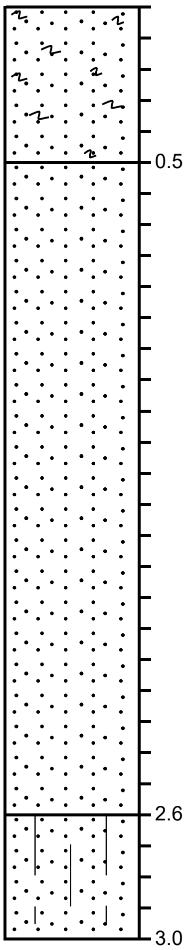
PROFILE SHEET

TP72

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457637
Y -088846



Moist, light brown, silty SAND with few fine roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be loose, weakly cemented SILTY SAND.
Weakly cemented aeolian.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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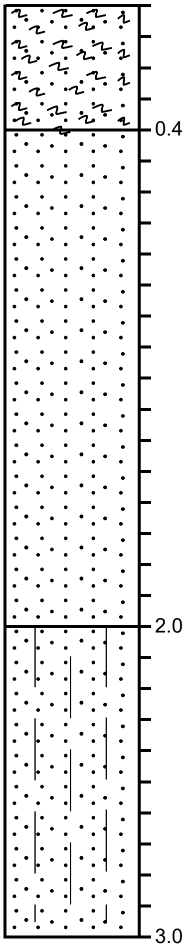
PROFILE SHEET	**TP73**
Epoch Resources (Pty) Ltd **Namakwa Sands - RSF**	**X 3457635** **Y -088247**



0.0–0.4: Moist, light brown, silty SAND with abundant fine roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

0.4–2.0: Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears <u>very loose</u> and <u>medium dense to dense</u> below 1,5 m.

2.0–3.0: Moist, yellow brown, appears to be <u>medium dense</u>, weakly cemented SILTY SAND. *Aeolian.*

Appears to become <u>dense</u> with depth.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 27-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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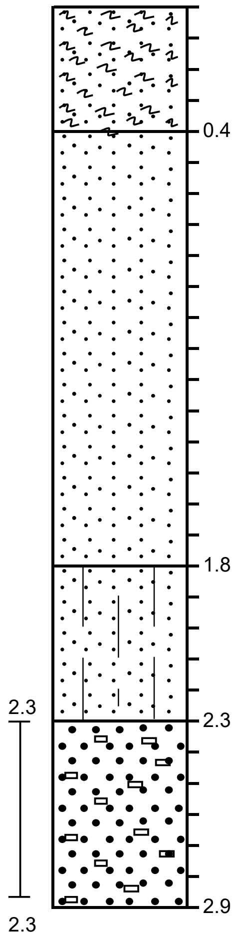
PROFILE SHEET

TP74

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457660
Y -087843



Moist, orange brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, orange brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, yellow brown, appears to be loose, SILTY SAND with pockets of medium dense to dense weakly cemented silty sand. *Weakly cemented aeolian.*

Matrix supported, coarse to fine calcareous NODULES and scattered coarse gravels in a matrix of moist, yellow brown, silty coarse sand. *Residual granite gneiss?*

Appears dense.

NOTES:
1. Bottom of hole at 2,9 m. Partial refusal on dense sand.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 2,3 to 2,9 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
Ⅰ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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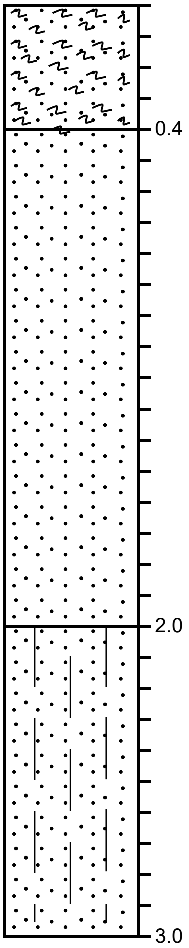
PROFILE SHEET

TP75

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457689
Y -087598



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Moist, orange brown, appears to be medium dense, SILTY SAND with pockets of weakly cemented silty sand with thin calcareous veins. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer/MC Shuping
Date profiled: 24-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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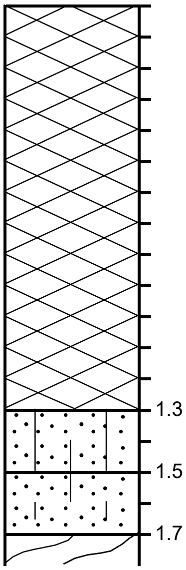
PROFILE SHEET

TP76

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457789
Y -088392



Moist to very moist, orange brown, very loose, SAND with scattered roots. *Fill.*

Moist, dark brown, loose to medium dense, SILTY SAND. *Aeolian.*

Moist, white stained black and yellow brown speckled grey and orange, very dense, relict jointed, well cemented SILTY coarse SAND. *Well cemented residual granite gneiss.*

In places occur as highly weathered very soft rock.

NOTES:
1. Bottom of hole at 1,7 m. Refusal on very soft rock granite gneiss.
   Hole located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 2-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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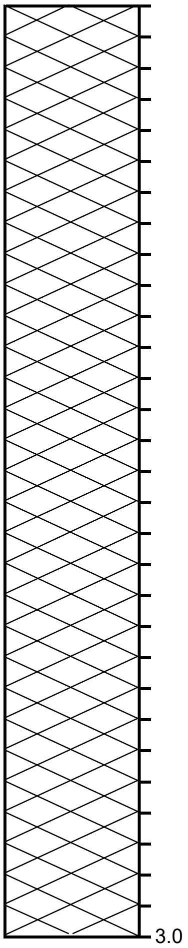
PROFILE SHEET

TP77

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457868
Y -088919



Moist to very moist, orange brown, very loose, SAND. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage ■ Undisturbed sample ⌶ Bulk sample
▼ Standing water ● Disturbed sample ⊢⊣ *In-situ* test

Ref: 2027/g

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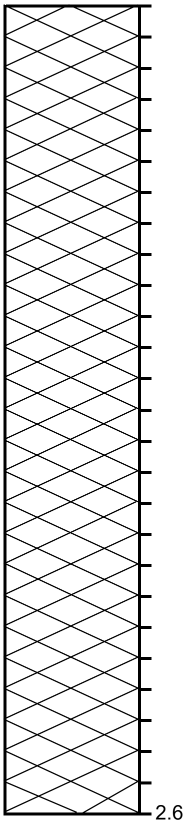
PROFILE SHEET

TP78

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457790
Y -089162



Moist to very moist, orange brown, very loose, SAND. *Fill.*

NOTES:
1. Bottom of hole at 2,6 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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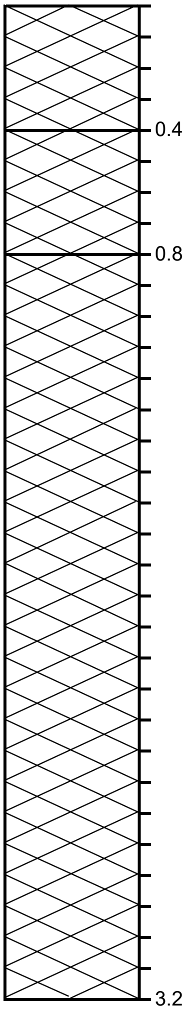
PROFILE SHEET

TP79

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457763
Y -089328



0.0 – 0.4: Clast supported, sub-angular, coarse GRAVEL and COBBLES in a matrix of moist, dark brown, silty sand. *Fill.*

0.4 – 0.8: Matrix supported, sub-rounded sandstone small BOULDERS in a matrix of very moist, orange brown, silty sand. *Fill.*

0.8 – 3.2: Moist to very moist, orange brown, very loose, SAND. *Fill.*

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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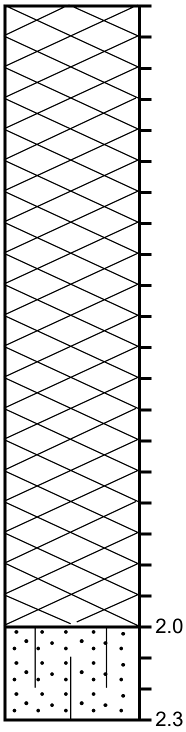
PROFILE SHEET

TP81

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457951
Y -089264



0.0 – 2.0: Moist to very moist, light brown, <u>very loose</u>, SAND. *Fill.*

2.0 – 2.3: Moist, orange brown, appears to be <u>dense</u>, SILTY SAND with abundant gravels, cobbles. *Aeolian.*

NOTES:
1. Bottom of hole at 2,3 m. Not to refusal. Hole stopped due to collapse.
   Hole profiled from outside due to sidewall collapse. Located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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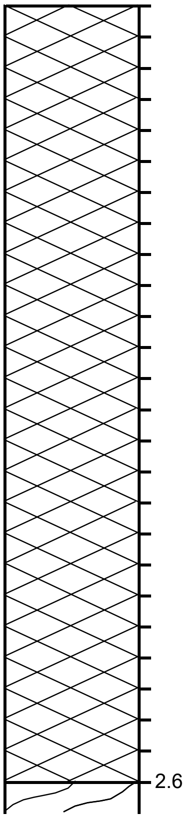
PROFILE SHEET

TP83

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457940
Y -088641



Very moist, orange brown, <u>very loose</u>, SAND with scattered nodules on surface. *Fill.*

NOTES:
1. Bottom of hole at 2,6 m. Refusal on <u>very soft rock</u> granite gneiss? Hole profiled from outside due to sidewall collapse. Hole located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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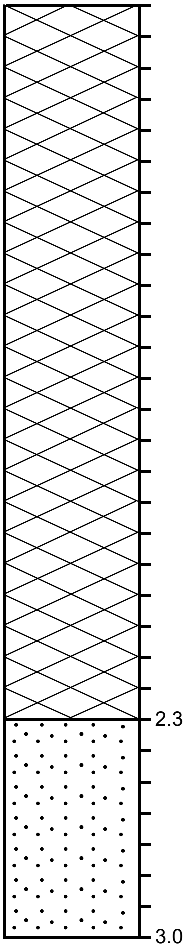
PROFILE SHEET

TP84

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458023
Y -088396



Very moist, orange brown, very loose, SAND with scattered friable nodules on surface.
Fill.

2.3

Very moist, dark brown, silty SAND with abundant friable calcareous nodules.
Aeolian/Dune.

Appears very loose.

3.0

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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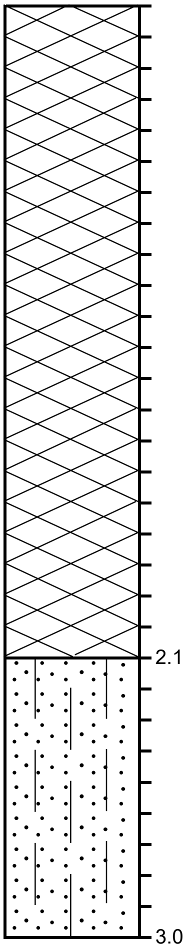
PROFILE SHEET

TP85

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3457913
Y -088000



Moist to very moist, orange brown, very loose, SAND. *Fill.*

Very moist, reddish brown mottled yellow brown, appears to be loose, SILTY SAND with scattered friable nodules. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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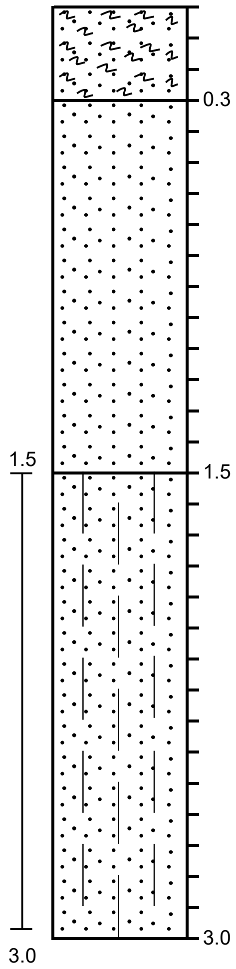
PROFILE SHEET

TP86

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458009
Y -087772



Moist, light brown, silty SAND with abundant roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Slightly moist, orange brown, appears to be medium dense, SILTY SAND with abundant weakly cemented pockets. *Aeolian.*

Appears to become dense below 2,7 m.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,5 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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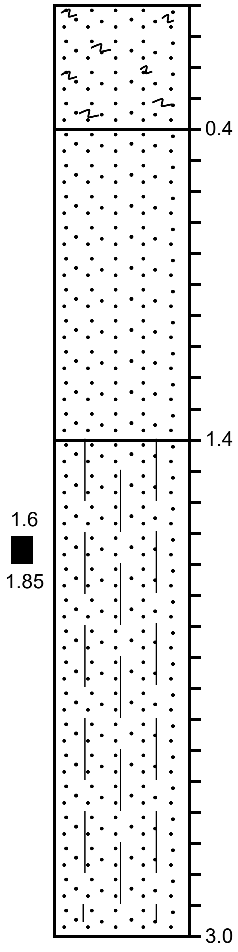
PROFILE SHEET

TP87

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458109
Y -087660



Depth (m)	Description
0.0 – 0.4	Moist, light brown, very loose, silty SAND with few roots. *Aeolian/Dune.*
0.4 – 1.4	Moist becoming slightly moist with depth, light brown, very loose, silty SAND with scattered fine roots. *Aeolian/Dune.* Becomes slightly moist and loose with depth
1.4 – 3.0	Slightly moist, brown becoming orange brown below 2,0 m, loose becoming medium dense to dense below 2,0 m, fissured SILTY SAND with abundant friable concretions. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole positioned on top of dunes.
2. Undisturbed sample taken from 1,6 to 1,85 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 24-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g

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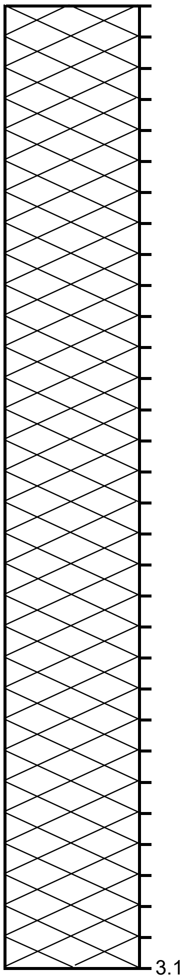
PROFILE SHEET

TP89

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458123
Y -087849



Moist to very moist, orange brown, very loose, SAND. *Fill.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 24-Aug-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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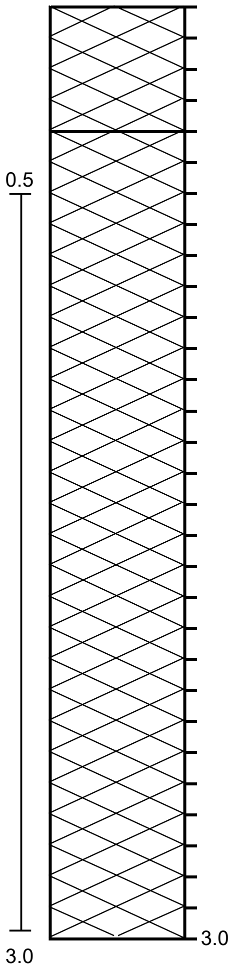
PROFILE SHEET

TP91

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458180
Y -088041



Moist to very moist, orange brown, very loose, SAND. *Fill.*

Contains scattered friable cobbles and boulders at top 0,5 m.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Located in rehabilitated area.
2. Bulk sample taken from 0,5 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 24-Aug-20

▽ Water seepage	■ Undisturbed sample	Ɪ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

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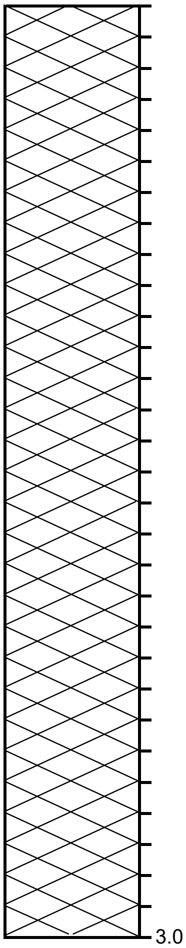
PROFILE SHEET

TP92

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458122
Y -088147



Very moist, orange brown, very loose, SAND with scattered roots. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 31-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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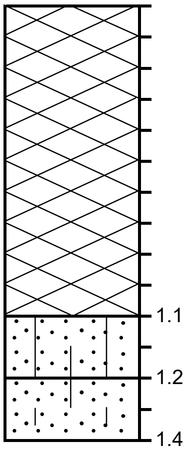
PROFILE SHEET

TP95

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458242
Y -088612



Moist to very moist, orange brown, very loose, SAND with scattered friable nodules on surface. *Fill.*

Moist, dark brown, loose to medium dense, SILTY SAND. *Aeolian.*

Slightly moist to moist, light yellow and white stained black mottled reddish brown, very dense, relict jointed, well cemented SILTY coarse SAND. *Well cemented residual granite gneiss.*

Very soft rock in places.

NOTES:
1. Bottom of hole at 1,4 m. Refusal on very soft rock granite gneiss?
   Hole located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 2-Sep-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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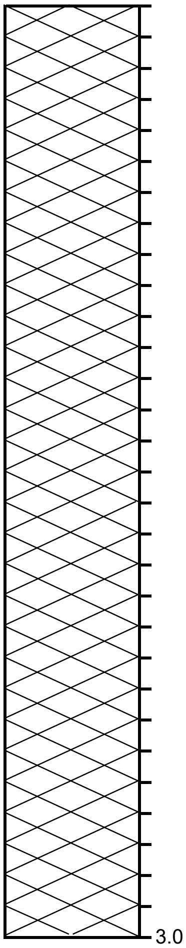
PROFILE SHEET

TP96

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458089
Y -088990



Moist to very moist, orange brown, very loose, SAND with scattered friable nodules on surface. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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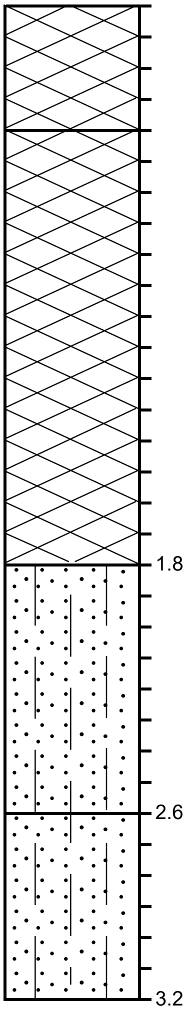
PROFILE SHEET

TP97

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458119
Y -089162



Moist to very moist, orange brown, very loose, SAND. *Fill.*

Moist, orange brown, appears to be dense, SILTY SAND with abundant moderately cemented gravels, cobbles and small boulders. *Aeolian.*

Moist, orange brown, appears to be loose, SILTY SAND with pockets of weakly cemented silty sand. *Aeolian.*

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal. Hole located in rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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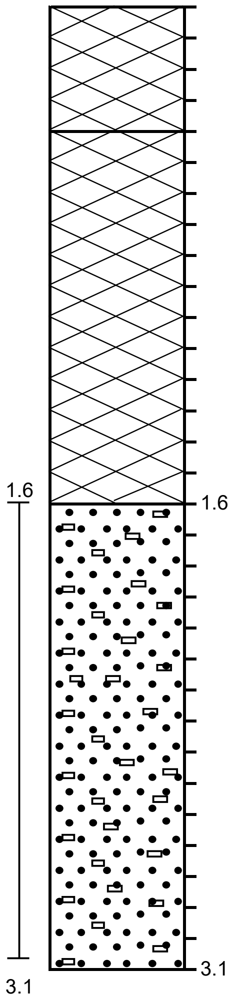
PROFILE SHEET

TP99

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458281
Y -089034



Moist to very moist, orange brown, very loose, SAND with scattered cobbles and gravels on surface. *Fill.*

Moderately cemented BOULDERS in a matrix of moist, orange brown, silty sand.
Moderately cemented aeolian.

Appears to be dense.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal. Hole located in rehabilitated area (valley). Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,6 to 3,1 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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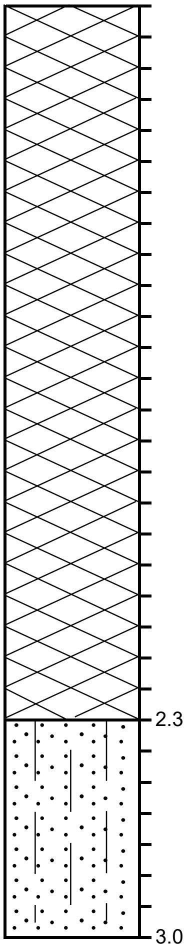
e-mail: admin@inroads-sa.co.za

PROFILE SHEET

TP101

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458336
Y -088819



Moist to very moist, orange brown, very loose, SAND with scattered cobbles and gravels on surface. *Fill.*

Contains abundant highly weathered gneiss & silcrete cobbles at base of horizon below 1,7 m.

Moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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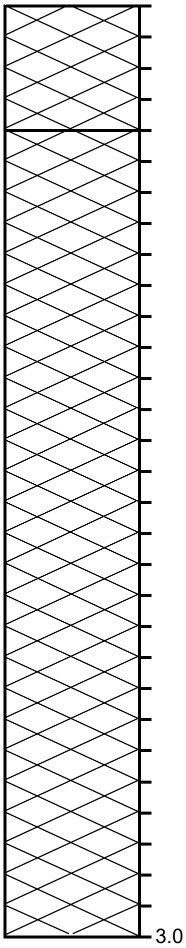
PROFILE SHEET

TP103

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458385
Y -088595



Moist to very moist, orange brown, very loose, SAND with scattered gravel on surface. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal. Hole located in rehabilitated area. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

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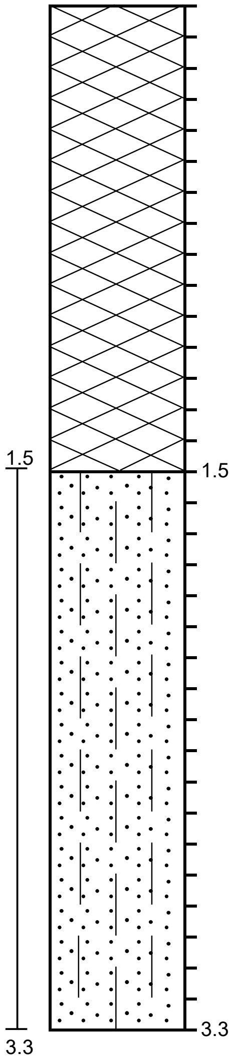
PROFILE SHEET

TP105

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458360
Y -088406



Moist to very moist, orange brown, very loose, SAND with scattered gravel on surface. *Fill.*

Very moist, reddish brown, appears to be very loose, SILTY SAND. *Aeolian/Fill?*

Becomes orange brown with depth.

NOTES:
1. Bottom of hole at 3,3 m. Not to refusal. Hole located in rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 1,5 to 3,3 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 25-Aug-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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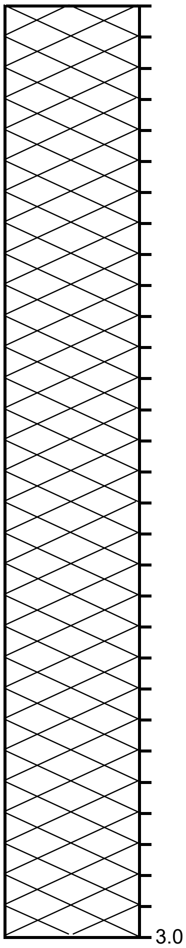
PROFILE SHEET

TP106

Epoch Resources (Pty) Ltd
Namakwa Sands - RSF

X 3458313
Y -088214



Moist to very moist, orange brown, <u>very loose</u>, SAND. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Located in rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 24-Aug-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

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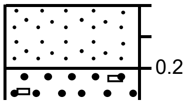
PROFILE SHEET

TP117

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3456810
Y -090049



Very moist, light brown, very loose, silty SAND. *Aeolian/Dune.*

NOTES:
1. Bottom of hole at 0,2 m. Refusal on very soft rock hardpan dorbank. Approximately 2,0 m of soil has been removed/mined off the present ground surface.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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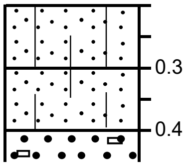
PROFILE SHEET

TP118

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3456928
Y -090164



Moist, orange brown, loose, SILTY SAND. *Aeolian.*

Slightly moist, light greyish brown speckled orange, dense, SILTY SAND. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 0,4 m. Refusal on very soft rock hardpan dorbank. Aeolian/dune layer has been removed/mined off the present ground surface.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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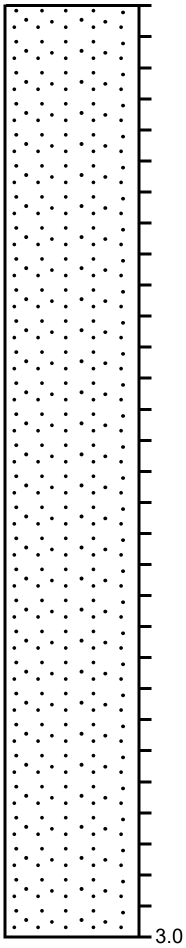
PROFILE SHEET

TP119

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457026
Y -090260



Moist, light brown, very loose, silty SAND with few roots. *Aeolian/Dune.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g

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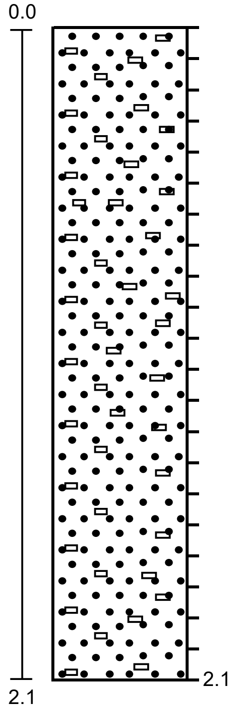
PROFILE SHEET

TP120

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457134
Y -090352



Clast supported, sub-angular, moderately cemented coarse GRAVELS, COBBLES and BOULDERS in a matrix of moist, brown, silty sand. *Boulder dorbank.*

Overall consistency is very dense.

NOTES:
1. Bottom of hole at 2,1 m. Not to refusal.
   Aeolian/dune horizon has been removed/mined off the present ground.
2. Bulk sample taken from 0,0 to 2,1 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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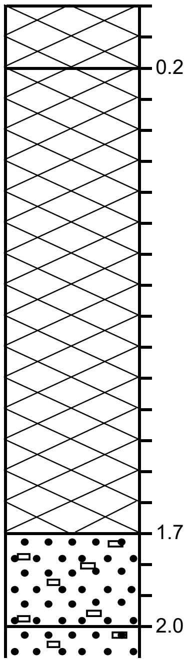
PROFILE SHEET

TP121

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457227
Y -090450



Moist, light brown, silty SAND with abundant roots. *Fill?*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Fill?*

Appears very loose.

Clast supported, sub-rounded and sub-angular, moderately cemented dorbank COBBLES and small BOULDERS in a matrix of moist, orange brown, silty sand. *Boulder dorbank?*

Appears to be dense to very dense.

NOTES:
1. Bottom of hole at 2,0 m. Partial refusal on dense boulders?
   Hole profiled from outside due to sidewall collapse.
   Hole located within the old rehabilitation area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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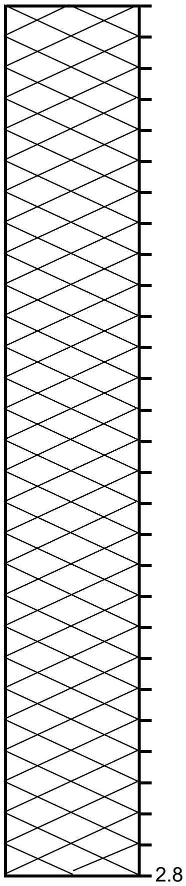
PROFILE SHEET

TP122

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457317
Y -090535



Very moist, brown, appears to be very loose, slightly silty SAND. *Fill.*

Contains occasional up to 1,0 m diameter moderately cemented dorbank boulders.

NOTES:
1. Bottom of hole at 2,8 m. Partial refusal on sub-rounded and sub-angular moderately cemented dorbank cobbles and boulders in a matrix of moist, orange brown silty sand. Appears to be dense. Fill?
   Hole profiled from outside due to sidewall collapse.
   Hole located on old rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
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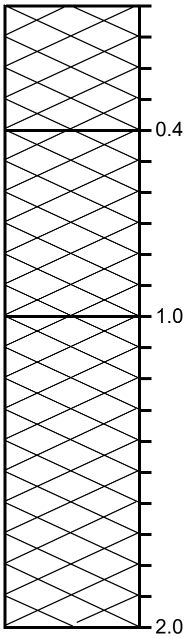
PROFILE SHEET

TP123

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457423
Y -090448



Moist, light brown, very loose, silty SAND with abundant roots. *Fill.*

0.4

Matrix supported, angular, fine, medium and coarse GRAVELS in a matrix of moist, dark brown, silty sand. *Fill.*

Overall consistency is medium dense.

1.0

Matrix supported, sub-rounded dorbank COBBLES and small BOULDERS in a matrix of moist, light brown, sand. *Fill.*

Overall consistency is medium dense.

2.0

NOTES:
1. Bottom of hole at 2,0 m. Partial refusal on boulders.
   Hole located in old rehabilitated area.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
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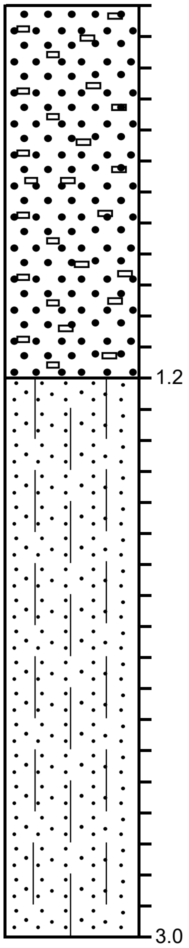
PROFILE SHEET

TP124

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457517
Y -090318



Clast supported, sub-angular dorbank COBBLES and small BOULDERS in a matrix of moist, brown, silty sand. *Boulder dorbank.*

Consistency appears to be dense.

Moist, orange brown, appears to be medium dense, SILTY SAND with friable weakly cemented pockets. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

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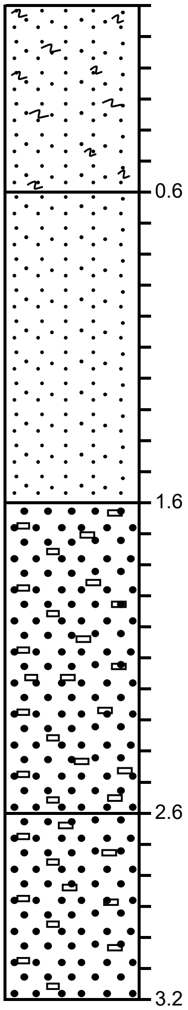
PROFILE SHEET

TP125

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457622
Y -090223



Moist, light brown, silty SAND with few roots. *Aeolian/Dune.*

Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Clast supported ferricrete COBBLES and BOULDERS in a matrix of moist, orange brown, silty sand. *Boulder ferricrete.*

Appears to be dense.

Matrix supported friable NODULES in a matrix of moist, orange brown, silty sand. *Nodular ferricrete?*

Overall consistency is medium dense.

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

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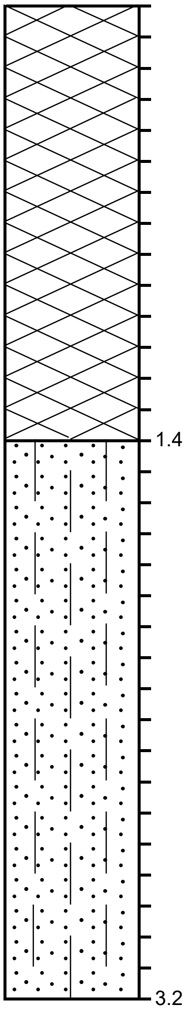
PROFILE SHEET

TP126

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457714
Y -090122



Very moist, light brown, appears <u>very loose</u>, SAND with abundant roots. *Fill.*

Moist to very moist, orange brown, <u>loose</u>, pinholed, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,2 m. Not to refusal.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

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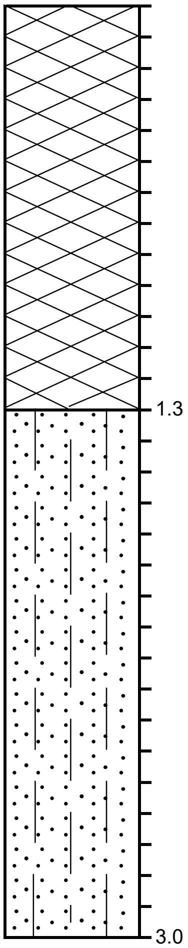
PROFILE SHEET

TP127

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457805
Y -090034



Moist, light brown, appears very loose, SAND with abundant roots to 0,4 m. *Fill.*

Moist to very moist, orange brown, appears loose, SILTY SAND with pockets of medium dense weakly cemented silty sand. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole located in rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 2-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

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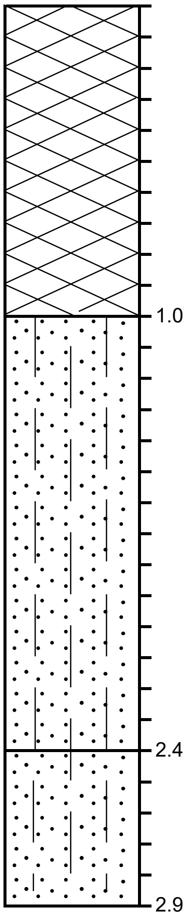
PROFILE SHEET

TP128

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457691
Y -089926



Moist to very moist, light brown, very loose, SAND with few roots . *Fill.*

Moist to very moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

Moist, orange brown mottled yellow brown, appears to be medium dense, SILTY SAND with pockets of weakly cemented silty sand. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 2,9 m. Refusal on very dense sand. Hole located on old rehabilitated area.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 1-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
I Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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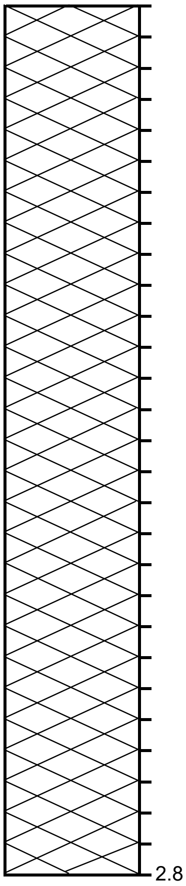
PROFILE SHEET

TP129

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457591
Y -089830



Moist to very moist, light brown, <u>very loose</u>, SAND with few roots to 0,5 m. *Fill.*

NOTES:
1. Bottom of hole at 2,8 m. Not to refusal. Hole located in old rehabilitated area. Hole keeps collapsing without getting deeper. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 1-Sep-20

▽	Water seepage	■	Undisturbed sample	Ɪ	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
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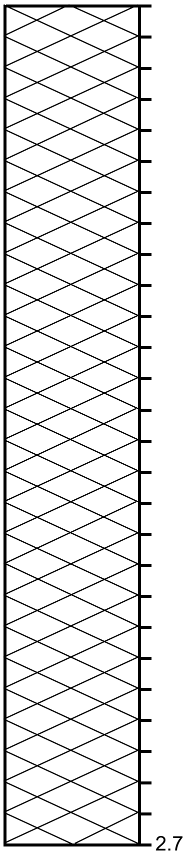
PROFILE SHEET

TP130

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457490
Y -089734



Moist to very moist, light brown, very loose, SAND with few roots to 0,5 m. *Fill.*

NOTES:
1. Bottom of hole at 2,7 m. Not to refusal. Hole located in old rehab area. Hole keeps collapsing without getting deeper. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 1-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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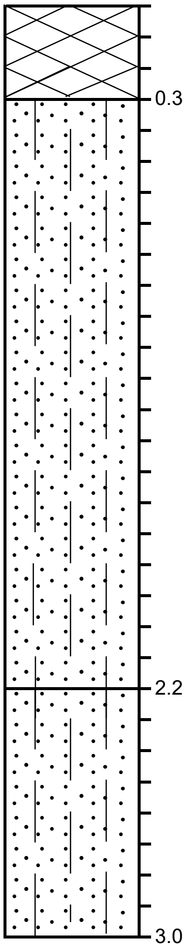
PROFILE SHEET

TP132

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457265
Y -089564



Depth (m)	
0.3	Moist, orange brown, appears to be loose, SAND. *Fill.*
2.2	Moist, orange brown mottled yellow brown appears to be loose, SILTY SAND. *Aeolian/Fill?*
3.0	Moist, orange brown mottled yellow brown, appears to be loose to medium dense, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to the ramp being on the road.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 3-Sep-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
Sheet 1 of 1

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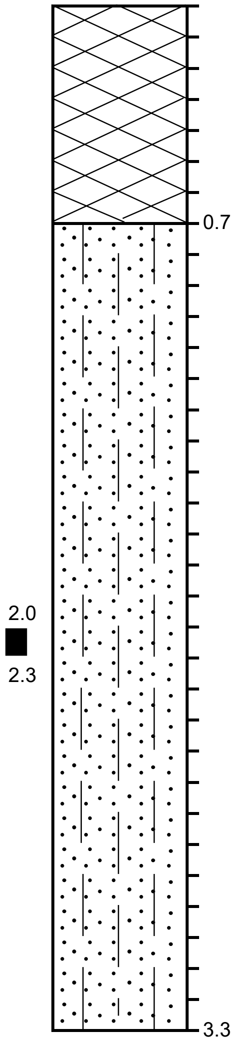
PROFILE SHEET

TP133

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457156
Y -089669



Very moist, dark brown, very loose, SILTY SAND with abundant fine roots below 0,4 m. *Fill.*

Moist to very moist, orange brown, medium dense to dense, SILTY SAND. *Aeolian.*

Loose between 2,3 to 2,7 m.

Medium dense below 2,7 m.

Contains occasional 0,2 m wide and vertical pockets of loose sand and abundant dense dorbank cobbles to 1,2 m.

NOTES:
1. Bottom of hole at 3,3 m. Not to refusal.
   Hole excavated next to the road and moved slightly from the original position.
2. Undisturbed sample taken from 2,0 to 2,3 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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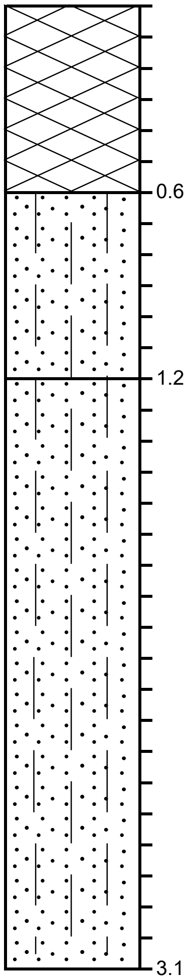
PROFILE SHEET

TP134

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457083
Y -089754



Very moist, dark brown, very loose, silty SAND with abundant roots. *Fill.*

Very moist, orange brown, appears to be medium dense to dense, SILTY SAND with occasional pockets of light brown sand and friable cobbles and small boulders. *Weakly cemented aeolian.*

Very moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Hole excavated on side of road.
   Hole profiled from outside due to the ramp being on the road.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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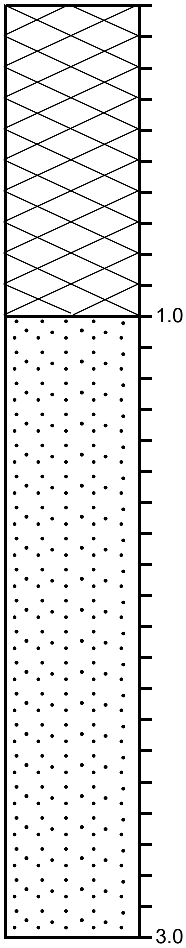
PROFILE SHEET

TP135

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3456986
Y -089866



Moist to very moist, light brown, appears to be <u>very loose</u>, silty SAND with few fine gravels. *Fill/Stockpile.*

Very moist, light brown, silty SAND with scattered roots. *Aeolian/Dune.*

Appears <u>very loose</u>.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage ■ Undisturbed sample ⌶ Bulk sample
▼ Standing water ● Disturbed sample ⊢⊣ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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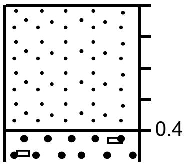
PROFILE SHEET

TP136

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3456893
Y -089975



Very moist, light brown, very loose, silty SAND. *Aeolian/Dune.*

NOTES:
1. Bottom of hole at 0,4 m. Refusal on very soft rock hardpan dorbank. Approximately 4,0 m of aeolian/dune has been removed/mined off the present ground and hole is moved off the adjacent stockpile slope.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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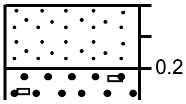
PROFILE SHEET

TP137

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3456966
Y -090043



Very moist, light brown, very loose, silty SAND. *Aeolian/Dune.*

NOTES:
1. Bottom of hole at 0,2 m. Refusal on very soft rock hardpan dorbank.
   Hole moved out of road.
   Aeolian/dune layer has been removed/mined off the present ground surface.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g
Sheet 1 of 1

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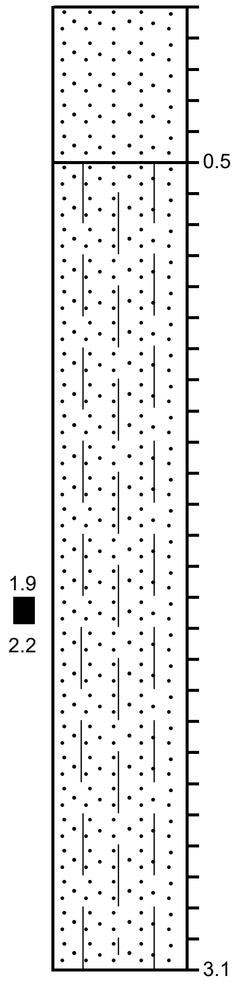
PROFILE SHEET

TP138

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457145
Y -090151



Very moist, light brown, very loose, silty SAND . *Aeolian/Dune.*

Very moist, orange brown, loose, SILTY SAND. *Aeolian.*

Below 2,5 m becomes mottled yellow brown, loose to medium dense with scattered friable nodules.

Medium dense at base.

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
2. Undisturbed sample taken from 1,9 to 2,2 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping
Date profiled: 3-Sep-20

▽ Water seepage	■ Undisturbed sample	⌶ Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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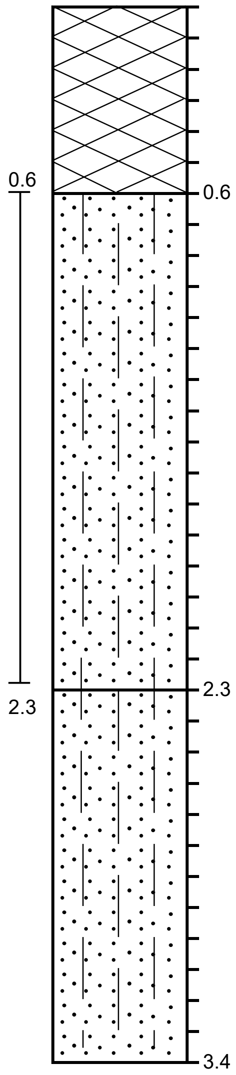
PROFILE SHEET

TP139

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457131
Y -089937



0.0 – 0.6: Moist, light brown, loose, SILTY SAND with scattered friable cobbles. *Fill.*

0.6 – 2.3: Moist, orange brown, dense, moderately cemented SILTY SAND with pockets of very dense friable cobbles and small boulders. *Moderately cemented aeolian.*

2.3 – 3.4: Moist, orange brown, medium dense, slightly pinholed, SILTY SAND. *Aeolian.*

Becomes loose below 2,6 m.

NOTES:
1. Bottom of hole at 3,4 m. Not to refusal.
   Hole moved out of road. Aeolian/dune layer has been removed/mined off the present ground surface.
2. Bulk sample taken from 0,6 to 2,3 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
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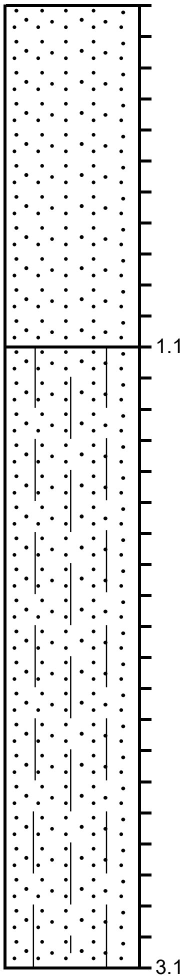
PROFILE SHEET

TP140

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457299
Y -089740



Very moist, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

Varies from 1,1 to 1,8 m in thickness.

Very moist, orange brown, appears to be loose, SILTY SAND with pockets of friable ferricrete boulders. *Weakly cemented aeolian.*

NOTES:
1. Bottom of hole at 3,1 m. Not to refusal.
   Topsoil removed. Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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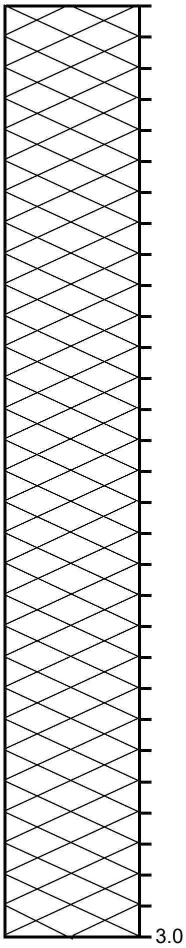
PROFILE SHEET

TP141

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457305
Y -089938



Moist to very moist, orange brown, very loose, SAND with scattered friable ferricrete boulders. *Fill.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole keeps collapsing without getting deeper. Hole profiled from outside due to sidewall collapse.
   Hole positioned on fill stockpile about 1,5 m above natural ground surface.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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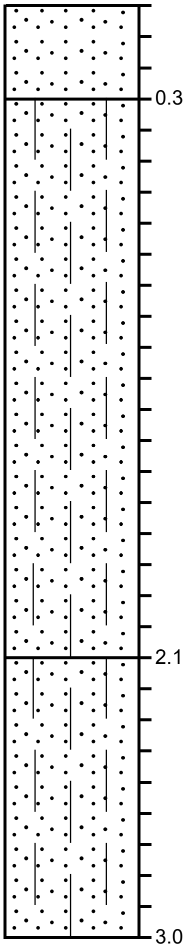
PROFILE SHEET

TP142

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457308
Y -090144



0.3	Very moist, light brown, <u>very loose</u>, silty SAND. *Aeolian/Dune.*
2.1	Slightly moist, orange brown, appears to be <u>medium dense to dense</u>, weakly cemented SILTY SAND. *Weakly cemented aeolian.*
3.0	Moist, orange brown, appears to be <u>loose</u>, SILTY SAND. *Aeolian.*

NOTES:

1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole moved off stockpile slope.
   About 2,5 m of aeolian/dune layer has been removed/mined off the present ground surface.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽	Water seepage	■	Undisturbed sample	⌶	Bulk sample
▼	Standing water	●	Disturbed sample	⊢⊣	*In-situ* test

Ref: 2027/g

Sheet 1 of 1

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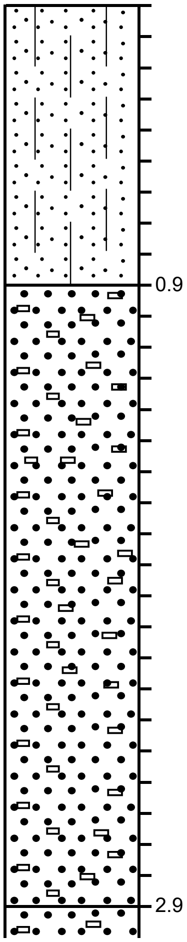
PROFILE SHEET

TP143

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457311
Y -090338



Moist, light brown, SILTY SAND with scattered dorbank boulders. *Disturbed Aeolian.*

Appears very loose.

Clast supported, sub-angular, dorbank coarse GRAVELS, COBBLES and scattered small BOULDERS in a matrix of moist, orange brown, silty sand. *Boulder dorbank.*

Appears to be dense and moderately cemented.

NOTES:
1. Bottom of hole at 2,9 m. Partial refusal on cemented dorbank boulders.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: MC Shuping/L Richer
Date profiled: 3-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g

Sheet 1 of 1

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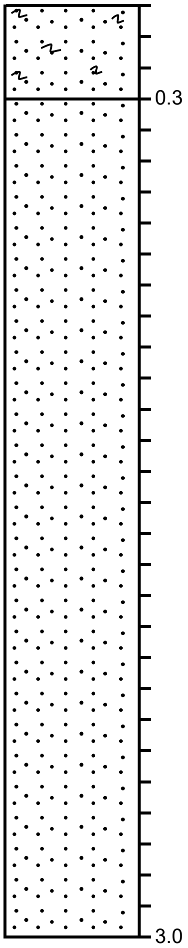
PROFILE SHEET

TP144

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457486
Y -090130



Moist, light brown, silty SAND with few roots. *Aeolian/Dune.*
Appears very loose.

Moist becoming slightly moist with depth, light brown, silty SAND. *Aeolian/Dune.*

Appears very loose.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse. Hole moved out of road.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage	■ Undisturbed sample	I Bulk sample
▼ Standing water	● Disturbed sample	⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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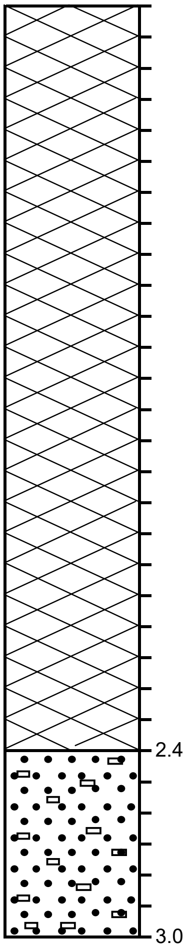
PROFILE SHEET

TP145

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457471
Y -089920



Moist to very moist, orange brown, very loose, SAND. *Fill.*

Matrix supported, friable ferricrete COBBLES and coarse NODULES in a matrix of moist, orange brown, silty sand. *Nodular ferricrete.*

Overall consistency is medium dense to dense.

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. No groundwater seepage encountered.
3. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
⌶ Bulk sample
⊢⊣ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

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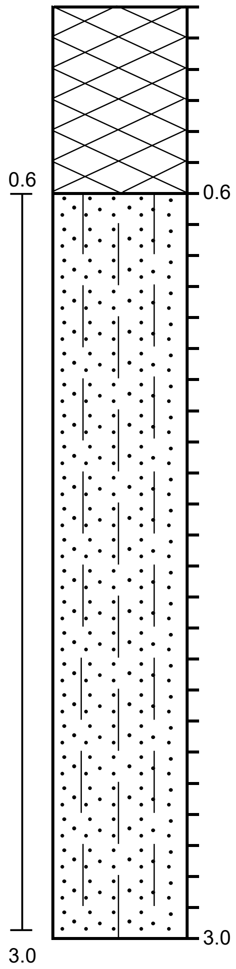
PROFILE SHEET

TP146

Epoch Resources (Pty) Ltd
Namakwa Sands - Overburden Facility

X 3457638
Y -090031



Moist to very moist, orange brown, very loose, SAND. *Fill.*

Moist, orange brown, appears to be loose, SILTY SAND. *Aeolian.*

NOTES:
1. Bottom of hole at 3,0 m. Not to refusal.
   Hole profiled from outside due to sidewall collapse.
2. Bulk sample taken from 0,6 to 3,0 m.
3. No groundwater seepage encountered.
4. Co-ordinates determined from Garmin hand-held GPS to WGS 84 system.

Contractor: Joetsie
Machine: Volvo BL71B

Profiled by: L Richer
Date profiled: 2-Sep-20

▽ Water seepage
▼ Standing water
■ Undisturbed sample
● Disturbed sample
Ɪ Bulk sample
├┤ *In-situ* test

Ref: 2027/g
Sheet 1 of 1

Summary of Profiles 1 - Namakwa Sands RSF

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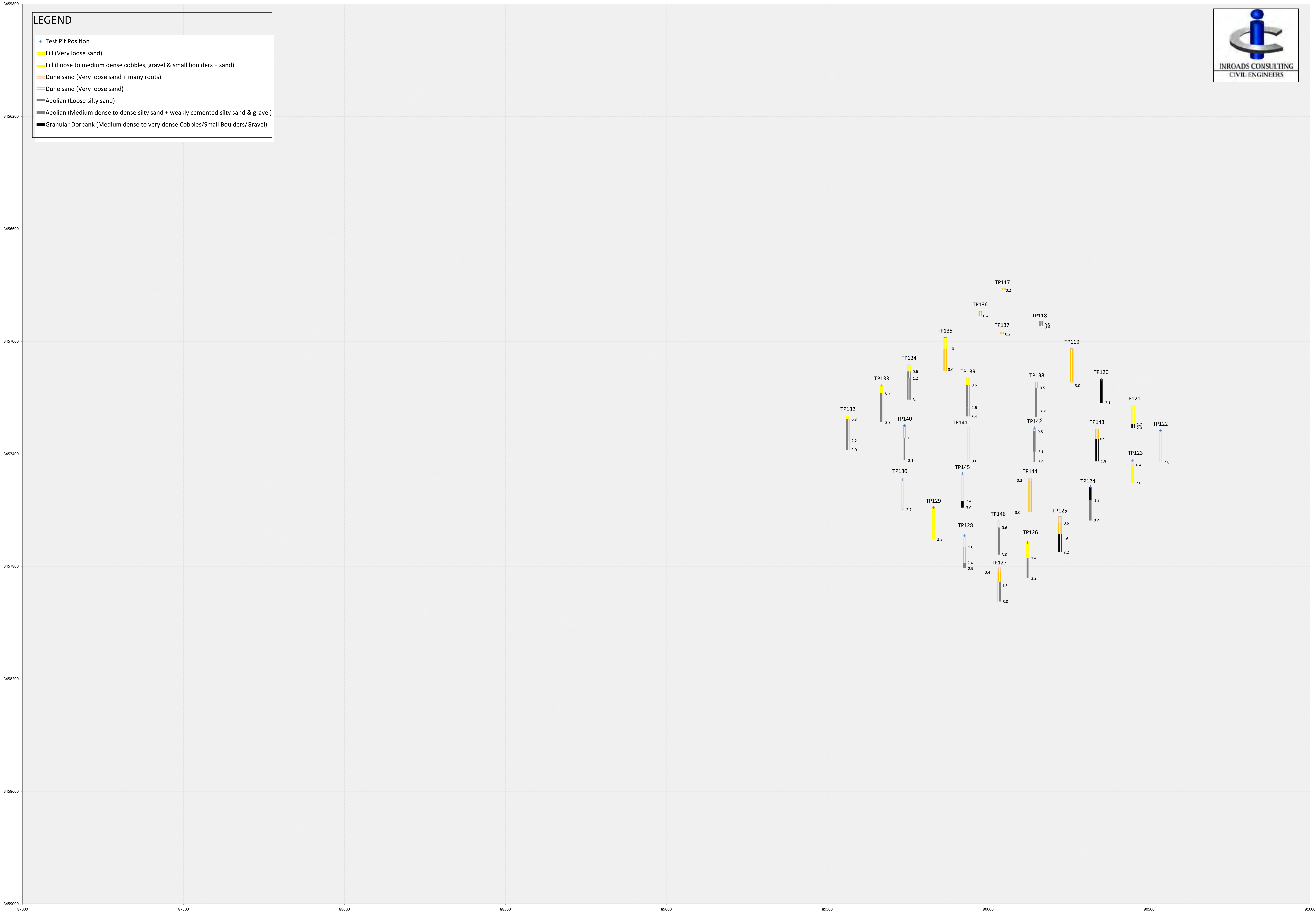
Summary of Profiles 2 - Namakwa Sands - Overburden Facility



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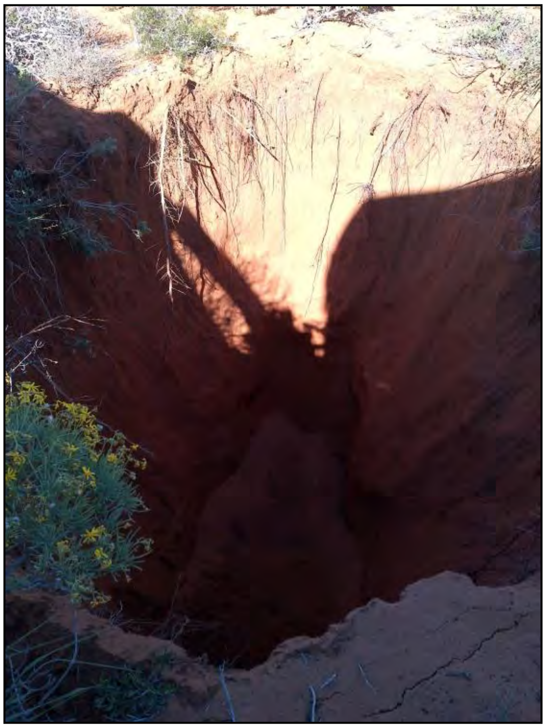
APPENDIX E

Photographs of Test Pits

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **1**	
Comments: TP01	
PHOTOGRAPH **2**	
Comments: TP03	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

3

Comments: TP05

PHOTOGRAPH

4

Comments: TP06

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **5**	
Comments: TP07	
PHOTOGRAPH **6**	
Comments: TP08	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **7**	
Comments: TP10	
PHOTOGRAPH **8**	
Comments: TP11	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

9

Comments: TP13

PHOTOGRAPH

10

Comments: TP16

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

11

Comments: TP17

PHOTOGRAPH

12

Comments: TP18

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

13

Comments: TP20

PHOTOGRAPH

14

Comments: TP22

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

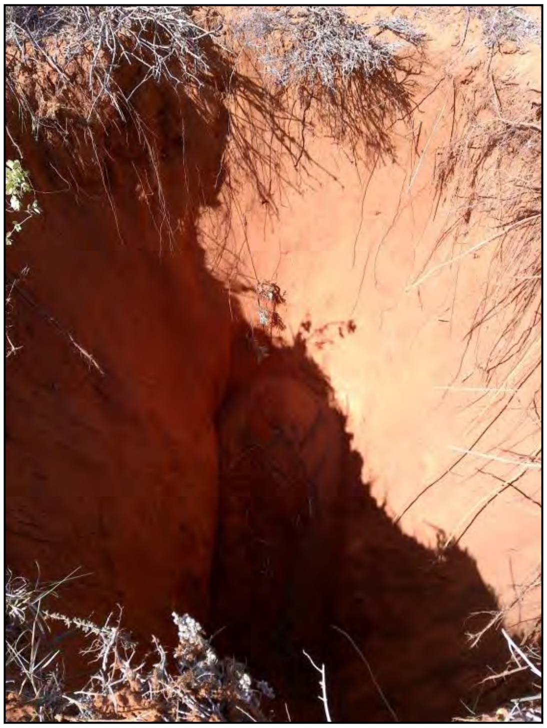
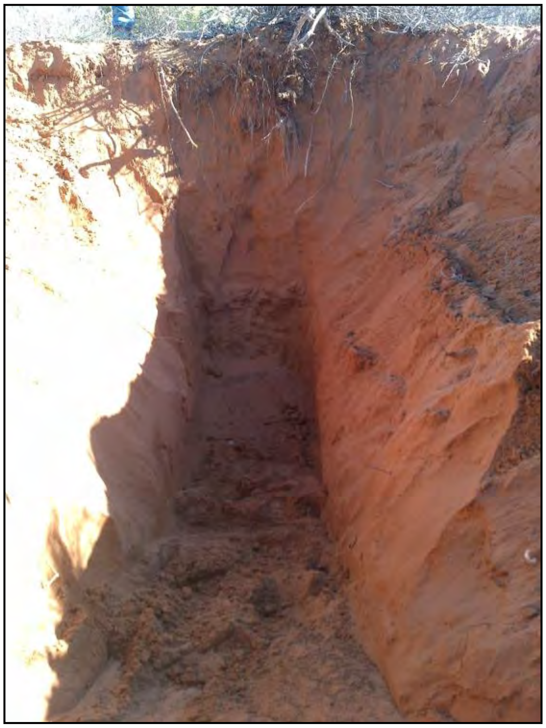
15

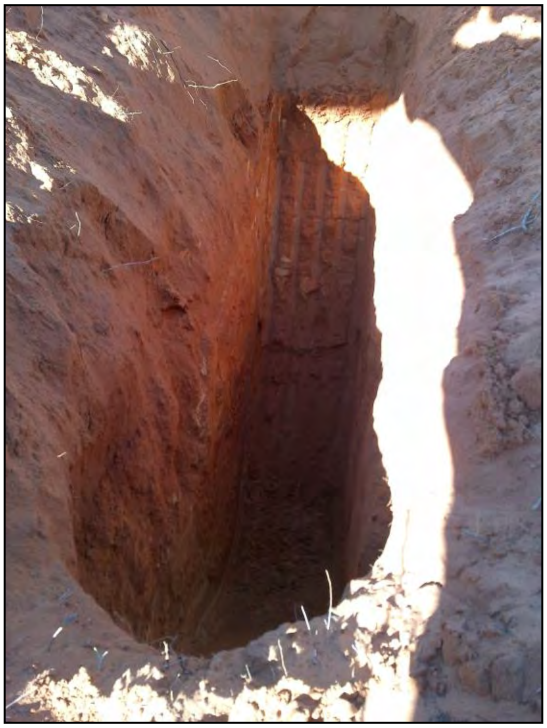
Comments: TP23

PHOTOGRAPH

16

Comments: TP24

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH 17	
Comments: TP25	
PHOTOGRAPH 18	
Comments: TP26	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **19**	
Comments: TP27	
PHOTOGRAPH **20**	
Comments: TP29	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

21

Comments: TP30

PHOTOGRAPH

22

Comments: TP31

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

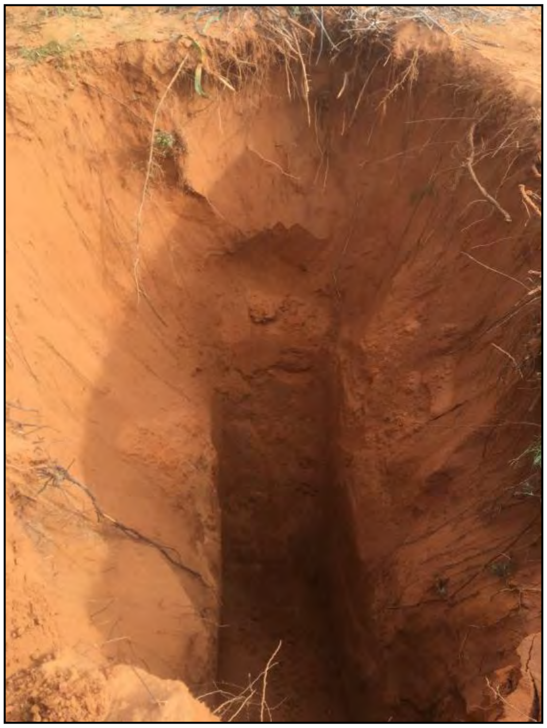
23

Comments: TP34

PHOTOGRAPH

24

Comments: TP35

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **25**	
Comments: TP36	
PHOTOGRAPH **26**	
Comments: TP37	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **27**	
Comments: TP38	
PHOTOGRAPH **28**	
Comments: TP39	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **29**	
Comments: TP40	
PHOTOGRAPH **30**	
Comments: TP41	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

31

Comments: TP42

PHOTOGRAPH

32

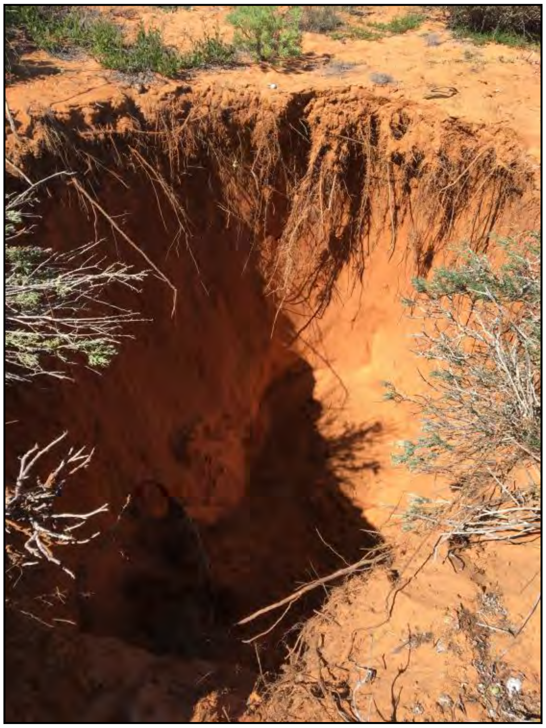
Comments: TP43

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **33**	
Comments: TP44	
PHOTOGRAPH **34**	
Comments: TP47	

TEST PIT PHOTOGRAPHS

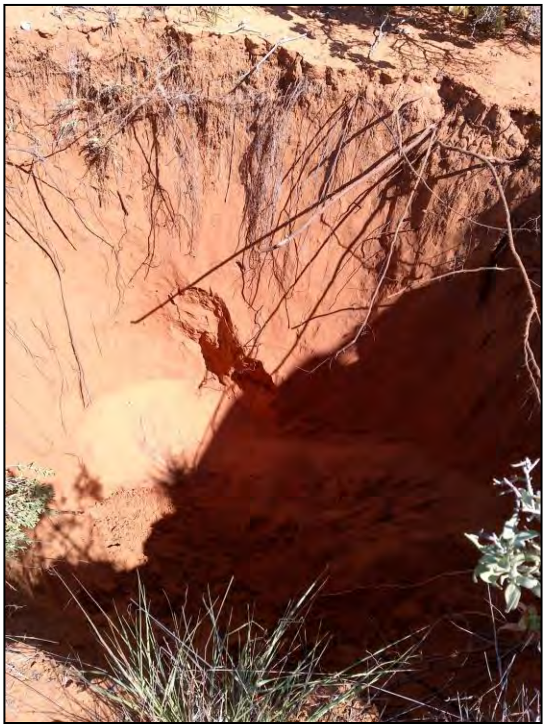
SITE NAME: Namakwa Sands RSF

PHOTOGRAPH **35**	
Comments: TP48	
PHOTOGRAPH **36**	
Comments: TP49	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **37**	
Comments: TP50	
PHOTOGRAPH **39**	
Comments: TP52	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH 38	
Comments: TP55	
PHOTOGRAPH 40	
Comments: TP56	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **41**	
Comments: TP57	
PHOTOGRAPH **42**	
Comments: TP59	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **43**	
Comments: TP60	
PHOTOGRAPH **44**	
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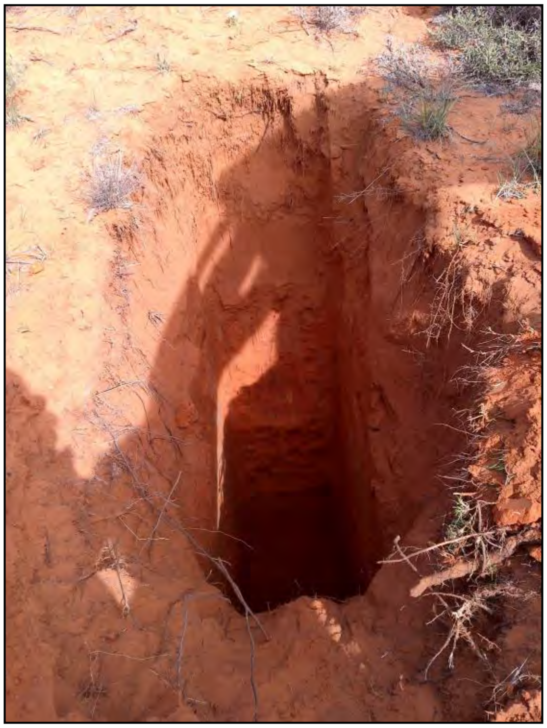
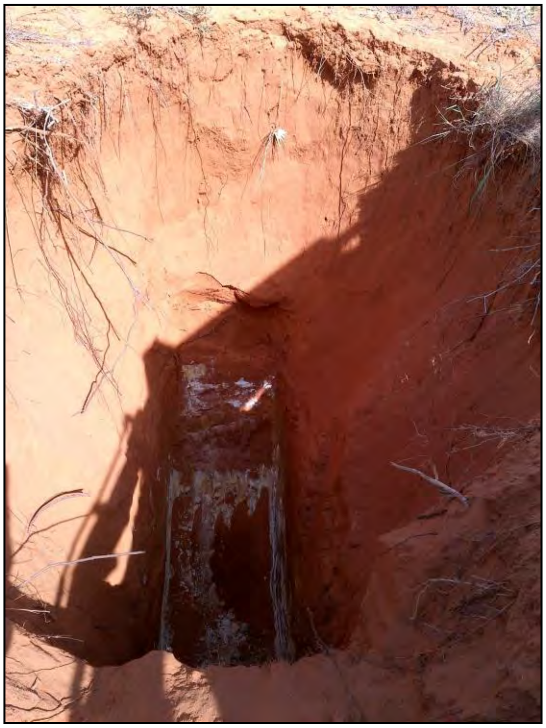
TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **45**	
Comments: TP62	
PHOTOGRAPH **46**	
Comments: TP64	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **47**	
Comments: TP65	
PHOTOGRAPH **48**	
Comments: TP66	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **49**	
Comments: TP67	
PHOTOGRAPH **50**	
Comments: TP68	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **51**	
Comments: TP70	
PHOTOGRAPH **52**	
Comments: TP72	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **53**	
Comments: TP73	
PHOTOGRAPH **54**	
Comments: TP74	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

55

Comments: TP75

PHOTOGRAPH

56

Comments: TP76

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

57

Comments: TP77

PHOTOGRAPH

58

Comments: TP78

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **59**	
Comments: TP79	
PHOTOGRAPH **60**	
Comments: TP81	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH **61**	

Comments: TP83

PHOTOGRAPH **62**	

Comments: TP84

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **63**	
Comments: TP85	
PHOTOGRAPH **64**	
Comments: TP86	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

65

Comments: TP87

PHOTOGRAPH

66

Comments: TP89

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

67

Comments: TP92

PHOTOGRAPH

68

Comments: TP95

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **69**	
Comments: TP96	
PHOTOGRAPH **70**	
Comments: TP97	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **71**	
Comments: TP99	
PHOTOGRAPH **72**	
Comments: TP101	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands RSF

PHOTOGRAPH

73

Comments: TP103

PHOTOGRAPH

74

Comments: TP105

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands RSF	
PHOTOGRAPH **75**	
Comments: TP106	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **76**	
Comments: TP117	
PHOTOGRAPH **77**	
Comments: TP118	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **78**	
Comments: TP119	
PHOTOGRAPH **79**	
Comments: TP120	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

80

Comments: TP121

PHOTOGRAPH

81

Comments: TP122

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

82

Comments: TP123

PHOTOGRAPH

83

Comments: TP124

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

84

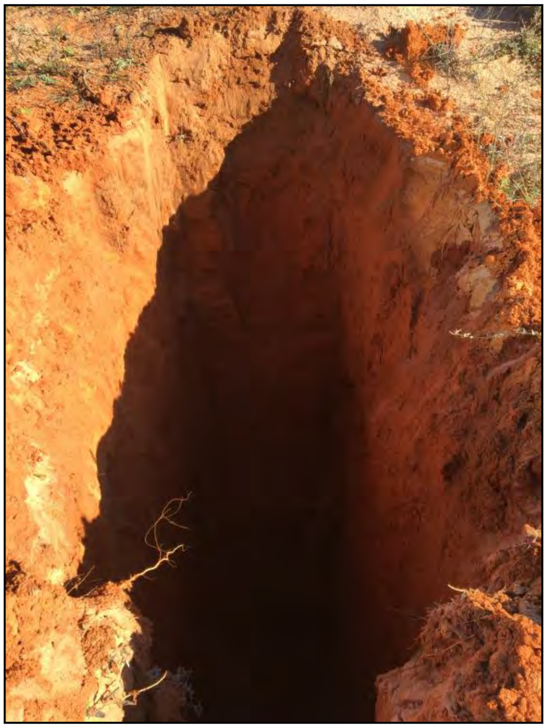
Comments: TP125

PHOTOGRAPH

85

Comments: TP128

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **86**	
Comments: TP129	
PHOTOGRAPH **87**	
Comments: TP130	

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **88**	
Comments: TP132	
PHOTOGRAPH **89**	
Comments: TP133	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

90

Comments: TP134

PHOTOGRAPH

91

Comments: TP135

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

92

Comments: TP136

PHOTOGRAPH

93

Comments: TP137

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH **94**	

Comments: TP138

PHOTOGRAPH **95**	

Comments: TP139

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **96**	
Comments: TP140	
PHOTOGRAPH **97**	
Comments: TP141	

TEST PIT PHOTOGRAPHS

SITE NAME: Namakwa Sands Overburden Facility

PHOTOGRAPH

98

Comments: TP142

PHOTOGRAPH

99

Comments: TP144

TEST PIT PHOTOGRAPHS	
SITE NAME: Namakwa Sands Overburden Facility	
PHOTOGRAPH **100**	
Comments: TP145	
PHOTOGRAPH **101**	
Comments: TP146	

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APPENDIX F

Borehole Logs

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BOREHOLE LOG

Borehole No
NRSF01

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457398
Y -088101

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	-					
	NWD4	0	0	-			1.0		
	SPT	0	0		↓	N= 32	2.0		
	NWD4	0	0	-			3.0		Dark brown becoming slightly reddish brown mottled and stained black with depth, SAND. *Dune sand/Aeolian.*
	SPT	0	0		↓	N= 28			Contains abundant friable weakly cemented sand below 4,8 m.
	NWD4	0	0	- -			4.0		
	SPT	0	0		↓	Ref.	5.0		
	NWD4	0	0	-			6.0		5.5
	SPT	0	0		↓	Ref.			
	NWD4	0	0	- -			7.0		Light brown mottled dark red brown, SAND with abundant friable cemented pockets/gravel. *Aeolian.* Becomes orange and more silty below 8,0 m.
	SPT	0	0		↓	N= 57	8.0		
	NWD4	0	0	-			9.0		Contains scattered gravel at base. 9.0
	NWD4	0	0	-			10.0		Dark orange mottled light brown, SILTY SAND. *Aeolian.*

------ Drilling progress/shift
═ Casing depth
▼ Standing water
↓ SPT Test
█ Undisturbed sample
● Disturbed sample
P Point load test (MPa)
N SPT result

Contractor: Geogroup
Driller: A Mboneni
Machine: P100 (Delta)
Logged by: MC Shuping

Drilling started: 11-Dec-20
Drilling completed: 14-Dec-20
No of core boxes: 3
Date: 25-Jan-21

BOREHOLE LOG

Borehole No
NRSF01 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457398
Y -088101

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	-					Dark orange mottled light brown, SILTY SAND. *Aeolian.* 10.7
	NWD4	0	0	-			11.0 12.0		
	NWD4	0	0	- -			13.0		
	NWD4	0	0	-			14.0		Khaki mottled and speckled orange, slightly clayey SILTY SAND. *Weakly cemented aeolian?*
	NWD4	0	0	-			15.0 16.0		Becomes more orange below 19,8 m.
	NWD4	0	0	- -			17.0		
	NWD4	0	0	-			18.0 19.0		
	NWD4	0	0	-			20.0		

------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 11-Dec-20
═ Casing depth	● Disturbed sample	Driller: A Mboneni	Drilling completed: 14-Dec-20
▼ Standing water	P Point load test (MPa)	Machine: P100 (Delta)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF01 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457398
Y -088101

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
	NWD4	0	0	-					Orange brown, slightly clayey SILTY SAND. *Weakly cemented aeolian?* 20.85

Bottom of hole at 20.85 m.

-------	Drilling progress/shift	■	Undisturbed sample	Contractor:	Geogroup
═	Casing depth	●	Disturbed sample	Driller:	A Mboneni
▼	Standing water	P	Point load test (MPa)	Machine:	P100 (Delta)
↓	SPT Test	N	SPT result	Logged by:	MC Shuping

Drilling started: 11-Dec-20
Drilling completed: 14-Dec-20
No of core boxes: 3
Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF02

Project: Namakwa Sand EOFS RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457998
Y -089153

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NXC	0	0	-					
							1.0		Brown mottled dark brown, slightly silty SAND. *Fill/Dune sand?*
	NXC	0	0	-					
	SPT	0	0		↓	N= 12	2.0		1.95
	NWD4	0	0	-					Core loss.
							3.0		3.0
	SPT	0	0		↓	N= 9			Abundant, angular dorbank GRAVELS in a matrix of reddish brown, silty sand. *Gravelly dorbank?* 3.55
				-					
	NWD4	0	0				4.0		Orange brown, SILTY SAND. *Aeolian.*
				-	↓	Ref.			4.5
							5.0		
	NWD4	70	11	>20					Orange brown stained dark red brown, fine grained, highly fractured, very soft rock. DORBANK.
							6.0		
				12					
									6.8
	NWD4	85	34				7.0		
				5					Khaki mottled and speckled dark grey, very fine to fine grained with scattered very coarse particles, highly to moderately fractured, very soft to soft rock and medium hard to hard. DORBANK/SILCRETE?
							8.0		
	NWD4	96	38	15					
									8.8
							9.0		
									Highly weathered, grey mottled light brown and dark orange brown, very fine grained, very highly to highly fractured, hard to very hard rock. ???
	NWD4	89	0	>20					In places appears as angular GRAVELS and COBBLES in a matrix of weakly cemented sandy silt.
							10.0		

------ Drilling progress/shift
═ Casing depth
▼ Standing water
↓ SPT Test

■ Undisturbed sample
● Disturbed sample
P Point load test (MPa)
N SPT result

Contractor: Geogroup
Driller: T Thatelo
Machine: P237 (YWE)
Logged by: MC Shuping

Drilling started: 15-Dec-20
Drilling completed: 17-Dec-20
No of core boxes: 3
Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF02 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457998
Y -089153

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	89	0	>20					10.35
		65	65						
	TNW	8	8				11.0		
				>20					
							12.0		
	NWD4	36	0	>20					Completely to highly weathered, light grey streaked white, very fine to fine grained, very highly to highly fractured, <u>very stiff to very soft rock</u>. LIMESTONE?
							13.0		Becomes highly to moderately fractured below 13.5 m.
				>20					
	NWD4	100	27				14.0		
				10					
							15.0		15.0
	NWD4	8	0	-					15.2 Grey, CLAYEY SILT with abundant gravel. *Completely weathered limestone?*
							16.0		Core loss.
				-					16.5
	NWD4	0	0						16.7 Angular, coarse GRAVELS. *Residual?*
							17.0		
				-					Core loss.
							18.0		18.0
	NWD4	0	0	-					Core loss.
							19.0		19.0
	SPT	0	0	-	↓	N= 84			Sub-angular, fine medium and coarse GRAVEL in a matrix of dark grey, sandy clayey silt. *Residual?* 19.45

Bottom of hole at 19,45 m.

-------- Drilling progress/shift	■ Undisturbed sample	Contractor: Geogroup	Drilling started: 15-Dec-20
═ Casing depth	● Disturbed sample	Driller: T Thatelo	Drilling completed: 17-Dec-20
▼ Standing water	P Point load test (MPa)	Machine: P237 (YWE)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF03

Project: Namakwa Sand EOFS
Overburden Facility

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457402
Y -089664

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m
Rotary Core Drilling	NXC	0	0	-			1.0
	NXC	0	0	-			
	SPT	0	0		↓	N= 3	2.0
	NWD4	0	0	-			3.0
	SPT	0	0	-	↓	N= 16	
	NWD4	0	0				4.0
	NWD4	0	0	-			
	SPT	0	0		↓	N= 22	5.0
	NWD4	0	0	-			
	NWD4	0	0				6.0
	SPT	0	0	-	↓	N= 21	
	NWD4	0	0	-			7.0
	SPT	0	0		↓	N= 54	8.0
	NWD4	0	0	-			
	NWD4	0	0				9.0
	SPT	0	0	-	↓	N= 60	
	NWD4	0	0				10.0

Depth to base	Description
4.95	Brown, SAND with occasional dark grey SILTY SAND below 0,9 to 1,5 m and 3,0 to 4,95 m. *Dune sand/Fill?*
7.5	Dark grey brown speckled reddish brown. SILTY SAND. *Aeolian?* Contains abundant grey and orange brown friable weakly cemented sand below 7,0 m.
	Alternating orange brown, light yellow brown and light brown, SAND. *Aeolian.*

- - - - - Drilling progress/shift
═ Casing depth
▼ Standing water
↓ SPT Test
█ Undisturbed sample
● Disturbed sample
P Point load test (MPa)
N SPT result

Contractor: Geogroup
Driller: T Thatelo
Machine: P237 (YWE)
Logged by: MC Shuping

Drilling started: 10-Dec-20
Drilling completed: 14-Dec-20
No of core boxes: 3
Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF03 Cont.

Project: Namakwa Sand EOFS
Overburden Facility

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457402
Y -089664

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	-					
	SPT	0	0		↓	N= 63	11.0		
	NWD4	0	0	-			12.0		
	SPT	0	0	-	↓	Ref.			
	NWD4	0	0	-			13.0		Alternating orange brown, light yellow brown and light brown, SAND. *Aeolian*.
	SPT	0	0		↓	N= 55	14.0		Contains grey to light brown clayey silt between 12,1 to 12,2 m and 13,5 to 13,6 m.
	NWD4	0	0	-			15.0		
	SPT	0	0	-	↓	N= 69			
	NWD4	0	0	-			16.0		
	SPT	0	0		↓	N= 66	17.0		
	NWD4	0	0	-			18.0		
	SPT	0	0	-	↓	N= 77			
	NWD4	0	0	-			19.0		
	SP	0	0		↓	Ref.			19.87

Bottom of hole at 19.87 m.

------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 10-Dec-20
═ Casing depth	● Disturbed sample	Driller: T Thatelo	Drilling completed: 14-Dec-20
▼ Standing water	P Point load test (MPa)	Machine: P237 (YWE)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF05

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3458175
Y -088194

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NXC	0	0	-			1.0		Dark brown, SAND. *Fill/Dune sand.*
	NXC	0	0	-					
	SPT	0	0		↓	N= 17	2.0		
	NWD4	0	0	-			3.0		
	SPT	0	0	-	↓	N= 9			
	NWD4	0	0	-			4.0		3.5 Dark reddish brown, SILTY SAND. *Aeolian.*
	SPT	0	0		↓	N= 21	5.0		Contains abundant ferruginised hard gravel at base.
	NWD4	0	0	-					
	NWD4	0	0				6.0		5.4 Orange and light yellow brown, SAND. *Aeolian.*
	SPT	0	0	-	↓	N= 27			
	NWD4	0	0	-			7.0		
	SPT	0	0		↓	N= 39	8.0		
	NWD4	0	0	-			9.0		Contains abundant friable weakly cemented sand between 8,0 to 9,2 m and 10,5 to 11,0 m.
	SPT	0	0	-	↓	N= 75			
	NWD4	0	0				10.0		

- - - - -	Drilling progress/shift	▮	Undisturbed sample
═	Casing depth	●	Disturbed sample
▼	Standing water	P	Point load test (MPa)
↓	SPT Test	N	SPT result

Contractor:	Geogroup	Drilling started:	18-Dec-20
Driller:	T Thatelo	Drilling completed:	19-Dec-20
Machine:	P237 (YWE)	No of core boxes:	3
Logged by:	MC Shuping	Date:	26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF05 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3458175
Y -088194

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol		Description
Rotary Core Drilling	NWD4	0	0	-						Orange and light yellow brown, SAND. *Aeolian.* Contains abundant friable weakly cemented sand between 10,5 and 11,0 m.
	SPT	0	0		↓	N= 69	11.0		11.0	
	NWD4	0	0	-			12.0		12.0	Slightly dark orange brown, SAND with abundant friable weakly cemented sand and gravel. *Weakly cemented aeolian/weak dorbank.*
	NWD4	92	71	11			13.0			Completely weathered, dark red brown becoming orange brown mottled white with depth, very fine to medium grained, moderately fractured, very dense to very soft rock. WEAKLY CEMENTED & COMPLETELY WEATHERED GRANITE GNEISS. Contains weakly cemented very soft rock WEAK DORBANK to 13,0 m. Contains abundant weathered feldspar vein at base. Breaks into clayey sand.
				4			14.0			
	NWD4	100	97	2			15.0			
	NWD4	85	76	1			16.0			
				-					16.5	
	NWD4	7	0				17.0			Orange brown speckled and mottled white becoming light pink speckled white with depth, SILTY coarse SAND and CLAYEY SANDY SILT. *Residual granite gneiss.*
	NWD4	0	0	-			18.0		18.0	
	NWD4	0	0	-			19.0			White speckled light grey, relict jointed, SILTY coarse SAND. *Residual granite gneiss.*
	NWD4	0	0	-			20.0		20.0	Bottom of hole at 20,0 m.

- - - - Drilling progress/shift
═ Casing depth
▼ Standing water
↓ SPT Test

■ Undisturbed sample
● Disturbed sample
P Point load test (MPa)
N SPT result

Contractor: Geogroup
Driller: T Thatelo
Machine: P237 (YWE)
Logged by: MC Shuping

Drilling started: 18-Dec-20
Drilling completed: 19-Dec-20
No of core boxes: 3
Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF06

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456032
Y -088624

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	-			1.0		
				-					Dark brown, SAND. *Dune sand.*
	SPT	0	0		↓	N= 24	2.0		
	NWD4	0	0	-	↓	Ref.	3.0		3.0
	NWD4	0	0	-			4.0		
				-			5.0		
	NWD4	0	0	-			6.0		Light orange brown, SILTY SAND with occasional friable weakly cemented sand pockets. *Aeolian.*
	NWD4	0	0	-			7.0		Contains abundant friable weakly cemented sand between 8,0 to 9,0 m.
				-			8.0		
	NWD4	0	0	-			9.0		
	SPT	0	0	-	↓	N= 72			
	NWD4	0	0				10.0		

-------	Drilling progress/shift	■	Undisturbed sample
═	Casing depth	●	Disturbed sample
▼	Standing water	P	Point load test (MPa)
↓	SPT Test	N	SPT result

Contractor: Geogroup
Driller: A Mboneni
Machine: P100 (Delta)
Logged by: MC Shuping

Drilling started: 17-Dec-20
Drilling completed: 17-Dec-20
No of core boxes: 3
Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF06 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456032
Y -088624

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m
Rotary Core Drilling	NWD4	0	0	-			
	SPT	0	0		↓	N= 77	11.0
	NWD4	0	0	-			12.0
	SPT	0	0	-	↓	N= 74	
	NWD4	0	0	-			13.0
	SPT	0	0		↓	N= 68	14.0
	NWD4	0	0	-			15.0
	NWD4	12	0	- 7			16.0
	NWD4	100	77	7 -			17.0 18.0
	NWD4	30	23	-			19.0
	NWD4	0	0				20.0

Depth - m	Description
14.7	Orange brown, SILTY SAND with occasional friable weakly cemented sand pockets. *Aeolian.*
16.2	Khaki, weakly cemented SILTY SAND with scattered quartz gravels. *Transported.*
17.7	Khaki mottled orange, fine to medium grained, moderately fractured, very dense to very soft rock. WEAKLY CEMENTED AEOLIAN/DORBANK? Breaks into silty sand similar as above.
18.45	Completely weathered, khaki/cream white, very fine grained, moderately fractured, very stiff to very soft rock. SCHIST?
	Cream white speckled maroon and purple, CLAYEY SILT with little quartz sand. *Completely weathered schist?* Appears to be stiff to very stiff.

-------	Drilling progress/shift
═	Casing depth
▼	Standing water
↓	SPT Test
■	Undisturbed sample
●	Disturbed sample
P	Point load test (MPa)
N	SPT result

Contractor: Geogroup
Driller: A Mboneni
Machine: P100 (Delta)
Logged by: MC Shuping

Drilling started: 17-Dec-20
Drilling completed: 17-Dec-20
No of core boxes: 3
Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF06 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456032
Y -088624

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
		0	0	-					20.1

Bottom of hole at 20.1 m.

-------	Drilling progress/shift	■	Undisturbed sample	Contractor:	Geogroup	Drilling started:	17-Dec-20
═	Casing depth	●	Disturbed sample	Driller:	A Mboneni	Drilling completed:	17-Dec-20
▼	Standing water	P	Point load test (MPa)	Machine:	P100 (Delta)	No of core boxes:	3
↓	SPT Test	N	SPT result	Logged by:	MC Shuping	Date:	26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF07

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456526
Y -087825

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	-			1.0		Dark brown, slightly silty SAND. *Dune sand.* Contains abundant friable weakly cemented sand pockets below 1,5 m.
				-					
	SPT	0	0		↓	N= 20	2.0		1.95
	NWD4	0	0	-			3.0		Light yellow brown, slightly silty SAND. *Aeolian.* Becomes dark orange between 4,5 to 4,95 m and 7,1 to 7,5 m.
	SHELBY	0	0	-					
	SPT	0	0		↓	N= 48	4.0		
	NWD4	0	0	-					
	SPT	0	0		↓	N= 84	5.0		
	NWD4	0	0	-			6.0		
	SPT	0	0	-	↓	Ref.			
	NWD4	0	0				7.0		
				-					7.5
	SH	0	0		↓	Ref.	8.0		
	NWD4	0	0	-			9.0		Khaki mottled orange and orange brown, slightly SILTY SAND with abundant friable weakly cemented sand. Aeolian.
	SPT	0	0	-	↓	N= 78			
	NWD4	0	0				10.0		

- - - - Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 15-Dec-20
═ Casing depth	● Disturbed sample	Driller: A Mboneni	Drilling completed: 16-Dec-20
▼ Standing water	P Point load test (MPa)	Machine: P100 (Delta)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF07 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456526
Y -087825

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result
Rotary Core Drilling	NWD4	0	0	-		
	NWD4	3	0	-		
	NWD4	0	0	- -		
	NWD4	29	16	-		
	NWD4	0	0	- -		
	NWD4	0	0	-		
	SPT	0	0		↓	N= 54
	NWD4	0	0	-		
	SPT	0	0	-		N= 53

Depth - m: 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0

Depth - m	Description
13.6	Khaki mottled orange and orangish brown, slightly SILTY SAND with abundant friable weakly cemented sand. *Aeolian.*
13.8	Highly weathered, khaki stained purple, very fine grained, moderately fractured, very soft rock.
14.1	Highly weathered, dark brown, fine grained, highly fractured, very soft rock. WEAKLY CEMENTED AEOLIAN/WEAK DORBANK?
15.0	Core loss.
19.95	Light yellow mottled dark orange brown to 16,65 m, SAND. *Aeolian?* Contains abundant friable weakly cemented sand below 18,6 m.

Bottom of hole at 19.95 m.

------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 15-Dec-20
═ Casing depth	● Disturbed sample	Driller: A Mboneni	Drilling completed: 16-Dec-20
▼ Standing water	P Point load test (MPa)	Machine: P100 (Delta)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 25-Jan-21

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BOREHOLE LOG

Borehole No
NRSF08

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456950
Y -089123

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NWD4	0	0	- -			1.0		Slightly dark reddish brown, slightly SILTY SAND. *Dune sand/Fill?*
	SPT	0	0		↓	N= 30	2.0		
	NWD4	0	0	-			3.0		3.0
	SPT	0	0	-	↓	N= 49			Slightly orange brown, SILTY SAND. *Aeolian.*
	NWD4	0	0	-			4.0		
	SPT	0	0		↓	N= 48	5.0		
	NWD4	0	0	-			6.0		
	SPT	0	0	-	↓	N= 40			Becomes mottled light brown below 6,5 m.
	NWD4	0	0	-			7.0		
	SPT	0	0		↓	N= 59	8.0		
	NWD4	0	0	-			9.0		9.0
	SPT	0	0	-	↓	Ref.			Light brown/khaki stained dark brown, SAND. *Dune sand/beach sand?*
	NWD4	0	0				10.0		

------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 7-Jan-21
═ Casing depth	● Disturbed sample	Driller: A Mboneni	Drilling completed: 13-Jan-21
▼ Standing water	P Point load test (MPa)	Machine: P100 (Delta)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
NRSF08 Cont.

Project: Namakwa Sand EOFS
RSF

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3456950
Y -089123

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Description
Rotary Core Drilling	NWD4	0	0	-				
	SPT	0	0		↓	N= 40	11.0	
	NWD4	0	0	-			12.0	
	SPT	0	0		↓	N= 65		
	NWD4	7	0	-			13.0	Light brown/khaki stained dark brown, SAND. *Dune sand/beach sand?*
				-				Contains occasional friable weakly cemented gravel between 13,4 to 13,5 m.
	NWD4	0	0	-			14.0 15.0	
	SPT	0	0		↓	N= 68	15.5	
	NWD4	0	0	-			16.0	
	SPT	0	0	-	↓	N= 36	17.0	
	NWD4	0	0	-				Brown, SAND. *Dune sand/beach sand?*
							18.0	
	SPT	0	0		↓	N= 35		
	NWD4	0	0	-			19.0	
				-			19.5	
	NWD4	0	0				20.0	Angular, quartz GRAVELS in a matrix of orange silty sand. *Transported?*
							20.0	Bottom of hole at 20,0 m.

- - - - - - Drilling progress/shift
═ Casing depth
▼ Standing water
↓ SPT Test

▮ Undisturbed sample
● Disturbed sample
P Point load test (MPa)
N SPT result

Contractor: Geogroup
Driller: A Mboneni
Machine: P100 (Delta)
Logged by: MC Shuping

Drilling started: 7-Jan-21
Drilling completed: 13-Jan-21
No of core boxes: 3
Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
CD08

Project: Namakwa Sand EOFS
Overburden Facility

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457567
Y -090274

Elevation:

Orientation: Vertical

Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Symbol	Description
Rotary Core Drilling	NXC	0	0	-			1.0		Slightly dark reddish brown, slightly silty SAND. *Dune sand/Fill?*
	NXC	0	0	-					
	SPT	0	0		↓	N= 13	2.0		2.0
	NWD4	0	0	-			3.0		Orange brown becoming light yellowish brown below 7,8 m, slightly silty SAND. *Aeolian.* Contains scattered friable gravels in places.
	SPT	0	0	-	↓	N= 8			
	NWD4	0	0				4.0		
				-					
	SPT	0	0		↓	N= 61	5.0		
	NWD4	0	0	-			6.0		
	SPT	0	0	-	↓	N= 48			
	NWD4	0	0				7.0		
				-					
	SPT	0	0		↓	N= 61	8.0		
	NWD4	0	0	-			9.0		
	SPT	0	0	-	↓	N= 57			
	NWD4	0	0				10.0		

------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 8-Jan-21
═ Casing depth	● Disturbed sample	Driller: T Thatelo	Drilling completed: 11-Jan-21
▼ Standing water	P Point load test (MPa)	Machine: P237 (YWE)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 26-Jan-21

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BOREHOLE LOG

Borehole No
CD08 Cont.

Project: Namakwa Sand EOFS
Overburden Facility

Location: Tronox Namakwa Sands, Brand-Se-Baai

Ref No: 2027/g

Co-ordinates: X 3457567
Y -090274

Elevation:

Orientation: Vertical

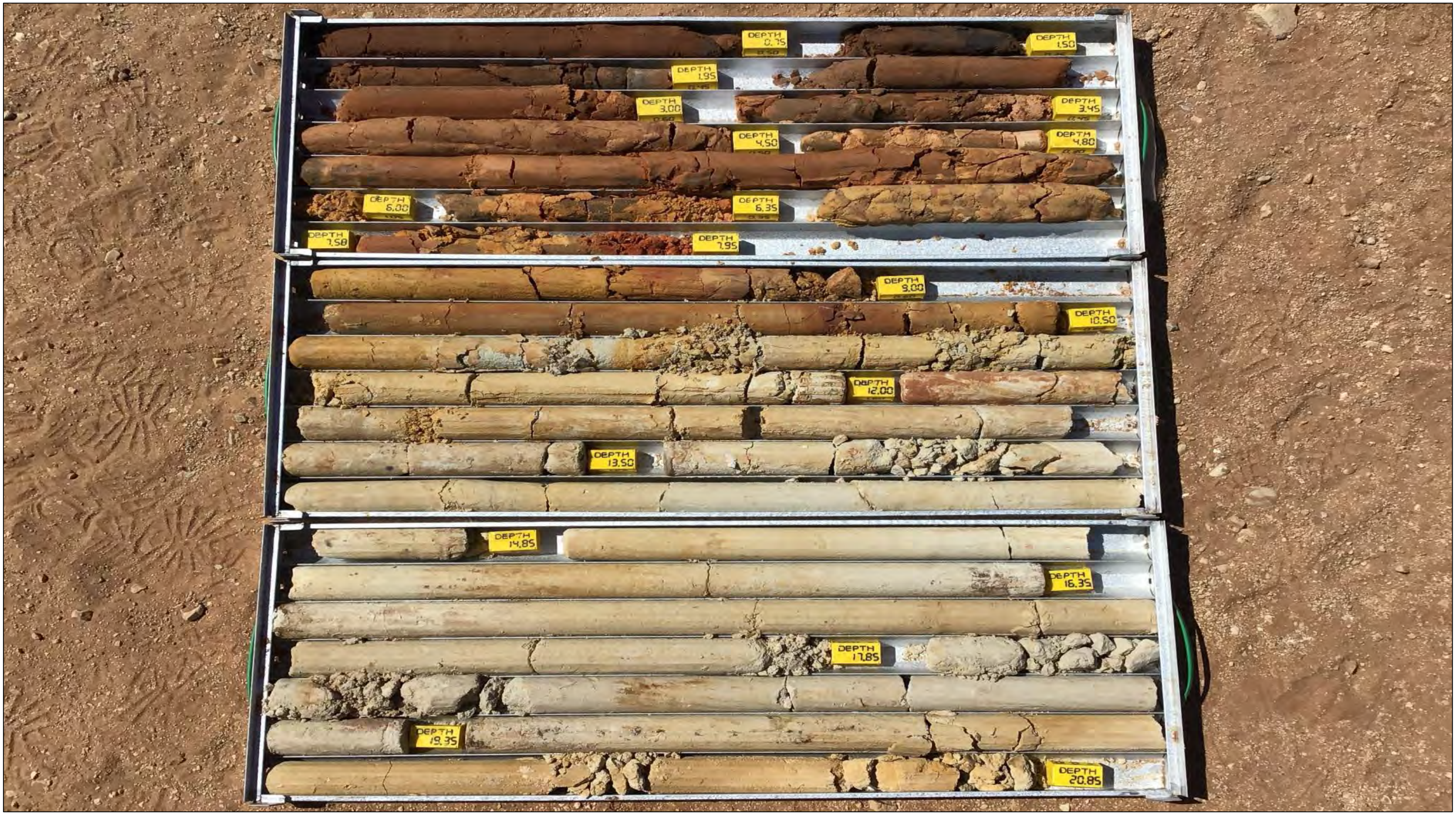
Drilling Method	Size	Core Recovery - %	RQD - %	Fracture Frequency	Test or Sample Type	Test Result	Depth - m	Description
Rotary Core Drilling	NWD4	0	0	-				
	SPT	0	0		↓	N= 56	11.0	
	NWD4	0	0	-			12.0	
	SF	0	0		↓	Ref.		
	NWD4	0	0	- -			13.0	Light yellowish brown, slightly silty SAND. *Aeolian.* Contains light grey brown clayey silt between 10,95 to 11,2 m.
	NWD4	0	0	-			14.0 15.0	Contains scattered friable gravels.
	SPT	0	0		↓	N= 93		
	NWD4	0	0	- -			16.0	
	SPT	0	0		↓	N= 87	17.0	
	NWD4	0	0	-			18.0	
	SF	0	0		↓	Ref.		
	NWD4	0	0	- -			19.0	19.5
	NWD4	0	0				20.0	20.0 Core loss.

Bottom of hole at 20,0 m.

-------- Drilling progress/shift	▮ Undisturbed sample	Contractor: Geogroup	Drilling started: 8-Jan-21
═ Casing depth	● Disturbed sample	Driller: T Thatelo	Drilling completed: 11-Jan-21
▼ Standing water	P Point load test (MPa)	Machine: P237 (YWE)	No of core boxes: 3
↓ SPT Test	N SPT result	Logged by: MC Shuping	Date: 26-Jan-21

APPENDIX G

Borehole Photographs



Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - RSF

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

NRSF01

Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - RSF

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

NRSF02

Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - OVERBURDEN FACILITY

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

NRSF03

Ref: 2027/g	**NAMAKWA SANDS EOFS PROJECT - RSF**	**Borehole**
	PHOTOGRAPHS OF BOREHOLE CORE	**NRSF05**

Ref: 2027/g	**NAMAKWA SANDS EOFS PROJECT - RSF**	**Borehole**
	PHOTOGRAPHS OF BOREHOLE CORE	**NRSF06**

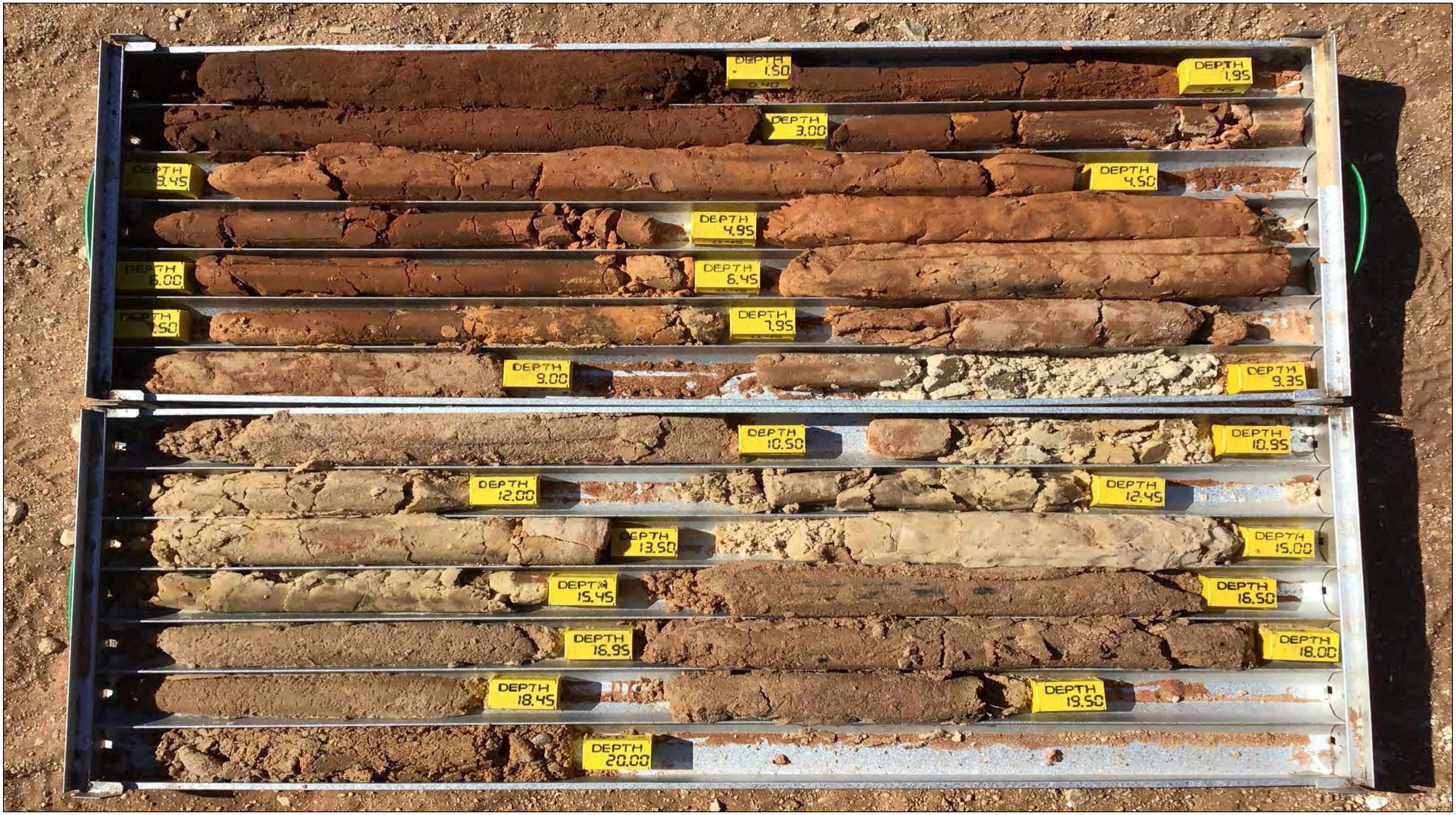
Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - RSF

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

NRSF07



Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - RSF

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

NRSF08

Ref: 2027/g

NAMAKWA SANDS EOFS PROJECT - OVERBURDEN FACILITY

PHOTOGRAPHS OF BOREHOLE CORE

Borehole

CD-08

APPENDIX H

Laboratory Test Results

ROADLAB

Roadlab Laboratories (Pty) Ltd

Civil Materials Testing
BBBEE Level 1 Contributor
Registration No: 2011/005423/07
VAT No: 4670261090

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info@roadlab.co.za
1 Palmiet Road,
Stikland Industrial,
Cape Town ,7530

› material **Passion.**
› trusted **Accuracy.**
› timeous **Excellence.**

CLIENT	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041
ATTENTION:	Mr. Moruti Shuping

TEST REPORT

Job No	CTS01183 B
Ref. No	C.O.D
Date	28.09.2020
Tested/Sampled By:	Client
Date Sampled / Received	16.09.2020
Date Tested	28.09.2020
Sampling Method	As per client
Test Method	(TMH 1 Method A1(a),A2,A3,A4,A5,A6)
Project	Namakwa Sands
Test Type	FOUNDATION INDICATOR
Sampled By	Client
Delivered By	Client
Temp. °C	25°C
Laboratory Tester	Mr. E. Johnson & Me. M. Pitus
Environmental Conditions	Sunny
Remarks / notes	None
Number of pages	19

Special instructions
None

Remarks:

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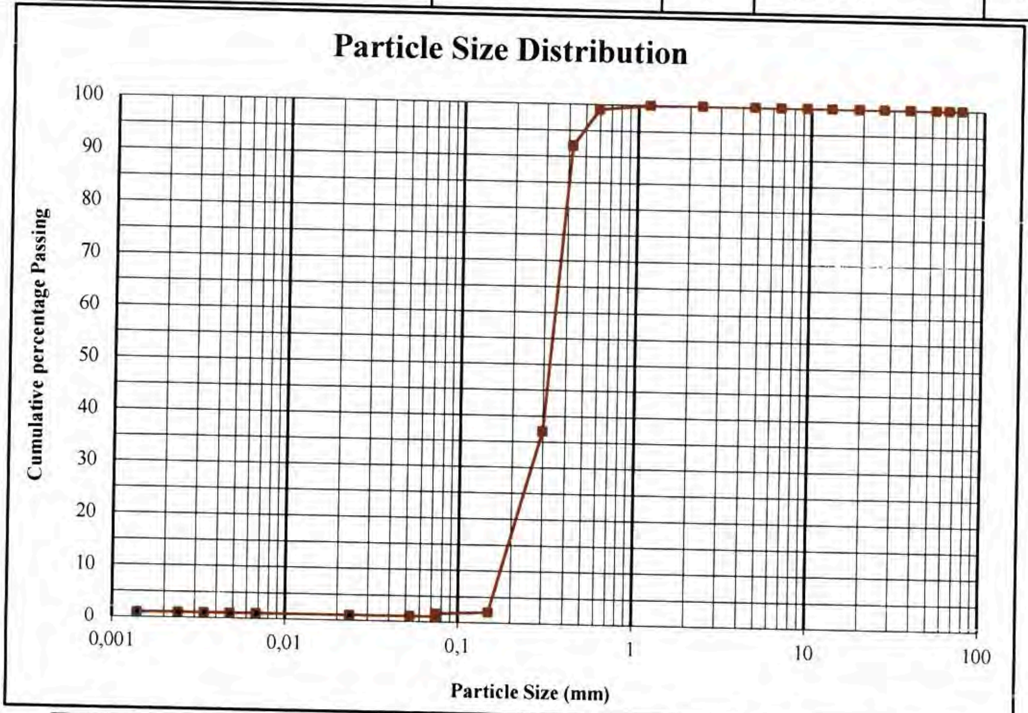
Attention : Mr. Moruti Shuping

Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

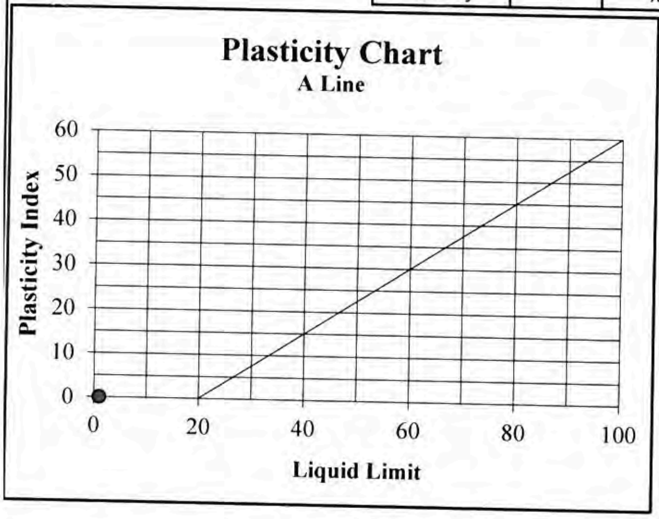
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

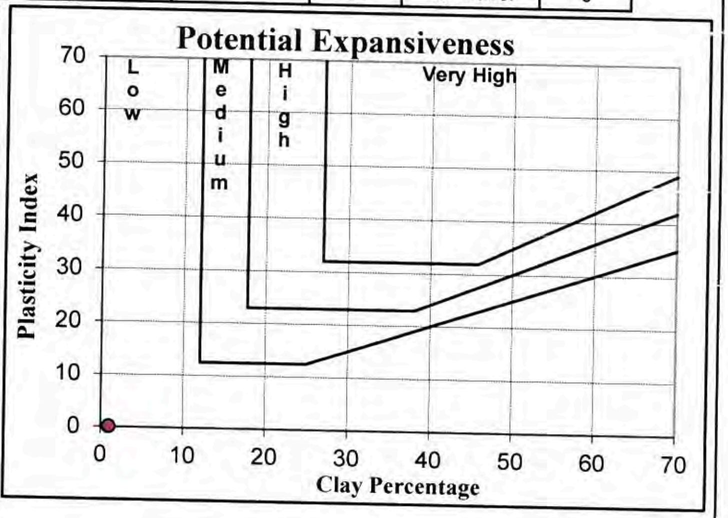
Material Description:	Brown Sand	Sample Number:	51311		
Position:	TP20	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	1.4-1.8m	Plasticity Index	NP	Insitu M/C%	4,8

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	92
0,300	37
0,150	2
0,075	1,6
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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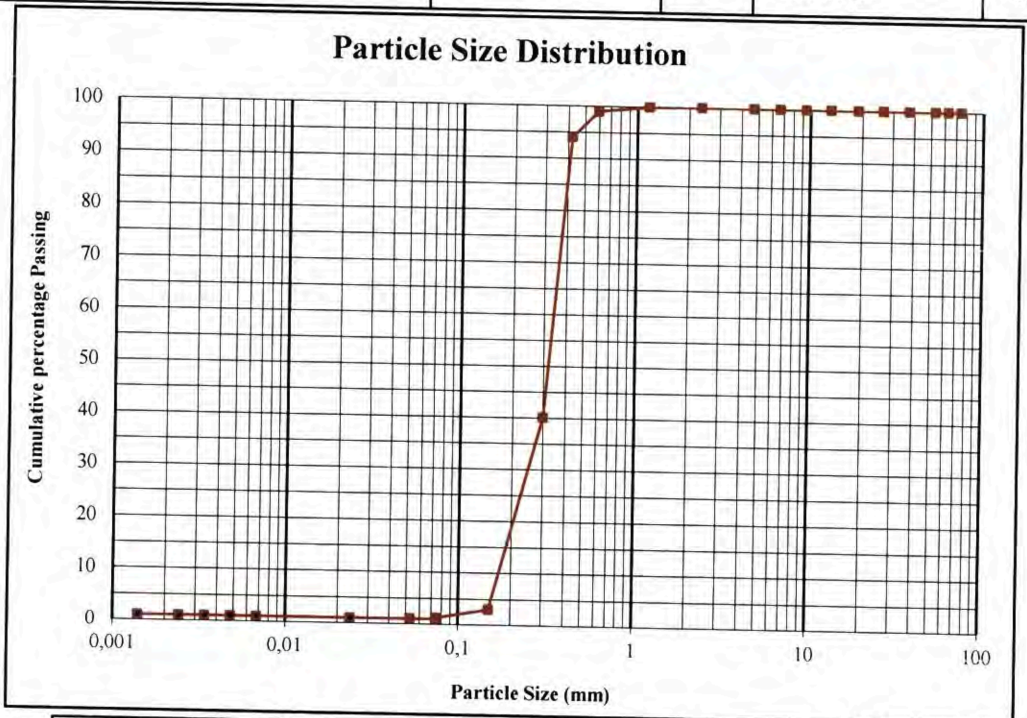
Attention :	Mr. Moruti Shuping	Req. Number :	C.O.D

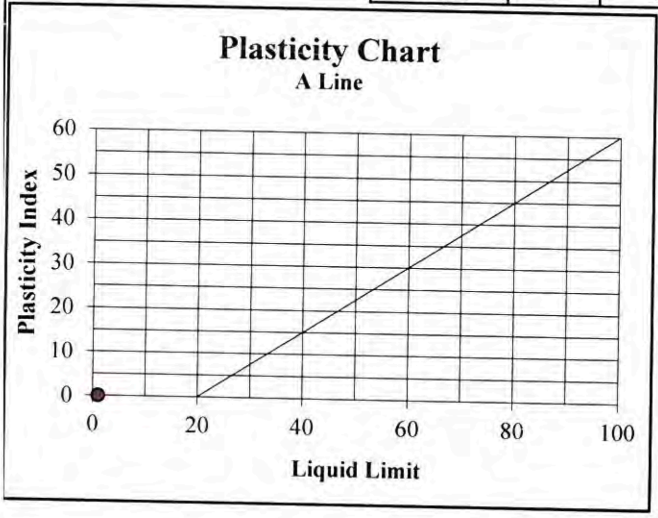
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

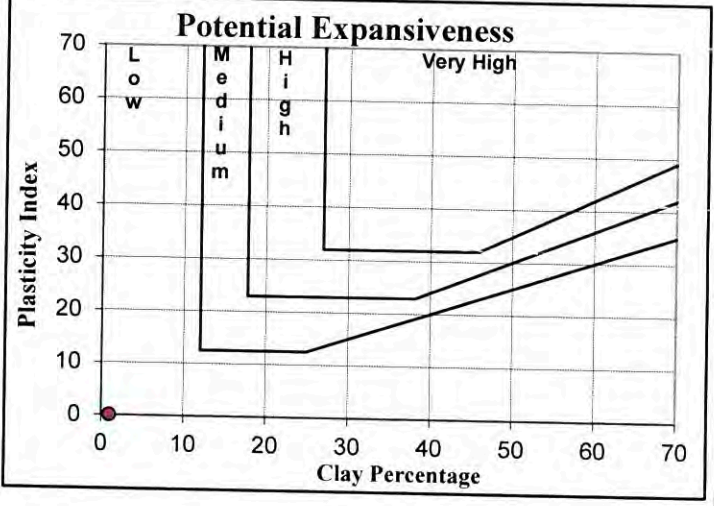
Material Description:	Dark Brown Sand	Sample Number:	51312		
Position:	TP27	Liquid Limit	-	Linear Shrinkage	1,2
Depth:	1.2-1.5m	Plasticity Index	SP	Insitu M/C%	5,2

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	94
0,300	40
0,150	3
0,075	1,3
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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Project : Namakwa Sands
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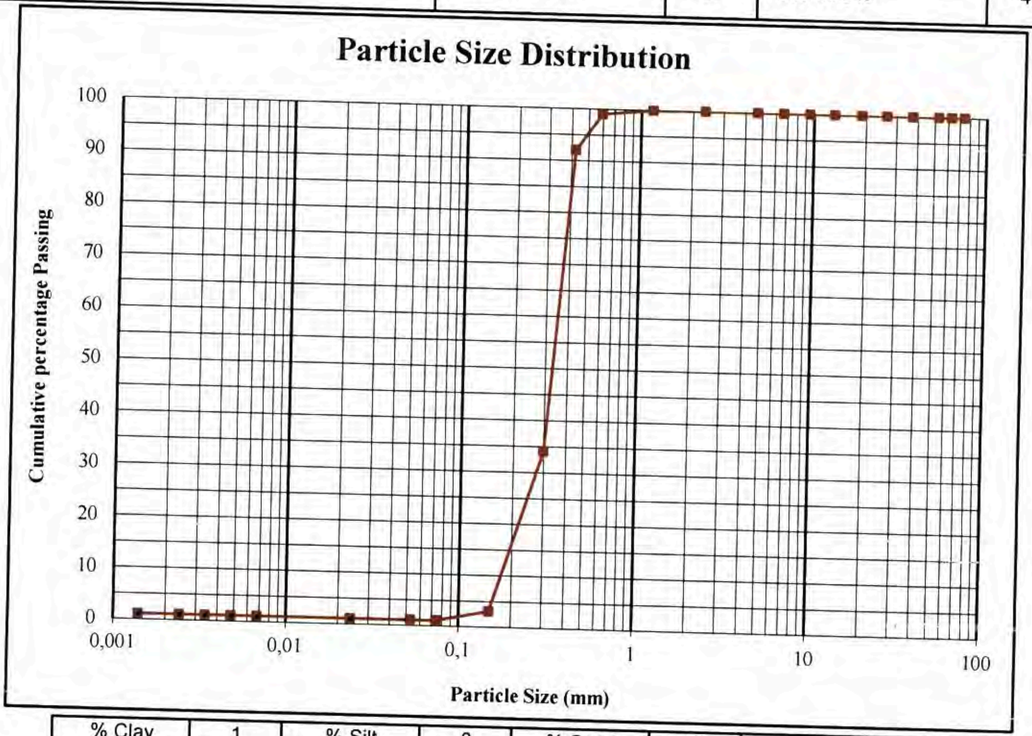
Date Reported : 28.09.2020
Req. Number : C.O.D

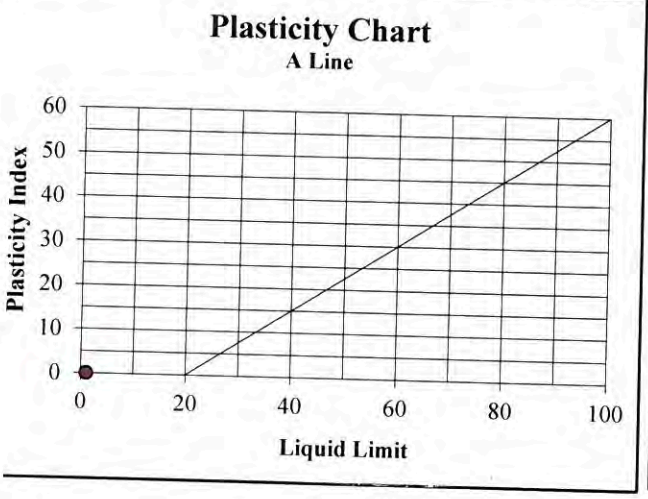
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

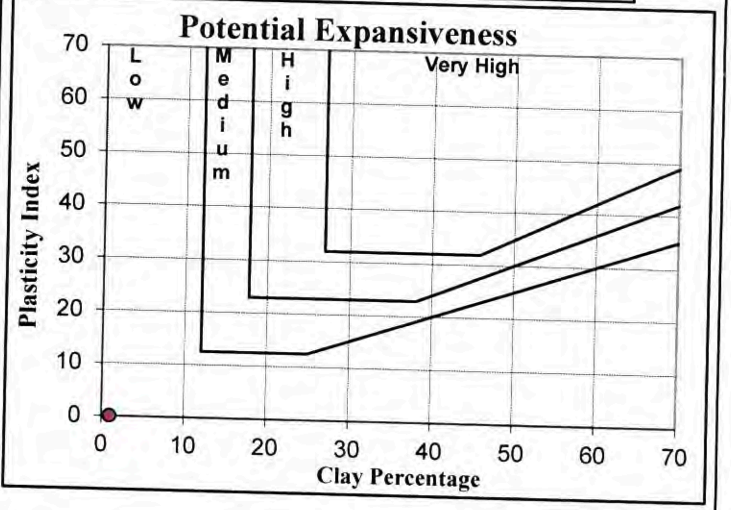
Material Description:	Brownish Olive Sand	Sample Number:	51314		
Position:	TP45	Liquid Limit	-	Linear Shrinkage	1,1
Depth:	1.3-1.8m	Plasticity Index	SP	Insitu M/C%	4,6

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	92
0,300	34
0,150	3
0,075	1,0
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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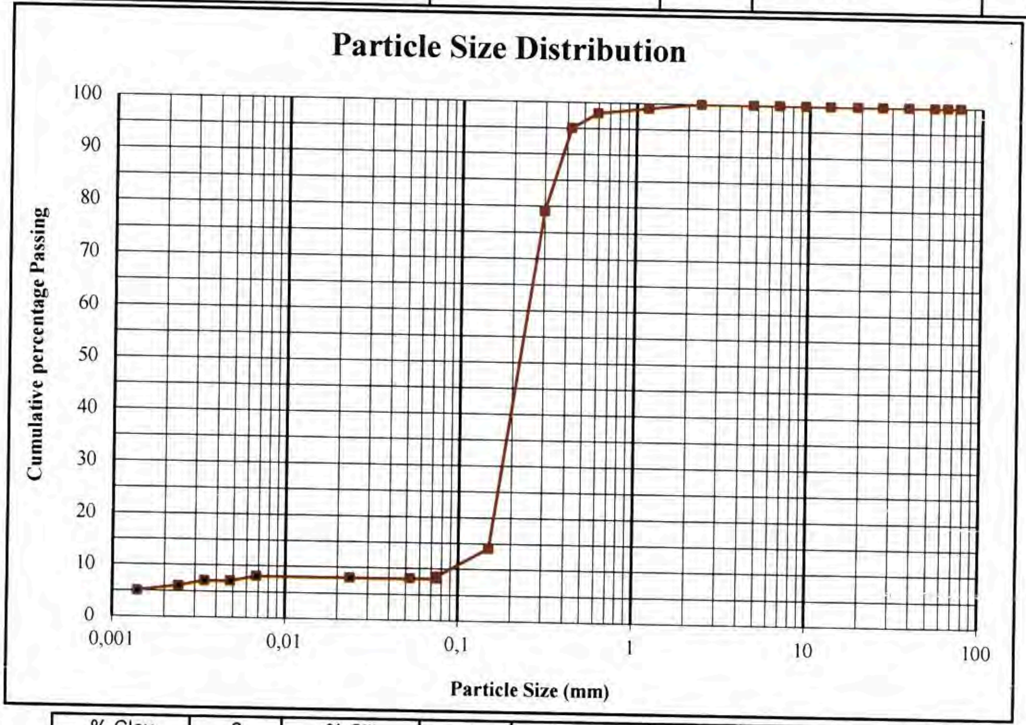
Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

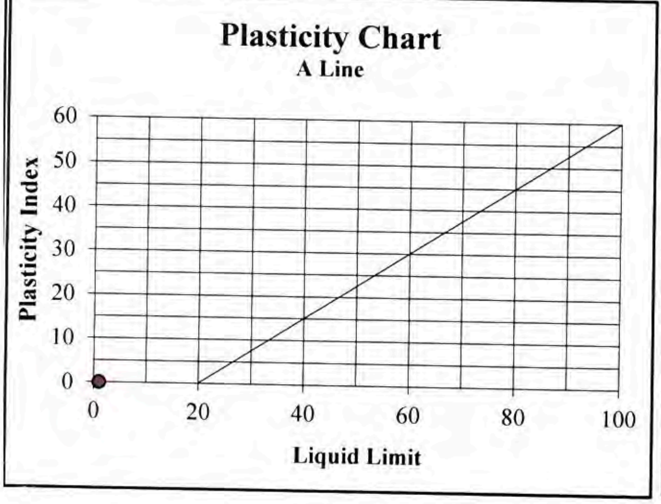
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

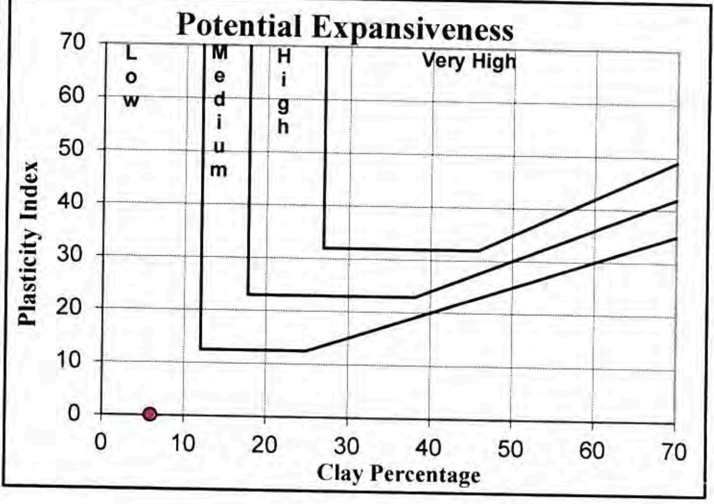
Material Description:	Dark Reddish Brown Sand	Sample Number:	51314		
Position:	TP56	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	1.8-3.0m	Plasticity Index	NP	Insitu M/C%	2,1

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	99
0,600	98
0,425	95
0,300	79
0,150	14
0,075	8,4
0,0753	8
0,0532	8
0,0238	8
0,0069	8
0,0049	7
0,0034	7
0,0024	6
0,0014	5



% Clay	6	% Silt	2	% Sand	92	% Gravel	0





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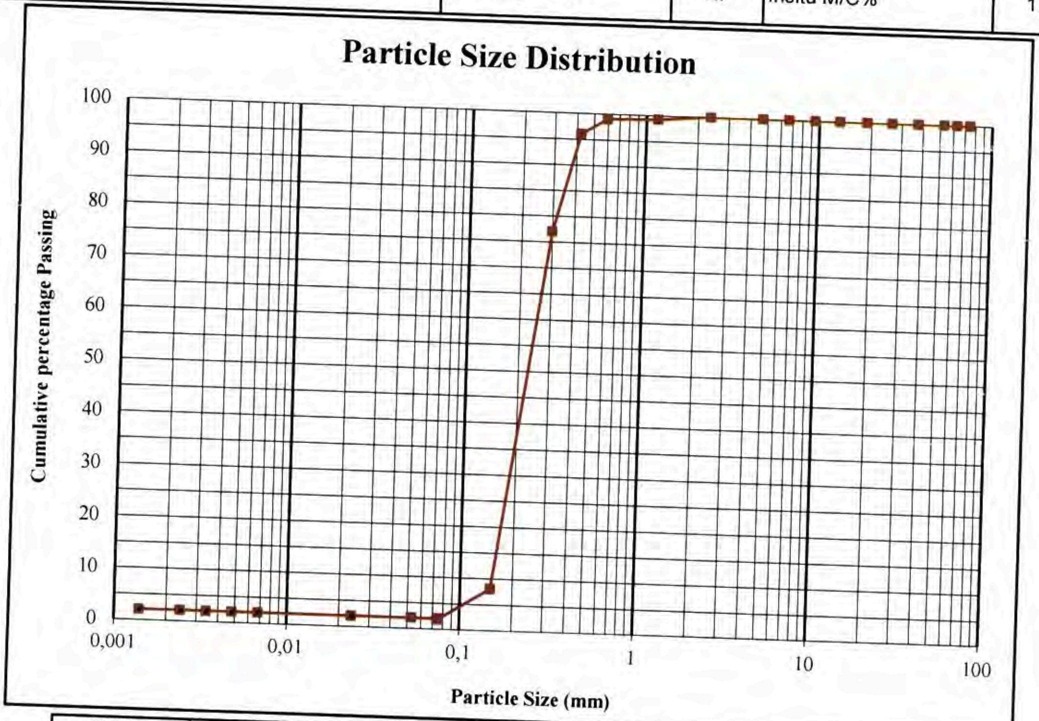
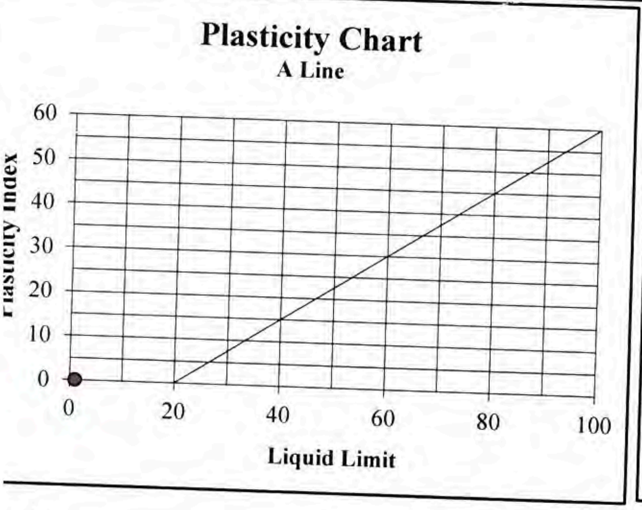
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

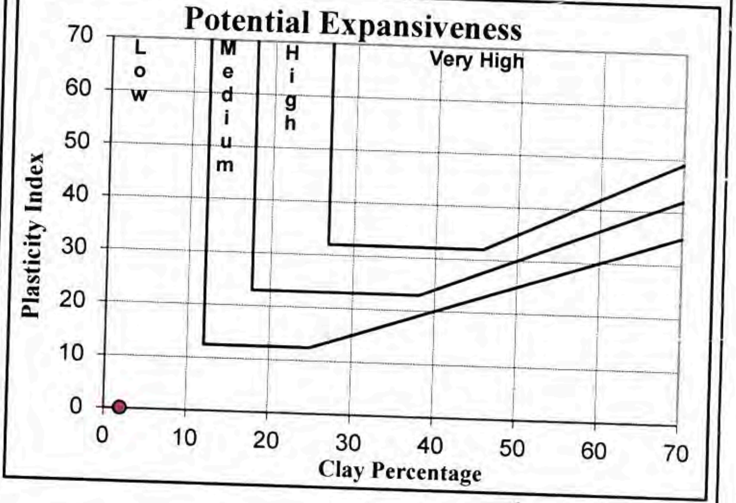
Material Description:	Dark Reddish Brown Sand	Sample Number:	51315		
Position:	TP57	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.3-1.8m	Plasticity Index	NP	Insitu M/C%	1,6

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	99
0,600	99
0,425	96
0,300	77
0,150	8
0,075	1,8
0,0753	2
0,0532	2
0,0238	2
0,0069	2
0,0049	2
0,0034	2
0,0024	2
0,0014	2



% Clay	2	% Silt	0	% Sand	98	% Gravel	0





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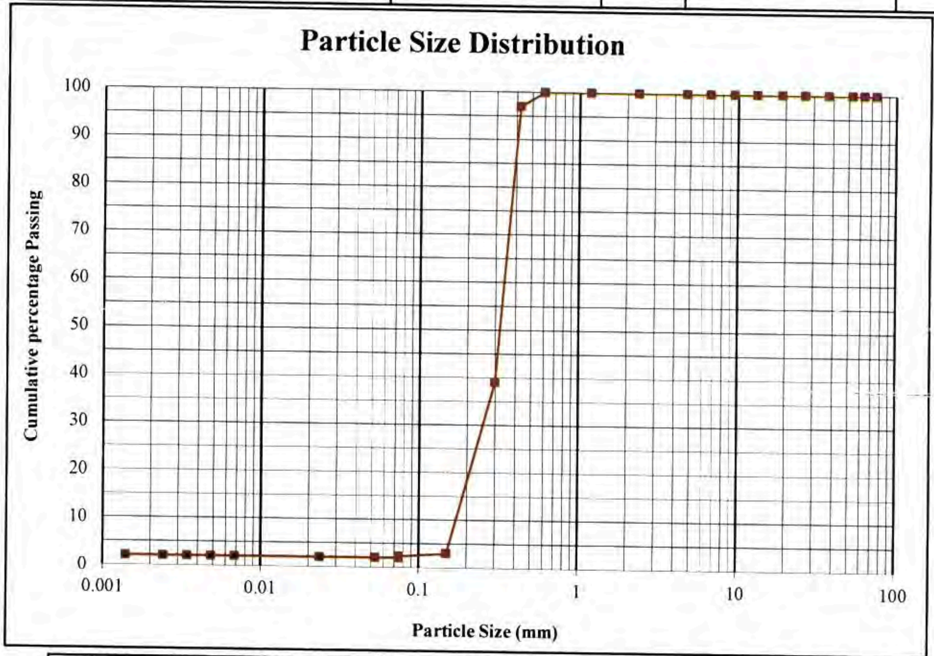
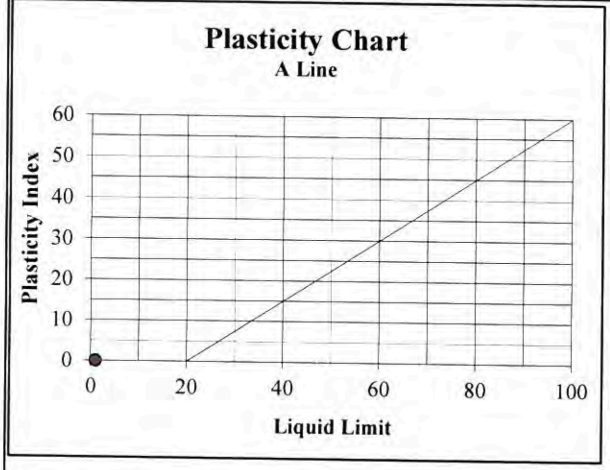
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

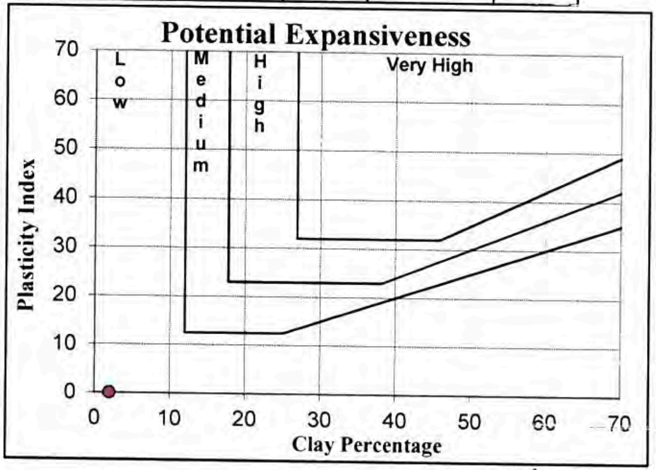
Material Description:	Orange Sand	Sample Number:	51321		
Position:	TP133	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	2.0-2.3m	Plasticity Index	NP	Insitu M/C%	3.7

Sieve Size(mm)	% Passing
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
19.0	100
13.2	100
9.5	100
6.7	100
4.75	100
2.36	100
1.18	100
0.600	100
0.425	97
0.300	39
0.150	3
0.075	2.3
0.0753	2
0.0532	2
0.0238	2
0.0069	2
0.0049	2
0.0034	2
0.0024	2
0.0014	2



% Clay	2	% Silt	0	% Sand	98	% Gravel	0





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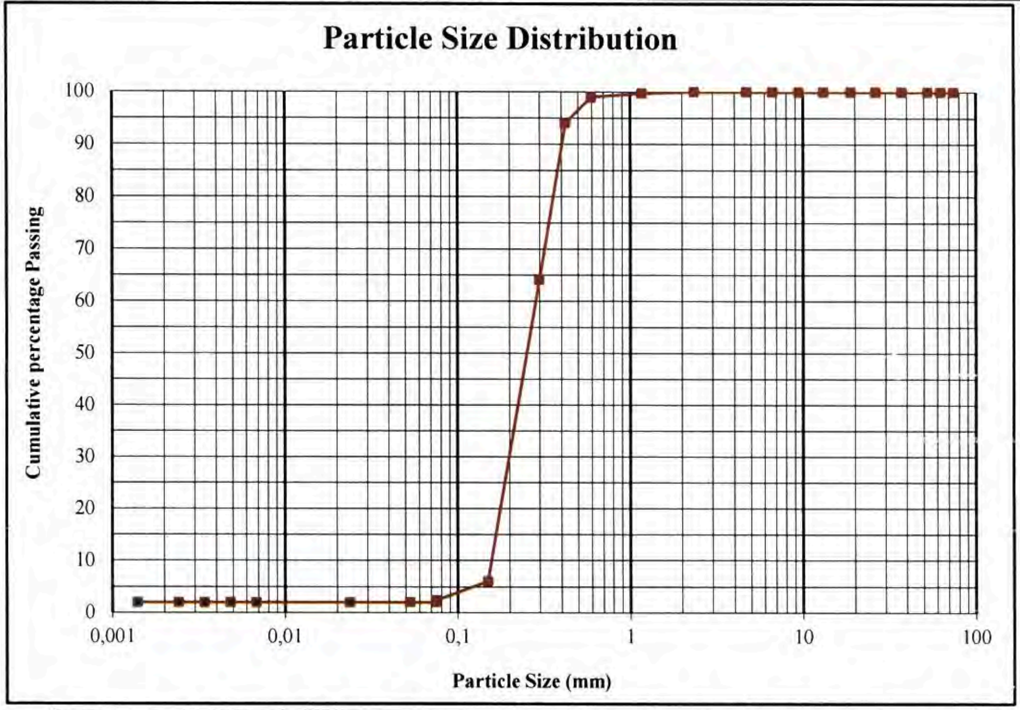
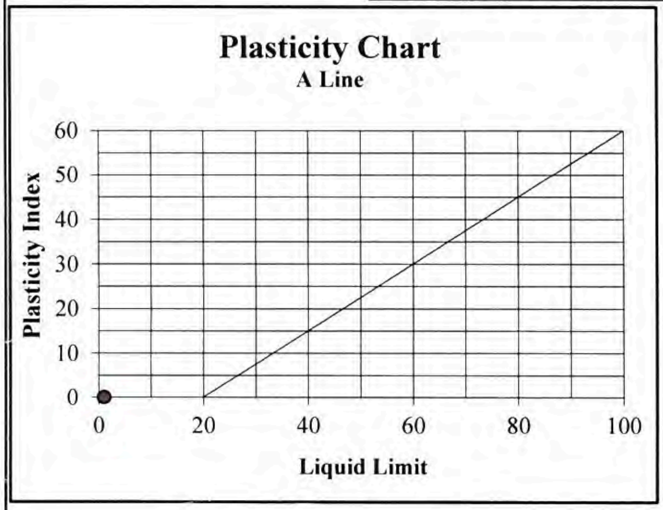
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

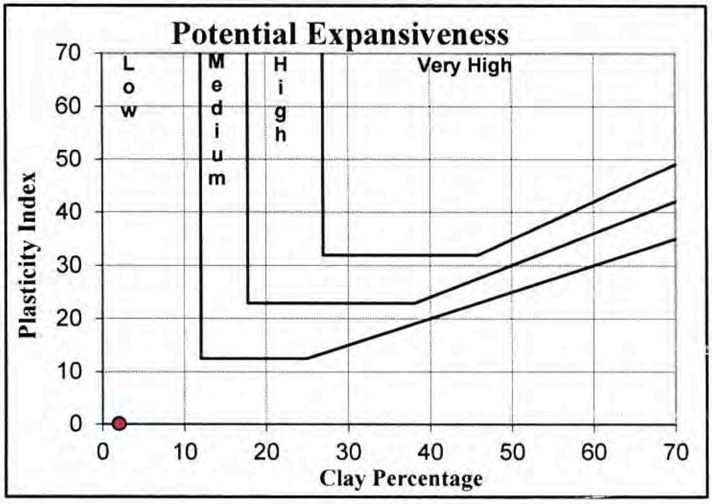
Material Description:	Brownish Sand	Sample Number:	51319		
Position:	TP138	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	1.9-2.2m	Plasticity Index	NP	Insitu M/C%	8,6

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	94
0,300	64
0,150	6
0,075	2,4
0,0753	2
0,0532	2
0,0238	2
0,0069	2
0,0049	2
0,0034	2
0,0024	2
0,0014	2



% Clay	2	% Silt	0	% Sand	98	% Gravel	0





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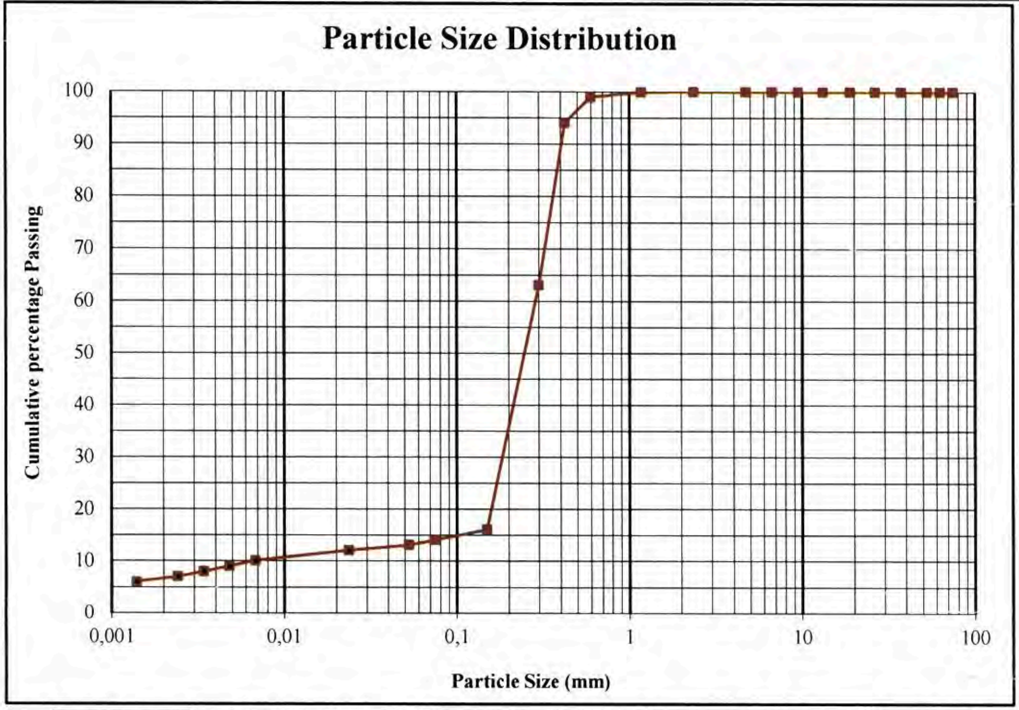
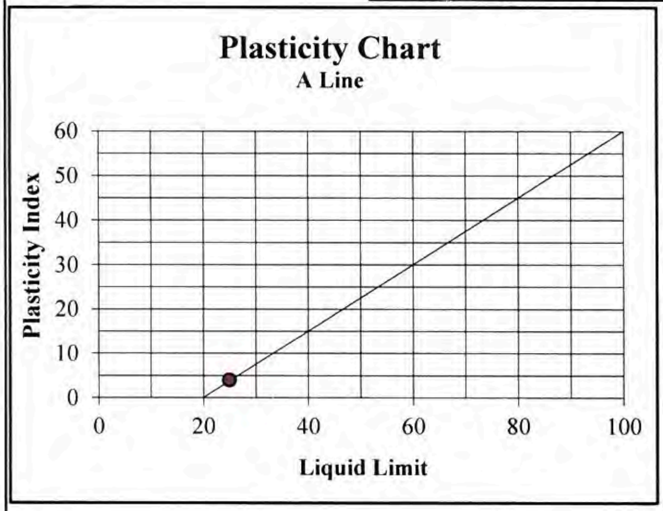
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

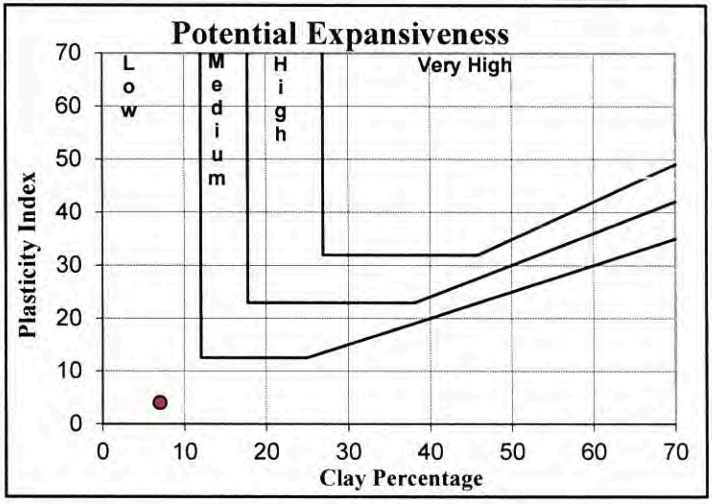
Material Description:	Light Brown Orange Silty Sand	Sample Number:	51320		
Position:	TP146	Liquid Limit	25	Linear Shrinkage	2
Depth:	0.3-3.3m	Plasticity Index	4	Insitu M/C%	5,7

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	94
0,300	63
0,150	16
0,075	14,0
0,0753	14
0,0532	13
0,0238	12
0,0069	10
0,0049	9
0,0034	8
0,0024	7
0,0014	6



% Clay	7	% Silt	6	% Sand	87	% Gravel	0





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Technical Signatory

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Civil Materials Testing
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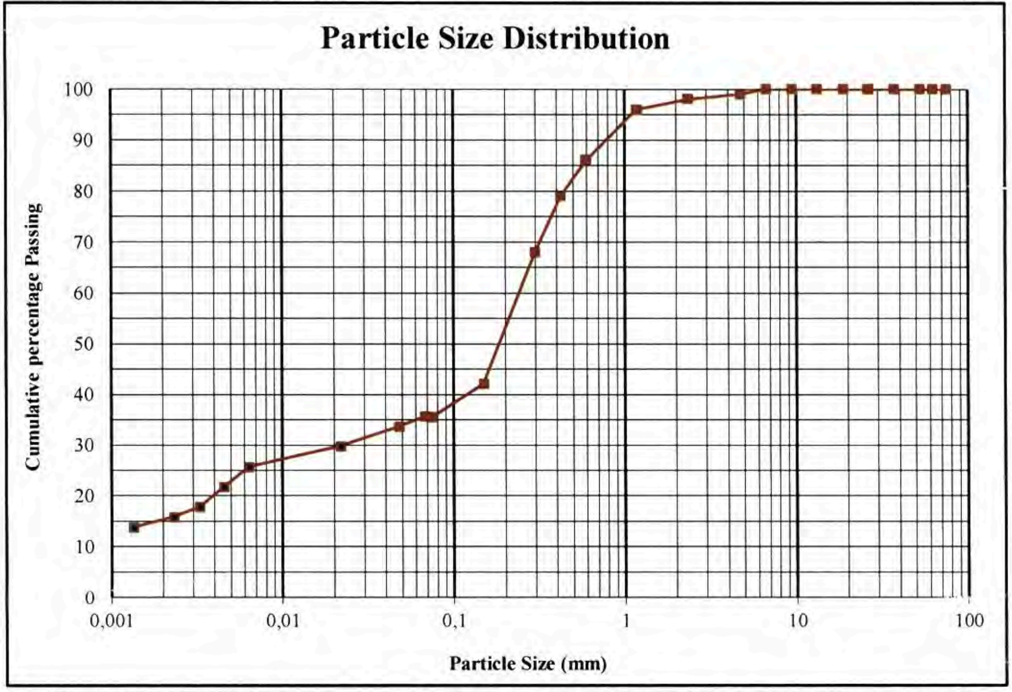
Customer :	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041	Project :	Namakwa Sands
		Date Received :	16.09.2020
		Date Reported :	28.09.2020
		Req. Number :	C.O.D
Attention :	Mr. Moruti Shuping		

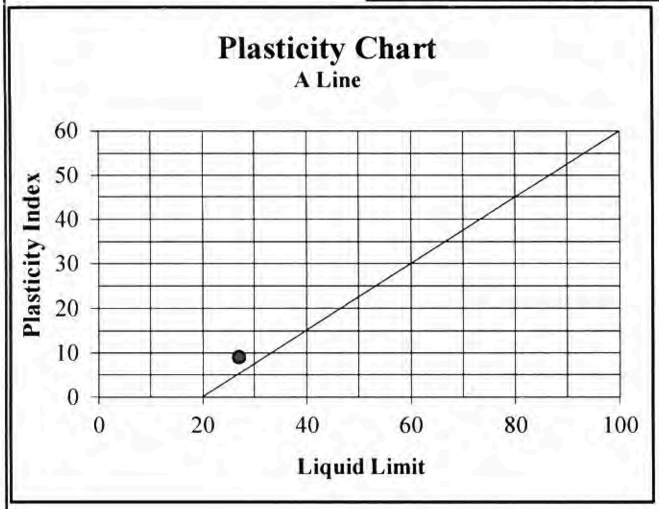
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

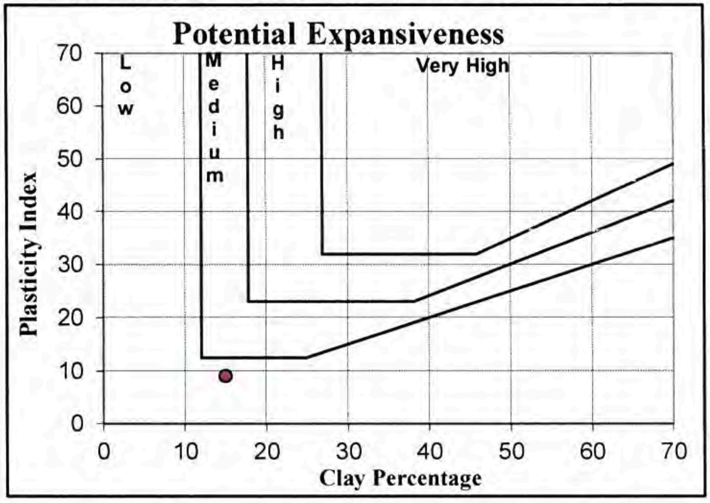
Material Description:	Light Olive Silty Sand	Sample Number:	51322		
Position:	BORROW PIT	Liquid Limit	27	Linear Shrinkage	4,6
Depth:	-	Plasticity Index	9	Insitu M/C%	7,9

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	99
2,36	98
1,18	96
0,600	86
0,425	79
0,300	68
0,150	42
0,075	36
0,0680	36
0,0484	34
0,0219	30
0,0064	26
0,0046	22
0,0033	18
0,0023	16
0,0014	14



% Clay	15	% Silt	20	% Sand	62	% Gravel	3





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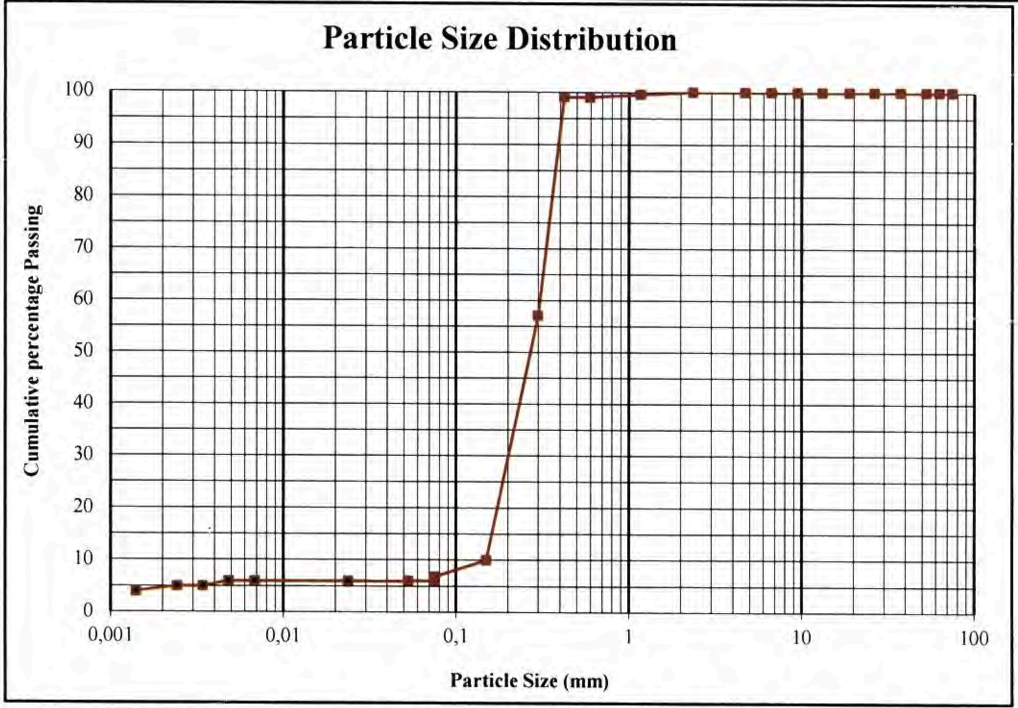
Customer :	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041	Project : Date Received : Date Reported : Req. Number :	Namakwa Sands 16.09.2020 28.09.2020 C.O.D
Attention :	Mr. Moruti Shuping		

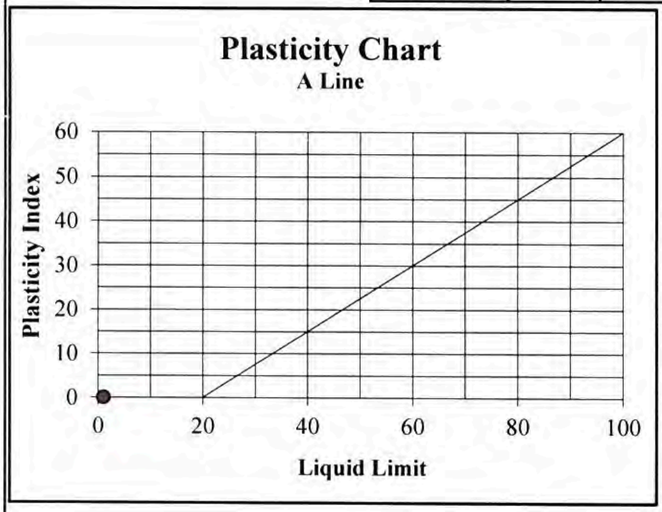
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

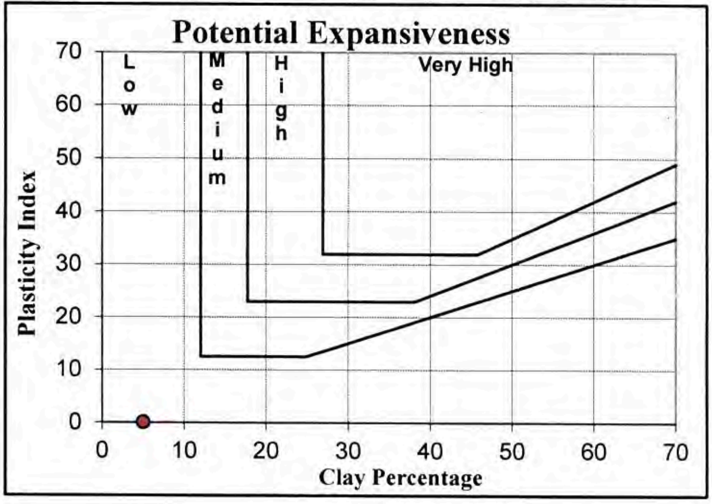
Material Description:	Brown Sand	Sample Number:	51324		
Position:	TP87	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	Foundation	Plasticity Index	NP	Insitu M/C%	1,5

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	99
0,300	57
0,150	10
0,075	6,8
0,0753	6
0,0532	6
0,0238	6
0,0069	6
0,0049	6
0,0034	5
0,0024	5
0,0014	4



% Clay	5	% Silt	1	% Sand	94	% Gravel	0





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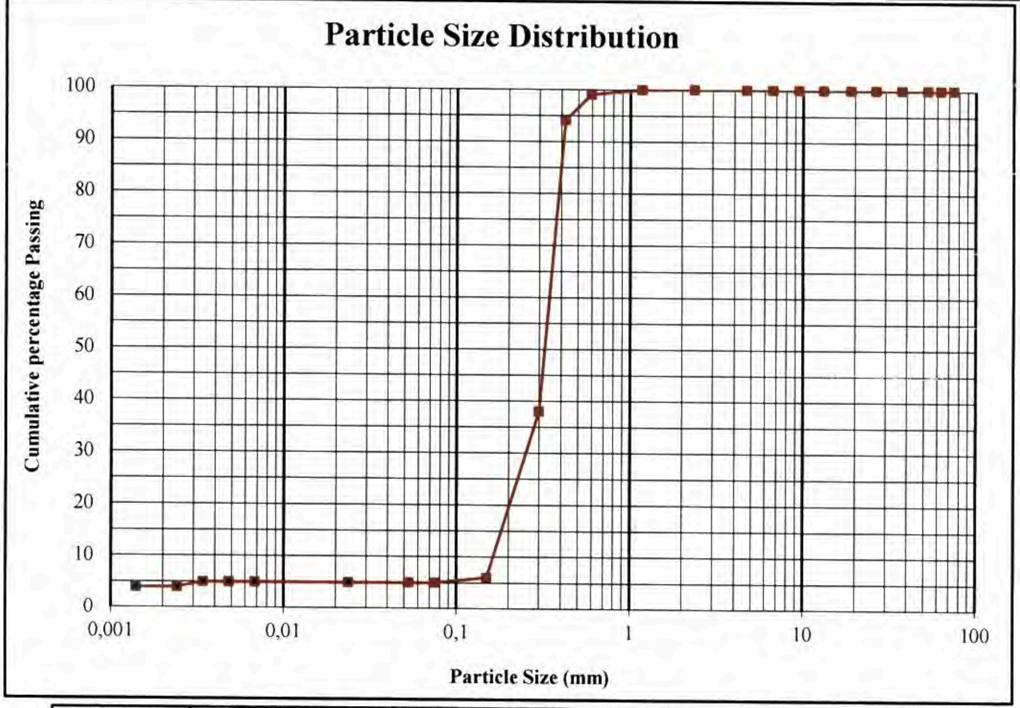
Johannesburg
2041
Attention : Mr. Moruti Shuping

Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

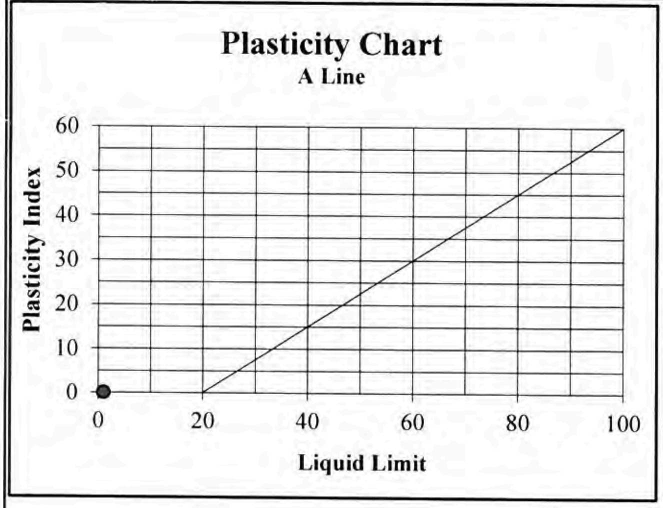
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

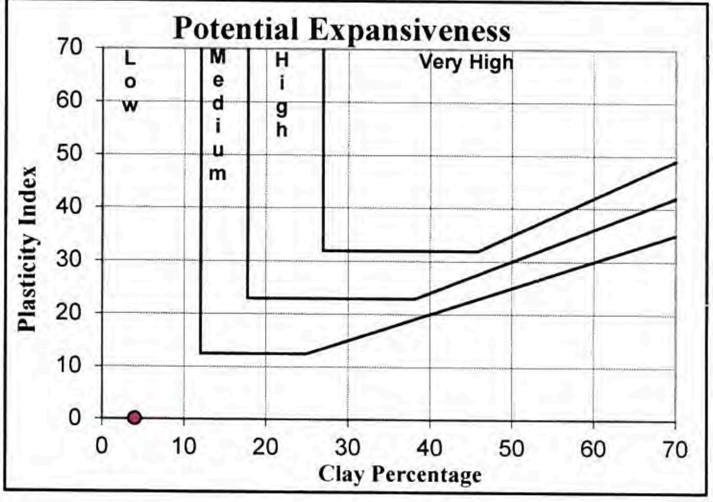
Material Description:	Brownish Orange Sand	Sample Number:	51323		
Position:	TP64	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	1.7-2.0m	Plasticity Index	NP	Insitu M/C%	4,7

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	94
0,300	38
0,150	6
0,075	5,0
0,0753	5
0,0532	5
0,0238	5
0,0069	5
0,0049	5
0,0034	5
0,0024	4
0,0014	4



% Clay	4	% Silt	1	% Sand	95	% Gravel	0





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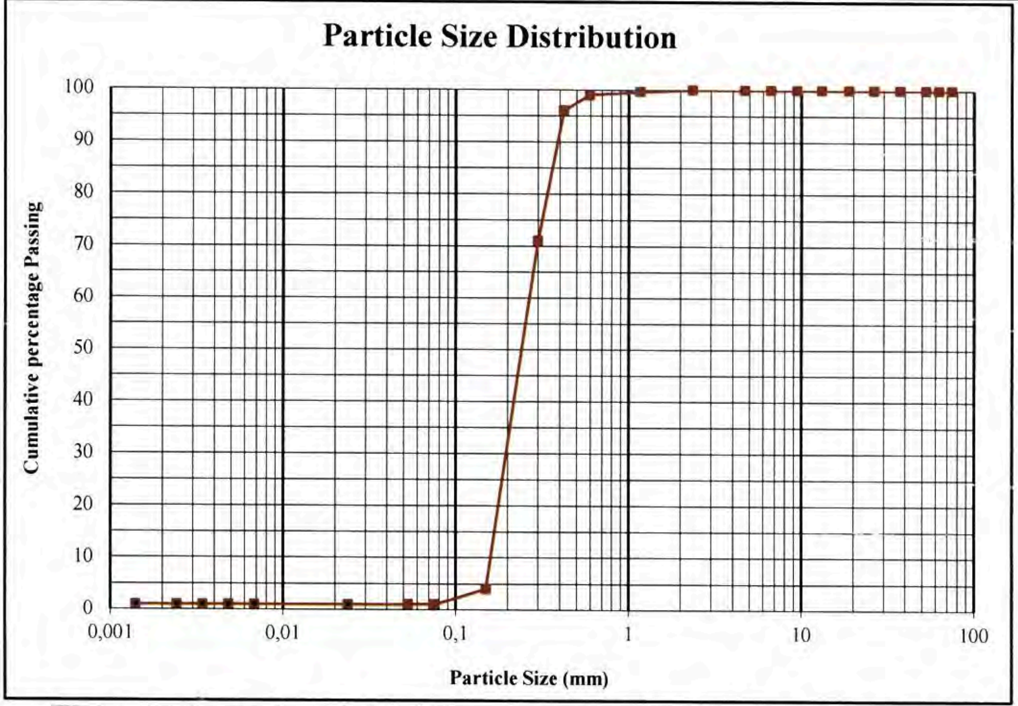
Attention :	Mr. Moruti Shuping		

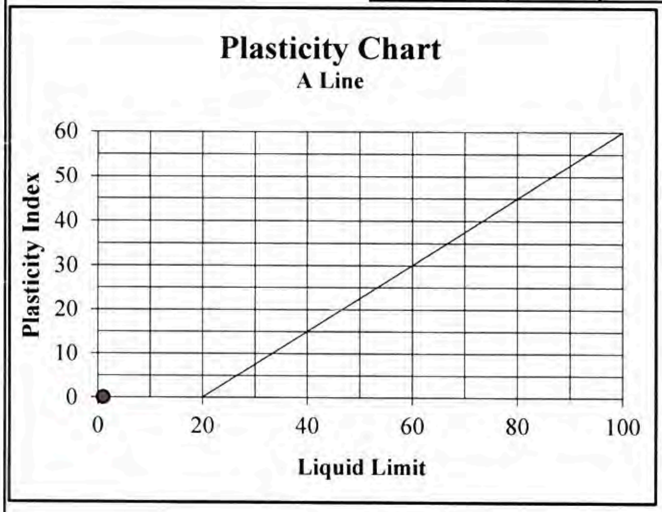
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

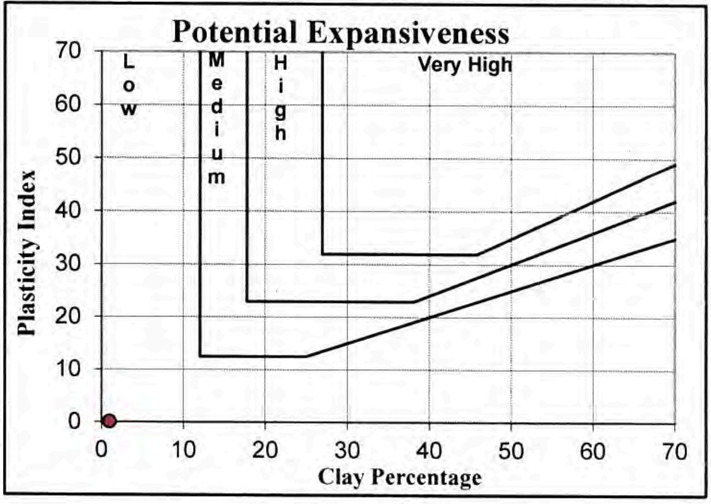
Material Description:	Light Brown Orange Sand	Sample Number:	51325		
Position:	TP91	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.3-3.0m	Plasticity Index	NP	Insitu M/C%	2,4

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	96
0,300	71
0,150	4
0,075	1
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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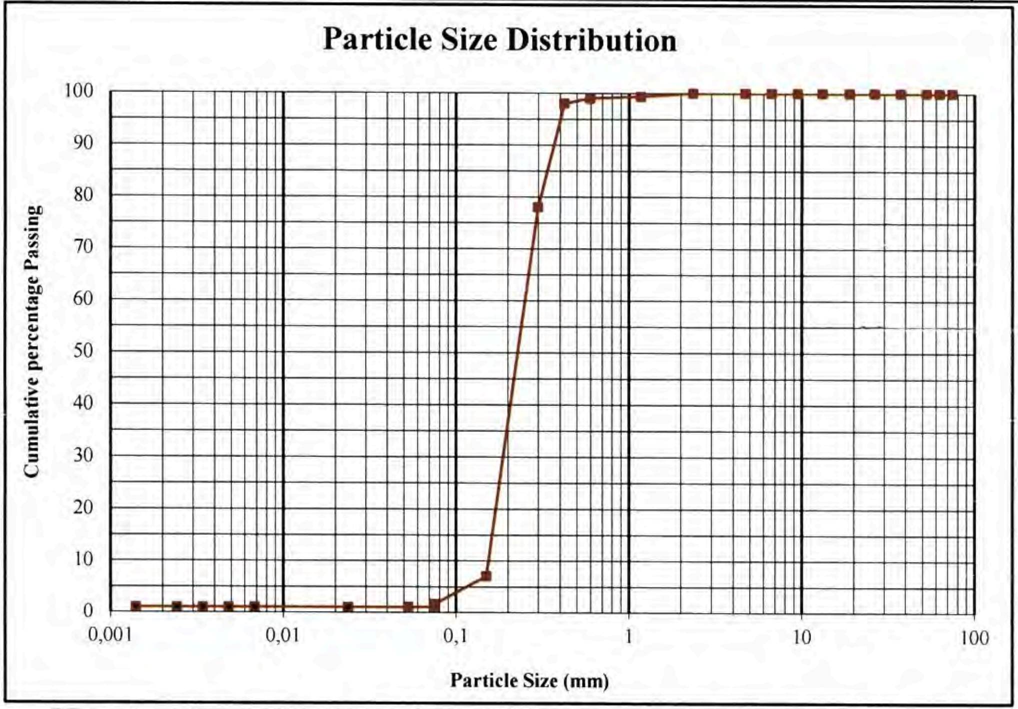
2041
Attention : Mr. Moruti Shuping

Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

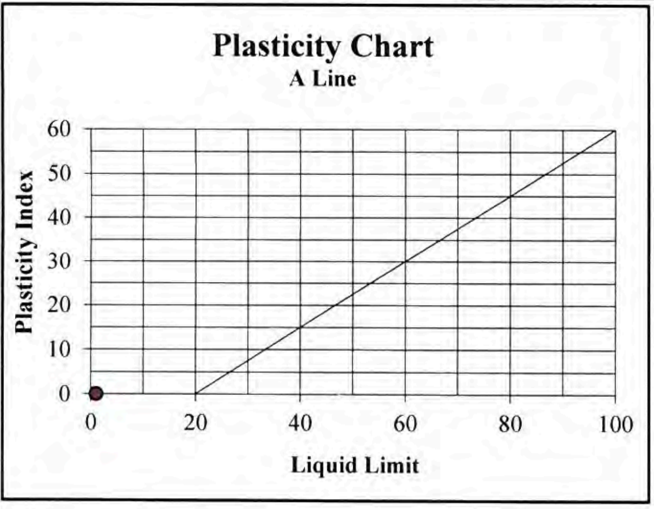
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

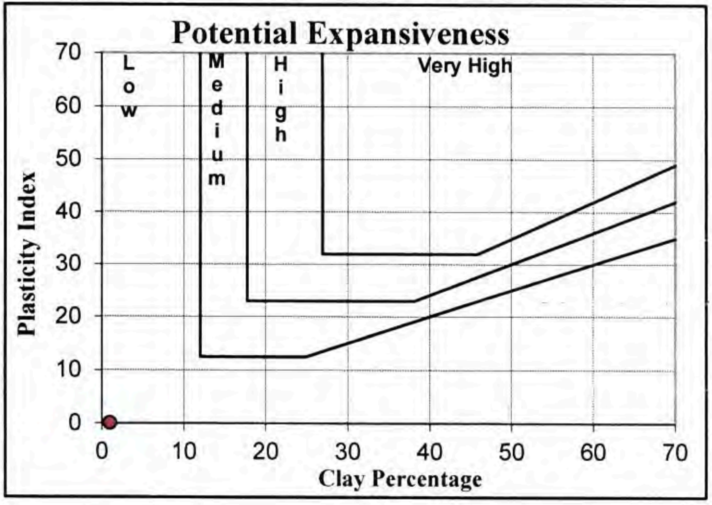
Material Description:	Light Brown Orange Sand	Sample Number:	51326		
Position:	DAM01	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.3-1.3m	Plasticity Index	NP	Insitu M/C%	0.8m

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	99
0,600	99
0,425	98
0,300	78
0,150	7
0,075	1,6
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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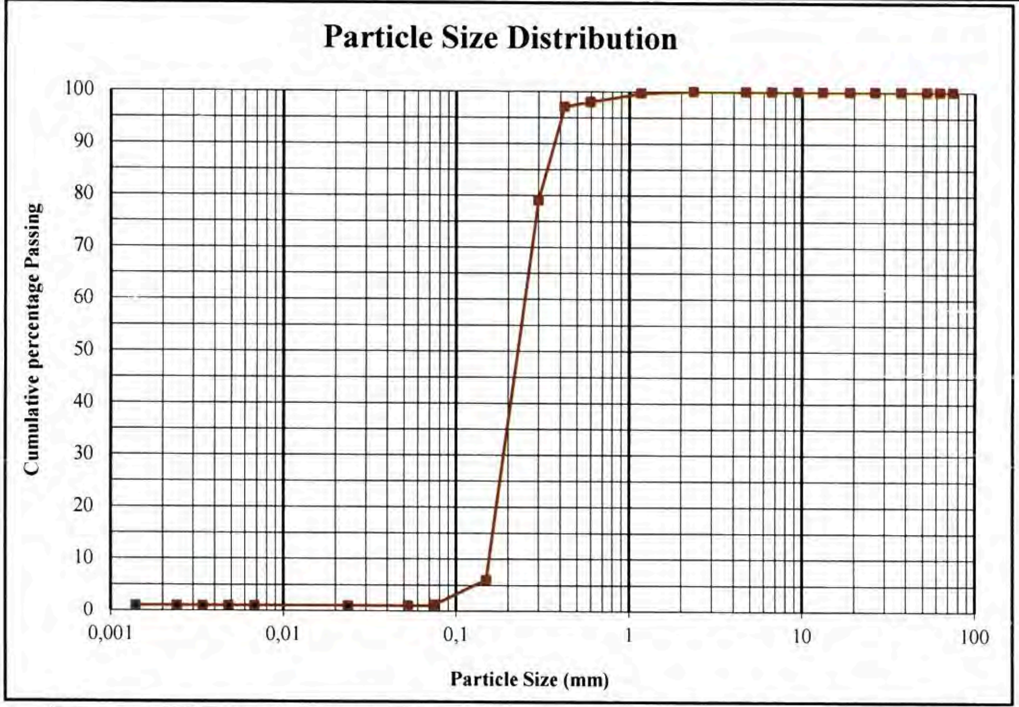
Johannesburg
2041
Attention : Mr. Moruti Shuping

Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

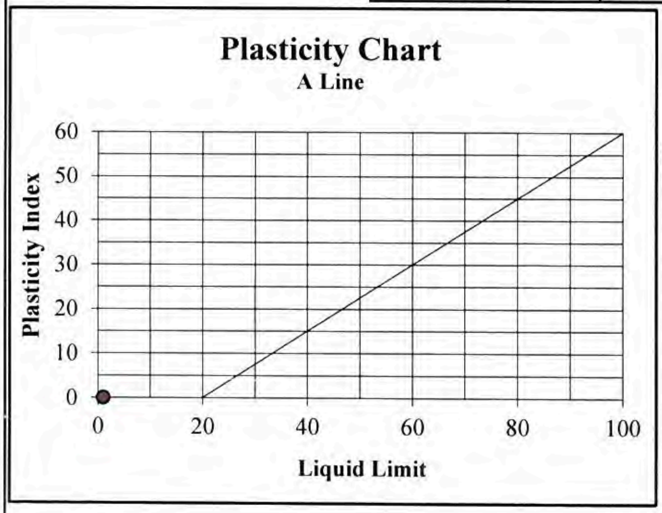
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

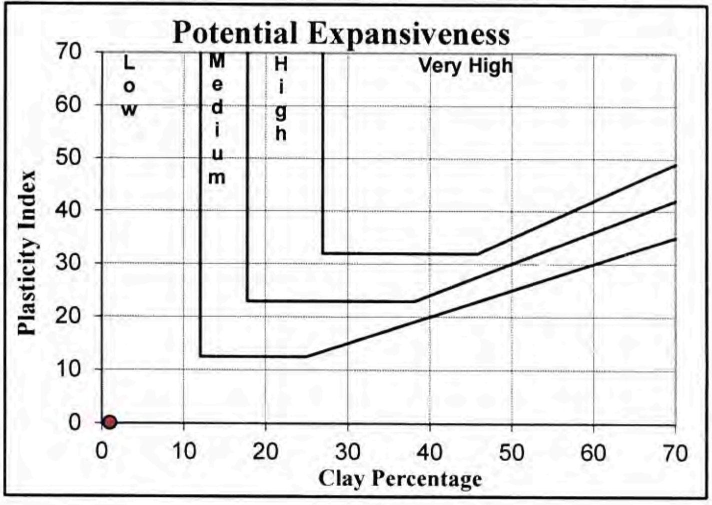
Material Description:	Light Brown Sand	Sample Number:	51327		
Position:	TPT8B	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.6-1.9m	Plasticity Index	NP	Insitu M/C%	1.0m

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	98
0,425	97
0,300	79
0,150	6
0,075	1,2
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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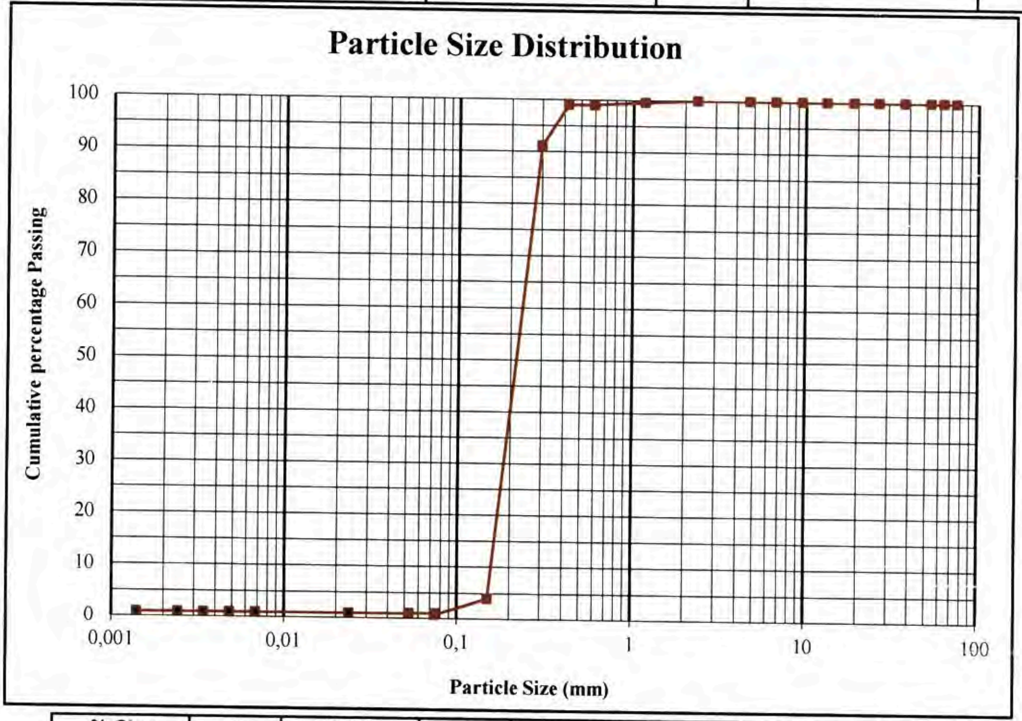
Attention : Mr. Moruti Shuping

Project : Namakwa Sands
Date Received : 16.09.2020
Date Reported : 28.09.2020
Req. Number : C.O.D

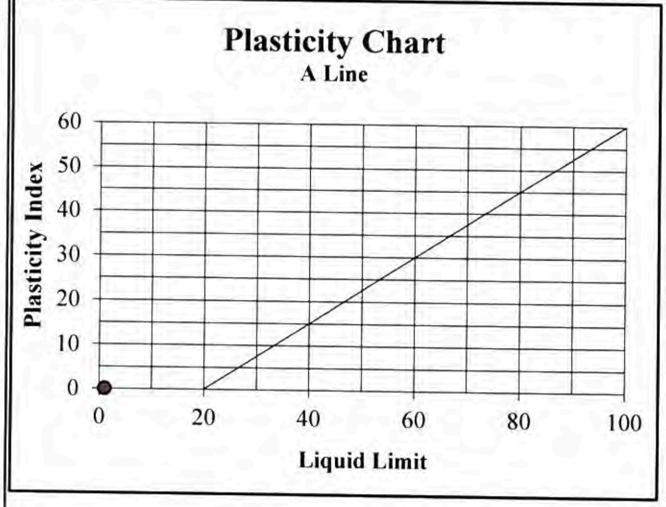
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

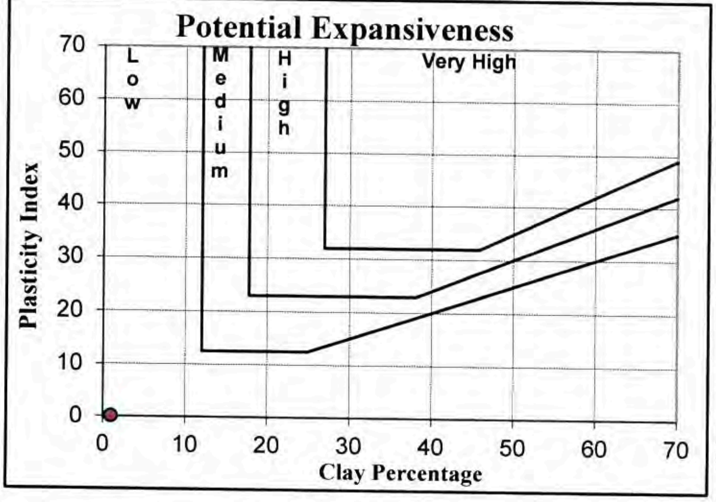
Material Description:	Reddish Brown Sand	Sample Number:	51328		
Position:	TPT 16	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.3-1.9m	Plasticity Index	NP	Insitu M/C%	1,1

Sieve Size(mm)	% Passing
75,0	100
63,0	100
53,0	100
37,5	100
26,5	100
19,0	100
13,2	100
9,5	100
6,7	100
4,75	100
2,36	100
1,18	100
0,600	99
0,425	99
0,300	91
0,150	4
0,075	1
0,0753	1
0,0532	1
0,0238	1
0,0069	1
0,0049	1
0,0034	1
0,0024	1
0,0014	1



% Clay	1	% Silt	0	% Sand	99	% Gravel	0





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Compiled By: N. v. d. Westhuizen

Approved By: H. Range

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2041

ATTENTION: Mr. Moruti Shuping

Job No	CTS01183 A
Ref. No	C.O.D
Date	15.09.2020
Tested/Sampled By:	Client
Date Sampled / Received	04.09.2020
Date Tested	15.09.2020
Sampling Method	As per client
Test Method	ASTM D698
Project	Namakwa Sands
Test Type	Proctor MOD
Sampled By	Client
Delivered By	Client
Temp. °C	25°C
Laboratory Tester	Mr. N. Fredericks
Environmental Conditions	Sunny
Remarks / notes	None
Number of pages	8

Special instructions
None

Remarks:

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JOB NO:	CTS01183 A	REFERENCE NO: C.O.D	DATE: 15.09.2020
CLIENT	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041	PROJECT	Namakwa Sands
		POSITION / LAYER	Not Specified
		KM / SV	TP56 (1.8-3.0m)
		SAMPLE NUMBER	51219
ATTENTION	Mr. Moruti Shuping	MATERIAL DESCRIPTION	Light Orange Sand with Sandstone
		ENVIRONMENTAL CONDITIONS	Sunny
SAMPLED BY	Client	LABORATORY TESTER	Mr. S. Venge
TEMP.'C INSIDE LABORATORY	25°C	SAMPLE METHOD	As per client

COMPACTION STANDARD EFFORT PROCTOR METHOD ASTM D698

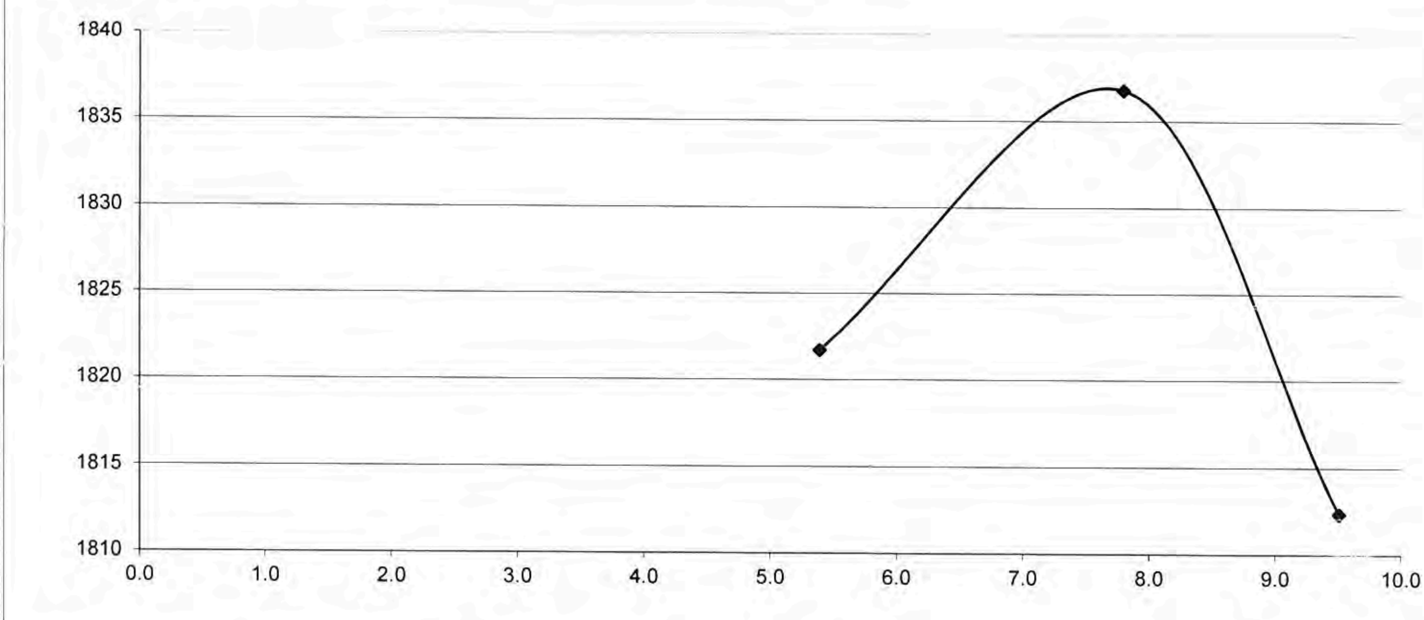
COMPACTION DATA

Moisture Content %	4	6	8		
Mass Mould & Wet Mat	9341	9482	9493		
Mass Mould	4833	4833	4833		
Mass of Wet Mat	4508	4649	4660		
Mould Factor	42.59	42.59	42.59		
Wet Density	1846	1868	1838		

MOISTURE DATA

Mass Wet Mat	600	600	600		
Mass Dry Mat	569.3	556.6	547.9		
Mass Moisture	30.7	43.4	52.1		
Hygroscopic Moisture Content %	1.4	1.8	1.5		
Actual Moisture Content %	5.4	7.8	9.5		
Dry Density	1822	1837	1812		

MAXIMUM DRY DENSITY Kg/m3	**1837**
OPTIMUM MOISTURE CONTENT	**7.8%**



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Technical Signatory

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JOB NO:	CTS01183 A	REFERENCE NO:	C.O.D	DATE:	15.09.2020
CLIENT	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041		PROJECT	Namakwa Sands	
			POSITION / LAYER	Not Specified	
			KM / SV	TP57 (0.5-1.8m)	
			SAMPLE NUMBER	51220	
ATTENTION	Mr. Moruti Shuping		MATERIAL DESCRIPTION	Light Orange Sand with Ferricrete	
			ENVIRONMENTAL CONDITIONS	Sunny	
SAMPLED BY	Client		LABORATORY TESTER	Mr. S. Venge	
TEMP.'C INSIDE LABORATORY	25°C		SAMPLE METHOD	As per client	

COMPACTION STANDARD EFFORT PROCTOR METHOD ASTM D698

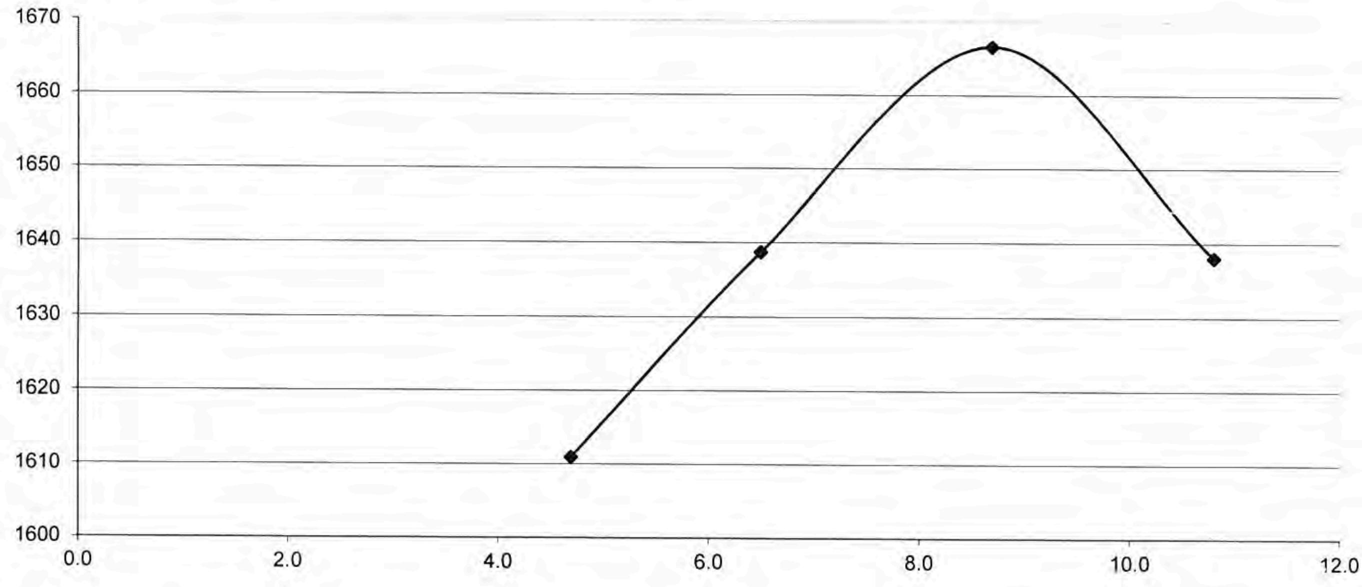
COMPACTION DATA

Moisture Content %	4	6	8	10	
Mass Mould & Wet Mat	8806	8942	9096	9104	
Mass Mould	4891	4891	4891	4891	
Mass of Wet Mat	3915	4051	4205	4213	
Mould Factor	43.08	43.08	43.08	43.08	
Wet Density	1622	1646	1677	1650	

MOISTURE DATA

Mass Wet Mat	600	600	600	600	
Mass Dry Mat	573.1	563.4	552	541.5	
Mass Moisture	26.9	36.6	48.0	58.5	
Hygroscopic Moisture Content %	0.7	0.5	0.7	0.8	
Actual Moisture Content %	4.7	6.5	8.7	10.8	
Dry Density	1611	1639	1667	1638	

MAXIMUM DRY DENSITY Kg/m3	**1667**
OPTIMUM MOISTURE CONTENT	**8.7%**



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JOB NO: CTS01183 A
REFERENCE NO: C.O.D
DATE: 15.09.2020

CLIENT Inroads Consulting Civil Engineers
P.O Box 87318 , Houghton
Johannesburg
2041
ATTENTION Mr. Moruti Shuping

SAMPLED BY Client
TEMP.'C INSIDE LABORATORY 25°C

PROJECT Namakwa Sands
POSITION / LAYER Not Specified
KM / SV TP91 (0.5-3.0m)
SAMPLE NUMBER 51221
MATERIAL DESCRIPTION Light Orange Sand with Ferricrete
ENVIRONMENTAL CONDITIONS Sunny
LABORATORY TESTER Mr. S. Venge
SAMPLE METHOD As per client

COMPACTION STANDARD EFFORT PROCTOR METHOD ASTM D698

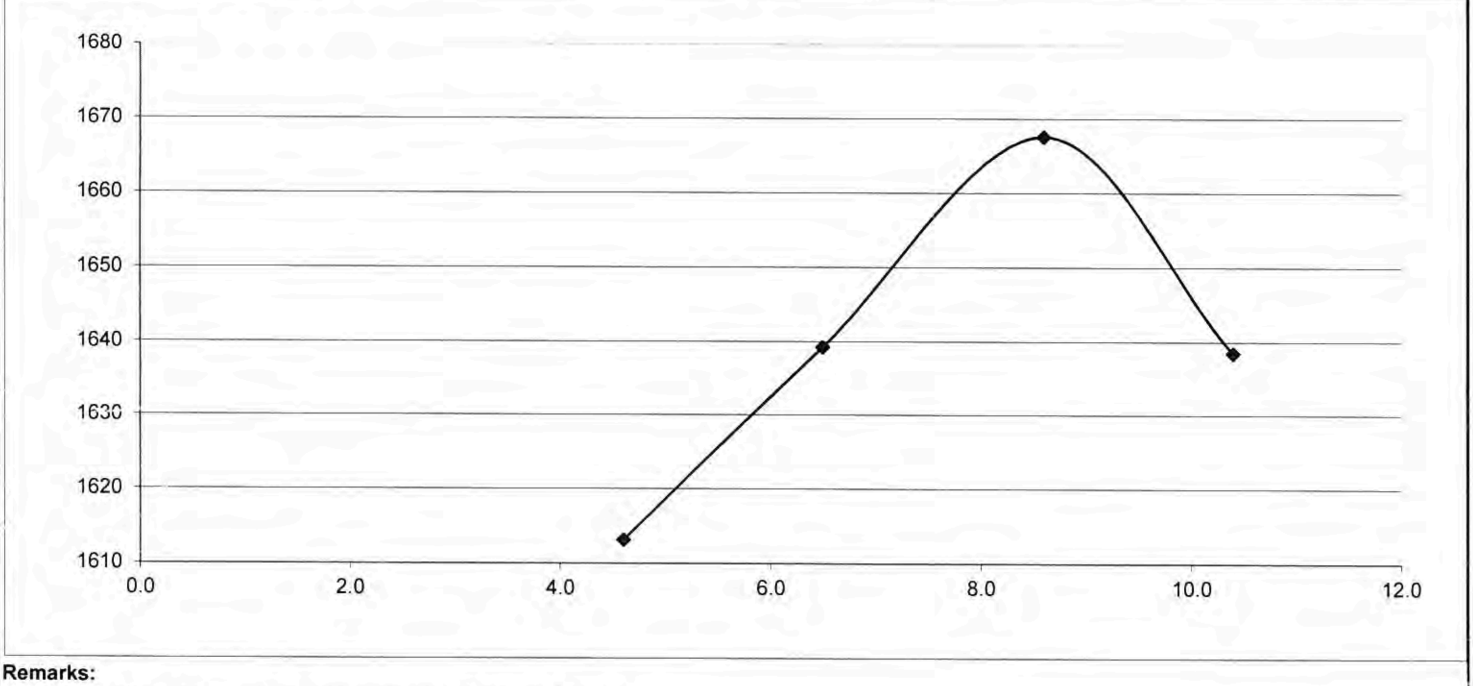
COMPACTION DATA

Moisture Content %	4	6	8	10	
Mass Mould & Wet Mat	8795	8932	9085	9080	
Mass Mould	4833	4833	4833	4833	
Mass of Wet Mat	3962	4099	4252	4247	
Mould Factor	42.59	42.59	42.59	42.59	
Wet Density	1623	1647	1677	1644	

MOISTURE DATA

Mass Wet Mat	600	600	600	600	
Mass Dry Mat	573.6	563.4	552.5	543.5	
Mass Moisture	26.4	36.6	47.5	56.5	
Hygroscopic Moisture Content %	0.6	0.5	0.6	0.4	
Actual Moisture Content %	4.6	6.5	8.6	10.4	
Dry Density	1613	1639	1668	1638	

MAXIMUM DRY DENSITY Kg/m3	**1668**
OPTIMUM MOISTURE CONTENT	**8.6%**



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JOB NO:	CTS01183 A	REFERENCE NO: C.O.D	DATE: 15.09.2020
CLIENT	Inroads Consulting Civil Engineers P.O Box 87318 , Houghton Johannesburg 2041	PROJECT	Namakwa Sands
		POSITION / LAYER	Not Specified
		KM / SV	Bottom Pit
		SAMPLE NUMBER	51217
ATTENTION	Mr. Moruti Shuping	MATERIAL DESCRIPTION	Light Brown Sand with Sandstone
		ENVIRONMENTAL CONDITIONS	Sunny
SAMPLED BY	Client	LABORATORY TESTER	Mr. S. Venge
TEMP.'C INSIDE LABORATORY	25°C	SAMPLE METHOD	As per client

COMPACTION STANDARD EFFORT PROCTOR METHOD ASTM D698

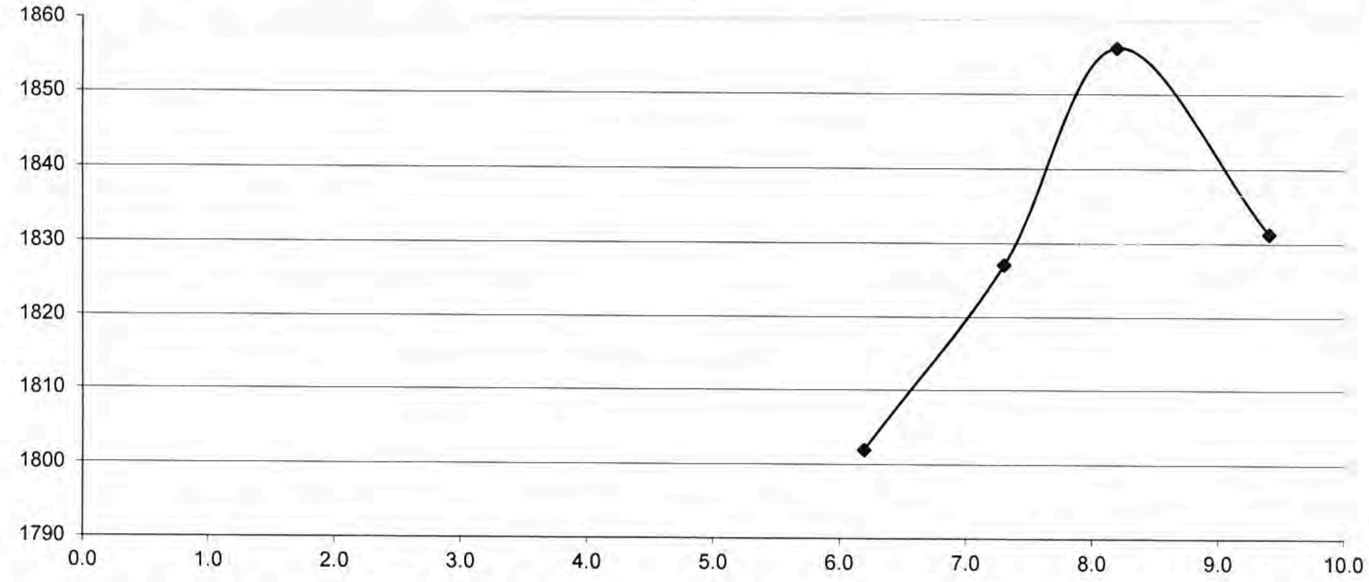
COMPACTION DATA

Moisture Content %	5	6	7	8	
Mass Mould & Wet Mat	9324	9431	9540	9529	
Mass Mould	4966	4966	4966	4966	
Mass of Wet Mat	4358	4465	4574	4563	
Mould Factor	43.91	43.91	43.91	43.91	
Wet Density	1822	1850	1877	1855	

MOISTURE DATA

Mass Wet Mat	629	658	685	600	
Mass Dry Mat	592.3	613.2	633.1	548.4	
Mass Moisture	36.7	44.8	51.9	51.6	
Hygroscopic Moisture Content %	1.2	1.3	1.2	1.4	
Actual Moisture Content %	6.2	7.3	8.2	9.4	
Dry Density	1802	1827	1856	1831	

MAXIMUM DRY DENSITY Kg/m3	**1856**
OPTIMUM MOISTURE CONTENT	**8.2%**



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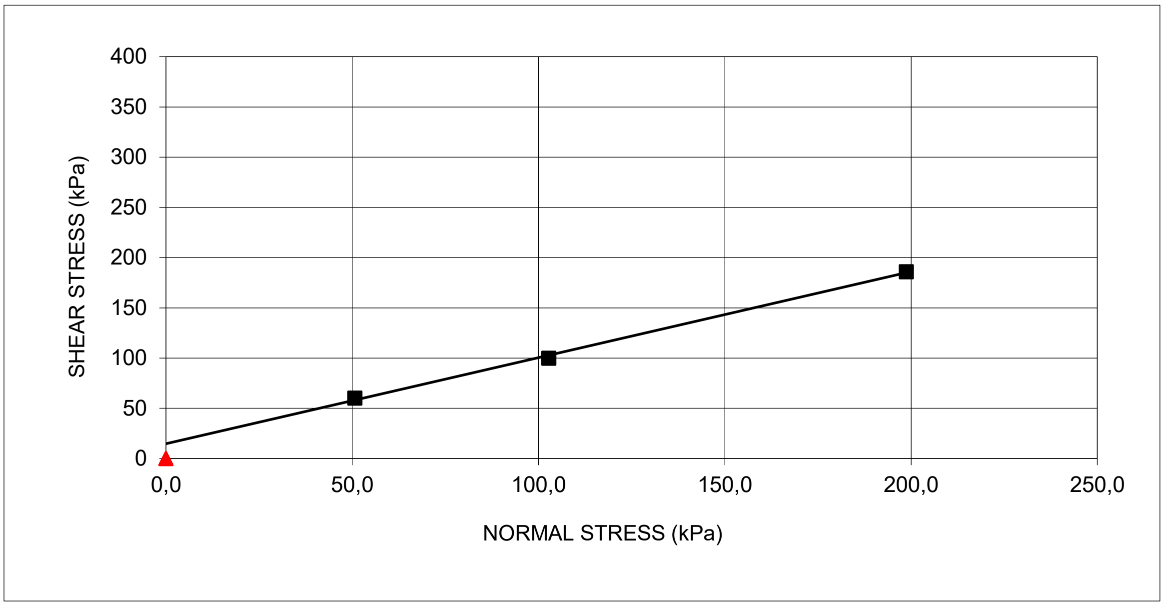
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33057	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 20 @ 1,4-1,8m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		
RESULTS AT START OF TEST			
Void Ratio	0,48	0,48	0,52
Moisture Content %	7,20	7,20	7,20
Dry Density	1794	1794	1745
RESULTS AT END OF TEST			
Void Ratio	0,48	0,47	0,51
Moisture Content %	16,40	15,59	17,36
PEAK SHEAR STRENGTH			
Shear Stress kPa	60,00	100,00	186,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	14,7	40,6

Apparent angle of internal shearing resistance given by regression (°)	40,6
Apparent cohesion given by regression (kPa)	14,7

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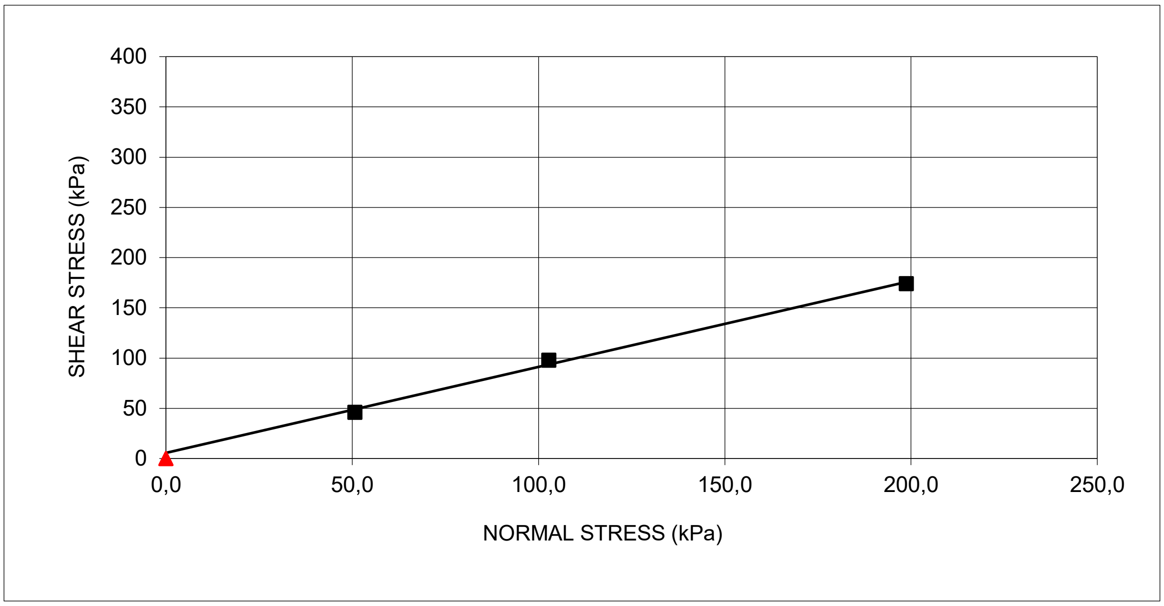
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33058	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 27 @ 1,2-1,5m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		
RESULTS AT START OF TEST			
Void Ratio	0,49	0,47	0,48
Moisture Content %	6,00	6,00	6,00
Dry Density	1774	1802	1796
RESULTS AT END OF TEST			
Void Ratio	0,46	0,44	0,44
Moisture Content %	16,98	15,68	16,06
PEAK SHEAR STRENGTH			
Shear Stress kPa	46,00	98,00	174,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	**Degrees**
Peak	5,5	40,6

Apparent angle of internal shearing resistance given by regression (°)	40,6
Apparent cohesion given by regression (kPa)	5,5

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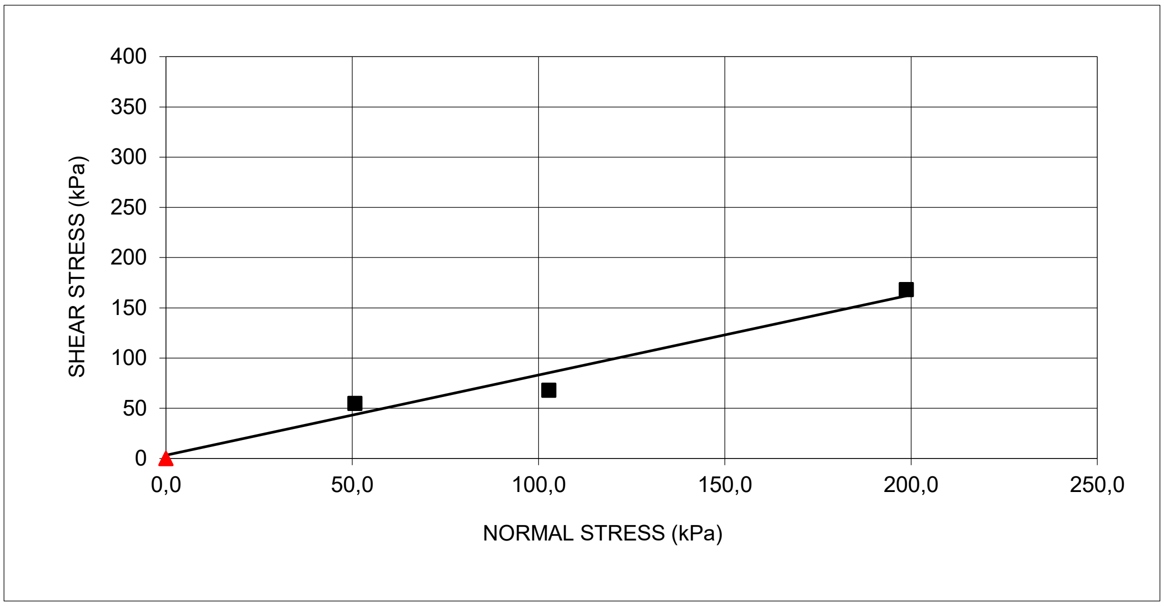
JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33059	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 45 @ 1,3-1,8m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		
RESULTS AT START OF TEST			
Void Ratio	0,65	0,66	0,59
Moisture Content %	6,00	6,00	6,00
Dry Density	1703	1715	1712
RESULTS AT END OF TEST			
Void Ratio	0,57	0,60	0,49
Moisture Content %	20,72	21,50	19,07
PEAK SHEAR STRENGTH			
Shear Stress kPa	55,00	68,00	168,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	3,3	38,6

Apparent angle of internal shearing resistance given by regression (°)	38,6
Apparent cohesion given by regression (kPa)	3,3

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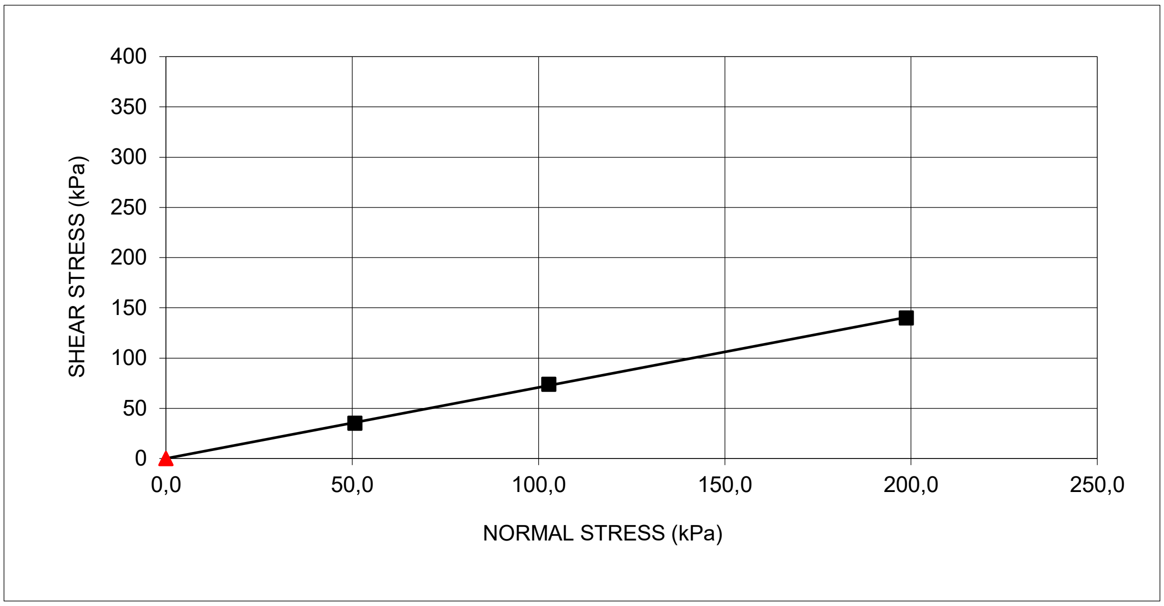
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33060	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 87 @ 1,6-1,85m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		
RESULTS AT START OF TEST			
Void Ratio	0,64	0,64	0,65
Moisture Content %	8,50	8,50	8,50
Dry Density	1614	1612	1610
RESULTS AT END OF TEST			
Void Ratio	0,59	0,60	0,60
Moisture Content %	22,26	19,42	18,92
PEAK SHEAR STRENGTH			
Shear Stress kPa	35,00	74,00	140,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	0,0	35,3

Apparent angle of internal shearing resistance given by regression (°)	35,3
Apparent cohesion given by regression (kPa)	0,0

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CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33051	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 133 @ 2,0-2,3m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		

RESULTS AT START OF TEST

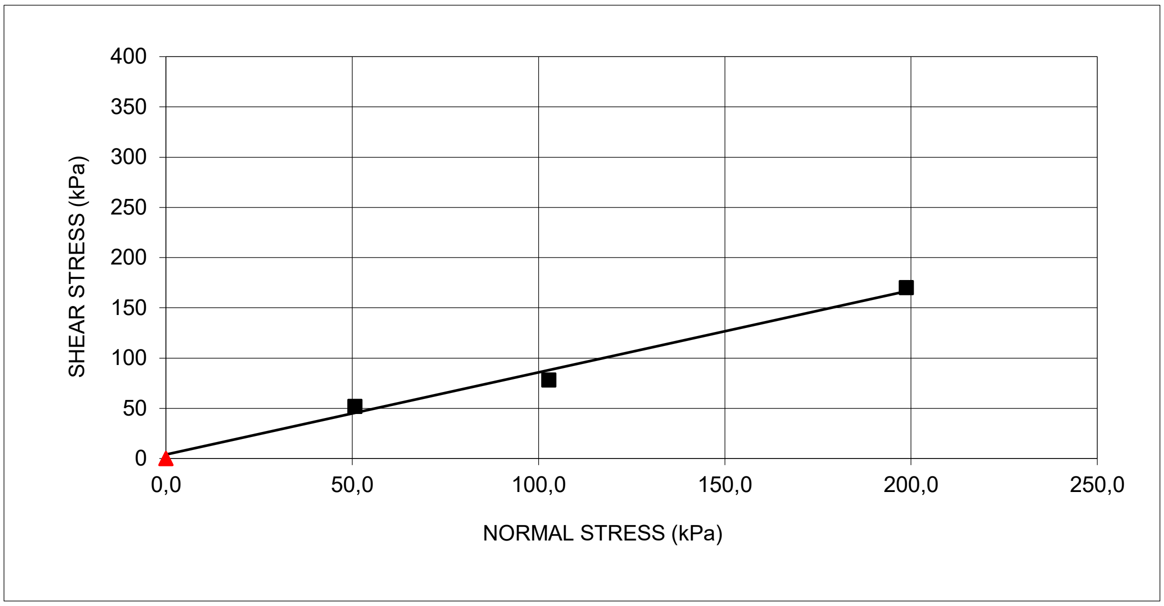
Void Ratio	0,54	0,54	0,53
Moisture Content %	4,70	4,70	4,70
Dry Density	1723	1716	1737

RESULTS AT END OF TEST

Void Ratio	0,51	0,53	0,50
Moisture Content %	19,69	18,91	18,11

PEAK SHEAR STRENGTH

Shear Stress kPa	52,00	78,00	170,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	4,0	39,3

Apparent angle of internal shearing resistance given by regression (°)	39,3
Apparent cohesion given by regression (kPa)	4,0

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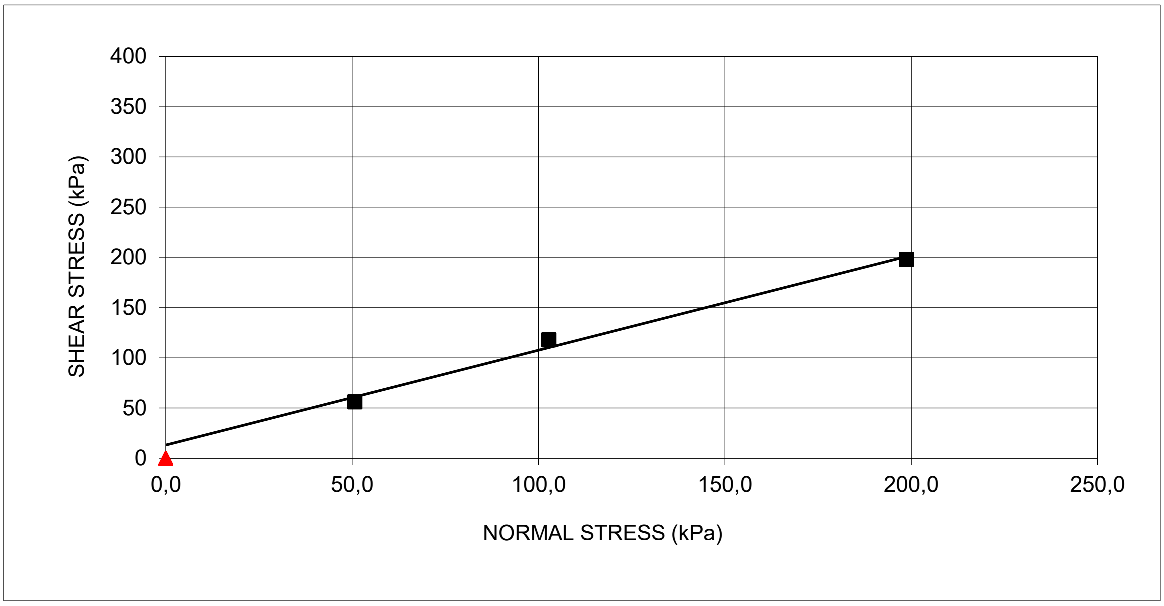
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33052	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 138 @ 1,9-2,2m
Sample Preparation	Undisturbed		
Displacement Rate mm/min	0.048 mm/min		
	RESULTS AT START OF TEST		
Void Ratio	0,49	0,46	0,46
Moisture Content %	9,60	9,60	9,60
Dry Density	1779	1816	1821
	RESULTS AT END OF TEST		
Void Ratio	0,47	0,44	0,45
Moisture Content %	15,39	14,72	13,85
	PEAK SHEAR STRENGTH		
Shear Stress kPa	56,00	118,00	198,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	13,2	43,3

Apparent angle of internal shearing resistance given by regression (°)	43,3
Apparent cohesion given by regression (kPa)	13,2

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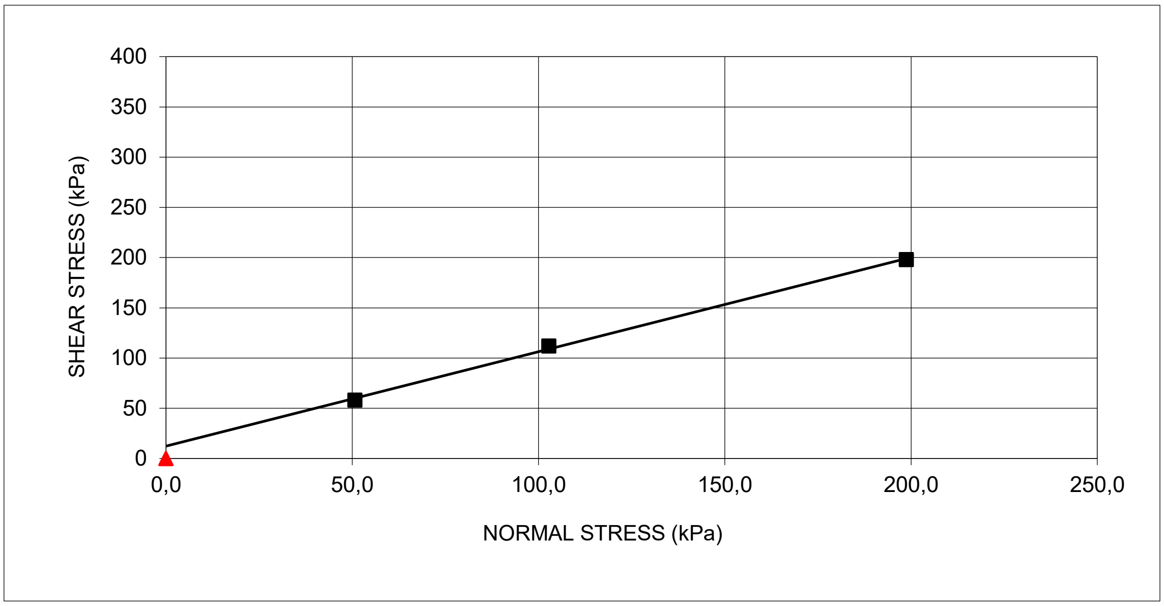
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33053	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 56 @ 1,8-3,0m
Sample Preparation	Remoulded to 98% MDD		
Displacement Rate mm/min		0.048 mm/min	
RESULTS AT START OF TEST			
Void Ratio	0,46	0,47	0,47
Moisture Content %	7,60	7,60	7,60
Dry Density	1825	1808	1823
RESULTS AT END OF TEST			
Void Ratio	0,45	0,46	0,45
Moisture Content %	18,02	18,25	17,71
PEAK SHEAR STRENGTH			
Shear Stress kPa	58,00	112,00	198,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	12,3	43,2

Apparent angle of internal shearing resistance given by regression (°)	43,2
Apparent cohesion given by regression (kPa)	12,3

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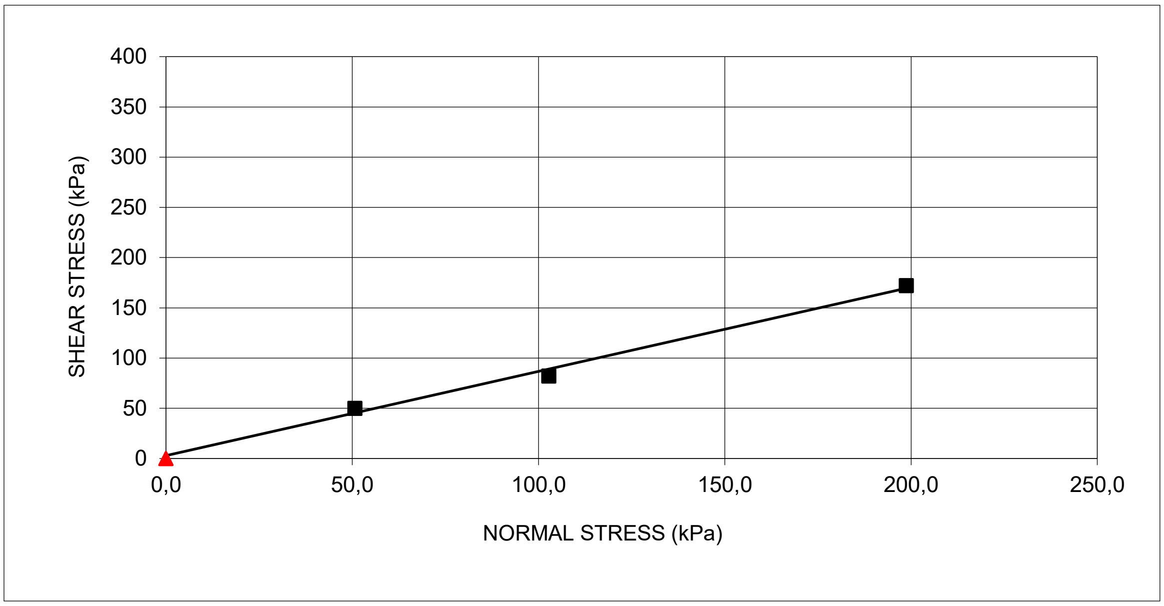
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33054	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 57 @ 0,3-1,8m
Sample Preparation	Remoulded to 98% MDD		
Displacement Rate mm/min		0.048 mm/min	
RESULTS AT START OF TEST			
Void Ratio	0,61	0,62	0,62
Moisture Content %	8,10	8,10	8,10
Dry Density	1642	1637	1640
RESULTS AT END OF TEST			
Void Ratio	0,60	0,57	0,59
Moisture Content %	20,72	21,03	20,02
PEAK SHEAR STRENGTH			
Shear Stress kPa	50,00	82,00	172,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	2,9	40,0

Apparent angle of internal shearing resistance given by regression (°)	40,0
Apparent cohesion given by regression (kPa)	2,9

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CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33061	**Test type**	Drained Consolidated
Description		**Sample Position**	TP 91 @ 0,5-3,0m
Sample Preparation	Remoulded to 98% MDD		
Displacement Rate mm/min		0.048 mm/min	

RESULTS AT START OF TEST

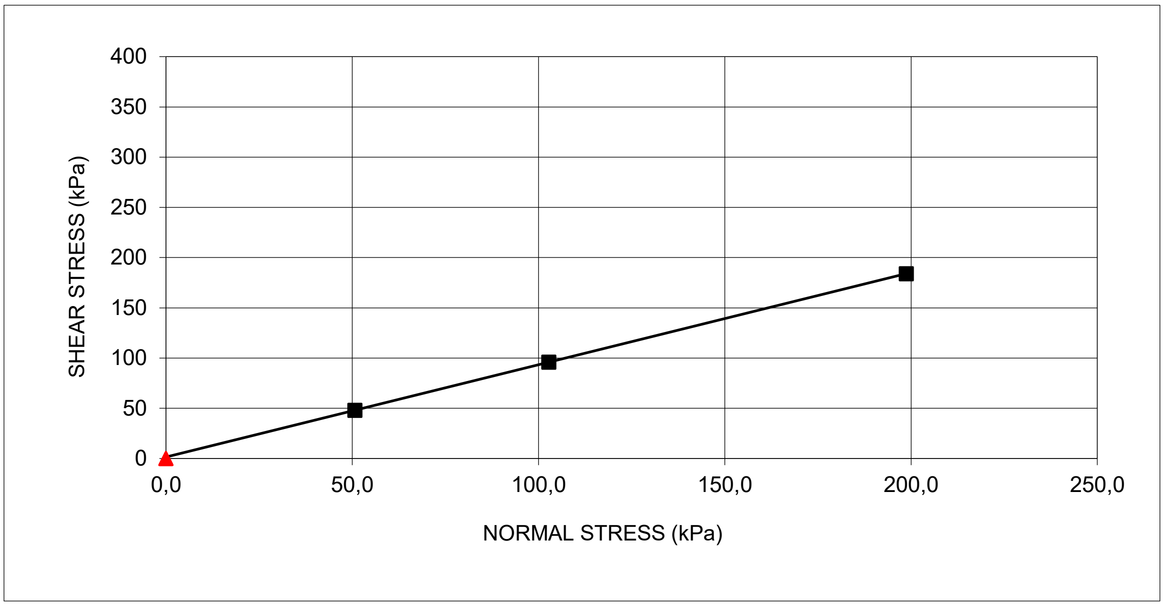
Void Ratio	0,62	0,62	0,62
Moisture Content %	8,50	8,50	8,50
Dry Density	1637	1637	1638

RESULTS AT END OF TEST

Void Ratio	0,60	0,61	0,59
Moisture Content %	22,40	21,88	22,20

PEAK SHEAR STRENGTH

Shear Stress kPa	48,00	96,00	184,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	**Degrees**
Peak	1,5	42,6

Apparent angle of internal shearing resistance given by regression (°)	42,6
Apparent cohesion given by regression (kPa)	1,5

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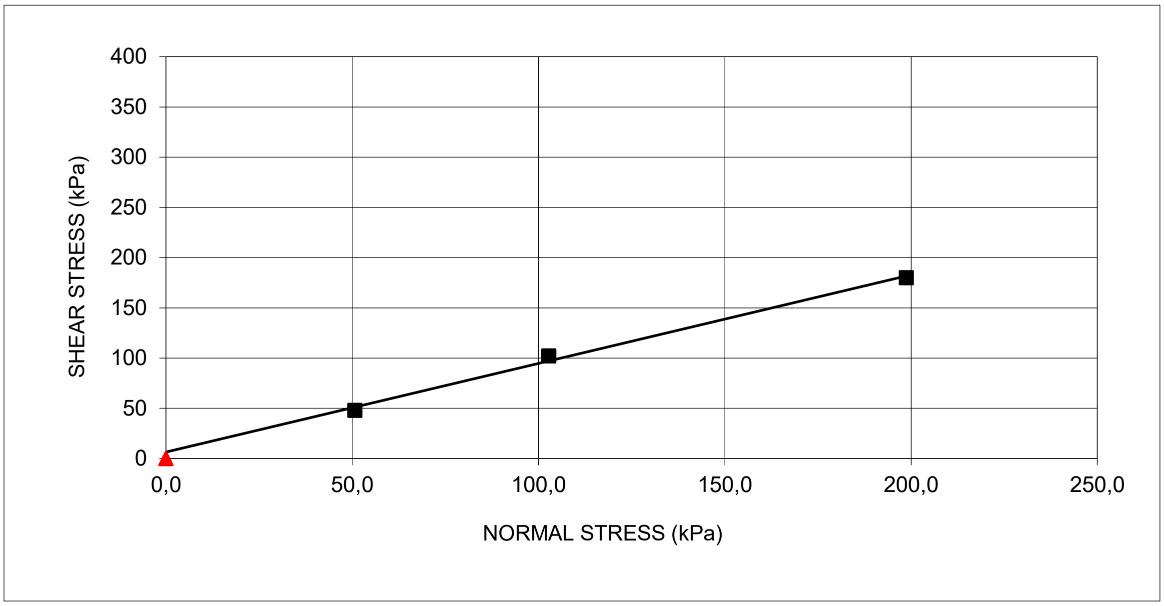
CLIENT: Roadlab **PROJECT:** Namakwa Sands

JOB NO: L200905

DIRECT SHEAR TEST (ASTM D3080)

Sample Number	33055	**Test type**	Drained Consolidated
Description		**Sample Position**	Borrow Pit
Sample Preparation	Remoulded to 98% MDD		
Displacement Rate mm/min		0.048 mm/min	
RESULTS AT START OF TEST			
Void Ratio	0,62	0,58	0,68
Moisture Content %	8,20	8,20	8,20
Dry Density	1856	1823	1849
RESULTS AT END OF TEST			
Void Ratio	0,60	0,55	0,61
Moisture Content %	22,30	21,04	20,73
PEAK SHEAR STRENGTH			
Shear Stress kPa	48,00	102,00	180,00
Normal Stress kPa	50,71	102,79	198,72



	C kPa	Degrees
Peak	6,4	41,4

Apparent angle of internal shearing resistance given by regression (°)	41,4
Apparent cohesion given by regression (kPa)	6,4

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OTHER BRANCH OFFICES: Cape Town, Kokstad, Johannesburg, Mthatha, Queenstown, Lusaka - Zambia

CLIENT : Roadlab Laboratories (Pty) Ltd
P O Box 1476
GERMISTON
1400

ATT: Mr G Pollman

PROJECT: NAMAKWA SANDS
O/N: CTPO 001939
DATE RECEIVED: 2020-09-23
DATE TESTED: 2020-10-01
DATE REPORTED: 2020-10-02
TEST REPORT NO.: 101087

PERMEABILITY CONSTANT HEAD (TRIAXIAL APPARATUS)

SAMPLE	SAMPLE DATA	In-Situ M.C	In-Situ	VOLUME	Time	PERMEABILITY
NO.	Client Sample Description.	%	DRY DENSITY	cm³	Sec	cm / SECOND
4558	TP 138 @ 1.9 - 2.2m - Brownish sand	8.2	1850	98.0	7200	9.47×10^{-5}
4559	TP133 @ 2.0 - 2.3m - Orange sand	5.0	1680	39.1	7200	3.78×10^{-5}
4560	TP20 @ 1.4 - 1.8m - Brown sand	4.9	2007	89.8	7200	7.99×10^{-5}
4562	TP 45 @ 1.3 - 1.8m - Brownish Olive sand	5.2	1558	552.8	7200	5.34×10^{-4}

DEGREE OF PERMEABILITY

over	$X 10^{-1}$	————	HIGH
$1 X 10^{-1}$	to $1 X 10^{-3}$	————	MEDIUM
$1 X 10^{-3}$	to $1 X 10^{-5}$	————	LOW
$1 X 10^{-5}$	to $1 X 10^{-7}$	————	VERY LOW
less than	$1 X 10^{-7}$	————	PRACTICALLY IMPERMEABLE

Technical Signatory: T Knight

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CLIENT : Roadlab Laboratories (Pty) Ltd
P O Box 1476
GERMISTON
1400

ATT: Mr G Pollman

PROJECT: NAMAKWA SANDS
O/N: CTPO 001939
DATE RECEIVED: 2020-09-23
DATE TESTED: 2020-10-06
DATE REPORTED: 2020-10-09
TEST REPORT NO.: 101087

PERMEABILITY CONSTANT HEAD (TRIAXIAL APPARATUS)

SAMPLE NO.	SAMPLE DATA Client Sample Description.	In-Situ M.C %	In-Situ DRY DENSITY	VOLUME cm^3	Time Sec	PERMEABILITY cm / SECOND
4563	TP 87 @ Foundation - Brown sand	13.5	1613	30.9	7200	3.03×10^{-5}
4564	TP 27 @ 1.2 - 1.5m - dark Brown sand	6.9	1584	3.4	7200	2.85×10^{-6}
NOTE: S/NO.: 4563 REMOULDED AT EST IN-SITU DENSITY & OMC, DUE TO NATURE OF SAMPLE RECEIVED						

DEGREE OF PERMEABILITY

over	X 10^{-1}	----------	HIGH
1 X 10^{-1}	to 1 X 10^{-3}	----------	MEDIUM
1 X 10^{-3}	to 1 X 10^{-5}	----------	LOW
1 X 10^{-5}	to 1 X 10^{-7}	----------	VERY LOW
less than	1 X 10^{-7}	----------	PRACTICALLY IMPERMEABLE

Technical Signatory:
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CLIENT : Roadlab Laboratories (Pty) Ltd
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GERMISTON
1400

ATT: Mr G Pollman

PROJECT: NAMAKWA SANDS
O/N: CTPO 001939
DATE RECEIVED: 2020-09-23
DATE TESTED: 2020-10-14
DATE REPORTED: 2020-10-15
TEST REPORT NO.: 101087

PERMEABILITY CONSTANT HEAD (TRIAXIAL APPARATUS)

SAMPLE	SAMPLE DATA	In Situ M.C	In-Situ	VOLUME	Time	PERMEABILITY
NO.	Client Sample Description.	%	DRY DENSITY	cm³	Sec	cm / SECOND
4557	TP 64 @ 1.7 - 2.0m - Brownish Orange sand	7.3	1658	98.1	7200	9.48×10^{-5}
4561	TP 116 @ 1.7 - 2.0m - Orange sand	7.4	1666	65.3	7200	6.40×10^{-5}

DEGREE OF PERMEABILITY

over	$X\ 10^{-1}$	------------	HIGH
$1\ X\ 10^{-1}$	to $1\ X\ 10^{-3}$	------------	MEDIUM
$1\ X\ 10^{-3}$	to $1\ X\ 10^{-5}$	------------	LOW
$1\ X\ 10^{-5}$	to $1\ X\ 10^{-7}$	------------	VERY LOW
less than	$1\ X\ 10^{-7}$	------------	PRACTICALLY IMPERMEABLE

Technical Signatory:
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CLIENT : Roadlab Laboratories (Pty) Ltd
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ATT: Mr G Pollman

PROJECT: NAMAKWA SANDS
O/N: CTPO 001939
DATE RECEIVED: 2020-09-23
DATE TESTED: 2020-10-15
DATE REPORTED: 2020-10-16
TEST REPORT NO.: 101087

PERMEABILITY CONSTANT HEAD (TRIAXIAL APPARATUS)

SAMPLE	SAMPLE DATA	REMOULDED M.C	REMOULDED	VOLUME	TIME	PERMEABILITY
NO. & (CLIENT)	Client Sample Description.	%	DRY DENSITY	cm^3	Sec	cm / SECOND
4545 (51322)	BORROW PIT - lt Olive Silty Sand	8.2	1819	9.7	7200	9.38×10^{-6}
4547 (51314)	TP 56 @ 1.8 - 3.0m - lt Reddish Brown Sand	7.8	1800	393.4	7200	3.80×10^{-4}
NOTE: SAMPLES REMOULDED AT 98% PROCTOR						

DEGREE OF PERMEABILITY

over	$X 10^{-1}$	------------	HIGH
$1 X 10^{-1}$	to $1 X 10^{-3}$	------------	MEDIUM
$1 X 10^{-3}$	to $1 X 10^{-5}$	------------	LOW
$1 X 10^{-5}$	to $1 X 10^{-7}$	------------	VERY LOW
less than	$1 X 10^{-7}$	------------	PRACTICALLY IMPERMEABLE

Technical Signatory: T Knight

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CLIENT : Roadlab Laboratories (Pty) Ltd
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1400

ATT: Mr G Pollman

PROJECT: NAMAKWA SANDS
O/N: **CTPO 001939**
DATE RECEIVED: 2020-09-23
DATE TESTED: 2020-10-16
DATE REPORTED: 2020-10-20
TEST REPORT NO.: 101087

PERMEABILITY CONSTANT HEAD (TRIAXIAL APPARATUS)

SAMPLE	SAMPLE DATA	REMOULDED M.C	REMOULDED	VOLUME	TIME	PERMEABILITY
NO. & (CLIENT)	Client Sample Description.	%	DRY DENSITY	cm^3	Sec	cm / SECOND
4548 (51315)	TP 57 @ 0.3 - 1.8m - dk Reddish Brown Sand	8.7	1634	400.8	600	4.65×10^{-3}
4549 (51325)	TP 91 @ 0.3 - 3.0m - lt Brown Orange Sand	8.6	1634	185	600	2.15×10^{-3}
4550 (51316)	TP 108 @ 1.2 - 3.0m - dk Brown Orange Sand	8.4	1795	203.4	600	2.36×10^{-3}
4551 (51317)	TP 109 @ 0.0 - 2.5m - lt Brown Sand	8.5	1635	193.8	1200	1.12×10^{-3}
NOTE: SAMPLES REMOULDED AT 98% PROCTOR						

DEGREE OF PERMEABILITY

over $X 10^{-1}$ ------------ HIGH
$1 X 10^{-1}$ to $1 X 10^{-3}$ ------------ MEDIUM
$1 X 10^{-3}$ to $1 X 10^{-5}$ ------------ LOW
$1 X 10^{-5}$ to $1 X 10^{-7}$ ------------ VERY LOW
less than $1 X 10^{-7}$ ------------ PRACTICALLY IMPERMEABLE

Technical Signatory: ______________
J Atterbury

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CONSOLIDATION TEST SUMMARY OF READINGS

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33059
POSITION: TP 45 @ 1,3-1,8m

INITIAL DIAL READING = 1,09 mm
RING DIAMETER = 76,3 mm
H1 = 18,95 mm
H_S = 12,65 mm

OEDOMETER NO : 5
BEAM RATIO : 11

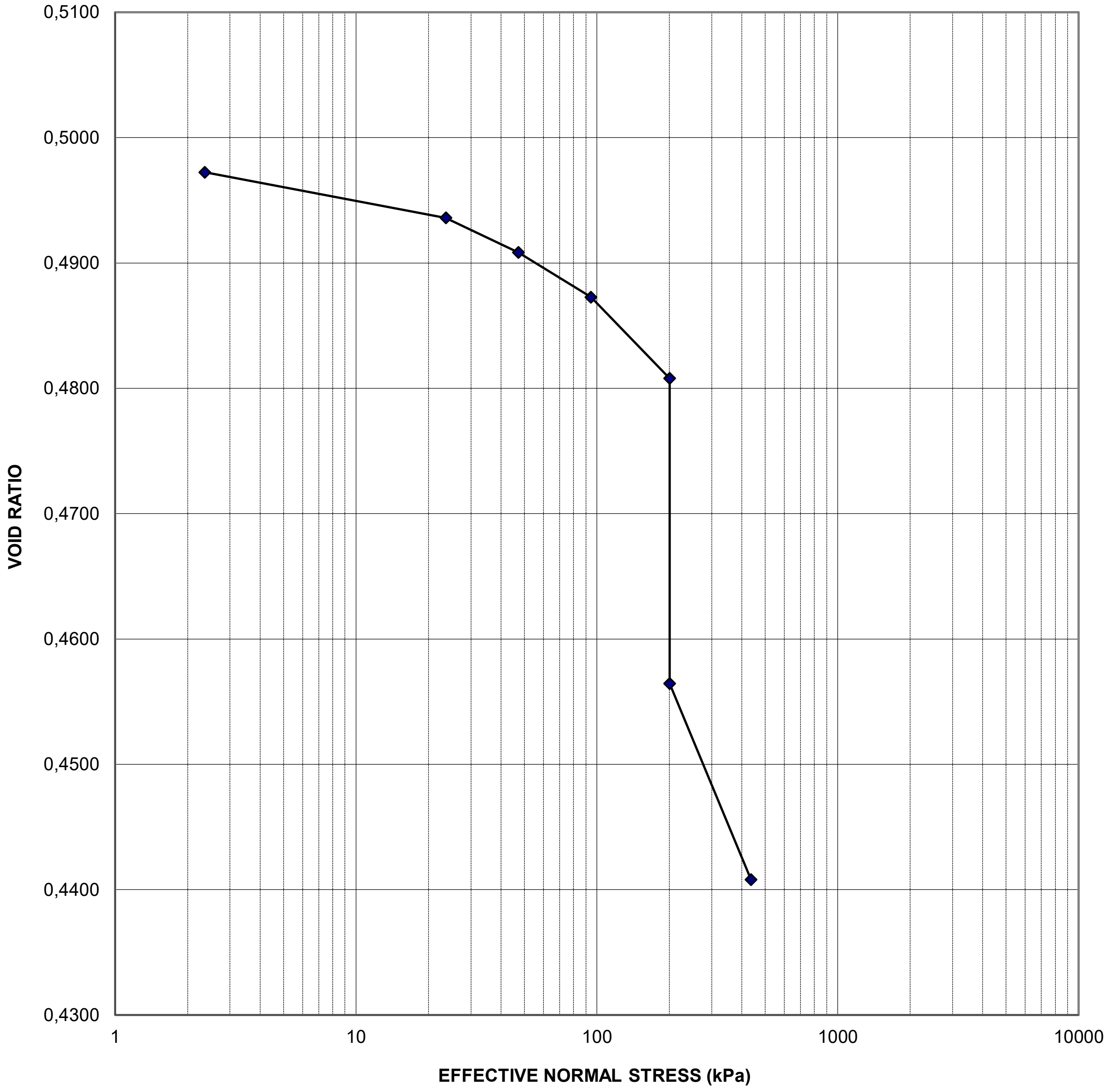
BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	1,090	1,090	0,000	0	18,950	0,4980
0,1		2,36	1,078	0,012	0,002	0,010	18,940	0,4972
1,0		23,60	1,008	0,082	0,026	0,056	18,894	0,4936
2,0		47,20	0,962	0,128	0,037	0,091	18,859	0,4908
4,0		94,40	0,904	0,186	0,050	0,136	18,814	0,4873
8,5		200,60	0,806	0,284	0,066	0,218	18,732	0,4808
8,5	SAT	200,60	0,498	0,592	0,066	0,526	18,424	0,4564
18,5		436,61	0,278	0,812	0,088	0,724	18,226	0,4408

COLLAPSE POTENTIAL: 1,63%

CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33059

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed
DRY DENSITY = 1769 Kg/m3
SPECIFIC DENSITY (EST) = 2,65
INITIAL SATURATION = 0,33
FINAL SATURATION = 0,86
INITIAL MOISTURE CONTENT = 6,26 %
FINAL MOISTURE CONTENT = 14,29 %
INITIAL VOID RATIO = 0,498
FINAL VOID RATIO = 0,4408



CONSOLIDATION TEST SUMMARY OF READINGS

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33060
POSITION: TP 87 @ 1,6-1,85m

INITIAL DIAL READING = 6,202 mm
RING DIAMETER = 50,05 mm
H1 = 20,55 mm
H_S = 12,45 mm

OEDOMETER NO : 8
BEAM RATIO : 11

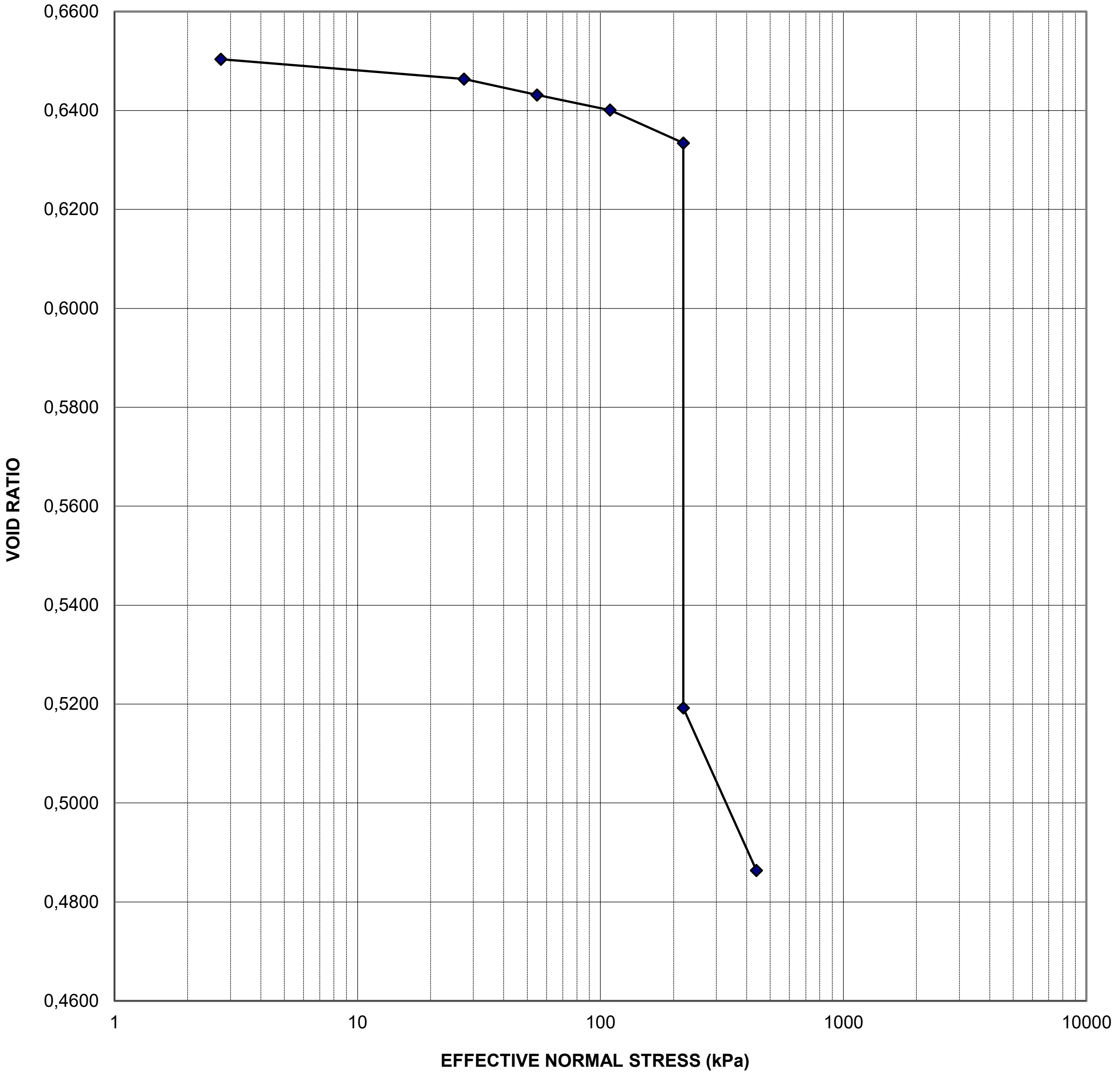
BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	6,202	6,202	0,000	0	20,550	0,6506
0,05		2,74	6,198	0,004	0,001	0,003	20,547	0,6504
0,5		27,42	6,133	0,069	0,016	0,053	20,497	0,6463
1,0		54,85	6,089	0,113	0,020	0,093	20,457	0,6431
2,0		109,70	6,042	0,160	0,029	0,131	20,419	0,6401
4,0		219,39	5,946	0,256	0,042	0,214	20,336	0,6334
4,0	SAT	219,39	4,524	1,678	0,042	1,636	18,914	0,5192
8,0		438,79	4,098	2,104	0,059	2,045	18,505	0,4863

COLLAPSE POTENTIAL: 6,92%

CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33060

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed
DRY DENSITY = 1605 Kg/m3
SPECIFIC DENSITY (EST) = 2,65
INITIAL SATURATION = 0,33
FINAL SATURATION = 0,79
INITIAL MOISTURE CONTENT = 8,01 %
FINAL MOISTURE CONTENT = 16,8 %
INITIAL VOID RATIO = 0,6506
FINAL VOID RATIO = 0,4863



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CONSOLIDATION TEST SUMMARY OF READINGS

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33062
POSITION: TP 116 @ 1,7-2,0m

INITIAL DIAL READING = 1,127 mm
RING DIAMETER = 50,05 mm
H1 = 20,4 mm
H_S = 13,23 mm

OEDOMETER NO : 4
BEAM RATIO : 11

BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	1,127	1,127	0,000	0	20,400	0,5420
0,05		2,74	1,115	0,012	0,001	0,011	20,389	0,5411
0,5		27,42	1,008	0,119	0,014	0,105	20,295	0,5340
1,0		54,85	0,917	0,210	0,021	0,189	20,211	0,5277
2,0		109,70	0,834	0,293	0,031	0,262	20,138	0,5221
4,0		219,39	0,752	0,375	0,044	0,331	20,069	0,5169
4,0	SAT	219,39	0,240	0,887	0,044	0,843	19,557	0,4782
8,0		438,79	0,039	1,088	0,060	1,028	19,372	0,4642

COLLAPSE POTENTIAL: 2,51%

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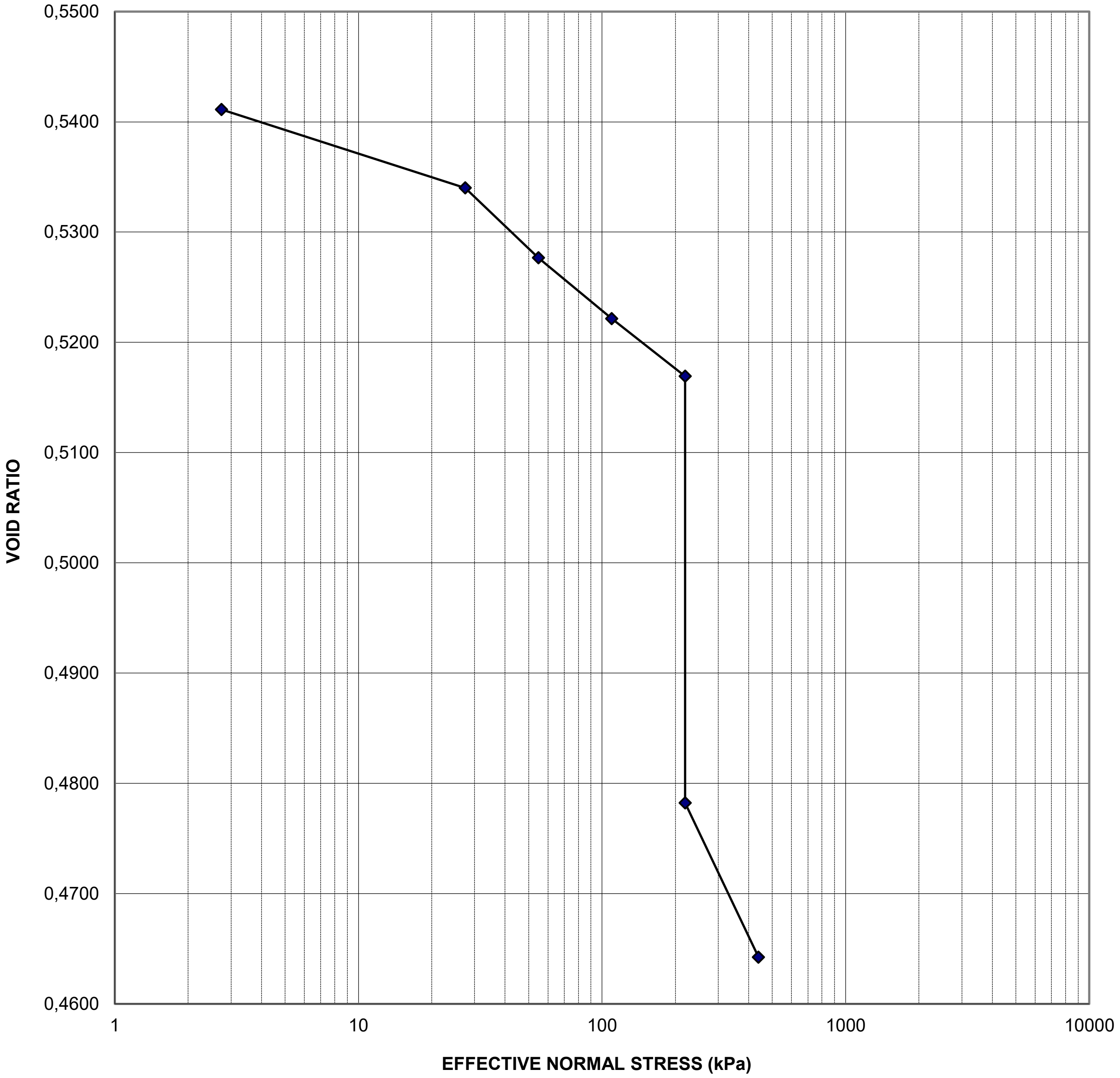
CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33062

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed

DRY DENSITY	=	1719 Kg/m3	SPECIFIC DENSITY (EST)	=	2,65
INITIAL SATURATION	=	0,26	FINAL SATURATION	=	0,94
INITIAL MOISTURE CONTENT	=	5,36 %	FINAL MOISTURE CONTENT	=	16,38 %
INITIAL VOID RATIO	=	0,542	FINAL VOID RATIO	=	0,4642



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CONSOLIDATION TEST

SUMMARY OF READINGS

PROJECT NO : L200905
SAMPLE NO : 33056
POSITION: TP 64 @ 1,7-2,0m

PROJECT : Namakwa Sands

INITIAL DIAL READING = 5,432 mm
RING DIAMETER = 76 mm
H1 = 19,3 mm
H_S = 12,35 mm

OEDOMETER NO : 3
BEAM RATIO : 11

BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	5,432	5,432	0,000	0	19,300	0,5628
0,1		2,38	5,417	0,015	0,002	0,013	19,287	0,5617
0,1	SAT	2,38	5,523	-0,091	0,002	-0,093	19,393	0,5703
0,5		11,89	5,218	0,214	0,009	0,205	19,095	0,5462
2,0		47,57	4,951	0,481	0,022	0,459	18,841	0,5256
4,0		95,15	4,751	0,681	0,032	0,649	18,651	0,5102
8,0		190,30	4,545	0,887	0,045	0,842	18,458	0,4946
18,0		428,17	4,245	1,187	0,066	1,121	18,179	0,4720
38,0		903,92	4,028	1,404	0,098	1,306	17,994	0,4570
73,0		1736,47	3,871	1,561	0,109	1,452	17,848	0,4452
38,0		903,92	3,932	1,500	0,107	1,393	17,907	0,4500
18,0		428,17	3,992	1,440	0,073	1,367	17,933	0,4521
4,0		95,15	4,076	1,356	0,037	1,319	17,981	0,4560
0,5		11,89	4,185	1,247	0,014	1,233	18,067	0,4629
0,1		2,38	4,260	1,172	0,004	1,168	18,132	0,4682

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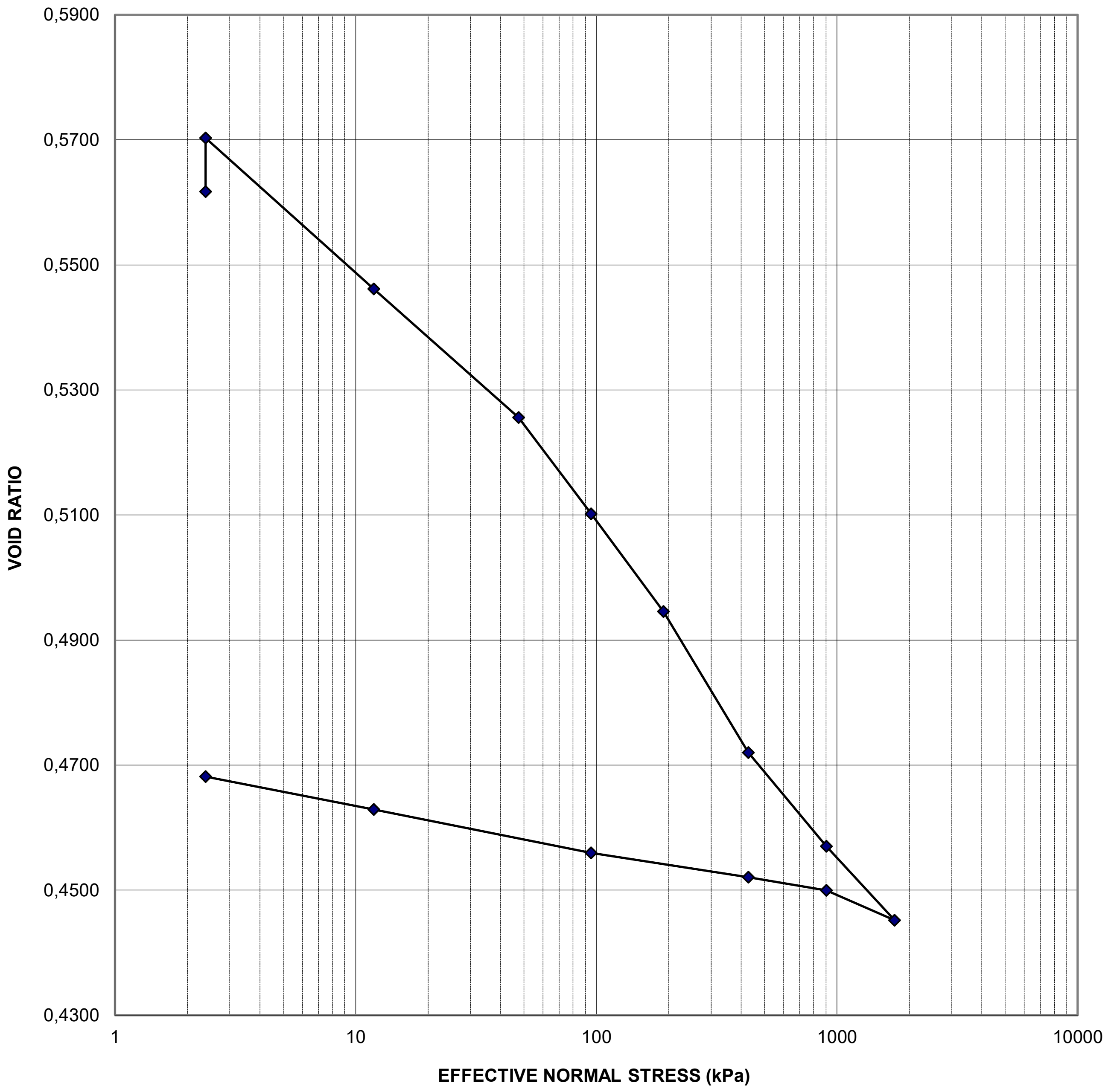
CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33056

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed
DRY DENSITY = 1696 Kg/m3
SPECIFIC DENSITY (EST) = 2,65
INITIAL SATURATION = 0,28
FINAL SATURATION = 0,87
INITIAL MOISTURE CONTENT = 5,86 %
FINAL MOISTURE CONTENT = 15,42 %
INITIAL VOID RATIO = 0,5628
FINAL VOID RATIO = 0,4682



CONSOLIDATION TEST SUMMARY OF READINGS

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33051
POSITION: TP 133 @ 2,0-2,3m

INITIAL DIAL READING = 1,308 mm
RING DIAMETER = 76,4 mm
H1 = 19,2 mm
H_S = 12,45 mm

OEDOMETER NO : 2
BEAM RATIO : 11

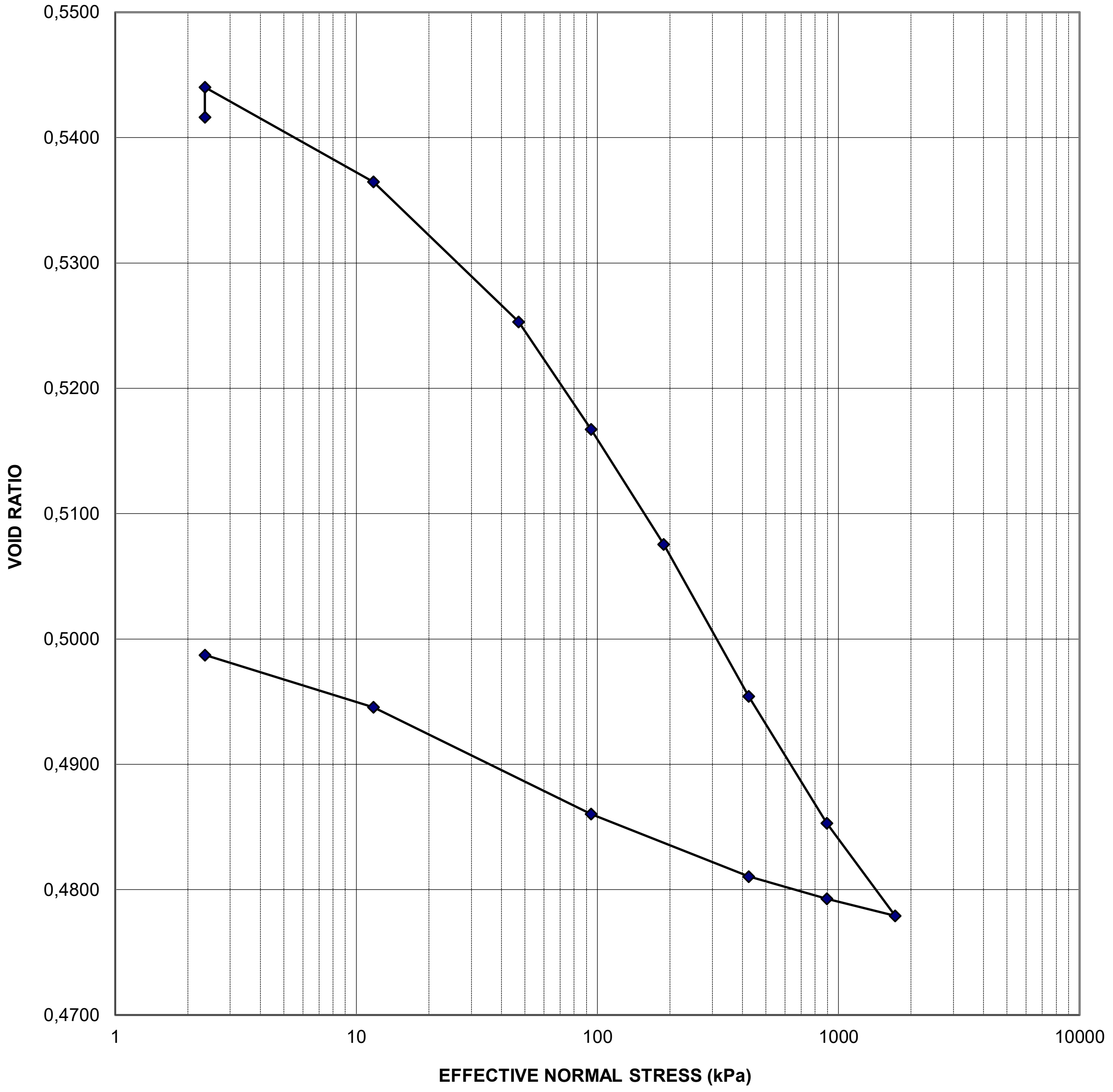
BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	1,308	1,308	0,000	0	19,200	0,5422
0,1		2,35	1,300	0,008	0,001	0,007	19,193	0,5416
0,1	SAT	2,35	1,330	-0,022	0,001	-0,023	19,223	0,5440
0,5		11,77	1,230	0,078	0,007	0,071	19,129	0,5365
2,0		47,08	1,080	0,228	0,018	0,210	18,990	0,5253
4,0		94,16	0,964	0,344	0,027	0,317	18,883	0,5167
8,0		188,31	0,836	0,472	0,041	0,431	18,769	0,5076
18,0		423,70	0,660	0,648	0,066	0,582	18,618	0,4954
38,0		894,48	0,500	0,808	0,100	0,708	18,492	0,4853
73,0		1718,34	0,350	0,958	0,158	0,800	18,400	0,4779
38,0		894,48	0,416	0,892	0,109	0,783	18,417	0,4793
18,0		423,70	0,476	0,832	0,071	0,761	18,439	0,4810
4,0		94,16	0,578	0,730	0,031	0,699	18,501	0,4860
0,5		11,77	0,704	0,604	0,011	0,593	18,607	0,4945
0,1		2,35	0,764	0,544	0,003	0,541	18,659	0,4987

CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33051

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed

DRY DENSITY	=	1719 Kg/m3	SPECIFIC DENSITY (EST)	=	2,65
INITIAL SATURATION	=	0,29	FINAL SATURATION	=	0,79
INITIAL MOISTURE CONTENT	=	5,88 %	FINAL MOISTURE CONTENT	=	14,87 %
INITIAL VOID RATIO	=	0,5422	FINAL VOID RATIO	=	0,4987



CONSOLIDATION TEST SUMMARY OF READINGS

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33052
POSITION: TP 138 @ 1,9-2,2m

INITIAL DIAL READING = 1,072 mm
RING DIAMETER = 76,1 mm
H1 = 18,75 mm
H_S = 12,93 mm

OEDOMETER NO : 1
BEAM RATIO : 11

BEAM LOAD	COMMENTS	PRESSURE	DIAL READING	UNCORRECTED DEFLECTION	MACHINE CORRECTION	CORRECTED DEFLECTION	HEIGHT CHANGE	VOID RATIO
(kg)		(Kpa)	(mm)	(mm)	(mm)	(mm)	(mm)	
0,0		0,00	1,072	1,072	0,000	0	18,750	0,4501
0,1		2,37	1,068	0,004	0,001	0,003	18,747	0,4499
0,1	SAT	2,37	1,076	-0,004	0,001	-0,005	18,755	0,4505
0,5		11,86	1,030	0,042	0,008	0,034	18,716	0,4475
2,0		47,45	0,924	0,148	0,022	0,126	18,624	0,4404
4,0		94,90	0,828	0,244	0,032	0,212	18,538	0,4337
8,0		189,80	0,704	0,368	0,045	0,323	18,427	0,4251
18,0		427,05	0,480	0,592	0,069	0,523	18,227	0,4097
38,0		901,54	0,250	0,822	0,107	0,715	18,035	0,3948
73,0		1731,91	0,012	1,060	0,159	0,901	17,849	0,3804
38,0		901,54	0,094	0,978	0,106	0,872	17,878	0,3827
18,0		427,05	0,158	0,914	0,062	0,852	17,898	0,3842
4,0		94,90	0,254	0,818	0,037	0,781	17,969	0,3897
0,5		11,86	0,356	0,716	0,014	0,702	18,048	0,3958
0,1		2,37	0,410	0,662	0,003	0,659	18,091	0,3991

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GEOTECHNICAL AND ENVIRONMENTAL SERVICES
A division of ControLab South Africa (Pty) Ltd – Accreditation Number: T0308
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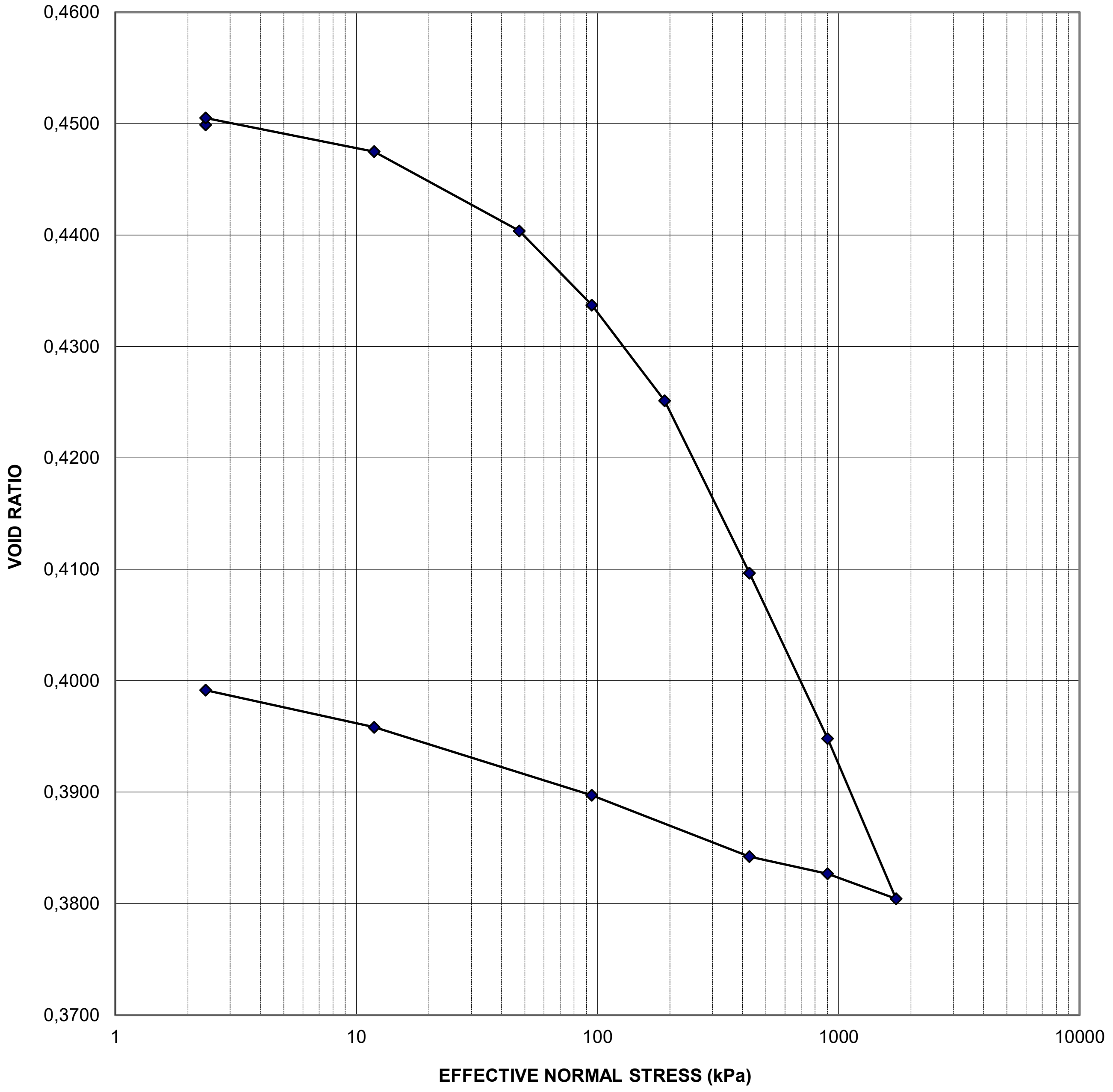
OTHER CONTROLAB BRANCH OFFICES: East London, Johannesburg, Mthatha, Kokstad, Queenstown, Lusaka - Zambia

CONSOLIDATION TEST

PROJECT NO : L200905
PROJECT : Namakwa Sands
SAMPLE NO : 33052

SAMPLE DESCRIPTION :
STATE OF SAMPLE : Undisturbed

DRY DENSITY	=	1831 Kg/m3	SPECIFIC DENSITY (EST)	=	2,65
INITIAL SATURATION	=	0,62	FINAL SATURATION	=	0,87
INITIAL MOISTURE CONTENT	=	10,46 %	FINAL MOISTURE CONTENT	=	13,02 %
INITIAL VOID RATIO	=	0,4501	FINAL VOID RATIO	=	0,3991



Appendix E SEEPAGE AND STABILITY ASSESMENT REPORT

Slope Stability Assessment of the Tronox EOFS Residue Storage Facility #6

epoch
resources (pty) ltd

mine residue and environmental engineering consultants

PROJECT NUMBER 126-005 REPORT NO.2 Draft December 2020

Slope Stability Assessment of the Tronox EOFS Residue Storage Facility #6

Prepared For

Tronox Mineral Sands (Pty) LRDRD

PROJECT NUMBER 126-005

REPORT NO.2 Draft

February 2021

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Author	Stephan Barkhuizen
Reviewer	Georgia Vagis
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Project No. 126-005 December 2020

Report No. 2 Draft

SLOPE STABILITY ASSESSMENT OF THE TRONOX EOFS RESIDUE STORAGE FACILITY #6

1. INTRODUCTION

Epoch Resources (Pty) Ltd (Epoch) carried out seepage and slope stability analyses as part of the Bankable Feasibility Study (FS) of the Residue Storage Facility (RSF) for Tronox Mineral Sands (Pty) Ltd (Namakwa) for their Tronox Namakwa Sands East OFS Project (EOFS Project). The Project is located in South Africa's Western Province, 54 km North-west of Lutzville and 385 km north of Cape Town.

The RSF will comprise a Residue Dam (RD) and associated infrastructure (i.e. stormwater diversion, access roads, etc.). The RD is a full containment facility that will store residue over the life of mine behind a two-phase, earth embankment. The embankment will be constructed using a tailings waste product from the plant. The intent of the facility is to store residue produced from the Orange Felspathic Sands mined at the East Mine.

This report documents the undertaking of the seepage assessments for the facility under varying operating conditions, and the consequential slope stability determined in terms of:

- Factor of Safety (*FoS*);
- Reliability Index (*RI*); and
- Probability of Failure (*PoF*).

2. TERMS OF REFERENCE

The terms of reference for the project include seepage and slope stability assessments of the RD. This is to confirm that the required FoS against failure for a short-term, medium-term, and long-term slope are satisfied as per the South African regulatory requirements.

The slope stability assessments investigated the effect of static and pseudo-static conditions on the stability of the proposed RD.

3. SCOPE OF WORKS

The scope of works carried out in addressing the terms of reference as described comprised:

- Review of the geotechnical investigation report (Inroads, 2020);
- Assessment of the RD geometry and seepage control infrastructure;

- A finite element seepage analysis to evaluate the development of the phreatic surface within the RD basin due to recharge associated with rainfall and delivery of slurry water, as well as evaluate the phreatic surface developed in the containment wall;
- Deterministic and probabilistic slope stability analysis of the RD, including the application of the results of the seepage analysis, to determine the FoS, RI, and PoF against failure of the facility; and
- Interpretation and evaluation of the results of the analyses against accepted criteria for the long-term stability of slopes.

4. PERTINENT REGULATIONS AND STANDARDS

South African regulations provide the framework to which the design of an RSF must comply. A multitude of design standard and specifications may be consulted if the South African National Standards (*SANS*) does not provide sufficient spectrum, or where SANS refers to or specifies another standard. In some instances, neither regulation nor design standard may provide enough design framework for compliance in which case industry best practice guidelines may be referred to.

4.1. SOUTH AFRICAN REGULATIONS

The management of clean and dirty/mine contaminated water is regulated by several Acts, namely:

- The National Environment Management: Waste Amendment Act No. 26 of 2014 (*NEMWA*);
- The National Water Amendment Act No. 27 of 2014 (*Water Act*);
- The National Minerals and Petroleum Resource Development Amendment Act No. 49 of 2008 (*Minerals Act*).

It must be noted that NEMWA will be assumed to supersede any similar regulations covered by the older Minerals Act.

5. INFORMATION RECEIVED

During the completion of the slope stability assessment of the RD, several variables needed to be identified and, if need be, quantified. This process required the use of various sources of information. These sources are listed below:

- Geotechnical investigation report in 2020 by Inroads Consulting (Inroads), including rotary core drilling and associated geotechnical laboratory test work; and
- Geotechnical laboratory testing on the residue and tailings products.

The information obtained from the above-named sources is discussed in the section below.

5.1. GEOTECHNICAL INVESTIGATION

A geotechnical investigation of the proposed site was undertaken by Inroads between the 21st of August and the 3rd of September, and the results of the near-surface investigation were published in their report: "*Report on a geotechnical investigation for the proposed residue storage facility for the Tronox Namakwa Sands EOFS project in Brans-se-Baai, Western Cape*".

The focus of the investigation was to determine the geotechnical parameters and depths of the in-situ soil horizons in the vicinity of the RSF for seepage and stability analyses, as well as to identify any problem soils which could affect stability or soil permeability. The location of the test pits (*TPs*) investigated relative to the proposed RSF geometry is illustrated in Figure 5-1.

During 10 to 19 December 2020 and 7 to 13 January 2021 a total of six rotary cored boreholes were drilled to 20 m within the RSF while an additional two holes were drilled in the overburden site. All test pits and boreholes were profiled by Inroads using standard methods and procedures set out in the document "*Guidelines for Soil and Rock Logging in South Africa (2002)".*

5.2. SOIL PROFILE

Inroads undertook to investigate and provide typical soil profiles of 116 Test Pits (TPs) within the area of the RSF. However, due to time constraints, a total of 24 TPs within the RSF were forgone during the investigation. A Tractor Loader Backhoe (TLB) was used to excavate the TPs to depths ranging between 0.2 and 3.5 m. Soil profiling was undertaken during the investigation in an attempt to determine the individual layers, or horizons, of the underlying soils.

The top horizon of the RSF area can be subdivided into two areas, namely the unmined and rehabilitated areas. The unmined area forms the largest portion of the RSF and is comprised of very loose dune sand that extends to an average depth of 2 m. Beneath the dune sand is a layer of silty sand of aeolian origin that was encountered at depths ranging between 0.9 to 3.3 m. The aeolian material was occasionally loose but mostly medium dense to dense silty sand with scattered friable weakly cemented pockets. The aeolian extended to the bottom of most of the test pits with a few test pits contained very dense aeolian material, causing the TLB to partial refuse.

Boreholes NRSF01, NRSF06 to NRSF08 drilled within the unmined area indicate that the aeolian horizon extends to depths greater than 20 m. Standard Penetration Tests (SPT) showcased that the soil horizon becomes very dense with N values increasing from between 20 to 32 at a depth of 2.2 to 3.5 m to mainly above 50 below 3.5 m.

The rehabilitated area comprises very loose fill to a depth of between 1.1 to 3.2 m. The fill material generally extended to the bottom of the pits or was underlain by loose aeolian and in some rare cases by moderately cemented very dense and very soft rock gneiss. No groundwater was encountered in any test pits excavated during the investigation.

Boreholes NRSF02 and NRSF05 drilled along the southern wall of the RSF and within the rehabilitated area, show either very soft rock dorbank or completely weathered granite gneiss to underly the fill and aeolian sand at depths between 4.5 and 12 m.

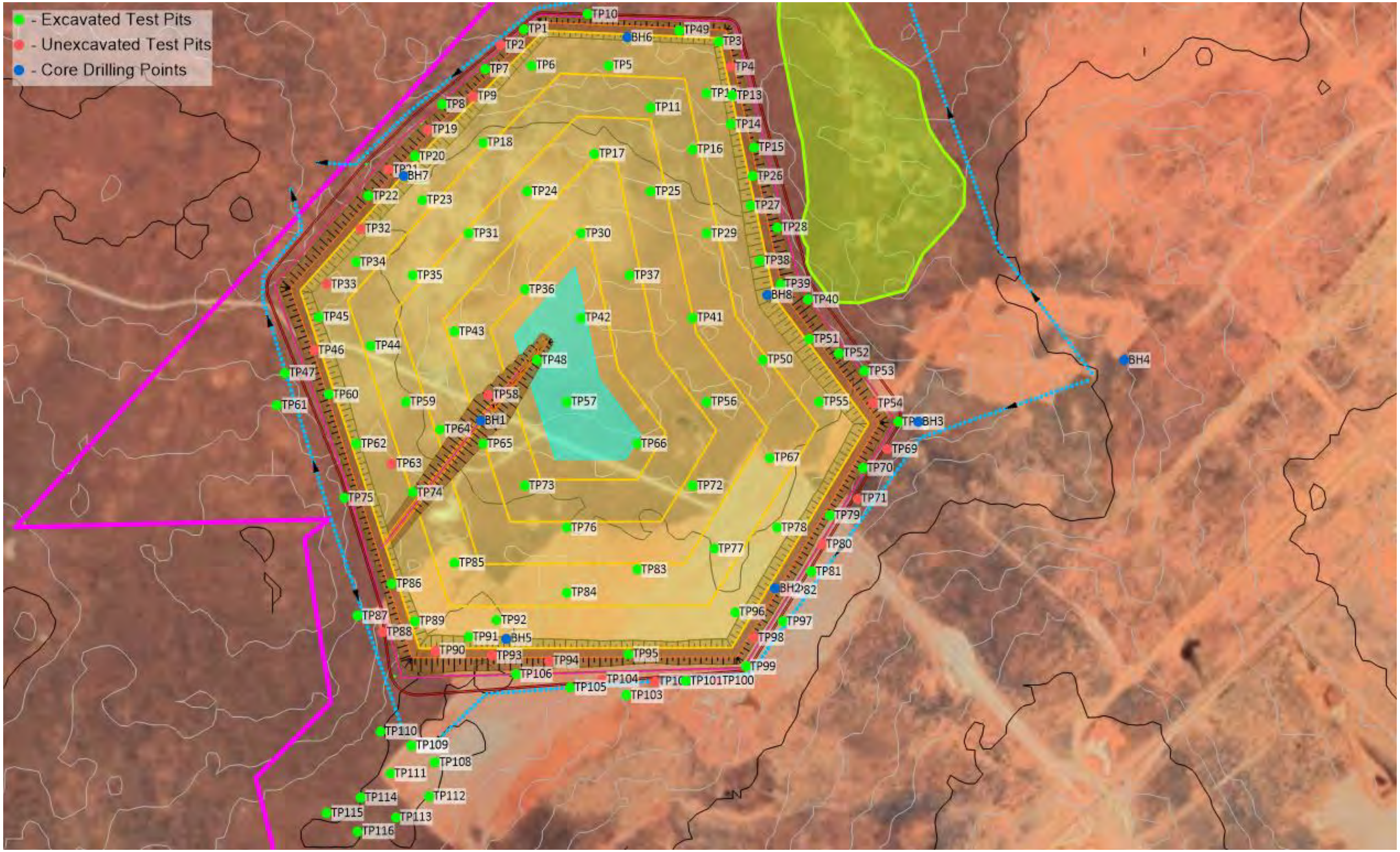


FIGURE 5-1: **RSF TEST PIT LOCATIONS**

5.3. MATERIAL STRENGTH PARAMETERS AND HYDRAULIC CONDUCTIVITY

Both disturbed and undisturbed representative soil samples were collected during the site investigation that took place from 21st August 2020 to 3rd September 2020. The Particle Size Distributions (PSDs) and Atterberg limits of the dune sand, fill and aeolian sand was determined. The results of the test indicate that the soils present within the RSF basin and beneath the embankment are uniformly non-plastic or slightly plastic. The samples tested consisted mainly of sand fractions, which comprised 87 to 99 % of the samples by mass, with the remainder including fractions of silt and clay. Other tests conducted on the sample include proctor compaction tests, slowly drained shear box tests, oedometer and saturated consolidometer tests. The permeability of the various selected soils samples was determined using the flexible wall triaxial cell test. The hydraulic conductivity values were then utilized in the seepage analyses of the RD. The strength parameters were used in the analysis of the slope stabilities in conjunction with the results of the seepage analyses. Table 5-1 presents the geotechnical parameters recommended by Inroads to be used for the design of the RSF.

TABLE 5-1: GEOTECHNICAL PARAMETERS OF MATERIALS CLASSIFIED IN TEST PITS

Soil Horizon	Layer Thickness (m)	Unified Classification	Φ' (degrees)	C' (kN/m²)	ρd (kN/m³)	K (m/sec)
Fill & dune sand (very loose in-situ)	3.5	SP	28	0	1400	10^{-4}
Fill & dune sand (compacted to 98 % proctor)		SP	35	0	1600	10^{-5}
Aeolian – silty sand (weakly cemented in places)	3.5	SP / SP - SM	32	0	1600	10^{-6}
Aeolian – silty sand (compacted to 98 % proctor)		SP / SP - SM	37	0	1800	10^{-5}
Weakly cemented aeolian, residual, weak dorbank (Very dense to very soft rock)	15	SP / SP - SM	40	0	1900	10^{-7}

Φ' = effective friction angle; c' = effective cohesion; ρ_d = dry density; k = coefficient of permeability

5.4. GEOTECHNICAL TESTING OF TAILINGS SAMPLES

Geotechnical testing was conducted on samples of the RAS and EOFS tailing products. The summary of the result of these tests are listed below:

- Friction Angle – 30°;
- Cohesion – 2 kPa;
- Unit weight – 16.6 kN/m^3; and
- Hydraulic conductivity – 2.3 x 10^{-5} m.s^{-1}.

6. RSF LAYOUT

The configurations of the RSF is based on the preferred site determined through a site selection process and has been optimised for efficient use of the available footprint area. The RSF is designed as a full containment facility with a two-phase embankment wall that will be built to the final elevation during the initial construction period with 1VH2.5H slopes for both the upstream and downstream slopes of the facility. Afterwards, the downstream slope will be reshaped to a 1V:5H slope for the closure phase of the project. The containment wall will be built from Product tailings transported from the Primary Concentration Plant (PCP) via conveyors or trucks. Conventional compaction methods will not be undertaken, instead the material will be shaped to the required embankment geometry, during which it is estimated that the traffic load will provide sufficient compaction to yield the required strength parameters, as discussed in the geotechnical investigation report. The method of construction stems from the previous facilities that have been constructed at the project location.

The embankment will also contain a blanket drain to prevent the phreatic surface from rising within the wall and saturating the downstream toe of the facility. Stormwater diversions are included in the design of the facility to prevent high runoff water from pooling at the downstream base of the embankment. The diversions also aim to keep water flowing at high velocity away from the embankment toe to prevent erosion from occurring. An illustration of the RSF, associated infrastructure and mining boundary (EMP boundary) can be seen in Figure 6-1.

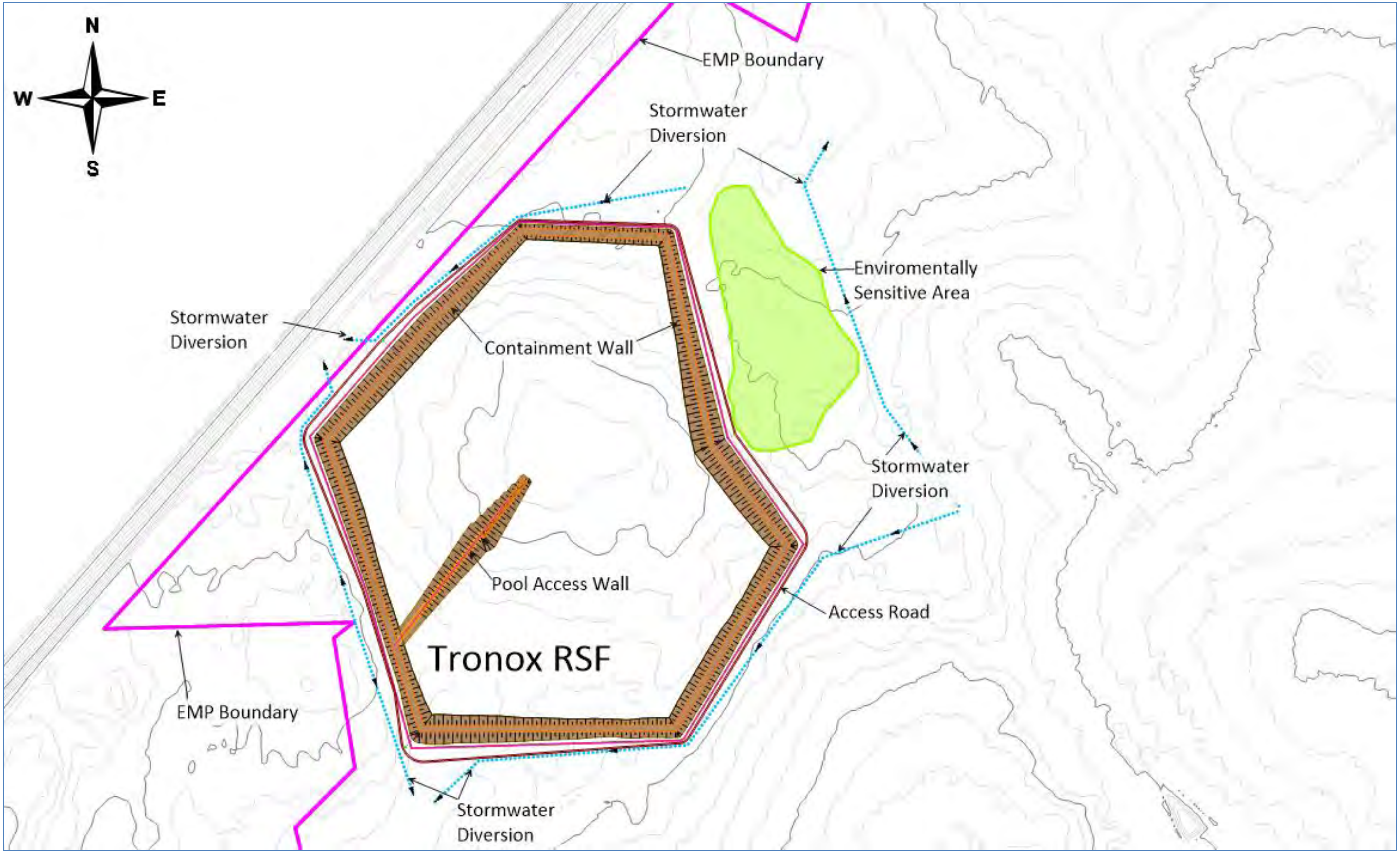


FIGURE 6-1: PLAN VIEW OF THE PROPOSED RSF AT FINAL ELEVATION

7. METHODOLOGY

Seepage and slope stability analyses were carried out based on the configuration of the RD at a critical section where the wall height is the greatest and the pool is the shortest distance from the embankment. The purpose of the analyses was to:

- Determine the phreatic surface in the RD based on various operational conditions; and
- Estimate the factor of safety against failure of the RD based on the shear strength parameters of the residue material, in-situ soils and containment wall construction material, as well as the phreatic surface profile within the RD wall for the different analysed scenarios.

The methodology of determining the seepage regimes within the RD and the associated FoSs against failure comprised:

- Review of the information arising from the geotechnical investigation of the site to incorporate the hydraulic conductivity and shear strength parameters of the in-situ foundation materials;
- Review of the information obtained from tests completed on residue and tailings samples to incorporate the shear strength parameters and hydraulic conductivity of the residue and tailings;
- The development and evaluation of seepage and slope stability models based on the configuration of the RD where necessary, to determine:
    - The likelihood of the phreatic surface rising to unsafe levels;
    - Factors of safety against failure of the facility;
    - The Probability of Failure of the facility; and
    - The Reliability Index of the facility.

Two separate sets of analyses were carried out on two-dimensional models using the GeoStudio 2021 suite. In the first set of analyses, all models conformed to the proposed RD configuration during the operational phase. The second set of analyses investigated a model that conformed to the closure phase. The most critical cross-section of the facility was modelled to obtain the Factor of Safety for the worst-case scenarios. The steady-state seepage regimes within the RD, for the critical cross-section, were determined using GeoStudio's Seep/W and were imported into Slope/W to analyse their stability.

8. SEEPAGE ANALYSES

Seepage analyses were undertaken to model the development of a phreatic surface within the RD under varying operating conditions. An increase in pore-water pressure, brought on by the onset of seepage, can result in the reduction in the stability of an earth structure's slope and has other adverse secondary effects, such as:

- Piping (erosive loss of material);
- Loss of effective strength of the material;
- Increase in the liquefaction potential of soils; and

- Increase in the collapse potential of sensitive soils.

It is therefore imperative not only for the designer to take cognisance of the above but also for the construction of the facility to be as per the design and for the operator of the RSF to ensure that best-operating practices are adhered to at all times.

8.1. SEEPAGE METHODOLOGY

Determination of the steady-state phreatic surface generated by the RD pool under varying conditions is conducted using Finite Element Methods (FEM) in the GeoStudio Seep/W suite. The software generates a "mesh" of elements across a typical geometry consisting of:

- RD cross-sectional geometry;
- An assumed residue and/or water level; and
- In-situ soil profile determined by Inroads during the geotechnical investigation.

Seepage analyses of the RD were carried out using the finite element program Seep/W to assess the location of the phreatic surface that would develop under various conditions, such as:

- During the operational phase:
  - Functional drains; and
  - Inactive drains;
- During the closure phase:
  - Functional drains; and
  - Inactive drains;

Each finite mesh element is assigned a set of parameters based on the geotechnical properties of the relevant material's hydraulic properties and assumed boundary conditions which may include:

- Hydraulic Conductivity;
- Volumetric water content;
- Anisotropy;
- A water source;
- Potential seepage faces; and
- Drainage points.

The phreatic surface may drastically affect the stability of a slope, which is due to the reduction in shear strength along a potential slip surface. The objective, therefore, is to ensure that the phreatic surface is correctly defined before determining the stability of the facility.

8.1.1. INPUT PARAMETERS TO SEEPAGE MODEL

The soil USCS classifications and hydraulic conductivities used are listed in Table 8-1.

TABLE 8-1: LIST OF HYDRAULIC PARAMETERS

Material	Anisotropy Ky'/Kx' Ratio	Saturated Hydraulic Conductivity ($m.s^{-1}$)	Saturated/Unsaturated Condition
Residue	0.5	4.03×10^{-8}	Saturated only
Embankment (Tailings)	1	1.00×10^{-5}	Saturated/Unsaturated
Drains	1	1.00×10^{-3}	Saturated only
Aeolian (Silt)	1	1.00×10^{-6}	Saturated/Unsaturated
Aeolian (Slightly Cemented)	1	1.00×10^{-7}	Saturated/Unsaturated

A critical 2-Dimensional section was selected for analysis based on the following:

- The height of the RD above ground level;
- The slopes associated with the RD containment walls;
- Relative location of supernatant water from sensitive RSF infrastructure;

8.1.2. CONFIGURATION OF SEEPAGE MODELS

Once all the required input parameters have been allocated as necessary, it is possible to compute the steady-state condition by determining the location of the water table (phreatic surface, or zero pore water pressure) under the given criteria and conditions. The Critical Section of the RD used for the Seepage and Stability analyses are illustrated in Figure 8-1. The typical model setup for the RD along the Critical Section is illustrated in Figure 8-2 to Figure 8-4. The RSF was assessed with a centre banket drain, upstream toe blanket drain and no drains, respectively, with both a normal operating pool and a storm pool.

The construction of the facility will be a two-phase process. During the initial phase, the facility will be constructed with 1V:2.5H side slopes for both the upstream and downstream slopes and a 30 m crest to allow adequate space for construction vehicles to spread the tailings material. During the second phase, the slope of the embankment's downstream face will be flattened to a 1V:5H by reshaping the existing material. Subsequently, the crest width will be reduced to 15 meters. All models feature a key with a depth of 0.5 m that extends from the downstream toe of the models to 5 meters past the downstream blanket drain.

It was assumed that the surface layer of dune sand will be removed and sent to the mines processing plant before the construction of the embankment starts. The facility was modelled on top of a 3.5 m layer of silty sand of Aeolian origin, underlain by a 15 m layer of slightly cemented Aeolian silty sand. A Layer of bedrock was included beneath the slightly cemented Aeolian silty sand layer to account for the very soft rock dorbank found in some of the boreholes.

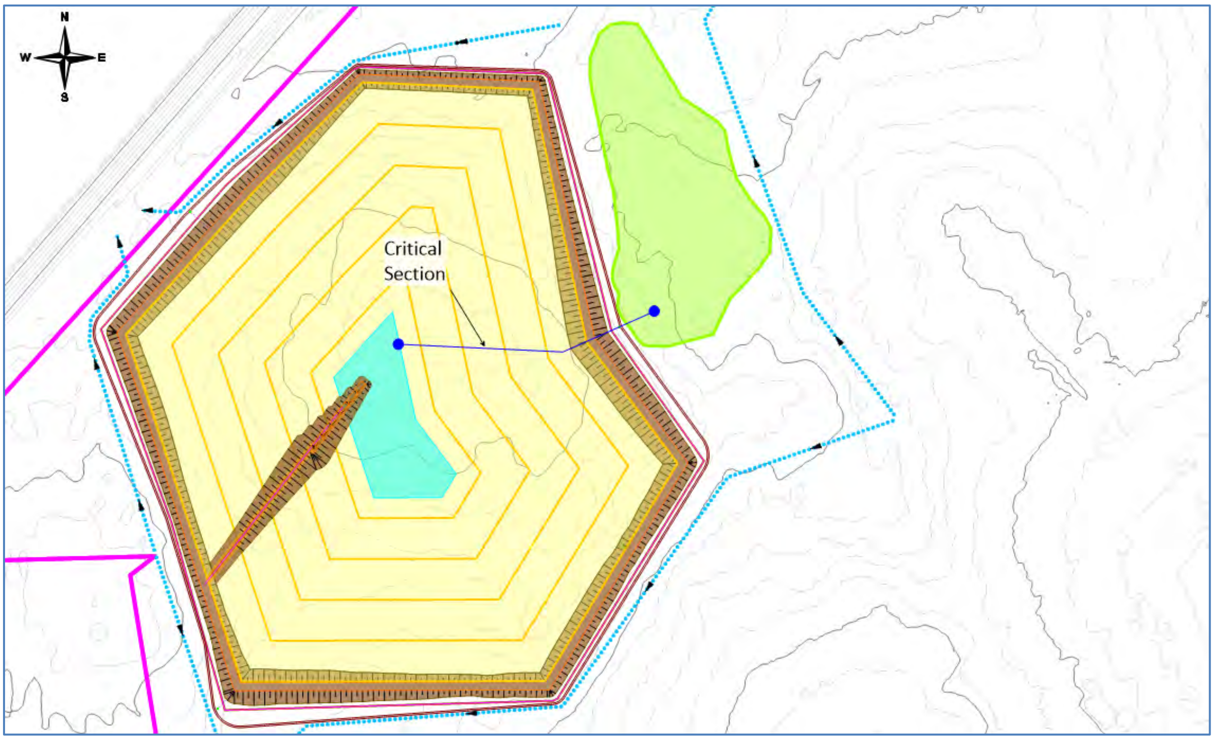


FIGURE 8-1: **CRITICAL SECTION ACROSS THE RD**

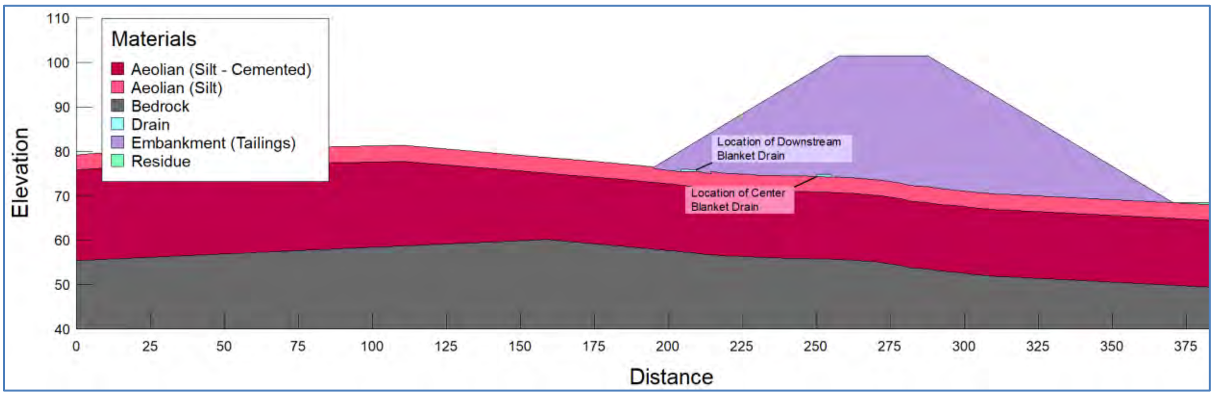


FIGURE 8-2: **OPERATIONAL PHASE - INITIAL**

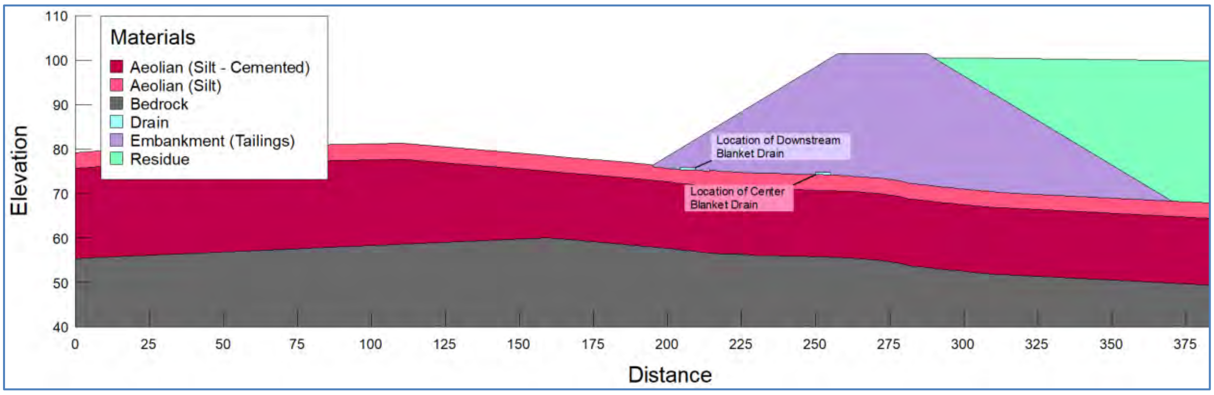


FIGURE 8-3: **OPERATIONAL PHASE – RESIDUE AT MAXIMUM CAPACITY**

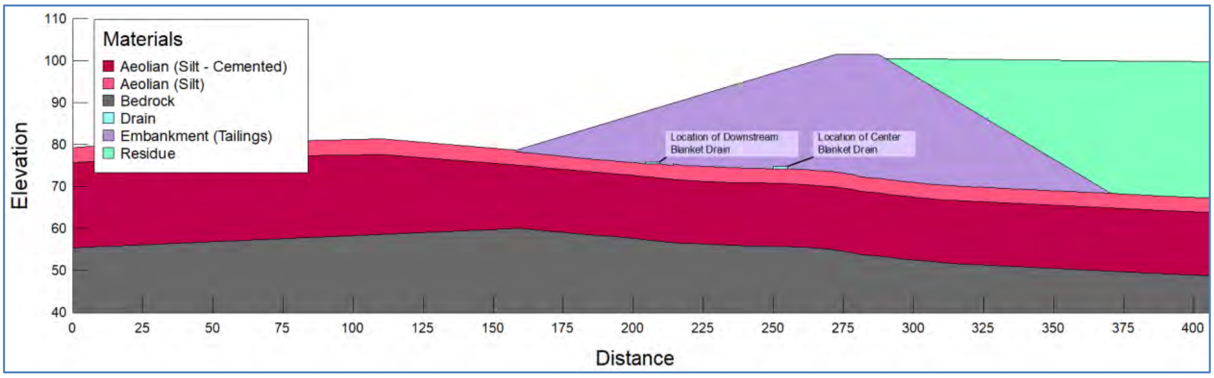


FIGURE 8-4: **CLOSURE PHASE**

Each scenario was modelled with both a storm pool and an operational pool. The storm pool was taken as the resulting pool with a perimeter a distance of 100 m away from the inside face of the facility. This is a worst-case scenario that is highly unlikely as the volume of water required to reach such a pool volume far exceeds that which is expected to be captured on the facility. However, the use of such a large pool volume is meant to showcase the robustness of the RSF design.

The operational pool was taken as the maximum estimated pool volume that would result from daily deposition as well as the estimated precipitation and evaporation cycle. A water balance conducted by Epoch titled "*Water Balance Study for the Tronox EOFS Residue Storage Facility*", revealed that the pool volume would not exceed 43 328 m^3 at any given point, during the operational life of the facility under normal operating conditions.

9. SEEPAGE ANALYSIS RESULTS

The critical cross-section was assessed for scenarios with an operational and storm pool. For cosiness, only models analysed with a storm pool were discussed in the following section. The results of all the seepage assessments for the RD are provided in Appendix I.

9.1. SEEPAGE ANALYSIS RESULTS OF INITIAL OPERATIONAL PHASE

The model presented in Figure 9-1 illustrates a typical cross-section along the Critical Section during the initial portion of deposition when the residue material starts encroaching on the upstream toe of the facility. This scenario is seen as the worst-case as the deposited material could lead to the saturation of the upstream toe should a significant storm event occur. Further analysis showed that increasing the residue level resulted in an increased FoS. These models were therefore not included in the main body of this report, however, they can be found in appendix I and II.

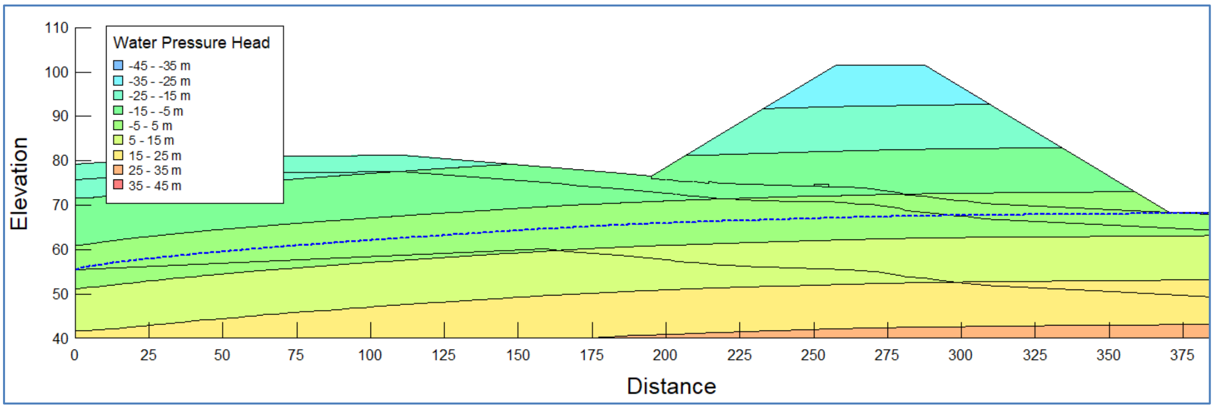


FIGURE 9-1: INITIAL OPERATIONAL PHASE, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN

The embankment illustrated in Figure 9-1 consists of upstream and downstream slopes equal to 1V:2.5H and a 5 m wide centre blanket drain. No further models were included for this scenario as it is shown that the phreatic surface remains below the blanket drain thus indicating that excluding the drains from the analysis would have no significant impact on the phreatic surface within the embankment.

9.2. SEEPAGE ANALYSIS RESULTS OF OPERATIONAL PHASE AT CAPACITY

Figure 9-2 to Figure 9-4 illustrates the effect a blanket drain would have on the phreatic surface within the embankment. It is shown that, due to the topography and underlying soil profile, a central blanket drain is the most effective means by which to decrease the phreatic surface (Figure 9-2). However, similarly due to the topography, significantly deep manholes will need to be excavated in order to reach the blanket drain outlets. Therefore, it is believed that a downstream toe drain is the most feasible means by which to prevent saturation of the downstream toe.

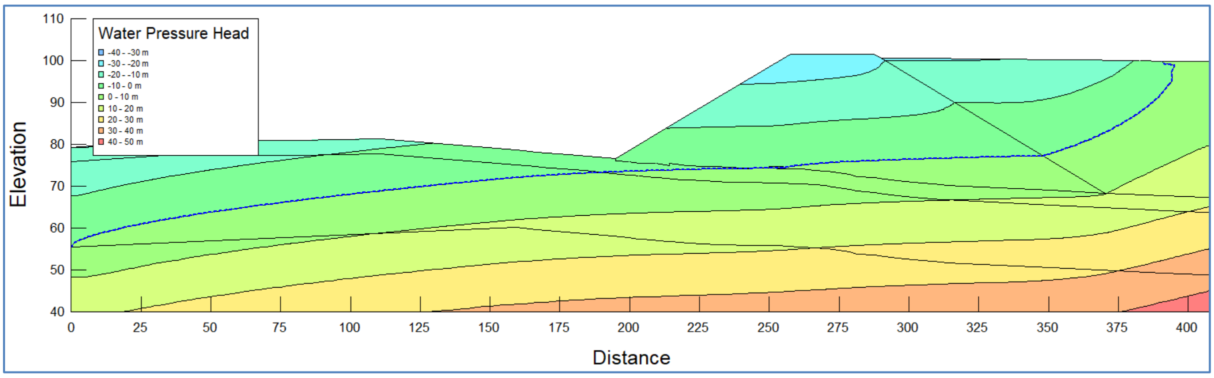


FIGURE 9-2: OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN

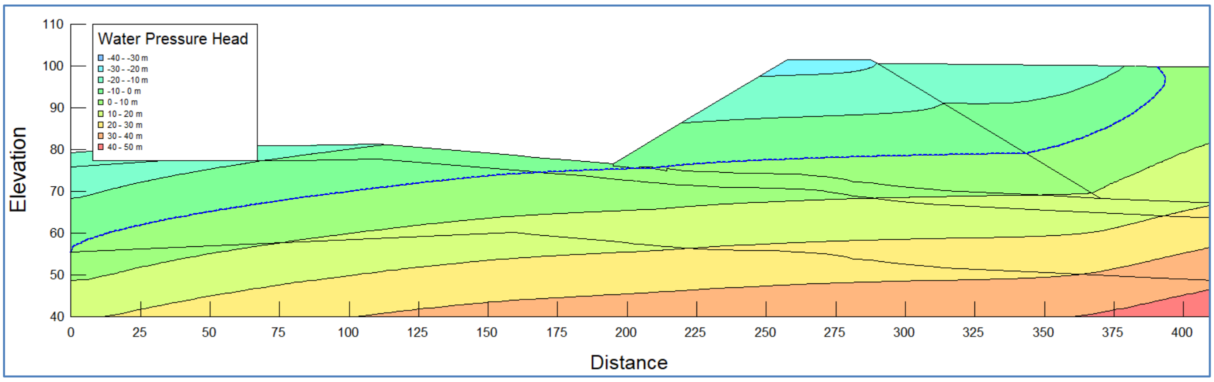


FIGURE 9-3: OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

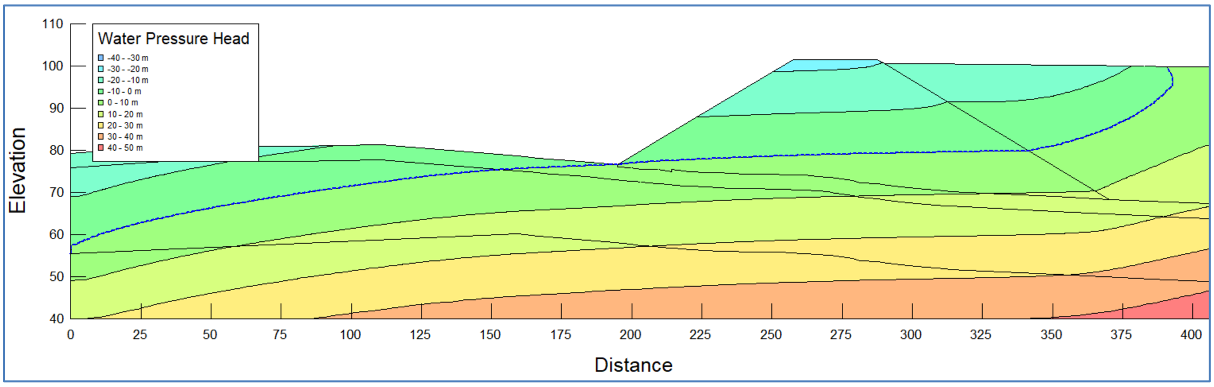


FIGURE 9-4: OPERATIONAL PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH NO ACTIVE DRAINS

9.3. SEEPAGE ANALYSIS RESULTS OF CLOSURE PHASE AT CAPACITY

The closure phase of the facility is depicted in Figure 9-5 to Figure 9-7. It is shown that, as during the operational phase, the downstream blanket drain is an effective means by which the phreatic surface can be decreased within the embankment. The inclined slope of the topography on which the embankment is to be built further improves the separation between the phreatic surface and downstream toe as downstream slopes are reshaped from a 1V:2.5H slope to a 1V:5H slope. This will decrease the likelihood that the downstream toe will become saturated, preventing piping as well as a decrease in the effective strength of the material as it becomes saturated.

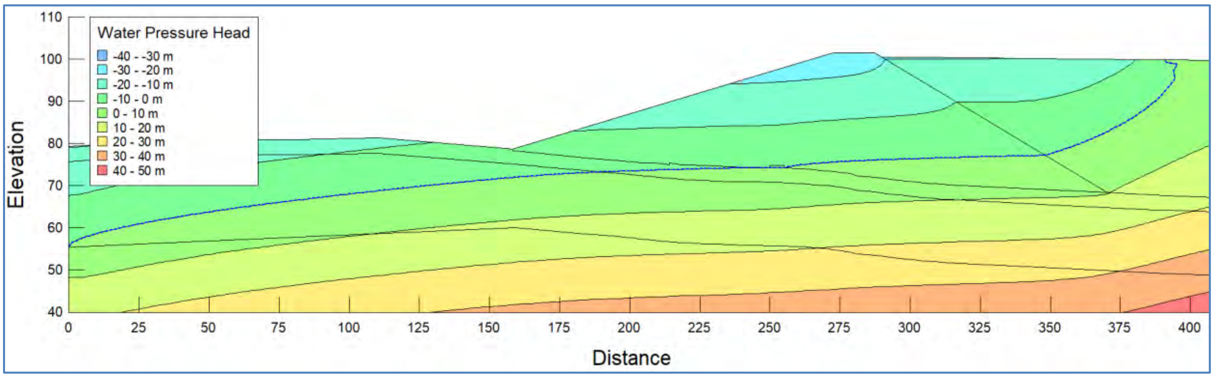


FIGURE 9-5: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE CENTRE BLANKET DRAIN

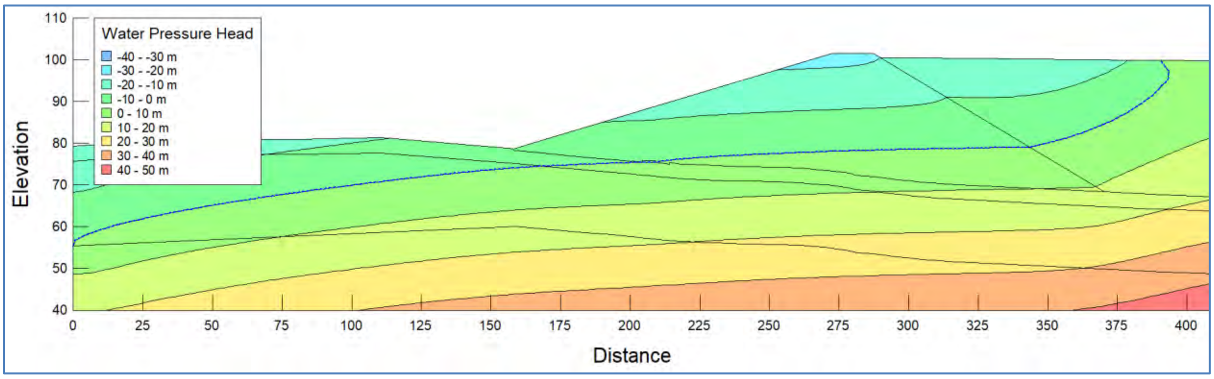


FIGURE 9-6: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

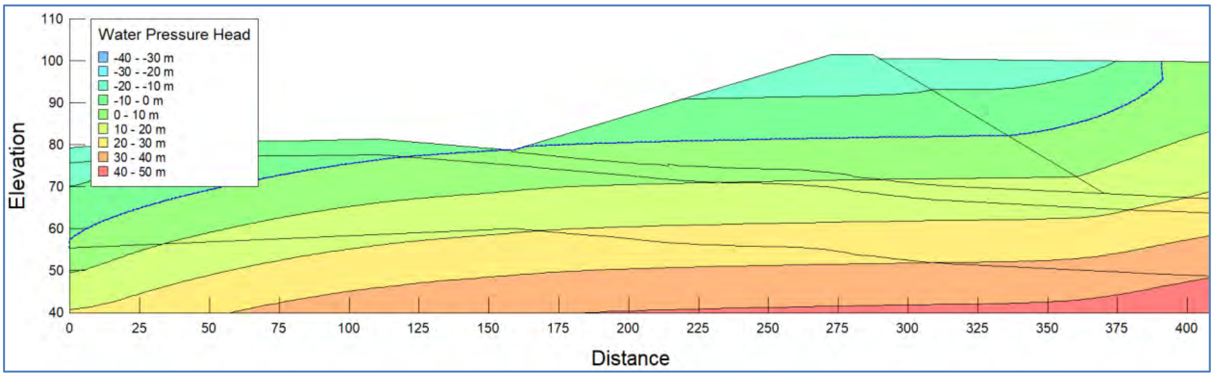


FIGURE 9-7: CLOSURE PHASE AT CAPACITY, SEEPAGE ASSESSMENT OF THE RD WITH NO ACTIVE DRAINS

9.4. DISCUSSION OF RESULTS

The addition of drains to the containment walls reduces the build-up of pore water pressures through the containment walls. While it is a fair assessment that the high permeability of the embankment material, compared to that of the residue material, results in the phreatic surface decreasing rapidly within the containment wall, it should be noted that the topography and underlying soil profile does not allow water to daylight a distance downstream of the facility. Instead, water seeps from the toe of the facility if no drains are included. This would result in the build-up of pore water pressure as the phreatic surface intersects the downstream toe, causing the material to perform undrained, reducing the effective strength of the material while also increasing the potential for erosion in the form of piping to occur. It is thus recommended that a blanket drain be included in the wall.

10. BASIN SEEPAGE ANALYSIS

An analysis of the expected seepage within the basin was conducted through the use of Seep/W along the critical section. The resulting seepage from a scenario with no drains as well as a scenario where the downstream toe blanket drain is active was investigated. In order to account for both the storm and operational pool scenarios, a water total head boundary condition representative of an operation pool with 150 000 m^3 was used to model the supernatant pool.

10.1. SEEPAGE ANALYSIS RESULTS

The results of the analysis can be seen in Figure 10-1 and Figure 10-2 for the scenario with no active drains and the scenario with a downstream blanket drain, respectively. It is shown that seepage results within the basin remain relatively unchanged for both analyses with the major difference occurring beneath the wall where the drains are located. As expected, it can be seen that the point where the maximum seepage occurs moves from the downstream toe of the facility to the area where the blanket drains is located once the drain is active. An additional spike in the water flux values occurs at the intersection of the fine tailings and the upstream toe of the embankment as the waters flow transitions from the low permeability residue to the high permeability tailings material.

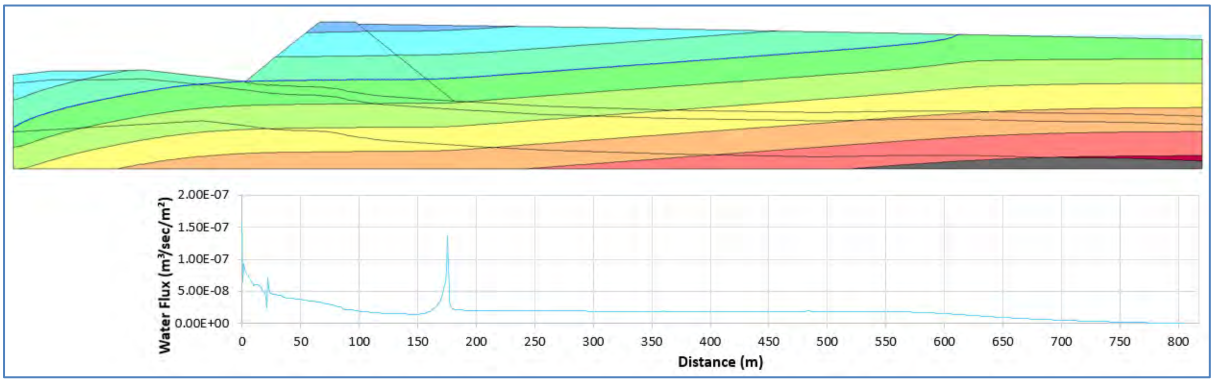


FIGURE 10-1: SEEPAGE ASSESSMENT OF THE TD BASIN WITH NO ACTIVE DRAIN

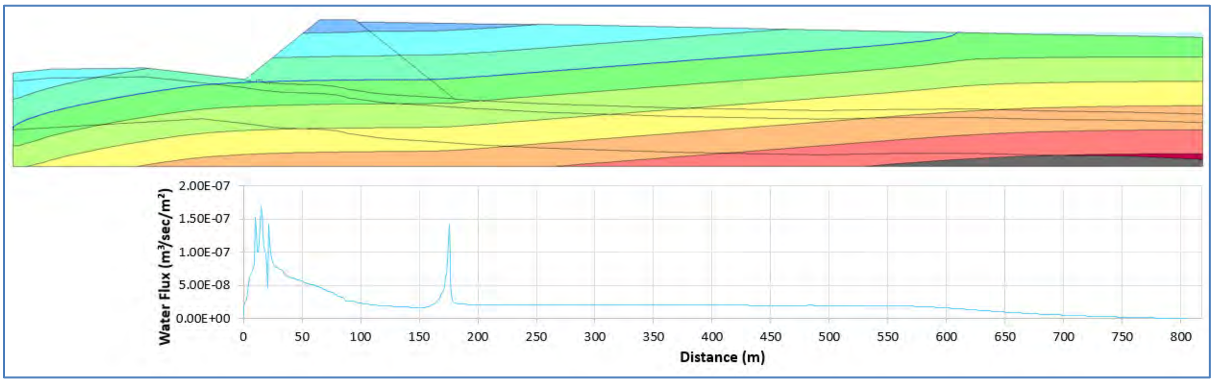


FIGURE 10-2: SEEPAGE ASSESSMENT OF THE TD BASIN WITH AN ACTIVE DOWNSTREAM BLANKET DRAIN

An average of the results was determined for 3 regions within the footprint of the facility (Figure 10-3). The first region represents the area beneath the embankment where seepage is high compared to the rest of the basin area due to presence of the blanket drain and the potential seepage interface placed on the downstream face of the embankment in combination with the high permeability of the embankment material. The second region corresponds to the relatively constant flux value shown in Figure 10-1 and Figure 10-2, between approximately 200 m and 550 m. The third region represents the final section of the cross-section where the seepage decreases as the cross-section draws closer to the centre of the facility. The average flux values for each region are listed in Table 10-1.

TABLE 10-1: BASIN SEEPAGE ASSESSMENT RESULTS

Drainage Condition	Seepage ($m^3/sec/m^2$)		
	Region 1	Region 2	Region 3
No Drains	3.26E-08	1.93E-08	8.20E-09
Downstream Blanket Drain	4.22E-08	2.02E-08	8.60E-09

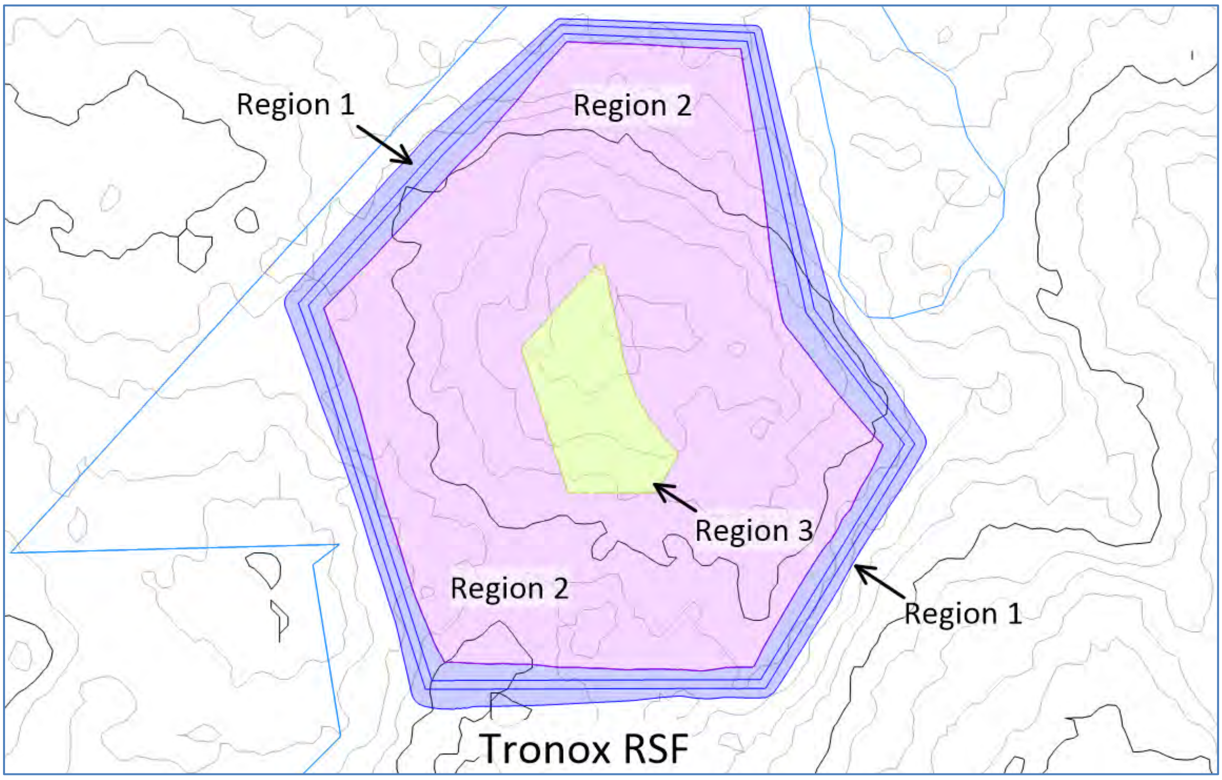


FIGURE 10-3: SEEPAGE REGIONS WITHIN THE TD FOOTPRINT

Additionally, due to the topography of the chosen site and the and the difference in permeability between the underlying soil profiles, the phreatic surface within the depression increases as deposition takes place until either a drain or the downstream toe of the facility is encountered. At this point water is removed from the system and the phreatic surface ceases to increase. It was determined that the model configuration shown in Figure 10-2 results in a water rate of 2.463E-07 m^3/s generated by the supernatant pool while the downstream blanket drain was able to intercept 1.334E-07 m^3/s. This indicates that a downstream blanket drain could reduce the amount of seepage migration beyond the embankment of the facility by up to 54 %.

11. SLOPE STABILITY ANALYSIS

A slope stability analysis was completed to assess the safety of the slopes of the RD under varying conditions. The following sections describe the process by which the analysis was undertaken.

11.1. METHODOLOGY

To analyse the stability of a slope requires that the Factor of Safety against the failure of the slope be determined as well as the associated Probabilities of Failure and the Reliability Index of the analysis. The level of uncertainty associated with the long-term stability of a slope is a function of the level of uncertainty associated with:

- The shear strength parameters of the materials comprising the slope and its foundation as expressed in terms of their friction angle and cohesion; and
- The location of the phreatic surface within the slope.

The risk level, or Probability of Failure that may be tolerated for a given slope, depends on:

- The level of risk to the stakeholders (including downstream property owners, authorities, the mine owner and consultants) are willing to accept;
- The level and extent of quality control and quality assurance undertaken during construction;
- Whether the facility is in the operational phase or post-closure phase; and
- Whether or not the side slopes are monitored.

11.1.1. FACTOR OF SAFETY

The Factor of Safety against the failure of a slope is a ratio between opposing forces: the forces causing failure (gravity forces of the material weight) and the forces preventing failure (shear strength of the soils).

South African legislation as documented in the NEMWA Act No. 59 of 2008 and Regulation 632 (24 July 2015) Chapter 2, 7 (4)(d), says:

"Other design considerations, as appropriate to the particular type of residue stockpile and residue deposit that must be incorporated include:

(d) keeping the pool away at least 50 meters from the walls and a factor of safety not less than 1,5; where there are valid technical reasons for deviating from this, adequate motivation must be provided, and the design must be reviewed by a competent person".

Therefore, the RD has been designed in order to achieve the factor of safety of 1.5 during the operational and closure phase under static loading and pseudo-static loading.

11.1.2. LIMIT EQUILIBRIUM METHODS

The slope stabilities under varying conditions as discussed are determined through Limit Equilibrium Methods (*LEM*) which assesses the equilibrium of forces and moments from a series of pre-defined slices through a potential slip surface of a slope. Many methods of LEM are available which make use of different assumptions of the equilibrium condition that exists between the slices. The following are some advantages of using limit equilibrium methods:

- Provides a single FoS for the whole slope;
- Relatively low calculation effort required; and
- Methods are well-calibrated to field methods.

The RD was assessed using the “Morgenstern-Price” method which takes cognisance of the following:

- Unit weight of each slice (W);
- Normal force to the slip surface (N);
- Shear force acting on the slip surface (S);
- Slice moment (M);
- Slice horizontal force (F);
- Inter-slice normal forces (E);
- Inter-slice shear forces (X); and
- Variable inclination between the results of the ratio of normal and shear forces (δ).

The main reasons for selecting this method are as follows:

- This method makes use of a differential equation that is derived for the equilibrium conditions thus this method ensures that the equilibrium of forces is adhered to;
- Integration along the failure plane ensures more accuracy by considering all materials on the failure plane;
- The solution is obtained once the boundary conditions are met which means that the zero inter-slice forces are present at the last slice which equates to equilibrium being met;
- Provides a single explicit number for Factor of Safety against failure; and
- This method is the most accurate compared to the other LEMs.

Typical slice forces and moment as per the Morgenstern-Price method are illustrated in Figure 11-1.

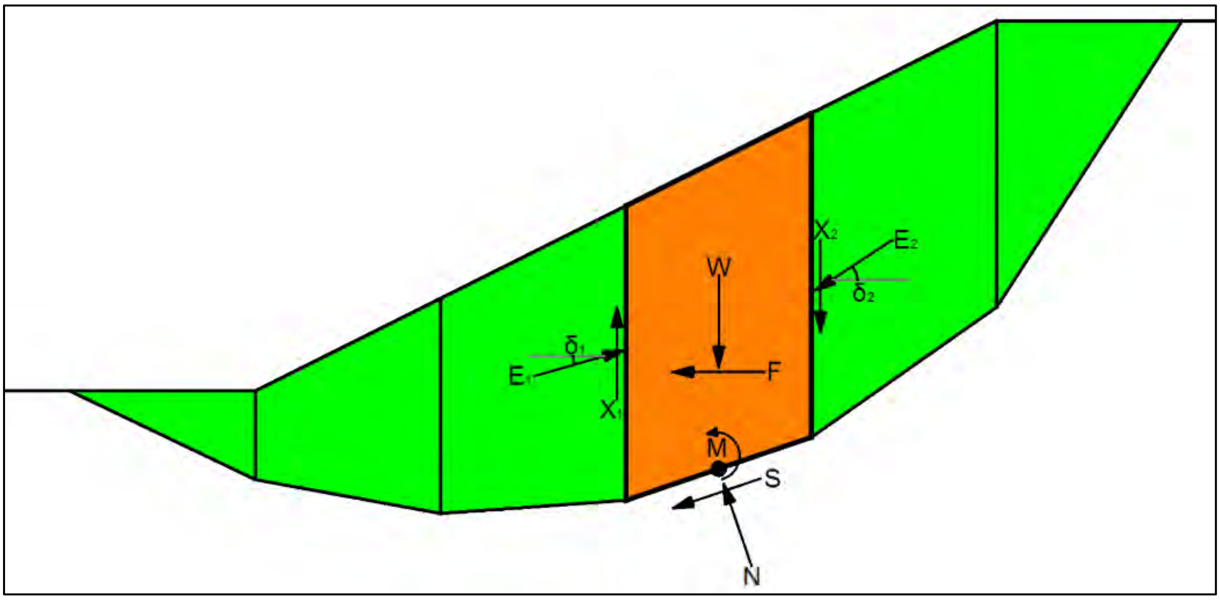


FIGURE 11-1: TYPICAL FORCE AND MOMENT DIAGRAM FOR THE MORGENSTERN-PRICE LEM

The forces and moments are solved assuming a state of equilibrium for each slice within an assumed slip surface iteratively until the solution converges to a constitutive FoS for the entire slip surface. A slip surface which presents the lowest FoS solution is considered the critical slip surface to which the RD design caters for.

As there is an infinite number of slip surfaces that may be analysed, with any of which yielding or not yielding the most critical slip surface, specialised software has been developed to efficiently determine the location and FoS of a critical slip surface. For the Kakula RSF, GeoStudio's 2018 version of Slope/W was used which utilises the method as explained to determine the critical slip surface within a user-defined region. The required inputs for the LEM to operate are:

- Initial pore water pressures (determined with seepage modelling);
- A material failure criterion (Mohr-Coulomb);
- Soil strength parameters including;
    - Cohesion (c');
    - Friction Angle (φ'); and
    - Bulk Density.

11.1.3. PROBABILISTIC ANALYSIS

To allow for variability in the input parameters, a probabilistic analysis is conducted. The software is provided with the probabilistic distribution of the design parameters which includes:

- Type of distribution i.e. Normal distribution, Log-normal distribution etc.;
- The mean; and
- The standard deviation.

A finite number of Monte Carlo trials are conducted which selects, at random, combinations of new parameters within the defined probabilistic distribution. These randomly selected parameters are applied to the critical slip surface which is determined by the deterministic analysis. The FoS from each of the Monte Carlo simulations is recorded as it converges to an overall solution from which a *Reliability Index (RI)* and *Probability of Failure (PoF)* is determined. A sufficient number of Monte Carlo trials are required to ensure that all materials strength parameter distributions have been accounted for in the stability analyses.

The PoF is defined as the number of Monte Carlo trials that resulted in a FoS less than one represented as a percentage of the total number of trials conducted. For long term slopes, a PoF less than 0.0007% (<1:143 000) is widely accepted. Recommended PoFs for short- and medium-term slopes should not exceed 0.07% (1:1 430) and 0,007% (1:14 300) respectively (Cole, 1993).

The RI is defined as the number of standard deviations separating the defined failure FoS of 1.0 from mean FoS that the Monte Carlo simulation converged towards. A Reliability Index of 4.83 correlates to the minimum acceptable PoF, thus values greater than (>) 4.83 is considered acceptable for a long term, or permanent slope.

11.1.4. SEISMICITY ASSESSMENT

The horizontal force imposed on the structure when undertaking a pseudo-static analysis is derived from the Peak Ground Acceleration (PGA) parameter. PGA values are based on prior earthquakes and fault studies and are measured as factors of the earth's gravitational acceleration (i.e. 1g is equivalent to 9.81 $m.s^{-2}$).

The minimum allowable Factor of Safety for side slopes, according to NEMWA, is 1.5. Deviations from the prescribed minimum FoS must be substantiated by the designer.

The Peak Ground Acceleration (PGA) for Namakwa will be about 0.04g, based on a 10% probability of exceedance in 50 years from the Global Seismic Hazard Assessment Program (GSHAP) study (Figure 3-1) and between 0.02g and 0.03g (10% probability of exceedance in 50 years) based on the PGA map produced by the Council of Geoscience for South Africa.

A value of 0.03g was used in the stability assessments for the RSF.

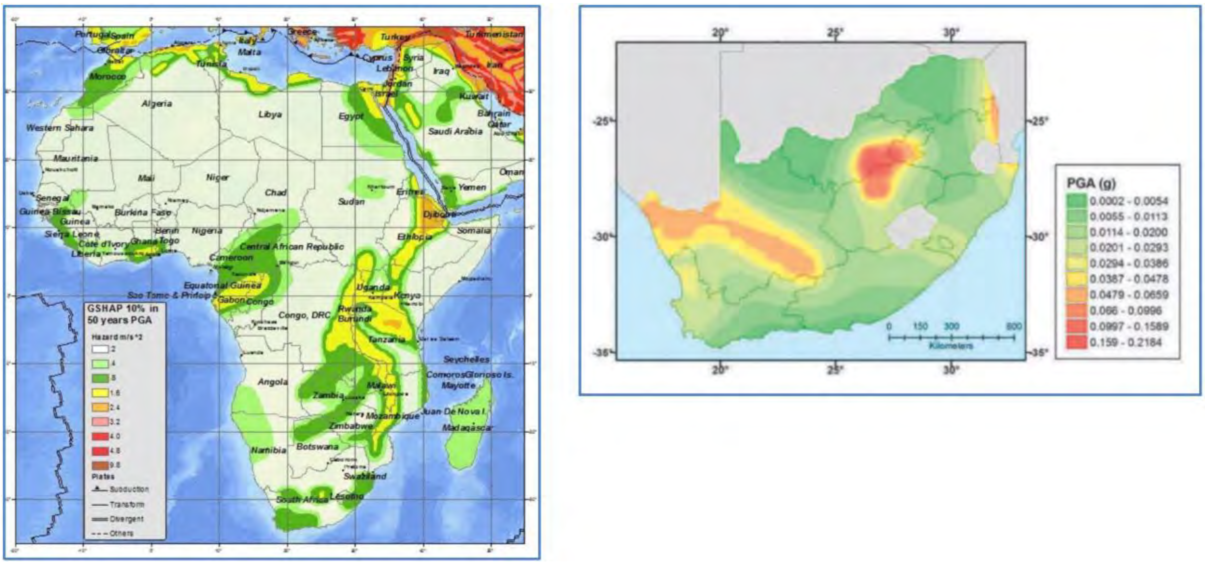


FIGURE 11-2: PEAK GROUND ACCELERATION (GHSAP (LEFT) AND COUNCIL OF GEOSCIENCE (RIGHT).

11.2. INPUT PARAMETERS TO THE SLOPE STABILITY MODELS

The slope stability model was defined in terms of the physical configuration of the structure and its foundations as well as the geotechnical properties of the residue and tailings material, and the foundation material. Two types of slope stability analyses are conducted:

- Static analyses which determine the FoS without the addition of PGA (i.e. an earthquake event); and
- Pseudo-static analysis which incorporates the PGA into the assessment to determine FoS during a seismic event.

11.2.1. CONFIGURATION OF THE STABILITY MODELS

The configuration of the slope stability model and its foundations is comprised of the following:

- The same geometry that was used in the associated seepage analysis;
- The phreatic surface determined by the associated seepage analysis;
- In-situ soils modelled with engineering properties obtained from laboratory testing;
- Pseudo-static analysis performed with a PGA of 0.03 g;

It is envisaged that the RD will be constructed in 2 phases as is illustrated in Figure 11-3 and Figure 11-4.

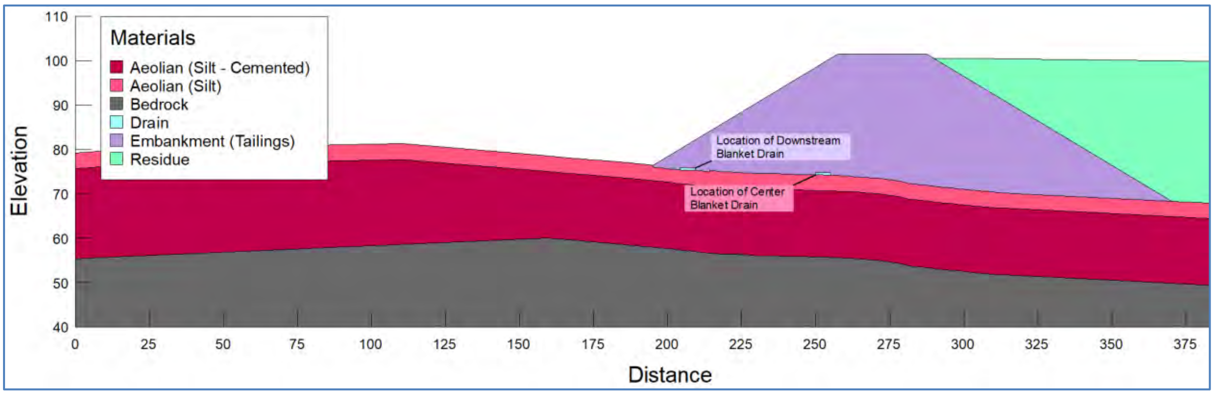


FIGURE 11-3: **OPERATIONAL PHASE AT CAPACITY**

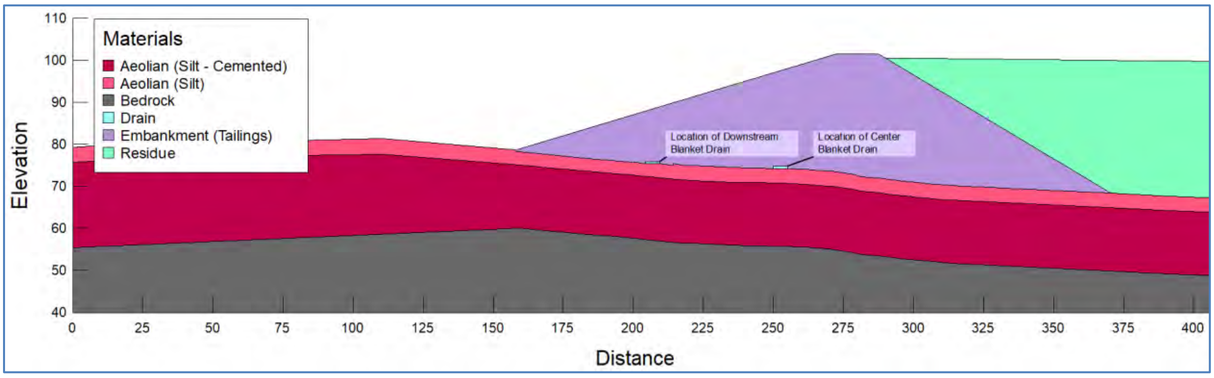


FIGURE 11-4: **CLOSURE PHASE AT CAPACITY**

The geometry used to analyse the operational and closure phase of the RD cross-section along the Critical section is listed in Table 11-1.

TABLE 11-1: **SUMMARY OF RD GEOMETRY FOR STABILITY ASSESSMENT**

Feature	Operational Phase	Closure Phase
Crest Elevation (m.a.m.s.l.)	101.5	101.5
Minimum Toe Elevation (m.a.m.s.l.)	74.26	74.41
Maximum Wall Height (m)	27.24	27.09
Crest Width (m)	30	15
Upstream Slope	1V:2.5H	1V:2.5H
Downstream Slope	1V:2.5H	1V:5H

11.2.2. MATERIAL PROPERTIES

The input geotechnical parameters used in the slope stability analysis of the RD is summarised in Table 11-2. It was assumed that RAS or EOFS tailings would be used to construct the containment wall of the facility. It was also assumed that the layer of dune sand that covers the area will be removed and sent to the mines processing plant. The remaining predominant soil profile consists of silty Aeolian sand that becomes weakly cemented with depth. It was assumed that a 3.5 m deep layer of Aeolian material overlays a 15 m deep layer of weakly cemented material before encountering bedrock in the form of very soft rock dorbank.

TABLE 11-2: GEOTECHNICAL PARAMETERS ASSOCIATED WITH THE RELEVANT MATERIALS FOR SLOPE STABILITY ANALYSIS

Region	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Residue	15.0	33	0
Embankment (Tailings)	16.0	30	2
Aeolian (Silt)	16.0	32	0
Aeolian (weakly cemented)	19.0	40	0

12. RD STABILITY RESULTS

The results of the slope stability assessment have been separated into three sections (Section 12.1, 0 and 12.3). The first section considers results from the analysis of the upstream face of the embankment with the residue encroaching on the toe of the upstream wall. The second section investigates the stability of the downstream face of the operation phase of the facility once the maximum deposition capacity of the RD has been reached. Finally, section 12.3 discusses the FoS against a failure of the downstream face of the closure phase. All critical slip surfaces generated for static conditions are provided in Appendix I and for pseudo-static conditions in Appendix II.

12.1. SLOPE STABILITY ANALYSIS RESULTS (OPERATIONAL PHASE – INITIAL DEPOSITION)

THE MODEL DISCUSSED IN THIS SECTION FEATURES AN UPSTREAM FACE WITH A 1V:2.5H SLOPES, WITH VARIATION IN POOL SIZE AND THE LOCATION OF THE BLANKET DRAIN, IF INCLUDED. THE RESULTS OBTAINED FROM THE SLOPE STABILITY ASSESSMENT OF THE UPSTREAM FACE OF THE FACILITY DURING INITIAL RESIDUE DEPOSITION ARE SUMMARISED IN

Table 12-1 with S indicating static loading conditions and PS indicating pseudo-static loading conditions.

FROM

Table 12-1 it can be seen that a minimum FoS of 1.561 was obtained for static load conditions while FoSs for pseudo-static conditions were equal to or greater than 1.427 with the lowest FoS noted for the analyses containing a storm pool.

TABLE 12-1: OPERATIONAL PHASE AT INITIAL RESIDUE (SLOPE STABILITY ASSESSMENT RESULTS)

Load condition	Active Drains			Pool Size		Deterministic	Probabilistic		
	Centre Blanket Drain	Downstream Blanket Drain	No Drains	Operating Pool	Storm Pool	FoS	FoS	PoF	RI
S	X			X		1.588	1.588	0	7.7004
S	X				X	1.566	1.561	0	8.1578
S		X		X		1.588	1.588	0	7.7004
S		X			X	1.566	1.561	0	8.1578
S			X	X		1.588	1.588	0	7.7004
S			X		X	1.566	1.561	0	8.1578
PS	X			X		1.462	1.462	0	5.2435
PS	X				X	1.427	1.427	0	5.7552
PS		X		X		1.462	1.462	0	5.2435
PS		X			X	1.427	1.427	0	5.7551
PS			X	X		1.462	1.462	0	5.2435
PS			X		X	1.427	1.427	0	5.7551

Figure 12-1 illustrates a typical critical slipe surface resulting from a seismic analysis on the upstream face of the embankment. Although a substantial slip surface has resulted from the analysis, it is noted that the greater majority of the embankment has remained untouched, implying that the wall will remain stable enough for the repair of the upstream face to take place. It should also be noted that the upstream face is a short to medium term slope as it will be covered with residue as residue deposition progresses.

Therefore, it is argued that a minimum FoS of 1.427 is adequate for the upstream slope of the facility. Results of the stability analysis showcasing the stability of the upstream slope at the point where the elevation of residue and supernatant pond is such that the phreatic surface within the embankment is just below the centre blanket drain can be found in Appendix I and Appendix II. It was found that FoS improve as deposition takes place, thus the results of the analysis were excluded from the main report.

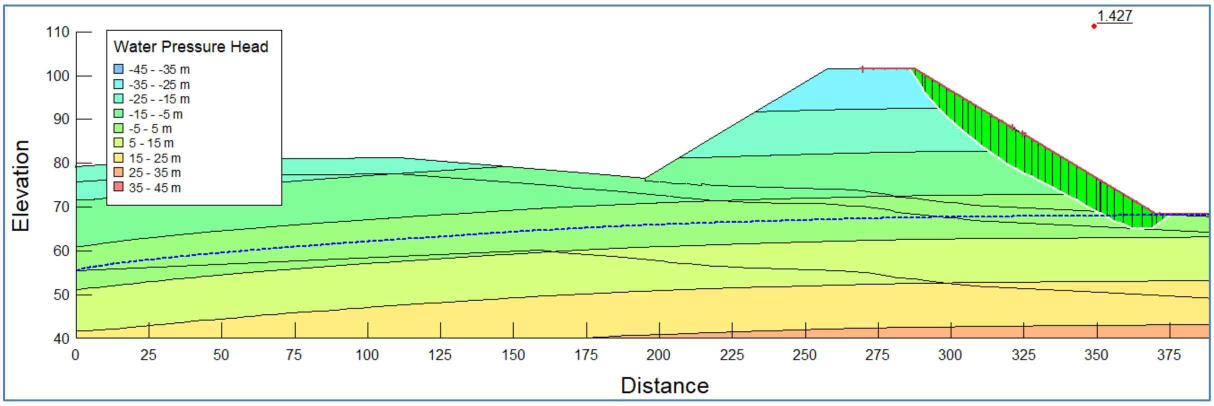


FIGURE 12-1: UPSTREAM FACE OF THE OPERATIONAL PHASE WITH INITIAL RESIDUE DEPOSITION (SEISMIC LOADING)

12.2. SLOPE STABILITY ANALYSIS RESULTS (OPERATIONAL PHASE – MAXIMUM RESIDUE CAPACITY)

It is shown that the FoSs are above the minimum required by SA regulations, for static loading with a minimum of 1.517. The Reliability Index for all models remain above the minimum required 4.83 and the Probability of failure does not exceed 0.07%.

The seismic analysis revealed the downstream face of the operational phase to have FoSs exceeding or achieving the minimum required value of 1.5 within an acceptable margin for models analysed with a blanket drain. The analysis of models where drains were excluded indicated that the FoSs decreases to 1.386 (Figure 12-2) if the phreatic surface is allowed to build up and saturate the downstream toe of the facility.

TABLE 12-2: OPERATIONAL PHASE AT MAXIMUM RESIDUE CAPACITY (SLOPE STABILITY ASSESSMENT RESULTS)

Load condition	Active Drains			Operating Pool		Deterministic	Probabilistic		
	Centre Blanket Drain	Downstream Blanket Drain	No Drains	Min	Max	FoS	FoS	RI	PoF
S	X			X		1.648	1.648	0	8.1097
S	X				X	1.648	1.648	0	8.1097
S		X		X		1.648	1.648	0	8.1097
S		X			X	1.648	1.648	0	8.1097
S			X	X		1.567	1.567	0	9.5781
S			X		X	1.517	1.517	0	9.0344
PS	X			X		1.518	1.518	0	5.8095
PS	X				X	1.518	1.518	0	5.7951
PS		X		X		1.518	1.518	0	5.7951
PS		X			X	1.518	1.518	0	5.7951
PS			X	X		1.440	1.440	0	6.4015
PS			X		X	1.386	1.386	0	5.5390

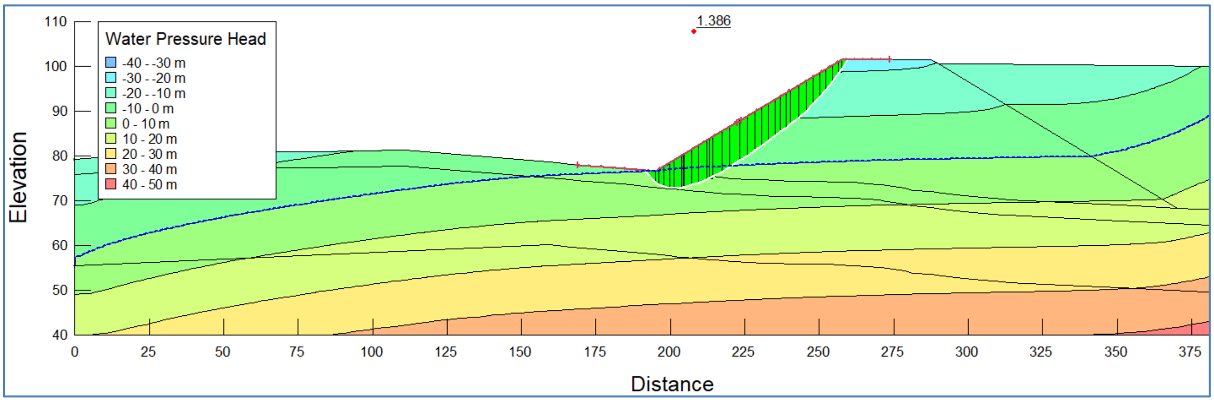


FIGURE 12-2: DOWNSTREAM FACE OF THE OPERATIONAL PHASE WITH RESIDUE AT MAXIMUM CAPACITY (SEISMIC LOADING)

12.3. SLOPE STABILITY ANALYSIS RESULTS (CLOSURE PHASE – MAXIMUM RESIDUE CAPACITY)

The results of the analysis on the downstream face of the closure phase of the RD is shown to far exceed the minimum requirements both in terms of the FoS and RI. A minimum FoS of 2.435 was noted for static loading and 2.097 for pseudo-static loading (Table 12-3). The minimum value for the RI is shown to be 10.792, significantly higher than the required value of 4.83.

TABLE 12-3: CLOSURE PHASE AT MAXIMUM RESIDUE CAPACITY (SLOPE STABILITY ASSESSMENT RESULTS)

Load condition	Active Drains			Operating Pool		Deterministic	Probabilistic		
	Centre Blanket Drain	Downstream Blanket Drain	No Drains	Min	Max	FoS	FoS	RI	PoF
S	X			X		3.094	3.094	0	13.617
S	X				X	3.094	3.094	0	13.719
S		X		X		3.094	3.094	0	13.617
S		X			X	3.094	3.094	0	13.719
S			X	X		2.658	2.658	0	17.136
S			X		X	2.435	2.435	0	16.240
PS	X			X		2.677	2.677	0	10.816
PS	X				X	2.677	2.677	0	10.792
PS		X		X		2.677	2.677	0	10.816
PS		X			X	2.677	2.677	0	10.792
PS			X	X		2.307	2.307	0	12.175
PS			X		X	2.097	2.097	0	10.987

12.4. DISCUSSION OF RESULTS

The results of the slope stability assessment indicate that the facility is stable under static loads for the short-, medium- and long-term slopes. A blanket drain, however, is required to achieve FoS above the minimum required value of 1.5 for the downstream slope of the operational phase in the event of pseudo-static conditions. Additionally, it is advised to include the drain as a means to prevent water seeping through the downstream toe of the embankment. The flow of water through the toe could potentially lead to the piping of material which may cause instability of the downstream face.

Similarly, to the downstream face, the upstream face of the embankment yielded FoS greater than 1.5 for static conditions. However, all pseudo-static loading conditions resulted in FoS below 1.5 with a minimum of 1.427. Again, it is argued that upstream slope will be buttressed with residue as residue deposition takes place. Additionally, the 30 m crest width of the operational phase and the relatively flat downstream slope of the closure phase will prevent a critical slipe failure from causing a breach in the containment wall, indicating that the design is robust enough to allow for the repair of side slopes should a critical slip occur.

13. CONCLUSIONS

The following conclusions were drawn from the seepage and slope stability analysis of the facility:

- The geometry of the RD adheres to the minimum acceptable FoS for both interim slopes and long-term slopes;
- Functional drains are effective in reducing the phreatic surface through the RD and preventing saturation of the downstream toe which could lead to piping and subsequent instability of the downstream slope;

- The drains functions as an effective means by which to intercept the movement of groundwater generated by the supernatant pool for the given topography and soil profiles assumed in this analysis.
- The FoS of the downstream slope against slope failure are above the 1.5 required for static and pseudo-static conditions provided active drains are included in the design;
- The FoSs of the analyses conducted on the upstream slope are satisfactory (i.e. greater than 1.5) for static loading conditions. Values lower than 1.5 were noted (with a minimum of 1.427) during the pseudo-static analysis of the upstream face of the facility, although, it should be taken into consideration that upstream face is a temporary slope that will be buttressed with residue as deposition progresses;
- The probabilities of failure for all models are below 0.007; and
- Should a slope failure occur, it is believed that the robust design will prevent a wall breach from occurring while allowing adequate time for repairs to be undertaken.

14. RECOMMENDATIONS

In consideration of the analyses and contents of this report, it is recommended that:

- The designed side slopes of the RD should be adhered to ensure the modelled factors of safeties are achieved;
- A competent and reputable construction team must undertake the construction of the RSF; and
- The drains provided for the RD were shown to be critical in preventing saturation of the downstream toe, therefore it will be necessary to ensure that these are constructed according to design specifications.

15. REFERENCES

Craig, R. F. (2012). *Craig's Soil Mechanics.* Abington: Spon Press.

Inroads. (2020). *REPORT ON A GEOTECHNICAL INVESTIGATION FOR THE PROPOSED RESIDUE STORAGE FACILITY, STORMWATER DAM & OVERBURDEN FACILITY FOR THE TRONOX NAMAKWA SANDS EOFS PROJECT IN BRAND-SE-BAAI, WESTERN CAPE.* Pretoria: Inroads.

Schneider, H. (1997). Panel discussion: Definition and determination of characteristic soil properties. *Proceeding of the Fourteenth International Conference on Soil Mechanics and Foundation Engineering*, (pp. 2271-2274). Zug.

Tuluka, G. M. (2010). *Seismic Hazard Assessment and Volcanogenic Seismicity for the Democratic Republic of Congo and Surrounding Areas, Western Rift Valley of Africa.* Johannesburg: University of Witwatersrand.

Report Author	Reviewer	Project Manager
Stephan Barkhuizen	**Georgia Vagis**	**Andrew Savvas**

epoch resources (pty) ltd

APPENDIX I STATIC RD SEEPAGE AND SLOPE STABILITY RESULTS

INFORMATION

In an attempt to avoid confusion, tables have been created by which to identify the information presented below, for static loading conditions. Results are separated based on the amount of residue deposited within the basin and RD phase they are associated with (i.e. Scenario A refers to the operational phase of the RD when residue deposition is in the initial stage).

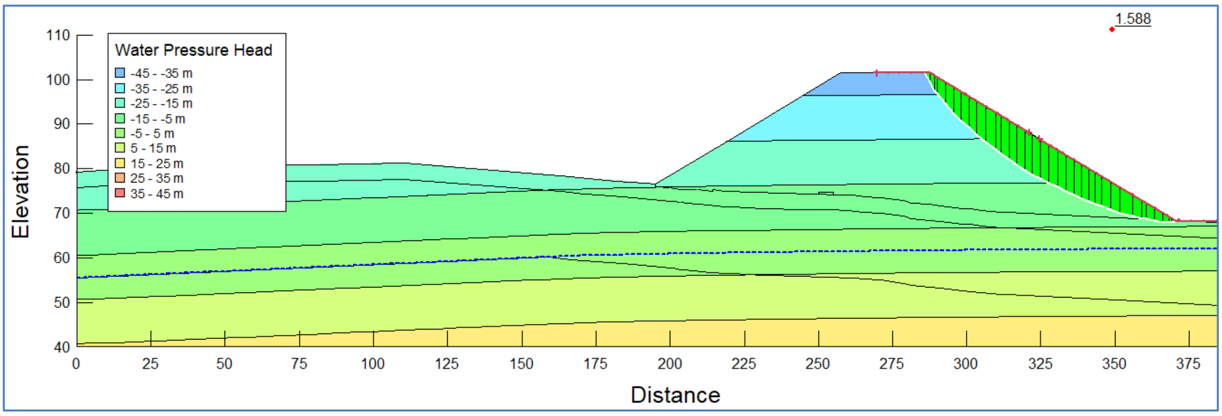
SUMMARY OF SCENARIOS ANALYSED

Scenario	Phase	Deposition Capacity reached	Slope Considered
A	Operational	Initial capacity	Upstream
B	Operational	Partial capacity	Upstream
C	Operational	Maximum capacity	Downstream
D	Closure	Maximum capacity	Downstream

Each scenario is further subdivided into subsections based on the active drainage condition and operating pool level. A table has been included at the start of results for each scenario, as shown below.

OPERATIONAL PHASE – INITIAL

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	Min	Max
A 1	X			X	
A 2	X				X
A 3		X		X	
A 4		X			X
A 5			X	X	
A 6			X		X



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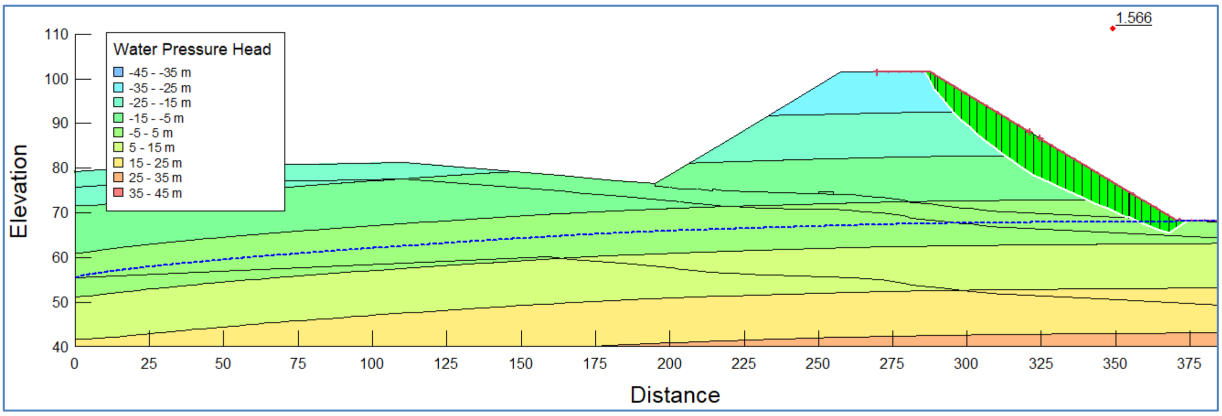

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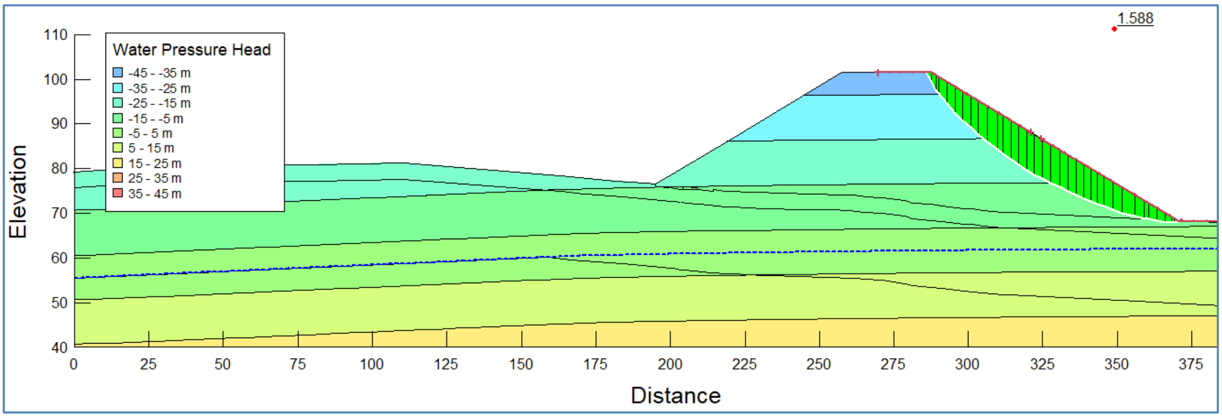

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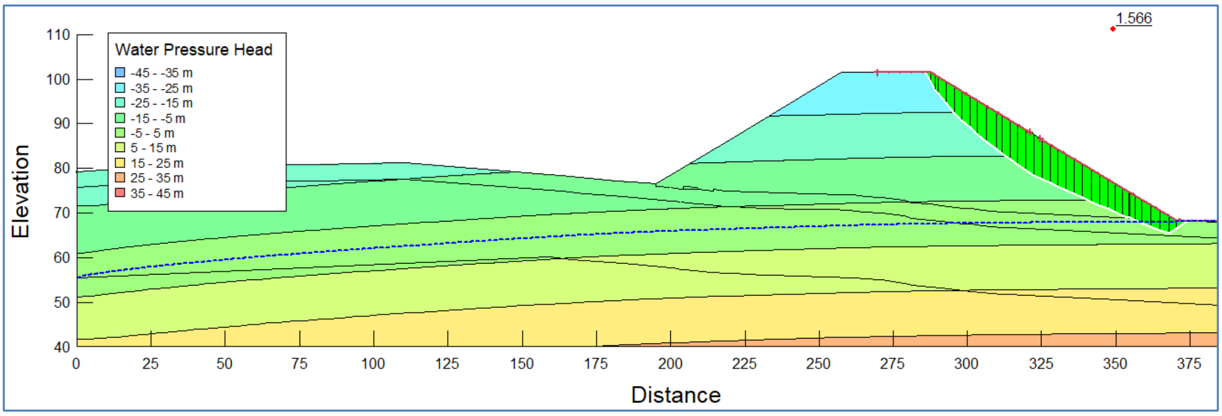

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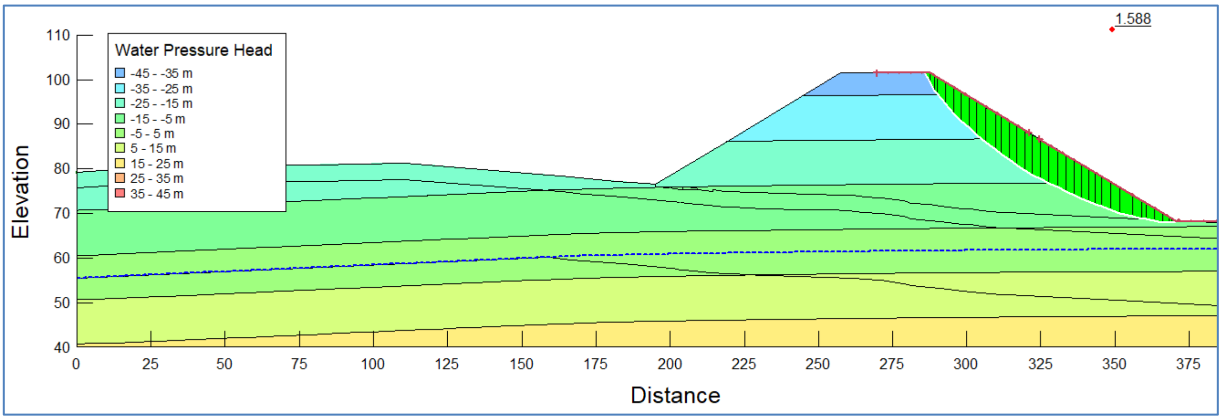

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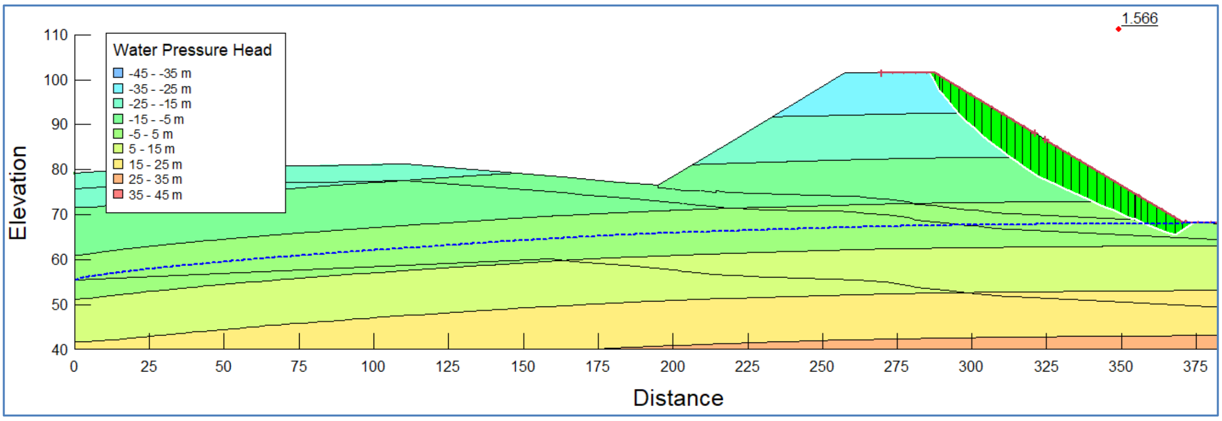
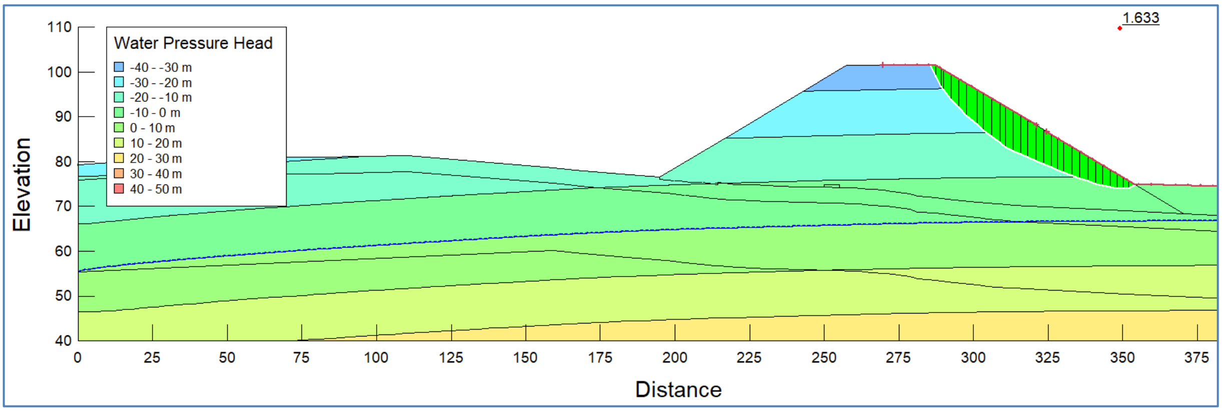


SCENARIO A6

OPERATIONAL PHASE – PARTIAL CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	Min	Max
B 1	X			X	
B 2	X				X
B 3		X		X	
B 4		X			X
B 5			X	X	
B 6			X		X



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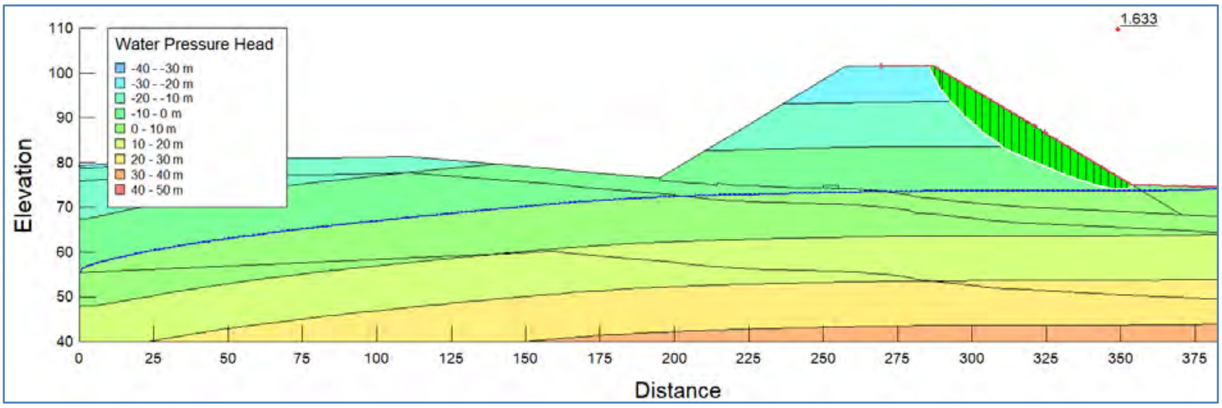

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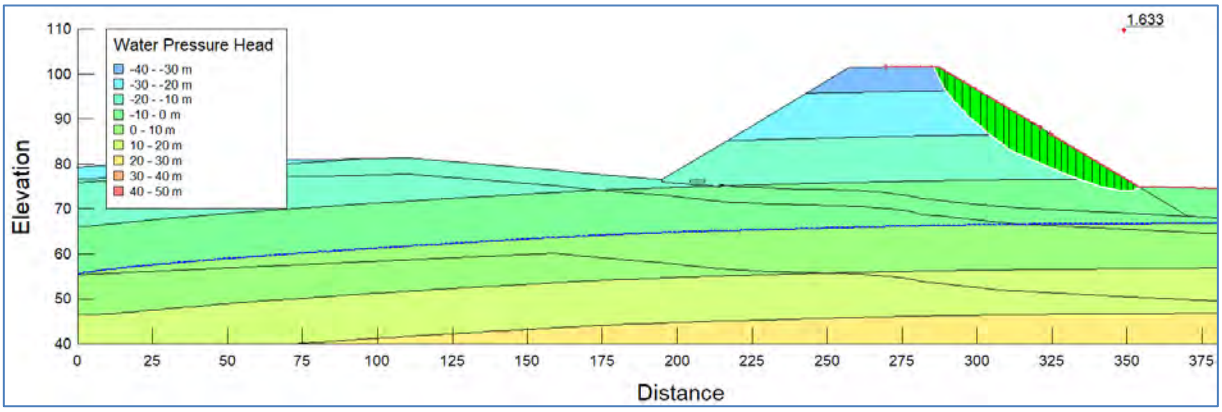

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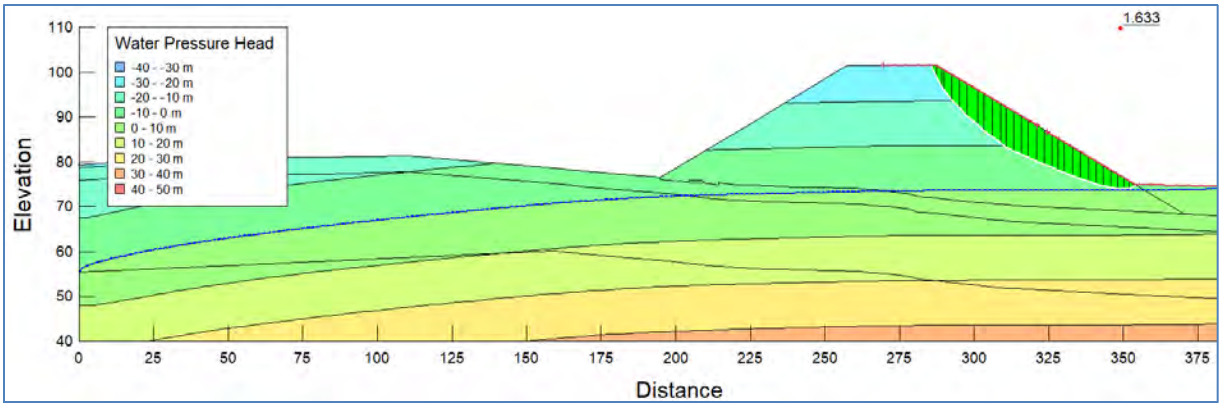

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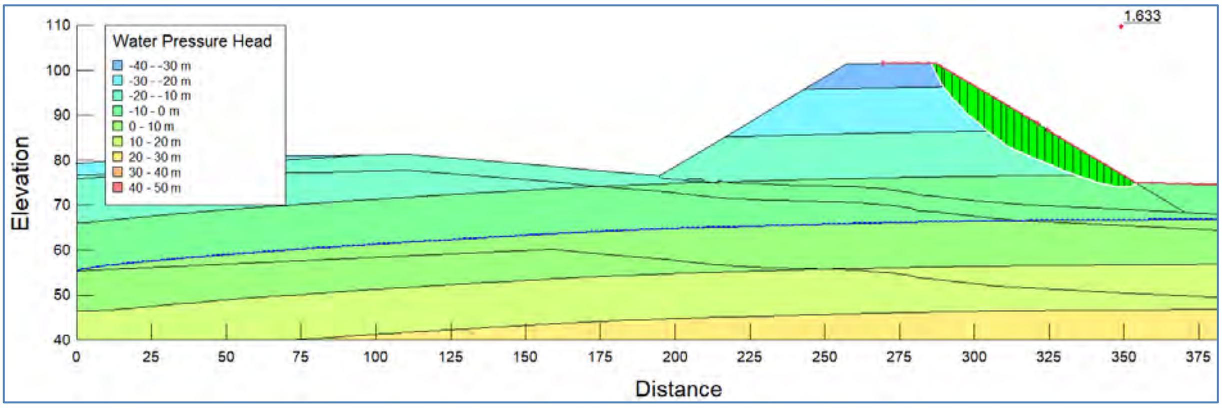

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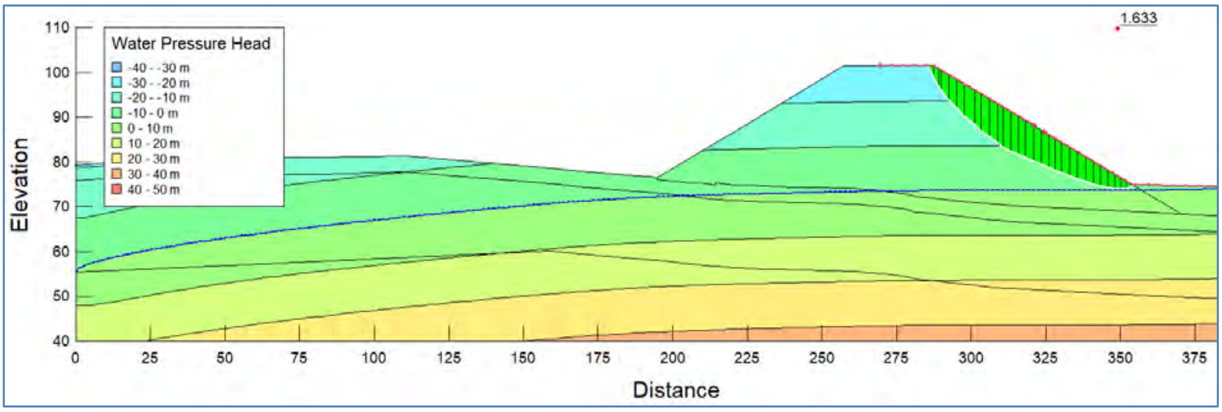
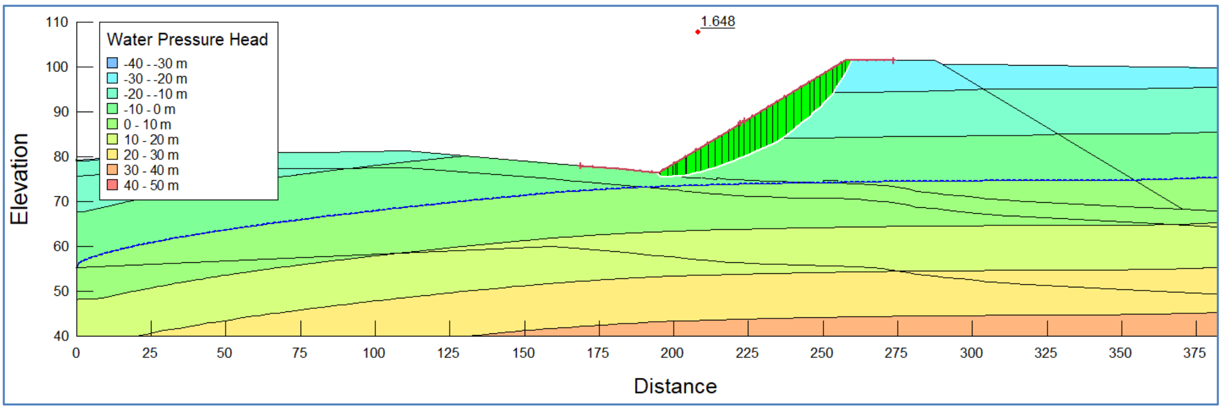


SCENARIO B6

OPERATIONAL PHASE – MAXIMUM CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	centre blanket drain	downstream blanket drain
C 1	X			X	
C 2	X				X
C 3		X		X	
C 4		X			X
C 5			X	X	
C 6			X		X



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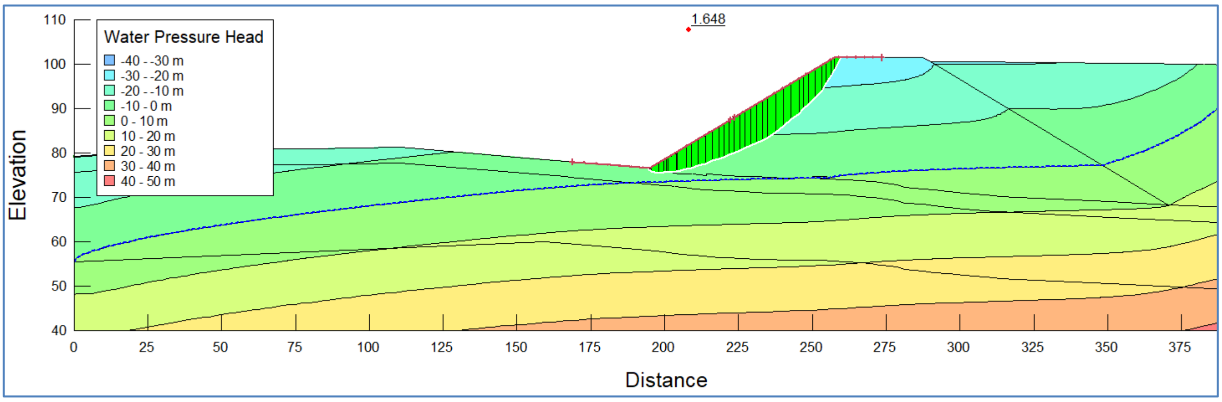

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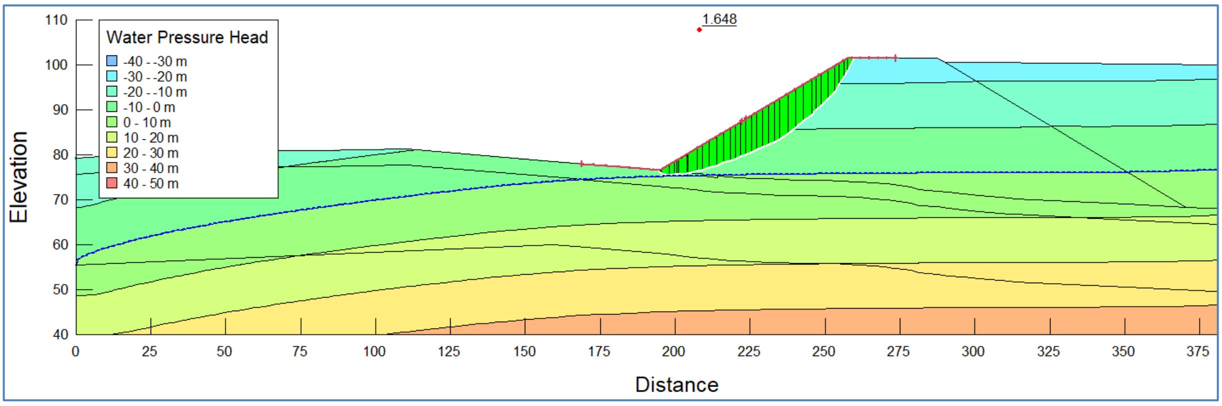

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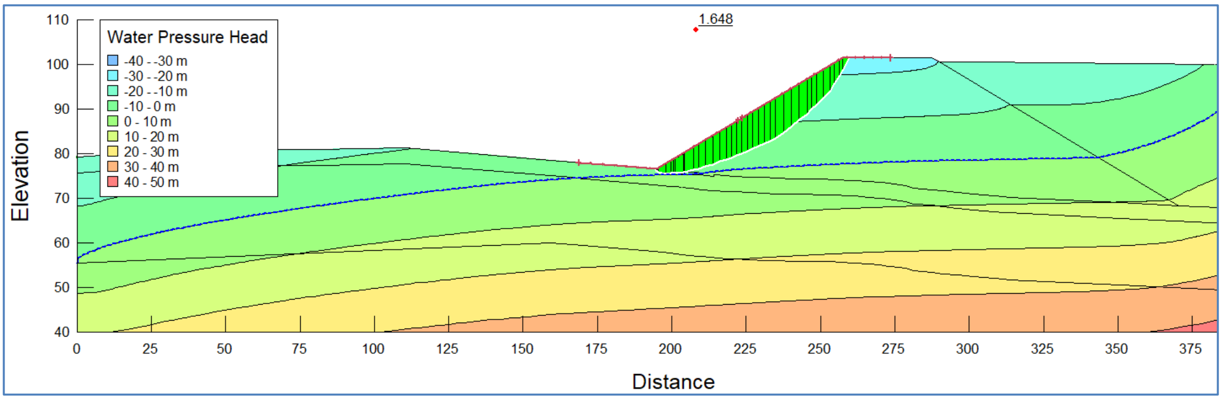

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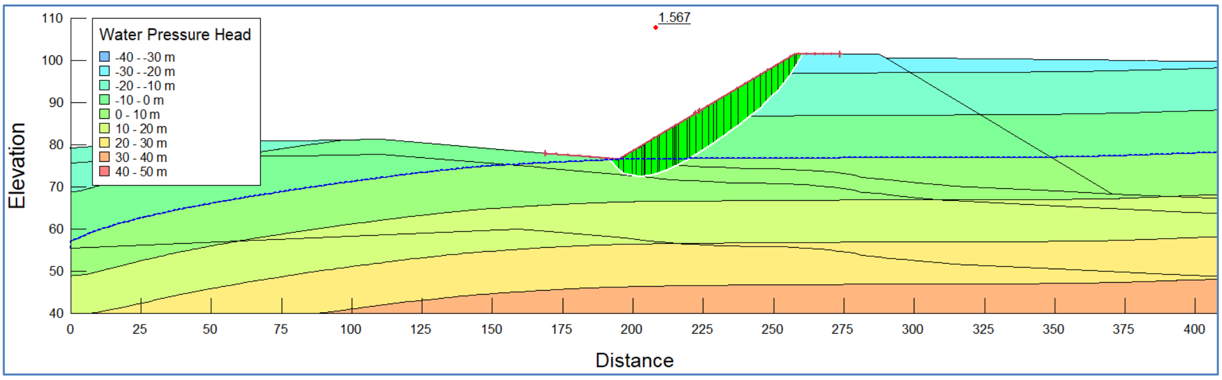

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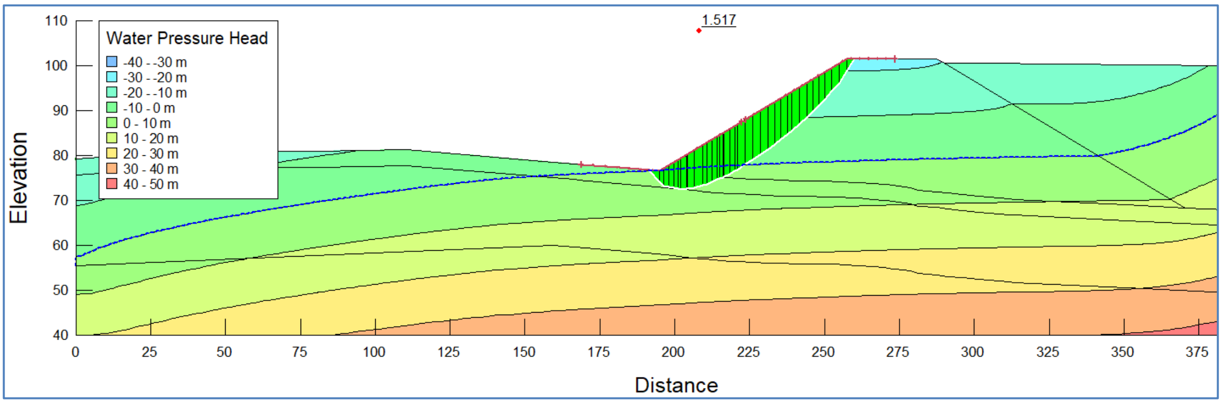
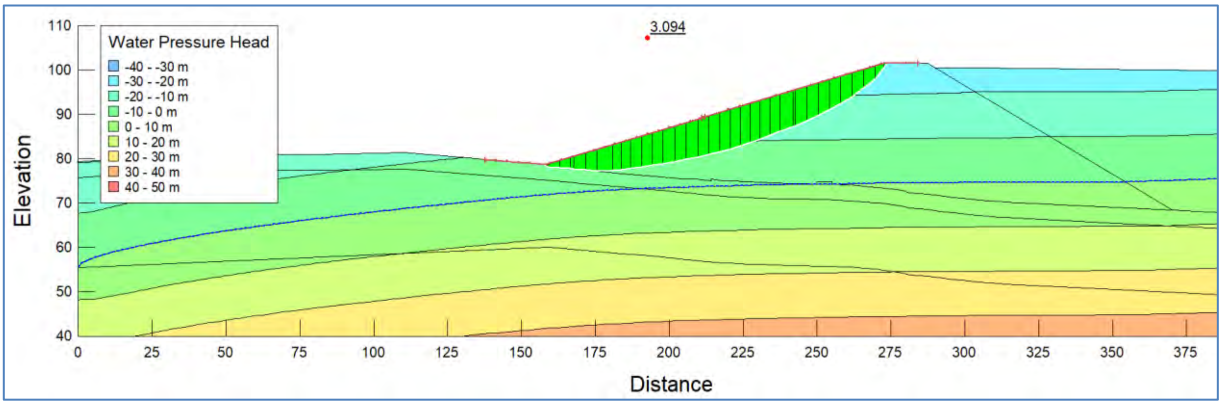


SCENARIO C6

CLOSURE PHASE – MAXIMUM CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	centre blanket drain	downstream blanket drain
D 1	X			X	
D 2	X				X
D 3		X		X	
D 4		X			X
D 5			X	X	
D 6			X		X



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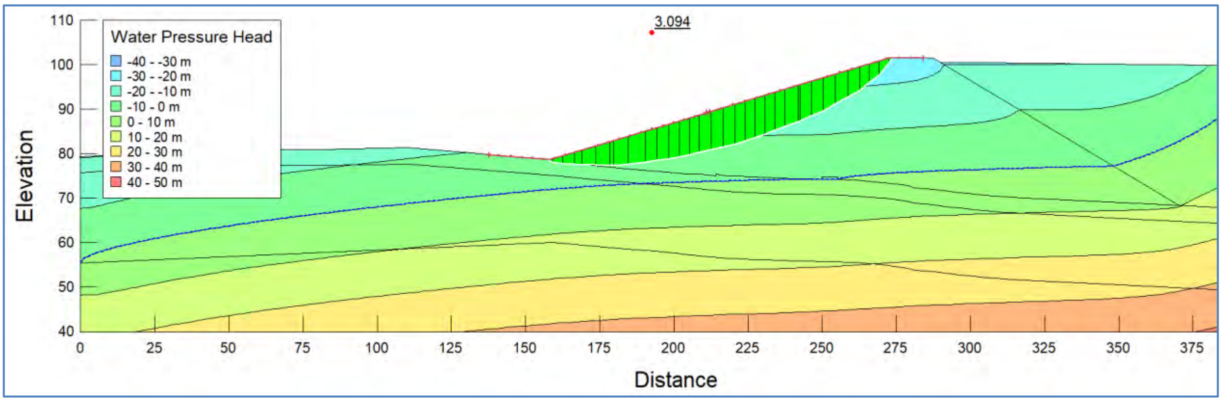

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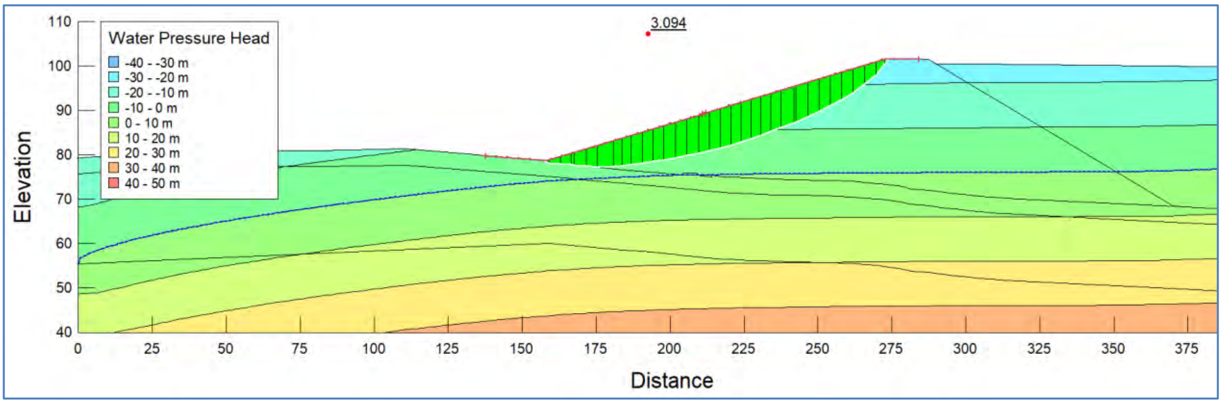

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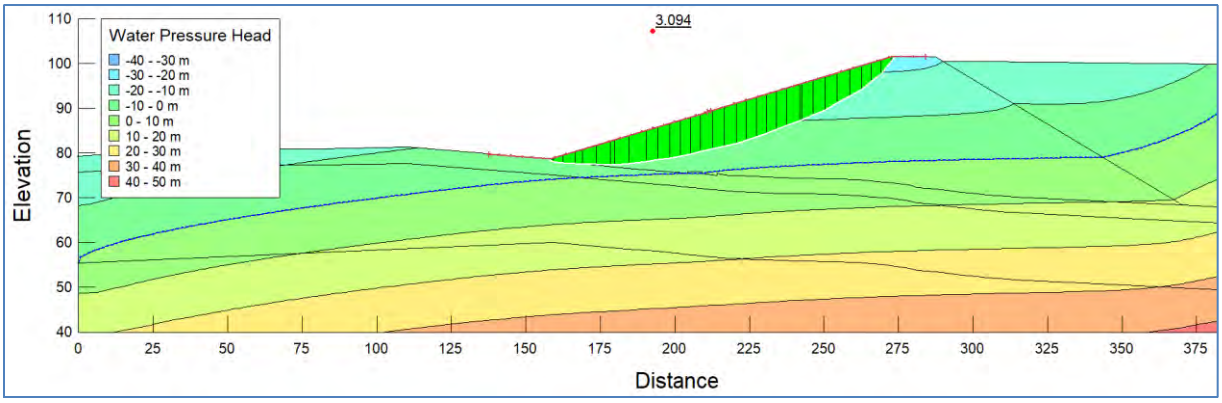

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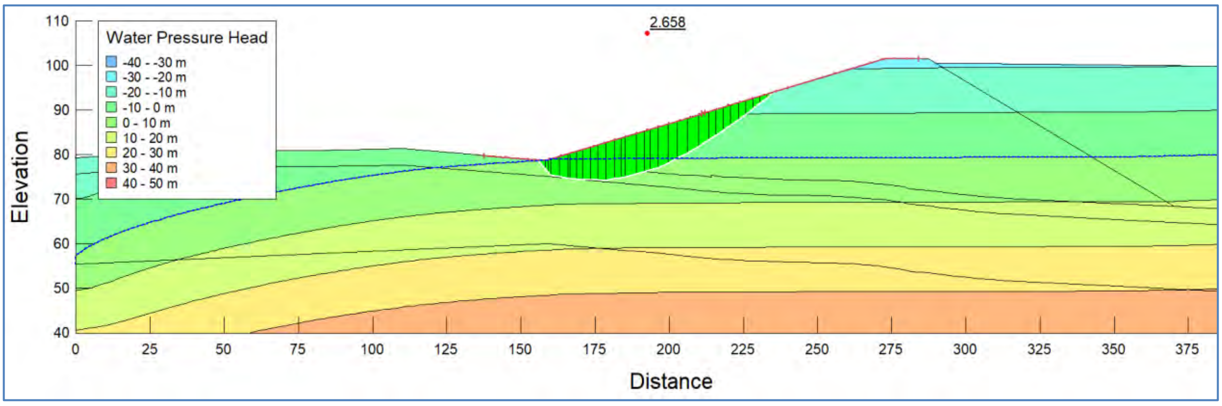

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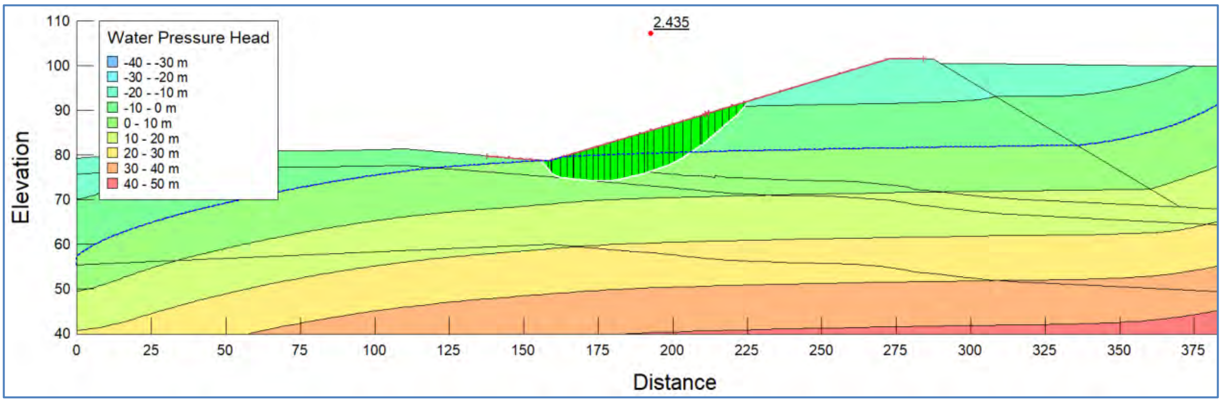

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APPENDIX II PSEUDO-STATIC RD SEEPAGE AND SLOPE STABILITY RESULTS

INFORMATION

As in APPENDIX I, tables have been created by which to identify the information presented below for pseudo-static loading conditions. Results are separated based on the residue capacity and RD phase they are associated with (i.e. the operational phase with residue at maximum capacity is identified as Scenario C).

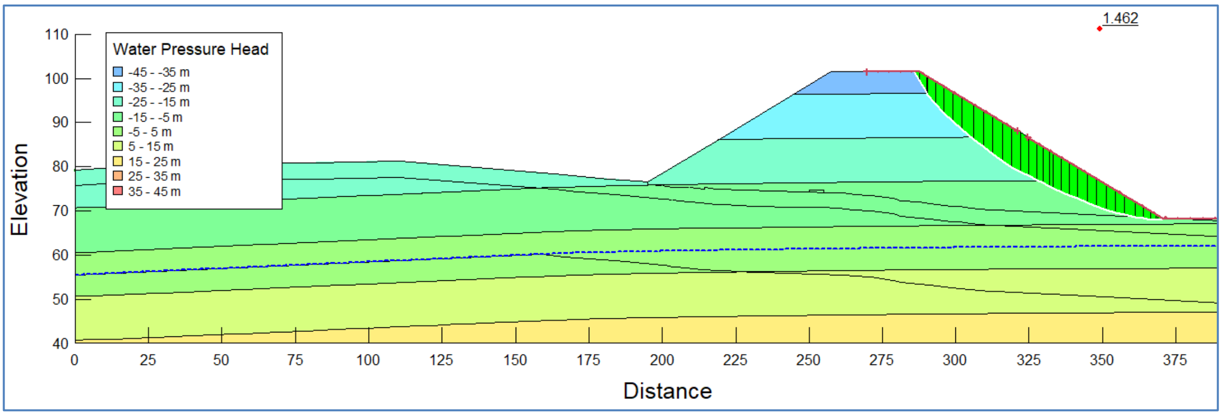
SUMMARY OF SCENARIOS ANALYSED

Scenario	Phase	Deposition Capacity reached	Slope Considered
A	Operational	Initial capacity	Upstream
B	Operational	Partial capacity	Upstream
C	Operational	Maximum capacity	Downstream
D	Closure	Maximum capacity	Downstream

Each scenario is further subdivided into subsections based on the active drainage condition and operating pool level. A table has been included at the start of results for each scenario, as shown below.

OPERATIONAL PHASE – INITIAL

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	Operational	Storm
A 1	X			X	
A 2	X				X
A 3		X		X	
A 4		X			X
A 5			X	X	
A 6			X		X



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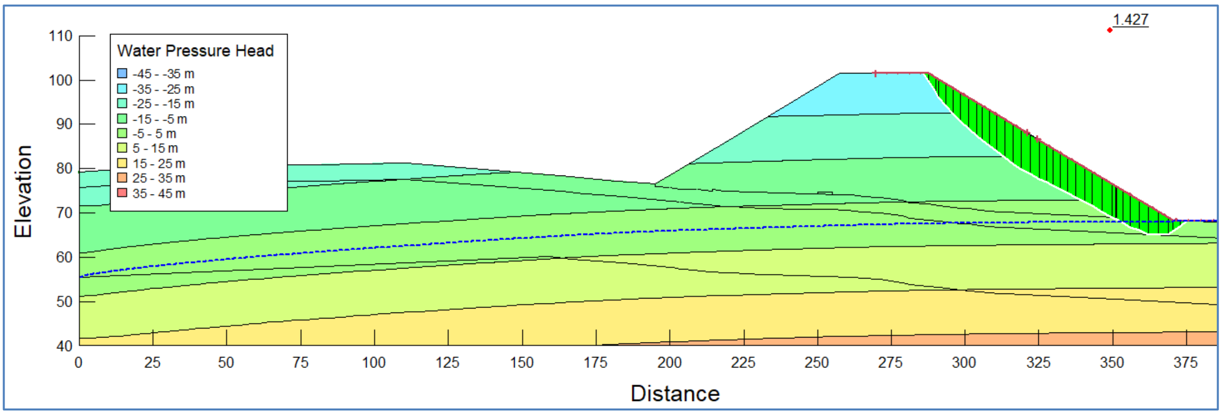

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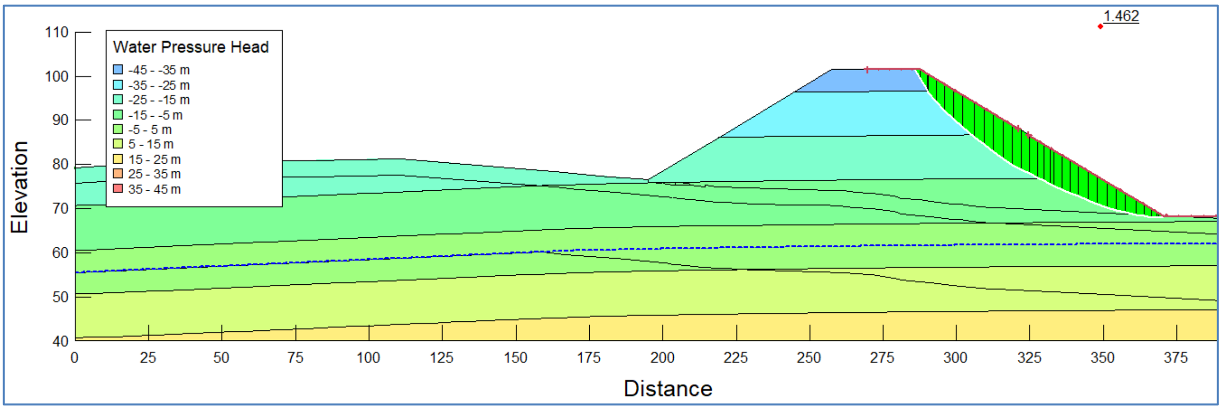

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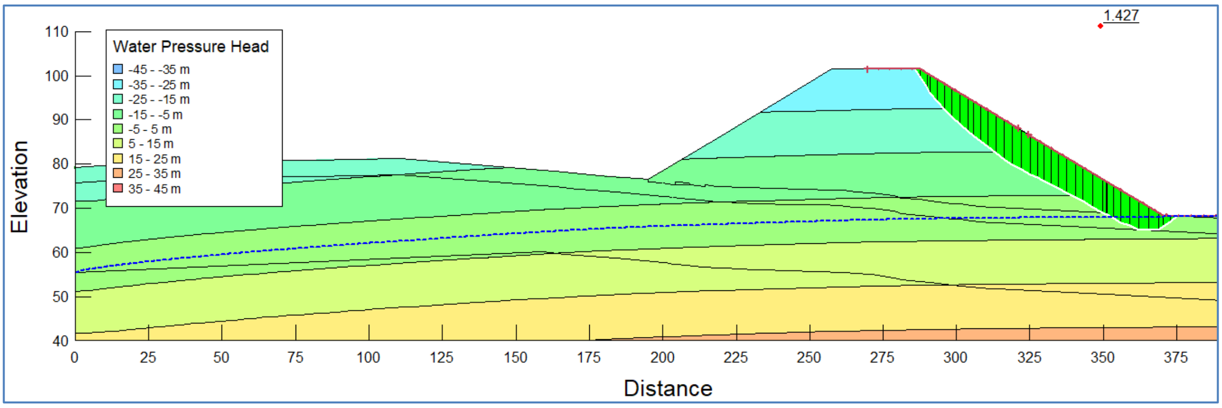

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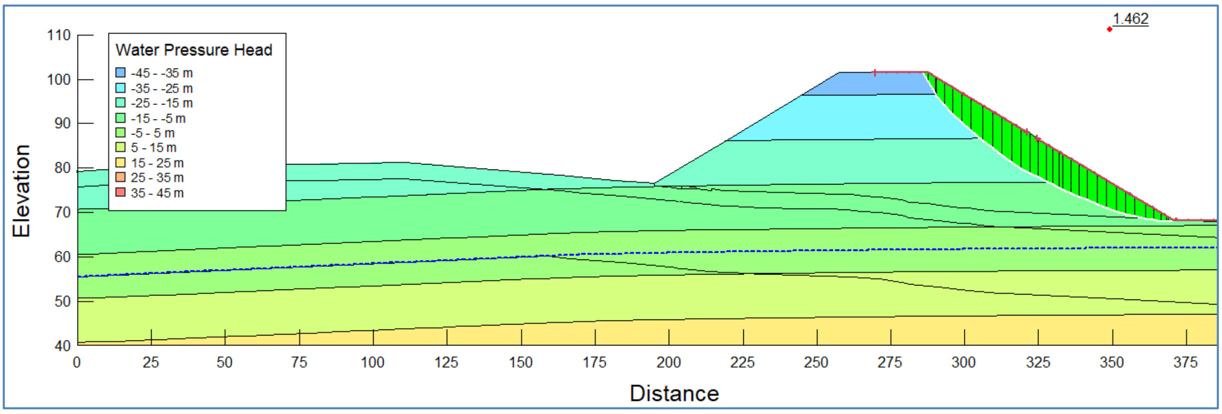

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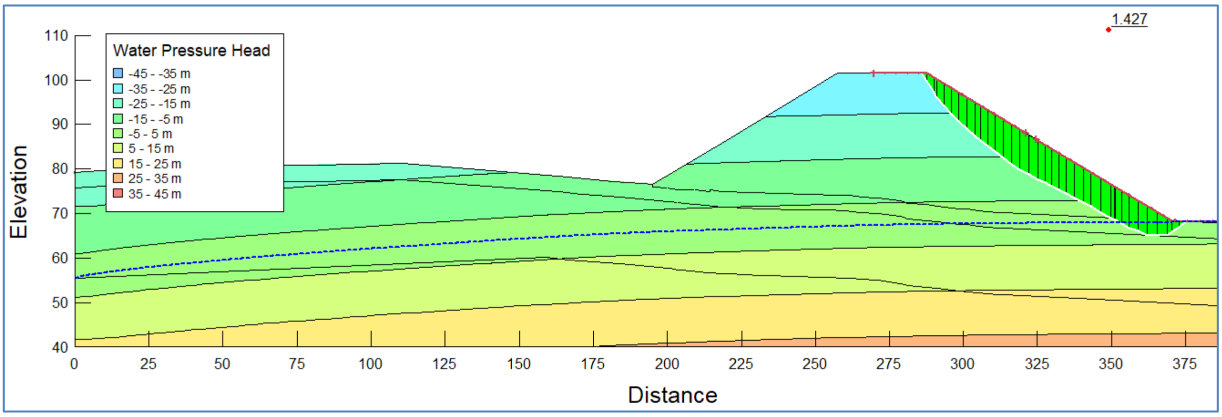
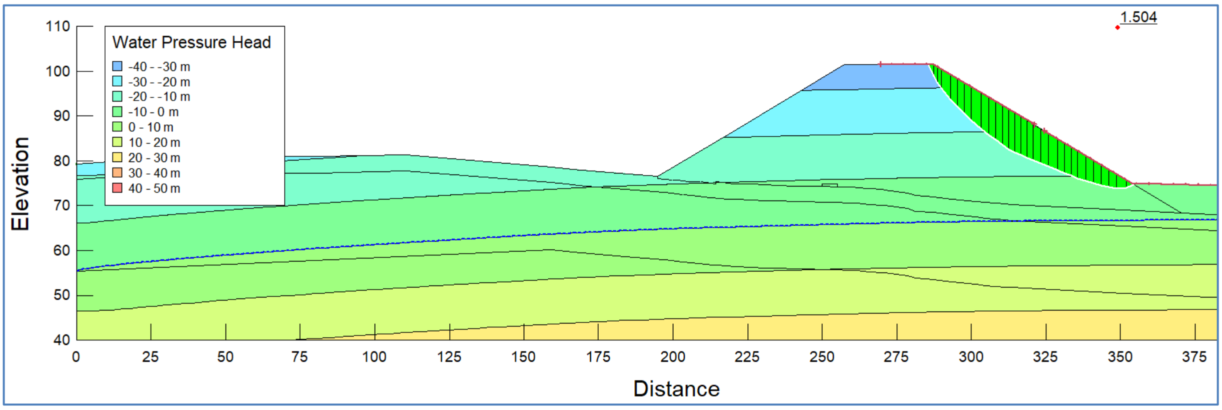


SCENARIO A6

OPERATIONAL PHASE – PARTIAL CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	Operational	Storm
B 1	X			X	
B 2	X				X
B 3		X		X	
B 4		X			X
B 5			X	X	
B 6			X		X



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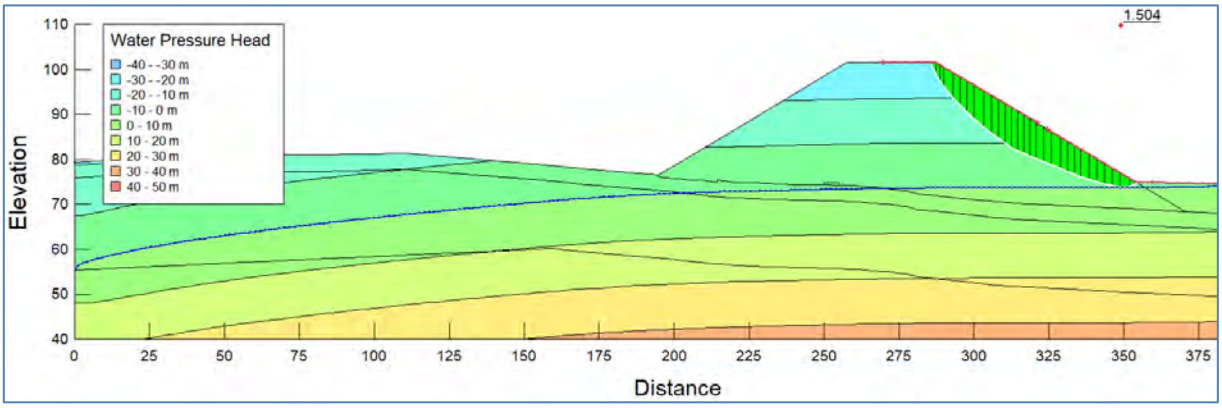

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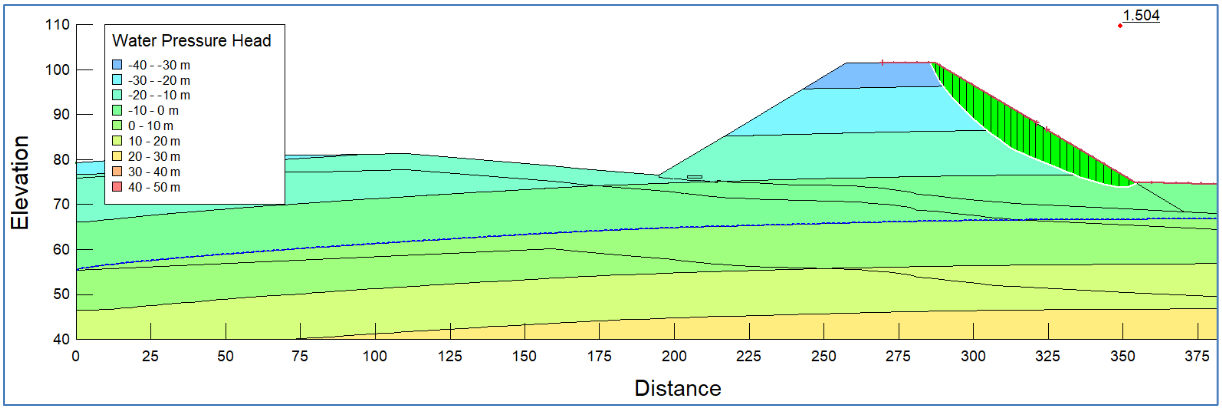

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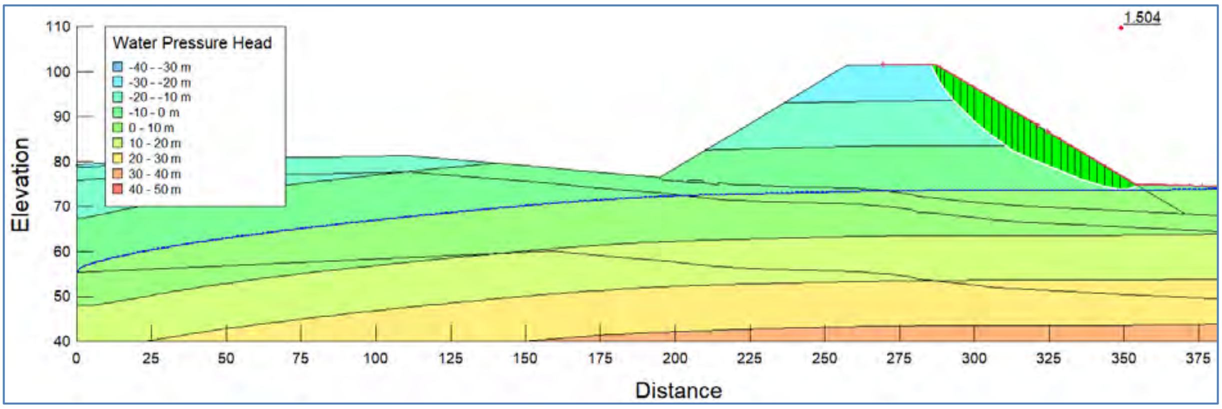

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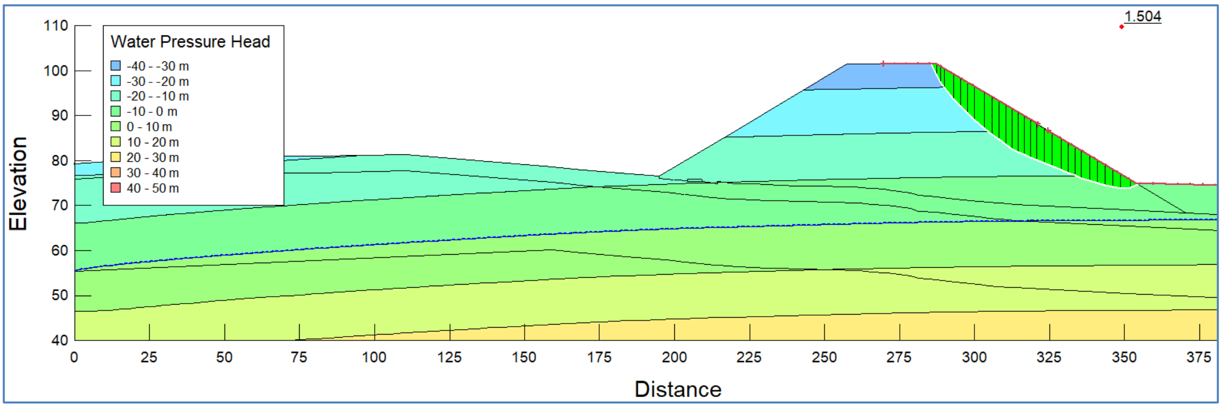

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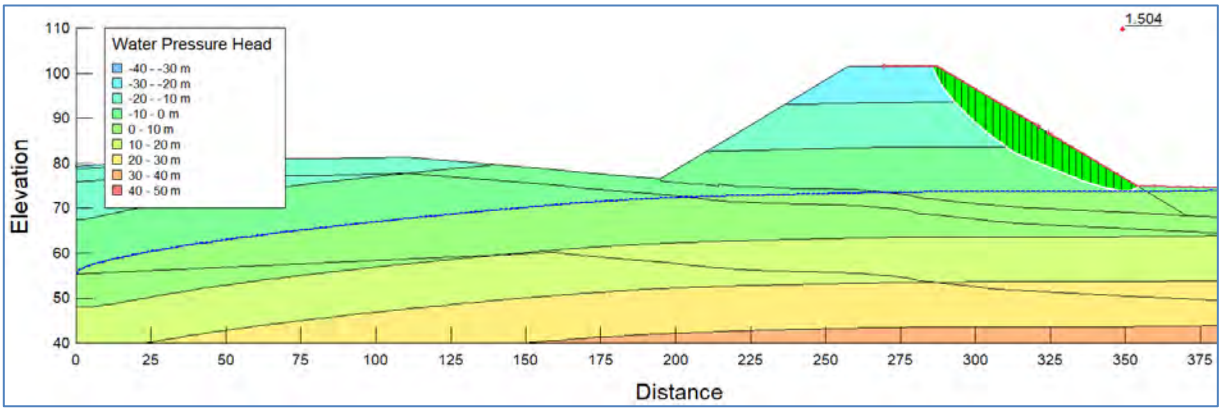
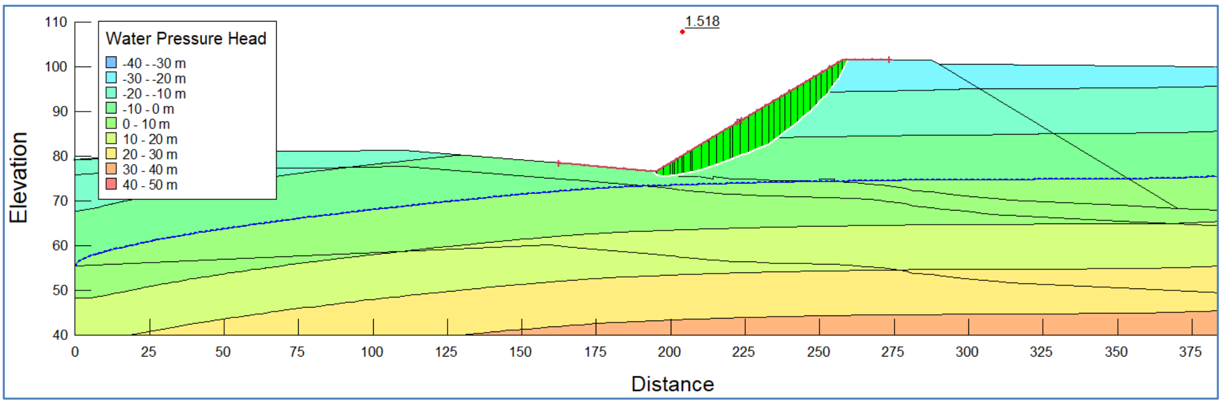


SCENARIO B6

OPERATIONAL PHASE – MAXIMUM CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	centre blanket drain	downstream blanket drain
C 1	X			X	
C 2	X				X
C 3		X		X	
C 4		X			X
C 5			X	X	
C 6			X		X



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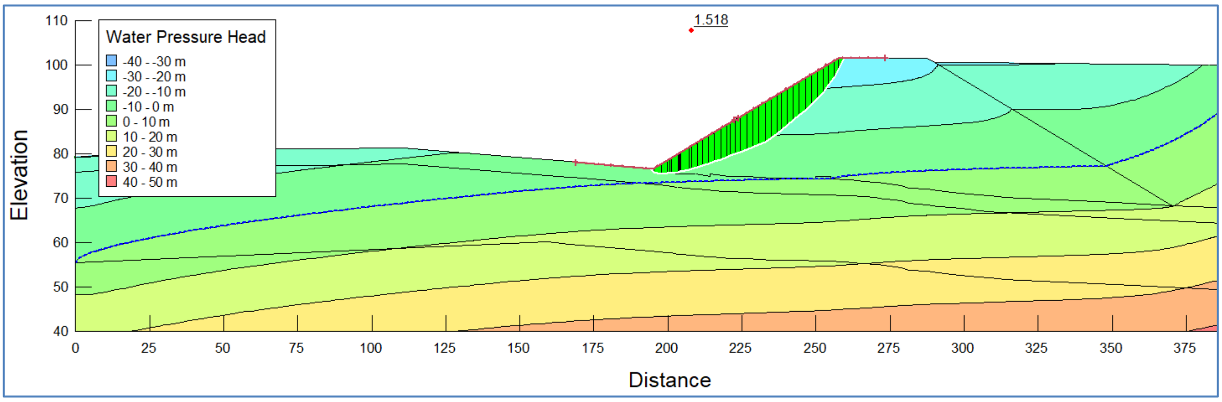

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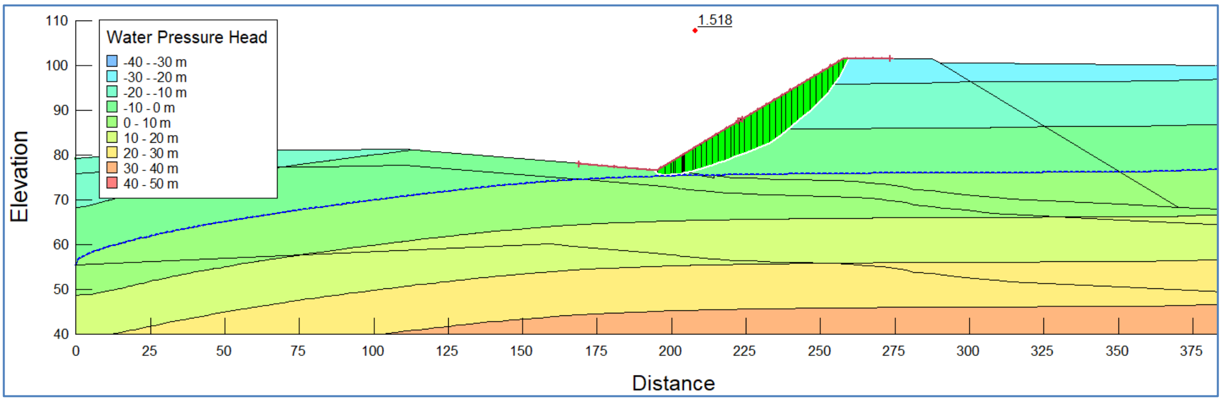

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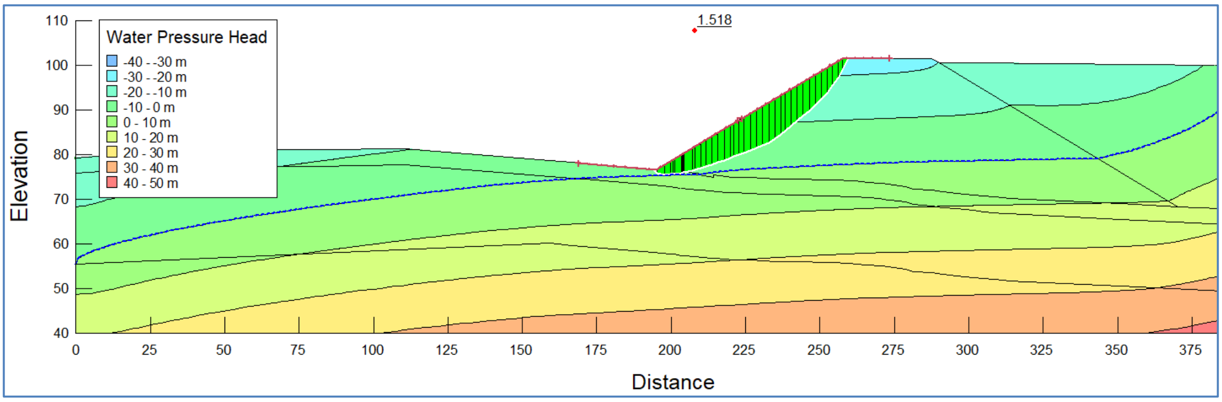

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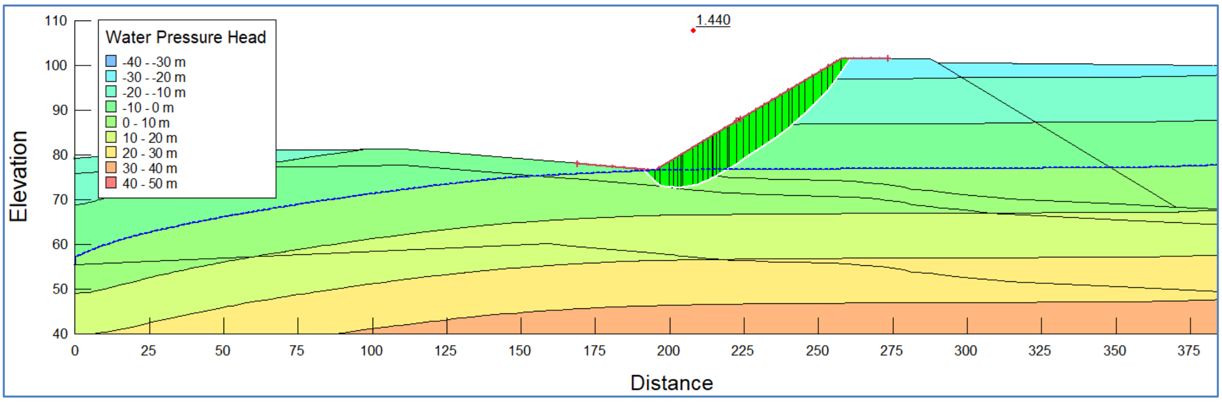

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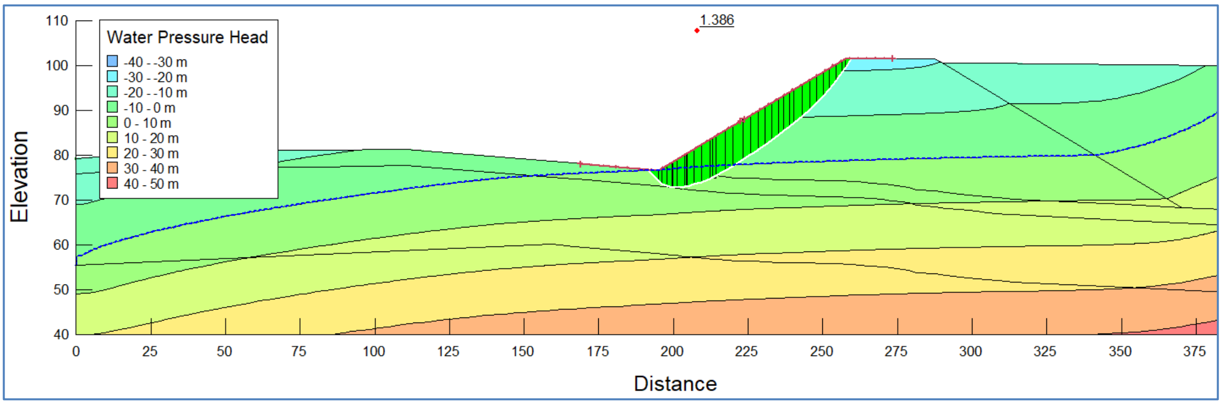
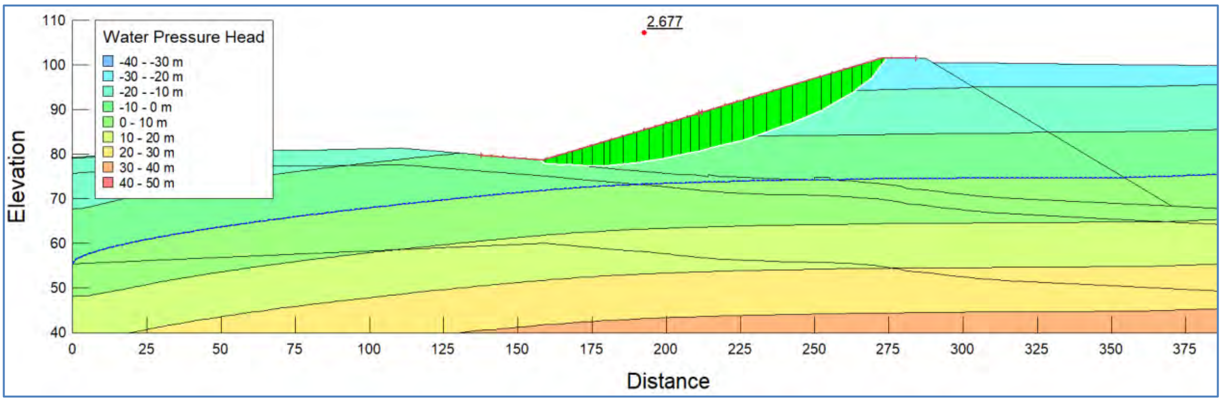


SCENARIO C6

CLOSURE PHASE – MAXIMUM CAPACITY REACHED

Scenario	Active Drains			Operating Pool	
	centre blanket drain	downstream blanket drain	No Drains	Operational	Storm
B 1	X			X	
B 2	X				X
B 3		X		X	
B 4		X			X
B 5			X	X	
B 6			X		X



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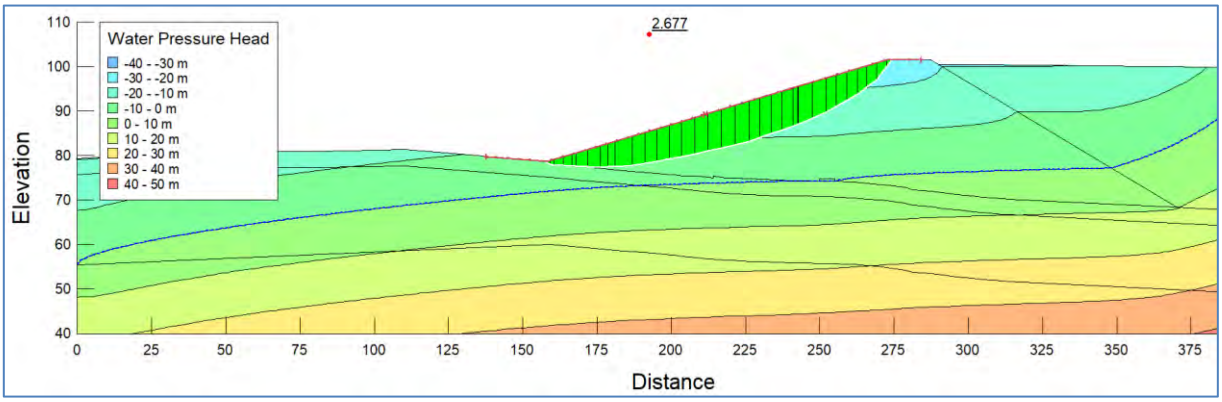

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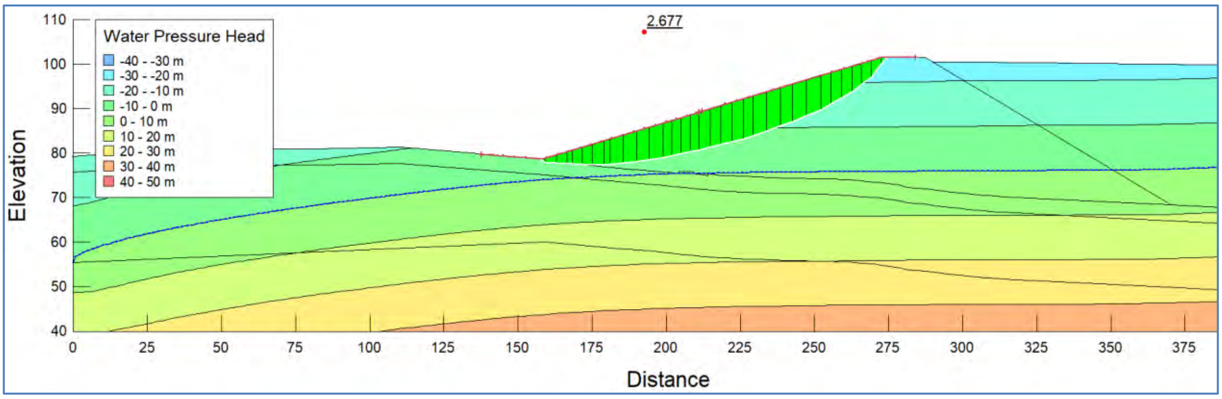

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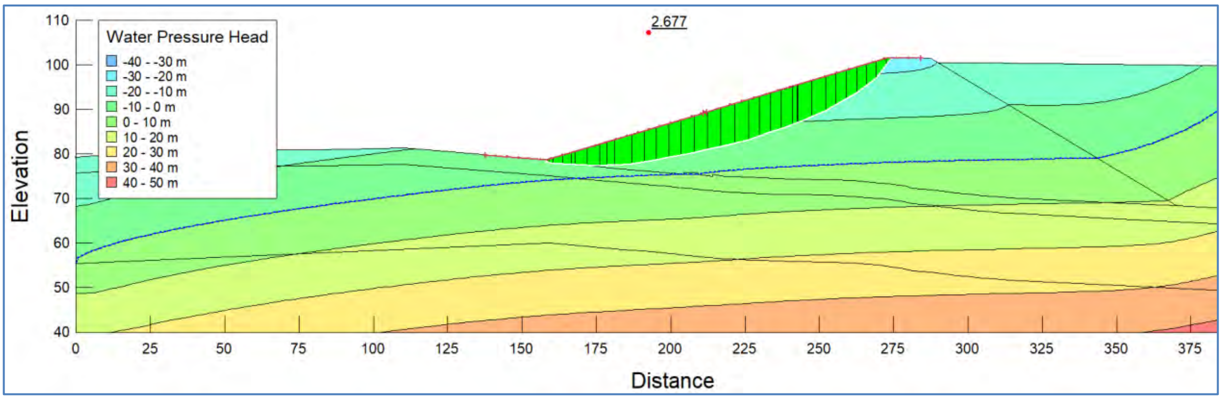

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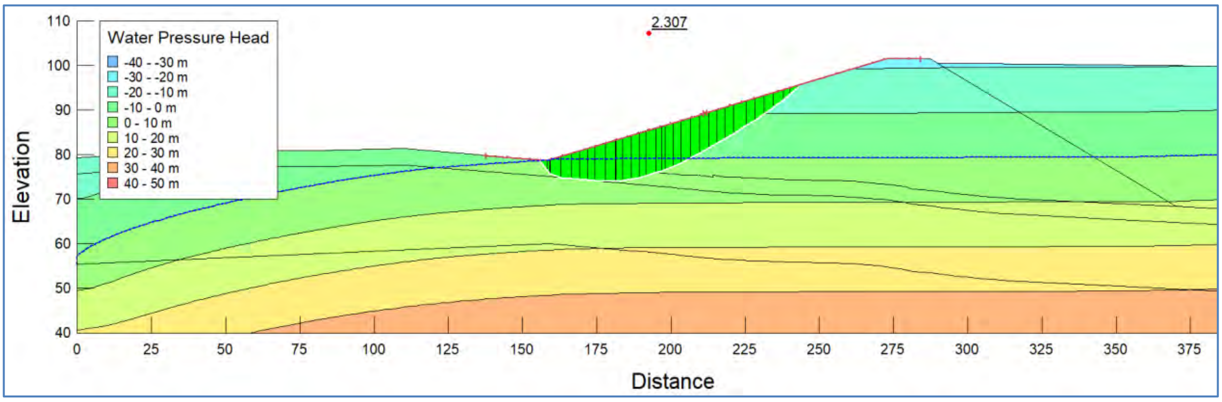

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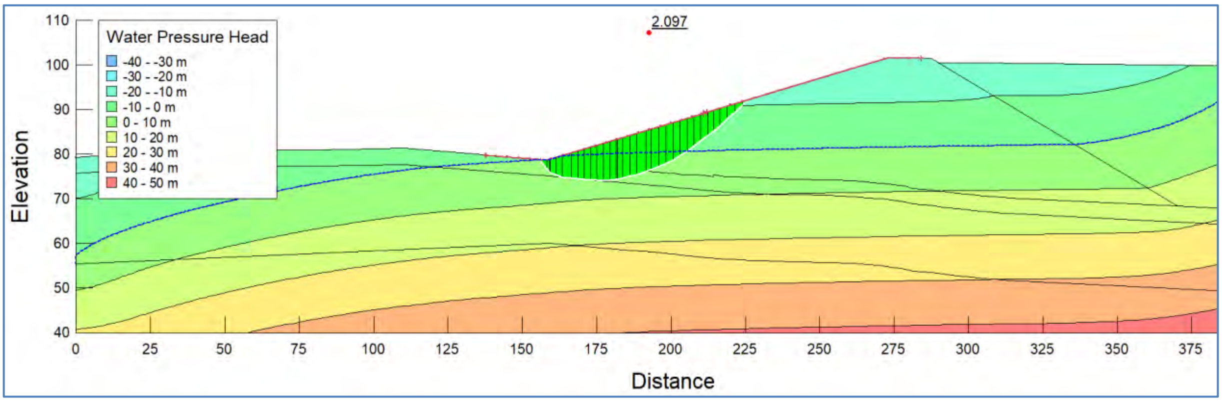

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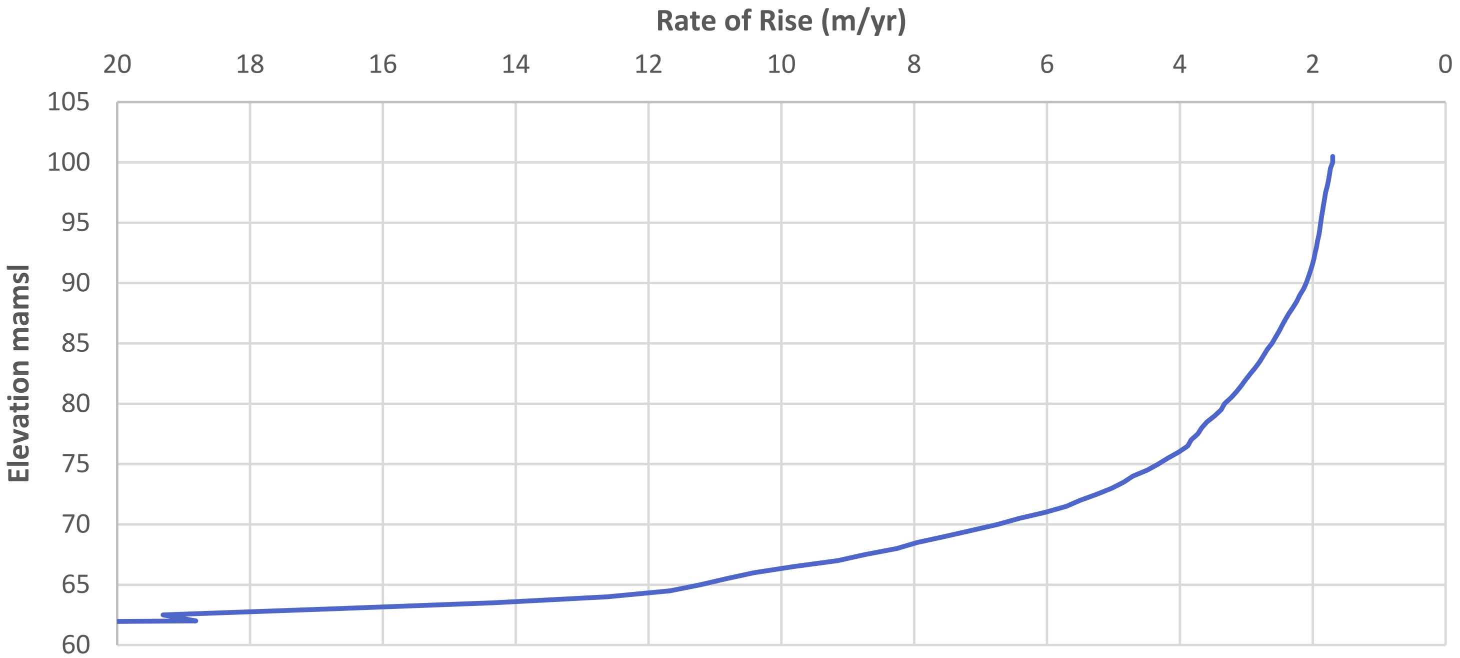
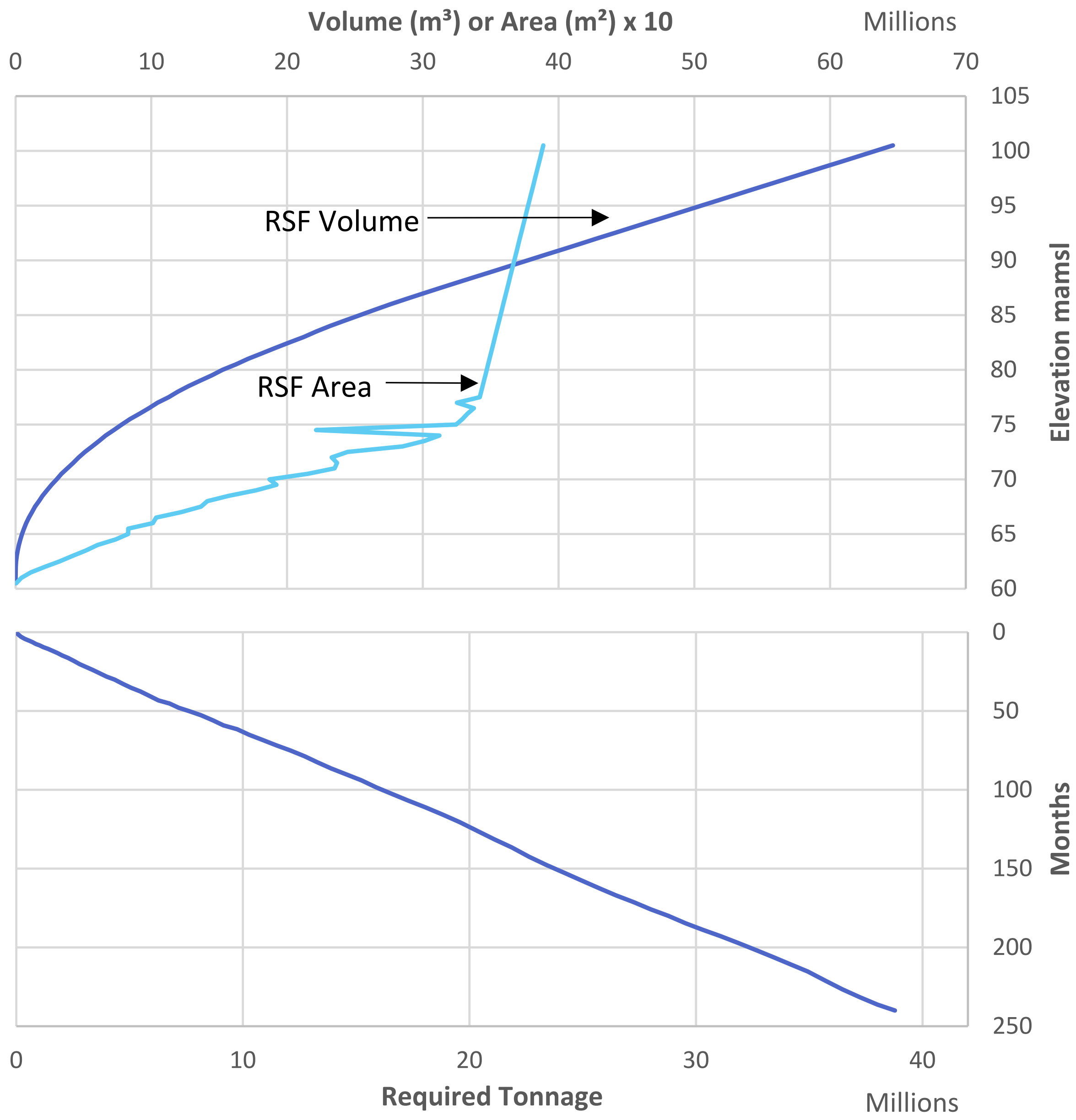
Appendix F STAGE CAPACITY CURVE





Tronox RSF		
Life of Mine	years	20.00
Max Tonnage	tons	38 900 000
Max Volume	m^3	64 338 333
Crest Elevation	m^3	101.50
Tailings Elev	m	100.50
Dry Density	m	0.60

TRONOX EAST RSF#6 - STAGE CAPACITY CURVE

Appendix G WATER BALANCE REPORT

Water Balance Study for the Tronox EOFS Residue Storage Facility

epoch resources (pty) ltd

mine residue and environmental engineering consultants

PROJECT NUMBER 126-005 REPORT NO.126-005-3 DRAFT November 2020

Water Balance Study for the Tronox EOFS Residue Storage Facility

Prepared For

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WATER BALANCE STUDY FOR THE TRONOX EOFS RESIDUE STORAGE FACILITY

1. INTRODUCTION

Epoch Resources (Pty) Ltd (Epoch) were appointed by Namakwa Sands (Pty) Ltd (Namakwa) to undertake the Feasibility Study (FS) of the Residue Storage Facility (RSF) for the Tronox Namakwa Sands EOFS Project (Tronox). A water balance study was conducted as part of the project deliverables. The study investigated the inflows and outflows associated with the RSF to determine the estimated amount of return water that can be expected over the life of the facility as well as to determine reasonable operating pool volume constraints. These constraints were then incorporated into the seepage and slope stability analysis conducted by Epoch.

1.1. STUDY BACKGROUND

The proposed Tronox RSF is a full-containment facility designed within a natural depression. Containment walls are used to increase the capacity of the depression and decrease the facilities overall footprint area. The RSF will facilitate the storage of the tailings produced by the Mine Process Plant over a 20-year Life of Mine (*LoM*). The tailings will be hydraulically placed in the RSF as a slurry, with water recovered (returned) from the RSF to the Process Plant. Recoverable water exceeding the Process Plant's demands will require temporary storage while any shortfall in recoverable water must be supplemented by additional sources.

1.2. PROJECT LOCATION

The Tronox project is located in the Matzikama Municipality District of the Western Cape Province of South Africa, illustrated in Figure 1-1, approximately 54 km North-west of the town of Lutzville and 385 km north of Cape Town. The mine consists of two mining areas namely the East and West Mine with a Satellite image of the Mine depicted in Figure 1-2.

The RSF is designed within a natural depression on the Eastern mine with embankments built along the edge of the depression to facilitate the containment of the tailings produced over the LoM. The run-off catchment area of the RSF is approximately 311 Ha, excluding the area downstream of the non-overspill crest.

FIGURE 1-1: LOCATION OF THE TRONOX NAMAKWA SANDS PROJECT IN SOUTH AFRICA

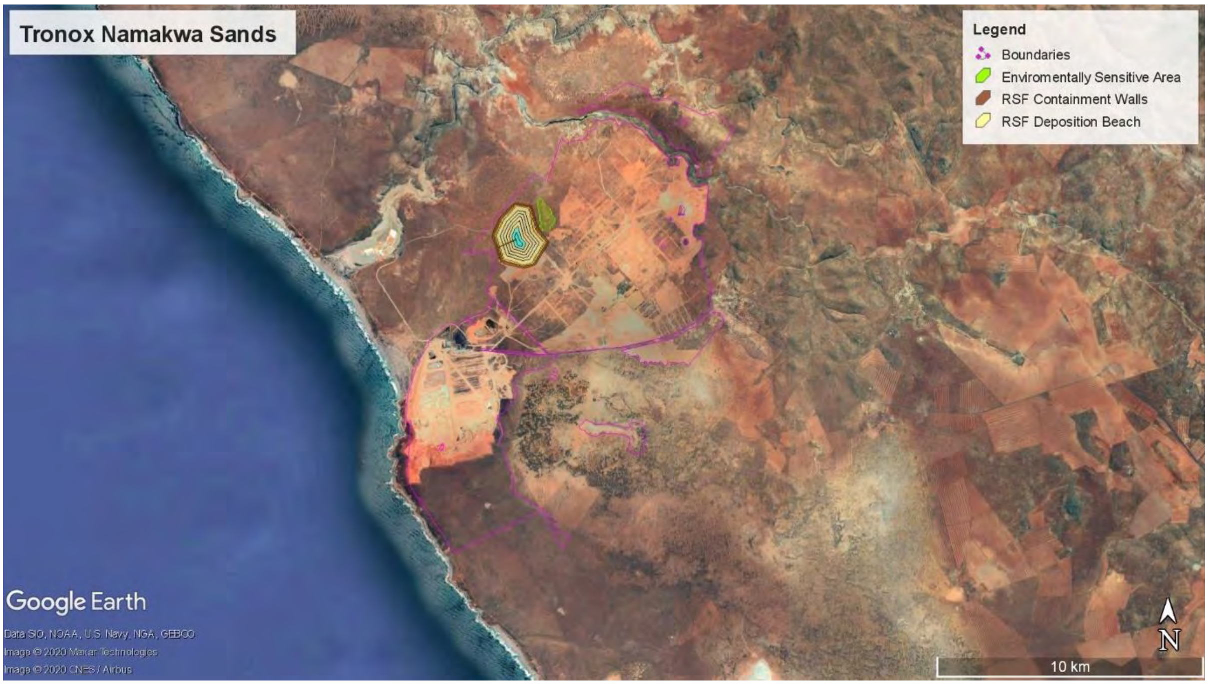

FIGURE 1-2: TRONOX RSF LOCATION

1.3. SCOPE OF WORK

The scope of work for the Tronox FS includes the undertaking of a Water Balance of the RSF which consist of the following:

- Collect and review all information made available;

- Compile a water balance model for the RSF;
- Determine the volume of return water available for return to the Mine Process Plant;
- Determine the volume of water returned as a percentage of slurry water requirement, and hence the shortfall to be made up from additional water resources; and
- Determine the volume of excess water that must be temporarily stored on the RSF in due to high rainfall events.

1.4. BATTERY LIMITS

The battery limits for the study are as follows:

- Downstream of the point where the slurry delivery pipeline intersects the RSF starter embankment;
- Upstream of the suction end of the return water pump(s); and
- For the collection manholes associated with these facilities, upstream of the first flange exiting the outlet pipe prior to the pumps (if any).

2. AVAILABLE INFORMATION

The following information was made available to Epoch to undertake the water balance:

- A 1 m contour interval digital terrain model covering the project area;
- Average monthly rainfall and evaporation depths of the project area;
- The design flood depths for the 2 to 200-year recurrence interval storm events;
- Tailings production rates; and
- Physical characteristics of the tailings.

2.1. CLIMATIC DATA

The project is in a region with characteristic wet and dry seasons. The wet season occurs during the winter months with the bulk of the annual precipitation experienced between the months of May to August, with the dry season occurring from September to April. During the summer period, when the ambient temperature is at its highest, the average monthly evaporation depths exceed 160 mm while the average monthly rainfall depths dwindle to below 5 mm. The evaporation depths exceed the rainfall depths for all months of the year.

The average S-Pan evaporation determined from the Water Resources of South Africa 2005 study (WR2005 BJ Middleton and AK Bailey) is 1 586.73 mm per annum. A coefficient of 0.75 was assumed to yield Lake Evaporation from the S-Pan depths and equates to 1 190.05 mm. No correction has been made for a reduction in evaporation due to salinity in the process water.

Rainfall data collected by Tronox on the West Mine from 1994 to 2015 was used to estimate the average monthly rainfall for the site.

The average monthly rainfall and evaporation depths are listed in **TABLE 2-1** as well as the variance between the two, indicating that annual evaporation exceeds the annual rainfall depth by over 1000 mm (1.0 m).

TABLE 2-1: AVERAGE RAINFALL AND EVAPORATION DEPTHS

Month	Average Monthly Rainfall (mm)	Average Monthly Evaporation – S-Pan (mm)	Average Monthly Evaporation – Lake (mm)	Variance (Rainfall – Evaporation) (mm)
January	4.9	218.0	163.5	-158.7
February	8.0	172.5	129.4	-121.4
March	8.0	147.1	110.3	-102.4
April	11.9	103.1	77.4	-65.5
May	24.2	75.9	56.9	-32.7
June	30.0	58.1	43.6	-13.5
July	32.2	62.5	46.9	-14.7
August	27.8	82.8	62.1	-34.3
September	11.9	111.2	83.4	-71.5
October	8.7	152.8	114.6	-105.9
November	8.6	186.0	139.5	-130.9
December	9.2	219.8	162.6	-153.4
Annual	185.2	1,589.7	1,190.1	-1,004.9

Daily rainfall data collected between 1925 and 1997 from the Nuwerus station, 43 km east of the Tronox RSF location, was used to conduct the water balance simulation. For each month of the year, monthly rainfall data was extracted from the Nuwerus data set that most closely matched the average monthly rainfalls determined from the West Mine rainfall dataset. These daily rainfall values were then repeated for each year over the life of the facility. A graphical representation of the average monthly lake evaporation, average monthly rainfall values from the West Mine dataset and the average monthly rainfall values for the selected months from the Nuwerus weather station is shown in Figure 2-1.

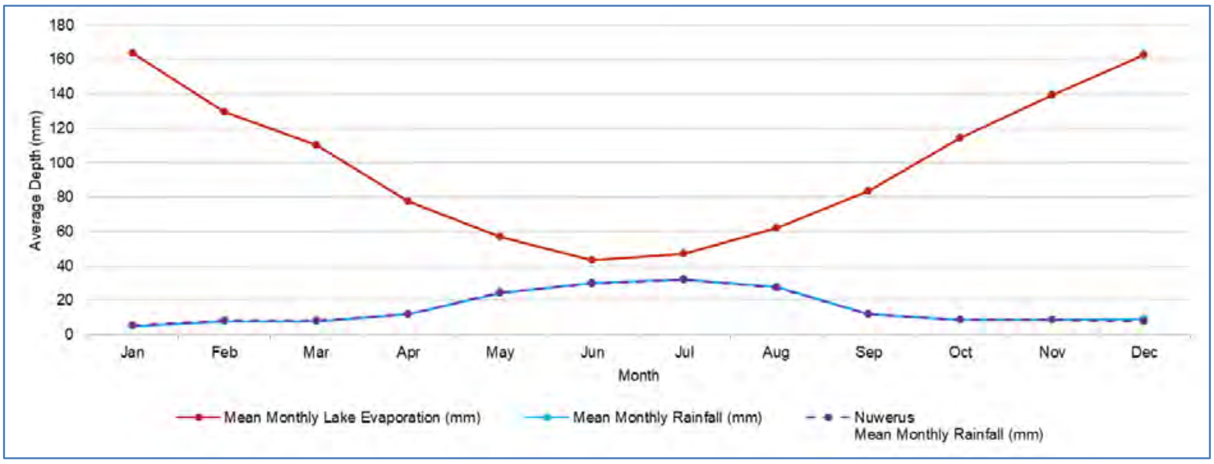

FIGURE 2-1: MONTHLY RAINFALL AND EVAPORATION DEPTHS

The storm event depths as listed for the Doringbaai Weather Station (Station 0106408W) were used in this study. The station is the one situated closest to the project area, with listed storm event depths, some 65 km south of Tronox, along the western coastline with a similar elevation (88 m.a.m.s.l) and 48 years of rainfall records.

In a study undertaken in 2017 by SRK on the West mine, SRK estimated the storm event depths for the West Mine using the Pearson Type III distribution based on the mine's 23 years of rainfall data. This study is documented in SRK Report "Namakwa Sands West Mine Slimes Dam 6 Report – Rev 2" of 2017. The 24hr design flood depths for the Doringbaai Weather station and the SRK study are depicted in

TABLE 2-2.

In order to accurately predict storm event depths, data is typically collected for a 30 year period or greater. The mine only has 23 years of records, as such the Doringbaai storm event depths were used in calculating the required storage capacity. It should however be noted that the SRK study results correlated well with the Doringbaai data for the greater return period events of 50 – 200 years.

TABLE 2-2: DESIGN FLOODS RECEIVED FOR THE TRONOX PROJECT

	Rainfall Depth (mm) for each Recurrence Interval						
	2 Years	5 Years	10 Years	20 Years	50 Years	100 Years	200 Years
Doringbaai	30	41	49	58	69	78	87
SRK study	8	15	28	41	60	76	92

2.2. PERTINENT REGULATIONS AND STANDARDS

The following list of South African regulations apply to the design and ownership of a RSF:

- The National Environment Management: Waste Amendment Act No. 26 of 2014 (*NEMWA*);
- The National Water Amendment Act No. 27 of 2014; and
- The National Minerals and Petroleum Resource Development Amendment Act No. 49 of 2008.

2.2.1. WASTE CLASSIFICATION AND SEEPAGE CONTAINMENT BARRIER DESIGN

A waste classification of the tailings based on NEMWA regulations stipulates that seepage control measures are required to be implemented at the RSF. A waste assessment study of the Tronox fine tailings completed by SRK in 2020 and documented in their report "Tronox Namakwa Sands EOFS Waste Classification study, June 2020" classifies the tailings as Type-3 waste that requires a Class-C or similar seepage containment barrier as described by NEMWA.

A groundwater study conducted by SRK in 2020, indicated that the contaminated plume, formed due to seepage of slurry water with a high salinity content, revealed that the topography of the depression and the lack of groundwater movement result in mainly localised contamination. Given this study and the fact that the tailings are non-acid forming, inert and with the Geochemical Abundance Index (GAI) showing no significant enrichment relative to the global soil medium concentration, it is argued that a Class-D or similar seepage containment barrier would be appropriate.

It can further be argued that given the low permeability of the tailings, being 3 orders of magnitude lower than that of the 150 mm base preparation layer required for a Class-D liner, the installation of a Class-D seepage containment barrier will yield equivalent results should no base preparation take place. As such the RSF Water Balance study was undertaken assuming the low permeability of the fine tailings being the seepage driving factor.

2.2.2. SEPARATION OF CLEAN AND DIRTY WATER

The Water Act stipulates that occurrences of clean water contamination may not occur more than once in 50 years. Deterministically this is equivalent to a 2% probability of annual occurrence and is achieved with the implementation of engineered measures. Therefore, the RSF has been designed with the 1:50 year storm event taken into consideration. Stormwater diversion trenches and berms have also been implemented to reduce to amount of run-off likely to enter the containment facility, further reducing the amount of clean water likely to be contaminated.

2.2.3. MINIMUM FREEBOARD

The Minerals Act and the Water Act respectively state the following on the provision of minimum freeboard:

- A minimum freeboard of 0.5 m with a 1:100-year recurrence interval; (*1% probability of exceedance*), 24-hour duration storm; and
- A minimum freeboard of 0.8 m 1:50-year recurrence interval; (*2% probability of exceedance*), 24-hour duration storm.

SANCOLD guidelines factor in consideration of the following elements affecting available freeboard:

- Wind-generated waves;
- Wind setup;
- Seiches (resonance);
- Flood surges;
- Landslide-induced waves; and
- Earthquake-induced waves.

The design uses a storm event with a 2% probability of exceedance (1:50-year) and duration of 24-hours. A minimum freeboard of 1 m is allowed for, which exceeds the Water Act requirements and provides additional freeboard to support the additional elements outlined by SANCOLD.

3. METHODOLOGY

A deterministic approach was followed during the assessment of the inflow and outflow relationship associated with the proposed RSF. The model makes use of daily rainfall values from the Nuwerus weather station as well as the natural topography associated with the site and deposition data determined from stage capacity calculations. An illustration of the RSF, associated infrastructure, mining boundary (EMP boundary), estimated beach slopes and catchment area can be seen in Figure 3-1.

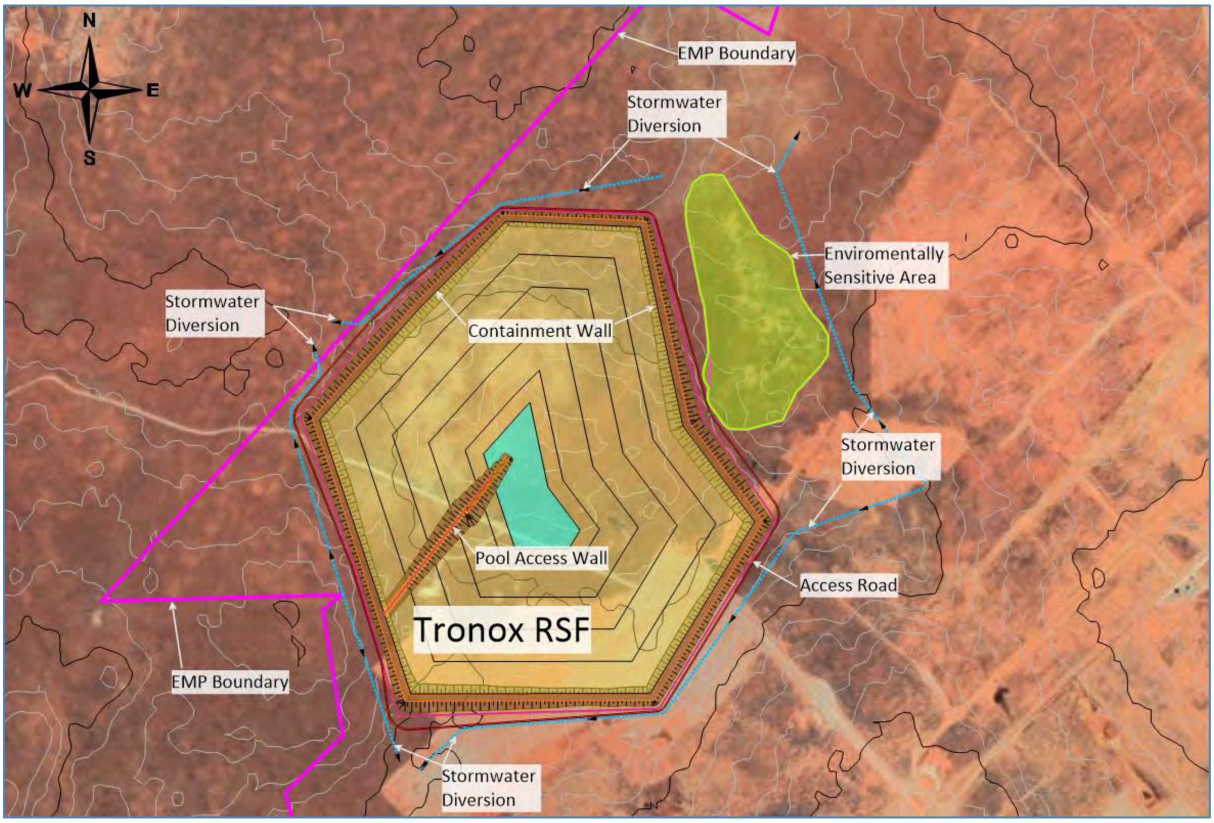

FIGURE 3-1: TRONOX RSF AT FULL CAPACITY

A penstock dewatering system typically consists of a vertical decant tower connected to a below ground outlet pipeline utilising a gravity feed to transport supernatant water, collected on the RSF, to a Return Water Dam (RWD). The natural topography of the depression does not allow for the supernatant water to be gravity fed to a RWD without excessive excavation, therefore, a penstock was not considered for the facility. A turret dewatering system will be used to decant water from the RSF. The system consists of a floating turret connected to a pump, stationed on the pool access wall a short distance away. The system allows water to be pumped directly to the Mine Process Plant, eliminating the need for a RWD.

3.1. MODEL SETUP

The water balance model assesses the volume of water that will be reporting to the RSF pool. The model quantifies the inflows and outflows of water that would affect the volumetric fluctuation of the pool.

Inflows into the RSF include:

- Rainfall run-off from the catchment area of 311 Ha, consisting of the deposition beach, pool surface area and natural topography downstream of the Stormwater Diversion trenches and berm. Clean water run-off emanating from the remainder of the upstream catchment area, illustrated in Figure 3-1, is assumed to be diverted away from the RSF and will not contribute to the water balance; and
- Slurry delivery water;

Outflows from the RSF include:

- Evaporation;

- Return water (via pumps);
- Interstitial lock-up between tailings particles; and
- Seepage (which is assumed to be minimal due to the low permeability of the tailings deposited within the basin).

The various inflows are calculated for each day based on the pool size, deposition tonnage and related deposition area as well as the remaining catchment area outside of the current deposition area. The daily outflows are subtracted from the daily inflows and the remainder is added to the pool volume of the previous day to determine the current day's pool volume. The area of the pool is then used in the next day's calculations to determine the run-off from rainfall, seepage and evaporation.

Table 3-1 lists the run-off coefficients used to determine the quantity of water which reaches the supernatant pool as a portion of the rainfall.

TABLE 3-1: ASSUMED RUN-OFF COEFFICIENTS

Daily Rainfall Depth (mm)	Run-off Coefficient			
	Catchment	Dry Tailings Beach	Wet Tailings Beach	Pool
< 2	0.001	0.00	0.00	1.0
< 4	0.025	0.25	0.40	
< 6	0.050	0.30	0.45	
< 8	0.075	0.35	0.50	
< 10	0.100	0.40	0.55	
< 15	0.125	0.45	0.60	
< 20	0.170	0.60	0.75	
≥ 20	0.200	0.75	0.90	

Certain constraints were applied to the model to improve the accuracy of the simulation of the operating conditions as well as geometric limitations present on site. Constraints include:

- Minimum supernatant pool volume;
- Maximum supernatant pool volume; and
- The number of active pumps (i.e. pumping rate).

A minimum pool volume of 20 000 m^3 was used in the water balance simulation. The actual minimum pool volume will depend on several factors:

- Topography (during the initial deposition period);
- Beach slope; and
- Settling characteristics of the fine tailings.

The maximum pool volume is based on the maximum allowable amount of water that is permitted to be stored on a dam before it is considered to be a dam with a safety risk. In the event that a dam is classified as having a safety risk, it would need to undergo further classification according to the regulations in terms of the size and hazard rating of the dam to comply with the requirements of the National Water Act of 1998. The Act states that any dam with a vertical wall height greater than 5 m, measured from the downstream toe point to the none overspill crest, and which stores more than 50 000 m^3 form part of a category of dams declared under section 118(2) or 118(3) of the Act to be dams with a safety risk. Therefore, the maximum tolerated capacity of the supernatant pool was limited to 49 000 m^3.

The model uses a pumping capacity of 860 m^3/h for each pump on the RSF. Water will be pumped off the RSF only when the pool volume is greater than 20 000 m^3. This constraint was introduced so as to prevent a very shallow pool which would result in fines being agitated and returned to the plant with the supernatant water. It would also help to prevent the beaching of the turret. Only one pump is considered active until the pool volume reaches a predetermined volume of 35 000 m^3, at which point a second pump will be employed to decant water off the RSF. This may not be the way in which the pumps will be operated in reality, however, it allowed the simulation to store water on the RSF, up to 49 000, thereby reducing the return water volumes on days when the available return water exceeds the amount required by the Mines Process Plant.

4. WATER BALANCE

The water balance for the Tronox RSF was conducted utilizing a deterministic approach based on an average rainfall record.

4.1. RESULTS OF ANALYSIS (NORMAL OPERATION)

The volume of water reporting to the RSF's supernatant pool varies based on several factors, including:

- Seasonal rainfall patterns;
- Changing deposition beach and pool areas;
- Fluctuating tailings production;

Figure 4-1 illustrates the pool volumes for an average yearly rainfall simulation over a 20-year period. From the graph, it is clear that water levels increase during the wet season (May – Aug) and reduce to the minimum pool level in the dry season (Sep – Apr). It is also noted that the amount of run-off collected from the catchment area increases over the life of the facility. This is due to the increase in the tailings beach area as deposition takes place. The lack of vegetation and low permeability associated with the sub-aerial and sub-aqueous beaches result in higher run-off coefficients, allowing more precipitation to collect in the supernatant pool of the RSF. The red line indicates the maximum pool limit of 49 000 m^3 while the blue line indicates the pool volume.

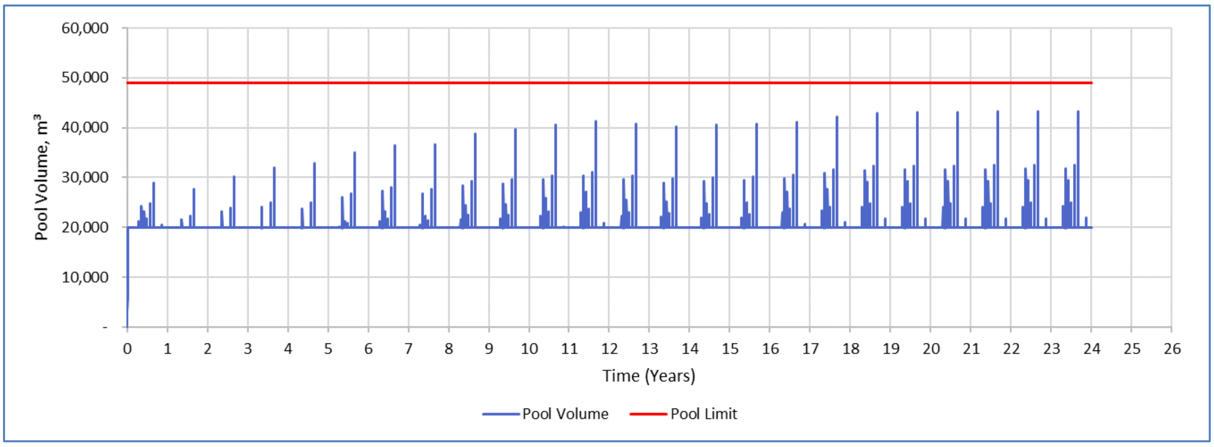

FIGURE 4-1: SUPERNATANT POOL VOLUMES DURING AN AVERAGE YEAR RAINFALL SIMULATION

The average and maximum supernatant pool volumes produced during the simulation is shown in Table 4-1. As expected, the maximum pool volume occurs during the wet season and reaches a capacity of 43 328 m^3 during the month of August. Although this value is close to the established maximum pool limit, it is also shown that the average pool limit for August barely exceeds the minimum pool limit at 21 177 m^3. It is therefore believed that instances of high rainfall will momentarily increase the pool volume close to the tolerable limit, where shortly after the high evaporation rate and generally low rainfall depths, coupled with an increase in the amount of returns water sent to the Process Plant, will cause the pool to quickly revert to the minimum allowable pool volume.

TABLE 4-1: OPERATING POOL VOLUME (THOUSAND M^3)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	19.9	20.0	20.0	20.1	20.7	20.4	20.4	21.2	20.0	20.0	20.0	20.0
Maximum	20.0	20.0	20.0	24.2	31.8	29.4	32.5	43.3	20.0	20.0	21.8	20.0

4.2. RESULTS OF ANALYSIS (STORM EVENT)

For the purpose of this analysis, a deposition model was set up using the topography of the project location, the geometry of the proposed RSF and the lowest expected beach slope observed on the Tronox West Mine Residue Storage Facilities being 1V:500H. The model was used to determine the available capacity on the RSF to capture stormwater run-off before decanting the excess water to the Process Plant. The actual design supernatant pool volume that is to be designed for over the life of the RSF without spillage is equivalent to:

- The volume of water due to normal operations, rainfall etc.; and
- The 1:50-year recurrence interval flood event occurring over and above this.

The design of the Tronox RSF does not rely on an external facility for the storage and handling of any stormwater released from it. Temporal storage for excess water not required by the Process Plant must be provided for on the RSF before being appropriately handled/decanted. Enough freeboard must be provided so as to prevent the possibility of dirty water spillage within the design allowances.

It is proposed that the RSF containment walls will be constructed to their maximum elevation before deposition commences. As a result, the facility's ability to contain water is at a maximum before any tailings have been deposited within the RSF. The available capacity decreases as deposition takes place and is at a minimum once the maximum tailings capacity of the facility has been reached. For this study, a minimum freeboard of 1 m has been assumed before available water storage capacity is terminated, or Full Supply Level (*FSL*) is reached. The maximum estimated pool volume resulting from a 1:50 year storm event as well as the maximum water storage capacity of the RSF is illustrated in Figure 4-2.

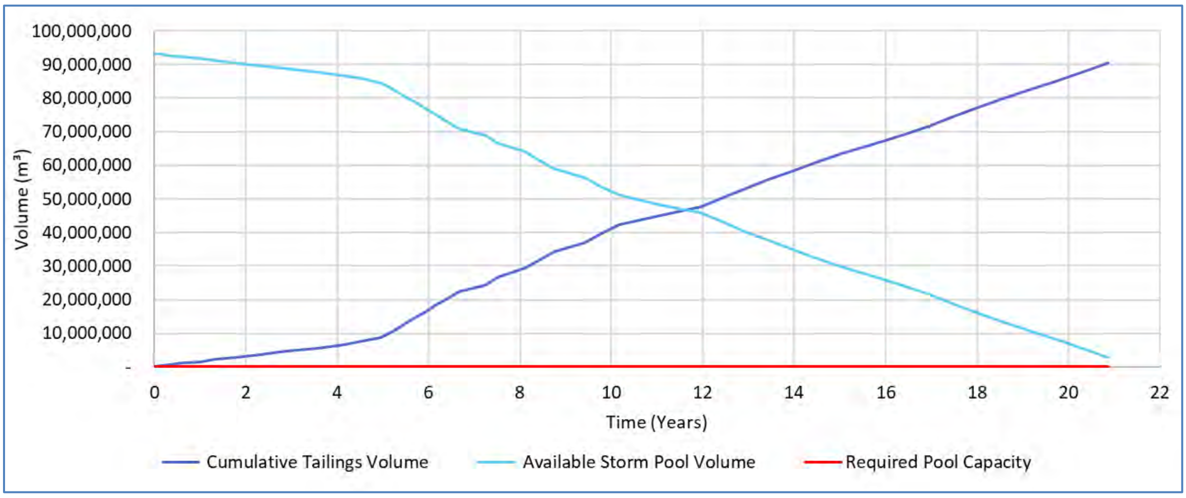

FIGURE 4-2: SUPERNATANT POOL VOLUMES DURING THE WETTEST YEAR SIMULATION

The result of the analysis shows that the RSF has sufficient capacity to accommodate the 1:50 year storm event, calculated to be 214 349 m^3. The facility is able to temporarily store a maximum of 1.80 million m^3 of water, far exceeding the 0.29 million m^3 required to store both the operating pool volume and run-off from the design storm event.

4.2.1. FREEBOARD

The total freeboard of a dam is defined as the vertical distance between the normal Full Supply Level (FSL) and the nominal Non-Overspill Crest (NOC) of the dam. Freeboard is divided into two components namely the flood surcharge rise above the FSL, the primary component, and a secondary component allowing for wind, wave and surge effects (SANCOLD, 2011). In the case of an RSF, the beach freeboard developed by the deposition of the tailings provides additional storage of water within the basin. The different freeboard components are illustrated in Figure 4-3.

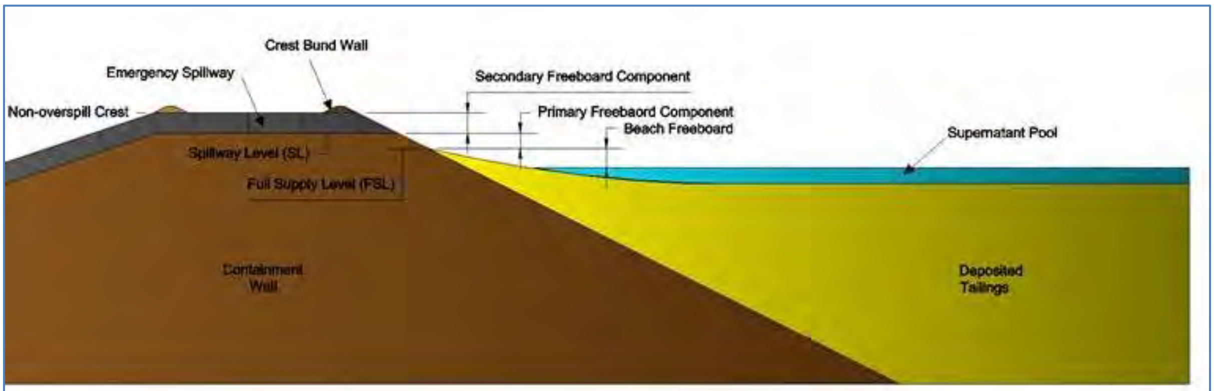

FIGURE 4-3: TYPICAL PROVISION OF FREEBOARD ON A FULL CONTAINMENT RSF

Pool water on a RSF needs to be adequately managed taking cognisance of the hydraulic requirement as well as the South African regulations and guidelines or best practices where no regulation or guideline is specified. Based on the regulations the required minimum freeboard for the Tronox RSF is 0.8 m, which includes the 1 in 50-year design flood.

As the facility will be constructed to its final elevation before deposition takes place, this results in a substantial freeboard that slowly decreases as tailings is deposited within the basin of the RSF. Geometric modelling of the RSF indicates that the minimum available freeboard between the surface of the maximum operating pool and the none overflow crest of the facility is estimated to be 2.61 m, with a beach freeboard of 1.67m and a primary freeboard of 1m. Thus, adequate freeboard is available to accommodate the 1:50 year storm event as well as its accompanying wave action.

4.3. RETURN WATER VOLUMES

The expected daily returns for each month, during an average rainfall year, are presented in Figure 4-4. Maximum returns occurred during periods of higher rainfall when the total available return water equals that of the slurry water, while minimum returns indicate that further decanting could not take place as a result of the minimum pool volume requirement. From the figure, it is evident that a slight increase in return water can be expected during the wet season, with a 5.5 % difference noted between the average daily returns for the wet and dry seasons.

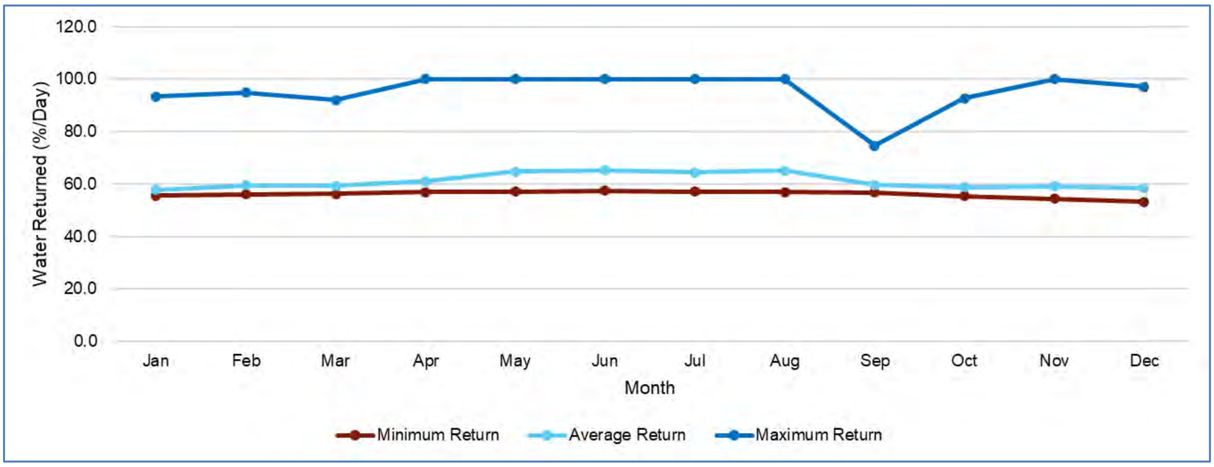

FIGURE 4-4: EXPECTED DAILY RETURN VOLUMES FOR AN AVERAGE RAINFALL YEAR

A summary of the returns is listed in Table 4-2. The results show that an average annual return of 61.2 % of the slurry water reporting to the RSF can be expected during an average rainfall year. During periods of high rainfall, it may be required to return up to 100 % of the slurry water reporting to the RSF. The simulation also indicated that a pump with a decanting capacity of 860 m^3/day would be active for an average of 12.36 hours per day. Periods of peak activity (24 hr active pumping hours) followed days of substantial rainfall due to the increase in available return water.

TABLE 4-2: EXPECTED DAILY RETURN VOLUMES FOR AN AVERAGE YEARLY RAINFALL

Descriptor	Unit	Values
Wet Season Average Daily Return	m^3	10,867.6

Descriptor	Unit	Values
(May to Aug)	%	64.2
Dry Season Average Daily Return (Sep to Nov)	m^3	10,135.4
	%	59.0
Average Daily Return per Yearly	m^3	10,440.5
	%	61.2
Minimum Daily Return	m^3	2,640.9
	%	53.2
Maximum Daily Return	m^3	21,732.6
	%	100.0
Minimum Monthly Return	m^3	84,271.9
	%	54.8
Maximum Monthly Return	m^3	438,276.1
	%	66.9

The progressive inflows and outflows for the average rainfall year simulation is illustrated in Figure 4-5 for both the daily and monthly returns. The general trend remains the same as those described in earlier sections of the report, with spikes indicating an increase in return water volumes over the wet season, as the pool volume increases. A reduction in the pool volume over the dry season limits the amount of available return water as the pool volume decreases towards the minimum required volume. It should be noted that the monthly outflows mirror the monthly inflows, showing that the average net flow tends towards zero. This forces the pool volume to reduce to the minimum established pool volume at any given time over the life of the facility.

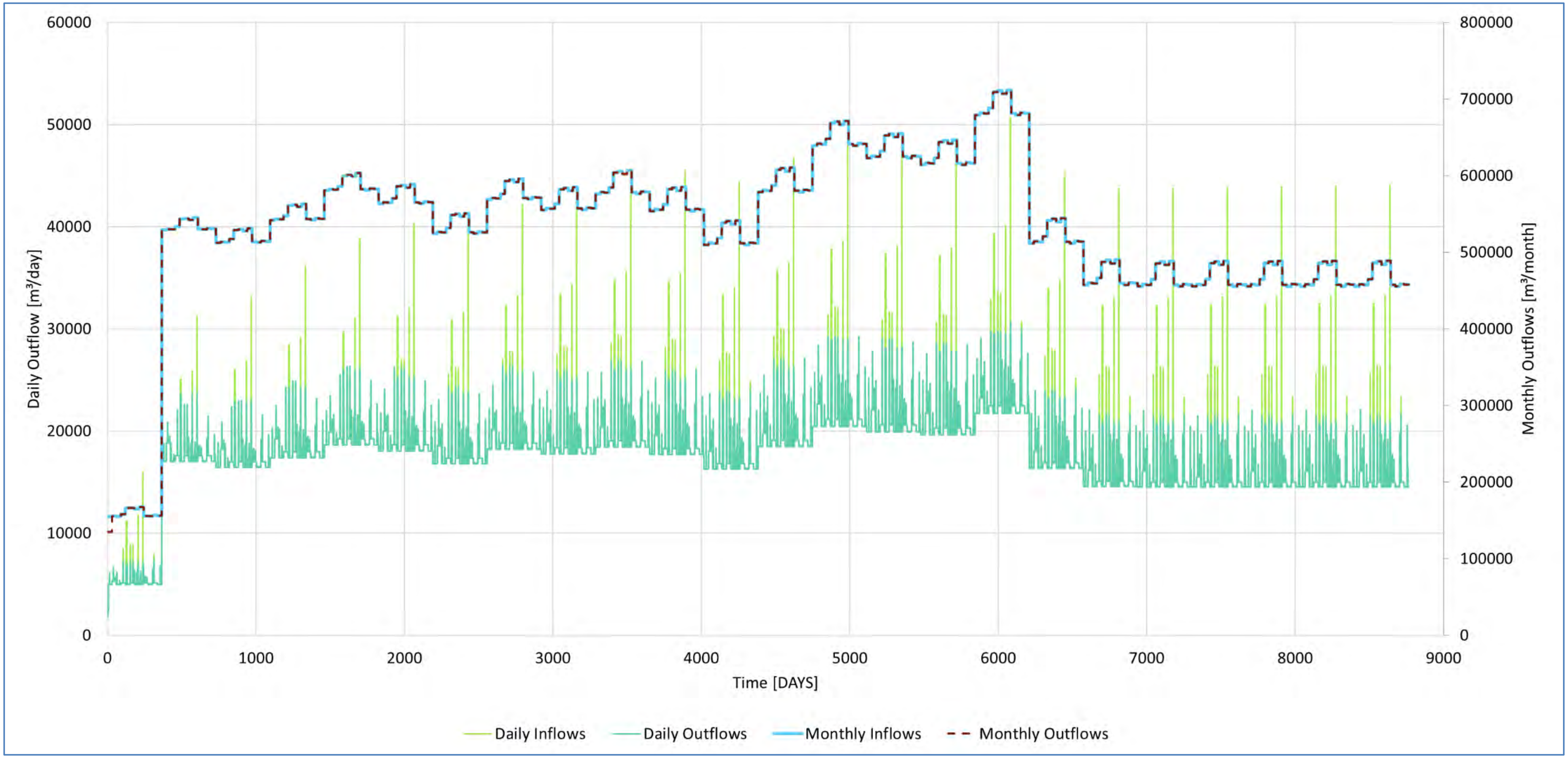

FIGURE 4-5: RETURNS REQUIRED BASED ON AVERAGE YEAR RAINFALL

5. POOL MANAGEMENT

As supernatant water from the RSF will not be stored in a separate dedicated storm water control facility, it will be required to manage the water returns from the RSF such that:

- The minimum beach freeboard is not breached during the wet season and flood events; and
- The supernatant pool does not breach its minimum storage capacity which may risk loss or damage to decanting infrastructure as a result of it beaching.

5.1. SEASONAL MANAGEMENT PHILOSOPHY

As tailings are deposited in the RSF, a beach is formed by the consolidated tailings, providing a profile in which the supernatant pool is controlled by the operator. The tailings beach profile provides a form of freeboard that prevents the pool from encroaching upon the upstream face of the containment wall (Figure 5-1), that would otherwise inherently increase the risk of seepage, environmental spillage, and overtopping.

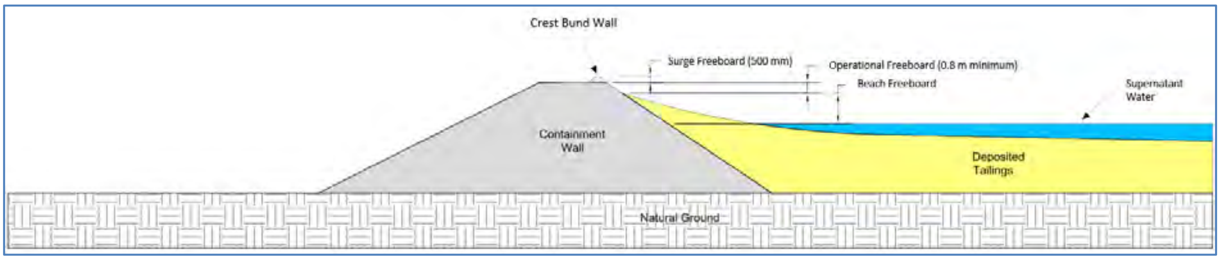

FIGURE 5-1: BEACH FREEBOARD

The large catchment area of the RSF combined with instances of high rainfall result in a substantial increase in the supernatant pool volume during the wet season. Careful monitoring during this period is required to ensure that the maximum pool volume is not exceeded.

The dry season of the project typically experiences a notable net negative inflow of run-off water as evaporation exceed the volume of recharge received by rainfall. It would be expected that an overall decrease in the supernatant pool volume will occur in the dry seasons. The risk of beaching the decanting system is increased if the supernatant pool volume decreases too rapidly. It is thus essential to manage the returns from the RSF such that the minimum permissible storage volume is maintained to prevent the damage or loss of the decant equipment. It is assumed that a minimum dead storage volume of 20 000 m^3 must be maintained on the Tronox RSF to mitigate the risk of damage or loss of the decanting infrastructure.

A gradual drawdown approach is proposed that balances the water returns from the RSF such that the minimum dead storage is not depleted by the end of the dry season.

5.2. REQUIRED RETURNS

The RSF supernatant pool must be operated such that it does not breach the minimum freeboard in the wet season and provide enough storage volume to appropriately handle a storm event. Additionally, the drawdown of the supernatant pool should not result in the potential beaching of the decanting equipment resulting in possible financial loss and operational risk.

This provides a framework for determining the continuous return water requirement from the RSF in mitigating the risk of:

- Exceeding the minimum freeboard;
- Insufficient storage capacity for storm events resulting in spills below the design storm (contravening legal requirements);
- Insufficient flow capacity of the spillway resulting in damage to the spillway and downstream infrastructure;
- Financial loss (e,g, pumping equipment, repairs, etc.); and
- Loss of tailings capacity resulting from excessive sub-aqueous deposition.

6. CONCLUSIONS

Base on the results of the water balance, the following conclusions can be made:

- A minimum pool volume of 20 000 m^3 is required to prevent the decanting system from becoming beached on the tailings, resulting in possible damage and financial loss;
- A maximum day to day operating pool volume must not exceed 49 000 m^3;
- During both the wet and dry season, the difference between the evaporation and rainfall experienced at Tronox results in the supernatant pool reducing to the minimum required pool volume (20 000 m^3). During the wet season, it is estimated that 64.2 % of the slurry water will be available as return water. During the dry season, on average, only 59 % of the slurry water will be returned to the plant during a year of average rainfall. Additional water sources will be required to supplement any shortfalls in required process water;
- Due to the large storage capacity associated with the RSF and the fact that the minimum pool volume is reached during each dry season indicate that adequate capacity should be available to store the 1:50 year storm event, as no build-up of the supernatant pool volume takes place;
- It was determined that during an average year of rainfall that only 1 pump would be required to maintain an adequate pool level. During periods of higher than usual rainfall and during storm events, 1 additional pump would be required to reduce the pool volume to within the acceptable limit;
- The average return water volumes per day, for the average rainfall year simulation, were estimated to be 10 440 m^3 (61.2 %), with a maximum return of 21 732 m^3 (100 %) and a minimum of 2 641 m^3 (53.2 %) once a supernatant pool has been established;
- During periods of high rainfall, up to 100% of the slurry water may need to be returned/removed from the RSF, to ensure the pool volume is kept below 49 000 m^3. The design of the pumping system (or standby pumps) would need to allow for these volumes; and
- The model relies on the assumptions provided. If the management of the RSF does not occur as per the assumptions, then the results may differ. Similarly, with other model assumptions, i.e. rainfall, tailings beach slopes, water sent to RSF, etc.

7. RECOMMENDATIONS

The following recommendations are made regarding the operation of the RSF:

- A competent and reputable team must undertake the management of the RSF to ensure:

- The minimum required freeboard is maintained;
- The minimum pool volume is adhered to, preventing damaging the decanting system; and
- Maximum daily operating pool be kept below 49 000 m^3;
- Prevent excessive subaqueous deposition from taking place (i.e. keep the pool as small as possible), reducing deposition capacity.

8. REFERENCES

SANCOLD. (2011). *Guidelines on Freeboard for Dams, 2011-01-01, Volume II.* Stellenbosch.

Report Author	**Reviewer**	**Project Manager**
Stephan Barkhuizen	**Georgia Vagis**	**Andrew Savvas**

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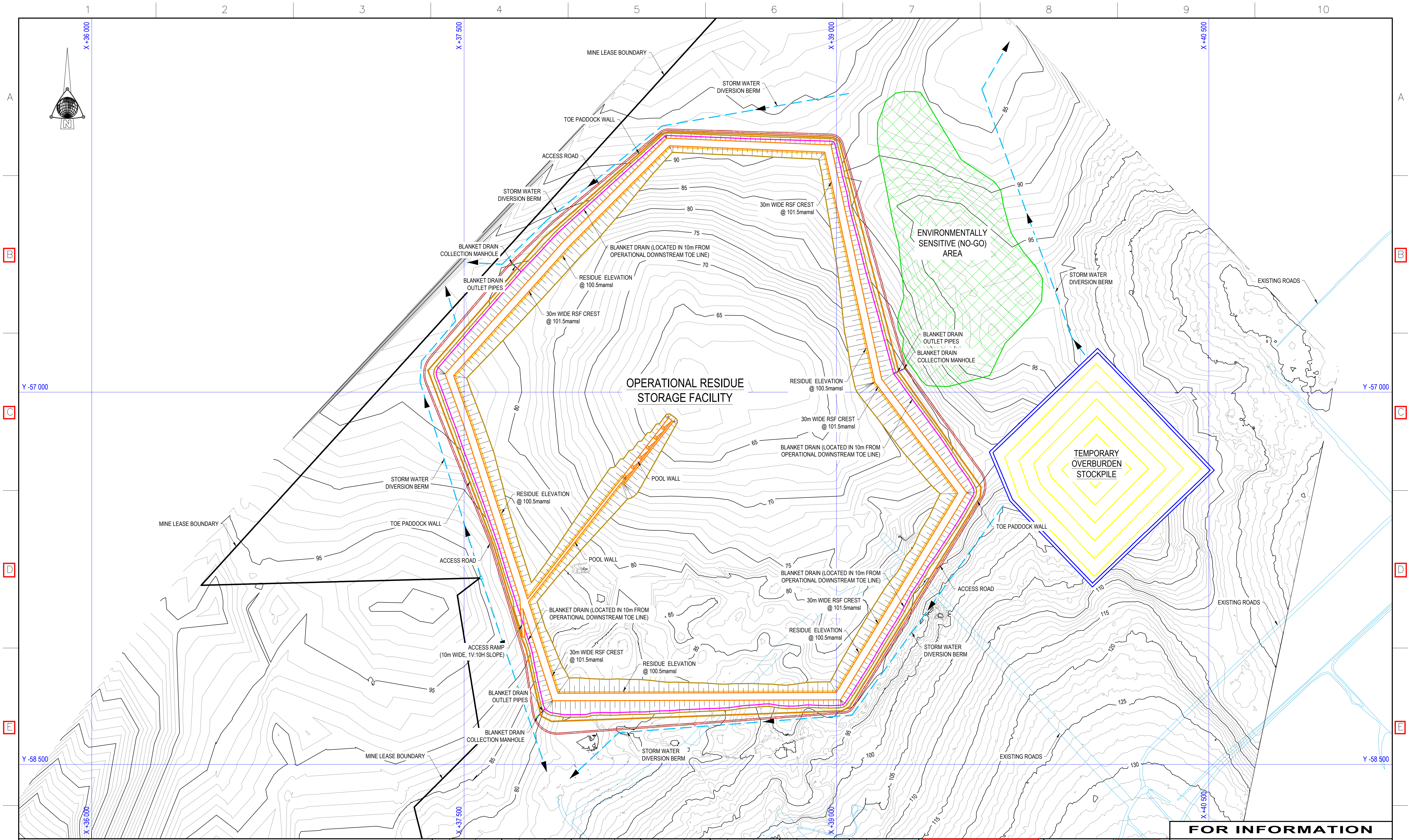
Appendix H DRAWINGS



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CO-ORD SYSTEM	SCALE	
LOCAL	A1	1:7000
	A3	1:14 000

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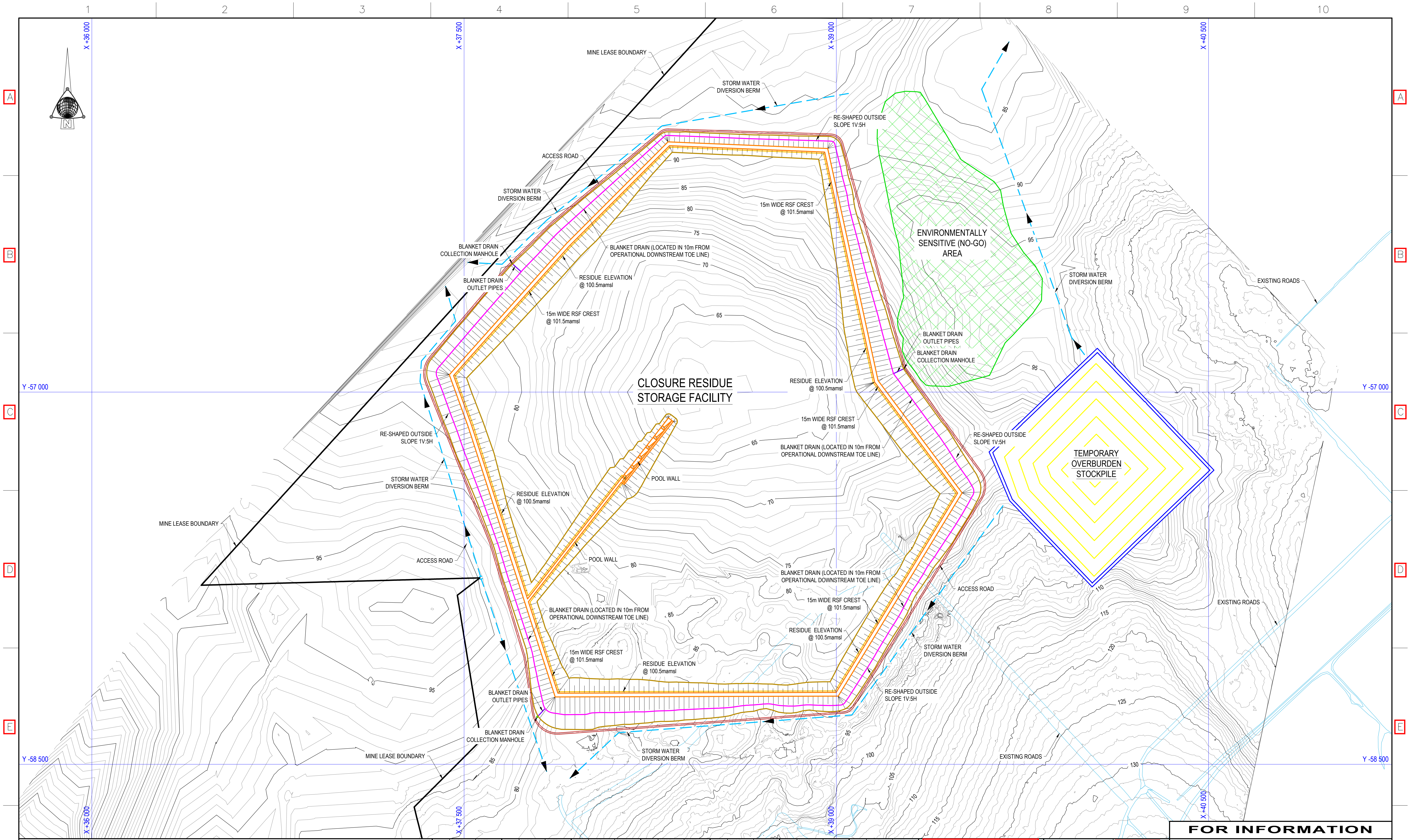
TRONOX FS
RESIDUE STORAGE FACILITY
OPERATIONAL GENERAL ARRANGEMENT

DRG No. 126-005-800
REV. B

A1



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CO-ORD SYSTEM	SCALE	
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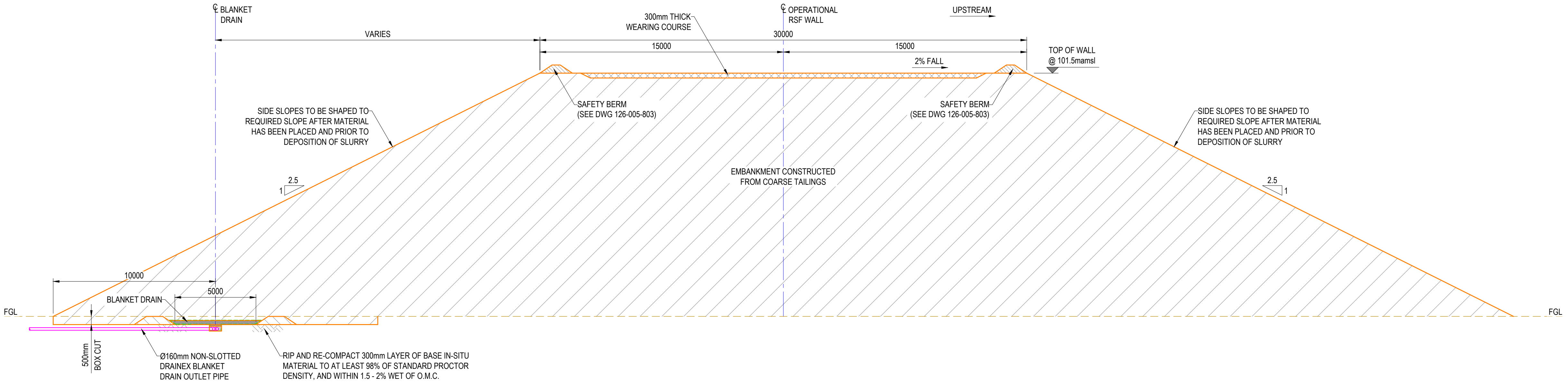
TITLE
TRONOX FS
RESIDUE STORAGE FACILITY
CLOSURE GENERAL ARRANGEMENT

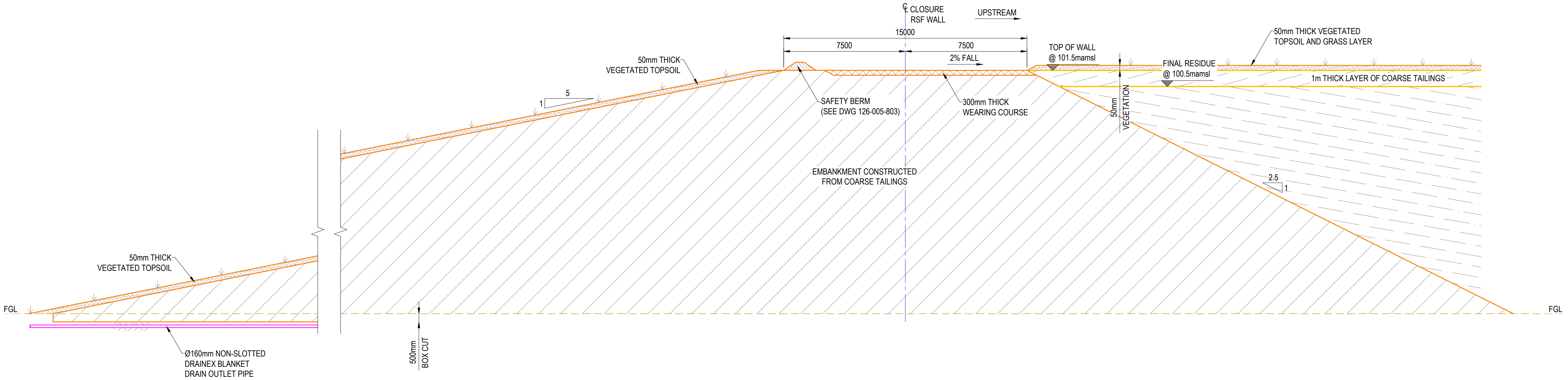
DRG No. 126-005-801
REV. B

A1



TYPICAL SECTION THROUGH OPERATIONAL RESIDUE STORAGE FACILITY WALL

SCALE - 1:150



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SCALE - 1:150

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TITLE
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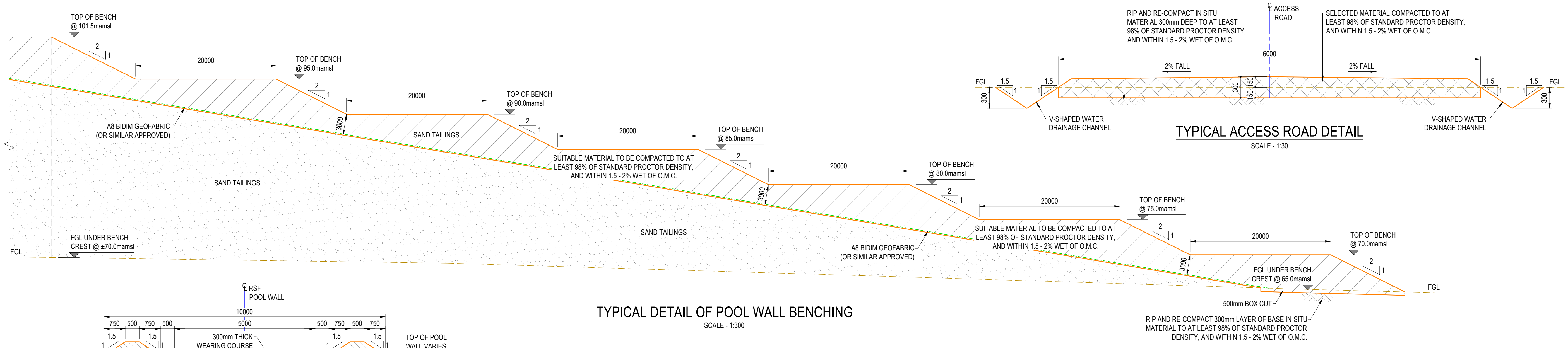
CROSS SECTIONS

DRG No. 126-005-802
REV. C

A1

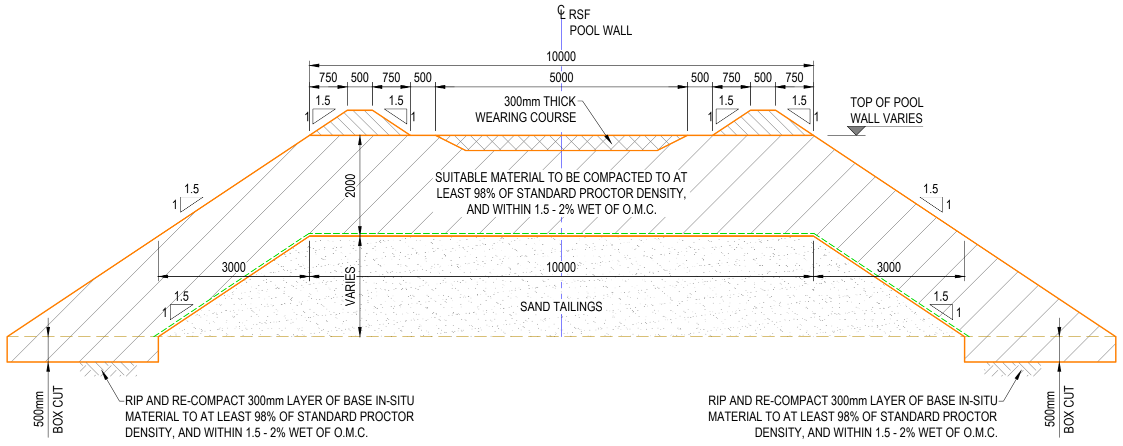


TYPICAL DETAIL OF POOL WALL BENCHING

SCALE - 1:300

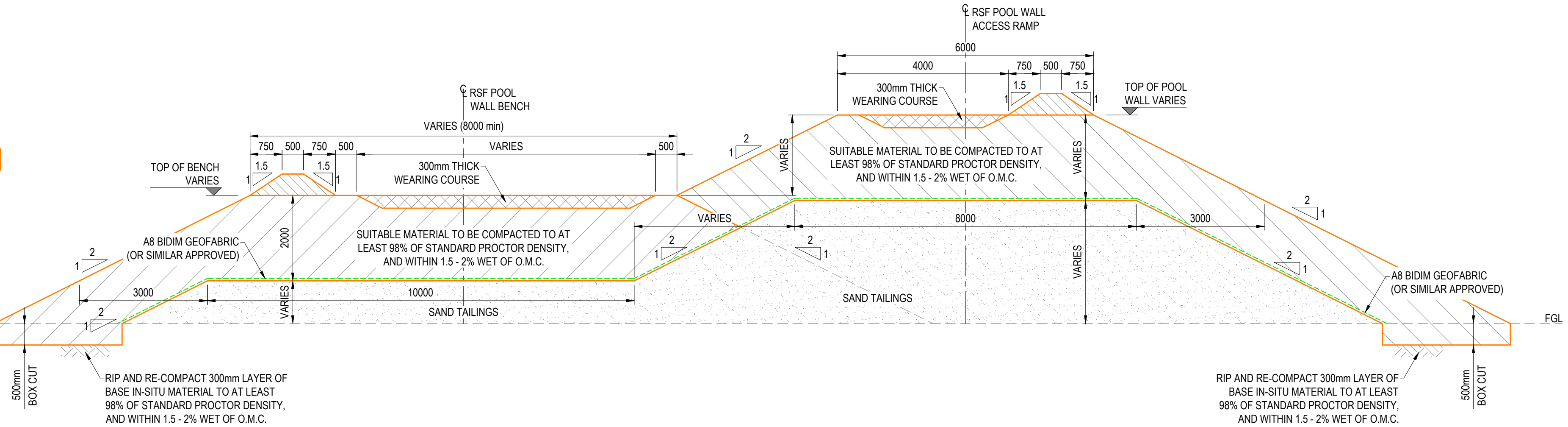
TYPICAL ACCESS ROAD DETAIL

SCALE - 1:30



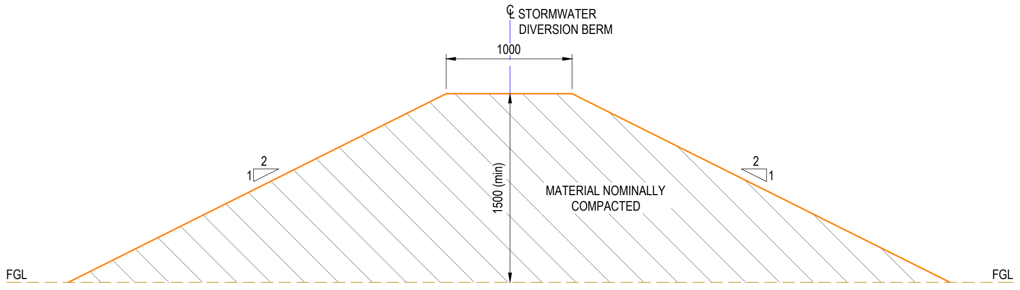
TYPICAL SECTION THROUGH RSF POOL WALL
(main access ramp - leading to benching)

SCALE - 1:75



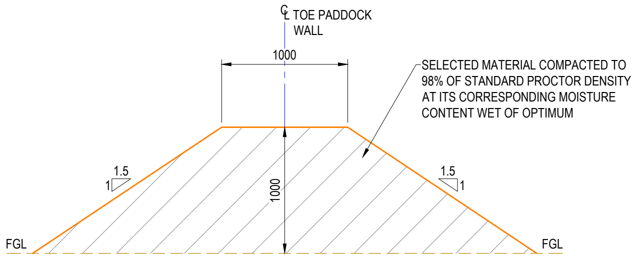
TYPICAL SECTION THROUGH RSF POOL WALL
(where benching is present)

SCALE - 1:75



TYPICAL STORMWATER DIVERSION BERM DETAIL

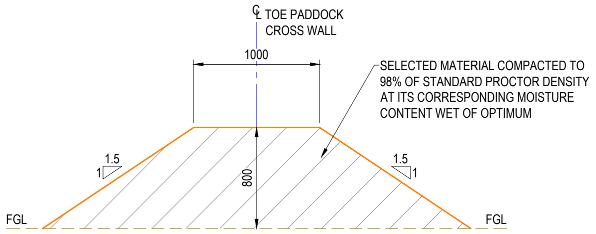
SCALE 1:30



TYPICAL TOE PADDOCK WALL DETAIL

SCALE 1:30

NOTE:
TOE PADDOCK
CROSS WALLS TO BE
SPACED 25m APART



TYPICAL TOE PADDOCK CROSS-WALL DETAIL

SCALE 1:30

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TRONOX FS
RESIDUE STORAGE FACILITY
EARTHWORKS DETAILS

DRG No. 126-005-803

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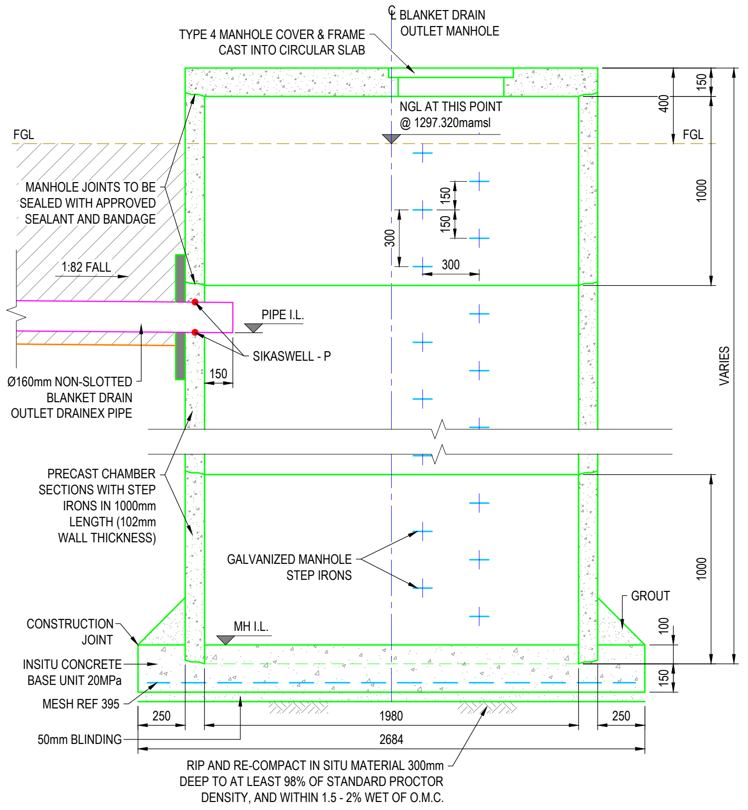
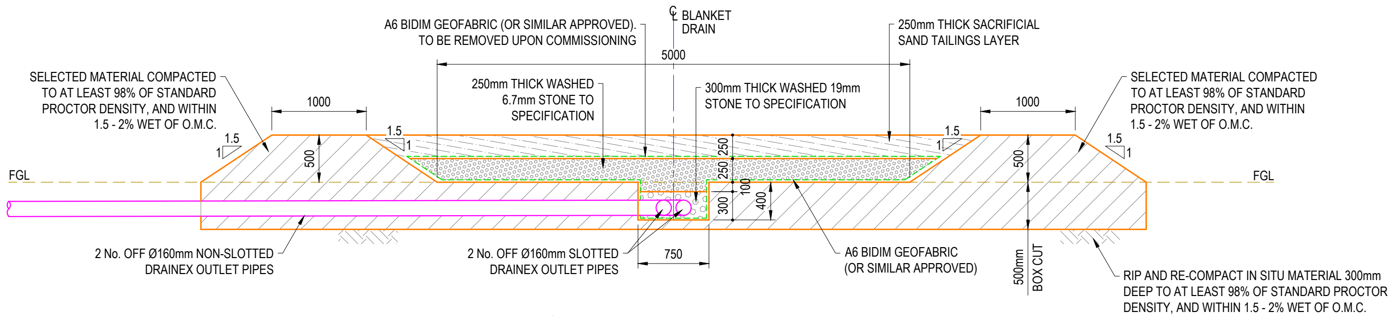


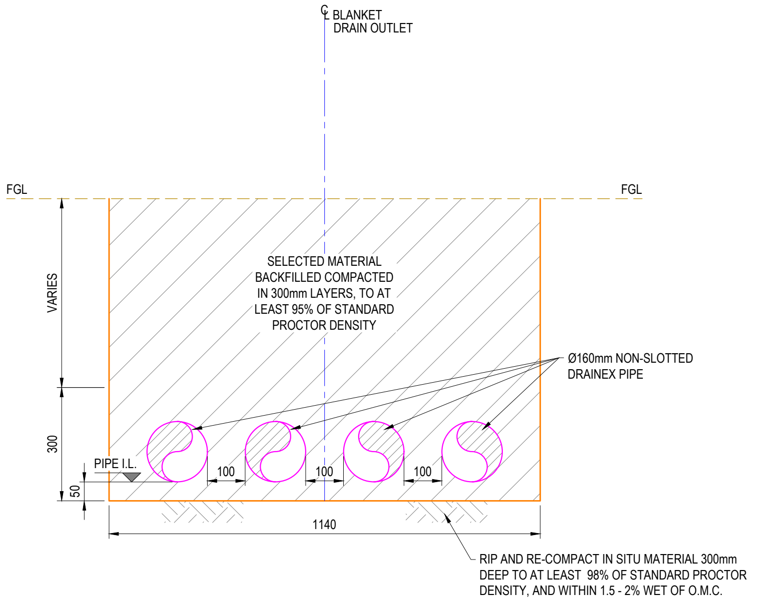
TYPICAL BLANKET DRAIN COLLECTION MANHOLE DETAIL

SCALE - 1:20



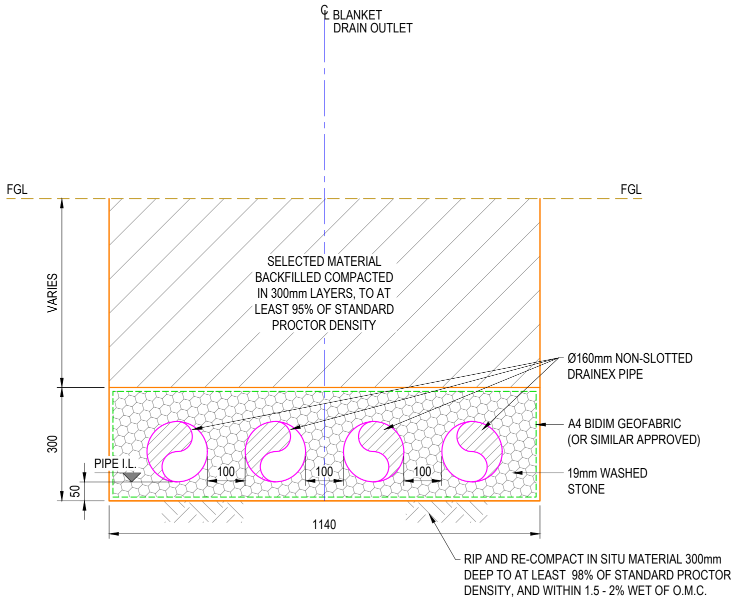
TYPICAL BLANKET DRAIN DETAIL

SCALE 1:40



BLANKET DRAIN OUTLET PAST DOWNSTREAM TOE OF RSF WALL DETAIL

SCALE - 1:10



BLANKET DRAIN OUTLET UNDER RSF WALL DETAIL

SCALE - 1:10

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