MSP ENGINEERING PTY LTD

WHITE WELL PROJECT
TAILINGS STORAGE FACILITY
GEOTECHNICAL ASSESSMENT REPORT

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[redacted]

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1.0 INTRODUCTION

4DGeotechnics Pty Ltd (4DG) have been requested by MSP Engineering Pty Ltd (MSP) to conduct an assessment of a Tailings Storage Facility (TSF) proposed for the White Well Project. 4DG previously conducted an assessment for a TSF at White Well, however a change to the mining plan has resulted in the location of the TSF being changed, and prompting a review of the proposed TSF contained herein. This report should be considered in conjunction with 4DG's 2012 report (024500REP01_Rev2) and subsequent additional information memo (024500LET01) which contain investigation locations, material characterisation and stability analysis results. These reports are provided in Appendix A for convenience.

2.0 DESKTOP STUDY

The desktop study comprised review of previous work, published geological mapping and investigation data from the previously and currently proposed tailings storage facility locations. The previous assessment found the proposed TSF to have a Category 2 hazard rating based on the Hazard Rating classification as adopted by the Department of Mines and Petroleum (1999). Based on this rating, a desktop review of the revised TSF location with additional analysis as required was deemed appropriate.

2.1 Geology

Published 1:250,000 geological mapping data suggests the original tailings dam location is sited entirely on quaternary colluvium, which site investigations showed to be underlain by lateritic deposits approximately 3 metres thick on average, underlain by saprolitic kaolin material.

The new proposed TSF location is also located on quaternary colluvium and laterite deposits. Existing RAB drilling data across the TSF footprint was reviewed and it was found that the shallow lateritic deposits were present as in the original location; however they were recorded to be much thicker than at the previous location, with logged thicknesses typically in the order of 10 to 20 m, underlain by saprolitic kaolin material similar to the original location.

Figure 1 shows an overlay of the proposed mine layout on the published 1:250,000 geological mapping data.

2.2 TSF design and location

The original TSF location was for three embankments constructed on an easterly facing slope and planned to abut an existing waste dump on the western side. The present TSF is planned for two perimeter embankments a north facing slope abutting a large, new proposed waste dump on the north side of the enclosure. The basic TSF design, that is, the embankment geometry and construction material, has not changed with the change in location, and as such, no further stability analysis was required as the previous stability analysis is considered adequate and equally applicable for the new location.

The previous TSF design included a cut off trench through the lateritic material to the underlying saprolitic kaolin material to reduce seepage. Due to the increased thickness of lateritic material at the new location, a cut off trench is no longer considered economically feasible and placement of a reduced permeability floor to act as a liner to the TSF is recommended to assist with seepage control. As with the embankment, the floor for the TSF should be constructed from saprolitic waste material from the mine.

The present conceptual designs have considered the construction of the TSF using either downstream construction, or centreline construction techniques. These were considered the more appropriate construction methods due to the likely weak tails produced by the processing of the kaolinite ore.

3.0 SEEPAGE ANALYSIS

The current planned TSF is located on deep ferricrete materials that are considered a significant seepage risk with associated elevated groundwater and the development of seepage plumes. The thickness of the ferricrete is considered too great to cut-off likely seepage with a trench, so the alternative of a horizontal blanket is proposed.

In order to assess the impact of the construction of a lower permeability liner material blanketing the floor of the TSF, a series of seepage analysis are carried out modelling various thicknesses of the liner from 0 to 3.0 m, on two typical sections representing both the centreline and downstream construction approaches. The seepage analysis was carried out using commercially available finite element software package Seep/W (Version 7.23) prepared by GEO-SLOPE.

3.1 Assumptions

Based on the available information, the following assumptions are made for the seepage analyses:

- The tailings storage facility is to be up to 15 m high and constructed in stages;
- Each stage is assumed to be 5.0 m in height and tailings placement is considered to be placed within 8 months;
- The analyses relate to the highest wall situation;
- The tails are assumed to be spiggotted off the wall, with the deposition of coarser materials close to the embankment, and finer materials further out in the pond;
- The ponded tailings water will be kept away from the embankment walls, with decant recovery system on the northern side of the storage area;
- Seepage analysis is carried out for a period of 5 (five) years;
- The natural water table level is assumed to be at approximately 25 to 30 m below ground surface as reported in the previous investigations; and
- The permeability values, considered for each layer, are presented in Table 1.

TABLE 1: PERMEABILITY VALUES FOR EACH LAYER

Material	Thickness (m)	Permeability (m/sec)
Compacted Embankment Fill	Var.	1×10^{-8}
Proposed low permeable liner on the floor	Var. (0.0 to 3.0 m)	1×10^{-8}
Fine Tailings	5.0 to 15.0	1×10^{-7}
Coarse Tailings	5.0 to 15.0	5×10^{-7}
In situ Ferricrete	10.0	1×10^{-5}
In situ Kaolin	N.A.	1×10^{-10}

3.2 Analysis and Results

The seepage analyses have been completed for two typical sections representing the Centreline and Downstream construction profiles for various thicknesses of lower permeable material of 0.0 m, 0.5 m, 1.0 m, 2.0 m and 3.0 m. The outputs are presented on Figures 2 to 11. The analyses are 2-D assessments that represent seepage conditions likely to develop and show both the modelled geometry and the calculated flow conditions at the end of the fifth year when the site is considered to have reached a steady state condition.

On the basis of the results obtained from the analyses, the discharge rate versus time (covering a 5 year time period) per unit width for both Centreline and Downstream sections are presented on Figures 12 and 13, respectively. These both illustrate the progressive increase in seepage to be expected as the stored head increases, but as the modelling incrementally adds a completed 5 m depth of wall and saturated tailings instantaneously, the discharge curves show a sudden step up in discharge with each lift. In actuality, these would be slow increases as the tailings depth comes up. For each lift, the discharge is shown to tend to steady state discharge.

The total cumulative discharge curves for times up to 5 years are plotted per unit width for both Centreline and Downstream sections on Figures 14 and 15, respectively.

According to the above results the following conclusions are made:

- The discharge rate for the TSF constructed using downstream construction techniques is indicated to be slightly more (15% to 20%) than the equivalent wall built from centreline construction techniques. This is attributed to the placement during centreline construction of lower permeability embankment fill materials over the coarse tails near the wall, thus breaking up the continuity of any developed seepage paths;
- The discharge rate per unit width for the Centreline section with no compacted liner constructed on the floor is shown to be around 2.3×10^{-6} m/sec at the time of completion of the tailing storage filling. This value is shown to decrease incrementally by 18%, 30%, 45% and 55% for 0.5 m, 1.0 m, 2.0 m, and 3.0 m thick compacted liner constructed on the floor;
- The discharge rate for per unit width the Downstream section with no compacted liner constructed on the floor is shown to be around 2.46×10^{-6} m/sec at the time of completion of the tailing storage filling. This value is shown to decrease incrementally by 17%, 28%, 42% and 50% for 0.5 m, 1.0 m, 2.0 m, and 3.0 m thick compacted liner constructed on the floor;
- The total discharge per unit width for the Centreline section with no compacted liner constructed is shown to be around 330 m^3 within five years. This value is shown to decrease by 22%, 35%, 50% and 60% for 0.5 m, 1.0 m, 2.0 m, and 3.0 m thick compacted liner constructed on the floor; and
- The total discharge per unit width for the Downstream section with no compacted liner constructed is shown to be around 370 m^3 within five years. This value is shown to decrease by 20%, 33%, 47% and 55% for 0.5 m, 1.0 m, 2.0 m, and 3.0 m thick compacted liner constructed on the floor.

On the basis of the analyses, it is recommended that a 2.0 m thick compacted liner be incorporated in the design of the conceptual TSF.

4.0 CONSTRUCTION CONSIDERATIONS

4.1 General

The TSF is planned to be built in parallel with the adjoining waste dump, and conceptually requires three stages, each representing a raising of the wall height by a maximum of approximately 5 metres. Figures 16 to 18 respectively conceptually show the three stages of the TSF embankment lifting using downstream construction. The footprints shown are schematic and show the general location of the footprint of a full height embankment. The actual toe of the embankment and the required heights at various stages will need to be defined following approvals when detailed contour information will be available. The toe of the embankment will be controlled by ground level relative to the embankment crest and will in some areas sit inside the footprint shown. The initial bund will in fact range in height from 5 m maximum down to ~0.5m in height at the highest part of the site. Thereafter, the following lifts will all be of 5 m height.

4.2 Borrow materials

4.2.1 Kaolin

It would be expected that the waste dump and TSF walls would be constructed from mine waste 'borrow' from the active pit area. Laboratory testing of the materials obtained from the site during 2012 investigations indicate that the *in situ* kaolin waste from the mining operations would provide suitably low permeability materials for the TSF embankment walls and floor. Permeability analyses of sampled kaolin material obtained a result of 1.7×10^{-8} m/s. The Atterberg Limits obtained from the laboratory analysis classify the material as medium plasticity silt (MI), and the dispersivity of the soils is potentially a constraint on the dam design due to scour potential on the faces of the embankment. This could be mitigated by the use of a thin layer of laterite gravels on the final embankment face as part of the rehabilitation.

4.2.2 Laterite deposits

The sandy gravels and cemented ferricrete deposits in the disturbance area are anticipated to be suitable for use as a higher strength fill for scour protection of the TSF embankment. The ferricrete fill will provide additional strength to the embankment dam and help minimise significant erosion of the outside embankment face. Potential sources of this unit are from within footprint of the TSF, below the footprint of the waste dump and near surface within the open pit mine

It is recommended that sufficient lateritic materials are stockpiled early in the mining operations for use in the later stages of the TSF construction and rehabilitation for embankment protection.

4.3 Foundation preparation

All topsoil should be removed for the TSF footprint to a nominal depth of 100 mm. All vegetation, including roots, should also be removed. It is recommended that the foundation be inspected after clearing and prior to proof compaction and any local areas of fine materials associated with drainages be removed. The foundation area beneath both the embankment and the wider floor area of the storage should be deeply cross ripped to break up the continuity of any cemented zones that typically occur within ferricrete materials. The area should then be thoroughly wetted and proof compacted by a minimum of 6 passes of a 16 tonne vibrating "padfoot" roller. This process will provide a strong platform on which to build the embankment walls, as well as reducing the potential for local seepage paths.

4.4 Fill Placement

4.4.1 Embankment Fill Placement

The kaolin fill direct from the mine is recommended to be placed in 350 mm thick loose lifts and compacted to 92% MMDD at +/- 2% of Optimum Moisture Content (OMC) using a padfoot roller. Where the embankment abuts the waste dump, it should be "keyed" into the waste dump by a minimum 5 metres. Where the embankment fill is placed at the same time as waste dump material, the key can be roller compacted to the same specification as the rest of the embankment for a length of 5 metres into the waste dump footprint. Where the waste dump has been built to a height greater than the embankment fill being placed, a benched slot trench will be need to be dug into the waste dump for the key. Where a trench is dug, each bench should be no greater than 300 mm high to allow for compaction through the edge of the newly placed material.

4.4.2 TSF Floor Fill Placement

It is recommended the floor liner of the TSF be constructed in lifts, each not to exceed 350 mm loose thickness, and compacted to 92% MMDD at +/- 2% OMC. The floor fill should extend a minimum of 5 m under the waste dump footprint, and as such should be placed prior to constructing the waste dump. Where the waste dump must be constructed prior to the TSF, a TSF floor lift should be placed under the outer 5 metres and compacted to at least 10 metres into the TSF footprint. When the remainder of the TSF floor is to be constructed, the pre placed material should have a 2 metre wide 250 mm deep section taken from the edge at which the remainder of the floor will be constructed to ensure proper cohesion between the separately constructed floor sections.

4.4.3 Waste Dump TSF Fill Placement

The waste dump will form two walls of the proposed TSF. As the waste dump material is extremely broad compared to the embankment walls, it is not subject to the same requirements for construction, however where the waste dump will form the TSF wall, certain construction modifications are recommended to improve erosional characteristics.

The outer edge of waste dumps is typically formed by loose material dumped over the edge of the waste by trucks, or pushed over by dozers. It is recommended that where the dump forms the TSF wall, material be dumped longitudinally along the edge of the waste dump, spread, and traffic compacted (by truck and / or dozer) rather than pushed perpendicularly over the edge. This will help produce a dumped wall with lower permeability as well as improving the compaction of the dumped material and hence reducing the erodibility of waste material adjacent to the TSF.

4.5 Testing

Compaction testing should be performed to ensure the placed material has met the required compaction for the TSF embankment. The following Australian Standard test methods should be utilised to confirm compaction:

- Dry Density Ratio (AS 1289, 5.4.1); and
- Field Moisture and Field Dry Density (using nuclear gauge) (AS 1289, 5.8.1).

Each test should be performed at a minimum frequency of 1 test per 5,000 m^3 of placed embankment and floor fill.

5.0 MONITORING & INSPECTION

Figure 19 shows proposed locations for monitoring bores and piezometers for the tailings facility. Six piezometers and six monitoring bores are proposed for the site. The proposed locations are approximate and should be located such that they are accessible but not likely to be impinged upon by mining works.

Piezometers and monitoring bores should be installed and initial baseline measurements taken prior to commissioning of the TSF. Each lift of the TSF walls will require reinstallation of piezometers, however if there is no significant change in water levels recorded during the monitoring period prior to the second lift, reinstallation of embankment piezometers may not be required, however this should be assessed at the time of the second lift.

Table provides details of monitoring recommendations for the monitoring points.

TABLE 2: WATER MONITORING

Monitoring Point	Frequency	Analysis/Assessment
Embankment Piezometers	Weekly	Standing water level
Monitoring Bores	Fortnightly	Standing water level
	Monthly	Electrical conductivity, pH and CN (on site lab)
	Quarterly	Electrical conductivity, pH and CN (NATA accredited laboratory)
Monitoring bores Decant Water	Annually	Extended water analysis (Total Dissolved Solids, pH, Carbonate, Bicarbonate, Hydroxide, Chloride, Sulphate, Nitrate Sodium, Potassium, Calcium, Magnesium, Hardness, Iron, Manganese, Silicon, Aluminium, Arsenic, Barium, Boron, Beryllium, Cadmium, Cobalt, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium, Zinc, Strontium, Titanium, Vanadium)

All water samples will be taken in accordance with AS/NZS 5667.1:1998. Samples will either be analysed in an on-site laboratory or submitted to a NATA accredited laboratory to be analysed in accordance with current "Standard Methods for Examination of Water and Wastewater-APHA-AWWA-WEF". Results of analysis should be reported in the Annual Environmental Report, submitted to both the Department of Environment and Conservation and the Department of Mines and Petroleum.

Inspections of the TSF should be conducted regularly to ensure it is performing as required and there are no erosion issues. Inspections should also occur following significant rainfall events which may cause erosion or higher than normal water levels.

Piezometers will allow early detection of embankment seepage.

Bores should be constructed in accordance with:

- Mining and Mineral Processing Series, Water Quality Protection Guidelines (2000) number 4 for the installation of mine site ground water monitoring bores; and
- Water Quality Protection Note 30 for Groundwater monitoring bores.

All bores will be constructed according to the following specifications:

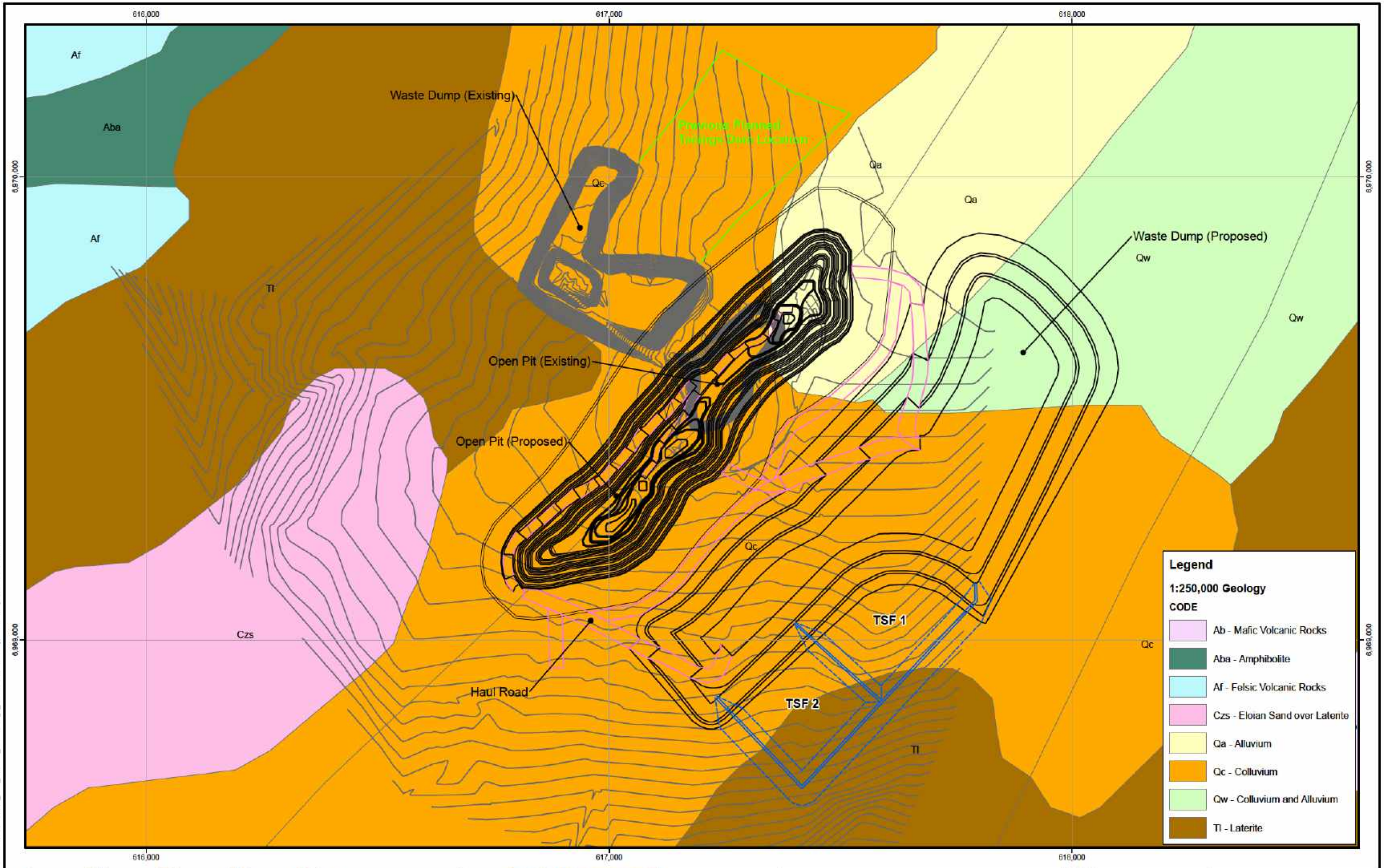
- Vertical;
- Between 50 and 100m from the TSF embankment wall / waste dump;
- 3 m of steel at surface, cemented with quick cement;
- 160 mm wide;
- Slotted from approximately 4m depth to base of hole;
- Base cap;
- 40 m deep;
- 80 mm Class 9 PVC;
- 1.5 – 3.2 mm gravel pack to the base;
- ~1 m gravel bentonite plug 2 m above top of slots.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The seepage analysis represents a worst case scenario for seepage where the tailings level remains at full embankment height for the life of the structure. This approach was used to simplify the model and allow comparison of different floor thicknesses for the compacted liner. Actual seepages from the TSF will be smaller than those calculated. A 2.0 m thick floor for the TSF is recommended to control seepage through the laterite foundations underlying the TSF in lieu of the cut off trench designed for the previous TSF location. The compacted floor thickness may be reduced if not economically feasible; however a minimum compacted floor thickness of 0.5 m should be adopted.

Sufficient suitable materials for TSF construction are expected to be available from the open pit waste, including lateritic materials for erosion protection of the final embankment, which should be stockpiled such that they are available for this use following completion of the final lift of the TSF.

FIGURES



Notes:
1. Coordinate System: GDA 94 MGA Zone 50.
2. Software: ArcGIS 10.3

4DGeotechnics pty ltd

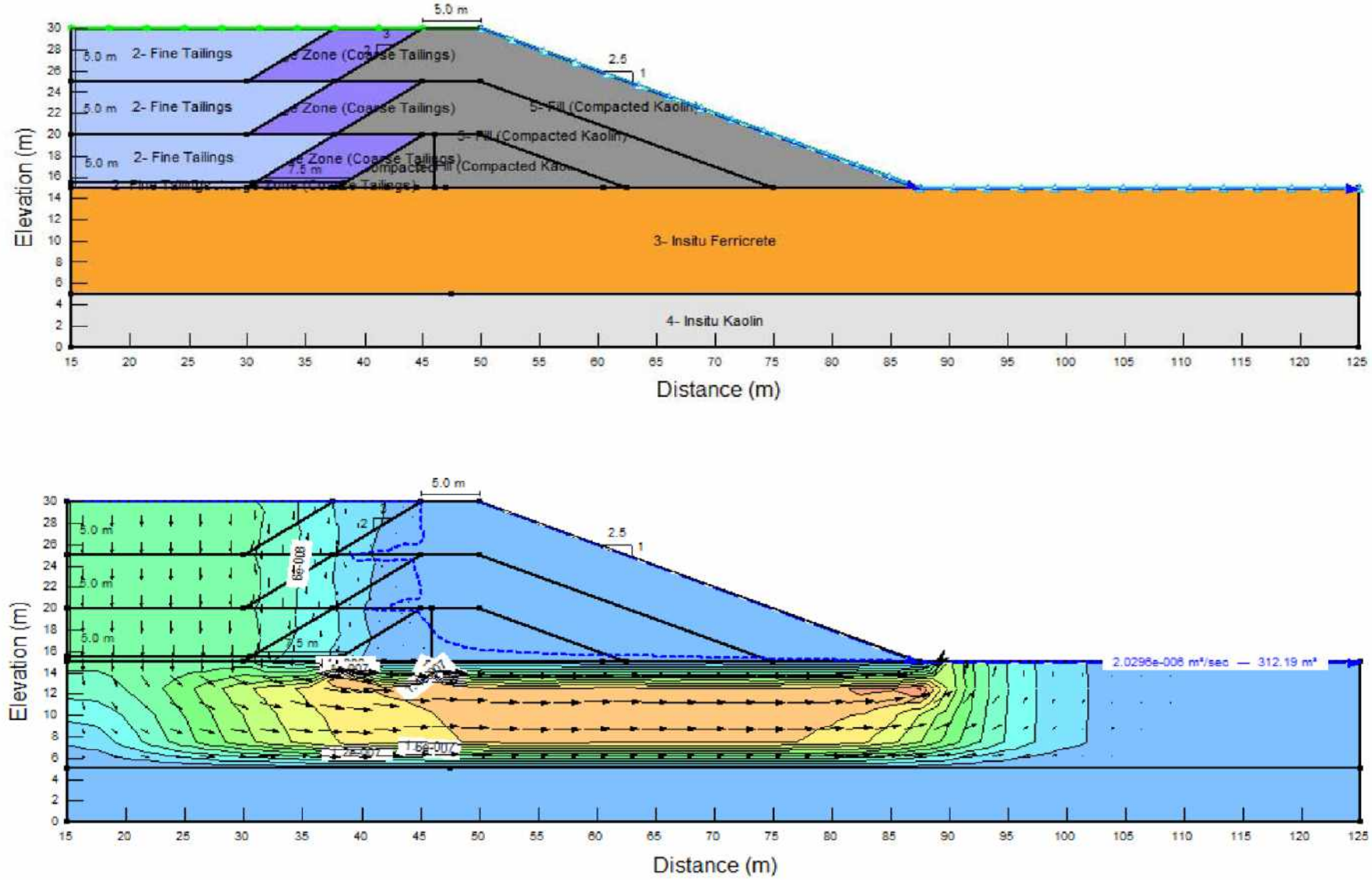
White Well Project

Tailing Storage Facility

Site Layout - 250K Geology

DRAWN	VBJ	DATE	18/01/2016
CHECKED	IHL	DATE	18/01/2016
SCALE	1:7,500		A3
PROJECT No	4DG036400	FIGURE No.	1

Centreline Section - No Compacted Liner Material



Title: Seepage Analysis for Centreline Section - No Compacted Liner Material
Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 2
Drawn by: PXS
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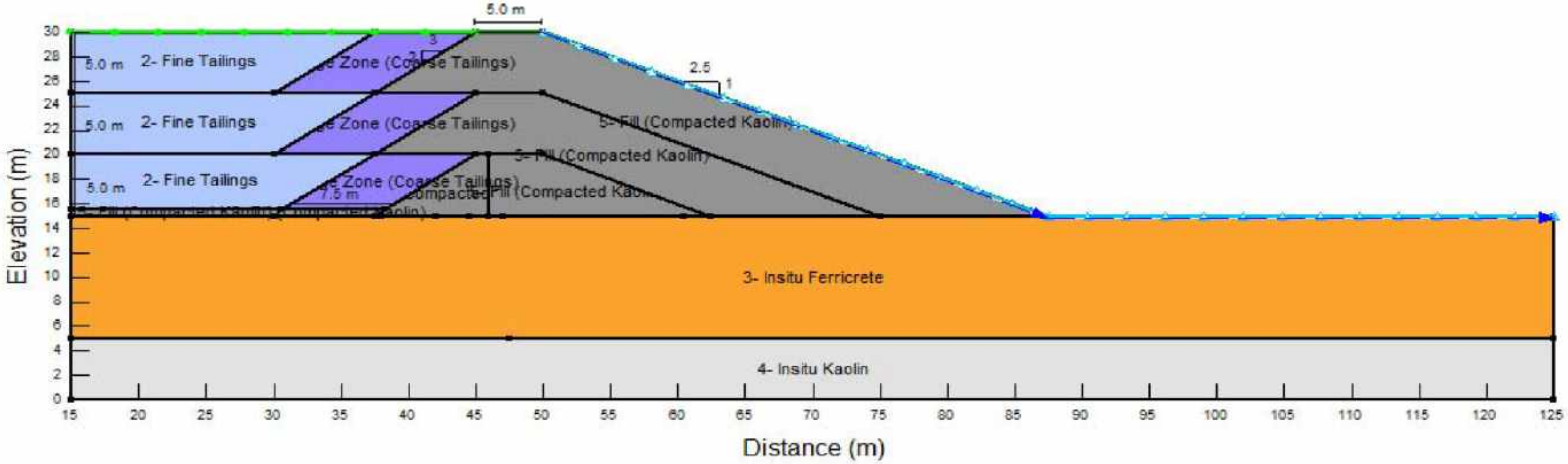
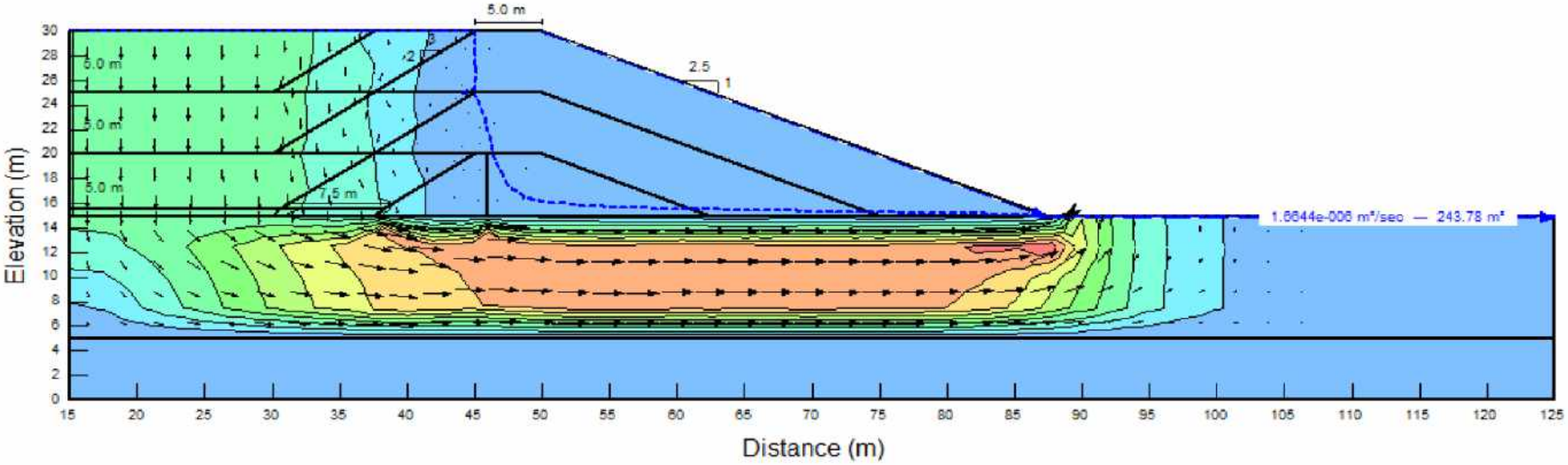
Centreline Section - 0.5 m Thick Compacted Liner Material





Title: Seepage Analysis for Centreline Section - 0.5 m Thick Compacted Liner Material

Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY

Client: MSP Engineering Pty Ltd

Date: 15 January 2016

Figure No: 3

Drawn by: PXS

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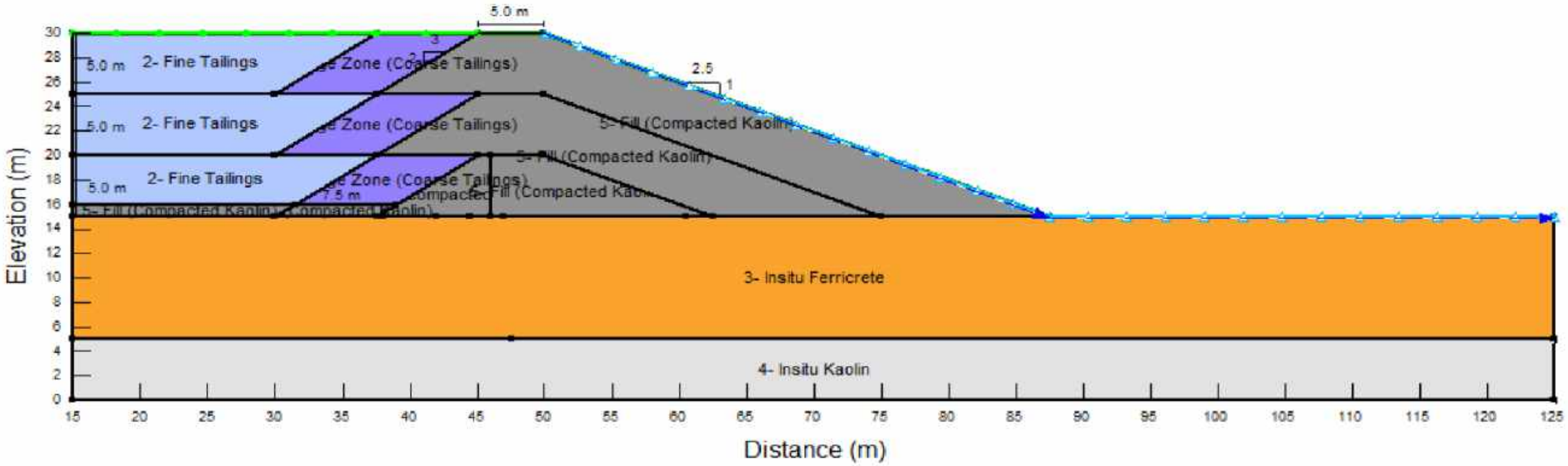
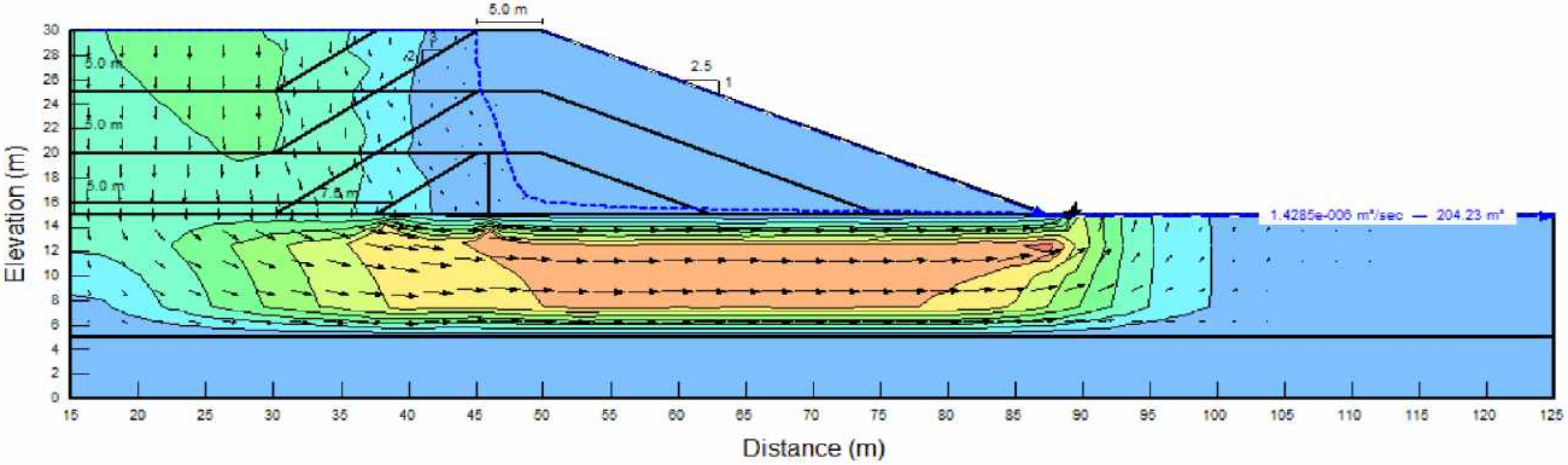
Centreline Section - 1.0 m Thick Compacted Liner Material





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Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 4
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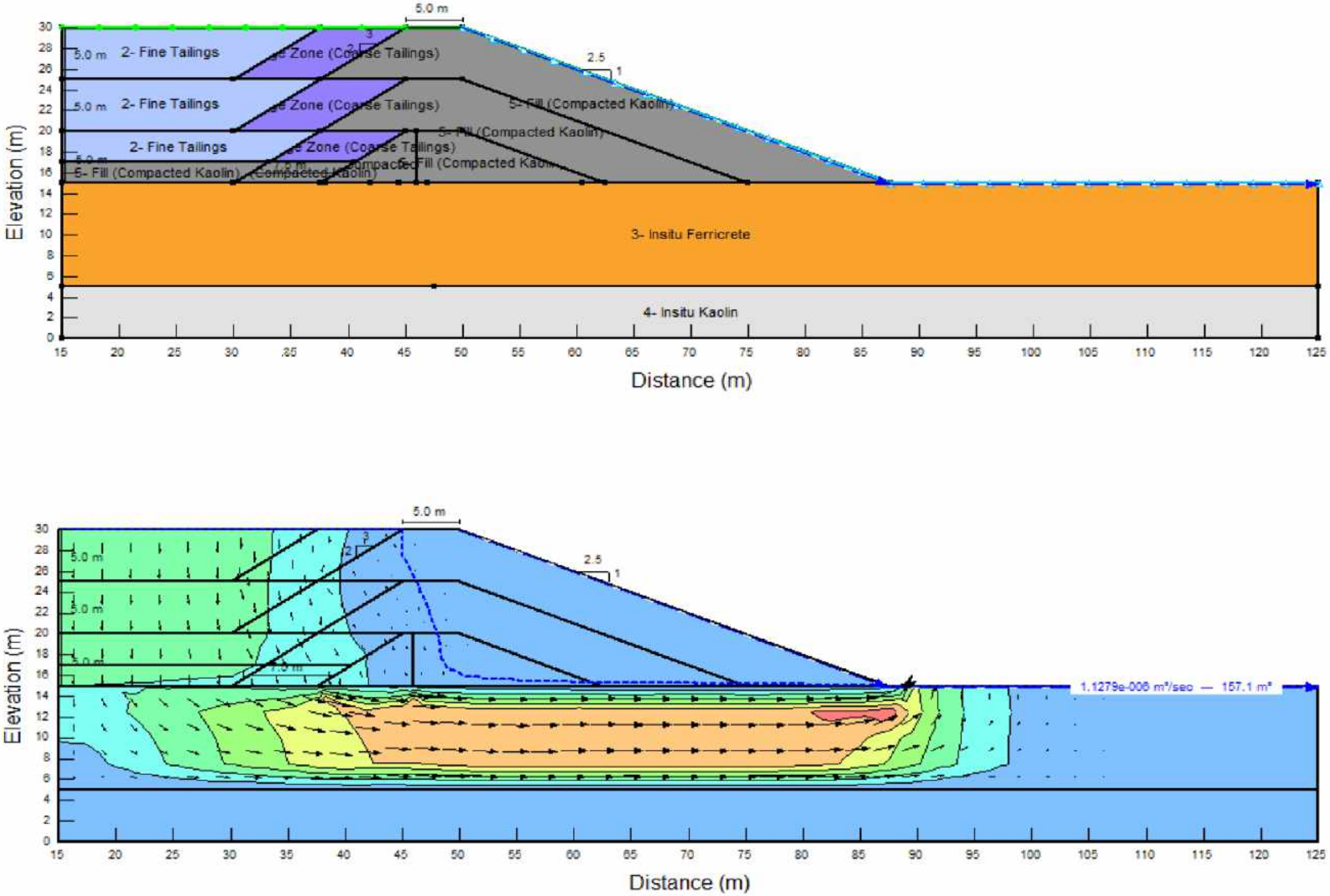
Centreline Section - 2.0 m Thick Compacted Liner Material



Title: Seepage Analysis for Centreline Section - 2.0 m Thick Compacted Liner Material

Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY

Client: MSP Engineering Pty Ltd

Date: 15 January 2016

Figure No: 5

Drawn by: PXS

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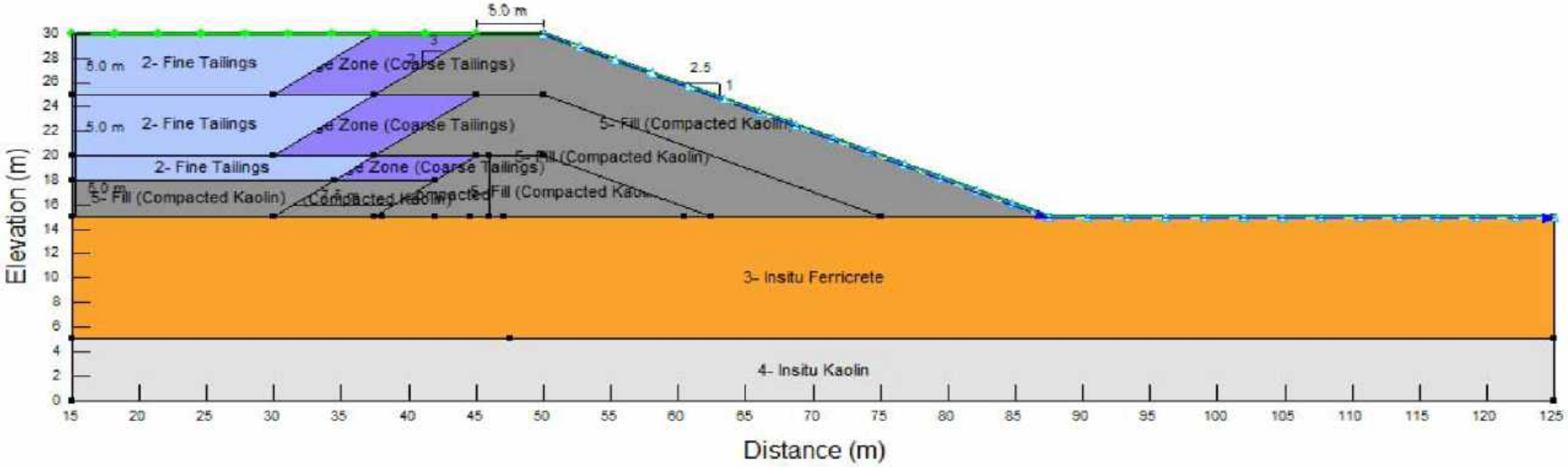
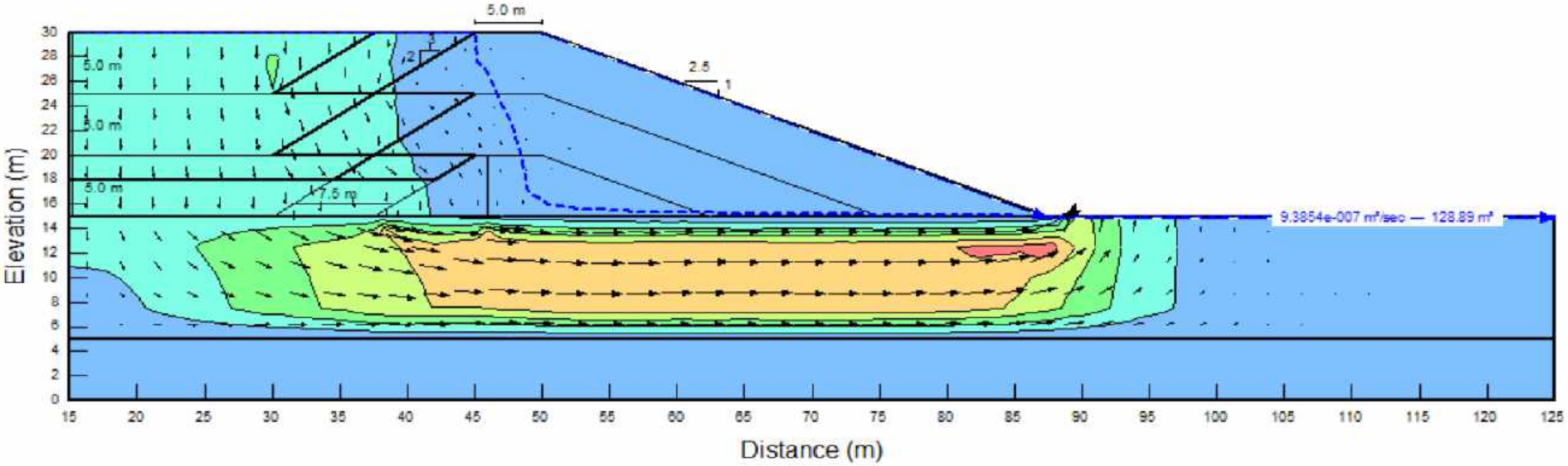
Scale: NTS

Centreline Section - 3.0 m Thick Compacted Liner Material





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Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 6
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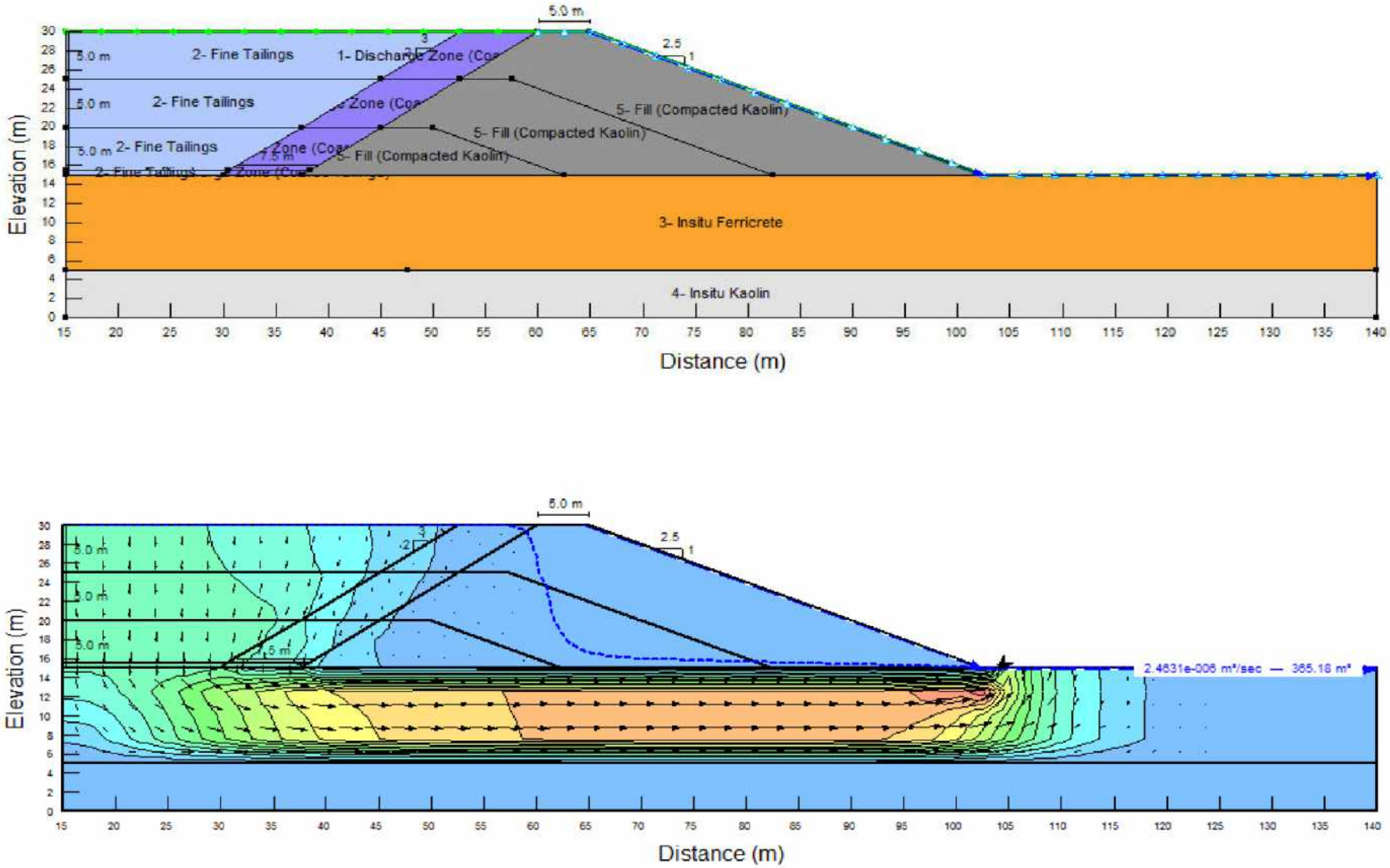
Downstream Section - No Compacted Liner Material



Title: Seepage Analysis for Downstream Section - No Compacted Liner Material
Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 7
Drawn by: PXS
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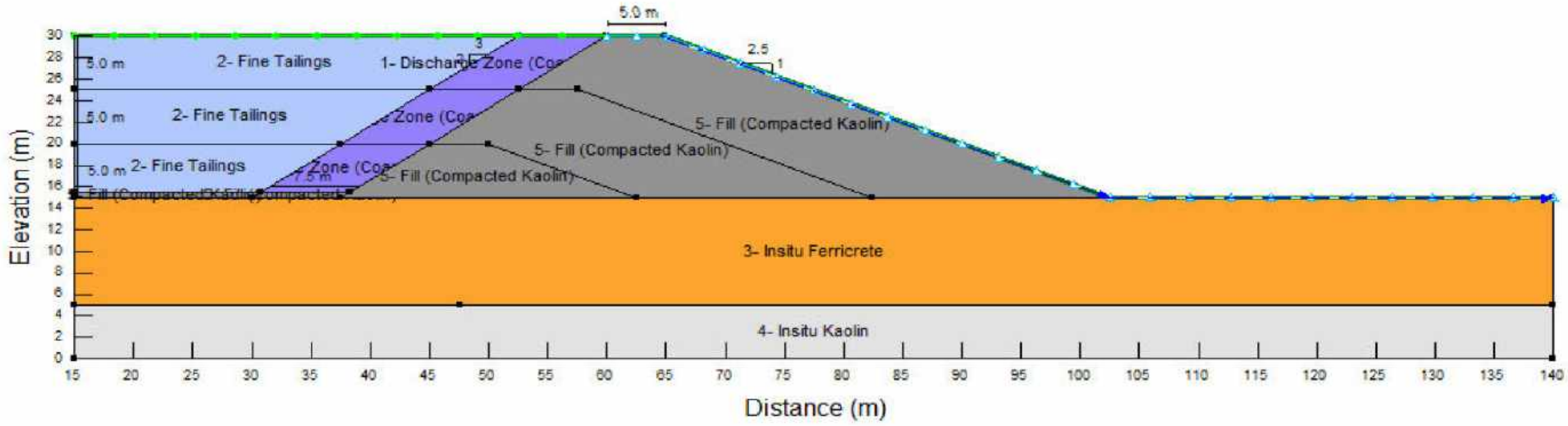
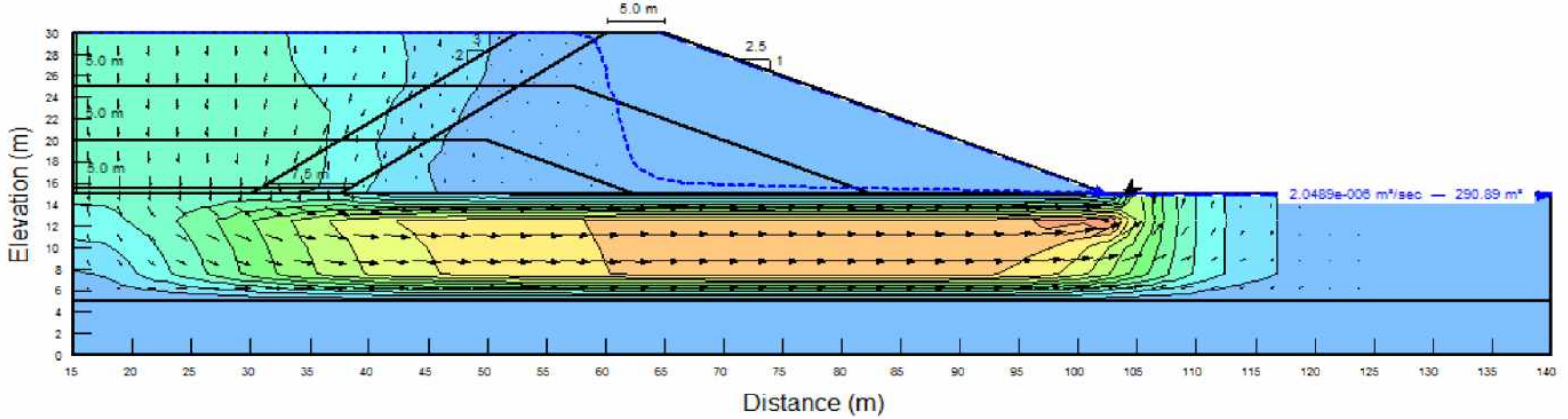
Scale: NTS

Downstream Section - 0.5 m Thick Compacted Liner Material





Title: Seepage Analysis for Downstream Section - 0.5 m Thick Compacted Liner Material
Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 8
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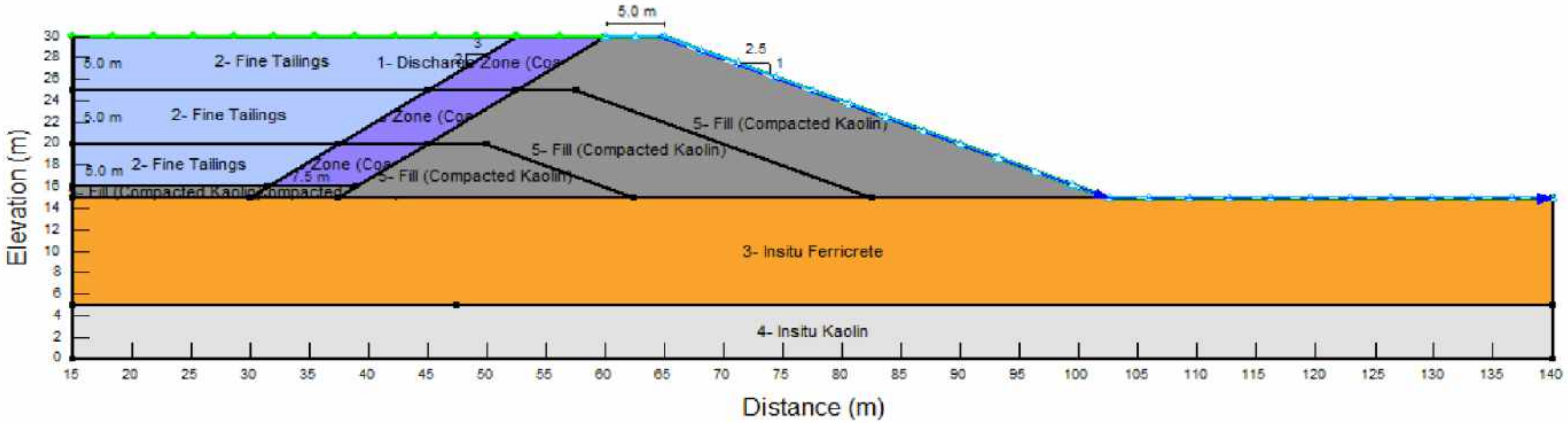
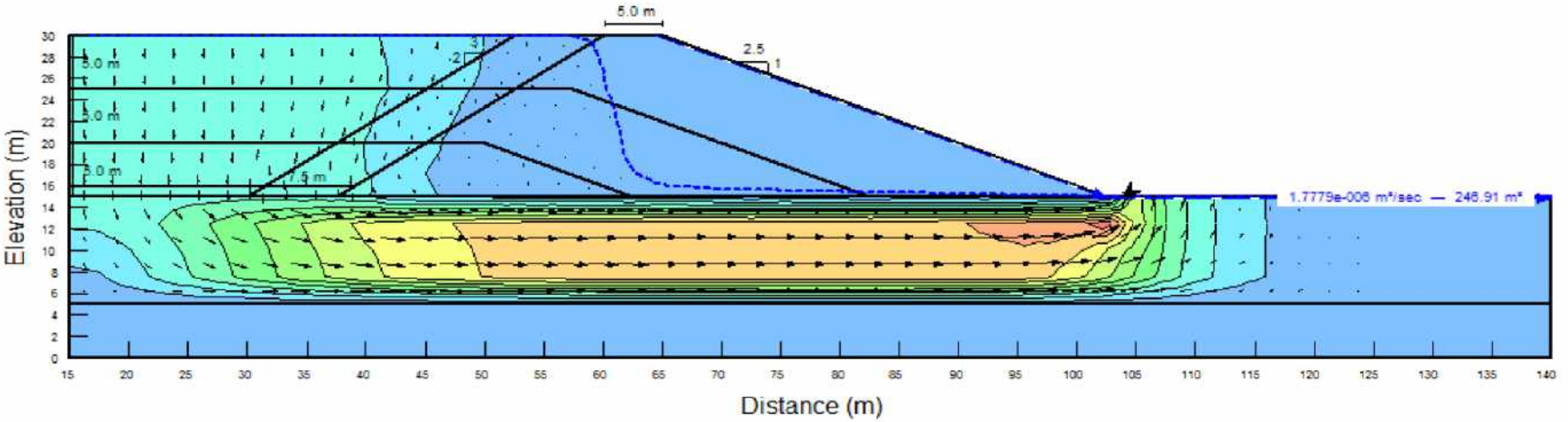
Downstream Section - 1.0 m Thick Compacted Liner Material





Title: Seepage Analysis for Downstream Section - 1.0 m Thick Compacted Liner Material
Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY
Client: MSP Engineering Pty Ltd
Date: 15 January 2016

Figure No: 9
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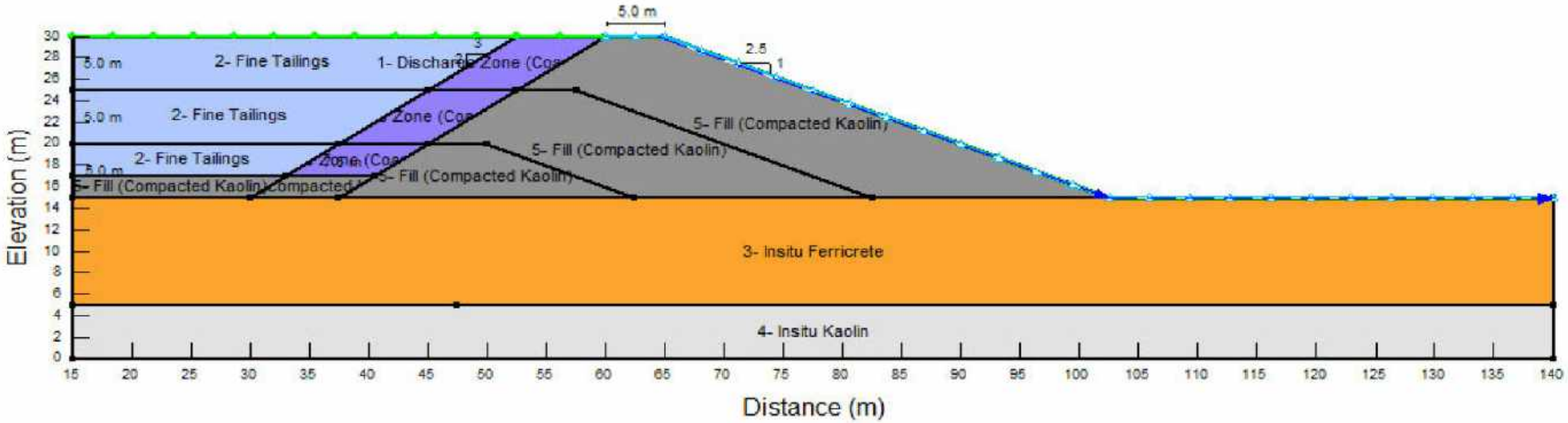
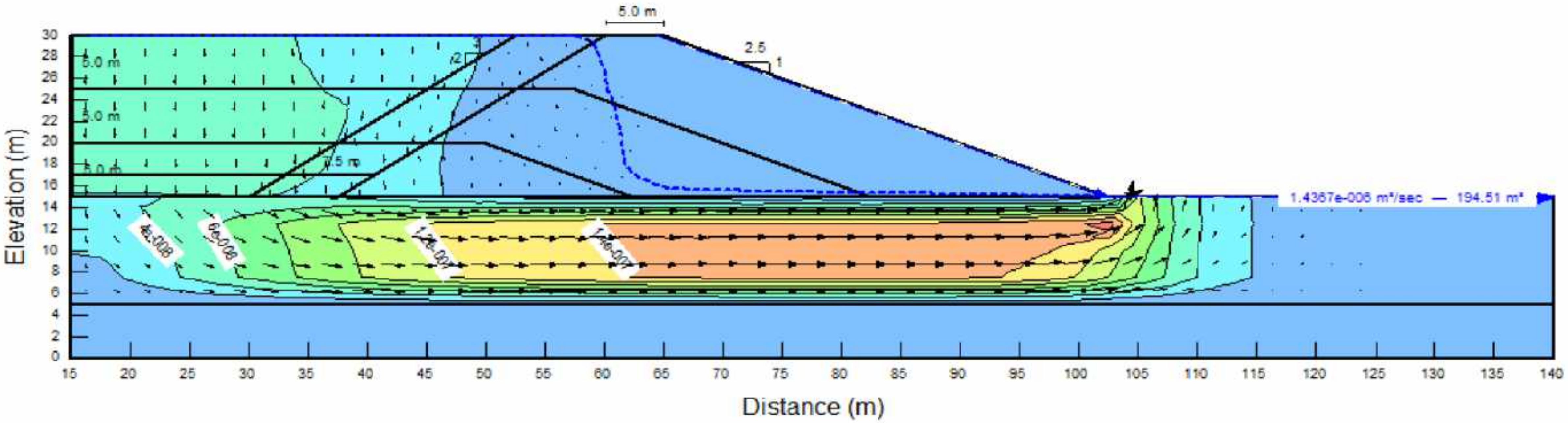
Scale: NTS

Downstream Section - 2.0 m Thick Compacted Liner Material





Title: Seepage Analysis for Downstream Section - 2.0 m Thick Compacted Liner Material

Project: WHITE WELL PROJECT- TAILINGS STORAGE FACILITY

Client: MSP Engineering Pty Ltd

Date: 15 January 2016

Figure No: 10

Drawn by: PXS

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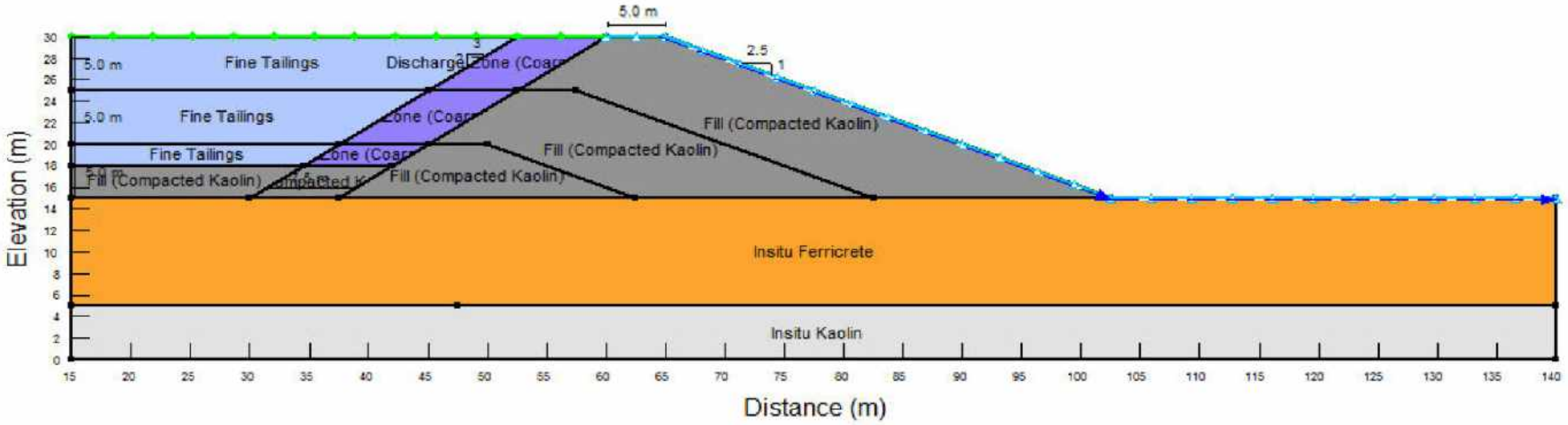
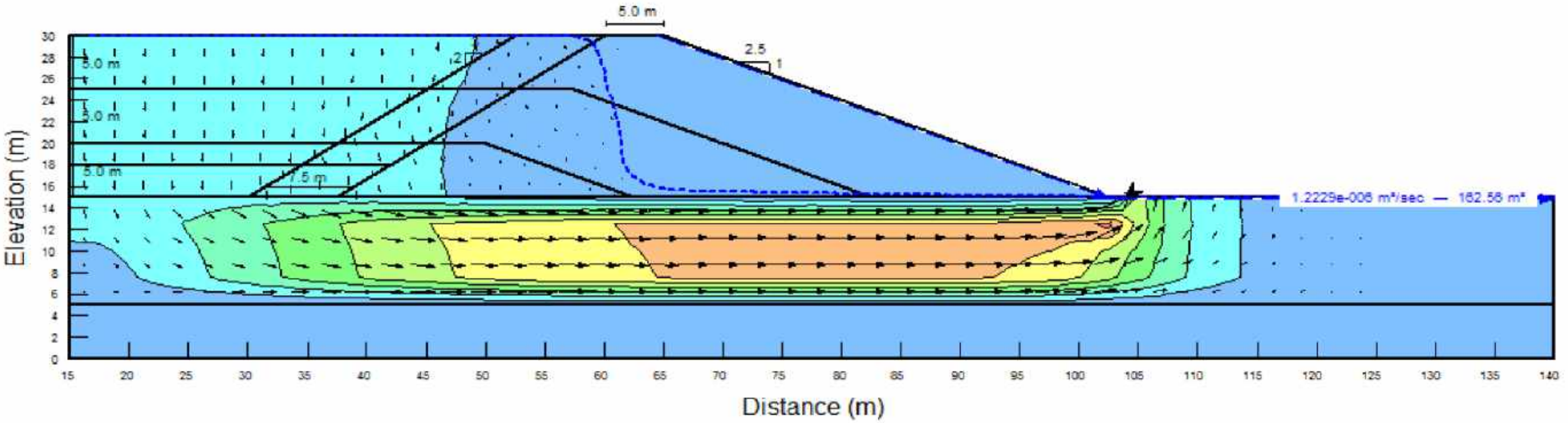
Scale: NTS

Downstream Section - 3.0 m Thick Compacted Liner Material





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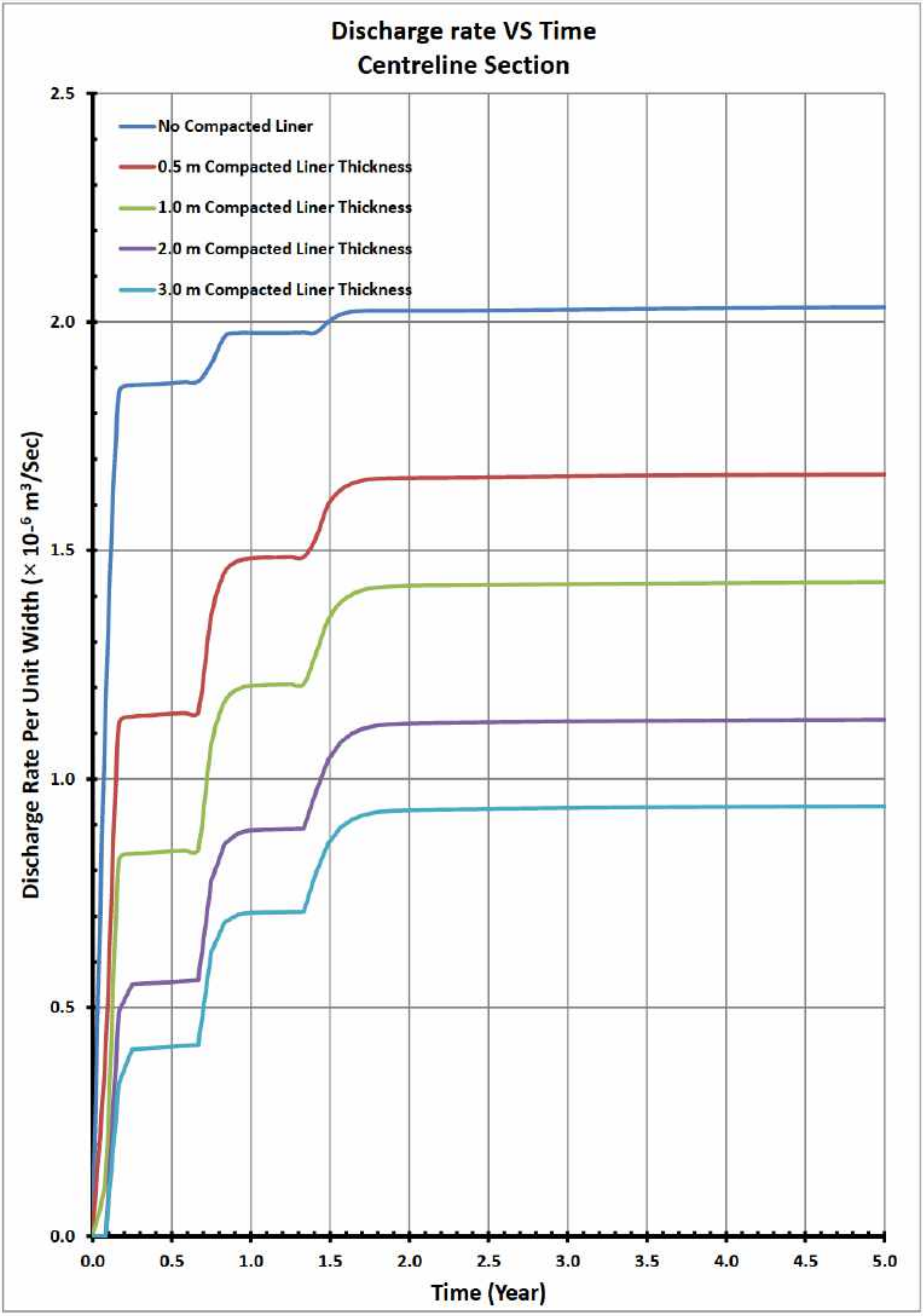
Client:	MSP Engineering Pty Ltd	Checked:	
Date:	15 January 2016	Scale:	NTS



Title:	Discharge rate VS Time Centreline Section	**Figure No:**	12
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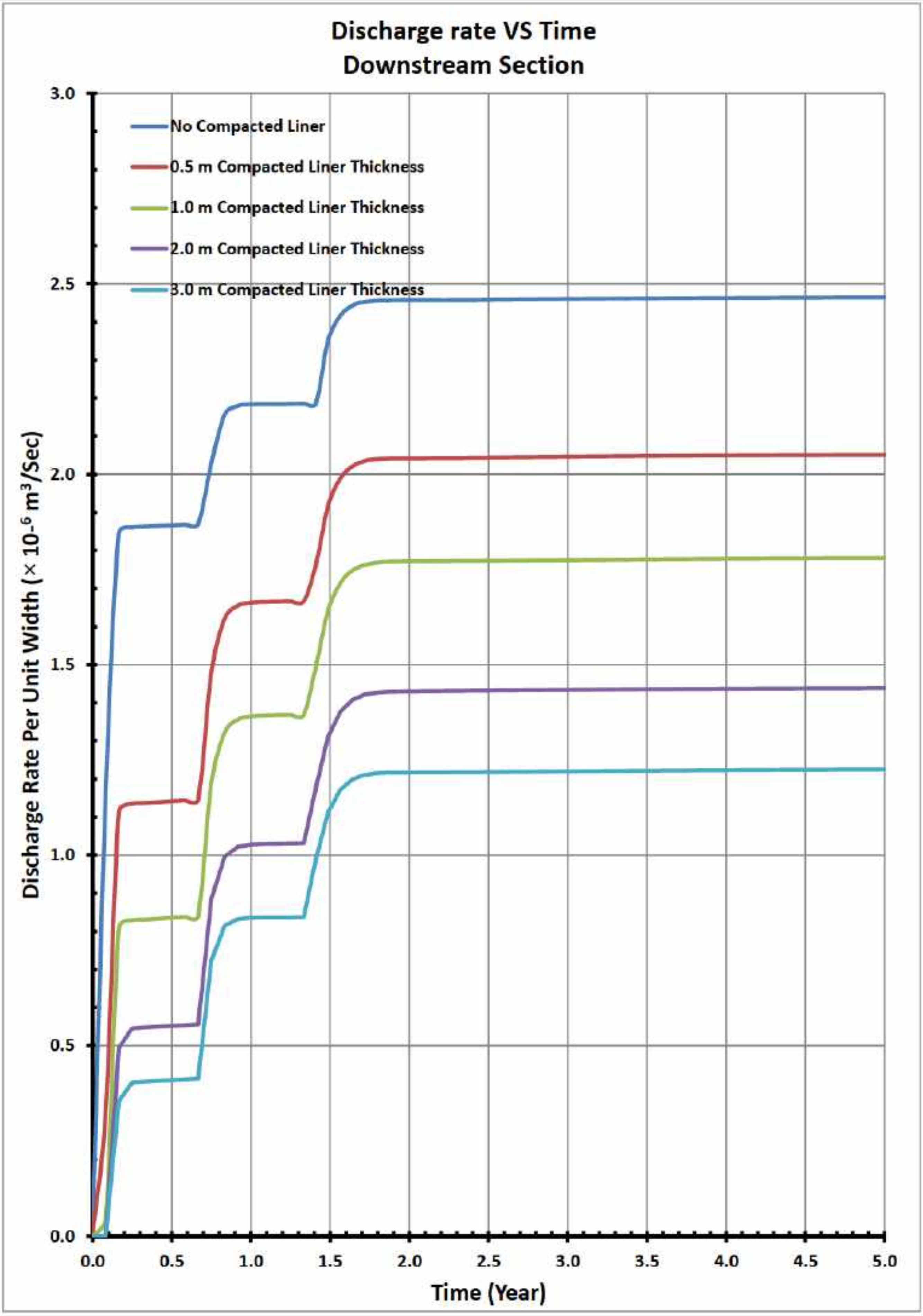
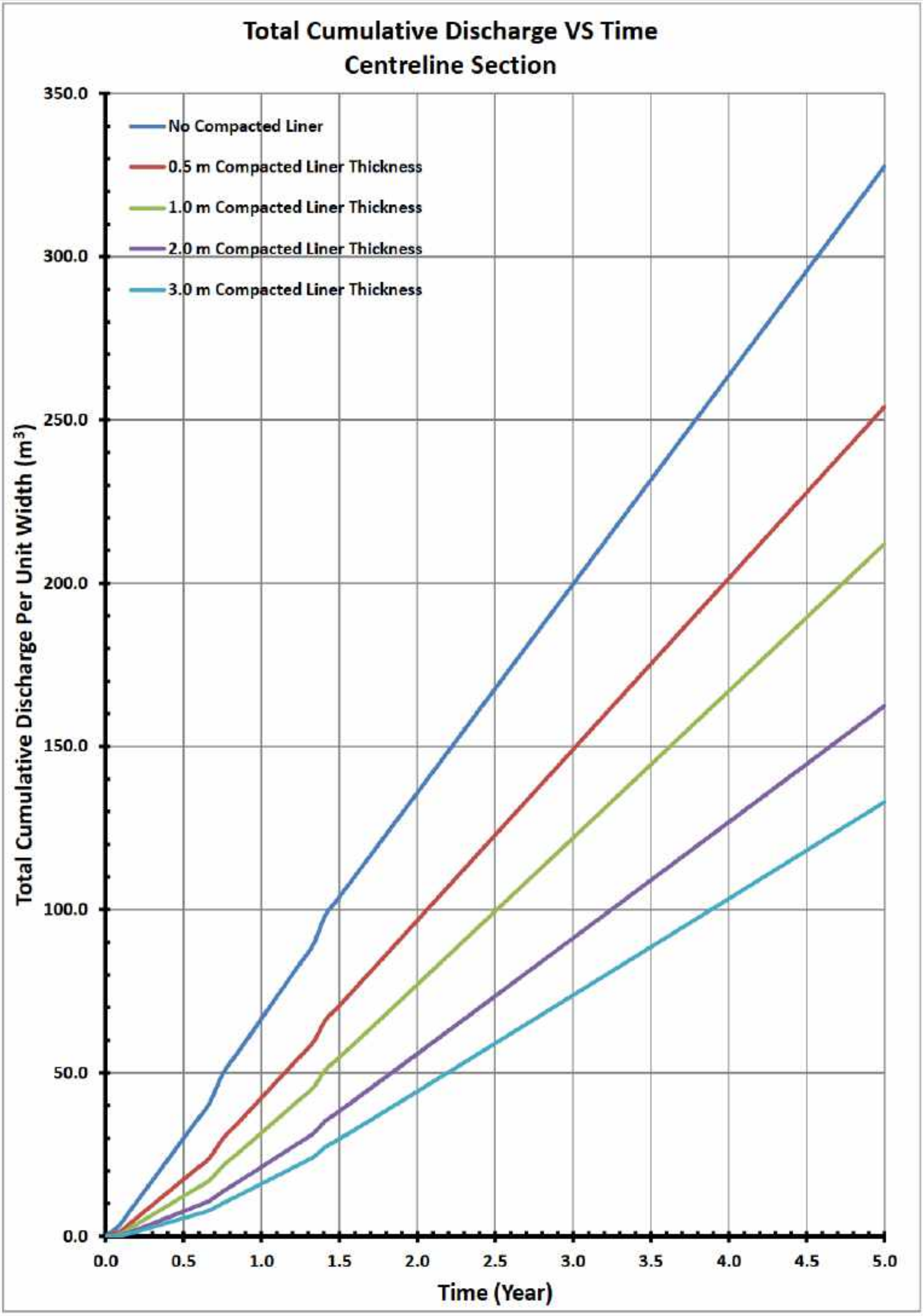
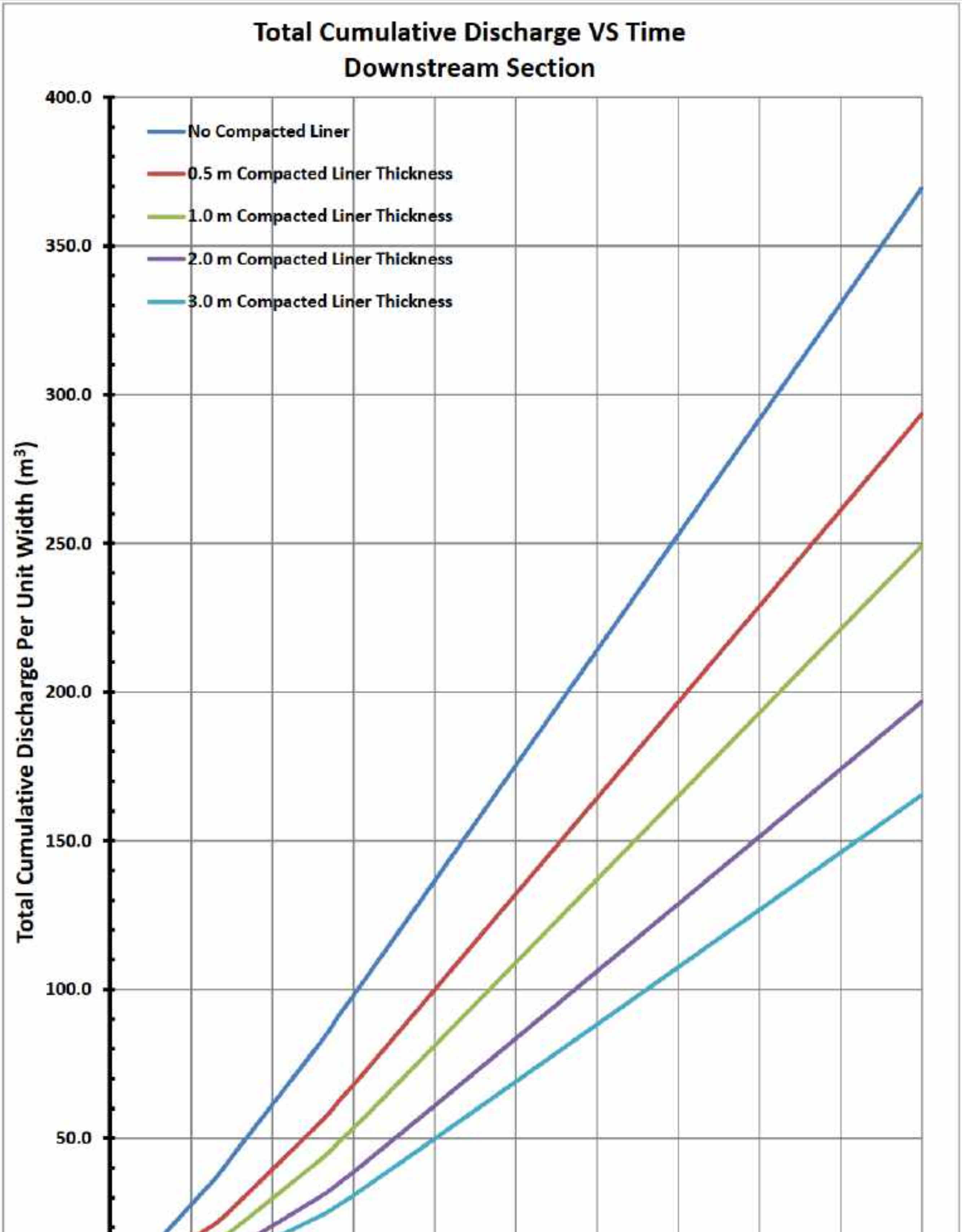
Project:	WHITE WELL PROJECT- TAILINGS STORAGE FACILITY	**Checked by:**	
Client:	MSP Engineering Pty Ltd	**Date:**	15/01/2016



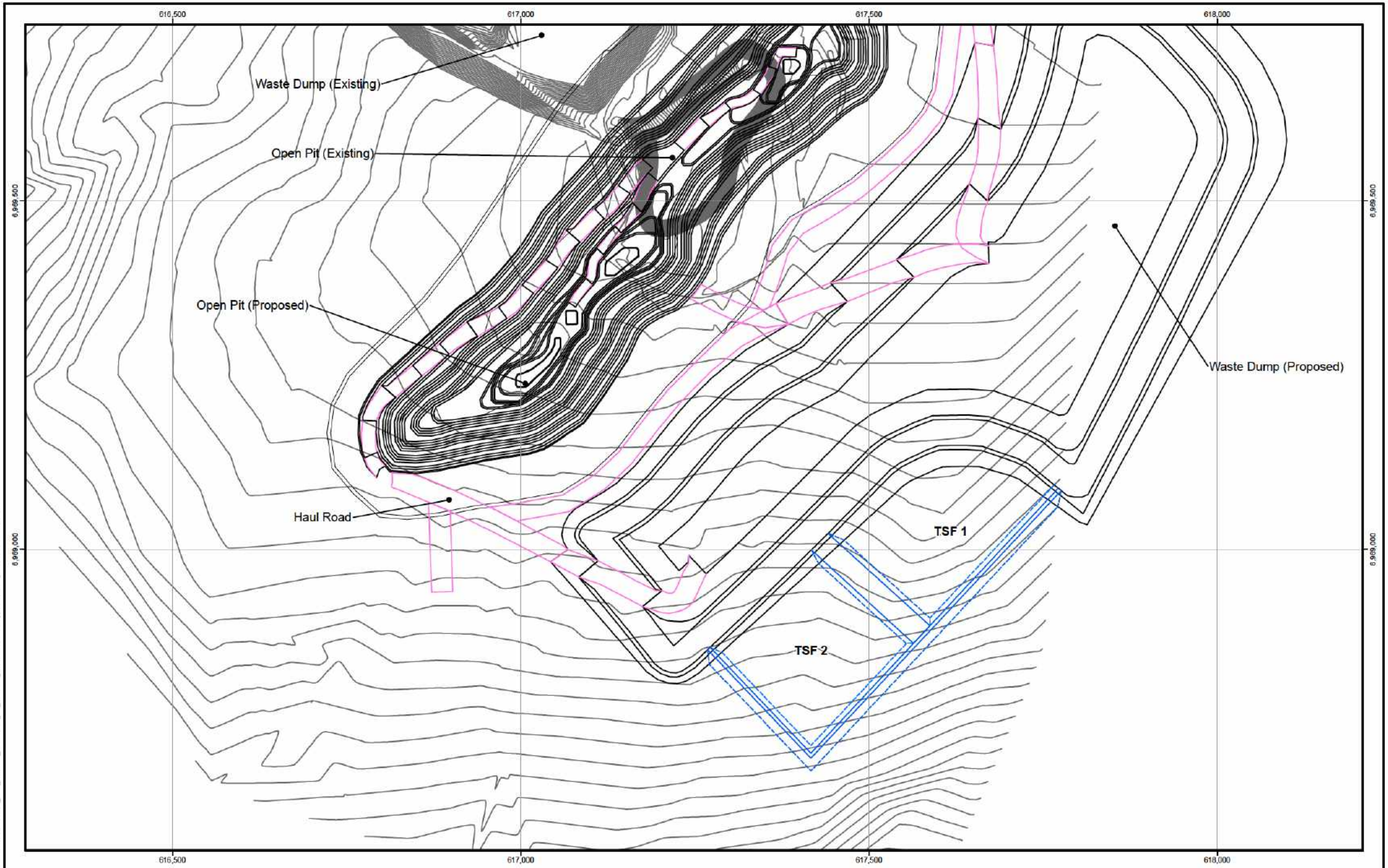
4DG	**Title:**	Discharge rate VS Time Downstream Section	**Figure No:**	13
			Prepared by:	PXS
	Project:	WHITE WELL PROJECT- TAILINGS STORAGE FACILITY	**Checked by:**	
	Client:	MSP Engineering Pty Ltd	**Date:**	15/01/2016



4DG	**Title:**	Total Cumulative Discharge VS Time Centreline Section	**Figure No:**	14
			Prepared by:	PXS
	Project:	WHITE WELL PROJECT- TAILINGS STORAGE FACILITY	**Checked by:**	
	Client:	MSP Engineering Pty Ltd	**Date:**	15/01/2016



Title:	Total Cumulative Discharge VS Time Downstream Section	**Figure No:**	15
		Prepared by:	PXS
Project:	WHITE WELL PROJECT- TAILINGS STORAGE FACILITY	**Checked by:**	
Client:	MSP Engineering Pty Ltd	**Date:**	15/01/2016



0 100 200 300 400 m

Notes:
1. Coordinate System: GDA 94 MGA Zone 50.
2. Software: ArcGIS 10.3

N

Location Plan

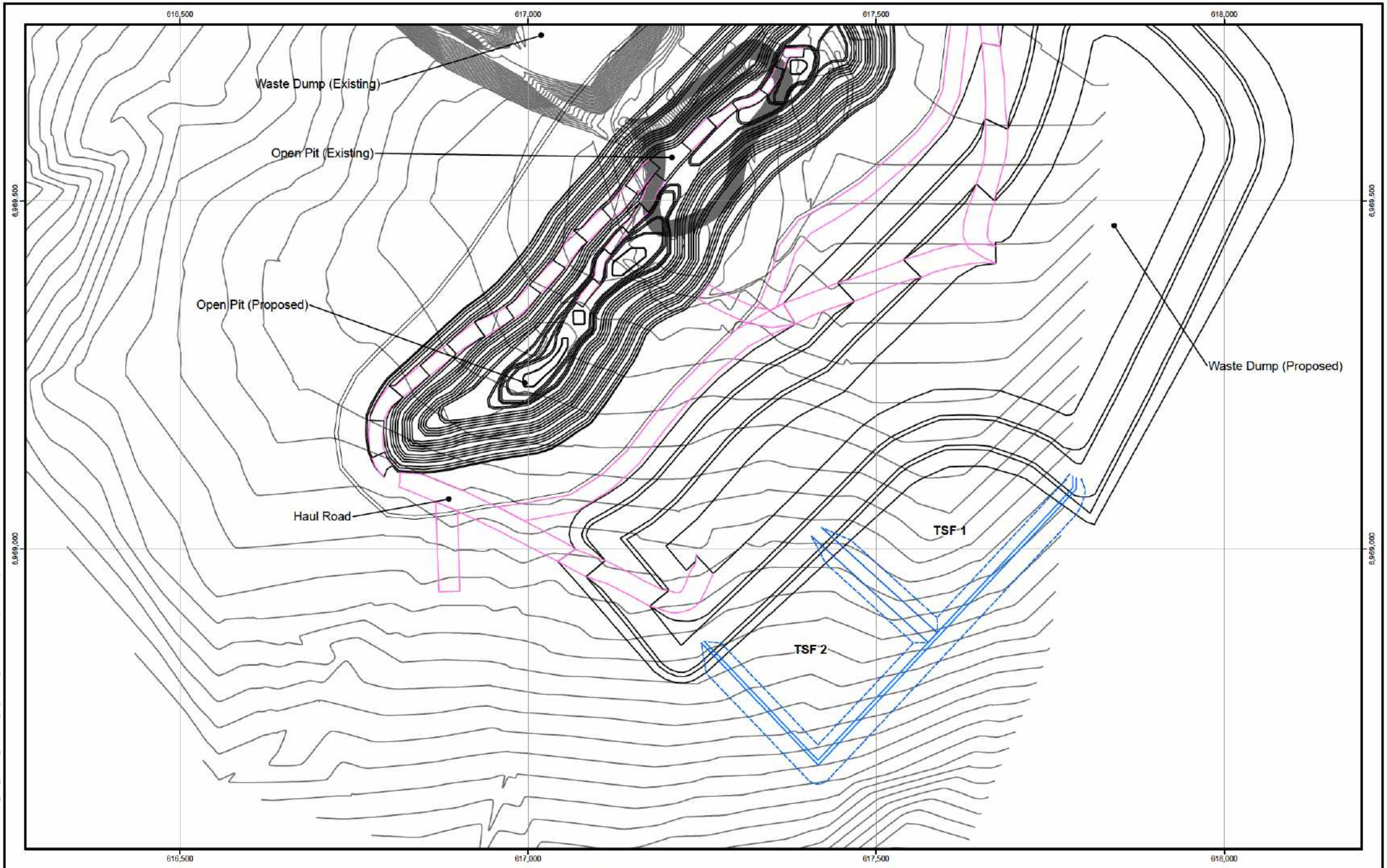
4DGeotechnics pty ltd

White Well Project

Tailing Storage Facility

TSF Stage 1 - Schematic Footprint

DRAWN	VBJ	DATE	18/01/2016	
CHECKED	IHL	DATE	18/01/2016	
SCALE	1:5,000			A3
PROJECT No	4DG036400	FIGURE No.	16	



Notes:
1. Coordinate System: GDA 94 MGA Zone 50.
2. Software: ArcGIS 10.3

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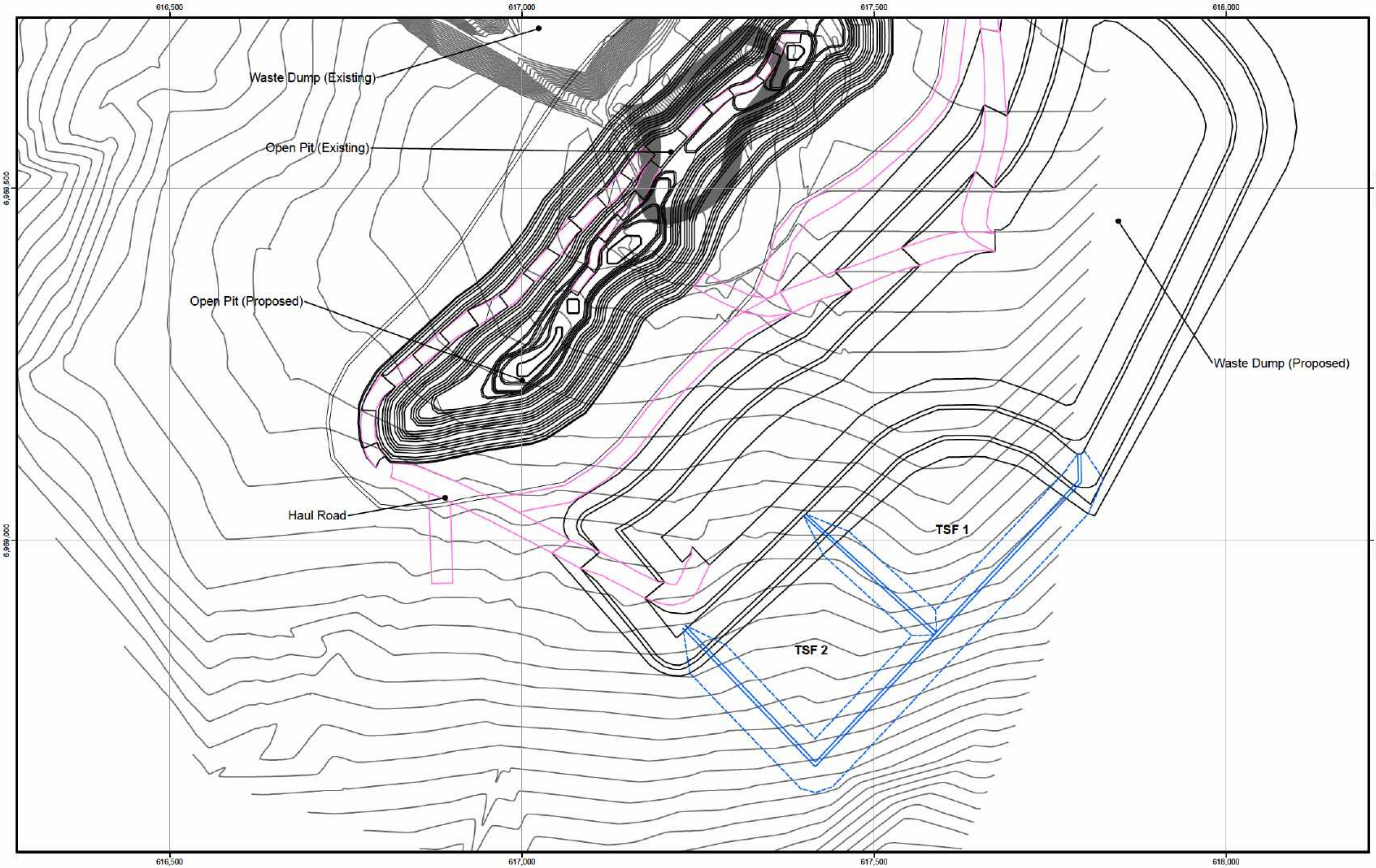
4DGeotechnics pty ltd

White Well Project

Tailing Storage Facility

TSF Stage 2 - Schematic Footprint

DRAWN	VBJ	DATE	18/01/2016
CHECKED	IHL	DATE	18/01/2016
SCALE	1:5,000		A3
PROJECT No	4DG036400	FIGURE No.	17



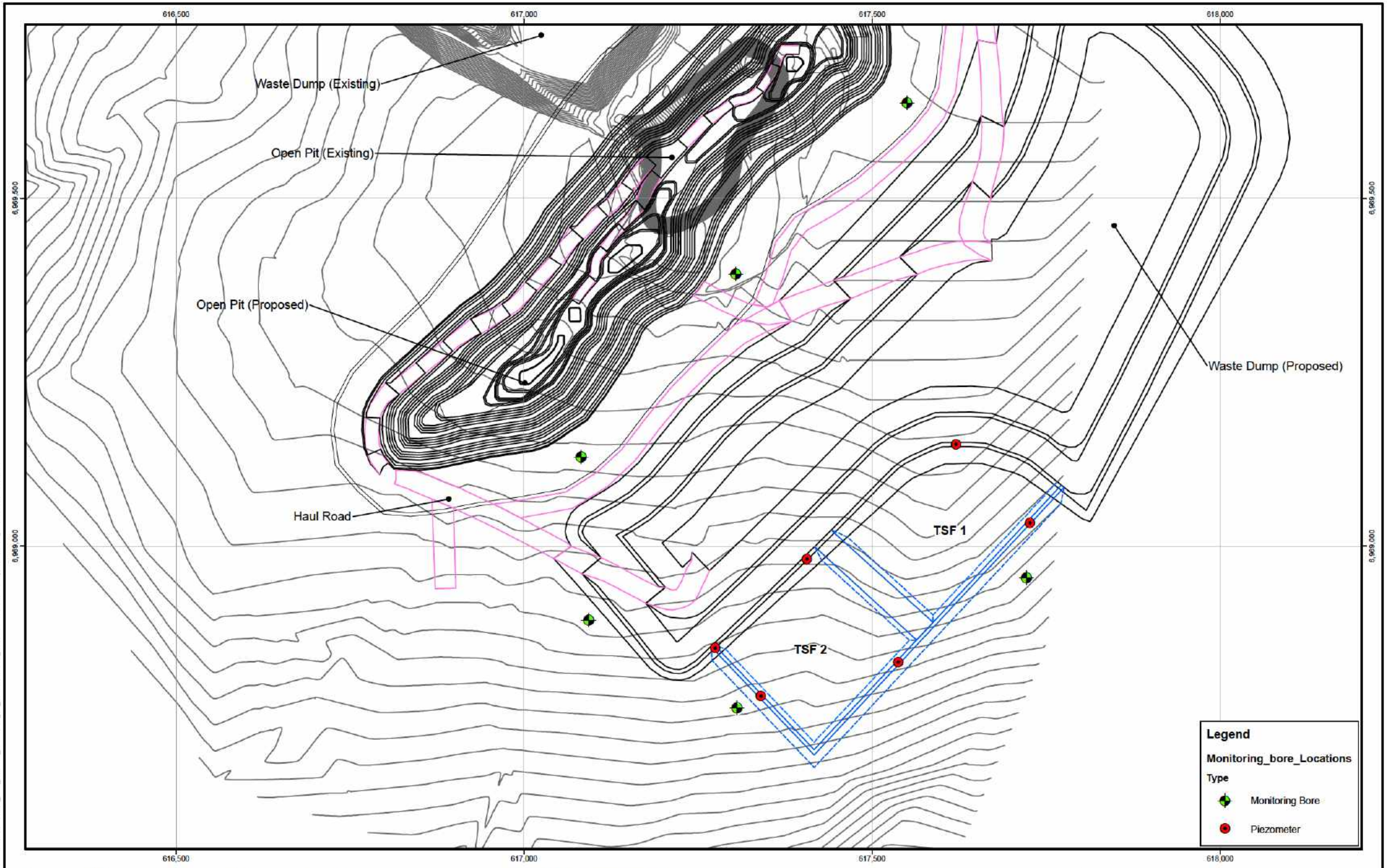
Notes:
1. Coordinate System: GDA 94 MGA Zone 50.
2. Software: ArcGIS 10.3

Location Plan

4DG
4DGeotechnics pty ltd

White Well Project
Tailing Storage Facility
TSF Stage 3 - Schematic Footprint

DRAWN	VBJ	DATE	18/01/2016
CHECKED	IHL	DATE	18/01/2016
SCALE	1:5,000		A3
PROJECT No	4DG036400	FIGURE No.	18



Notes:
1. Coordinate System: GDA 94 MGA Zone 50.
2. Software: ArcGIS 10.3

4DGeotechnics pty Ltd

White Well Project
Tailing Storage Facility
Monitoring Bore Locations

DRAWN	VBJ	DATE	18/01/2016
CHECKED	IHL	DATE	18/01/2016
SCALE	1:5,000		A3
PROJECT No	4DG036400	FIGURE No.	19

APPENDIX A
2012 TSF ANALYSIS REPORT

TEL: (08) 9443 9994
FAX: (08) 9443 9991
[redacted]
WEB: www.4dg.com.au

201-203 Bulwer St, Perth WA 6000 / PO Box 509, Leederville WA 6903 / ABN 11 073 742 604

5 May 2012

Ref: 024500REP01_Rev2

Cobra Mining Ltd
159 Stirling Highway
Nedlands
WA 6009

[redacted]

[redacted]

RE: White Well Tailings Storage Facility: Geotechnical Investigation

In accordance with your purchase order GT002, please find enclosed our Geotechnical Report (Rev 2) for the proposed White Well Mine Tailings Storage Facility updated with your the downstream method.

If you have any queries with regard to this report, please do not hesitate to contact the undersigned or [redacted] n this office.

Yours sincerely,

[redacted]

Distribution: Original held by 4DG

1 Electronic Copy Cobra Mining Ltd

Cobra Mining Ltd

White Well Mine
Proposed Tailings Storage Facility
Geotechnical Assessment

April 2011
Ref: 024500REP01

[redacted]

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A. Site Photographs

B. Test Pit Logs

C. Laboratory Test Certificates

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1.0 INTRODUCTION

1.1 Scope of Works

4DGeotechnics Pty Ltd (4DG) was engaged by Cobra Mining Ltd to conduct a geotechnical investigation and stability analysis for the concept design phase of their White Well tailings storage facility, 35km north east of Cue, Western Australia.

The scope comprised:

- Excavation of 15 test pits around the perimeter of the proposed tailings storage facility,
- Collect samples from test pits for classification as suitable for use in embankment construction,
- Inspect the existing mine pit wall to assess the possible range of depths of the surfical laterised zone,
- Laboratory testing including, Particle Size Distribution, Atterberg Limits, moisture content, compaction, falling head permeability and remoulded triaxial (CU) testing,
- Undertake preliminary stability analysis for centreline and downstream construction methods, and
- Produce construction details for use in the concept design of the tailings storage facility.

The design is intended at a preliminary design level to provide typical geometry and construction details for the tailings embankment dam.

1.2 Proposed Development

The concept for the tailings storage facility (TSF) is to have a staged construction to keep pace with tailings deposition using either a centreline or downstream embankment construction method, an earthfill embankment dam utilising local materials and a cut off trench.

The TSF concept essentially comprises the following:

- Staged construction to keep pace with tailings deposition,
- Centreline or downstream embankment construction method,
- Earthfill embankment,
- Ferricrete scour protection on outside batter, and
- Cut off trench.

The earthfill materials are proposed to be sourced from within the TSF footprint and from future mine waste excavations from the kaolin soils located in either the existing waste dump or mine waste from mining operations. The scour protection source is the laterised zone and ferricrete layer which can be sourced from the cut-off trench excavations, or from an extension of the mine pit.

It is proposed that the bulk of the TSF embankment is constructed using the kaolin as this is the most abundant local material source. The ferricrete will provide a higher strength scour protection layer located on the outside face of the TSF. The ferricrete will resist the effects and minimise the scour of the outside TSF slopes.

The TSF embankment should have batter slopes 2.5H:1V on the downstream side and 1.5H:1V on the upstream side with maximum staging heights of 5m before the tailings are filled to within 1.5m of the dam crest.

There is a potential that the future mine waste dump will be constructed surrounding (encapsulating) the TSF. This has not been considered in this report.

Where the TSF is to abut against the existing waste dump, it is recommended that the cut off trench is installed and the TSF embankment can be constructed against the waste dump. To ensure the long term stability of the TSF, the waste dump should be left intact to within at least 30m (horizontally) of the TSF unless additional works are conducted to increase the stability and prevent groundwater seepage beneath the TSF. If the waste dump is to be removed in the future, a specific geotechnical assessment should be carried out at that stage to determine what works are required.

The cut off trench is designed to restrict water seeping beneath the dam through the relatively high permeability laterised zone.

1.3 Supplied Information

- Cobra Mining advised 4DG that the tailings storage facility is to be up to 15 m high and constructed in stages,
- A 1991 Dames & Moore, Tukabianna Gold Mine, open pit mine Geotechnical Investigation Report for the White Well Prospect, and,
- Topographical survey of the mine and proposed site of the tailings storage facility.

2.0 REVIEW OF EXISTING REPORT

The 1991 Dames & Moore Tukabianna Gold Mine Report presents the results of a geotechnical investigation comprising four (4) diamond drill holes to depths of between 71 and 87 m. That report focused on the open pit mine stability and not specifically on the proposed tailings storage facility.

Dames & Moore summarise the geology of the pit as comprising a 60 to 75 m deep laterite profile underlain by andesitic and porphyritic volcanic rocks.

Dames & Moore describe the surfical deposits as generally being comprised of red-brown gravelly sand topsoil underlain by a pisolitic lateritic hard pan (the laterised zone). Beneath which is a light grey calcified and silicified altered clayey siltstone.

Underlying the surfical deposits Dames & Moore describe the kaolinised zone as comprising kaolin-altered felsic and porphyritic bedrock, typically light grey, stiff to weak strength and clayey silt/siltstone in composition, occurring between 430 m RL and 470 m RL. The lower contact of the unit was noted as irregular.

At the time of the 1991 site investigations the groundwater level was at 454 m RL (Dames & Moore, 1991). The existing pit currently has water ponding to a similar elevation and it is not known if significant quantities of surface water have flowed into the pit or this level represents the long term groundwater level across the site.

3.0 4DG SITE INVESTIGATIONS

3.1 Test Pitting

A total of fifteen test pits were excavated using a 30 tonne excavator and were terminated when the excavator could no longer effectively penetrate (refusal) or at the maximum reach of the excavator. The test pits were excavated between 2 and 3 February 2012.

Twelve (12) test pits were located on the perimeter of the proposed TSF and were excavated to depths ranging from 0.1m to 1.0m, typically refusing on the top of the Ferricrete (also referred to as hard pan in the Dames & Moore report). The 30 tonne excavator could not penetrate the Ferricrete in the test pits, however, a trial was conducted where there was a free face on the existing pit where the excavator could excavate the laterised zone with difficulty.

White Well TSF Site Plan

Three (3) test pits were excavated within the face of the existing waste dump to depths ranging from 3.3m to 4.0m.

A 4DG Engineering Geologist supervised the fieldwork, logged the exposures and obtained representative soil samples so that an assessment of the subsurface materials could be made. The fieldwork was undertaken in general accordance with AS1726-1993 "Geotechnical Site Investigations" and 4DG's logging standards.

The locations of the test pits are shown on the site plan below.

Engineering geological logs of the test pits are presented in Appendix B together with the engineering geology terminology explanation sheets defining the terms and symbols utilised in the log preparation.

3.2 Pit Wall Inspection

The existing pit wall adjacent to the proposed tailings facility was inspected including measuring the changes in depth along the laterite deposit.

3.3 Laboratory Testing

Selected samples were collected during the site investigations and transported to a NATA registered laboratory in Perth, Western Australia.

The 4DG geotechnical investigation laboratory test certificates are presented in Appendix C. The combined 4DG and representative Dames & Moore laboratory test results are presented in Table 1.

Table 1: Combined Laboratory Test Results

<table>
<tr><th rowspan="2">Borehole, Test Pit No.</th><th rowspan="2" colspan="2">Depth Below Ground Surface (m)</th><th rowspan="2">c' (kPa)</th><th rowspan="2">Φ' (degrees)</th><th rowspan="2">Dry Density (kg/m3)</th><th rowspan="2">Moisture content (%)</th><th colspan="3">Atterberg Limits</th></tr>
<tr><th>LL (%)</th><th>PI (%)</th><th>LS (%)</th></tr>
<tr><td>TP13</td><td>0</td><td>3</td><td>4</td><td>27</td><td>1.66</td><td>2</td><td>47</td><td>13</td><td>2.5</td></tr>
<tr><td>TP15</td><td>0.05</td><td>4.1</td><td>4</td><td>25</td><td>1.59</td><td>2.9</td><td>48</td><td>13</td><td>1</td></tr>
<tr><td>R0001</td><td>0.2</td><td>1</td><td>-</td><td>-</td><td>1.6</td><td>0.7</td><td>NO</td><td>NO</td><td>1.5</td></tr>
<tr><td>ADH 81</td><td>6.6</td><td>7.8</td><td>92</td><td>25</td><td>1.56</td><td>23.1</td><td>40</td><td>10</td><td>1.5</td></tr>
<tr><td>ADH 83</td><td>15.30</td><td>16.30</td><td colspan="4"></td><td>47</td><td>14</td><td>3.0</td></tr>
<tr><td>ADH 80</td><td>18.85</td><td>19.90</td><td colspan="4"></td><td>43</td><td>11</td><td>1.5</td></tr>
<tr><td rowspan="4">ADH 83</td><td rowspan="4">19.8</td><td rowspan="4">20.8</td><td colspan="2">For σ'_n <200 kPa</td><td rowspan="4">1.41</td><td rowspan="4">32.5</td><td rowspan="4">63</td><td rowspan="4">23</td><td rowspan="4">3.0</td></tr>
<tr><td>27</td><td>31</td></tr>
<tr><td colspan="2">For σ'_n >200 kPa</td></tr>
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<tr><td>ADH 81</td><td>25.20</td><td>25.70</td><td colspan="4"></td><td>50</td><td>17</td><td>2.5</td></tr>
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<tr><td rowspan="4">ADH 81</td><td rowspan="4">34.9</td><td rowspan="4">35.8</td><td colspan="2">For σ'_n <200 kPa</td><td rowspan="4">1.41</td><td rowspan="4">32.5</td><td rowspan="4">66</td><td rowspan="4">26</td><td rowspan="4">2.5</td></tr>
<tr><td>32</td><td>32</td></tr>
<tr><td colspan="2">For σ'_n >200 kPa</td></tr>
<tr><td>70</td><td>24</td></tr>
<tr><td>ADH 80</td><td>37.90</td><td>38.80</td><td colspan="4"></td><td>43</td><td>10</td><td>1.0</td></tr>
<tr><td>ADH 83</td><td>38.1</td><td>39.1</td><td>70</td><td>26</td><td>1.38</td><td>35.0</td><td>61</td><td>18</td><td>3.0</td></tr>
<tr><td>ADH 81</td><td>52.90</td><td>53.80</td><td colspan="4"></td><td>59</td><td>22</td><td>4.0</td></tr>
</table>

4.0 SITE CONDITIONS

4.1 Published Geology

The 1:250,000 Cue geological map indicates that the White Well site is underlain by Quaternary age colluvial and alluvial and Tertiary age laterite deposits.

4.2 Geomorphology

The geomorphology of the project area comprises a localised low point, gently sloped ground surfaces and few shallowly incised drainage paths. A mine pit and waste dump are present near the proposed tailings storage facility on the eastern and southern sides (respectively).

Minor local thin layers of non-engineered fill is present at various locations about the existing mine area which are likely to have been placed during the previous mining activities.

The ground surface elevations at the project site range from 475 to 485m AHD.

4.3 Groundwater Conditions

No groundwater was encountered in the test pits excavated during the site investigations. Water is noted as being present in the base of the existing open pit, however, it is not known if this is groundwater or surface water ponding in the base of the pit.

Groundwater and in-situ permeability analysis was not possible at the time of the site investigation.

Groundwater levels are anticipated to be similar to the pre commissioned state of the Dames and Moore Report, at approximately 25 to 30m below ground surface. The laterised zone was observed to contain abundant sub-horizontal defects, as pictured, (Appendix A). As a result, the permeability of the laterised zone is anticipated to be in the order of 1×10^{-5} m/s.

The remoulded kaolin falling head permeability test results indicate a relatively low permeability in the order of 1×10^{-8} m/s.

4.4 Subsurface Conditions

Based on the 4DG site investigations described above, the excavatable depths of the surficial materials ranged from 0.1 to 0.9 m with the use of the 30 tonne excavator and refusing on the ferricrete, as such, information regarding the depth to the base of the ferricrete was not able to be obtained directly under the proposed facility. Observations of the mine pit wall indicate that the depth of the laterised zone varied and was typically in the order of 2 to 3 metres bgs with a maximum depth of approximately 5 metres. It is therefore inferred that the cut off trench depth is likely to vary, and the actual depth it is required to be excavated to should be confirmed during construction.

Typical descriptions of the sub-surface materials are as follows:

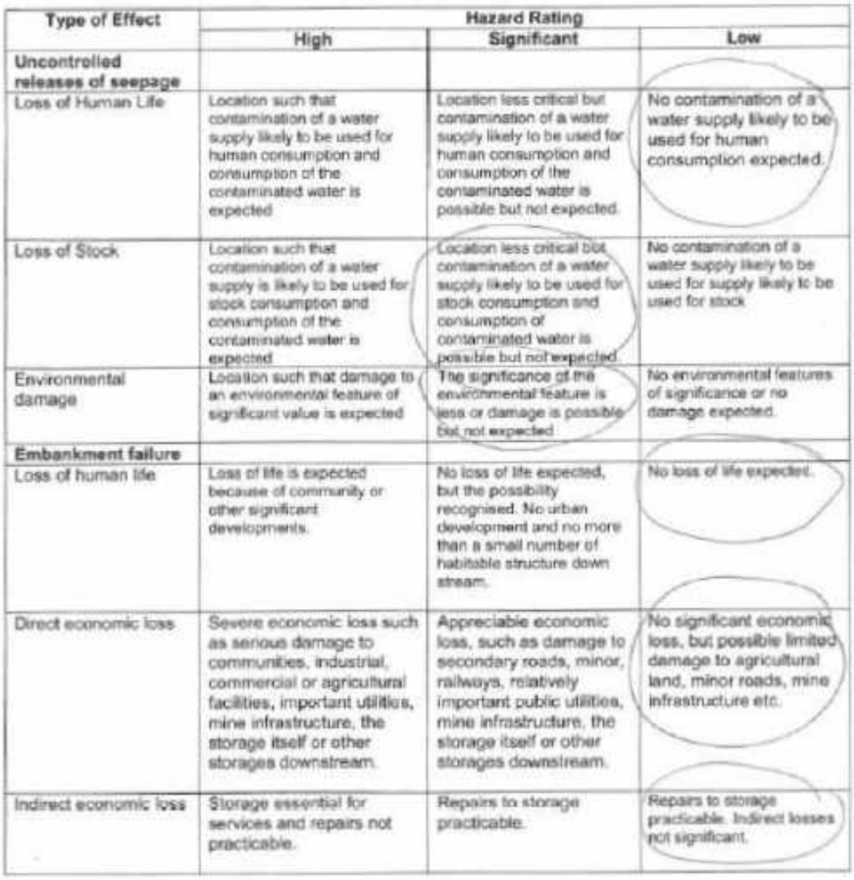
- **Local wash materials:** locally occurred in or adjacent to ephemeral wash channels and typically comprised sandy gravelly SILT; low plasticity, red brown, dry, firm.
- **Laterised zone:** the deposits typically comprised silty sandy Gravel, fine to coarse grained, sub-angular, dry to moist, dense to very dense, reddish brown, slightly cemented (increasing with depth). Thickness typically 0.5 to 1.0m.
- **Ferricrete:** low to medium strength, reddish yellowish brown, moderately cemented, thinly bedded with a gradational lower contact. There are many sub-horizontal curved, rough defects throughout this unit. The defects have lengths of between 2 and 3m. This unit is interpreted to have formed by iron cementation of the overlying gravel laterite zone. Two discrete channelised laterite deposits were observed. The ferricrete of the laterite zone was generally very low to low strength with abundant persistence sub-horizontal defects.

- **Kaolin:** the kaolin is generally a clayey Silt to clayey silt/siltstone, stiff to very low strength, medium plasticity, dry to moist, pale greyish white with widely spaced steeply dipping defects (generally quartz veins and minor faults). The Dames & Moore 1991 report indicates that this unit is up to 75m deep below the TSF site.

5.0 TSF HAZARD RATING CATEGORY

Based on the Hazard Rating classification as adopted by the Department of Mines and Petroleum (1999), the Hazard Rating is assessed to be "Low" to "Significant" as shown in Table 2 below.

Table 2: Basis of Hazard Rating: Mine Tailings Storage Facilities (after DoIR – OLQ, 1995a)



Type of Effect	Hazard Rating		
	High	Significant	Low
Uncontrolled releases of seepage			
Loss of Human Life	Location such that contamination of a water supply likely to be used for human consumption and consumption of the contaminated water is expected	Location less critical but contamination of a water supply likely to be used for human consumption and consumption of the contaminated water is possible but not expected	No contamination of a water supply likely to be used for human consumption expected.
Loss of Stock	Location such that contamination of a water supply is likely to be used for stock consumption and consumption of the contaminated water is expected	Location less critical but contamination of a water supply likely to be used for stock consumption and consumption of contaminated water is possible but not expected	No contamination of a water supply likely to be used for supply likely to be used for stock
Environmental damage	Location such that damage to an environmental feature of significant value is expected	The significance of the environmental feature is less or damage is possible but not expected	No environmental features of significance or no damage expected.
Embankment failure			
Loss of human life	Loss of life is expected because of community or other significant developments.	No loss of life expected, but the possibility recognised. No urban development and no more than a small number of habitable structure down stream.	No loss of life expected.
Direct economic loss	Severe economic loss such as serious damage to communities, industrial, commercial or agricultural facilities, important utilities, mine infrastructure, the storage itself or other storages downstream.	Appreciable economic loss, such as damage to secondary roads, minor, railways, relatively important public utilities, mine infrastructure, the storage itself or other storages downstream.	No significant economic loss, but possible limited damage to agricultural land, minor roads, mine infrastructure etc.
Indirect economic loss	Storage essential for services and repairs not practicable.	Repairs to storage practicable.	Repairs to storage practicable. Indirect losses not significant.

Table 3: Hazard Rating/Height Matrix to derive TSF Category

		TSF		
Hazard Rating		**High**	**Significant**	**Low**
Embankment Height	>15 m	1	1	1
	5-15 m	1	2	2
	< 5 m	1	2	3

The White Wells TSF is designed for a maximum height of 15 m. Based on Tables 2 and 3, the proposed TSF has a Category 2 hazard rating.

5.1 Category 2 TSF Requirements

The Department of Mines and Petroleum (1999) requirements for a Category 2 TSF are summarised as;

- Completion of a Tailings Data Storage Sheet,

- Preparation of design report by Geotechnical or Engineering specialist,
- Brief construction report with as built drawings,
- Inspection and audit every 2 years by Geotechnical or Engineering specialist,
- Inspection and decommissioning report by Geotechnical or Engineering specialist,
- Provision of an emergency action plan, and
- Routine daily inspection by site personnel.

This report covers the requirements of the geotechnical design report. The other aspects noted above will be conducted by others or in the future if requested.

6.0 STABILITY ANALYSES

6.1 General

Stability analyses have been undertaken based upon the proposed concepts from Cobra Mining and 4DG's experience with existing and previous TSF's in Western Australia.

Factors such as the geology and history of the site, proposed TSF geometries and expected groundwater conditions have been taken into account using the results of the investigations. Laboratory test data has been utilised to evaluate the soil strength parameters together with interpretations made from previous experience.

Stability analyses have been undertaken using the limit equilibrium program Slope/W. The program uses limit equilibrium analysis (the Morgenstern-Price method), with a half-sine inter-slice force function to ensure both moment and force equilibrium are satisfied. The lowest factor of safety in an analysis was assessed by searching through potential circular failure surfaces (grid and radius method).

Analyses were undertaken for the centreline and downstream construction methods.

The outputs from the slope stability analyses are presented in Appendix D.

6.2 Analysis Methodology

The stability criteria adopted for design are set out in Table 4.

Table 4: Stability Design Criteria

Design Event	Seismic Stability
Long term groundwater levels	g=0.9 PGA
FOS > 1.2	FOS > 1.0

The overall stability of a slope is expressed as the factor of safety (FOS), which is the ratio of the internal soil forces resisting instability to the driving forces causing instability. Theoretical failure of a slope is possible when the FOS is 1.0, while increasing values above 1.0 indicate improving stability/ a lower probability of failure.

We recommend the adoption of 0.04g as the design earthquake (90% of 0.05g) loading on the TSF based on the guidelines presented in Australian Standard, AS 1170.4-2007.

For conventional pseudo-static seismic analysis (for slope stability where a factor of safety is calculated) it is generally accepted that a lower horizontal ground acceleration (equal to 0.9 x PGA) may be adopted to account for the very short duration that the peak acceleration applies to the slope. Where the FOS for 0.9 PGA is above 1.0 then the likelihood of detectable slope movements is negligible to very small and the slope is often considered stable with no further analysis required. This is the criterion adopted for assessing slope instability under seismic loading for the TSF.

6.3 Analysis Cases

A typical cross section through the concept TSF embankment was analysed to assess the overall stability for both static and pseudo-static cases. Analyses considered global and localised stability for the TSF considering both upstream (towards the tailings) and downstream (outside slope) slip surfaces. These analyses were repeated for the initial starter dam as well as cases assessing the embankment during each stage (assumed 3 stages) of the construction process.

The groundwater levels within the TSF and embankment were modelled assuming that the embankment has high groundwater levels under long term operating conditions, i.e. for the most unfavourable combination expected.

For these analyses, representative soil parameters for the existing site conditions were selected after a careful appraisal of the investigation findings, laboratory testing and on the basis of our general experience. The soil strengths utilised are considered to be lower bound values and are presented in Table 5.

Table 5: Soil Strength Parameters

Material	**Bulk Density (kN/m^3)**	**Cohesion (kPa)**	**Phi (°)**
Coarse Tailings	15	0	25
Fine Tailings	12	0	15
Kaolin Fill	15	10	32
Insitu Ferricrete	18	5	35
Insitu Kaolin	15	10	30

6.4 Stability Analysis Results

The stability analysis results are presented in Table 6. These results show that for the TSF design presented in this report, the Factors of Safety against slope instability are within the adopted design criteria and the TSF as modelled has acceptable slope stability during construction, during operation, upon decommissioning and for the design seismic loading case.

The TSF design geometry is controlled by the downstream slope stability in the upper lift, and that the TSF embankment should have maximum batter slopes 2.5H:1V on the downstream side and 1.5H:1V on the upstream side with maximum stage heights of 5m before the tailings are deposited.

Table 6: Stability Analysis Results

Loading Condition	Construction Method	Factor Of Safety		
		Downstream		Upstream
		Static	Pseudo-Static	Static
Stage 1	Centreline Method	2.07	1.84	2.21
Stage 2		1.60	1.41	1.60
Stage 3		1.25	1.11	1.61
Stage 1	Downstream Method	2.07	1.84	2.21
Stage 2		1.51	1.34	2.21
Stage 3		1.30	1.14	2.21

The analyses have not identified any specific remediation works which are required, however, works should be carried out according to good engineering practise.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 Borrow Sources

7.1.1 Kaolin

Laboratory testing of the materials obtained from the site indicate that the materials from the existing waste dump and/or the insitu kaolin would provide suitable impervious core materials for the embankment dam and cut off trench. Permeability analyses of the sample obtained a result of 1.7×10^{-8} m/s. The Atterberg Limits obtained from the laboratory analysis classify the material as medium plasticity silt (MI), and the dispersivity of the soils is potentially a constraint on the dam design due to scour potential on the inside face of the embankment. This could be mitigated by the use of a thin layer of ferricrete.

Possible sources of kaolin are from the existing waste dump or from waste mined from the expanded open pit operations.

7.1.2 Laterite Surficial Deposits

The sandy gravels and cemented ferricrete deposits are anticipated to be suitable for use as a higher strength fill for scour protection. The ferricrete fill will provide additional strength to the embankment dam and prevent significant erosion of the outside embankment face.

Potential sources of this unit are from within the cut off trench, near surface within the open pit mine and possibly stripping from within the centre of the tailings dam. It is recommended that sufficient materials are stockpiled for use in the later stages of the TSF construction as it is raised to keep pace with the tailings deposition.

7.2 Foundation Preparation

All vegetation including roots within the footprint of the works shall be removed.

All topsoil (where encountered) within the footprint of the works should be stripped to a nominal depth of 100mm and be stockpiled or removed from site to a location agreed with the Engineer. As soon as practical after completion of sections of the earthworks, topsoil shall be respread to a minimum thickness of 100mm over disturbed ground.

7.3 Cut-off Trench

To prevent seepage beneath the TSF embankment, a cut off trench is required. The cut off trench should be excavated to depth of not less than 0.5 metres into the kaolin horizon. The embedment into the kaolin layer should be inspected by the client representative prior to backfill commencing. The cut off trench should have a minimum basal width of 3 m so that compaction of the backfill can be easily completed using "padfoot" compactors which are widely used in the construction industry.

Cut off trench cut batters should be constructed within the laterised zone and kaolin at a maximum slope of 1V:1H up to 6 m high to ensure the stability of the excavation during construction. Where signs of instability such as tension cracks or ground movement is detected, a suitably qualified and experienced engineer should inspect the excavations to ensure the works are conducted in a safe manner.

The cut off trench should be backfilled with kaolin fill placed in accordance with the recommendations given in Section 7.5.

7.4 Excavatability

During the geotechnical investigation, the 30 tonne excavator was unable to excavate through the ferricrete substrate. An excavation trial was conducted with the excavator on the edge of the existing mine open pit wall. Due to the sub horizontal defects within the ferricrete substrate the excavator was able to rip the through the ferricrete with difficulty (it should be noted that the pit wall may have been weakened by previous blast damage).

It is anticipated that a D10 dozer or equivalent will be able to rip the surficial deposits; however some drill and blast may be required.

7.5 Fill Placement

The kaolin fill is recommended to be placed in 350 mm thick (loose) layers and compacted to 92% MMDD at ± 2% of Optimum Moisture Content (OMC).

It is recommended that the Laterised Zone and Ferricrete fill be moisture conditioned to ± 2% OMC, placed in 500 mm thick (loose) layers and compacted with 8 passes of a 16 tonne "padfoot" compactor or similar.

The TSF embankment should have batter slopes 2.5H:1V on the downstream side and 1.5H:1V on the upstream side with maximum staging heights of 5m before the tailings are filled to within 1.5m of the dam crest.

REFERENCES

1. Government of Western Department of Mines and Petroleum Environment, May 1999, *Safe Design and Operating Standards for Tailings Storage*, Perth, WA.
2. Dames & Moore, December 1991, Final Report – Geotechnical Investigation White Well Prospect Tuckabianna Gold Mine, Dames & Moore Proprietary Limited, South Perth, WA.

APPENDIX A

Site Photographs

Photograph 1: View of pit (facing northeast, 2/02/2012).

Photograph 2: View of pit (facing south, 2/02/2012).

Photograph 3: View of starter pit wall (facing northwest, 2/02/2012).

Photograph 4: Sandy gravel soil overlying ferricrete, note two distinct ferricrete substrate (2/02/2012).

Photograph 5: Laterite zone underlain by pale grey stiff to very stiff clayey silt (2/02/2012)

Photograph 6: Ripping trial of laterite zone (3/02/2012)

APPENDIX B

Test Pit Logs

Explanation and key for exploratory hole logs

SOIL DESCRIPTION:

1. Material is described as a soil if it can be remoulded or disintegrated by hand or in water. Soils described in the logs have been assessed by visual and tactile methods and have generally been described in accordance with AS1726 – 1993.
2. The soil name is based on particle size distribution and plasticity, which is summarised in the table below.
3. Soil fractions are based on estimated mass.
4. The smallest particle visible to the naked eye is approximately 0.075mm.
5. The order of the soil name is given as: **secondary component, tertiary component, PRIMARY COMPONENT.** If the origin of the soil can be deduced it is included at the end of the description.

SOIL CLASSIFICATION, IDENTIFICATION AND DESCRIPTION:

Major divisions		Particle size	Typical name		Group symbol	
COARSE GRAINED SOILS (>50% of material <63mm is >0.075mm)	Boulders	200mm			BO	▨
	Cobbles	60mm			CO	▨
	Gravel >50% of coarse fraction is >2.36mm	Coarse 20mm	Clean gravels	Well graded gravel, gravel-sand mixtures, little or no fines	GW	▨
		Medium 6mm		Poorly graded gravels, gravel-sand mixtures, little or no fines	GP	▨
		Fine 2.36mm	Gravels with fines	Silty gravels, gravel-sand-silt mixtures	GM	▨
				Clayey gravel, gravel-sand-clay mixtures	GC	▨
	Sand >50% of coarse fraction is <2.36mm	Coarse 0.6mm	Clean sands	Well graded sands, gravelly sands, little or no fines	SW	▨
		Medium 0.2mm		Poorly graded sands, gravelly sands, little or no fines	SP	▨
		Fine 0.075mm	Sands with fines	Silty sands, sand-silt mixtures	SM	▨
				Clayey sands, sand-clay mixtures	SC	▨

Major divisions			Dry Strength	Dilatancy	Toughness	Typical name	Group symbol	
FINE GRAINED SOILS (>50% of material is <0.075mm)	Silt and Clays	LL<50%	None to low	Quick to slow	None	Inorganic silts, rock flour, silty or clayey fine sands, clayey silts with slight plasticity	ML	▨
			Medium to high	None	Medium	Inorganic clays of low to medium plasticity gravelly clays, sandy clays, silty clays, lean clays	CL/CI	▨
			Low to medium	Slow to very slow	Low	Organic silts and organic silty clays of low plasticity	OL	▨
		LL>50%	Low to medium	Slow to very slow	Low to medium	Inorganic silts, clayey silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	▨
			High	None	High	Inorganic clays of high plasticity, fat clays	CH	▨
			Medium to high	None	Low to medium	Organic clays and silty clays of medium to high plasticity, organic silts	OH	▨
	Highly organic soils		Peat and other highly organic soils. Identified by colour, odour, spongy feel and generally by fibrous texture				Pt	▨

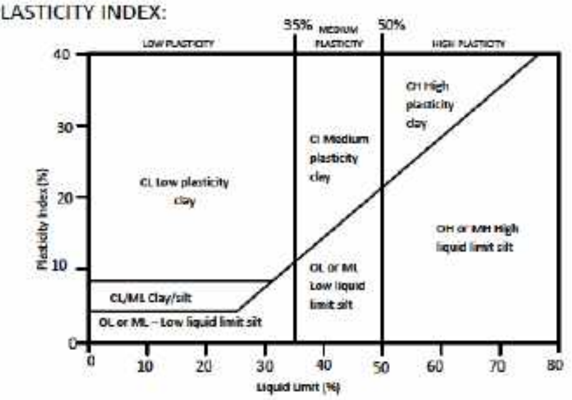
MINOR COMPONENTS:

Coarse grained soils		Fine grained soils	
% fines	Term	% coarse	Term
≤5	Omit, or use 'trace of'	≤15	Omit, or use 'trace of'
>5 and ≤12	Use 'with' clay/silt as applicable	>15 and ≤30	Use 'with' sand/gravel as applicable
>12	Use 'silty' or 'clayey' as a secondary or tertiary component	>30	Use 'sandy' or 'gravelly' as secondary or tertiary component

MOISTURE:

Symbol	Term
D	Dry
M	Moist
W	Wet

PLASTICITY INDEX:



SOIL DESCRIPTION (CONT):

SOIL STRUCTURE:

Zoning	Cementing	Defects
LAYERS: zone is continuous across exposure or sample	WEAKLY CEMENTED: particle aggregations can be easily fractured by hand when soil is saturated	FISSURE: An extensive, break or fracture, usually seen in cohesive soils.
LENSES: discontinuous layer of different material, with lenticular shape	MODERATELY CEMENTED: particle aggregations can be fractured by strong hand pressure when soil is saturated	CRACK: Generally formed near to the surface from the desiccation of medium to high plasticity clays in an irregular polygon pattern.
POCKETS: an irregular inclusion of different material	STRONGLY CEMENTED: particle aggregations cannot be fractured by hand pressure when soil is saturated. The soil has assumed rock properties and should be described in accordance with the AS1726 – 1993 classification for rocks	SHEARED SURFACE: A near planar surface in clayey soil. A polished or slickensided surface indicates movement has occurred along the defect, often only a small amount of motion has occurred.

CONSISTENCY OF COHESIVE SOILS:

Symbol	Term	Undrained shear strength (kPa)	Field guide
VS	Very soft	<12	Exudes between the fingers when squeezed in hand.
S	Soft	12 – 25	Can be moulded by light finger pressure.
F	Firm	25 – 50	Can be moulded by strong finger pressure.
ST	Stiff	50 - 100	Cannot be moulded by fingers, can be indented by thumb.
VSt	Very stiff	100 - 200	Can be indented by thumb nail.
H	Hard	>200	Can be indented with difficulty by thumb nail.

DENSITY OF GRANULAR SOILS:

Symbol	Term	Density Index (%)	SPT N-value
VL	Very loose	≤15	0-4
L	Loose	>15 - ≤35	4-10
MD	Medium dense	>35 - ≤65	10-30
D	Dense	>65 - ≤85	30-50
VD	Very dense	>85	>50

Note: The SPT correlations are not stated in AS1726 – 1993 and they may be subject to corrections for overburden and type of equipment used.

ROCK DESCRIPTION:

1. Material is described as a rock if it cannot be remoulded or disintegrated by hand or in water. Rocks described in the logs have been assessed by visual and tactile methods and have generally been described in accordance with AS1726 – 1993.
2. The rock type is based on Table A6(a) and (b) given in AS1726 - 1993.
3. Rock material is the consolidated and cemented assemblage of mineral particles that form the intact blocks between discontinuities in the rock mass. The strength terms given below refer to the rock material. For anisotrophic rocks the strength terms refer to the strength perpendicular to any anisotrophy.
4. Rock mass is described in terms of the rock material and the discontinuities that make up the rock mass.
5. Defects are any discontinuity or break in the continuity of a material.
6. Materials divided by a broken line(- - - - -)indicates an unclear boundary.
7. Fracture frequency is the number of natural fractures present in 1.0m of core. If a strata length is less than 1.0m then the number of fractures is normalised to 1.0m.
8. The colour is described in the moist condition.

PARTICLE SIZE:

Term	Grain size for sandstone	Mineral size for metamorphic and igneous rocks
Coarse grained	0.6mm to 2mm (if greater then rock is a conglomerate)	>2mm
Medium grained	0.2mm to 0.6mm	0.06mm to 2mm
Fine grained	0.06mm (if less then rock is a siltstone) to 0.2mm	< 0.06mm

FABRIC:

Term	Description
Massive	A homogenous rock with no layering or penetrative fabric (e.g. bedding, foliation, cleavage).
Bedding	Characteristic fabric of sedimentary rocks where layers of differing composition or grain size have been deposited on top of each other.
Foliation	The layered characteristics of metamorphic rocks. Can be structural, compositional or textural.

WEATHERING:

Symbol	Term	Field guide
RS	Residual soil	Mass structure and fabric no longer evident.
XW	Extremely weathered rock	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded in water.
DW	Distinctly weathered rock	Rock strength usually changed by weathering, may be highly discoloured.
SW	Slightly weathered rock	Rock is slightly discoloured but shows little or no change of strength of fresh rock.
FR	Fresh rock	Rock shows no sign of decomposition or staining.

STRENGTH:

Symbol	Term	Point Load Index (MPa), I_s50	Field guide
EL	Extremely low	≤0.03	Easily remoulded by hand to a material with soil properties. (Therefore the material should be described as a soil).
VL	Very low	>0.03 and ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife.
L	Low	>0.1 and ≤0.3	Easily scored with a knife; indentations 1-3mm show in specimen with firm blows of pick point.
M	Medium	>0.3 and ≤1.0	Readily scored with knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
H	High	>1.0 and≤3.0	A piece of core 150mm long and 50mm diameter cannot be broken by hand, but can be broken by a single firm blow from a pick.
VH	Very high	>3.0 and ≤10.0	Hand specimen breaks with pick after more than one blow. Rock rings under hammer.
EH	Extremely high	>10.0	Specimen requires many blows with geological pick to break through intact material. Rock rings under hammer.

MECHANICAL LOG:

TCR = Total Core Recovery (%) – ratio of length of core recovered to length of core drilled.
RQD: Rock Quality Designation (%) – ratio of length of full diameter core recovered in pieces of 100mm or longer to length of core drilled.

All lengths used to determine rock core mechanical properties have been taken along the centreline of the core. Obvious drilling induced fractures have been ignored.

ROCK DESCRIPTION (CONT):

DEFECT TYPE:

Symbol	Term
BG	Bedding
BP	Bedding plane parting
CN	Contact
CV	Cleavage
CZ	Crushed zone
DI	Drilling induced
DZ	Decomposed zone
FT	Fault
FZ	Fault zone
HJ	Healed joint
JN	Joint
SC	Schistosity
SR	Shear plane
SZ	Shear zone
VN	Vein
XN	Foliation

DEFECT COATING:

Symbol	Term
CN	Clean
CT	Coating
SN	Stain
VR	Veneer
FILLED	In filled

DEFECT INFILL:

Symbol	Term
CA	Calcite
CB	Carbonaceous material
CL	Clay
FE	Iron oxide
FE Clay	Iron oxide clay
G	Gravel
KT	Chlorite
LM	Limonite
MS	Secondary mineral
PY	Pyrite
RF	Rock fragments
SU	Sulphides
QZ	Quartz

DEFECT SHAPE:

Symbol	Term
PL	Planar
C	Curved
U	Undulating
St	Stepped
I	Irregular
DIS	Discontinuous

DISCONTINUITY ORIENTATION:

alpha (α):	the acute angle between the core axis and the long axis of ellipse (i.e. the bedding or foliation plane), between 0-90°
beta (β):	the angle between a reference line along the core and the ellipse apical trace measured in a clockwise sense (0-360°)

DEFECT ROUGHNESS:

Symbol	Term
VR	Very rough
R	Rough
SR	Slightly rough
S	Smooth
P	Slickenside

INVESTIGATION INFORMATION:

SPT TEST:

SPT	Standard Penetration Test, these have been carried out in accordance with AS1289.6.3.1 – 1993.
2,8,12 N=20	2,8,12 are the number of blows per 150mm of penetration. N value is the number of blows to complete a test drive of 300mm after a seating drive of 150mm, using a split spoon.
$N_c = 20$	The number of blows to complete a test drive of 300mm after a seating drive of 150mm, using a 50mm diameter, 60° solid cone.
30/72mm	Where refusal has occurred in accordance with the Australian Standard then the number of blows and penetration for that interval are reported.
Uncorrected	The stated N value has not been corrected in regards to depth, overburden, skin friction or other factors.
R	Refusal

DRILLING DETAILS:

R_1, R_2	Core run number
EOH	End of hole
EOP	End of pit
TD	Termination depth
CAS	Depth to base of casing
AD/T	Auger drilling with tc-bit
AV/V	Auger drilling with v-bit
AS	Auger screwing
B	Bulldozer blade
CPT	Cone penetration test
CT	Cable tool
DCP	Dynamic cone penetration test
E	Excavator
HA	Hand auger
HQ3	Diamond drilling with an HQ3 core barrel (core 61.1mm)
N	Natural exposure
NQ3	Diamond drilling with a NQ3 core barrel (core 45.0mm)
PQ3	Diamond drilling with a PQ3 core barrel (core 83.0mm)
R	Ripper
RR	Rock roller
X	Existing excavation

SAMPLING:

D	Small disturbed sample
B	Bulk disturbed test (approx 20kg)
LB	Large bulk sample (approx 40kg)
U	Undisturbed sample
ES	Environmental sample
W	Water sample
C	Core sample
BLK	Block sample

TESTING:

PSP	Perth sand penetrometer
FV	Field shear vane (kPa)
PP	Pocket penetrometers (kPa)
T	Triaxial test (kPa)
UCS	Unconfined compressive strength test (MPa)
PI	Plasticity Index (%)
LL	Liquid limit (%)
LS	Linear shrinkage (%)
NMC	Natural moisture content (%)
OMC	Optimum moisture content (%)
PSD	Particle size distribution (% passing)
CBR	Californian bearing ratio (%)
MMDD	Maximum modified dry density (t/m3)
MDCS	Maximum dry compressive strength (kPa)
$I_{s}50$	Point load index (MPa)

GROUNDWATER LEVELS:

Groundwater not observed – the observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the drillhole/test pit.

Groundwater not encountered – the drillhole/test pit was dry soon after excavation. However groundwater could be present in less permeable strata. Inflow may have been observed had the exploratory hole been left open for a longer period.

Ground water level:	▽	Groundwater inflow:	▷—
Groundwater rise:	$\overset{1}{\nabla}$	Groundwater outflow:	—◁
Seepage:	≈		

Location: 617032 **E** 6970055 **N** **RL:** 483.5m
Equipment: 30T Excavator
Date Logged: 2/02/2012
Logged By: MDH
TP No. TP001

Depth (m)	Site and Material Description	Laboratory Test Results
	FERRICRETE, very low strength, moderately cemented, red brown (iron cemented clayey sandy gravel) **EOP: 0.10 m (Refusal on ferricrete)**	Not sampled
1.0		
2.0		
3.0		
4.0		

Photograph

Location: 617078 **E** 6970192 **N** **RL:** 483.0m
Equipment: 30T Excavator
Date Logged: 2/02/2012
Logged By: MDH
TP No. TP002

Depth (m)	Site and Material Description	Laboratory Test Results
	Clayey gravelly SILT (TOPSOIL): Low fines, dark red brown, moist, firm, homogeneous soil structure.	**0.00 - 0.50 m: Sampled,(B) not tested**
	Ferricrete, extremely weak, moderately cemented, red brown (iron cemented gravelly sand). **EOP: 0.60 m (Refusal on ferricrete)**	
1.0		
2.0		
3.0		
4.0		

Photograph

Location: 617113 **E** 6970296 **N** **RL:** 483.0m
Equipment: 30T Excavator
Date Logged: 2/02/2012
Logged By: MDH
TP No. TP003

Depth (m)	Site and Material Description	Laboratory Test Results
	Sandy silty GRAVEL (GC-GM): Fine to medium grained, rounded, low fines, dark red brown, dry, medium dense becoming very dense, homogeneous soil structure. Pisolitic, non becoming weakly cemented. **EOP: 0.60 m (Refusal on cemented gravel)**	**0.00 - 0.60 m: Sampled,(B) not tested**
1.0		
2.0		
3.0		
4.0		

Photograph

Refer to Explanation Sheets for Classification System

Depth (m) **Graphic Log**

Location: 617226 **E** 6970233 **N** **RL:** 481.0m

Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 2/02/2012

Logged By: MDH

TP No. TP004

Site and Material Description

Sandy gravelly **SILT (TOPSOIL)**: Low fines, pale red brown, dry, soft, homogeneous soil structure.

Silty sandy GRAVEL (GM): Fine to medium grained, sub-angular to sub-rounded, low fines, red brown, dry, dense, homogeneous soil structure. Mottled pale grey. Weakly becoming moderately cemented.

EOP: 0.90 m (Refusal on cemented gravel)

0.40 - 0.90 m: Sampled,(B) not tested

1.0 2.0 3.0 4.0

Photograph

Depth (m) **Graphic Log**

Location: 617344 **E** 6970149 **N** **RL:** 480.0m

Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 3/02/2012

Logged By: MDH

TP No. TP005

Site and Material Description

Sandy gravelly **SILT (TOPSOIL)**: Low fines, pale red brown, dry, soft, homogeneous soil structure.

Ferricrete, very low strength, red brown mottled pale grey and purple, (iron cemented iron cemented sandy fine to medium GRAVEL, sub-angular to sub-rounded).

EOP: 0.30 m (Refusal on ferricrete)

Not sampled

1.0 2.0 3.0 4.0

Photograph

Depth (m) **Graphic Log**

Location: 617452 **E** 6970087 **N** **RL:** 479.0m

Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 3/02/2012

Logged By: MDH

TP No. TP006

Site and Material Description

Sandy gravelly **SILT (TOPSOIL)**: Low fines, pale red brown, dry.

Silty sandy GRAVEL (GM): Fine to medium grained, sub-angular to rounded, low fines, red brown, moist. Pisolitic.

EOP: 0.30 m (Refusal on cemented gravel)

0.20 - 0.30 m: Sampled,(B) not tested

1.0 2.0 3.0 4.0

Photograph

Refer to Explanation Sheets for Classification System

Location: 617376 **E** 6970004 **N** **RL:** 480.0m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP007

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results	Photograph
		Sandy gravelly SILT (TOPSOIL): Low fines, pale red brown, dry.	Not sampled	
		Silty sandy GRAVEL (GM): Fine to medium grained, sub-angular to rounded, low fines, red brown, moist.		
1.0		**EOP: 0.40 m (Refusal on cemented gravel)**		
2.0				
3.0				
4.0				

Location: 617297 **E** 6969923 **N** **RL:** 480.5m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP008

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results	Photograph
		Sandy gravelly SILT (TOPSOIL): Low fines, pale red brown, dry.	**0.20 - 0.50 m: Sampled,(B) not tested**	
		Silty sandy GRAVEL (GM): Fine to medium grained, sub-angular to rounded, low fines, red brown, moist.		
1.0		**EOP: 0.50 m (Refusal on cemented gravel)**		
2.0				
3.0				
4.0				

Location: 617213 **E** 6969806 **N** **RL:** 480.5m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP009

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results	Photograph
		Clayey gravelly SAND (FILL): Coarse to coarse grained, pale orangeish brown, m, medium dense, lensed soil structure.	**0.00 - 0.80 m: Sampled,(B) not tested**	
1.0		**Sandy silty GRAVEL (GC-GM)**: Fine to coarse grained, sub-angular to sub-rounded, low fines, reddish brown, w, very dense, homogeneous soil structure. Mottled yellow brown.		
		EOP: 0.90 m (Refusal on cemented gravel)		
2.0				
3.0				
4.0				

Refer to Explanation Sheets for Classification System

Location: 617107 **E** 6969848 **N** **RL:** 482.0m
Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 3/02/2012
Logged By: MDH

TP No. TP010

Site and Material Description

Sandy clayey GRAVEL with cobbles (FILL): Fine to coarse grained, sub-angular, medium fines, pale pink brown, dry, dense, homogeneous soil structure.

Sandy cobbley GRAVEL with silt (GW): Fine to coarse grained, sub-angular to rounded, low fines, red brown, dry, very dense, homogeneous soil structure. becoming weakly cemented.

EOP: 0.50 m (Refusal on cemented gravel)

Not sampled

Photograph

Depth (m): 1.0 2.0 3.0 4.0

Location: 616987 **E** 6969840 **N** **RL:** 483.5m
Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 3/02/2012
Logged By: MDH

TP No. TP011

Site and Material Description

Sandy clayey GRAVEL with cobbles (FILL): Fine to coarse grained, angular to sub-angular, low fines, pale pink brown, dry, medium dense.

Gravelly sandy SILT with clay (FILL): Medium fines, pale grey white, dry, firm.

Sandy silty GRAVEL (GC-GM): Sub-rounded to rounded, low fines, red brown, very dense. becoming moderately cemented.

EOP: 0.70 m (Refusal on cemented gravel)

Not sampled

Photograph

Depth (m): 1.0 2.0 3.0 4.0

Location: 617024 **E** 6969934 **N** **RL:** 483.0m
Equipment: 30T Excavator

Laboratory Test Results

Date Logged: 3/02/2012
Logged By: MDH

TP No. TP012

Site and Material Description

Gravelly clayey SAND (FILL): Fine to coarse grained, sub-angular, medium fines, pale pink brown, dry, medium dense, homogeneous soil structure.

Sandy silty GRAVEL (GC-GM): Fine to medium grained, sub-angular to rounded, low fines, red brown, m, dense, homogeneous soil structure. Weakly becoming moderately cemented.

EOP: 0.30 m (Refusal on cemented gravel)

Not sampled

Photograph

Depth (m): 1.0 2.0 3.0 4.0

Refer to Explanation Sheets for Classification System

Location: 617047 **E** 6969977 **N** **RL:** 484.5m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP013

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results
1.0 2.0 3.0		**Clayey SILT with sand and gravel (FILL)**: Angular, medium to high fines, pale grey white, dry, soft, homogeneous soil structure.	**0.00 - 3.00 m:** **LL=47%, PL=34%, PI=13%** **LS = 2.5%** **NMC = 2%** **MMDD = 1.66t/m^3 OMC = 13%** **% Passing 37.5mm: 100** **% Passing 2.36mm: 94** **% Passing 0.075mm: 83**
		FERRICRETE, very low strength, red brown, moderately cemented (iron cemented sandy silty GRAVEL).	
4.0		**EOP: 3.30 m (Refusal on ferricrete)** Site Description: Waste Dump.	

Photograph

Location: 617006 **E** 6969818 **N** **RL:** 485.0m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP014

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results
1.0 2.0 3.0		**Clayey SILT with sand and trace gravel (FILL)**: Medium fines, pale grey white, dry, soft, homogeneous soil structure.	**0.00 - 3.80 m:** **Sampled,(B) not tested**
4.0		**EOP: 3.80 m (Refusal on ferricrete)** Site Description: Waste Dump.	

Photograph

Location: 617169 **E** 6969807 **N** **RL:** 485.0m
Equipment: 30T Excavator
Date Logged: 3/02/2012
Logged By: MDH
TP No. TP015

Depth (m)	Graphic Log	Site and Material Description	Laboratory Test Results
		Sandy silty GRAVEL with cobbles (FILL): Fine to coarse grained, angular to sub-angular, low fines, red bluish, dry, dense, homogeneous soil structure. Weakly cemented..	
1.0 2.0 3.0 4.0		**Clayey SILT with sand (FILL)**: Angular, medium fines, pale grey white, dry, soft, homogeneous soil structure.	**0.05 - 4.10 m:** **LL=48%, PL=35%, PI=13%** **LS = 1%** **NMC = 2.9%** **MMDD = 1.59t/m^3 OMC = 14.5%** **% Passing 37.5mm: 100** **% Passing 2.36mm: 98** **% Passing 0.075mm: 90**

Photograph

Refer to Explanation Sheets for Classification System

4DGeotechnics

APPENDIX C

Laboratory Test Certificates

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PERMEABILITY BY FALLING HEAD TEST REPORT

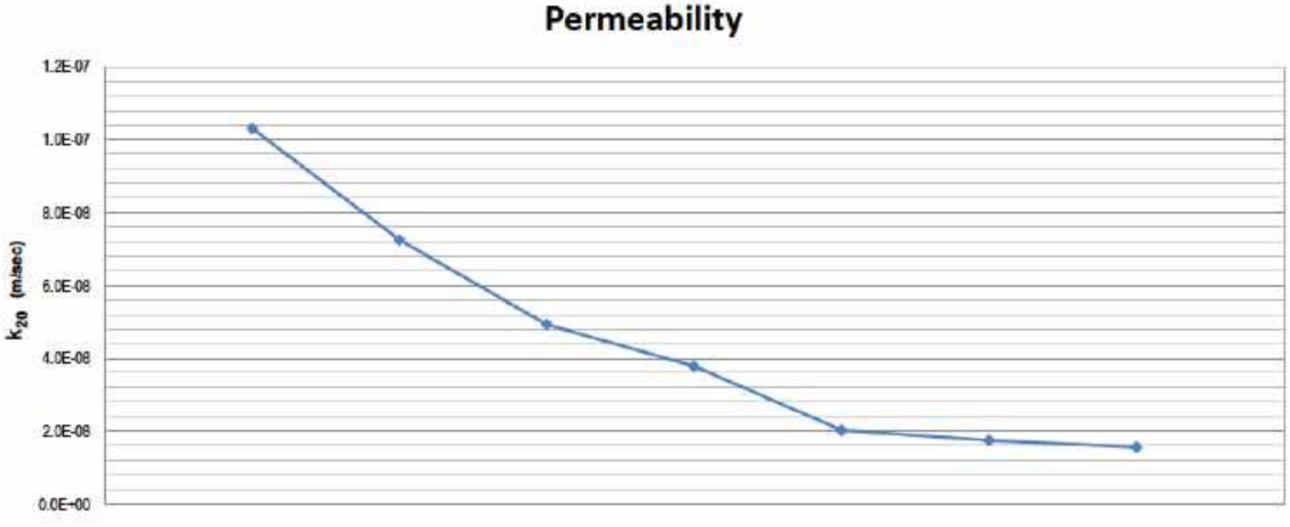
Test Method AS 1289 6.7.2, 5.1.1 , KH2 (Based on K H Head (1988) Manual of Laboratory Testing,10.7)

Client	Earth Materials Classification	**Report No.**	P 12030025-FHPT
Project	White Well TSF	**Test Date**	15/03/2012
		Report Date	21/03/2012
Client ID	R001 (OC12-0094)	**Depth (m)**	0.00-0.00
Descriptioi	CLAYEY SILT- pale grey	**Sample Type**	Disturbed

RESULTS OF TESTING

Compaction Method	**AS1289.5.1.1 - Standard Compaction**		
Maximum Dry Density (t/m^3)	1.60	Hydraulic Gradient	31.0
Optimum Moisture Content (%)	16.5	Surcharge (kPa)	0.0
Placement Moisture Content (%)	16.4	Head Pressure Applied (kPa)	12.16
Moisture Ratio (%)	99.4	Water Type	Distilled
Placement Wet Density (t/m^3)	1.52	Percentage Material Retained/Sieve Size (mm)	0 % on 19 mm
Density Ratio (%)	95.0	Sample Height and Diameter (mm)	40 by 61.7 mm

PERMEABILITY $k_{(20)}$ = **1.6E-08 (m/sec)**



Remarks: The above specimen was remoulded to a target of 98% of Modified Dry Density and at Optimum Moisture Content.

Sample/s supplied by client The compaction data was supplied by the client. Tested as received **Page: 1 of 1** REP36301

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[redacted]

NATA
TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Earth Materials Classification	**Report No.:**	P 12030025 - CU
Project:	White Well TSF	**Test Date:**	16/3/2012
		Report Date:	22/03/2012
Client Id.:	R001 (OC12-0094)	**Depth (m):**	0.00-0.00

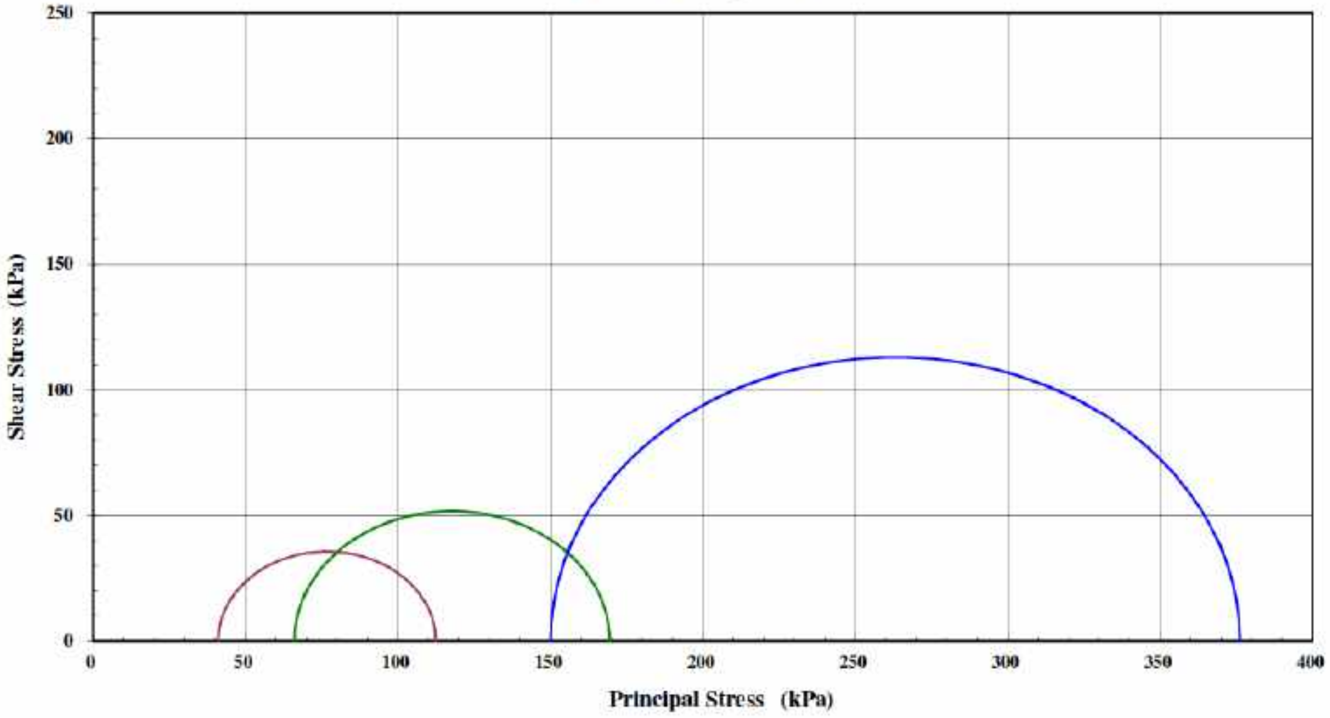
Description: CLAYEY SILT- pale grey

SAMPLE & TEST DETAILS

Initial Height:	127.2	mm	Initial Moisture Content:	16.8	%	Rate of Strain:	0.006	%/min
Initial Diameter:	63.0	mm	Final Moisture Content:	34.7	%	B Response:	97	%
L/D Ratio:	2.0 : 1		Wet Density:	1.82	t/m^3			
			Dry Density:	1.56	t/m^3			

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	6.2	2.2	3.5
Angle of Shear Resistance Φ' (Degrees) :	23.0	25.0	24.7

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

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[redacted]

Trilab Pty Ltd
ABN 25 065 630 506

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

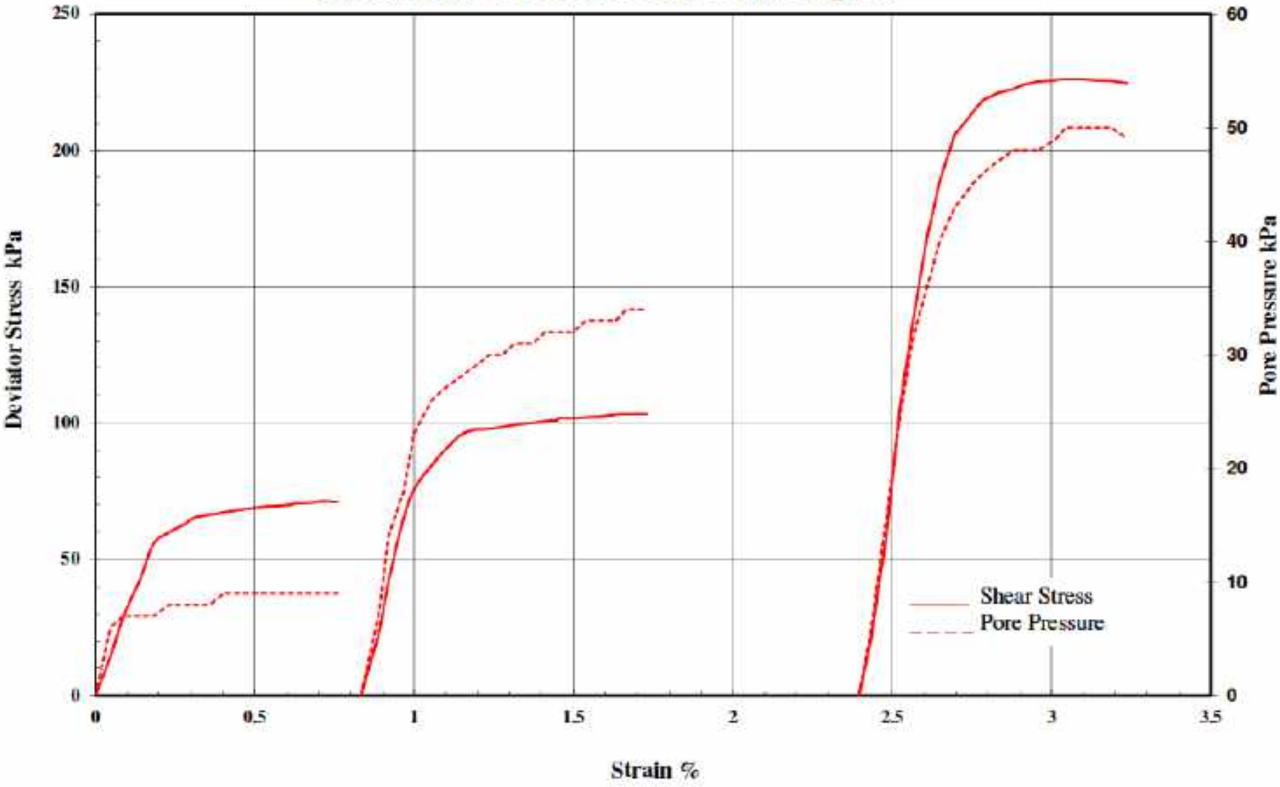
Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Earth Materials Classification	**Report No.:**	P 12030025 - CU
Project:	White Well TSF	**Test Date:**	16/3/2012
		Report Date:	22/03/2012
Client Id.:	R001 (OC12-0094)	**Depth (m):**	0.00-0.00
Description	CLAYEY SILT- pale grey		

Stress/Strain & PorePressure/Strain Diagram



FAILURE DETAILS

Confining Pressure	*Back Pressure*	*Initial Pore*	*Failure Pore*	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
551 kPa	501 kPa	501 kPa	510 kPa	112 kPa	41 kPa	2.740	71 kPa	0.71 %
606 kPa	506 kPa	506 kPa	540 kPa	169 kPa	66 kPa	2.567	103 kPa	1.67 %
710 kPa	510 kPa	510 kPa	560 kPa	376 kPa	150 kPa	2.508	226 kPa	3.05 %

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

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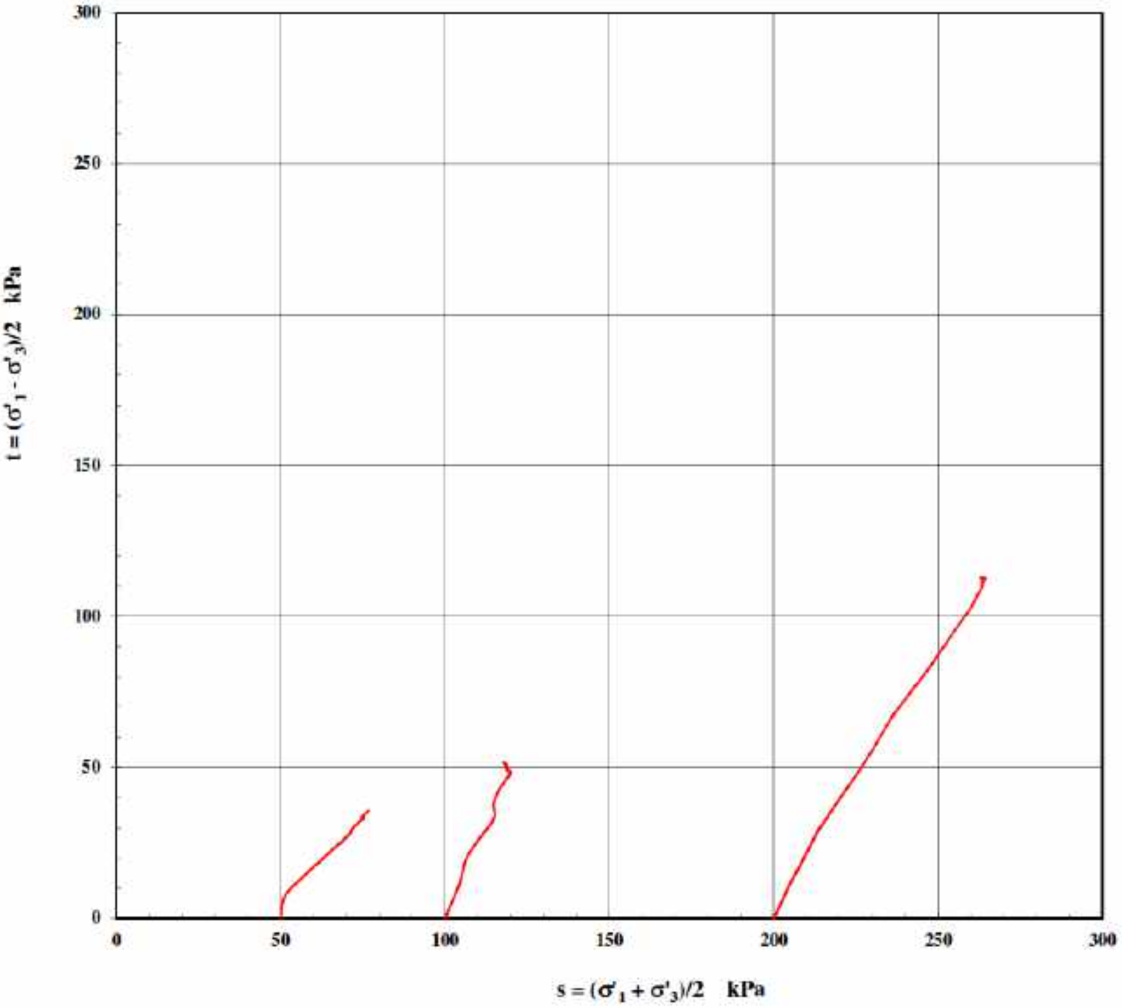
[redacted]

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Earth Materials Classification	**Report No.:**	P 12030025 - CU
Project:	White Well TSF	**Test Date:**	16/3/2012
		Report Date:	22/03/2012
Client Id.:	R001 (OC12-0094)	**Depth (m):**	0.00-0.00
Description	CLAYEY SILT- pale grey		

MIT Method - Effective Stress Path



Note: Graph not to scale.

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

[redacted]

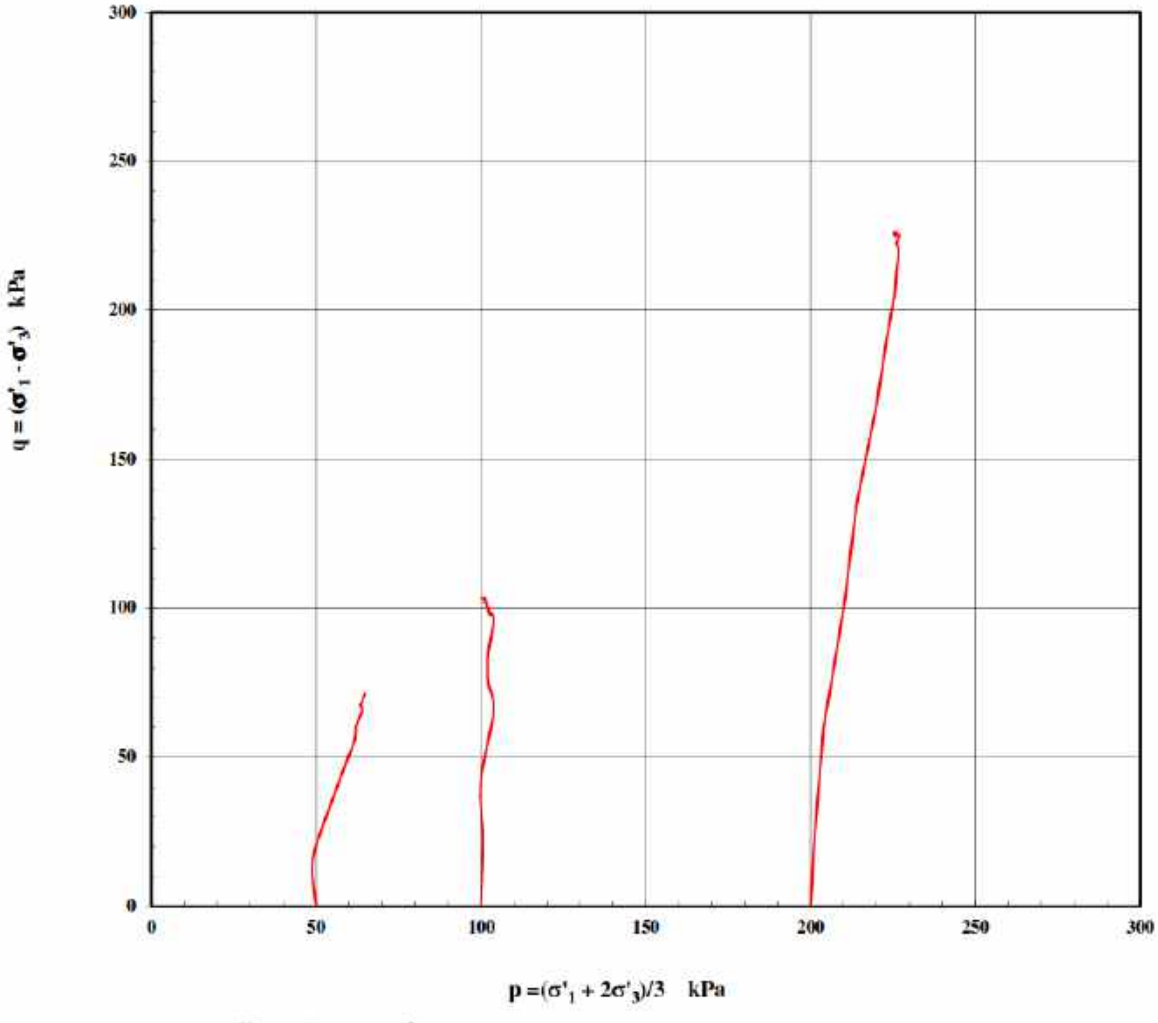
NATA Accredited Laboratory
Number 9926

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Earth Materials Classification	**Report No.:**	P 12030025 - CU
Project:	White Well TSF	**Test Date:**	16/3/2012
		Report Date:	22/03/2012
Client Id.:	R001 (OC12-0094)	**Depth (m):**	0.00-0.00
Description	CLAYEY SILT- pale grey		

Cambridge Method - Effective Stress Path



Note: Graph not to scale.

Sample Type:	Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content
Sample/s supplied by the client	Note: Graph not to scale

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NATA Accredited Laboratory
Number 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030025 - CU

Project: White Well TSF

Test Date: 16/3/2012

Report Date: 22/03/2012

Client Id.: R001 (OC12-0094)

Depth (m): 0.00-0.00

Description CLAYEY SILT- pale grey

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

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Number 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PERMEABILITY BY FALLING HEAD TEST REPORT

Test Method AS 1289 6.7.2, 5.1.1 , KH2 (Based on K H Head (1988) Manual of Laboratory Testing,10.7)

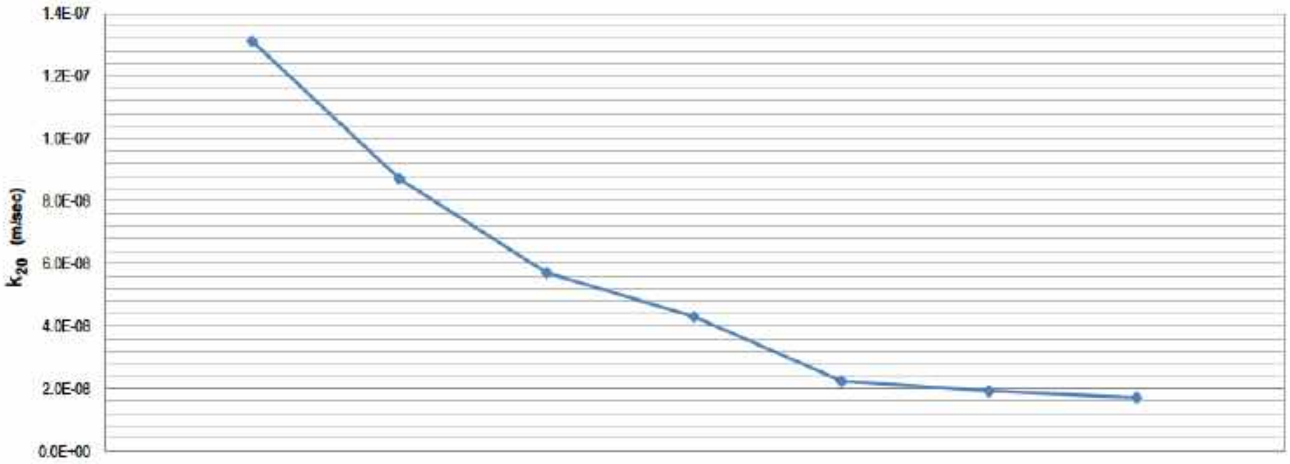
Client	Earth Materials Classification	**Report No.**	P 12030024-FHPT
Project	White Well TSF	**Test Date**	15/03/2012
		Report Date	21/03/2012
Client ID	TP013 (OC12-0092)	**Depth (m)**	0.00-3.00
Descriptio	CLAYEY SILT- pale grey	**Sample Type**	Disturbed

RESULTS OF TESTING

Compaction Method	**AS1289.5.1.1 - Standard Compaction**		
Maximum Dry Density (t/m^3)	1.66	Hydraulic Gradient	31.0
Optimum Moisture Content (%)	13.0	Surcharge (kPa)	0.0
Placement Moisture Content (%)	12.8	Head Pressure Applied (kPa)	12.16
Moisture Ratio (%)	98.7	Water Type	**Distilled**
Placement Wet Density (t/m^3)	1.66	Percentage Material Retained/Sieve Size (mm)	**0 % on 19 mm**
Density Ratio (%)	99.7	Sample Height and Diameter (mm)	**40 by 61.7 mm**

PERMEABILITY $k_{(20)}$ = **1.7E-08 (m/sec)**

Permeability



Remarks: The above specimen was remoulded to a target of 98% of Modified Dry Density and at Optimum Moisture Content.

Sample/s supplied by client The compaction data was supplied by the client. Tested as received **Page: 1 of 1** REP36301

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NATA
TECHNICAL COMPETENCE

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030024 - CU

Project: White Well TSF

Test Date: 16/03/2012

Report Date: 22/03/2012

Client Id.: TP013 (OC12-0092)

Depth (m): 0.00-3.00

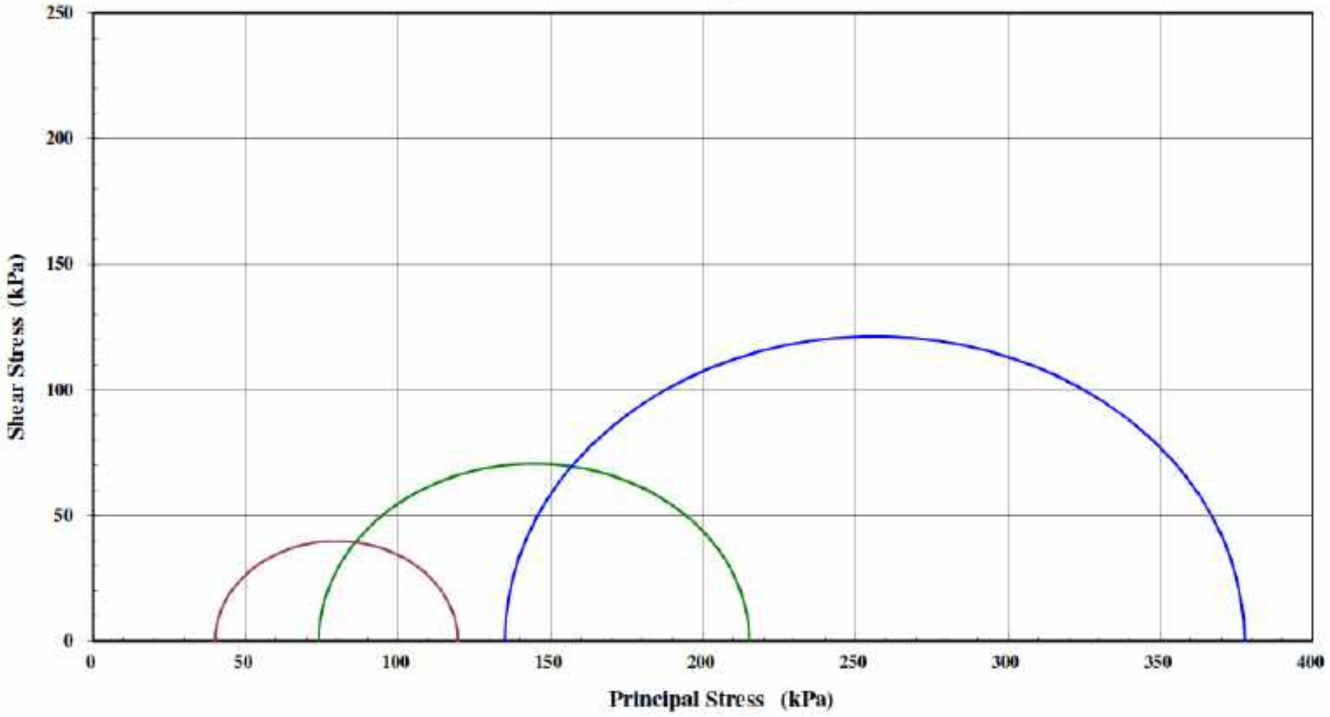
Description:

SAMPLE & TEST DETAILS

Initial Height:	127.2	mm	Initial Moisture Content:	13.9	%	Rate of Strain:	0.006	%/min
Initial Diameter:	63.2	mm	Final Moisture Content:	28.5	%	B Response:	97	%
L/D Ratio:	2.0 : 1		Wet Density:	1.81	t/m^3			
			Dry Density:	1.59	t/m^3			

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	2.1	5.6	3.8
Angle of Shear Resistance Φ' (Degrees) :	28.4	27.0	27.4

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

NATA
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NATA Accredited Laboratory Number 9926

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Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030024 - CU

Project: White Well TSF

Test Date: 16/03/2012

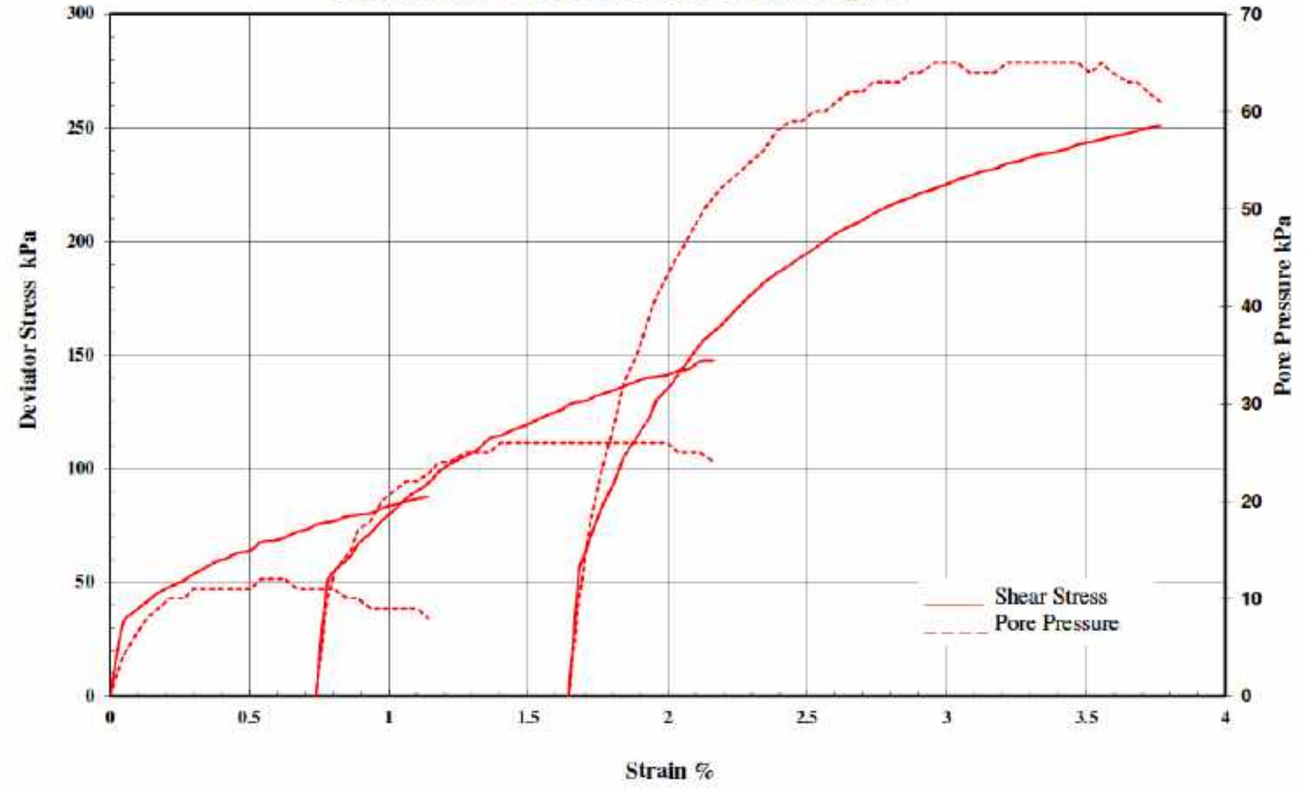
Report Date: 22/03/2012

Client Id.: TP013 (OC12-0092)

Depth (m): 0.00-3.00

Description

Stress/Strain & PorePressure/Strain Diagram



FAILURE DETAILS

Confining Pressure	*Back Pressure*	*Initial Pore*	*Failure Pore*	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
				σ'_1	σ'_3	σ'_1 / σ'_3		
555 kPa	505 kPa	505 kPa	514 kPa	120 kPa	40 kPa	2.990	80 kPa	0.89 %
605 kPa	505 kPa	505 kPa	530 kPa	215 kPa	74 kPa	2.908	141 kPa	2.00 %
706 kPa	506 kPa	506 kPa	569 kPa	378 kPa	135 kPa	2.797	243 kPa	3.47 %

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030024 - CU

Project: White Well TSF

Test Date: 16/03/2012

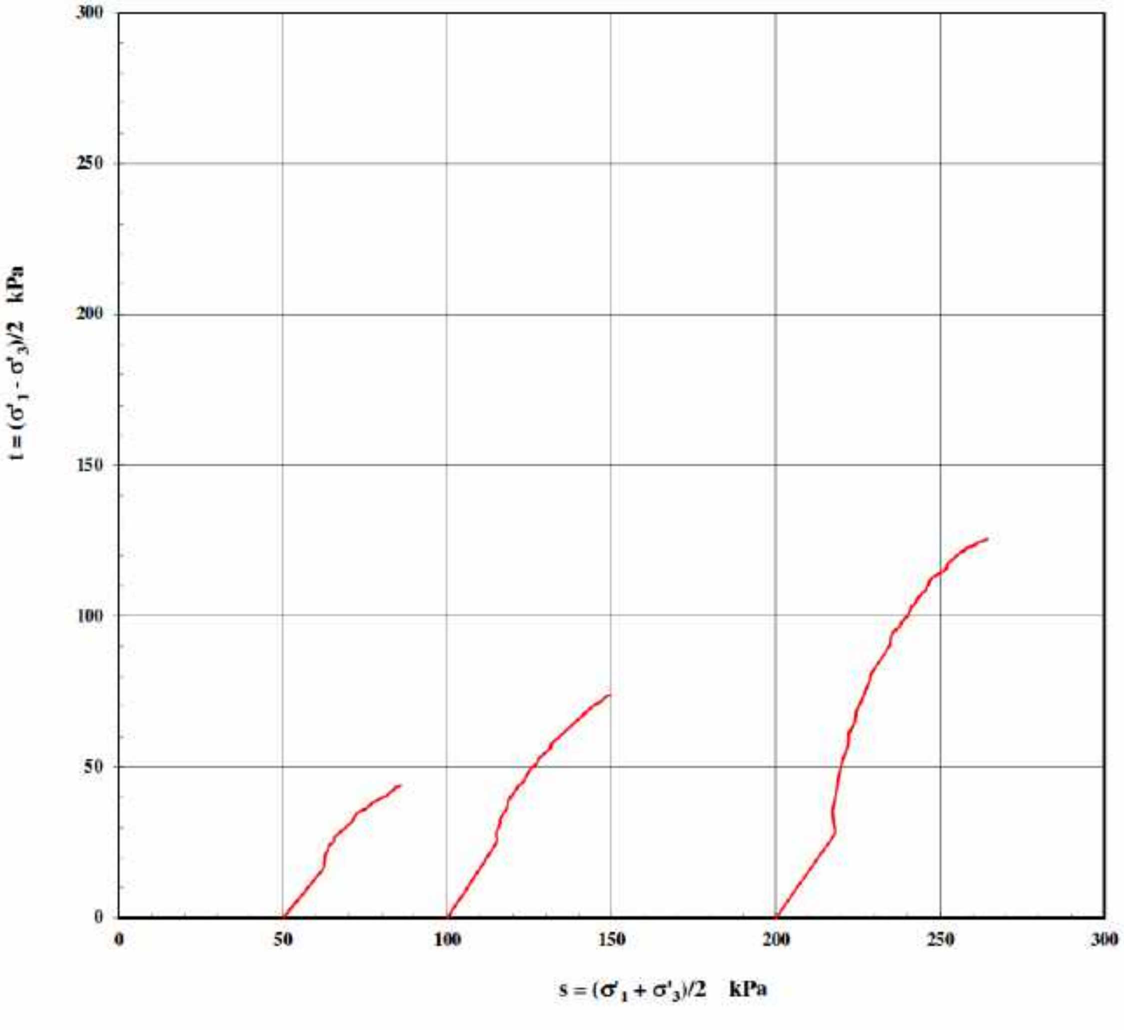
Report Date: 22/03/2012

Client Id.: TP013 (OC12-0092)

Depth (m): 0.00-3.00

Description

MIT Method - Effective Stress Path



Note: Graph not to scale.

Sample Type:	Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content
Sample/s supplied by the client	Note: Graph not to scale

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Number 9926

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030024 - CU

Project: White Well TSF

Test Date: 16/03/2012

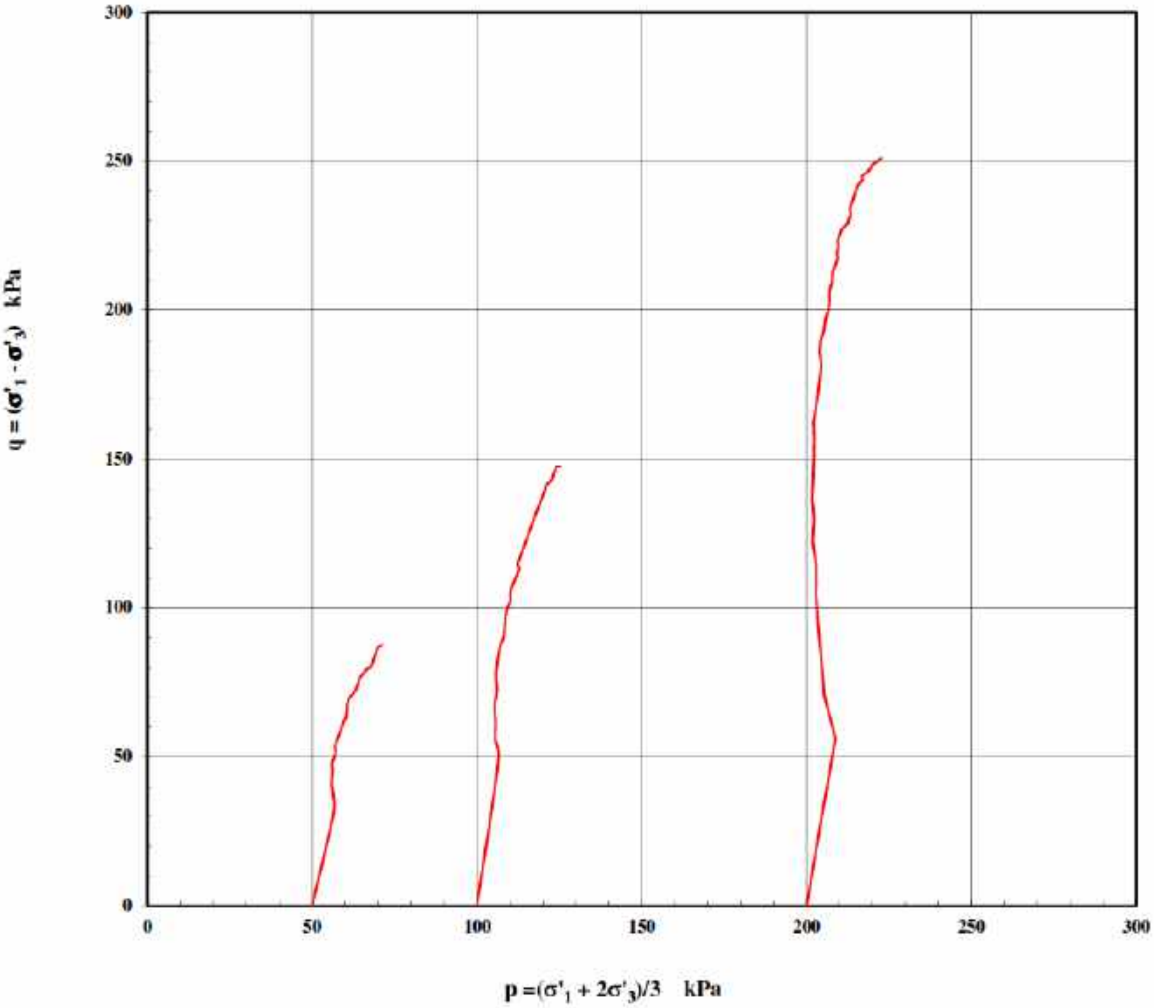
Report Date: 22/03/2012

Client Id.: TP013 (OC12-0092)

Depth (m): 0.00-3.00

Description

Cambridge Method - Effective Stress Path



Note: Graph not to scale.

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

[redacted]

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Earth Materials Classification

Report No.: P 12030024 - CU

Project: White Well TSF

Test Date: 16/03/2012

Report Date: 22/03/2012

Client Id.: TP013 (OC12-0092)

Depth (m): 0.00-3.00

Description

CLIENT: Earth Materials Classification
PROJECT: White Well TSF
AFTER TEST
LAB SAMPLE No. P 12030024
DATE: 20/3/12
BOREHOLE: TP013 (OC12-0092)
DEPTH: 0.00-3.00

Sample Type: Single Individual Specimen remoulded at 98% of Modified Maximum Dry Density and Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale

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NATA Accredited Laboratory Number 9926

[redacted]

TEST REPORT

Client:	**4DGeotechnics**
CLIENT SAMPLE ID:	**TP013**
DEPTH RANGE:	**0.00m - 3.00m**
Project:	White Well TSF
Location:	Cue
Lab test request:	12-0006
Lab location:	O'Connor
Date tested:	24/02/2012
Lab sample ID:	OC12-0092

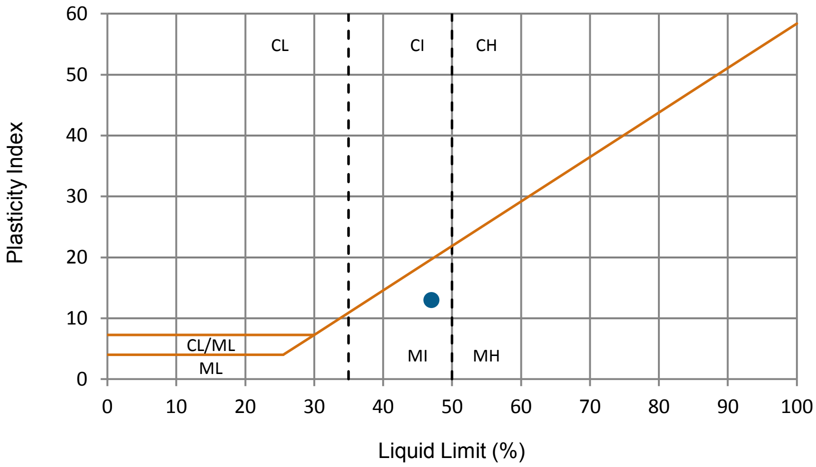
Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266

[redacted]

AS1289

3.1.1, 3.2.1, 3.3.2, 3.4.1

Atterberg Limits (Four point Casagrande)



PLASTIC LIMIT (%):	**34**
LIQUID LIMIT (%):	**47**
PLASTICITY INDEX:	**13**
LINEAR SHRINKAGE (%):	**2.5**
SAMPLE HISTORY:	Air Dried
SAMPLE PREPARATION:	Dry Sieve
LENGTH OF MOULD (mm):	250.0
SHRINKAGE OBSERVATION:	Crumbled

TEST NOTES:

1. Material supplied by the client.

[redacted]

Date:	27/02/2012
Accreditation number:	18548
Test Report No.:	12-0006 OC12-0092 ATT
Page:	1 of 1

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TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: **TP015**
DEPTH RANGE: **0.05m - 4.10m**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 24/02/2012
Lab sample ID: OC12-0093

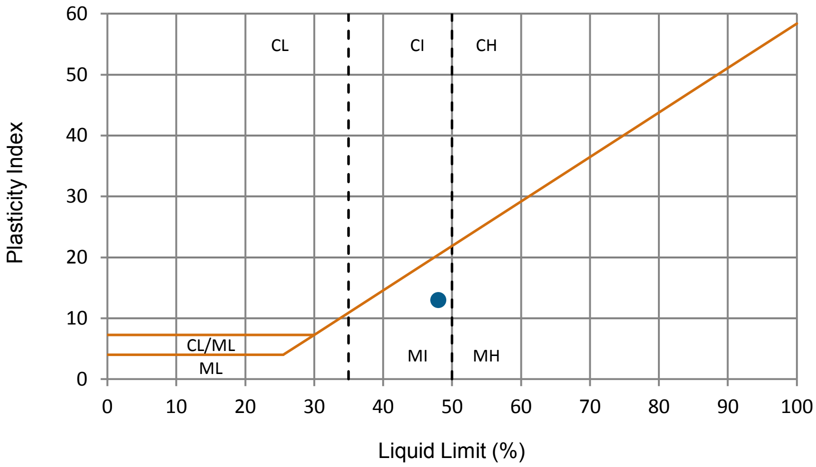
Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au

[redacted]

AS1289

3.1.1, 3.2.1, 3.3.2, 3.4.1

Atterberg Limits (Four point Casagrande)



PLASTIC LIMIT (%):	**35**
LIQUID LIMIT (%):	**48**
PLASTICITY INDEX:	**13**
LINEAR SHRINKAGE (%):	**1.0**
SAMPLE HISTORY:	Air Dried
SAMPLE PREPARATION:	Dry Sieve
LENGTH OF MOULD (mm):	250.0
SHRINKAGE OBSERVATION:	Crumbled

TEST NOTES:

1. Material supplied by the client.

[redacted]

Accreditation number: 18548
Test Report No.: 12-0006 OC12-0093 ATT

TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: **R001**
DEPTH RANGE: -
Project: White Well TSF
Location: Cue

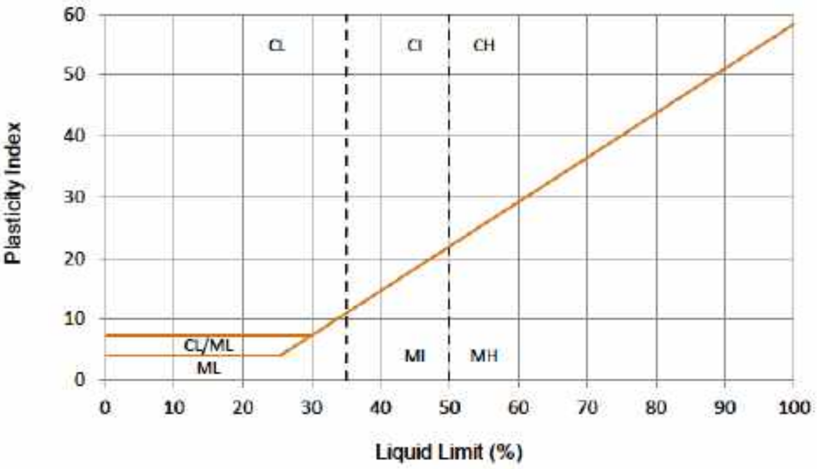
Lab test request: 12-0006
Lab location: O'Connor
Date tested: 24/02/2012
Lab sample ID: OC12-0094

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au

[redacted]

AS1289
3.1.1, 3.2.1, 3.3.2, 3.4.1

Atterberg Limits (Four point Casagrande)



PLASTIC LIMIT (%):	**36**
LIQUID LIMIT (%):	**Not obtainable**
PLASTICITY INDEX:	**Not obtainable**
LINEAR SHRINKAGE (%):	**1.5**
SAMPLE HISTORY:	Air Dried
SAMPLE PREPARATION:	Dry Sieve
LENGTH OF MOULD (mm):	250.0
SHRINKAGE OBSERVATION:	Crumbled

TEST NOTES:

1. Material supplied by the client.

[redacted]

Date: 27/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0094 ATT
Page: 1 of 1

TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: **TP013**
DEPTH RANGE: **0.00m - 3.00m**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 14/02/2012
Lab sample ID: OC12-0092

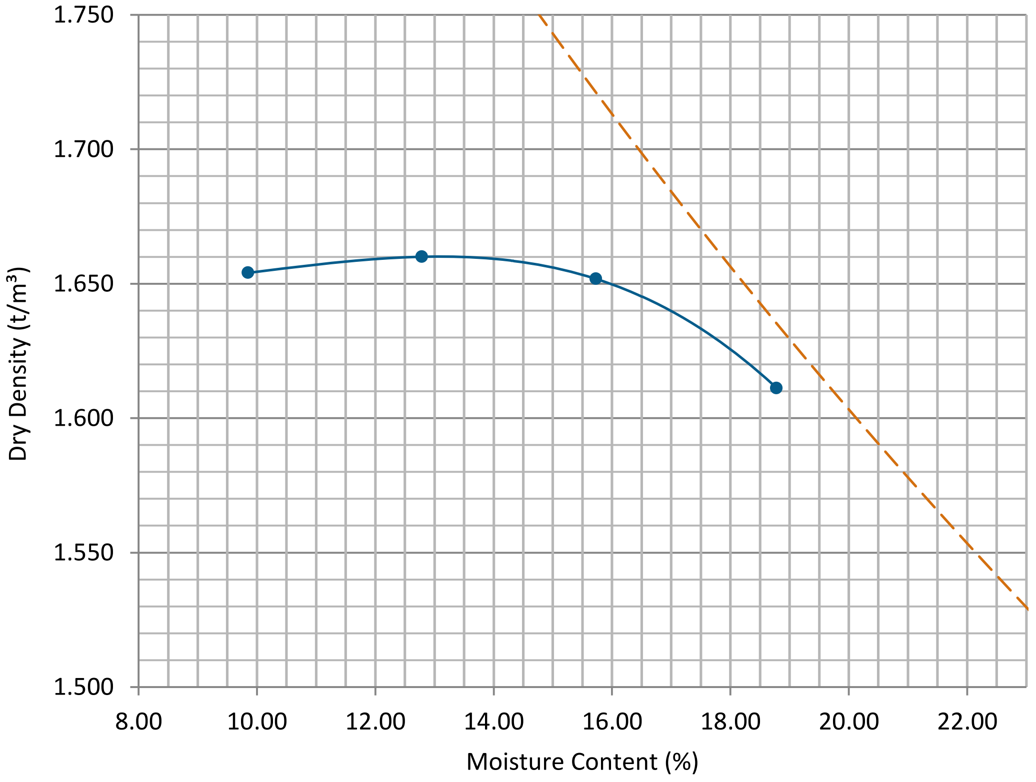
Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au

[redacted]

AS1289.5.2.1

Dry Density / Moisture Content Relationship

Modified Compactive Effort



MODIFIED MAXIMUM DRY DENSITY: **1.66** (t/m³)

MODIFIED OPTIMUM MOISTURE CONTENT: **13.0** (%)

RETAINED ON 19mm SIEVE: 0 (%)

RETAINED ON 37.5mm SIEVE: 0 (%)

AIR VOIDS LINE: 0 (%)

TEST NOTES:

1. Material supplied by the client.
2. Zero air void line calculated from an assumed particle density of 2.36
3. Where further analysis is required, MDD and OMC values of 1.660t/m³ and 13.1% may be used.

[redacted]

Date: 21/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0092 MDD
Page: 1 of 1

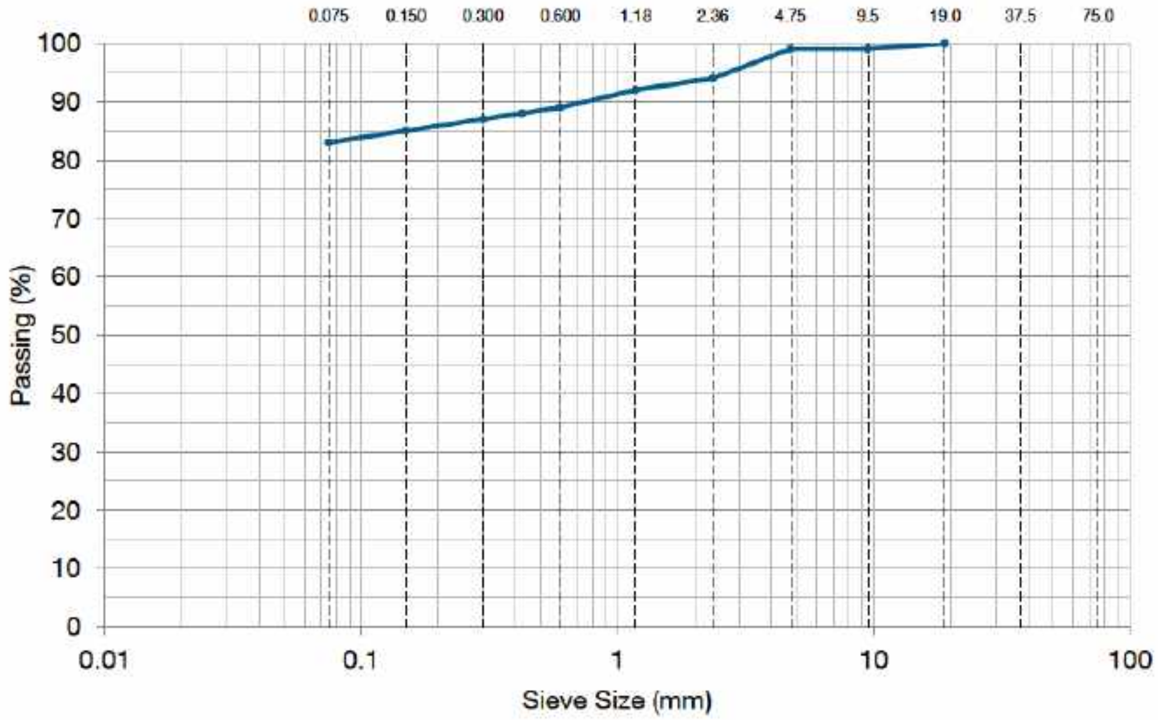
TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: **TP013**
DEPTH RANGE: **0.00m - 3.00m**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 15/02/2012 to 16/02/2012
Lab sample ID: OC12-0092

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au
[redacted]

AS1289.3.6.1 Particle Size Distribution



SIEVE SIZE (mm)	PASSING (%)	SIEVE SIZE (mm)	PASSING (%)
75.0		1.18	92
37.5		0.600	89
19.0	100	0.425	88
9.5	99	0.300	87
4.75	99	0.150	85
2.36	94	0.075	83

TEST NOTES:

1. Material supplied by the client.

[redacted]

Date: 21/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0092 PSD
Page: 1 of 1

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NATA
WORLD RECOGNISED ACCREDITATION

TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: VARIOUS
DEPTH RANGE: VARIOUS
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 10/2/12 to 13/2/12
Lab sample ID: VARIOUS

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au

[redacted]

AS1289.2.1.1

Moisture Content

Oven Method

CLIENT SAMPLE ID	DEPTH RANGE	MOISTURE CONTENT (%)	LAB SAMPLE ID
TP013	0.00m - 3.00m	**2.0**	OC12-0092
TP015	0.05m - 4.10m	**2.9**	OC12-0093
R001		**0.7**	OC12-0094

TEST NOTES:

1. Material supplied by the client.

[redacted]

Accreditation number: 18548
Test Report No.: 12-0006 OC12-0092 to 0094 MC
Page: 1 of 1

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WORLD RECOGNISED ACCREDITATION

TEST REPORT

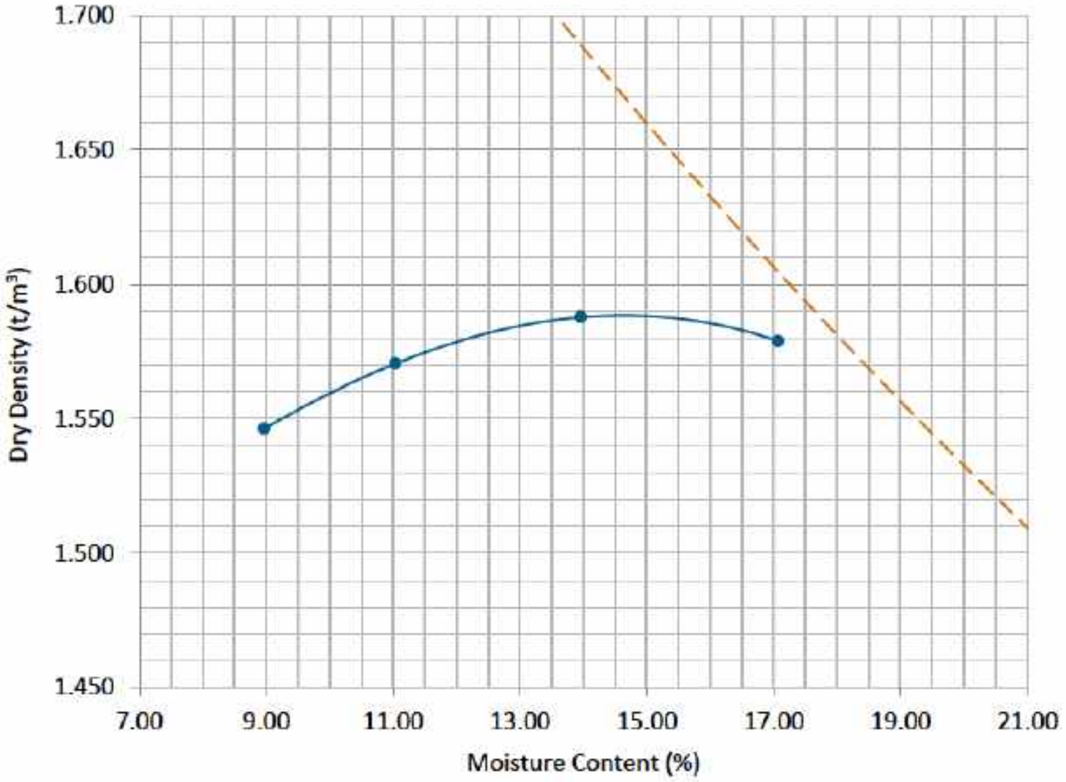
Client: **4DGeotechnics**
CLIENT SAMPLE ID: **TP015**
DEPTH RANGE: **0.05m - 4.10m**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 14/02/2012
Lab sample ID: OC12-0093

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
[redacted]

AS1289.5.2.1 Dry Density / Moisture Content Relationship

Modified Compactive Effort



MODIFIED MAXIMUM DRY DENSITY: **1.59** (t/m³)

MODIFIED OPTIMUM MOISTURE CONTENT: **14.5** (%)

RETAINED ON 19mm SIEVE: 1 (%)

RETAINED ON 37.5mm SIEVE: 0 (%)

AIR VOIDS LINE: 0 (%)

TEST NOTES:

1. Material supplied by the client.
2. Zero air void line calculated from an assumed particle density of 2.21
3. Where further analysis is required, MDD and OMC values of 1.588t/m³ and 14.6% may be used.

[redacted]

Date: 21/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0093 MDD
Page: 1 of 1

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NATA
WORLD RECOGNISED ACCREDITATION

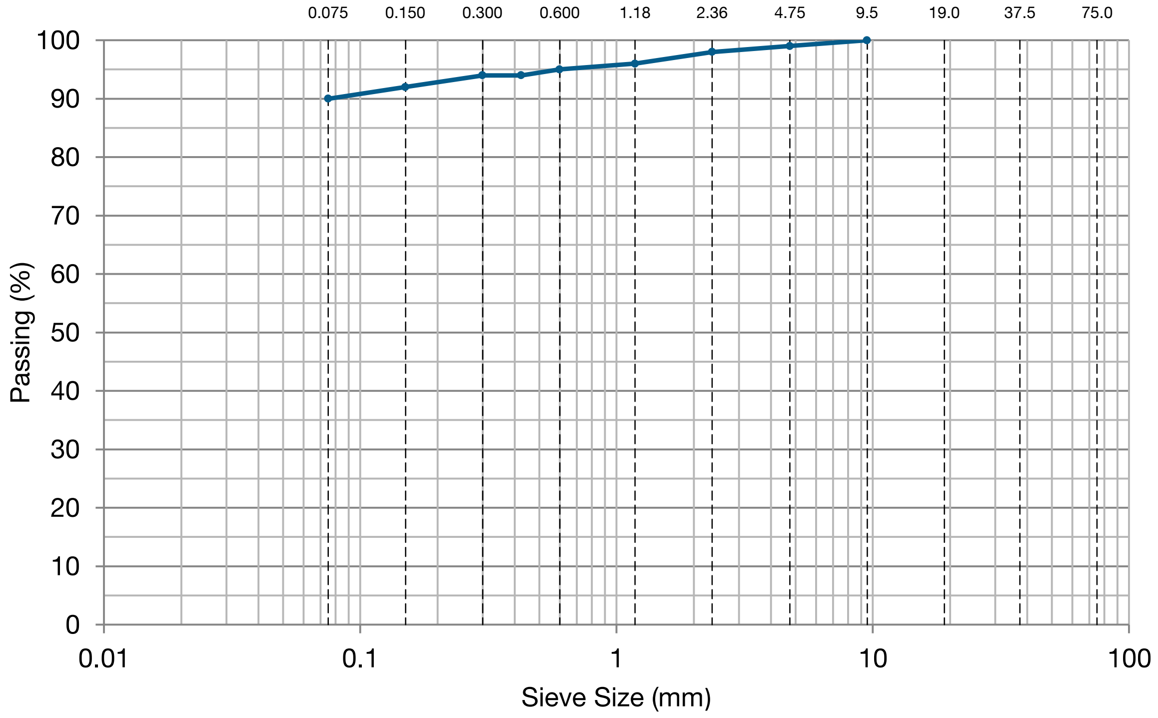
TEST REPORT

Client: **4DGeotechnics**
CLIENT SAMPLE ID: **TP015**
DEPTH RANGE: **0.05m - 4.10m**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 15/02/2012 to 16/02/2012
Lab sample ID: OC12-0093

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au
[redacted]

AS1289.3.6.1 Particle Size Distribution



SIEVE SIZE (mm)	PASSING (%)	SIEVE SIZE (mm)	PASSING (%)
75.0		1.18	96
37.5		0.600	95
19.0		0.425	94
9.5	100	0.300	94
4.75	99	0.150	92
2.36	98	0.075	90

TEST NOTES:

1. Material supplied by the client.

[redacted]

Accreditation number: 18548
Test Report No.: 12-0006 OC12-0093 PSD
Page: 1 of 1

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NATA
WORLD RECOGNISED ACCREDITATION

TEST REPORT

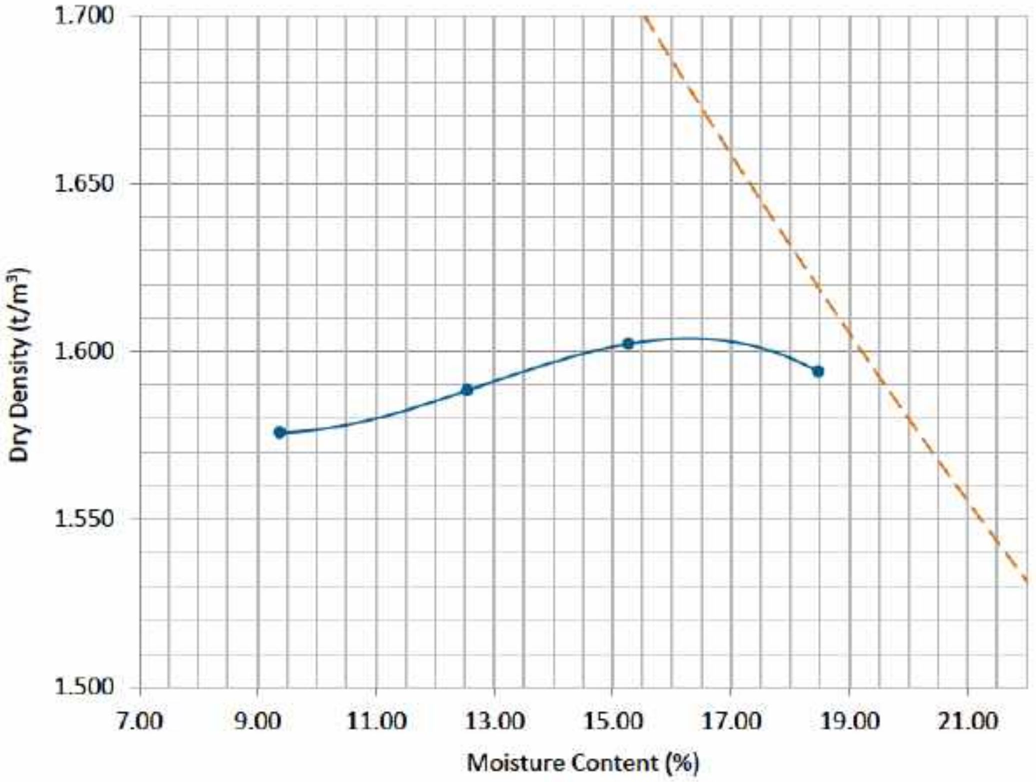
Client: **4DGeotechnics**
CLIENT SAMPLE ID: **R001**
DEPTH RANGE: -
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 14/02/2012
Lab sample ID: OC12-0094

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
[redacted]

AS1289.5.2.1 Dry Density / Moisture Content Relationship

Modified Compactive Effort



MODIFIED MAXIMUM DRY DENSITY:	**1.60**	(t/m³)
MODIFIED OPTIMUM MOISTURE CONTENT:	**16.5**	(%)
RETAINED ON 19mm SIEVE:	0	(%)
RETAINED ON 37.5mm SIEVE:	0	(%)
AIR VOIDS LINE:	0	(%)

TEST NOTES:

1. Material supplied by the client.
2. Zero air void line calculated from an assumed particle density of 2.31
3. Where further analysis is required, MDD and OMC values of 1.604t/m³ and 16.3% may be used.

[redacted]

Date: 21/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0094 MDD
Page: 1 of 1

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TEST REPORT

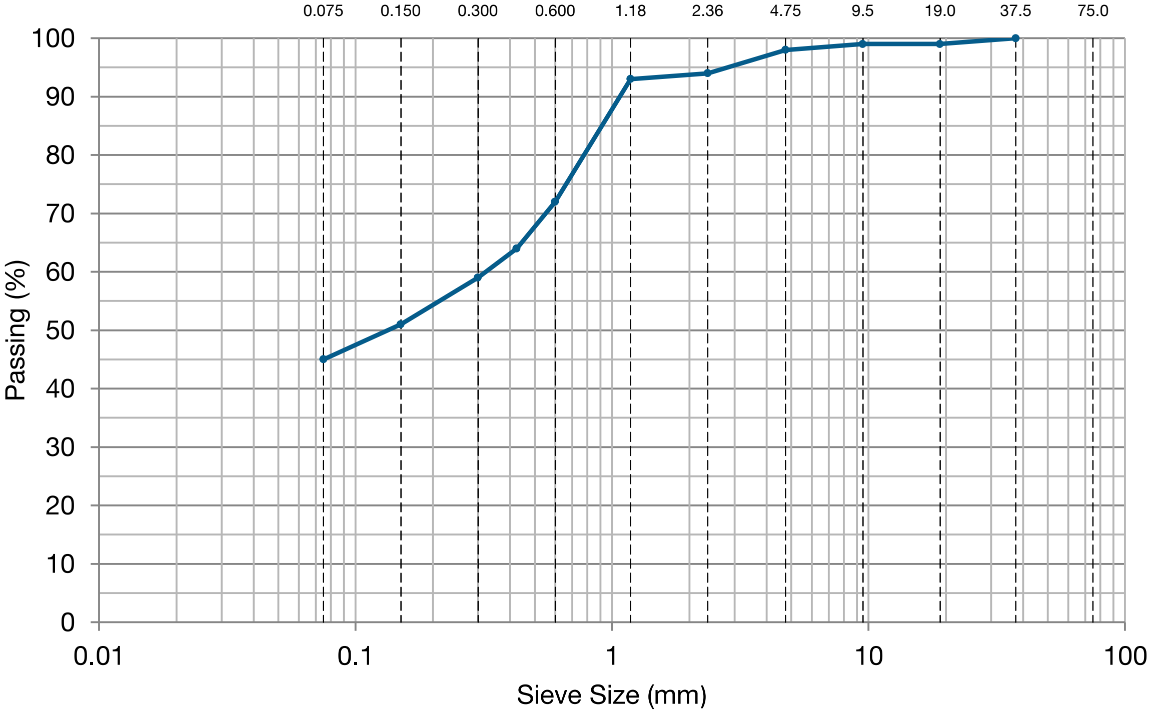
Client: **4DGeotechnics**
CLIENT SAMPLE ID: **R001**
DEPTH RANGE: **-**
Project: White Well TSF
Location: Cue

Lab test request: 12-0006
Lab location: O'Connor
Date tested: 15/02/2012 to 16/02/2012
Lab sample ID: OC12-0094

Earth Materials Classification
Unit 8 / 4 Pritchard Street
O'Connor, WA 6163
P (08) 9331 8981
F (08) 9331 1266
W www.emclabs.com.au

[redacted]

AS1289.3.6.1 Particle Size Distribution



SIEVE SIZE (mm)	PASSING (%)	SIEVE SIZE (mm)	PASSING (%)
75.0		1.18	93
37.5	100	0.600	72
19.0	99	0.425	64
9.5	99	0.300	59
4.75	98	0.150	51
2.36	94	0.075	45

TEST NOTES:

1. Material supplied by the client.

[redacted]

Date: 21/02/2012
Accreditation number: 18548
Test Report No.: 12-0006 OC12-0094 PSD
Page: 1 of 1

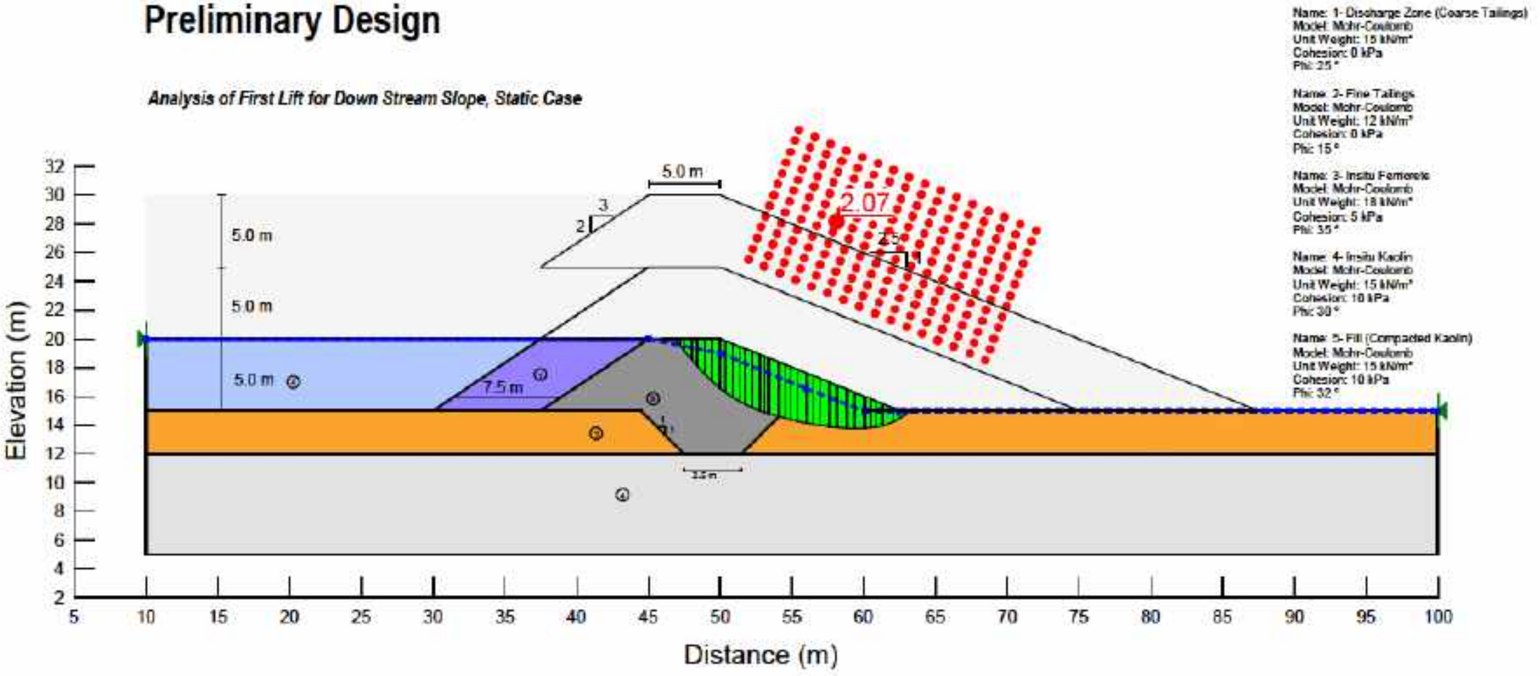
APPENDIX D

Slope Stability Analyses

White Well TSF

Preliminary Design

Analysis of First Lift for Down Stream Slope, Static Case


Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

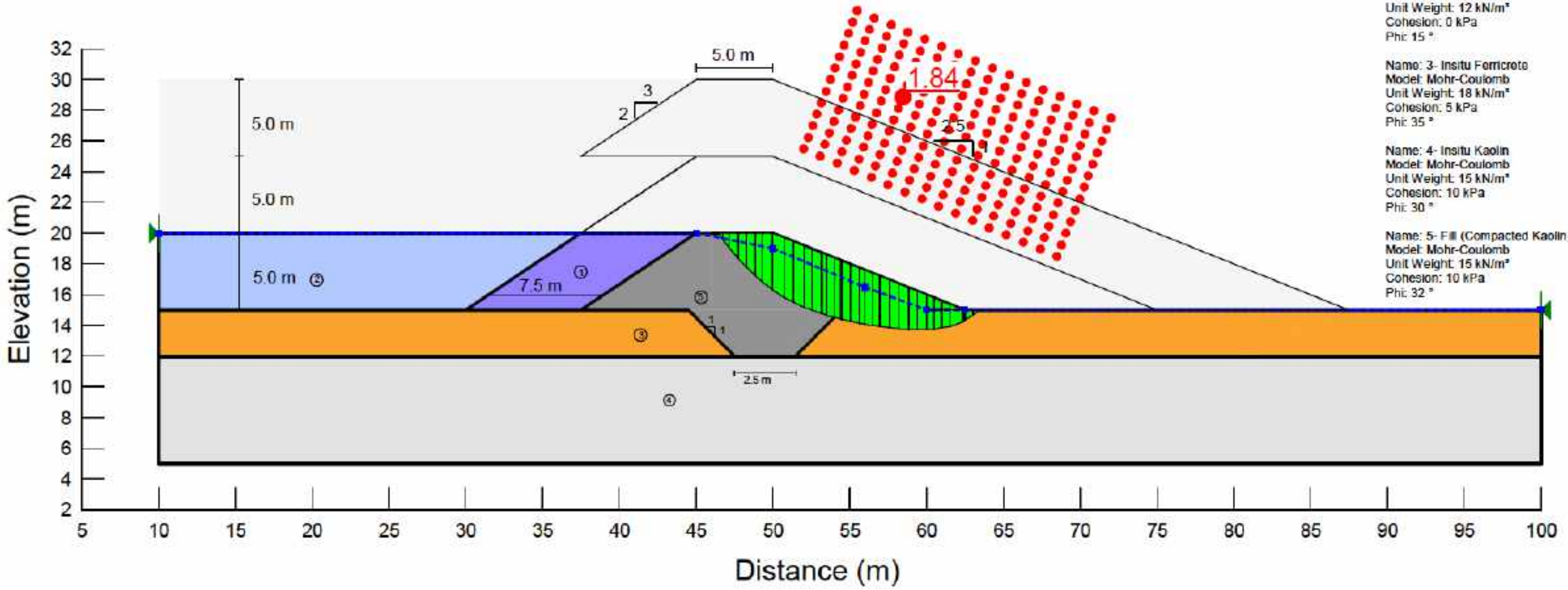
Name: 3- Insitu Ferrorete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

White Well TSF
Preliminary Design

Analysis of First Lift for Down Stream Slope, Psuedo-Static Case (Kh=0.04g)



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

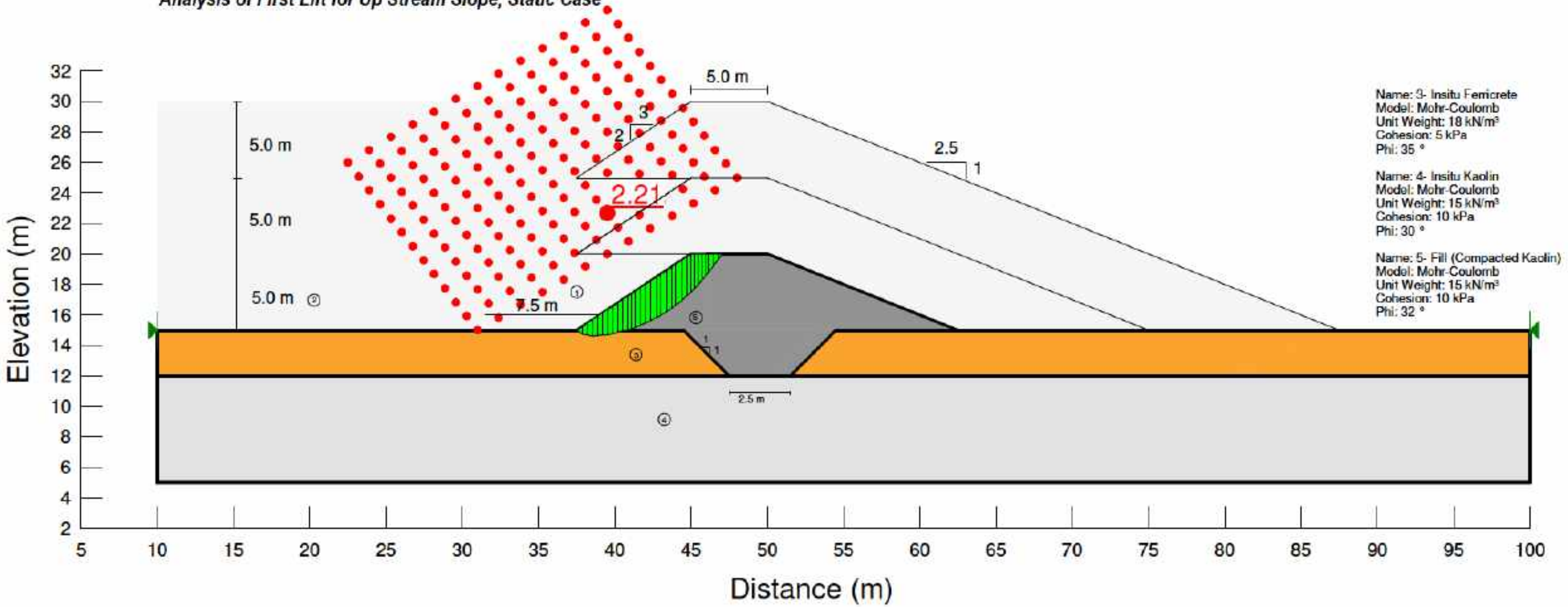
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

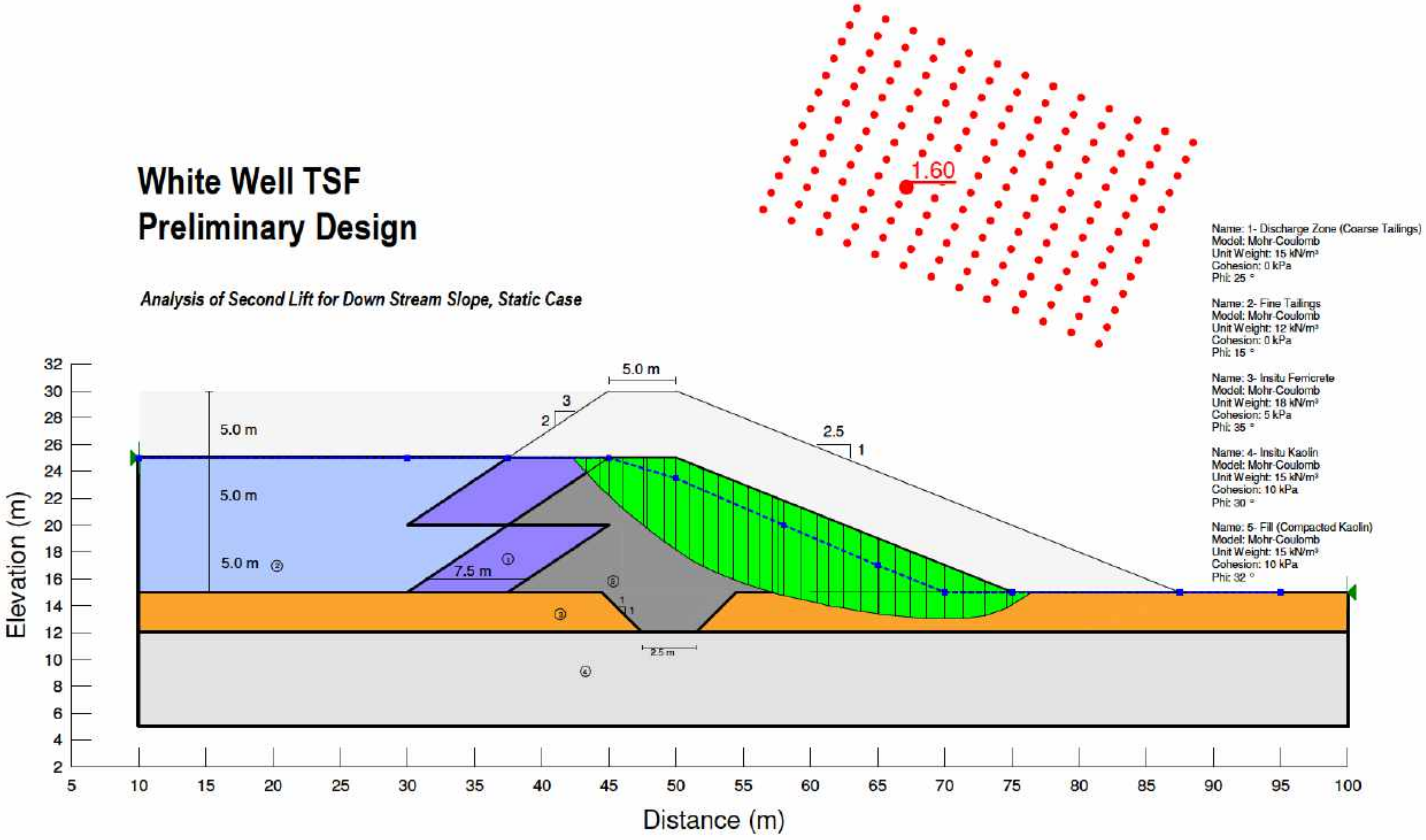
White Well TSF
Preliminary Design

Analysis of First Lift for Up Stream Slope, Static Case



White Well TSF
Preliminary Design

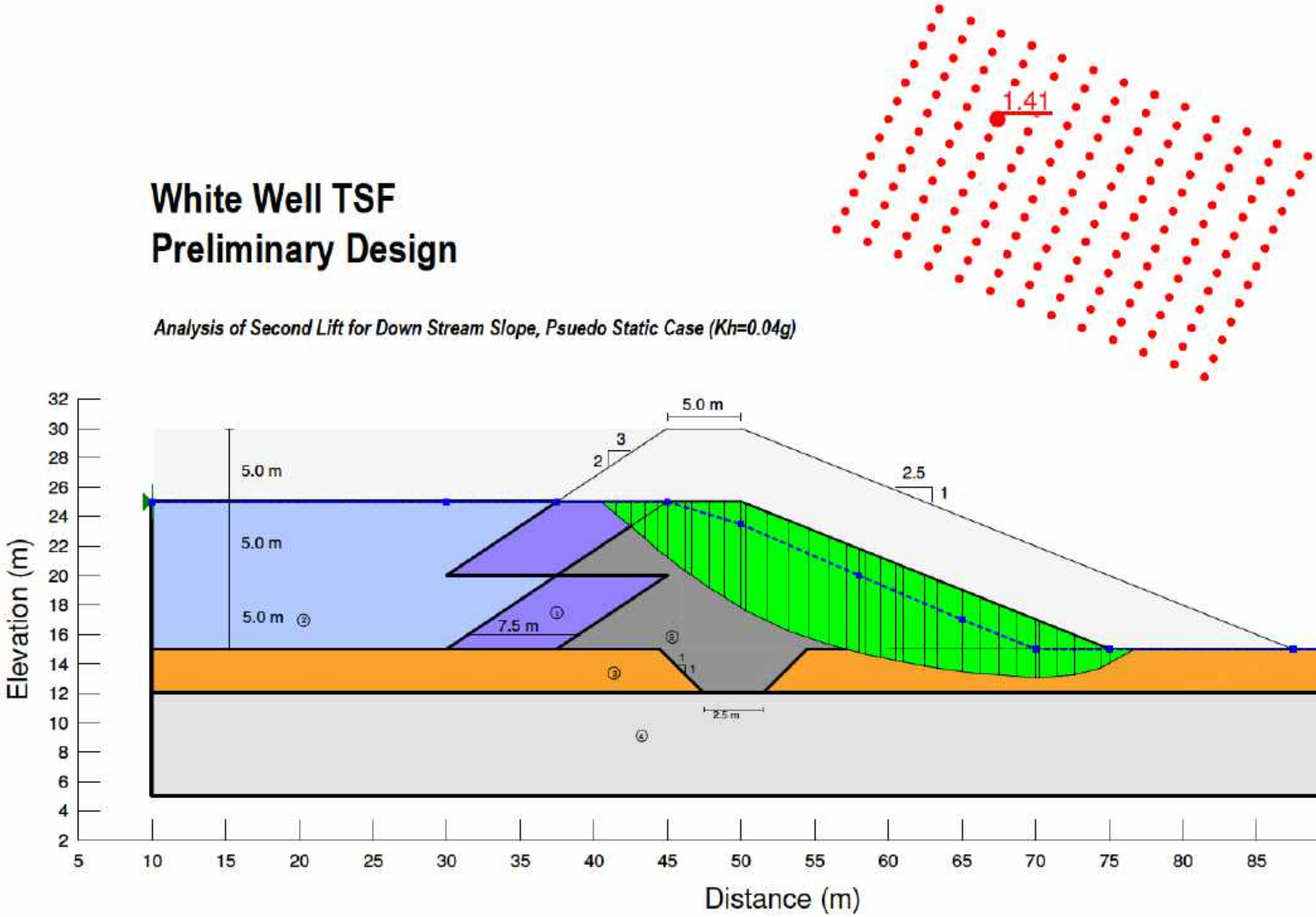
Analysis of Second Lift for Down Stream Slope, Static Case



White Well TSF

Preliminary Design

Analysis of Second Lift for Down Stream Slope, Psuedo Static Case (Kh=0.04g)



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

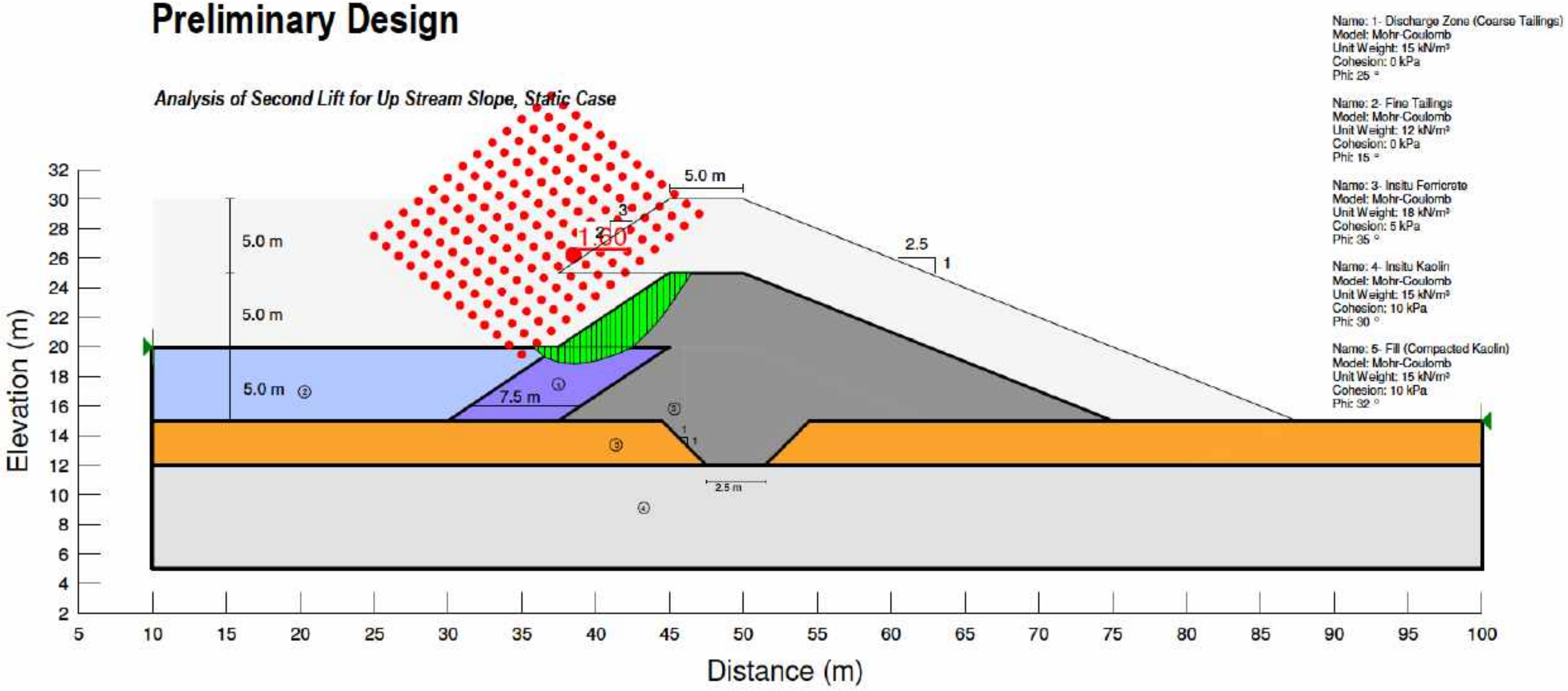
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

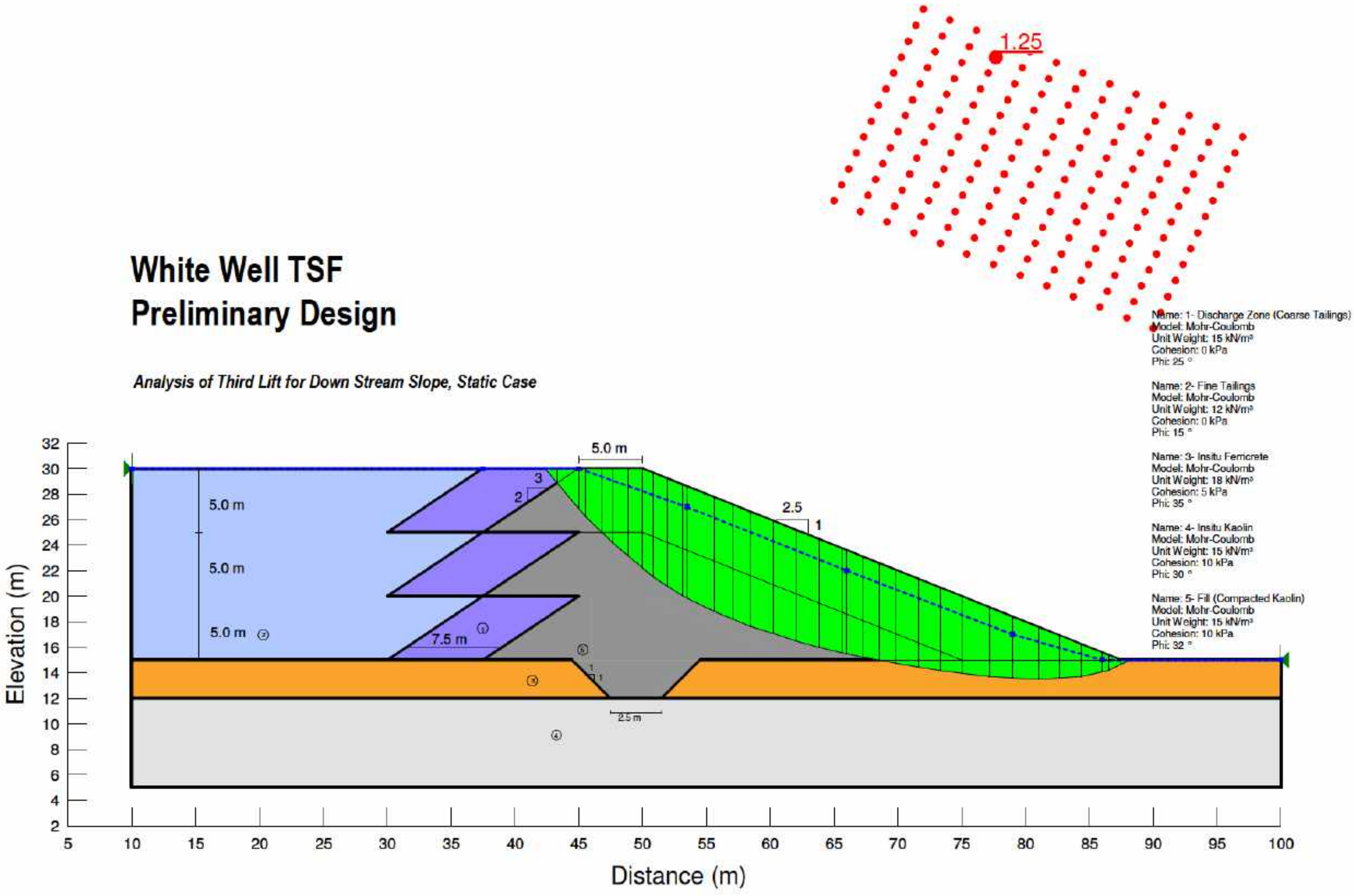
White Well TSF
Preliminary Design

Analysis of Second Lift for Up Stream Slope, Static Case



White Well TSF
Preliminary Design

Analysis of Third Lift for Down Stream Slope, Static Case



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

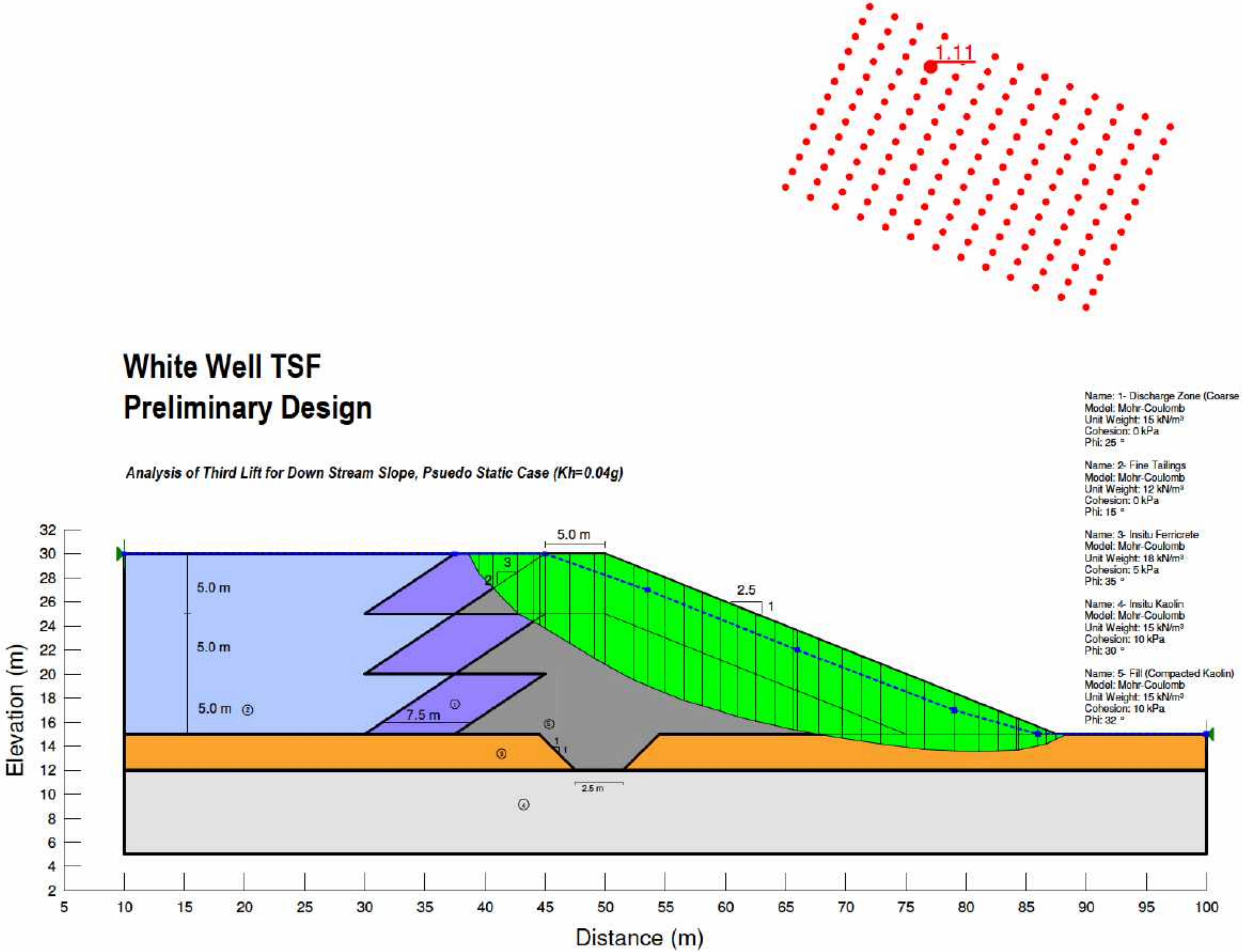
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

White Well TSF
Preliminary Design

Analysis of Third Lift for Down Stream Slope, Psuedo Static Case (Kh=0.04g)



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

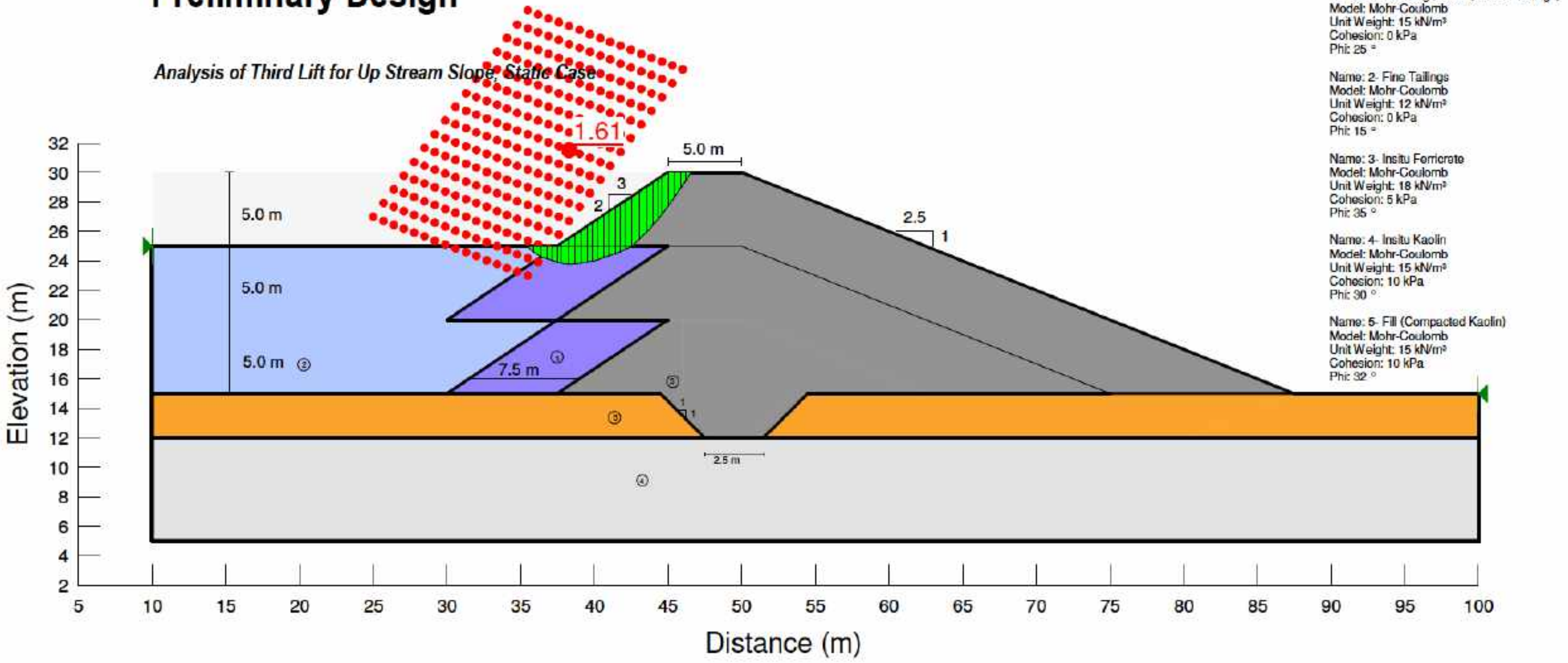
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

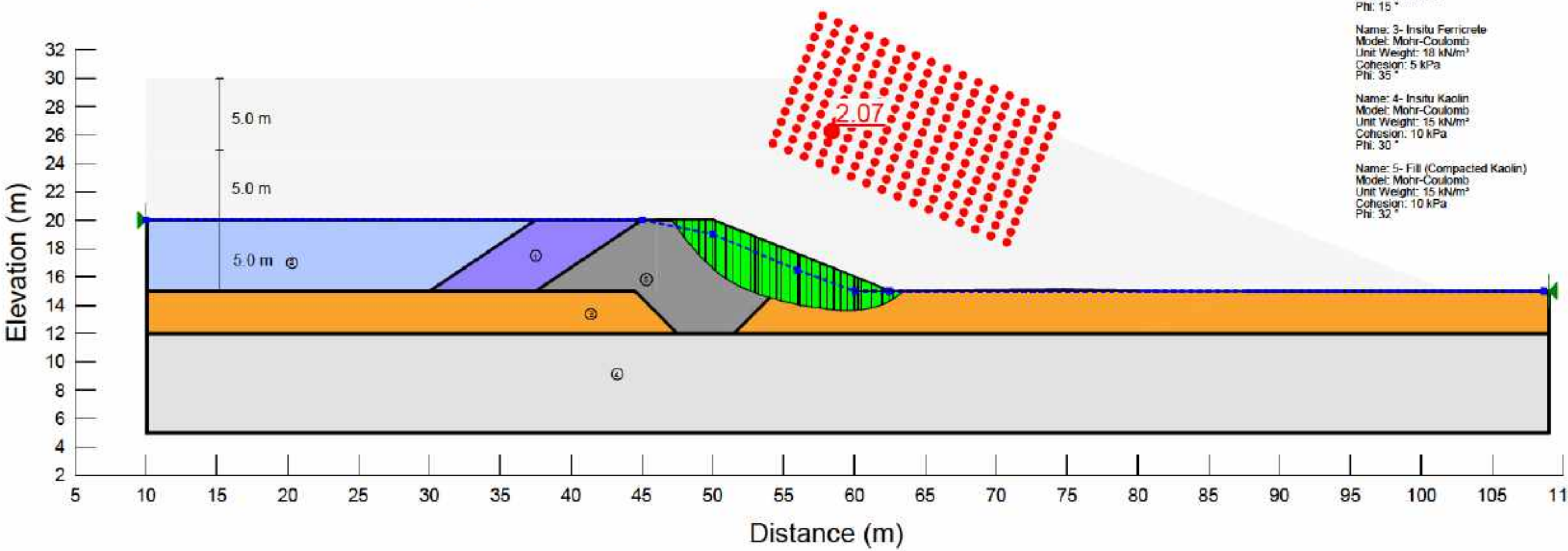
White Well TSF
Preliminary Design

Analysis of Third Lift for Up Stream Slope, Static Case



White Well TSF
Preliminary Design

Analysis of First Lift for Down Stream Slope, Static Case



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

White Well TSF
Preliminary Design

Analysis of First Lift for Down Stream Slope, Psuedo-Static Case (Kh=0.04g)

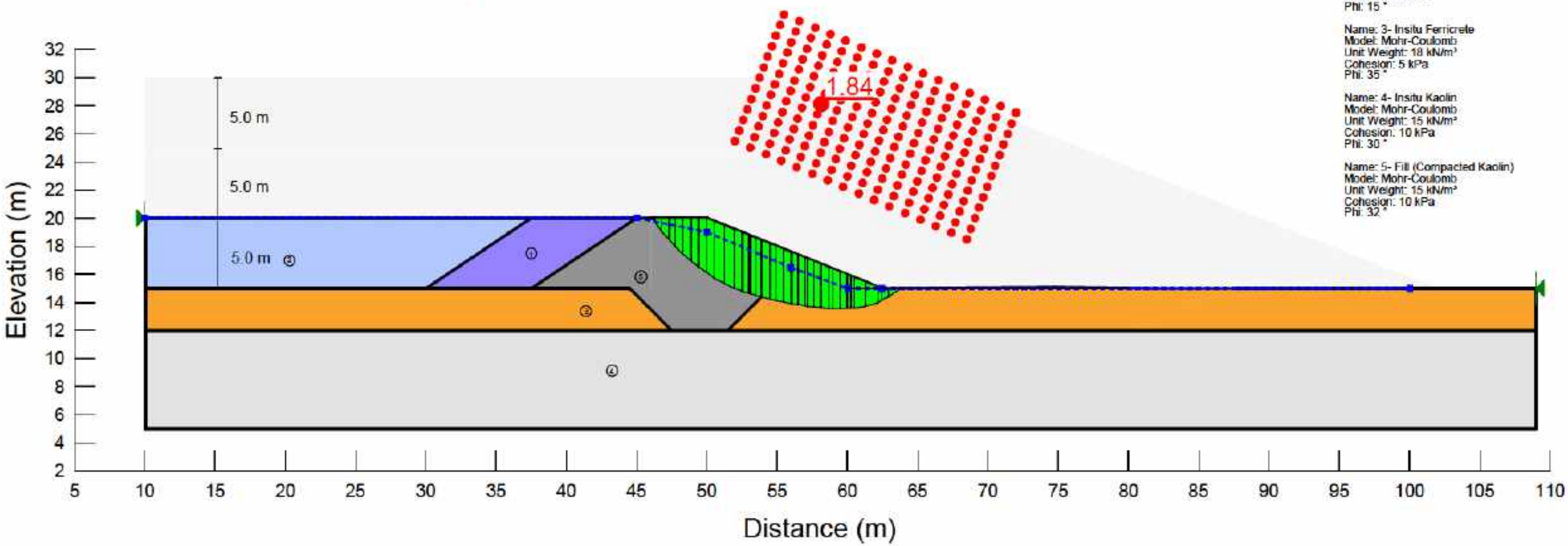
Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

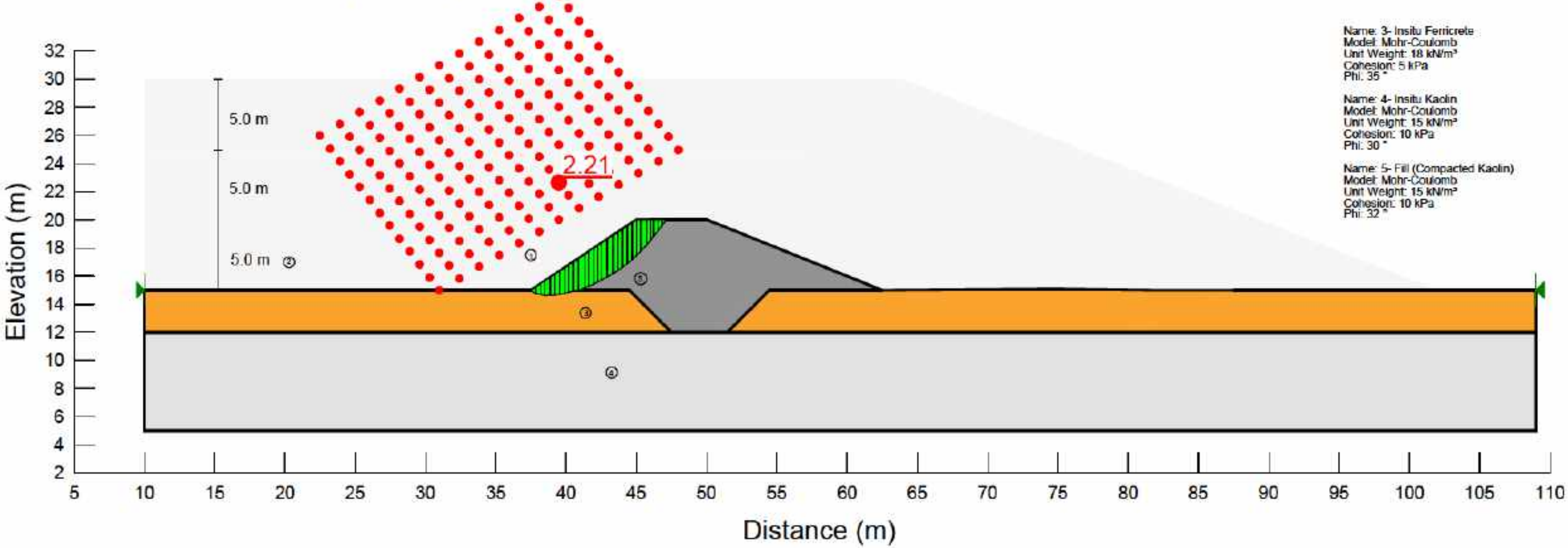
Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °



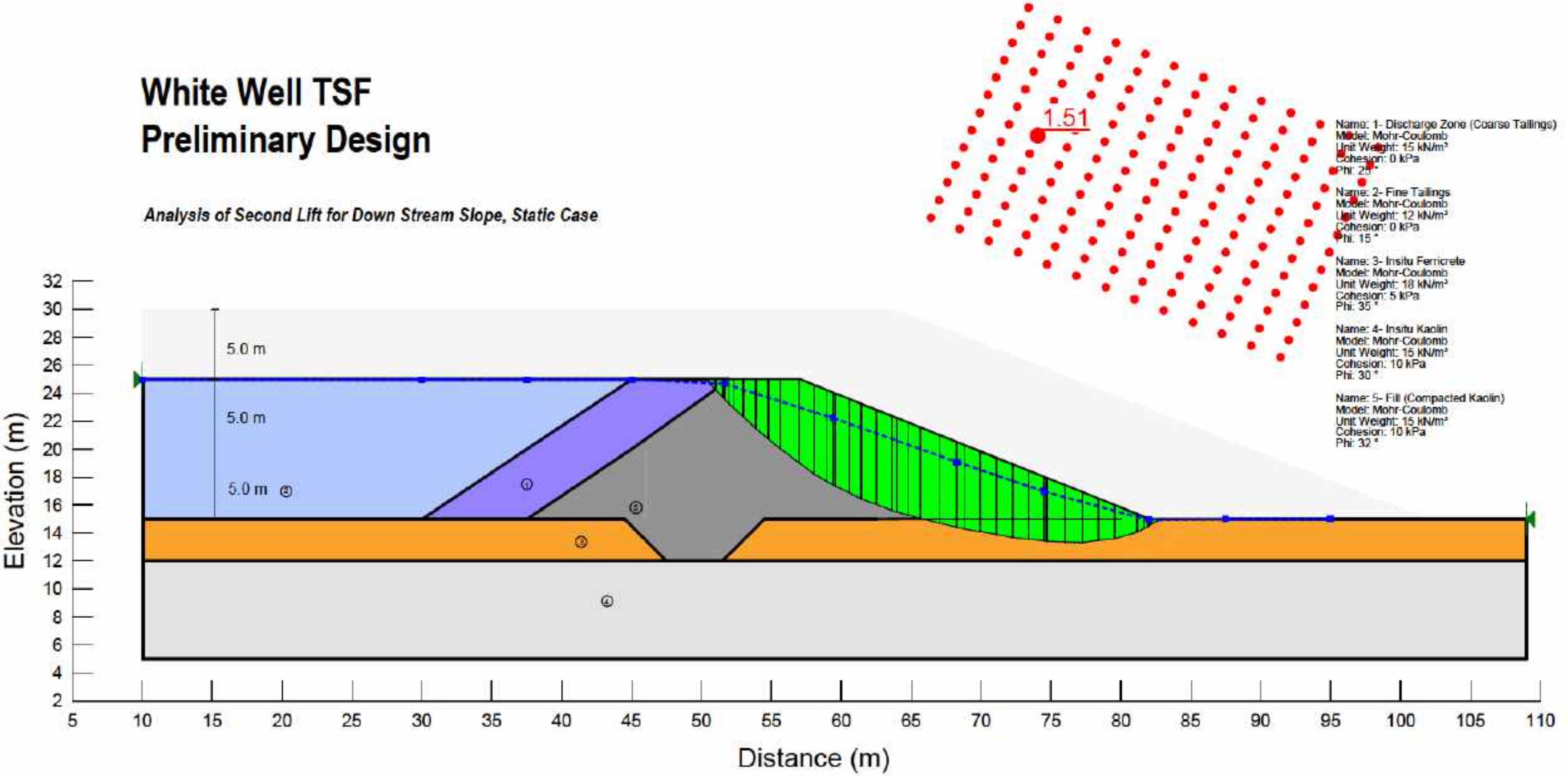
White Well TSF
Preliminary Design

Analysis of First Lift for Up Stream Slope, Static Case



White Well TSF
Preliminary Design

Analysis of Second Lift for Down Stream Slope, Static Case



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

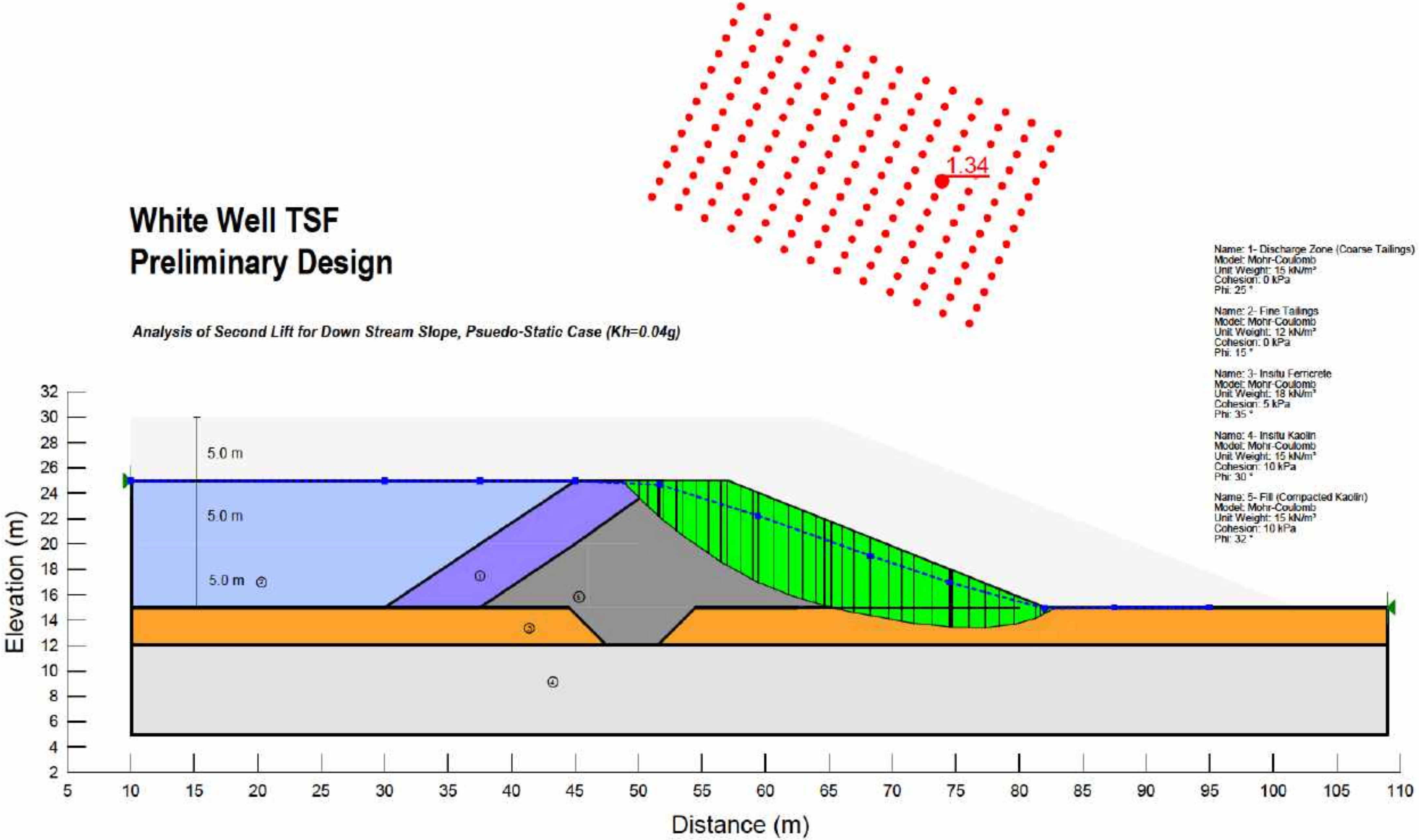
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

White Well TSF
Preliminary Design

Analysis of Second Lift for Down Stream Slope, Psuedo-Static Case (Kh=0.04g)



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

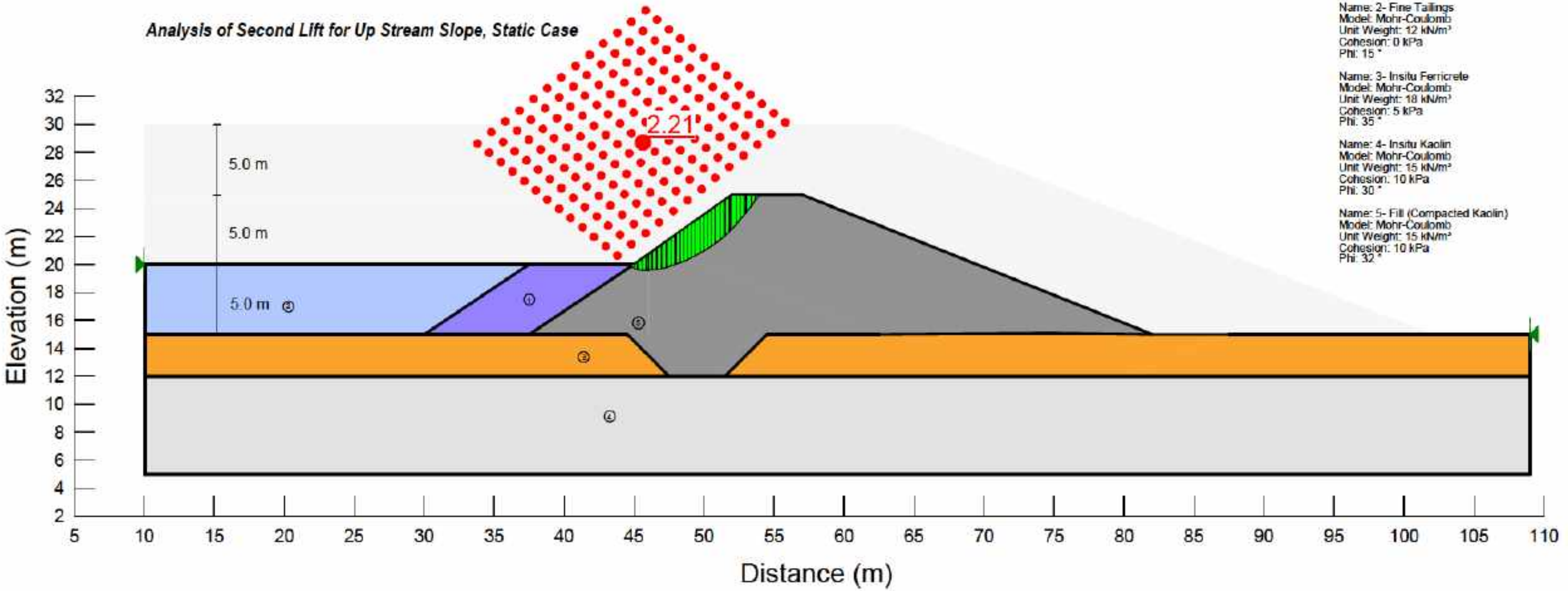
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

White Well TSF
Preliminary Design

Analysis of Second Lift for Up Stream Slope, Static Case



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 15 °

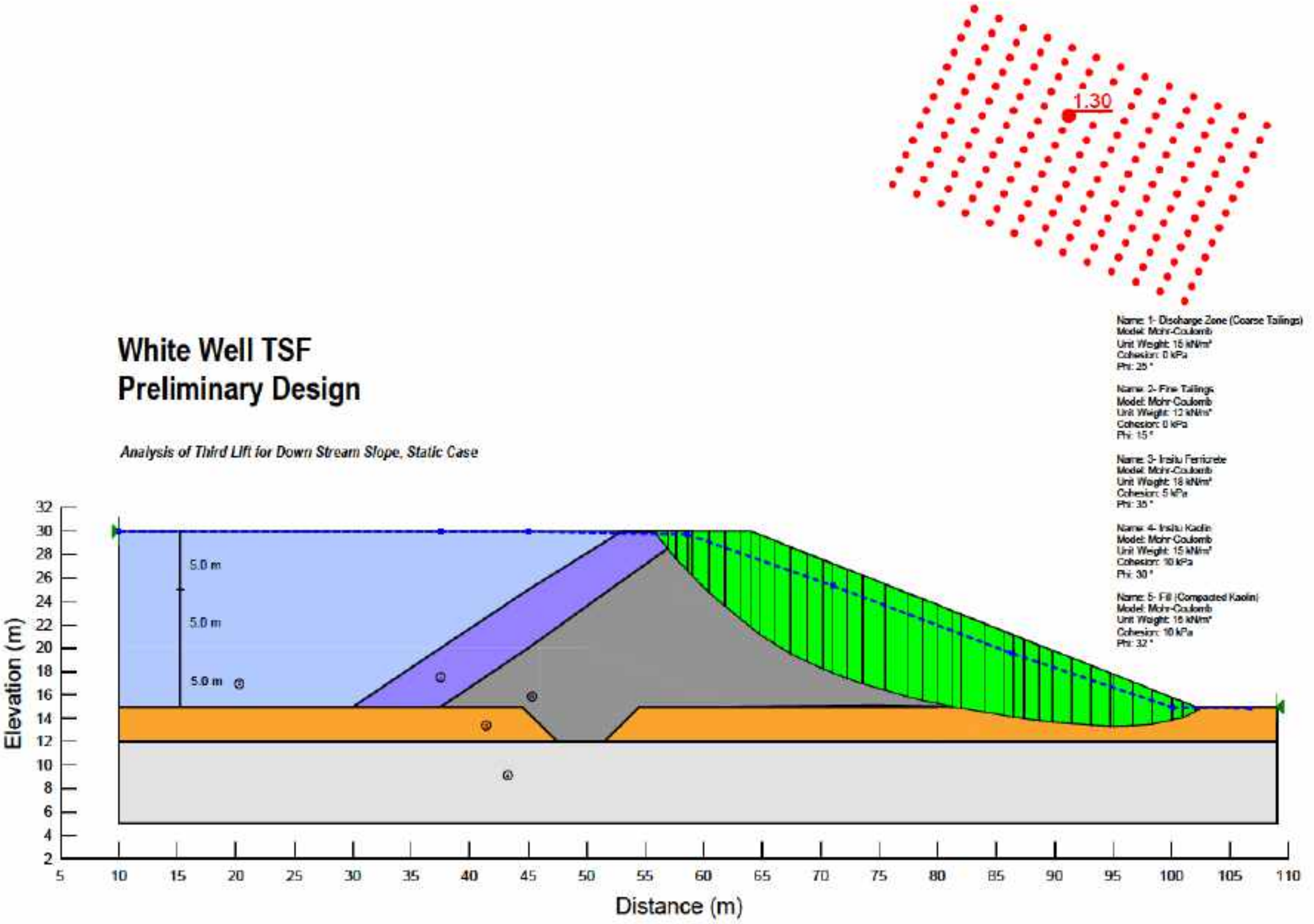
Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m³
Cohesion: 10 kPa
Phi: 32 °

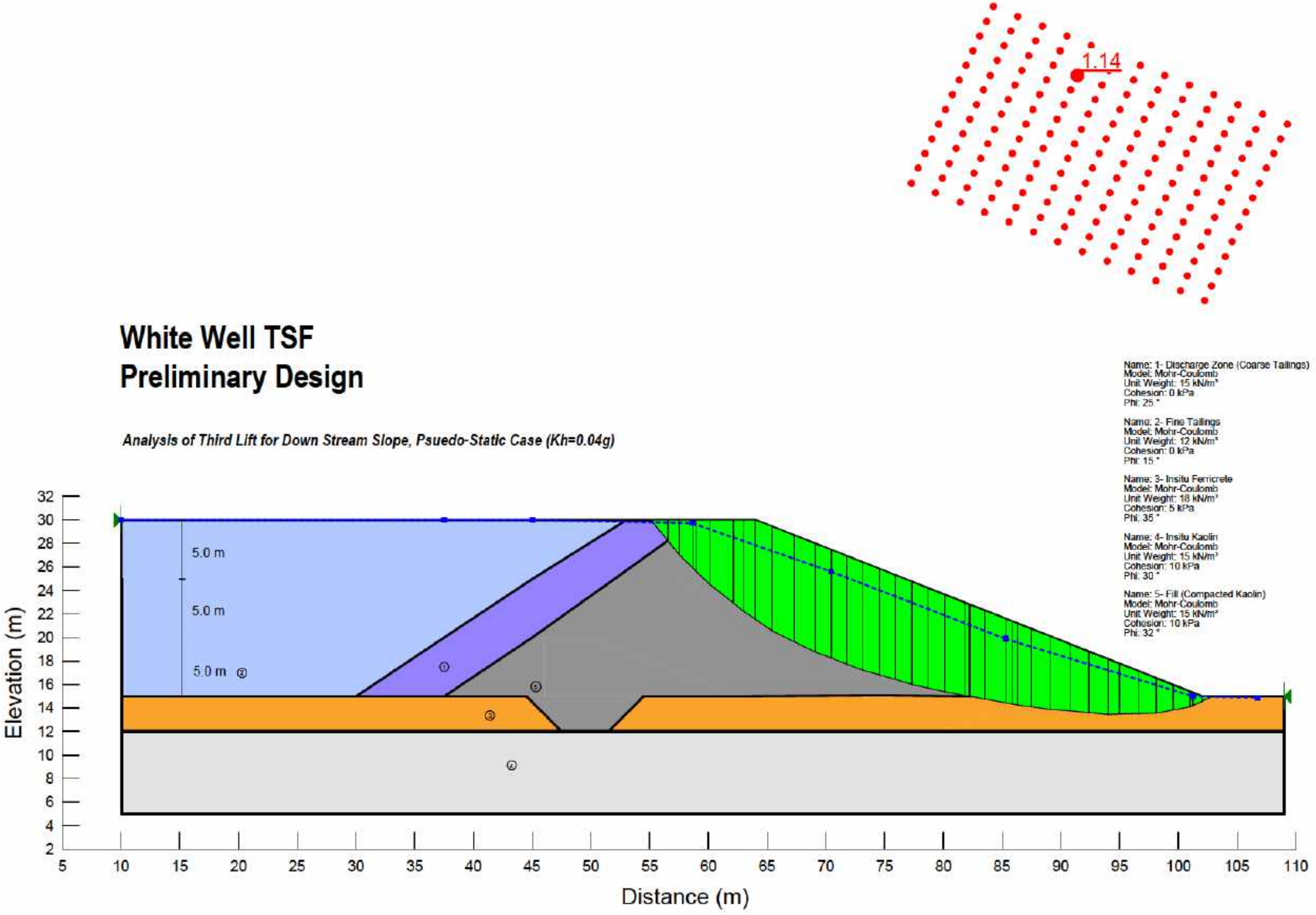
White Well TSF
Preliminary Design

Analysis of Third Lift for Down Stream Slope, Static Case



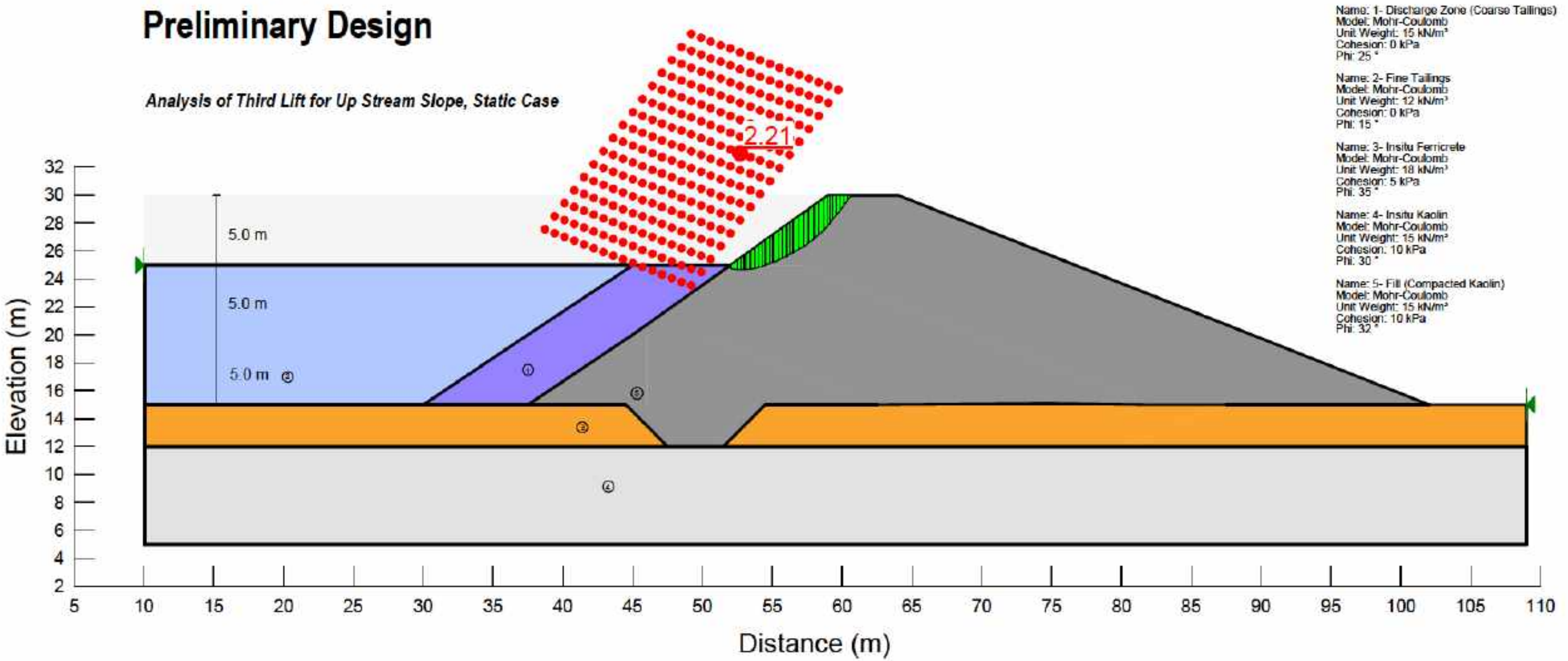
White Well TSF
Preliminary Design

Analysis of Third Lift for Down Stream Slope, Psuedo-Static Case (Kh=0.04g)



White Well TSF
Preliminary Design

Analysis of Third Lift for Up Stream Slope, Static Case



Name: 1- Discharge Zone (Coarse Tailings)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m^3
Cohesion: 0 kPa
Phi: 25 °

Name: 2- Fine Tailings
Model: Mohr-Coulomb
Unit Weight: 12 kN/m^3
Cohesion: 0 kPa
Phi: 15 °

Name: 3- Insitu Ferricrete
Model: Mohr-Coulomb
Unit Weight: 18 kN/m^3
Cohesion: 5 kPa
Phi: 35 °

Name: 4- Insitu Kaolin
Model: Mohr-Coulomb
Unit Weight: 15 kN/m^3
Cohesion: 10 kPa
Phi: 30 °

Name: 5- Fill (Compacted Kaolin)
Model: Mohr-Coulomb
Unit Weight: 15 kN/m^3
Cohesion: 10 kPa
Phi: 32 °

TEL: (08) 9443 9994
FAX: (08) 9443 9991
[redacted]
WEB: www.4dg.com.au

201-203 Bulwer St, Perth WA 6000 / PO Box 509, Leederville WA 6903 / ABN 11 073 742 604

13 July 2012

Ref: 024500LET01

Cobra Mining Ltd
159 Stirling Highway
Nedlands
WA 6009

[redacted]

RE: White Well Tailings Storage Facility: Additional Geotechnical Assessment

This letter report provides a preliminary Geotechnical Stability Assessment for the proposed White Well Mine TSF diversion drain, an assessment of the liquefaction potential of the Kaolin soils and a proposed field compaction test methodology. The stability assessment is in accordance with your email dated 3 July 2012. The liquefaction assessment and compaction test methodology are in response to a letter Cobra Mining Ltd received from the Department of Mines and Petroleum dated 9 July 2012.

The assessments and recommendations presented in this report are based on Ground Breaking Investigations and laboratory test results undertaken by 4DGeotechnics Pty Ltd (4DG) in February 2012 and other information which is presented in 4DG's report 024500REP01_Rev 2.

1.0 DRAIN STABILITY ANALYSIS

1.1 General

Stability analyses have been undertaken based upon the proposed concepts from Cobra Mining and 4DG's experience with existing and previous projects in Western Australia.

Factors such as the geology and history of the site, proposed geometries and expected flood level conditions (1:100 year, 72 hour rainfall event) have been taken into account using the results of the February 2012 investigations. Laboratory test data has been utilised to evaluate the soil strength parameters together with interpretations made from previous experience.

Stability analyses have been undertaken using the limit equilibrium program Slope/W. The program uses limit equilibrium analysis (the Morgenstern-Price method), with a half-sine inter-slice force function to ensure both moment and force equilibrium are satisfied. The lowest factor of safety in an analysis was assessed by searching through potential circular failure surfaces (grid and radius method).

Analyses were undertaken for the centreline and downstream construction methods.

The outputs from the slope stability analyses are attached to this letter.

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The stability criteria adopted for design are set out in Table 1.

Table 1: Stability Design Criteria

Drain At Capacity	Drain Empty	Rapid Drawdown
Flood level to 0.5m below crest	No flood water	Drain bund saturated, no water in drain
FOS > 1.5	FOS > 1.5	FOS > 1.2

The overall stability of a slope is expressed as the factor of safety (FOS), which is the ratio of the internal soil forces resisting instability to the driving forces causing instability. Theoretical failure of a slope is possible when the FOS is 1.0, while increasing values above 1.0 indicate improving stability/ a lower probability of failure.

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A typical cross section through the concept drain (refer to Figure 1) was analysed to assess the overall stability for the following cases:

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- Drain Empty; and
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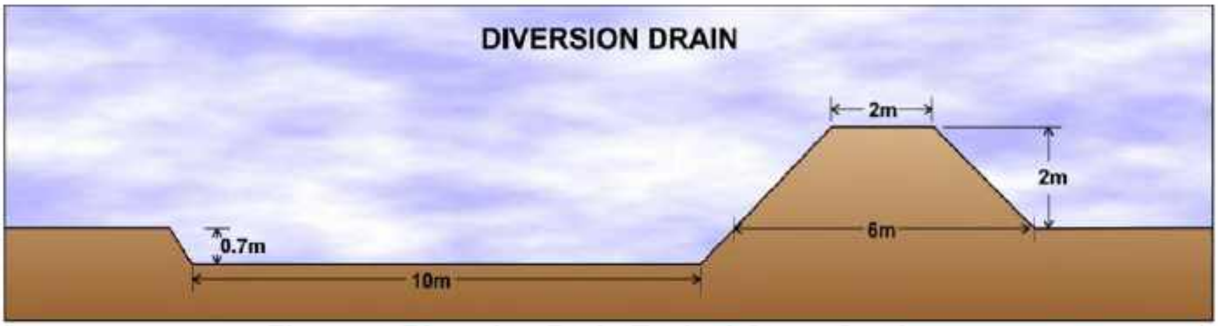

Figure 1: Diversion Drain Typical Cross Section

The batter slopes of the drain embankment should not be steeper than 45 degrees (1H:1V).

The groundwater levels within the drain embankment were modelled assuming that the embankment has high groundwater levels under long term operating conditions, i.e. for the most unfavourable combination expected.

For these analyses, representative soil parameters for the existing site conditions were adopted from 4DG report 024500REP01_Rev2. The soil strengths utilised are considered to be lower bound values and are presented in Table 2.

Table 2: Soil Strength Parameters

Material	Bulk Density (kN/m^3)	Cohesion (kPa)	Phi (°)
Kaolin Fill	15	6	28
Insitu Ferricrete	18	5	35
Insitu Kaolin	15	10	30

1.4 Stability Analysis Results

The stability analysis results are presented in Table 3. These results show that for the drain design presented in this report, the Factors of Safety against slope instability are within the adopted design criteria and the drain as modelled has acceptable slope stability.

Table 3: Stability Analysis Results

Case	Factor of Safety
Drain at Capacity	2.58
Drain Empty	1.90
Rapid Drawdown	1.25

The analyses have not identified any specific remediation works which are required, however, works should be carried out according to good engineering practice.

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The assessment of liquefaction potential of silt soils is described in "Geotechnical Engineering of Dams, Fell, MacGregor, Stapledon and Bell, 2005, page 501" and states that all of the following are required for a soil to be potentially liquefiable:

1. Clay content < 15%
2. $W_c > 0.9LL$
3. LL < 35%

Based on the laboratory test results presented in Table 4, the following can be determined:

1. Clay content not determined – criteria may be met;
2. $W_c = 47\%$, $0.9LL = 0.9x47=42.3$, thus $W_c > 0.9LL$ criteria not met;
3. LL = 47% which is greater than 35%, thus criteria not met.

The above methods indicate that the kaolin soils at the White Well mine are not susceptible to liquefaction.

The laboratory test results for kaolin presented in 4DG's report 024500REP01_Rev2 are presented in Table 4.

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Borehole, Test Pit No.	Depth Below Ground Surface (m)		c' (kPa)	Φ' (degrees)	Dry Density (kg/m3)	Moisture content (%)	Atterberg Limits		
							LL (%)	PI (%)	LS (%)
TP13	0	3	4	27	1.66	2	47	13	2.5
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3.0 PROPOSED COMPACTION CONTROL METHODS

The DMP letter dated 9 July requests a commitment for Cobra Mining to determine detailed strategies to ensure that the design specifications are met with regards to compaction control.

The information below could be adopted as part of Cobra Minings earthworks specification.

3.1 Test Methods

The following tests shall be carried out as specified or as instructed by the Company Representative to the relevant Australia Standards or other specified method.

Dry Density Ratio	AS 1289, 5.4.1
Field Moisture and Field Dry Density (using nuclear gauge)	AS 1289, 5.8.1

3.2 Testing Frequency

Dry Density Ratio	1 test per	5,000m^3
Field Density and Field Moisture Content	1 test per	5,000m^3

3.3 Criteria

The kaolin fill is recommended to be placed in 350 mm thick (loose) layers and compacted to 92% MMDD at ± 2% of Optimum Moisture Content (OMC).

It is recommended that the Laterised Zone and Ferricrete fill be moisture conditioned to ± 2% OMC, placed in 500 mm thick (loose) layers and compacted with 8 passes of a 16 tonne "padfoot" compactor or similar.

4.0 CLOSURE

Thank you for the opportunity to assist Cobra Mining with this project. Should you have any queries or require any further information please contact the undersigned at this office.

[redacted]

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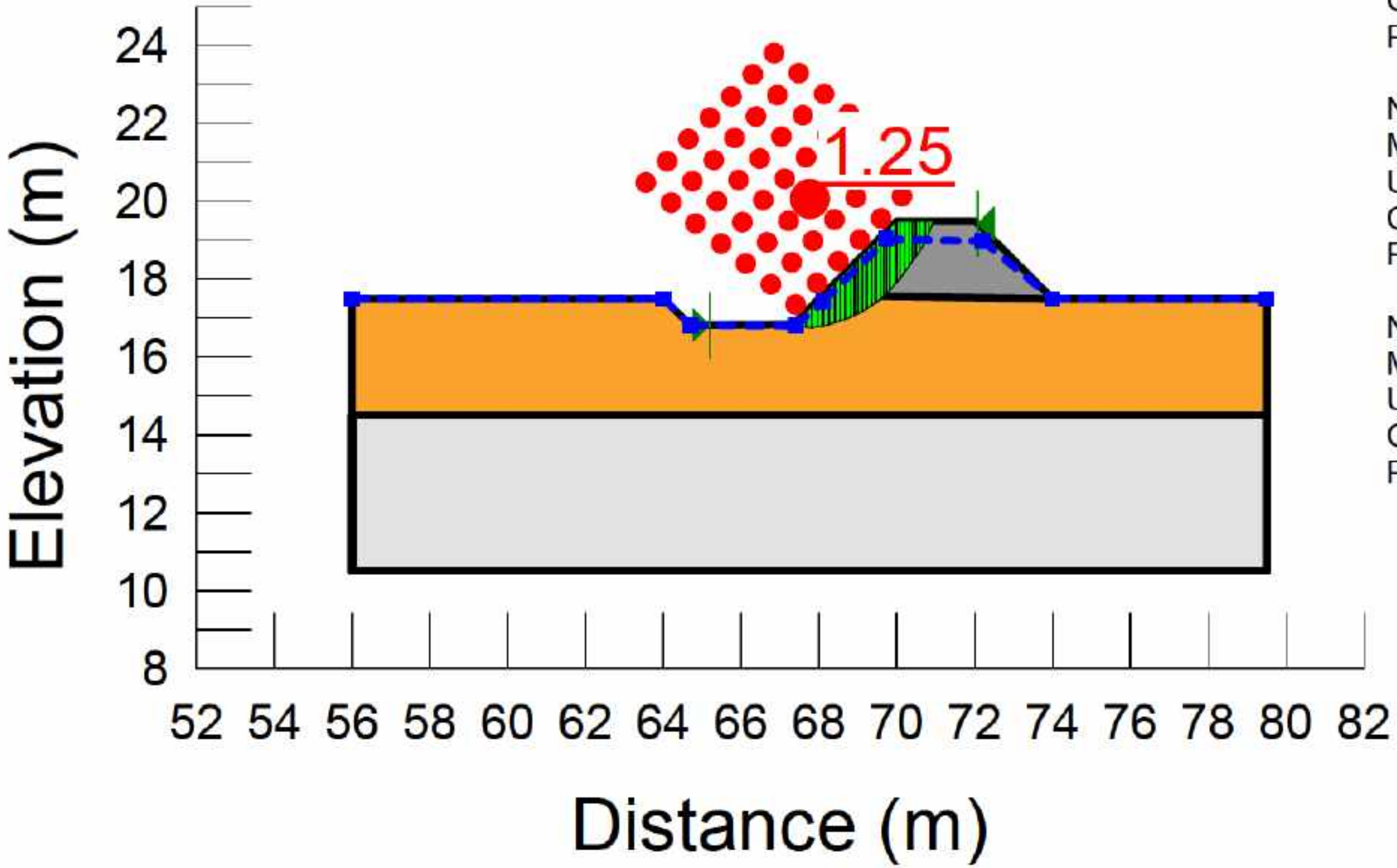
1 Electronic copy Calibre

Attachments: Stability Analysis Results

White Well Drain
Preliminary Design

Analysis of Drain after rapid drawdown



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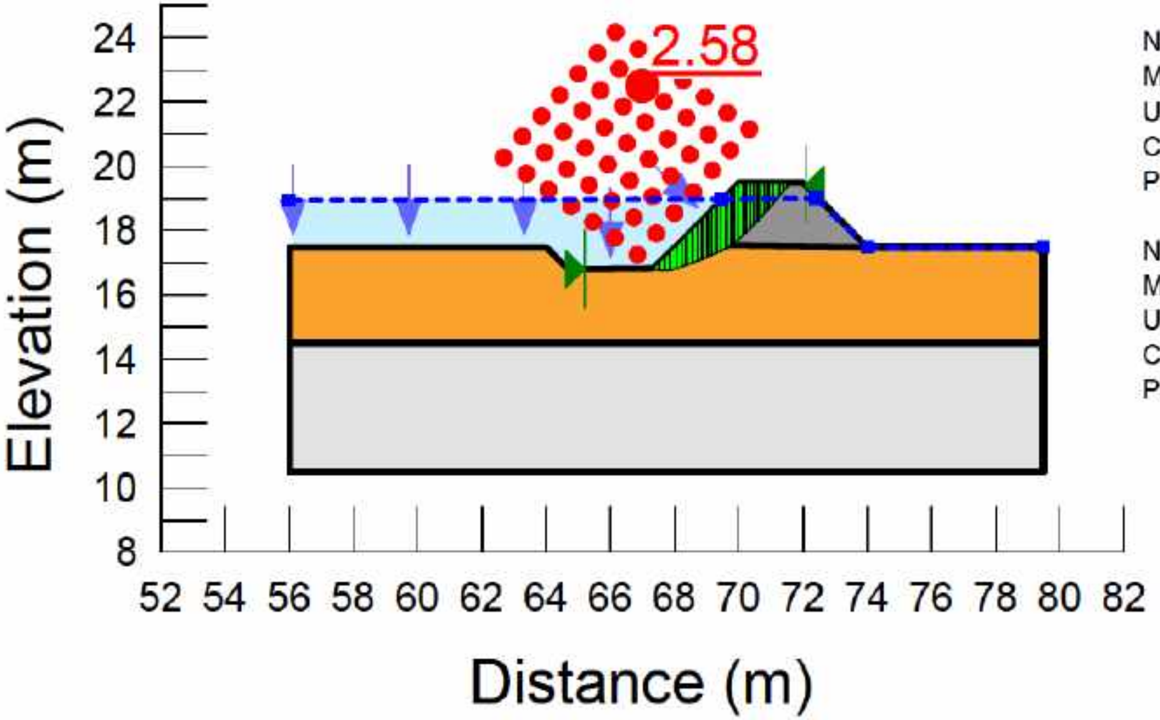
White Well Drain
Preliminary Design

Analysis of Drain at capacity



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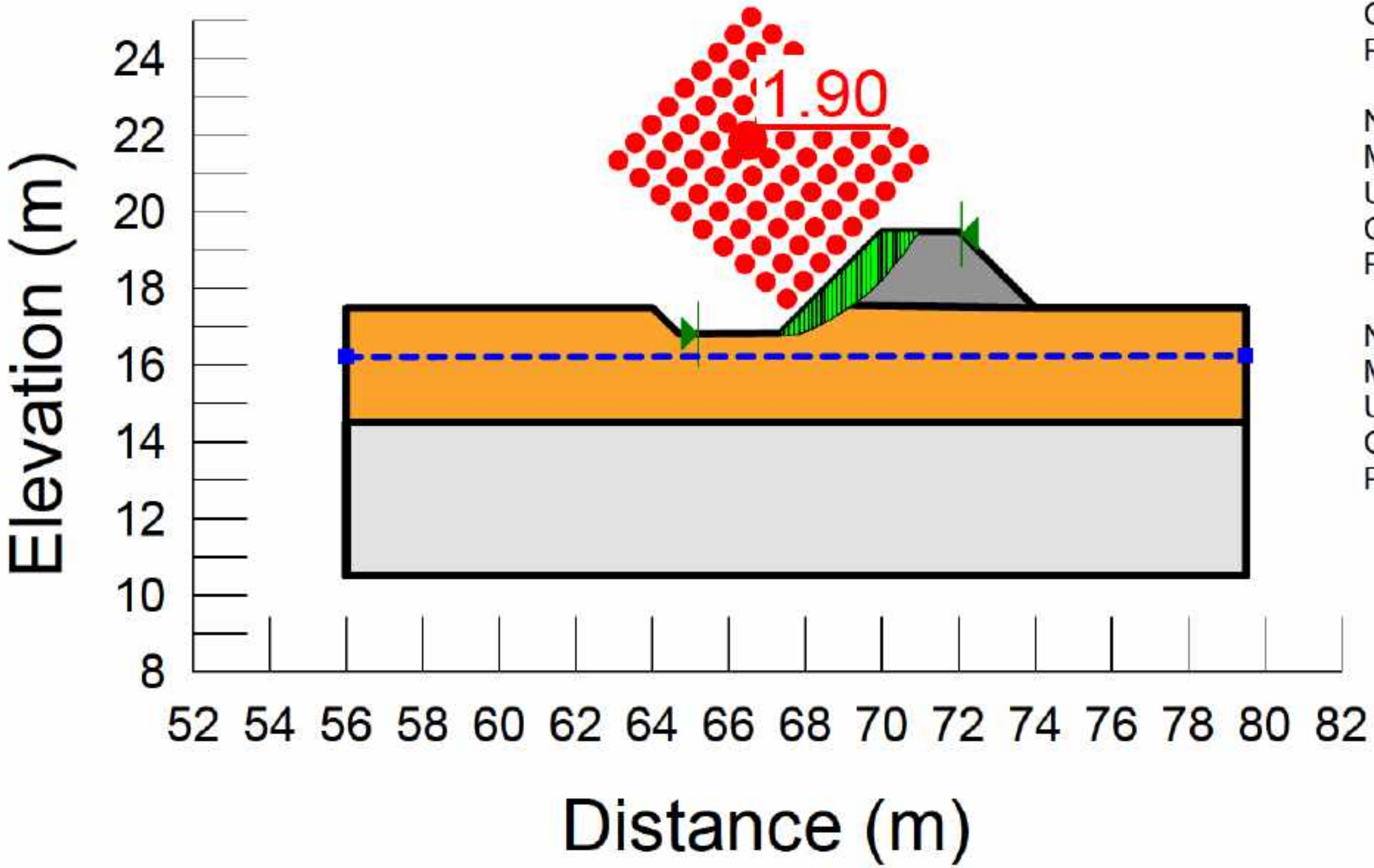
White Well Drain

Preliminary Design

Analysis of Drain when dry



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Cobra Mining – White Well Mining Proposal and Closure Plan review
Notes on questions from DMP Geotech queries dated 9th July 2012

It is noted that the proposed site drainage route passes between the pit wall and waste dump by mine development and the location of the open pit. It is not clear whether the drainage design has taken into account peak flow rates during a long-term design rainfall event (which would be the PMP if this drainage path remains important to the general environment at that location). Another potential concern is the construction of diversion drains within materials that seem to be prone to erosion. An assessment of flow rates and potential for erosion during .peak flow events is required.

Closure designs describe the use of a caprock cover to separate the kaolin from the topspoil. It is not clear whether there is sufficient volume of caprock available to cover all such structures. Given that the earlier mining has removed and used a large volume of this material, it is likely that a significantly larger area will need to be disturbed to obtain enough of this material. Also with respect to closure, the position of the abandonment bund and drainage structure need to be presented as a series of cross sections around the mine to verify that these are located outside .the potential zone of instability.

There is ample caprock available to provide for the closure landform designs. This is further discussed in 1.1, above.

The TSF is to be constructed as a 'paddock' structure using locally available kaolin clay material. The maximum height of the embankments is 15m. The design footprint of the TSF at completion of the project is understood to be approximately 11ha. The starter embankments will be raised in two separate 5m lifts using kaolinitic material. Two separate construction methods have been proposed - centreline and downstream. Whilst both methods appear to meet with departmental requirements, it is not clear which method the proponent will implement. (It is noted that the TSF datasheet indicates that the raising method will be centreline.) This will affect the area of disturbance and should thereby be clearly confirmed.

The tailings will be constructed via centreline construction, requiring 15ha of disturbance as proposed in the initial Mining Proposal submission. This is clarified in the attached 'Additional Geotechnical Assessment' completed by 4DGeotechnics and dated 19th July 2012.

The TSF will abut an existing ROM pad. Figure 3 in the operating manual suggests that it will terminate against the ROM pad. No details have been provided to clarify how this abutment will be addressed.

4DGeotechnics have provided a detailed response to this query in section 3 of the attached 'Additional Geotechnical Assessment', dated 19th July 2012. A cut-off trench will be installed along the toe of the ROM and the TSF bund will be constructed abutting against, and keying into to existing ROM. Keying into the ROM will require benches to be cut into the existing ROM. 4DG have advised that the width of the benches should be a minimum of 1m wide and maximum of 0.6m high. Furthermore, it is recommended that the cut-off trench is fully covered by the re-compacted TSF bund so that water or tailings do not pass over or around the trench.

The general characteristics of foundation and embankment materials, construction methods, operating procedures, emergency action plans and stability analyses for the project have been discussed. Whilst the information provided indicates that the proposal should meet with Departmental standards with respect to these issues, it is necessary for the proponent to confirm to what extent the foundation and embankment construction materials are prone to liquefaction.

4DGeotechnics have provided a detailed response to this query in section 2 of the attached 'Additional Geotechnical Assessment', dated 19th July 2012.

The proponent has not provided specifications for materials to be used or for verification that the as-constructed embankment characteristics have attained design limits. A commitment is .required from the proponent that detailed strategies will be developed for ensuring design specifications are met before construction commences.

4DGeotechnics have provided a detailed response to this query in section 5 of the attached 'Additional Geotechnical Assessment', dated 19th July 2012.

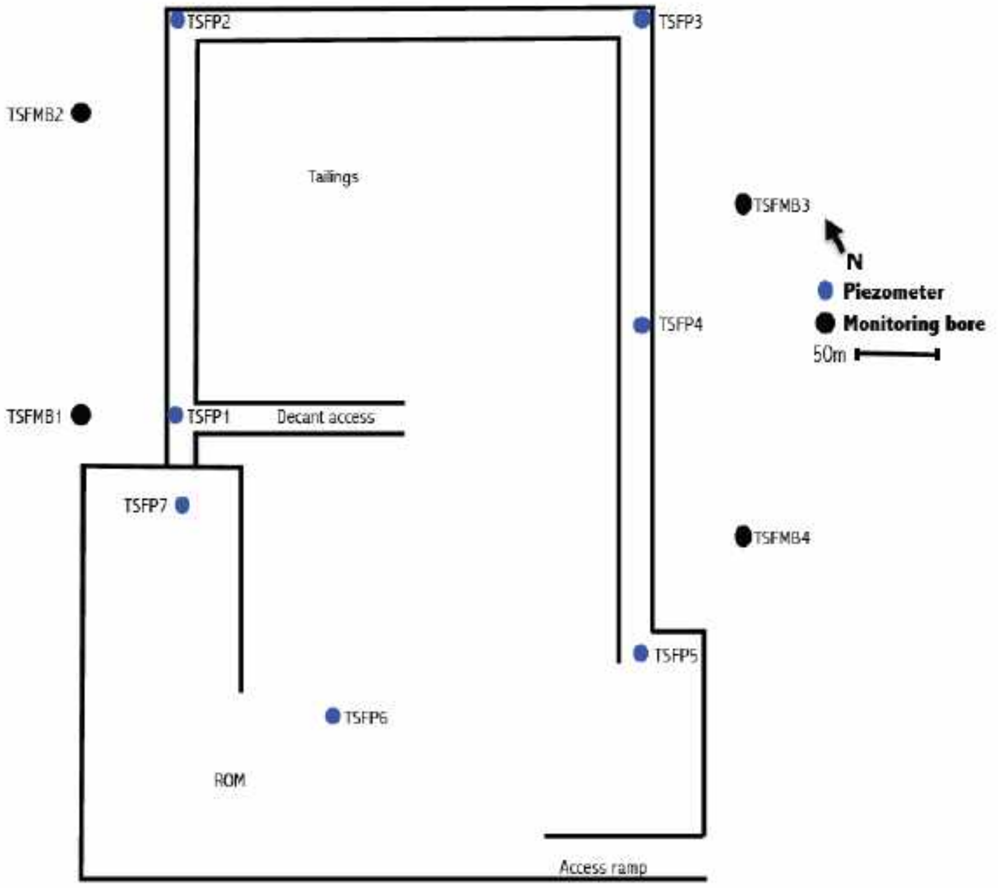
4DG has proposed a network of 5 monitoring bores will be constructed (around the perimeter of the TSF) and (an unspecified number of) piezometers will be installed in the downstream side of each cell embankment. A plan of the recommended monitoring sites has not been provided. This requires specification.

Surrounding the tailings facility, 4 monitoring bores will be installed to monitor groundwater quality. Within the embankment walls of the facility, 7 piezometers (5mm) will be installed. These will allow early detection of any embankment seepage. Bore locations are shown in the figure below.

Bore locations have been selected to intercept northwest regional groundwater flow (TSFMB1 and TSFMB2) and between the tailings and the mine pit (TSFMB3 and TSFMB4) assuming that the pit will act as a groundwater sink during dewatering.

White Well Tailings Facility

Monitoring Bores and Embankment Piezometers



The following monitoring schedule will be implemented

Table 4 Monitoring Schedule for Tailings monitoring points

Monitoring point	Frequency	Analysis/assessment
Embankment piezometers (7)	Weekly	Standing water level
Monitoring bores WMB1 - 4	Fortnightly Monthly Quarterly	Standing water level Electrical conductivity, pH and CN (on site lab) Electrical conductivity, pH and CN (NATA accredited laboratory)
Monitoring bores WMB1 – 4 Decant Water	Annually	Extended water analysis (Total Dissolved Solids, pH, Carbonate, Bicarbonate, Hydroxide, Chloride, Sulphate, Nitrate Sodium, Potassium, Calcium, Magnesium, Hardness, Iron, Manganese, Silicon, Aluminium, Arsenic, Barium, Boron, Beryllium, Cadmium, Cobalt, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium, Zinc, Strontium, Titanium, Vanadium)

All water samples will be taken in accordance with AS/NZS 5667.1:1998. As specified above, samples will either be analyzed in the on-site laboratory or submitted to a NATA accredited laboratory to be analyzed in accordance with current "Standard Methods for Examination of Water and Wastewater-APHA-AWWA-WEF". Results of analysis will be provided in the Annual Environmental Report, submitted to both the Department of Environment and Conservation and the Department of Mines and Petroleum.

Bores will be constructed according to ;

- ☐ Mining and Mineral Processing Series, water quality projection guidelines (2000) number 4 for the installation of mine site ground water monitoring bores, and
- ☐ Water Quality Projection Note 30 for Groundwater monitoring bores.

All bores will be constructed according to the following specifications unless otherwise required:

- ☐ Vertical
- ☐ Between 50 and 100m from the tailings embankment wall
- ☐ 3m of steel at surface, cemented with quick cement
- ☐ 160mm wide
- ☐ Slotted from ~4m to base
- ☐ Base cap
- ☐ 40m deep
- ☐ 80mm Class 9 PVC
- ☐ 1.5 – 3.2mm gravel pack to the base
- ☐ ~1m gravel plug

The details provided above be included in the version 2 submission of the Mining Proposal and Mine Closure Plan requested by the DMP.

4DG

TEL: (08) 9443 9994
FAX: (08) 9443 9991
[redacted]
WEB: www.4dg.com.au

201-203 Bulwer St, Perth WA 6000 / PO Box 509, Leederville WA 6903 / ABN 11 073 742 604

13 July 2012

Ref: 024500LET01

Cobra Mining Ltd
159 Stirling Highway
Nedlands
WA 6009

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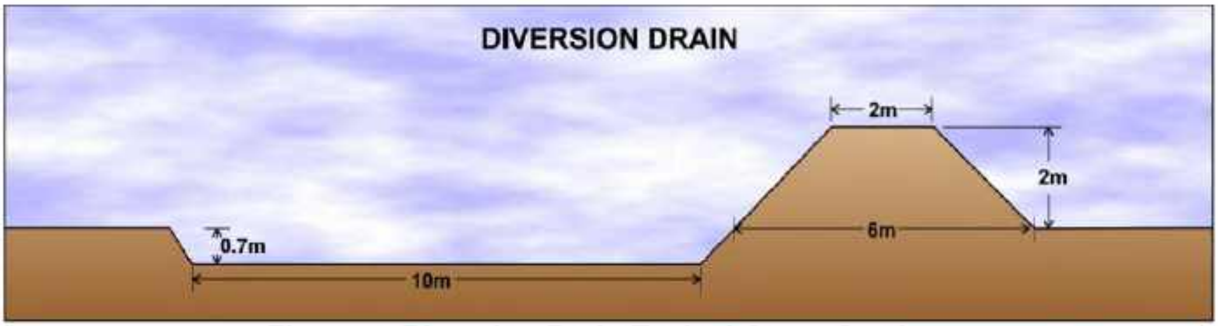

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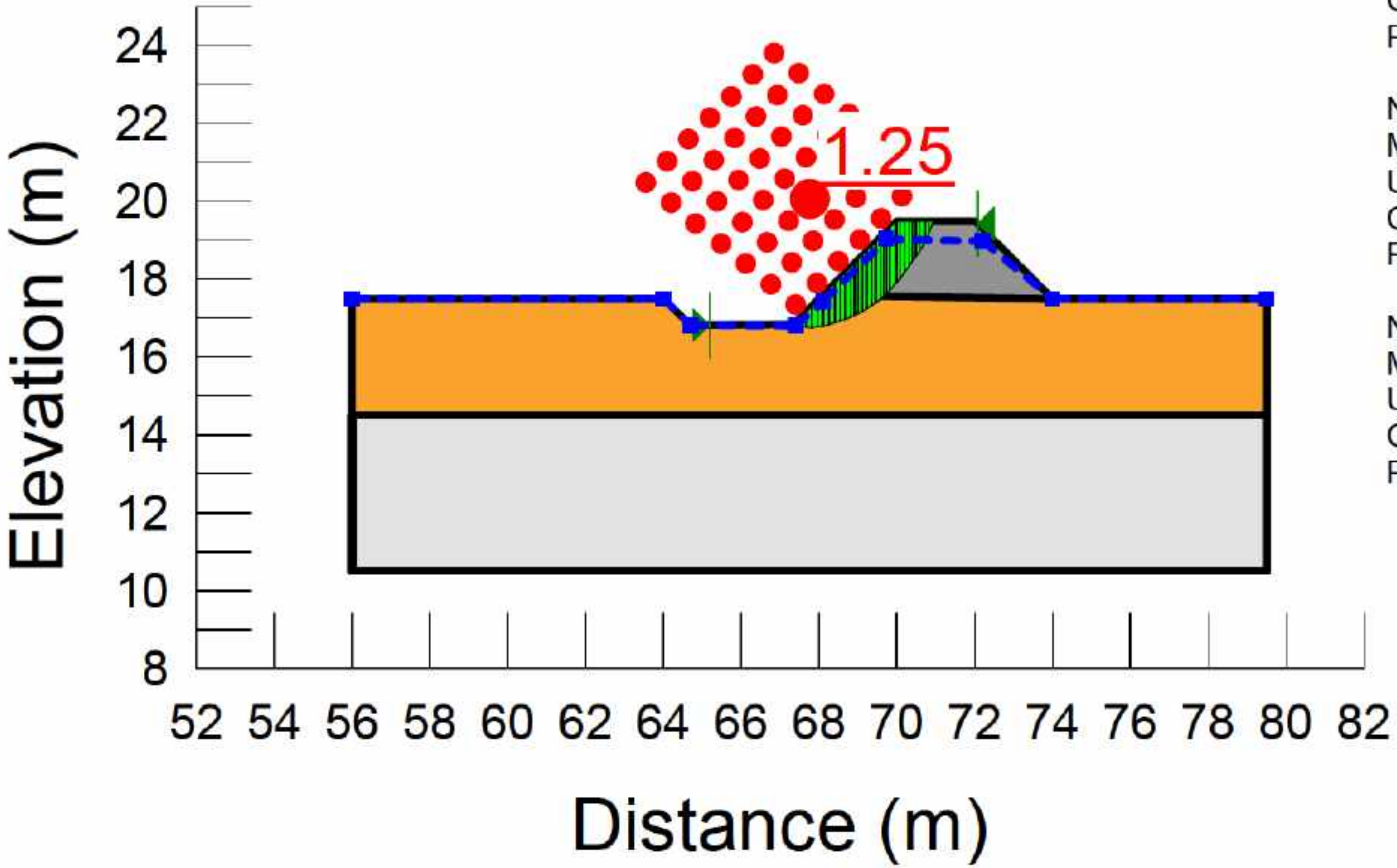

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White Well Drain
Preliminary Design

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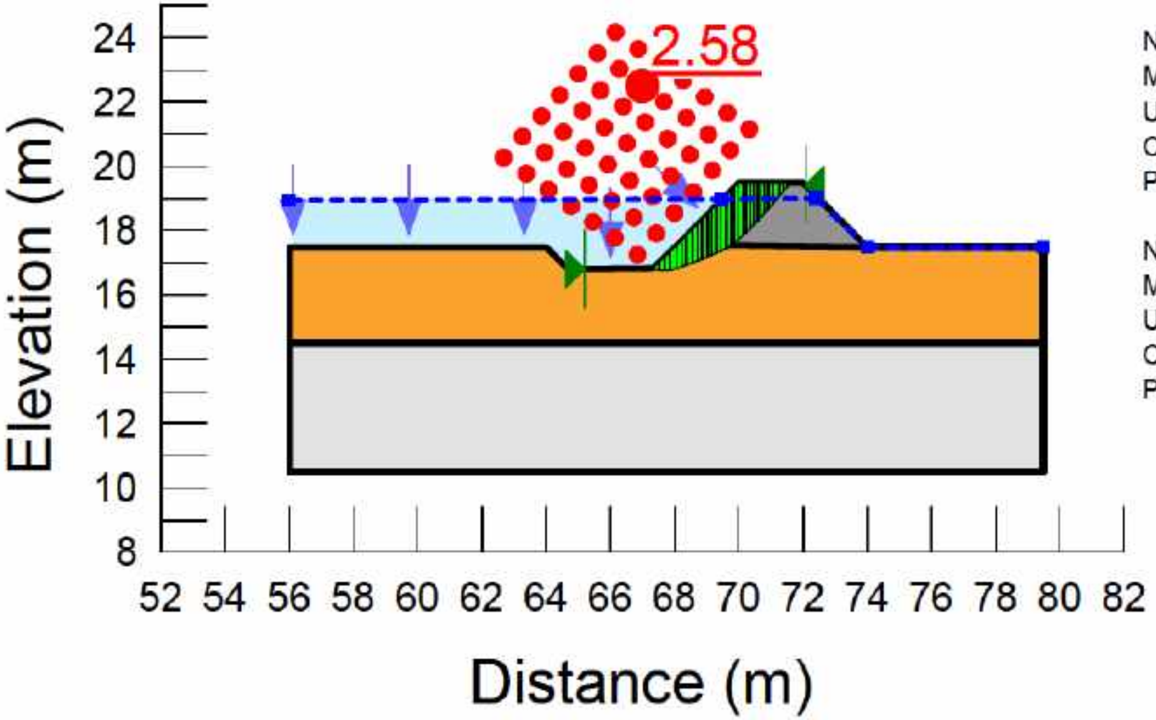

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White Well Drain
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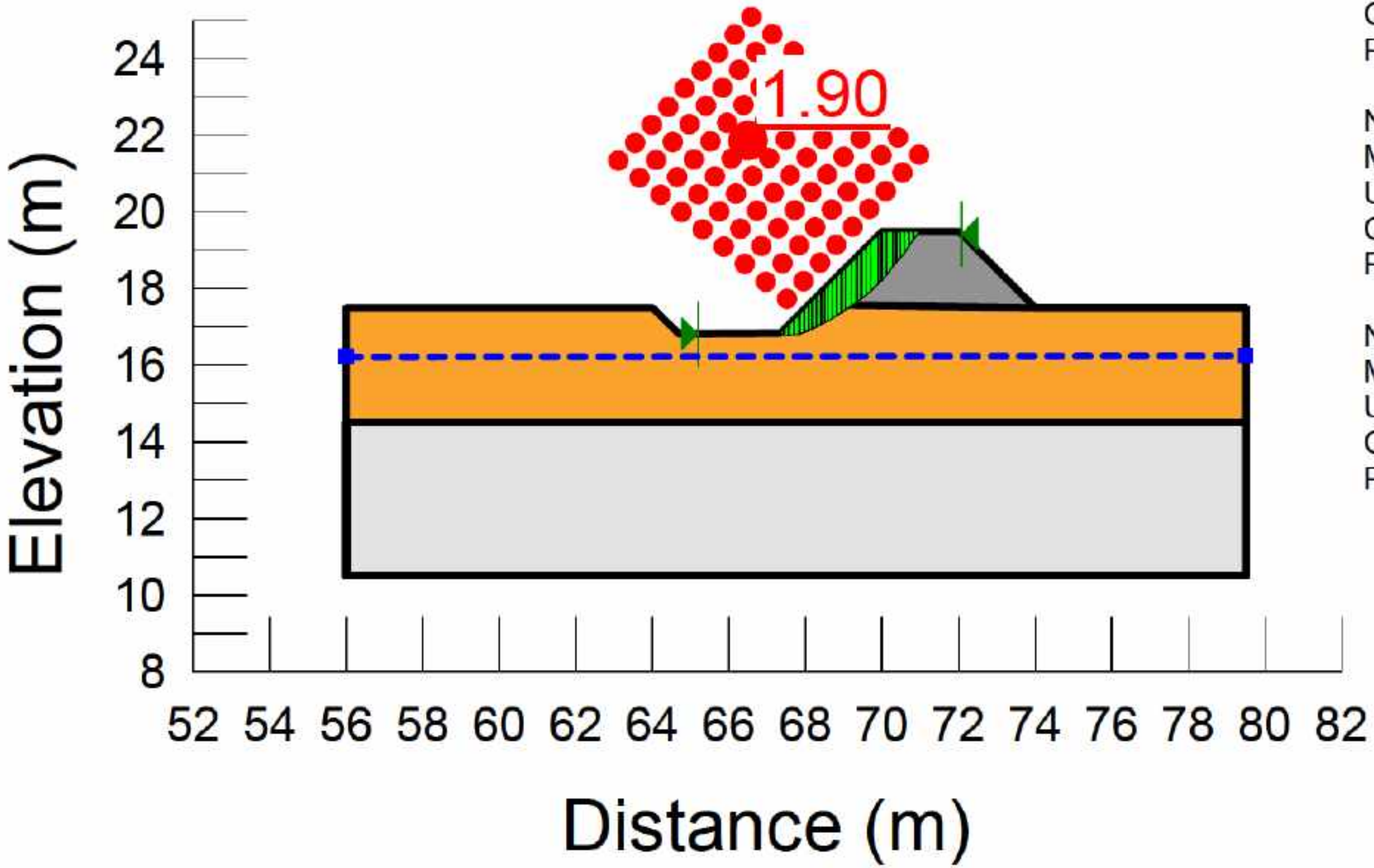

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