GEOTECHNICAL ASSESSMENT OF WATER TREATMENT PONDS, PART LOT 1 DP 3350 WHAKAMAHIA ROAD, WAIROA

Project Reference: 13322
17 August 2017

1 INTRODUCTION

Land Development & Exploration Ltd (LDE) was engaged to undertake a geotechnical assessment of the existing Wairoa District Council wastewater treatment ponds, located on a site at part Lot 1 DP 3350 Whakamahia Road, Wairoa. The purpose of the assessment was to provide geotechnical information on the:

- Geomorphology of the pond site.
- Nature and variations of the underlying geology and embankments, especially in relation to permeability.
- Nature of current liner system
- Potential for seepage through pond base and embankments
- Stability of embankments, including performance during seismic events.
- Possible raising of the embankments by up to say 2m to increase pond storage, and
- Information for the relocation of the primary pond further upslope to allow an increase in the size of the secondary pond.

Figure 1: Approximate location of Wairoa wastewater treatment ponds (source Google Earth).

2 INVESTIGATIONS

Our investigation of the site included the following work;

- A desk top study of published and unpublished information of the site.
- An analysis of historic stereographic aerial photographs to assess key geomorphological features of the site and surrounding area.
- A walkover assessment of the site and surrounding area to assess its geomorphology and any features which may potentially influence the long term behaviour of the site.
- Inspections of existing exposures of the underlying geology.
- Two machine boreholes put down to 10m depth or refusal. The soils encountered were generally logged to NZ Geotechnical Society Logging Guidelines for the field classification of soil and rock for engineering purposes.
- Four electronic cone penetrometer tests (CPTs) put down using a specialist rig to 15m depth or refusal.
- Two 50mm handaugered boreholes put down to 5m depth or refusal. Measurements of the undrained shear strength were taken at 200mm intervals within cohesive soils encountered down through the boreholes using a calibrated shear vane. The soils encountered were generally logged to NZ Geotechnical Society Logging Guidelines for the field classification of soil and rock for engineering purposes.
- Two dynamic penetrometer tests put down to 5m depth or refusal. The penetrometer tests were measured in 50mm increments to better identify lower strength zones beneath the surface.
- Observations and measurements of the soil moisture content and levels of groundwater encountered down through the boreholes. The possible seasonal variation of these levels was noted and compared to the regional groundwater table expected for the area and the timing of the investigation.

The locations of the subsurface investigations are shown on the appended Geotechnical Investigation Plan. Logs of the boreholes and penetrometer tests are also appended.

The field work was completed throughout May and June 2017.

All work was completed by a qualified geological-geotechnical specialist.

3 Site Characteristics

The water treatment ponds are located close to the river mouth of the Wairoa River approximately 3km to the south of the township (Figure 1). One large 235m long by some 40m wide, generally linear oxidation pond (secondary pond) is present within the base of a generally northeast to southwest trending valley. A smaller 79m by 28m aeration pond (primary pond) is located to the immediate south above the oxidation pond on a gentle to moderate 15° slope leading up Whakamahi Road and "Pilots Hill". The slope has been mechanically altered and excavated to allow for the wastewater treatment ponds and utility building. A moderately steep (25°) hillside rises to the immediate north of the secondary pond. This is generally vegetated in moderately sized pine trees and small shrubs, while the remainder of the property is generally under mown lawn.

The existing ponds have been excavated to approximately 2.5m depth with batter slopes around 2H:1V, and effective areas of approximately 11000m^2 and 2300m^2 respectively. Construction plans of the site (provided by Wairoa district council) reveal that the ponds were largely excavated into natural ground with fill placed in the adjacent areas. As such there are no raised embankments. The plans show the northern slope being cut into with fill material keyed in through the use of benches (Figure 4). Vee shaped cut off drains exist surrounding the secondary pond, with the depth to invert varying between 0.3m and 0.6m to provide an adequate fall to the outlet.

Figure 2: Aerial image of site, with potential location of primary pond (red) and potential extension area of secondary pond (yellow).

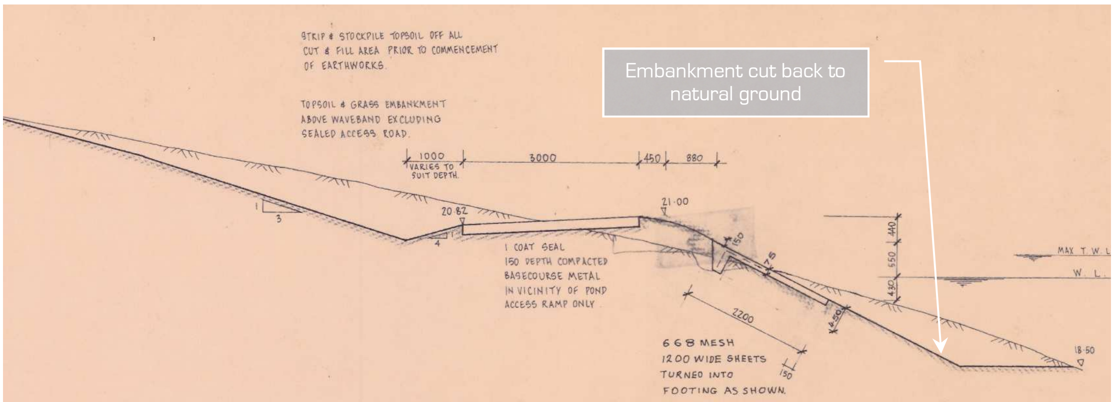

Figure 3: As built construction plans (Note: no liner material is documented).

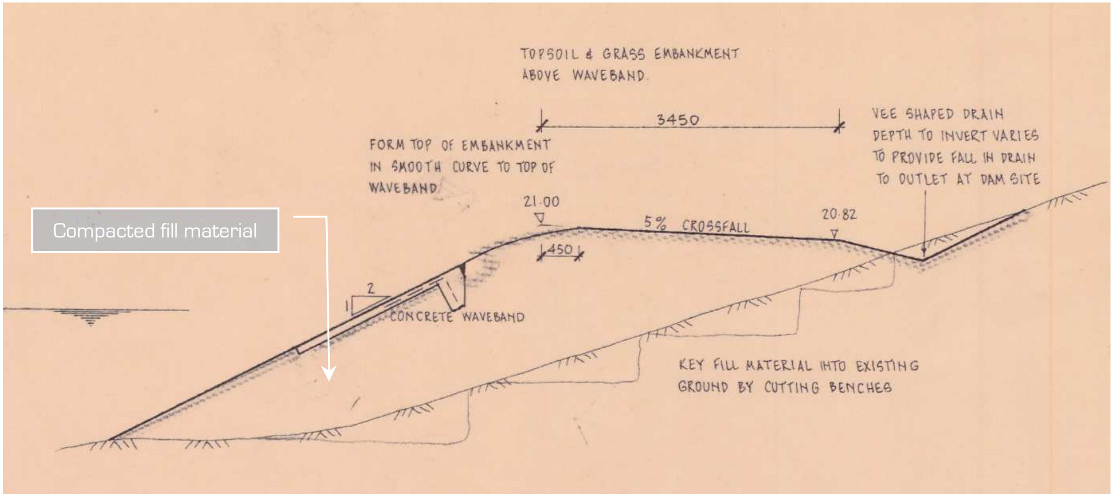

Figure 4: As built construction plan showing keyed in fill material to northern slope.

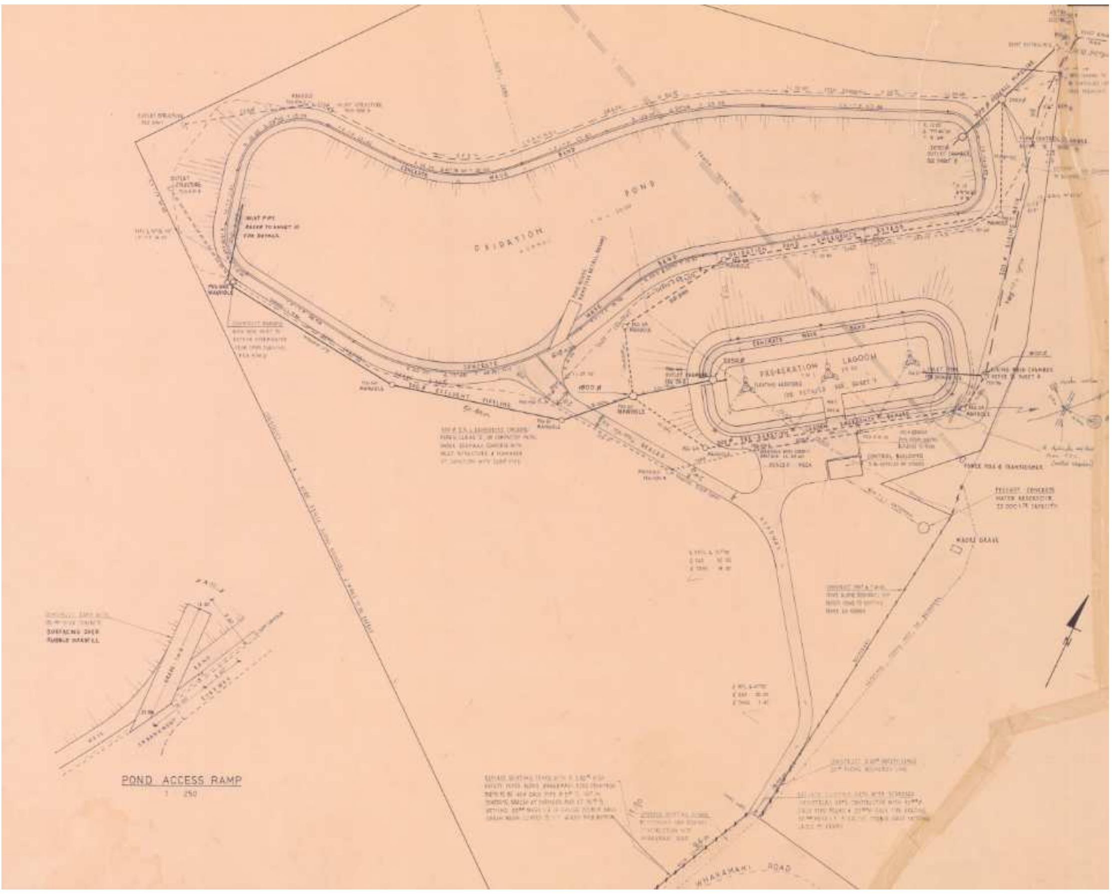

Figure 5: Asbuilt site services plan.

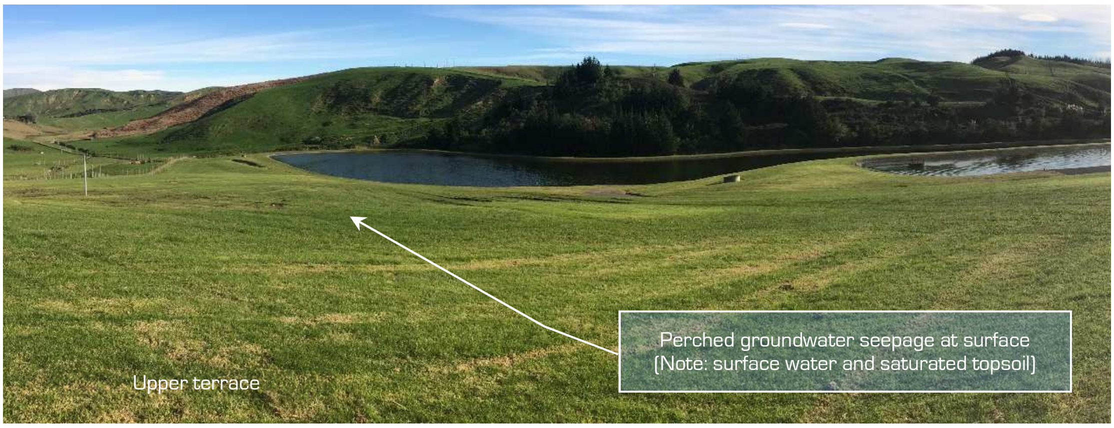

Figure 6: Panoramic view north over site (Note: Perched groundwater seepage at surface).

Figure 7: Western limit of secondary treatment pond. Note cutoff drain and northern slope.

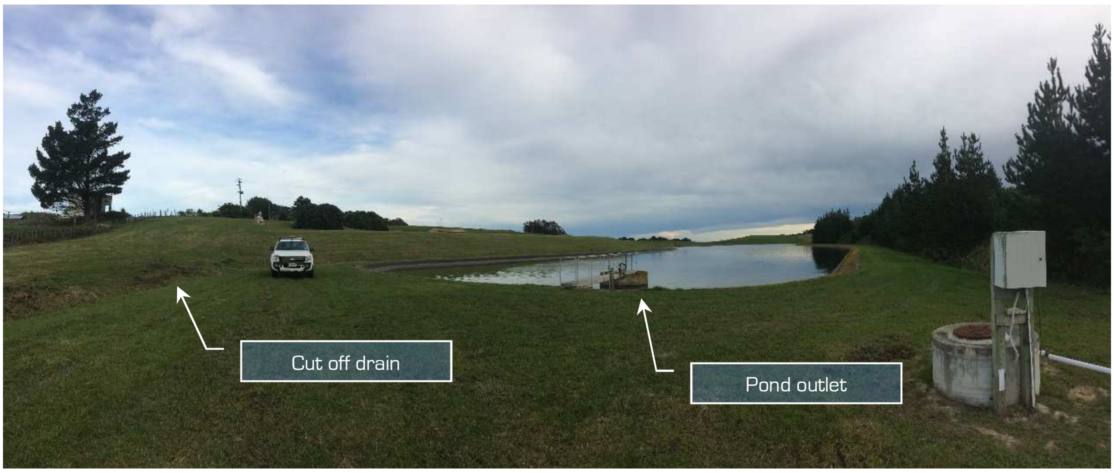

Figure 8: Panoramic view southwest. Note cutoff drain behind vehicle and pond outlet.

4 Engineering Geology

4.1 General

The engineering geology of the site is summarised below and in the appended cross sections. It is based on an integration of published and unpublished data, the geomorphology of the site, surface exposures of the underlying geology, and subsurface investigations carried out at discrete locations. The nature of the ground between the investigation points is inferred and may vary from that described. For details of the materials encountered and measurements of their respective strengths please review the appended investigation logs.

4.2 Geological Setting

The 1:250,000 geological map of the region[1] shows the site as being underlain by middle to late Pleistocene undifferentiated alluvial deposits (lQa) consisting of sand, silt, pumice and clay.

4.3 Subsurface Conditions

In summary, the soils encountered in our investigations are generally consistent with the mapped geology, comprising laterally persistent thinly layered moderate to high strength alluvial deposits of sand, silt and clay draped with volcanic ash up to 0.8m thick. Topsoil up to 0.5m thick was also found across the site. Fill is also present, in some areas directly overlying the topsoil.

4.3.1 Topsoil

In summary, the investigations indicate the site is underlain by moderately organic silt (Topsoil) down to 0.1m to 0.5m depth. The topsoil was generally found to be dark brown to black and moist to wet.

4.3.2 Tephra

Typically underlying this layer pumiceous sand and silt (Tephra) exists down to 1.3m depth. This layer appeared to be laterally persistent across the site. The tephra is generally light brown to white, with patches of dark brown staining and was wet to saturated at the time of the investigation.

4.3.3 Alluvium

Laterally persistent but vertically variable layers and mixtures of sand, silt and clays (moderate to high strength Alluvial and Pleistocene sediments) exists beneath the above layers, down to the extent of the investigations and probably to at least sea level based on the same materials being exposed around the shoreline cliffs of Pilots Hill to the south of the site. These materials are typically light brown to grey with orange and brown mottling and were moist to saturated at the time of the investigation. The undrained strength of the materials generally range from 5kPa to greater than 50kPa.

[1] Lee, J.M.; Townsend, D.; Bland, K.; Kamp, P.J.J. (compilers) 2011: "Geology of the Hawke's Bay area: scale 1:250,000 geological map 8".

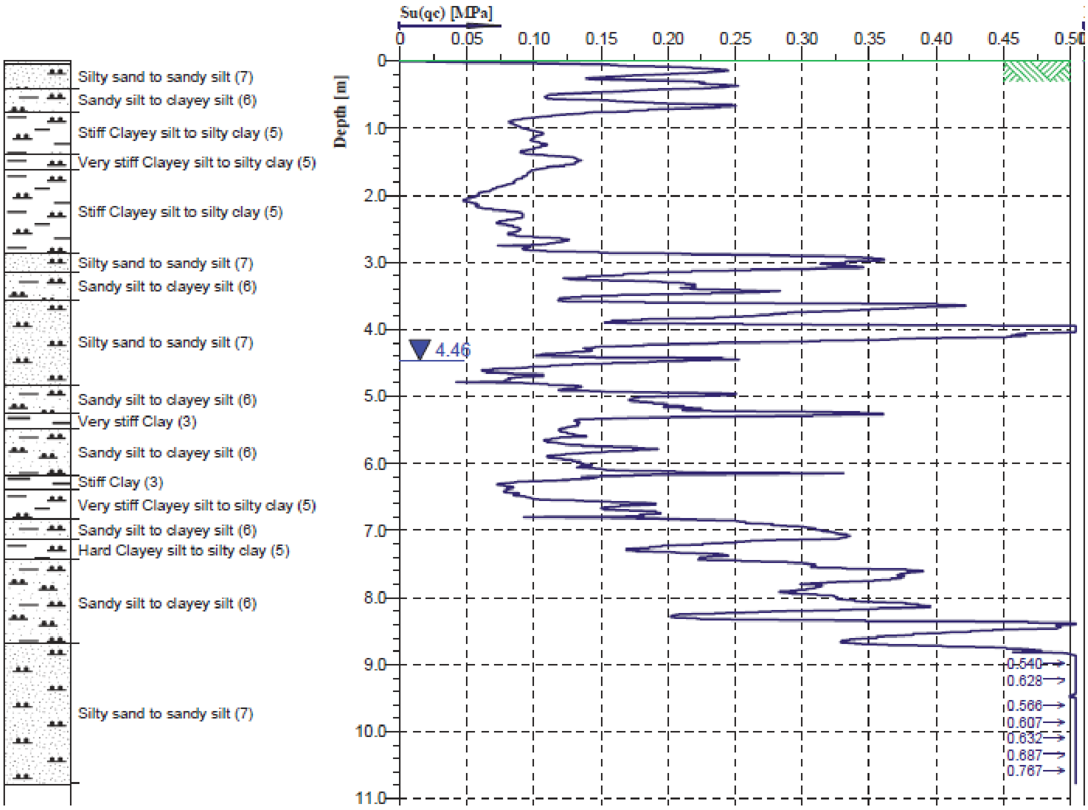

Figure 9: material and strength profile of ground at western end of secondary pond showing layered and stratified nature of ground typically beneath the property.

4.3.4 Pond Fill Materials

Fill materials up to 2m in thickness, were generally encountered adjacent to both the eastern and western end of the pond (Figure 10). The fill appears to have been used in landscaping and levelling the site at the time of the ponds construction, as the investigations adjacent to the oxidation pond indicate the presence of buried topsoil beneath the fill.

Figure 10: Approximate extent of landscape fill surrounding oxidation pond.

A review of as-built construction documents, CPT and machine boreholes (put down adjacent to the eastern and western end of the oxidation pond), reveals that the landscape fill material behind the main pond embankment typically consists of (stiff to very stiff) compacted and blended clays silts and sands from the ponds excavation. However there is no indication that the material was intended to be engineered fill or how compaction was achieved. Construction plans show the ponds embankments either consist of excavated natural ground or keyed in fill material. It is likely that the embankment fills are compacted to a reasonable level of compaction. In contrast, fill placed behind the pond embankments is possibly compacted to a lesser degree.

The ponds do not appear to have a liner as such, with either natural ground or compacted fill currently used to retain water. There is a 0.1m thick concrete apron around the perimeter of both ponds to prevent embankment erosion due to wave action.

4.4 Potential Permeability of Materials

The permeability of the existing materials within the embankments and beneath the ponds have been estimated using correlations of grainsize and compaction permeability tables[2] [3] with CPT and machine borehole data. The investigations were put down at the eastern and western ends of the secondary pond (within the landscape fill material) and in a potential location for the primary pond relocation further upslope.

A range of permeability is given for the following materials due to their inhomogeneous soil nature. It must be appreciated that estimation of soil permeability of this nature is subject to much uncertainty and should be used as a guide only. Further laboratory and/or insitu testing (e.g. packer testing) is recommended and required to further refine permeability.

Table 1: Range of permeability for soils beneath the site

Material Name	Range of Permeability (*k*)
Compacted Fill	≈ 1×10^{-7} to 1×10^{-8} (m/s)
Tephra	≈ 1×10^{-4} to 1×10^{-5} (m/s)
Alluvium	≈ 1×10^{-6} to 1×10^{-8} (m/s)

4.5 Soil Moisture Profile and Groundwater Conditions

The permanent groundwater table beneath the site was not encountered in any of the investigations, however we expect the permanent groundwater table to lie some 8m to 10m below the surface of the secondary oxidation pond based on the elevation of the pond relative to the surrounding watercourses, including the Wairoa River and Whakamahia Lagoon.

[2] Lunne T., Robertson P. and Powell J. 1997: "Cone Penetration Testing in Geotechnical Practice".
[3] Look B. 2007: "Handbook of Geotechnical Investigation and Design Tables".

Perched groundwater was encountered in the remainder of the boreholes and appeared to be laterally continuous across the site. The perched water was typically encountered within the 0.5m to 0.8m thick permeable tephra layer. It is expected that the perched groundwater flows through the laterally continuous tephra layers, eventually into the Wairoa River and Whakamahia Lagoon.

Perched groundwater occurs due to rain water percolating through near surface soils until it reaches the finer grained impermeable alluvial soils (underlying the tephra layer). In the upper terrace area, water was identified to be seeping through the laterally persistent tephra layer, until it discharged at the surface through exposures (coved by topsoil) in the cut areas of the slope (Figure 6).

Fill adjacent to the oxidation pond was typically moist to wet down to 2.4m to 4.8m depth where perched groundwater was encountered in the tephra layer. Soil moisture content generally returned to being moist to wet beneath this depth to the extent of the subsurface investigations.

The moist to wet nature of near surface soils identified in the machine boreholes adjacent to the oxidation pond may identify seepage is occurring. However from estimated permeability values (Section 4.4) and seepage analysis, small amounts of seepage is expected to occur through the ponds base and embankments. There is a strong likelihood that fluid from the ponds is seeping horizontally through the tephra layer and into surrounding watercourses.

The moisture content of the near surface soils is expected to be higher during the winter months or extended periods of wet weather resulting in their saturation at times. The extent of the wetting front will be dependent on the duration of the period of rainfall and is expected to continue to the base of the tephra layer (the low permeability alluvial material prevents wetting front extending deeper). Similarly, we consider the near surface soils adjacent to the oxidation pond is expected to be continually moist to wet due to seepage through the ponds base and embankments.

4.6 Material Properties

The material strength parameters given in Table 1 below, have been used in our analyses of the site and can be used for design. These were generally derived from published and unpublished correlation charts and tables for the particular materials encountered in the investigation. Results from laboratory testing of similar materials were also taken into consideration, as were results from numerical back analyses. Consideration has been given to the behaviour of the materials with long term loading, and also their strength under likely worst case moisture content levels.

Table 2: Material shear strength parameters and permeability.

Material name	Unit Weight (kN/m3) γ	Effective cohesion (kPa) c'	Effective friction angle Ø'	Permeability (m/s) *k*
Structural Fill (Engineered Fill)	18	5	30	$1x10^{8}$
Non-Structural Fill (Non-Engineered)	18	5	27	$1x10^{6}$
Tephra	16	0	32	$1x10^{5}$
Alluvium	20	5	27	$1x10^{7}$
Foundation Material (Pleistocene Alluvium)	20	7	32	$1x10^{8}$
Drainage Gravel for Piezometric Drawdown	22	0	35	$1x10^{2}$

5 Geotechnical Assessment

5.1 Earthquake Shaking

The site is located in a region of moderate to high seismicity. As such, the site can be expected to be subject to moderate earthquakes every 20 to 25 years, with a 10% probability of a large earthquake occurring within the 50 year design life of the structure. Potential ground deformation resulting from earthquake shaking is discussed in the following sections.

We consider that the site is a Class C shallow soil site as defined by NZS 1170.5 (2004) "Structural Design Actions: Part 5: Earthquake actions – New Zealand".

Accordingly, the site is expected to be subject to a peak ground acceleration of 0.37g during an Ultimate Limit State event (i.e. a large earthquake with a probability of exceedance of 1: 500 years).

For Serviceability Limit State seismic conditions the site can be expected to be subject to a peak ground acceleration of 0.09g during a moderate earthquake event with a probability of occurring once every 25 years.

5.2 Fault line Surface Rupture

The published geological maps do not show any faults passing beneath the site. In addition, the GNS Active Faults Database does not show any faults passing through or nearby the site (closest mapped active fault is fault #4614 approximately 16.5km away). There also does not appear to be any surface expressions which would indicate the presence of a fault line within the vicinity of the site. We therefore consider that the surface fault line rupture risk to be low.

5.3 Slope Stability

The stability of the site has been assessed taking into account:

1. natural and cut and fill slopes presently existing, and
2. slopes that could potentially be formed following the elevation of the secondary pond by up to 2m, an increase in the secondary pond size, and relocation of the primary pond upslope and to the south of its present position.

The stability assessments were based on the geomorphology, the underlying engineering geology and 2D numerical stability analyses. The soil strength parameters used in the analyses are generally as presented in Section 4.6, and are shown on the appended stability analysis printouts. Consideration of the strength of the materials and how these may behave under seismic loading was also taken into consideration. The seismic loads used in the analyses were those given in Section 5.1. Minimum factor of safety criteria used in the analyses were a Factor of Safety ≥1.5 for maximum storage level conditions and ≥1.2 for extreme groundwater conditions. The criteria used for seismic conditions were a maximum of 25mm of lateral movement under Serviceability Limit State seismic loads and a maximum of 100mm of lateral movement for Ultimate Limit State seismic load conditions.

5.3.1 Current Stability

Overall the site displays a geomorphology that is indicative of fundamental stability, with smooth natural slopes and cut and fill slopes. The fill slopes leading away to the east and west from the secondary pond are flat to very gently sloping with no elevation difference of significance to allow for slope instability or warrant numerical slope stability analysis.

The hillside to the north of the pond shows evidence of past shallow to moderately deep seated land slippage up to 15m in width, particularly the northwestern slope in the adjacent western property where the elevation of the hillside increases (Figure 6). Apart from some shallow seated instability in the steepest and unvegetated slopes, it appears that the landslip geomorphology existed prior to the development of the treatment ponds. Accordingly, the shorter slopes directly to the north of the secondary pond have been improved by the buttressing provided by the northern pond fill embankment and the presence of pond fluid (Figure 11). The steeper elevated hillside to the northwest of the pond is also isolated from the pond.

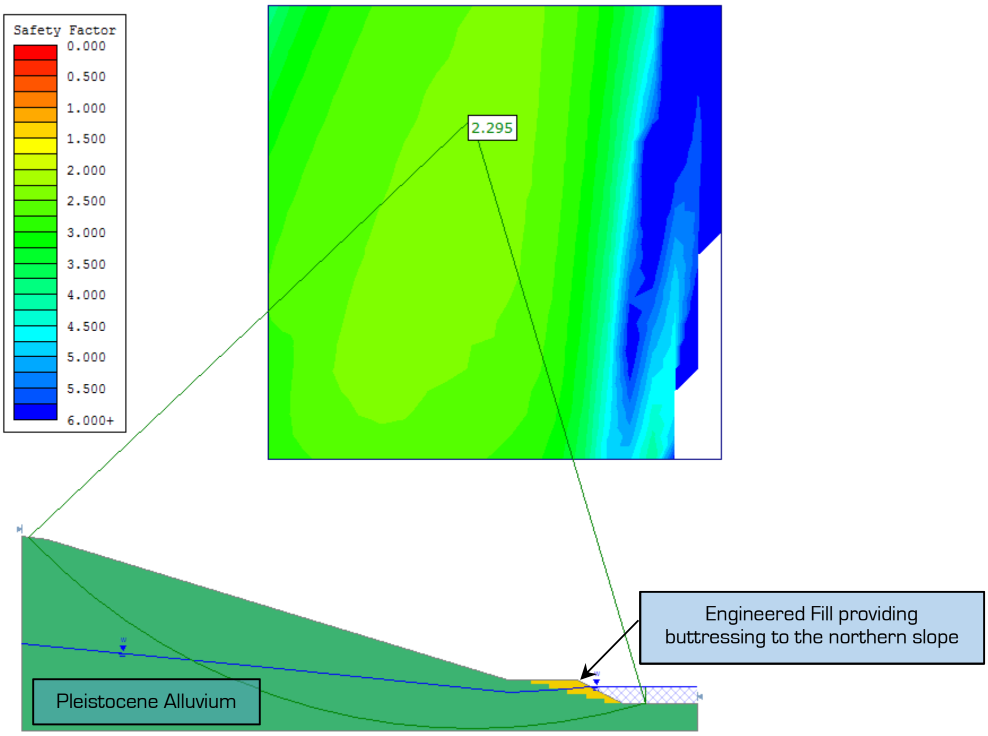

Figure 11: Numerical slope stability of northern slope above oxidation pond

Numerical analyses assessing the stability of the existing slopes leading up to the south from the secondary treatment pond show that the slopes have minimum factors of safety >1.5 under fully saturated conditions and >1.0 under ULS seismic loading, both well above minimum factor of safety criteria for these conditions (1.2 and 1.0 respectively).

5.3.2 Raised Oxidation Pond Embankment Stability

Stability analyses were carried out to determine the stability of embankments raised up to 2m above the existing embankment level. The numerical analyses included assessments of the raised embankment stability under maximum storage level conditions (full pond level), extreme groundwater conditions (fully saturated embankment with empty pond), and ULS and SLS seismic conditions for maximum storage levels.

Under design conditions (modelled using maximum pond storage level), numerical analysis identified the raised embankment to have a minimum factor of safety of >1.5 (Figure 12).

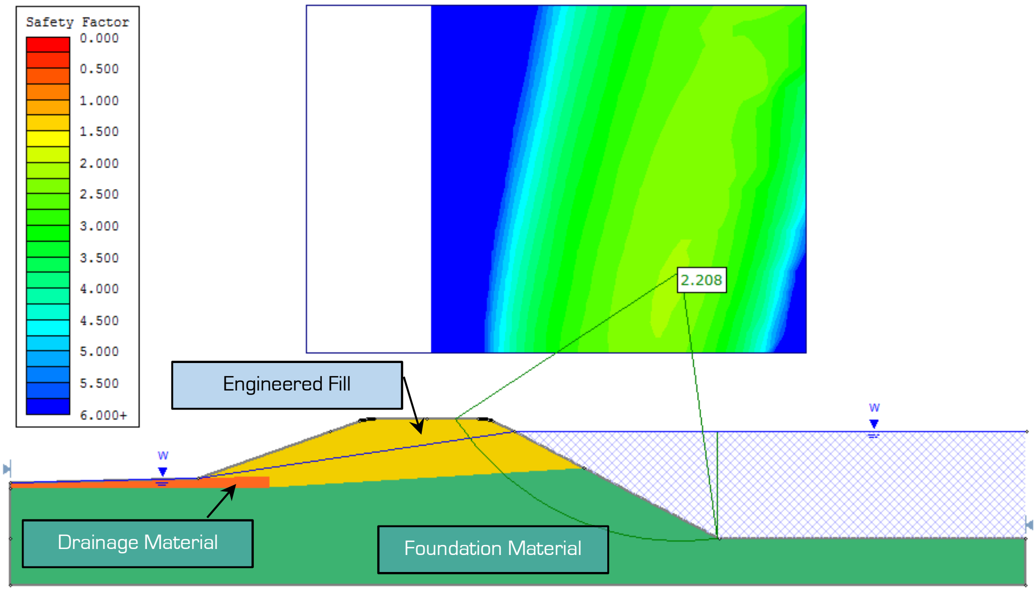

Figure 12: Minimum raised embankment factor of safety under design conditions

Numerical analysis identified that under the unlikely condition of a fully saturated embankment, (i.e. extreme groundwater conditions with an empty pond and saturated embankments) the internal embankments are shown to have minimum factor of safety values of >1.2 (i.e. meets the minimum criteria for stability under fully saturated conditions).

Under Serviceability Limit State conditions the minimum factor of safety of this slope is 1.5 which shows that seismic induced ground deformation is unlikely. Under Ultimate Limit State seismic loads the internal embankment slope is shown to have minimum factor of safety of 0.7. While catastrophic failure is unlikely to occur, the soils within the embankment may be expected to be subject minor yielding of 1mm to 8mm[4], which is relatively insignificant for the significance of the event.

5.3.3 Stability Following Potential Pond Extensions

Numerical stability analyses were undertaken for the southern slope taking into consideration the secondary pond extending into the position of the primary aeration pond. The analyses showed that the slopes leading into the secondary pond would have a factor of safety >1.5 under fully saturated conditions and >1.0 under ULS seismic loading, both well above minimum accepted factors of safety.

[4] Calculated using Makdisi and Seed (1978) methodology assuming a Magnitude 7.5 earthquake event

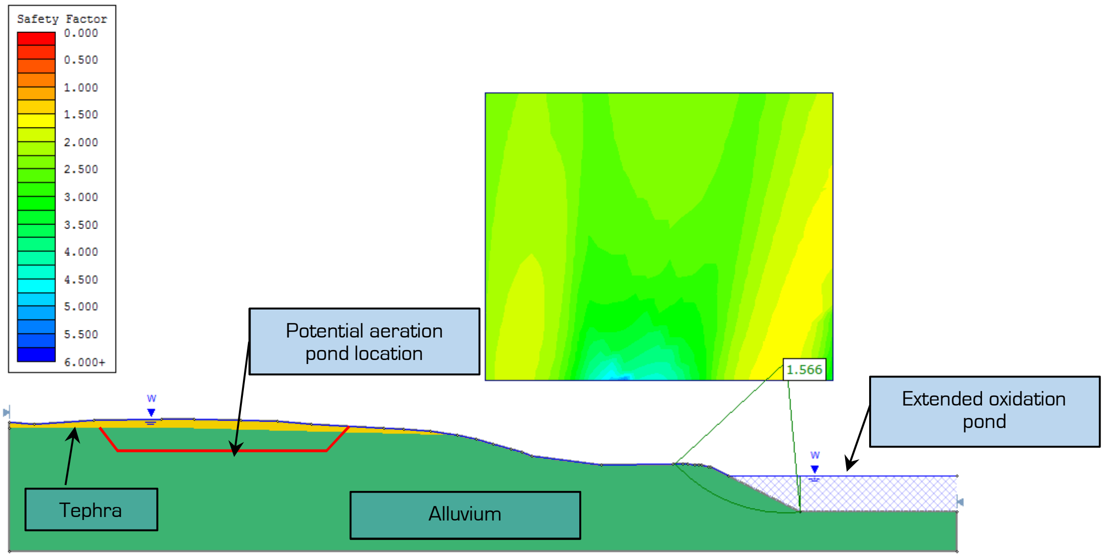

Figure 13: Worst case, fully saturated conditions for potential pond alterations

5.4 Liquefaction-induced Lateral Spreading

The site is underlain by a layer of pumiceous sands and silts of variable density and 0.5m to 0.8m in thickness within the perched water table (as described in Section 4.3). In addition, the site is classed to be within the very high liquefaction zone shown on Wairoa IntraMaps. The presence of liquefied pumiceous layers within the recovered core, indicates that some layers within the near surface pumiceous sand unit may be prone to liquefaction during moderate to large seismic events.

Saturated alluvial material was also encountered during investigations within the upper terrace area and may also be prone to liquefaction during seismic events, however saturated conditions were not identified within the tests undertaken in the lower portion of the site (adjacent to the existing oxidation pond).

The upper pumiceous sand layer and saturated alluvial material prone to liquefaction appears to be relatively persistent beneath the site and appears to continue beneath the ponds embankments. As such, there could be the potential for lateral spreading of the unsaturated ground towards the pond should liquefaction occur simultaneously along these layers.

To assess this potential we have carried out calculations of the magnitude of displacement[5] with a Moment Magnitude of 7.5, distance to nearest mapped active fault of 16.5km. The calculations reveal that there could be lateral movement in the order of up to 3m should liquefaction occur simultaneously along the tephra layer. However, it may be assumed that

[5] T.L. Youd, C.M. Hansen & S.F. Bartlett. 2002: "Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement – equation 6b" - Journal of Geotechnical and Environmental Engineering.

the probability of a significant earthquake occurring right in a period of saturation (i.e. during winter or periods of extended/intensive wet weather) could be considered low.

6 Engineering Recommendations

6.1 General

From our assessment of the natural hazards and ground deformation risks presented to the proposed developments, we consider that raising of the oxidation pond embankments by up to 2m in height and relocating the aeration pond further upslope can be safely achieved, provided that the recommendations given in the following subsections are adhered to.

It should be appreciated that the recommendations given below are based on the surface and subsurface conditions encountered at the time of the investigation. In addition to the possible variations in the subsurface conditions away from the investigation points within and around the site, changes to the site levels can have a dramatic effect on the recommendations given. Furthermore, cuts into the slopes above and below the site can significantly jeopardise its stability, unless an appropriate measure is put in place to restore the stability of the slope. Accordingly, we should be contacted prior to commencing any earthworks within the slopes to assess how this may affect the subject development. We should also be contacted immediately should the ground conditions encountered vary from that described in this report.

6.2 Raising of Embankments

Potential upgrades for the oxidation pond may include both enlarging the overall pond area and raising of the embankments by up to 2m in height. A possible increase in pond area has been presented in the appended geotechnical investigation plan. Numerical slope stability analysis undertaken and presented in Section 5.2 displays that the embankment may be raised safely.

The embankment shall have a minimum crest width of not less than 4.0m and slope angles of 2h to 1v for the ponds internal embankment and 3h to 1v for the external embankment slope. The non-organic portion of excavation material may be used for embankment fill, provided the recommendations given in Section 6.4 are adhered to.

We recommend a material coarser than gravelly sand with a permeability higher than 1 x 10^{-3} (m/s) shall be used for downstream drainage, which is required for piezometric drawdown within the raised embankment to prevent piping or erosion in the embankment.

6.3 New Aeration Pond

The site for a possible new aeration pond is 50m upslope to allow an increase in the size of the oxidation pond. A suitable location is presented in the geotechnical investigation plan appended.

It is expected a platform cut down by up to 0.7m may be required to allow an area for the excavation of the aeration pond. If this is the case, any cut slopes should be landscaped to at least 3h to 1v. The pond may be entirely excavated into the ground, or use a combination of excavation and built embankments, which should be specifically designed by a chartered professional engineer. It is expected the pond excavation will go through perched water layers and drainage would likely be required throughout the excavation. As such an allowance for pond underdrainage should be made in the design. There is sufficient area for the relocated pond to be constructed to similar dimensions as the existing pond.

During the excavation of the cut there may be defects (e.g. planes of weakness) or materials exposed which were not identified or differ from that described in this report. We should be contacted without delay to assess how these may alter the stability of the slope at the design gradient. A reduction in the slope gradient, or slope support (e.g. retaining walls etc) may be required to maintain the level of stability required for the aeration pond.

We recommend the aeration pond should be lined with a high density polythene liner to prevent seepage into the permeable tephra layers.

If compacted engineered fill material is to be used as the liner, we expect the material to achieve a permeability between 1×10^{-7} to 1×10^{-8} (m/s) provided the recommendations given in Section 6.4 are adhered to.

6.4 Engineered Fill as a Liner Material

It is possible that engineered fill (using excavation material) may be used as a liner. Using a natural liner is typically more cost effective than high density polythene particularly with large ponds.

If engineered fill is to be used as a liner material we recommend the following:

1. The material shall be well mixed (graded) and placed in horizontal layers not exceeding 200mm in thickness at the optimum moisture content of the material. Fill which is wet or saturated shall not be placed unless that is the optimum moisture content for the fill.

2. A vibrating pad foot roller shall be used to achieve a compaction within 95% of the materials maximum dry density to ensure lowest possible permeability is achieved for the material (we expect a permeability up to 1×10^{-8} (m/s) may be achieved.
3. The liner shall have a minimum compacted thickness of 700mm.
4. Any services or hard object extending through the liner shall be encased with a minimum 25mm of bentonite.
5. The liner shall be kept continually moist to prevent cracking (desiccation), a 0.1m thick covering of topsoil is considered appropriate to prevent desiccation prior to the dam being filled.
6. A specifically designed waveband shall be included to prevent the liner material eroding.

6.5 Embankment Fill Material

The non-organic material from excavated areas is considered to be generally adequate for fill. The site engineer must ensure the excavation material to be used as fill is well graded (mixed) to confirm maximum performance of the fill is reached.

The following specification is recommended:

1. All topsoil and unsuitable materials, including low strength ground, uncontrolled fill, rubbish etc shall be stripped from the footprint area of the fill.
2. All fill material to be placed on slopes shall be keyed in by cutting benches.
3. The fill footprint should be kept moist to prevent cracking of the foundation material and ensure a good bond is achieved with the dam fill.
4. The fill footprint area shall be inspected by the certifying engineer’s representative prior to the placement of fill.
5. Standard compaction and optimum moisture content testing shall be undertaken on a minimum of 5 samples of the fill material prior to placement to generate targets for the fill.
6. The fill shall be well graded and placed uniformly in horizontal layers not exceeding 200mm in thickness at the optimum moisture content of the material. Fill which is wet or saturated shall not be placed unless that is the optimum moisture content for the fill.

We recommend that a vibrating sheep’s foot or pad foot roller is used to achieve a compaction within 95% of the materials maximum dry density.

Provision should be made to ensure that the earth works are conducted with due respect for the weather, the fill should not be placed on to wet ground, especially if ponded water is present.

Verification of the fill should be undertaken to confirm the material has been placed to within 95% of the maximum dry density from the standard compaction test results.

Services should not be placed in the embankment fill material unless approved by a suitably qualified person to ensure the stability and permeability of the embankment is not compromised.

6.6 Site Contouring and Topsoiling

As soon as possible, all final cut-slopes and fill slopes should be covered with topsoil a minimum of 0.10m thick to prevent the ground from drying out readily resulting in the development of cracks.

Contouring should avoid the potential for concentration and discharge of surface water over point locations which could result in soil erosion or instability.

7 Other Considerations

This report has been prepared exclusively for Lowe Environmental Impact Ltd with respect to the particular brief given to us. Information, opinions and recommendations contained in it cannot be used for any other purpose or by any other entity without our review and written consent. Land Development & Exploration Ltd accepts no liability or responsibility whatsoever for or in respect of any use or reliance upon this report by any third party.

This report was prepared in general accordance with current standards, codes and practice at the time of this report. These may be subject to change.

Opinions given in this report are based on visual methods, and subsurface investigations at discrete locations. It must be appreciated that the nature and continuity of the subsurface materials between these locations are inferred and that actual conditions could vary from that described herein. We should be contacted immediately if the conditions are found to differ from that described in this report.

This report should be read in its entirety to understand the context of the opinions and recommendations given.

Our analyses and opinions of the stability of the site have been based on the site geomorphology and ground conditions at the time of the investigation. Alteration of the slope gradients by cutting or filling could result in significant changes to the stability of the site which could be detrimental. We should be contacted immediately if there are any proposed changes to the slope profile, as well as the incidence of landslippage within the vicinity of the site.

For and on behalf of LDE Ltd

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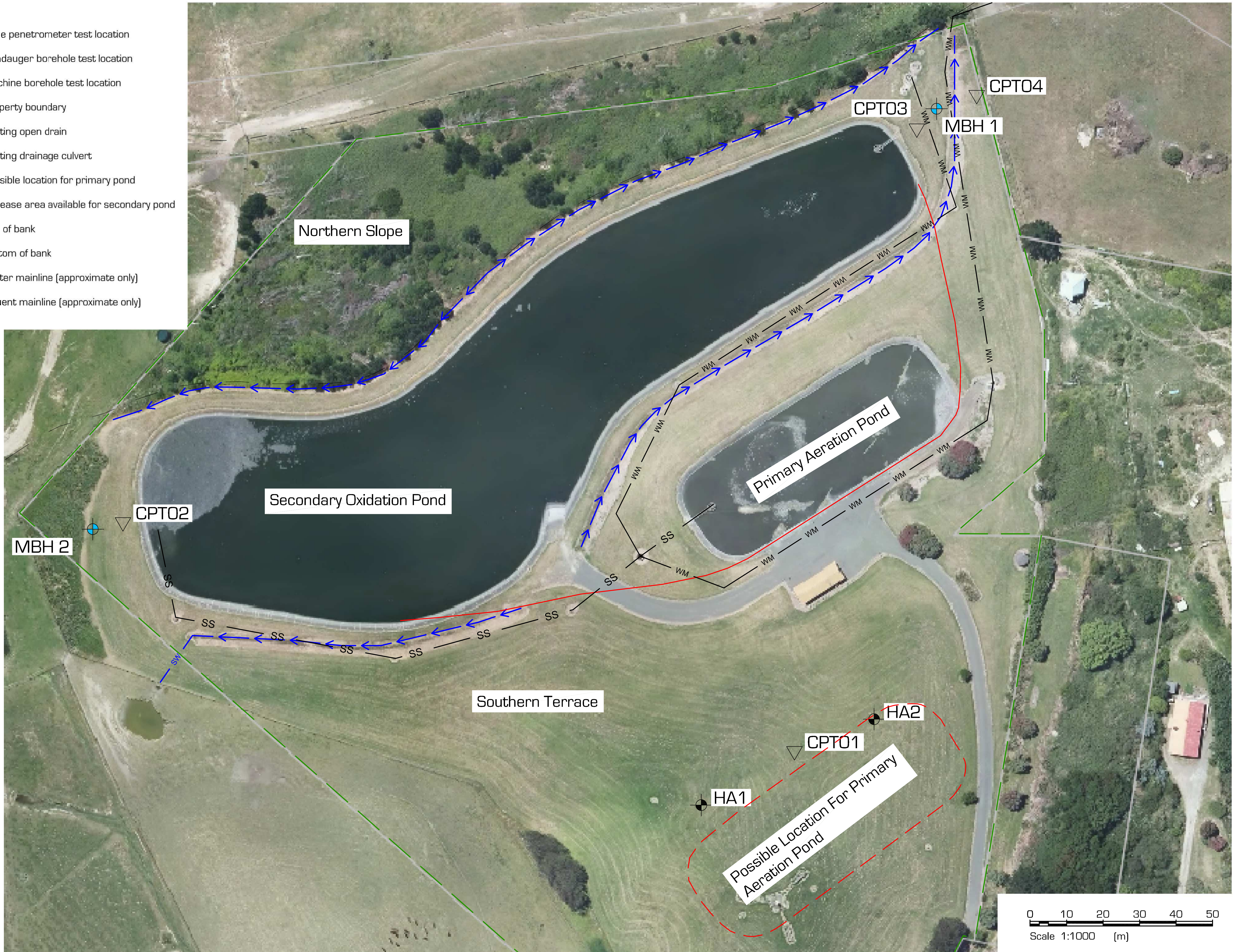
APPENDIX A

GEOTECHNICAL INVESTIGATION PLAN

Contractor shall check all dimensions on site prior to work commencing ©

Legend

▽ CPT01	Cone penetrometer test location
HA 01	Handauger borehole test location
MBH1	Machine borehole test location
green line	Property boundary
blue arrows	Existing open drain
SW	Existing drainage culvert
red dashed line	Possible location for primary pond
red line	Increase area available for secondary pond
dash-dot line	Top of bank
grey line	Bottom of bank
WM	Water mainline (approximate only)
SS	Effluent mainline (approximate only)



CLIENT	PROJECT	DRAWING TITLE
LOWE ENVIRONMENTAL IMPACT P.O. BOX 4667 PALMERSTON NORTH 4442	WAIROA WASTEWATER TREATMENT PLANT PART LOT 1 DP 3350 WHAKAMAHIA ROAD WAIROA	Geotechnical Investigation Plan

LDE LAND DEVELOPMENT & EXPLORATION LTD.

No.	REVISION	BY	DATE

DESIGN:	AHM
DRAWN:	AHM
DATE:	10.07.17
CHECKED:	
SCALE A3:	Shown

PROJECT STATUS

PROJECT:	SHEET:
13322	1 of 2

DRAWING No:	REV:
13322 - 01	0

CLIENT	PROJECT	DRAWING TITLE
LOWE ENVIRONMENTAL IMPACT P.O. BOX 4667 PALMERSTON NORTH 4442	WAIROA WASTEWATER TREATMENT PLANT PART LOT 1 DP 3350 WHAKAMAHIA ROAD WAIROA	Site Contour Plan

LDE LAND DEVELOPMENT & EXPLORATION LTD.

No.	REVISION	BY	DATE

DESIGN:	AHM	PROJECT STATUS:	
DRAWN:	AHM		
DATE:	10.07.17	PROJECT: 13322	SHEET: 2 of 2
CHECKED:			
SCALE A3:	Shown	DRAWING No: 13322 - 01	REV: 0

APPENDIX B

SUBSURFACE INVESTIGATION DATA

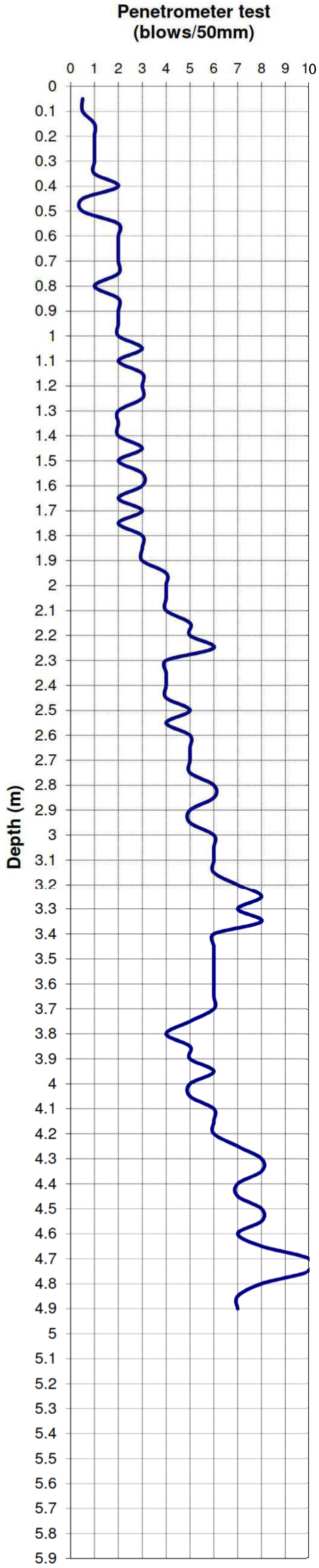
BOREHOLE LOG

LAND DEVELOPMENT & EXPLORATION LTD.

BOREHOLE No: HA1

Client: Lowe Environmental Impact Ltd	**Project:** Wairoa Wastewater Pond Investigation	**LDE Project No:** 13322
Project Location: Part Lot 1 DP 3350 Whakamahia Road, Wairoa	**Borehole Location:** Refer to Site Investigation Plan	**Hole started:** 23/05/2017 **Hole completed:** 23/05/2017
Co-ordinates: mN mE	**Drill method:** 50mm handauger	**Drilled by:** A.Mayhead **Logged by:** A.Mayhead

Depth (m)	Graphic	Moisture	Strength	Soil Description	Geology
0.0		M	VL	SILT, sandy, black, moderately organic, moist	TOPSOIL
0.1					
0.2					
0.3					
0.4					
0.5		M	MD	SAND, pumiceous, light brown, well graded, moist	TEPHRA
0.6		W		wet	
0.7					
0.8					
0.9					
1.0				becoming silty, brownish white with brown staining, moist-wet	
1.1	▽	S		saturated	
1.2					
1.3		S	MD	SAND, silty, light grey, no plasticity, saturated	ALLUVIUM
1.4					
1.5					
1.6		W-S	MD	SILT, some fine sand, light grey with orange mottling, low plasticity, wet-saturated	
1.7					
1.8				brownish mottling	
1.9					
2.0			D		
2.1					
2.2					
2.3	▽	S		borehole fills with groundwater	
2.4					
2.5				no retrieval	
2.6					
2.7					
2.8					
2.9					
3.0					
3.1					
3.2					
3.3					
3.4					
3.5					
3.6					
3.7					
3.8					
3.9					
4.0					
4.1					
4.2					
4.3					
4.4					
4.5					
4.6		M	D	SAND, silty, light grey with orange mottling, no plasticity, moist	PLEISTOCENE ALLUVIAL SEDIMENT
4.7					
4.8			VD	light brownish white with orange mottling	
4.9			D		
5.0				End of borehole at 5.0m, target depth reached	
5.1				Perched groundwater encountered at 1.1m and 2.3m	
5.2					
5.3					
5.4					
5.5					
5.6					
5.7					
5.8					
5.9					



Notes: Shear strength lines are indicative only.
Shear strength calibrated and adjusted for plasticity
UTP: Unable to penetrate

BOREHOLE LOG

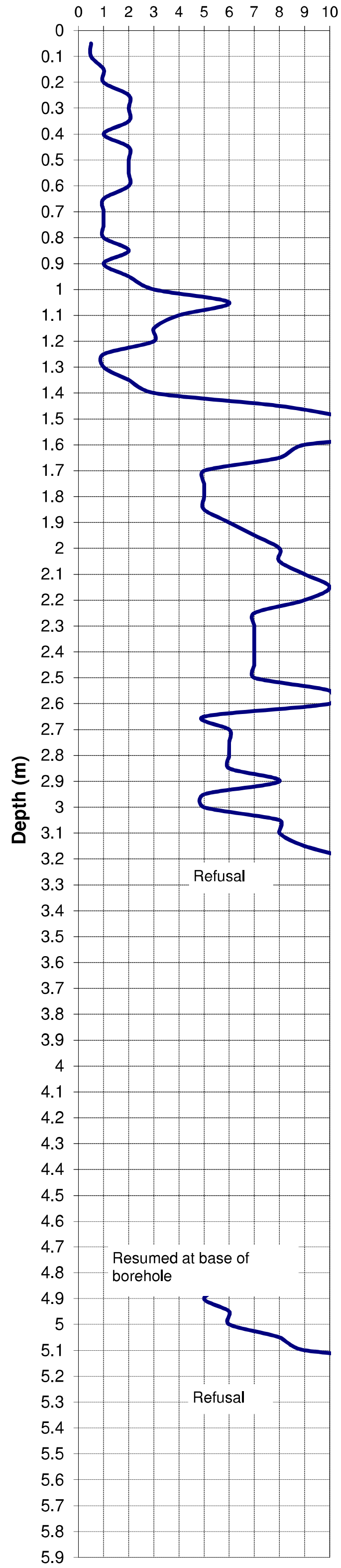
LAND DEVELOPMENT & EXPLORATION LTD.

BOREHOLE No: HA2

Client: Lowe Environmental Impact Ltd	**Project:** Wairoa Wastewater Pond Investigation	**LDE Project No:** 13322
Project Location: Part Lot 1 DP 3350 Whakamahia Road, Wairoa	**Borehole Location:** Refer to Site Investigation Plan	**Hole started:** 23/05/2017 **Hole completed:** 23/05/2017
Co-ordinates: mN mE	**Drill method:** 50mm handauger	**Drilled by:** A.Mayhead **Logged by:** A.Mayhead

Depth (m)	Moisture	Strength	Soil Description	Geology
0.0	M	VL-L	SILT, some sand, black, moderately organic, moist	TOPSOIL
0.2		MD		
0.5	M	L-MD	SAND, pumiceous, light brown, well graded, moist	TEPHRA
0.6	W		wet	
0.7			becoming silty, brownish white	
0.8			dark brown staining	
1.0	M		moist	
1.1		D		
1.3	M	L-MD	SILT, light brownish grey with orange mottling, moderate plasticity, moist	ALLUVIUM
1.5		VD		
1.7		D-VD		
1.8	M-W		moist-wet	
2.2	W		wet	
3.0	S		becoming sandy, no plasticity, saturated	
3.1			moderate groundwater inflow	
3.2	S	VD	SAND, silty, light brownish grey, no plasticity, saturated	
3.4			borehole fills with groundwater	
3.6			no retrieval	
4.7	D-M	D	SILT, trace sand, light grey with brownish mottling, moderate plasticity, dry-moist	PLEISTOCENE ALLUVIAL SEDIMENT
4.9			End of borehole at 4.8m, UTP high density ground	
5.0			Perched groundwater encountered at 3.0m	

Penetrometer test (blows/50mm)



Notes: Shear strength lines are indicative only.
Shear strength calibrated and adjusted for plasticity
UTP: Unable to penetrate

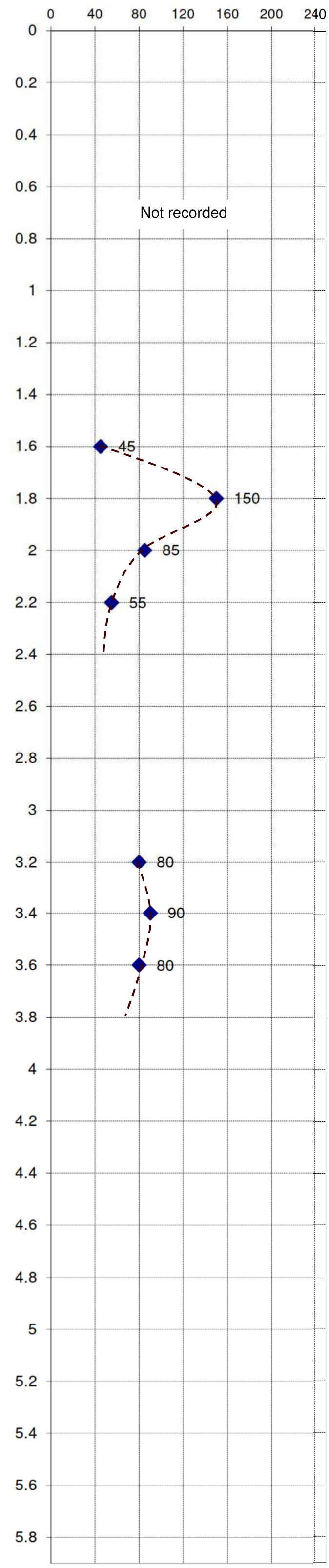
BOREHOLE LOG

BOREHOLE No: MBH 1

Client: Lowe Environmental Impact Ltd	**Project:** Wairoa Wastewater Treatment Plant Investigation	**LDE Project No:** 13322
Project Location: Part Lot 1 DP 3350 Whakamahia Road, Wairoa	**Borehole Location:** Refer to Site Investigation Plan	**Hole started:** 21/06/2017 **Hole completed:** 21/06/2017
Co-ordinates: mN mE	**Drill method:** 50mm machine direct push borehole	**Drilled by:** B. Archer **Logged by:** A. Mayhead

Depth (m)	Graphic	Moisture	Strength	Soil Description	Geology
0.0		M		SILT, sandy, fine, dark brownish black, moderately organic, fine rootlents, no plastictiy, moist	TOPSOIL
0.1		M			
0.2				Mixture of silt and fine sand with fat clay patches throughout, trace pumiceous sand, brownish grey to dark grey with slight orange mottling, moderate-low plasticity, moist	FILL
0.3					
0.4					
0.5					
0.6				trace fine mudstone gravel, light orangey brown with thin (< 1cm) grey clay veins	
0.7					
0.8					
0.9		M-W		no gravel or clay veins, moist-wet	
1.0					
1.1					
1.2				no retrieval	
1.3					
1.4		W	F	Mixture of silt and fine sand with fat clay patches throughout, trace mudstone gravel and pumiceous sand, brownish grey to brownish black with slight orange mottling, moderate-high plasticity, wet	FILL
1.5					
1.6			St		
1.7					
1.8			VSt		
1.9		M-W		moist-wet	
2.0			St		
2.1		M	St	SILT, black, moderately organic, slightly decomposed fine rootlets, pungent, moist	BURIED TOPSOIL
2.2					
2.3					
2.4	▽	S		SAND, pumiceous, silty, brownish grey with faint orange staining, well graded, saturated	TEPHRA
2.5					
2.6					
2.7					
2.8					
2.9					
3.0					
3.1					
3.2		M-W	St	SILT, sandy, fine, light blueish grey, low plasticity, moist-wet	ALLUVIUM
3.3					
3.4				becoming clayey, moderate-high plasticity	
3.5				brownish grey	
3.6				silty	
3.7					
3.8				End of borehole at 3.8m depth, no retrieval	
3.9				Perched groundwater encountered at 2.4m depth	
4.0					
4.1					
4.2					
4.3					
4.4					
4.5					
4.6					
4.7					
4.8					
4.9					
5.0					
5.1					
5.2					
5.3					
5.4					
5.5					
5.6					
5.7					
5.8					
5.9					

Undrained Shear Strength (kPa)



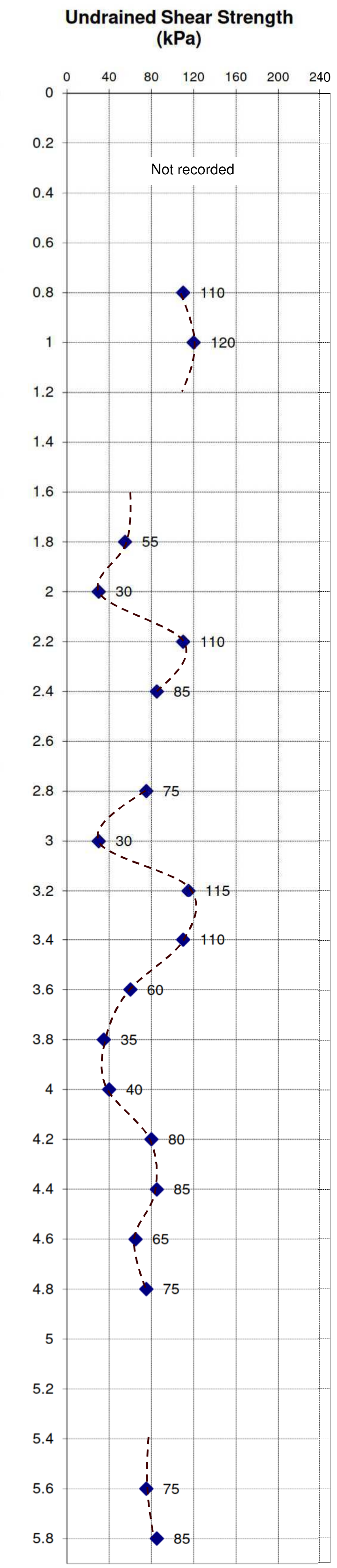
Notes: Shear strength lines are indicative only.
Shear strength calibrated and adjusted for plasticity
UTP: Unable to penetrate

BOREHOLE LOG

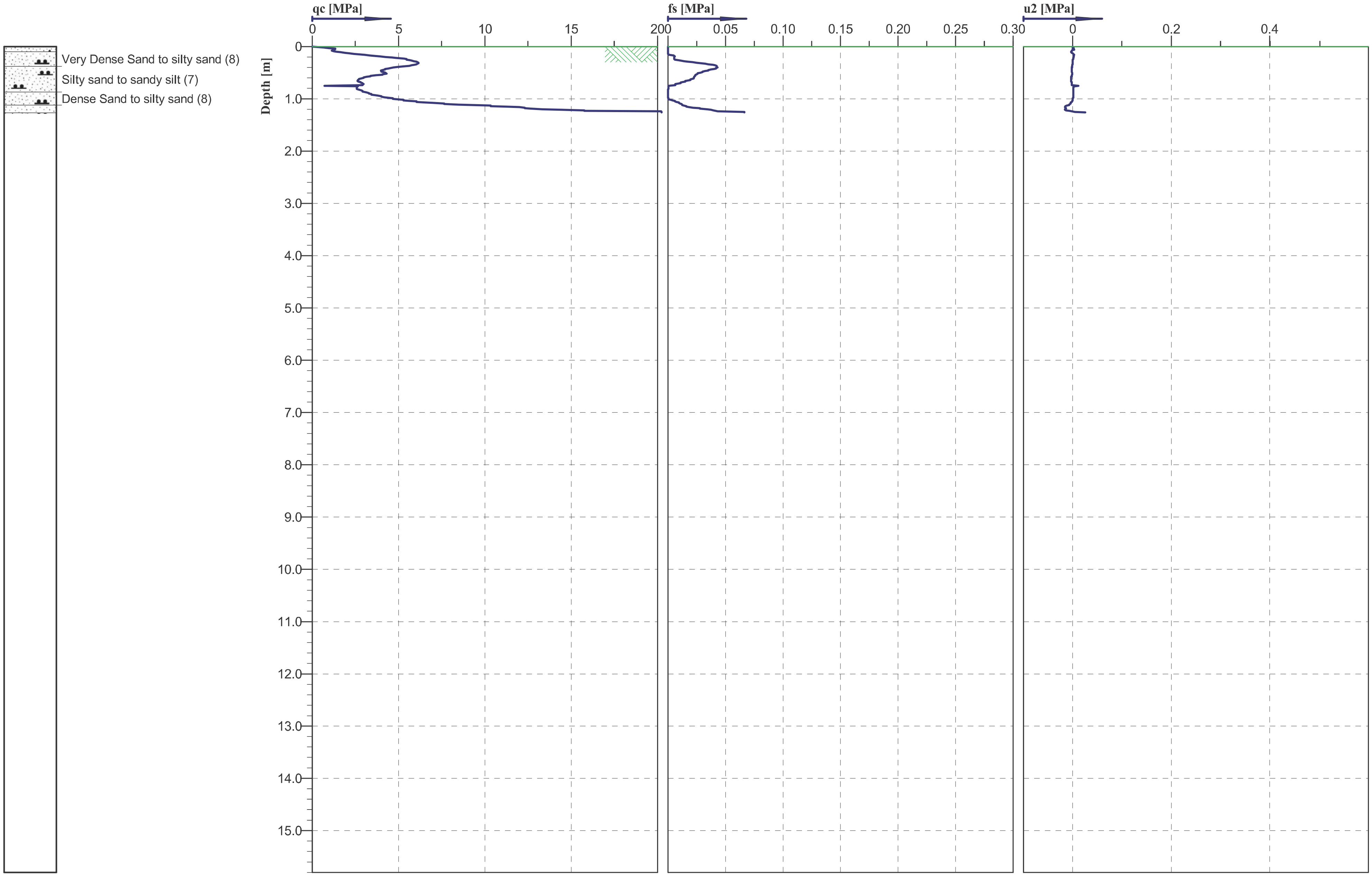
BOREHOLE No: MBH 2

Client: Lowe Environmental Impact Ltd	**Project:** Wairoa Wastewater Treatment Plant Investigation	**LDE Project No:** 13322
Project Location: Part Lot 1 DP 3350 Whakamahia Road, Wairoa	**Borehole Location:** Refer to Site Investigation Plan	**Hole started:** 21/06/2017 **Hole completed:** 21/06/2017
Co-ordinates: mN mE	**Drill method:** 50mm machine direct push borehole	**Drilled by:** B. Archer **Logged by:** A. Mayhead

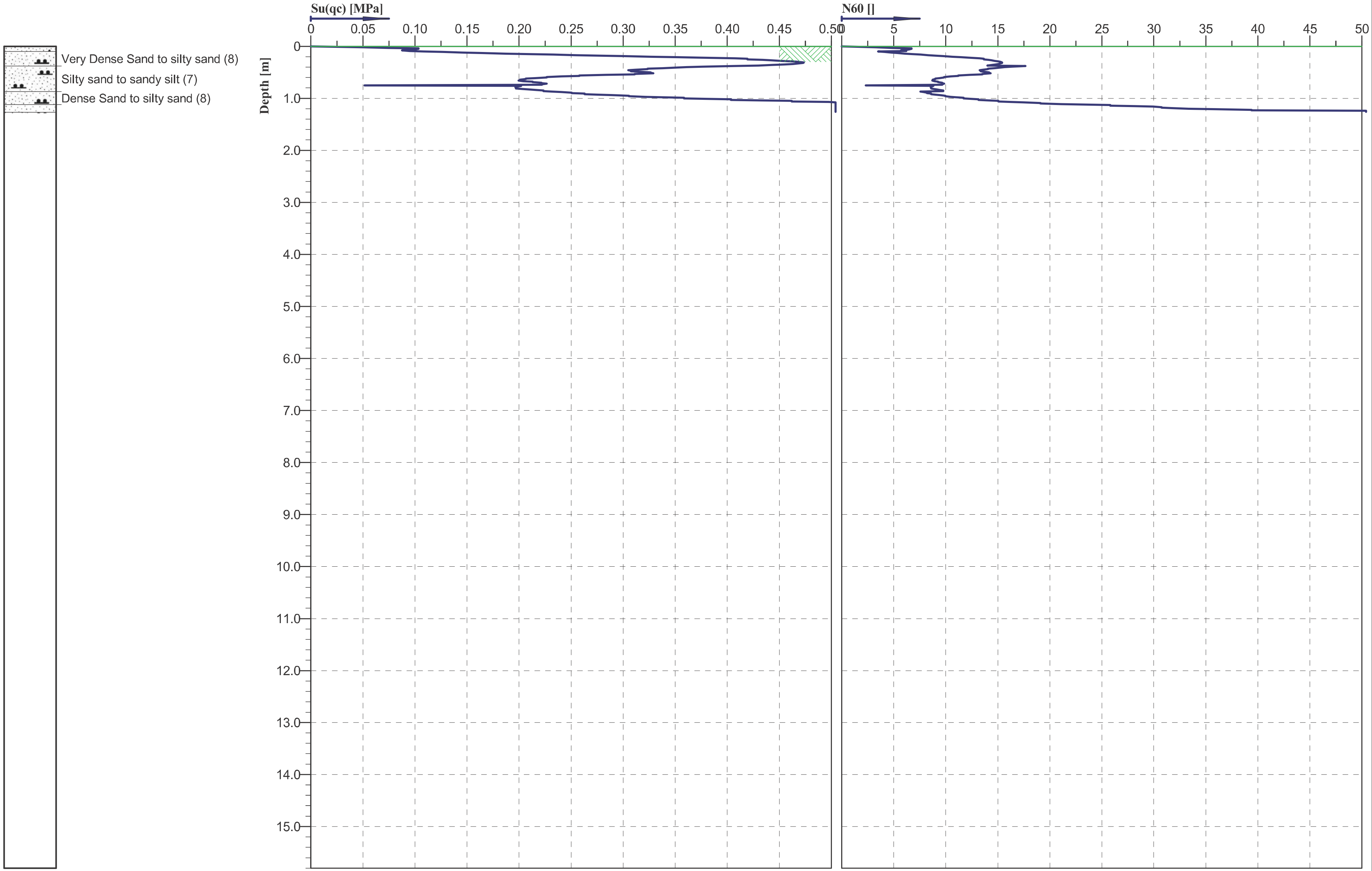
Depth (m)	Moisture	Strength	Soil Description	Geology
0.0	W		SILT, sandy, fine, dark brownish black, moderately organic, fine rootlents, no plasticity, wet	TOPSOIL
0.1	M			
0.2			Mixture of silt and fine sand with fat clay patches throughout, trace pumiceous sand, brownish grey to brownish black with slight orange mottling, moderate plasticity, moist	FILL
0.3				
0.4				
0.5	M		SILT, sandy, black, moderately organic, slightly decomposed fine rootlets, moist	BURIED TOPSOIL
0.6				
0.7	M	VSt	Thinly bedded (< 10cm) silts and clays with pumiceous sand throughout, yellowish brown to dark brownish grey, slight orange mottling, moderate plasticity, moist	ALLUVIUM
0.8				
0.9				
1.0				
1.1			fat clay inclusion, light yellowish brown	
1.2			no retrieval	
1.3				
1.4				
1.5				
1.6	M-W	St	Layering of thinly (< 10cm) bedded silty clay to sandy silt, trace pumiceous sand throughout, grey to light brown with slight orange mottling, moderate-low plasticity, moist-wet	ALLUVIUM
1.7				
1.8				
1.9				
2.0		F		
2.1				
2.2		VSt		
2.3				
2.4			no retrieval	
2.5				
2.6				
2.7	M-W	St	Layering of moderately (< 30cm) bedded silts and clays, trace pumiceous sand throughout, light brown to blueish grey, moderate-high plasticity, moist-wet	ALLUVIUM
2.8				
2.9				
3.0		F	slight orange mottling	
3.1				
3.2		VSt		
3.3				
3.4			no orange mottling	
3.5	M	St	trace fine mudstone gravel	
3.6				
3.7		F	no gravel	
3.8				
3.9				
4.0			grey, no pumiceous sand	
4.1				
4.2		St	blueish grey, trace fine mudstone gravel	
4.3				
4.4				
4.5	M-W			
4.6			trace pumiceous sand	
4.7				
4.8	S		SAND, pumiceous, silty, brownish grey, well graded, saturated	TEPHRA
4.9				
5.0				
5.1				
5.2				
5.3				
5.4	M	St	CLAY, blueish grey, high plasticity, moist	ALLUVIUM
5.5				
5.6				
5.7				
5.8	S		SAND, pumiceous, silty, brownish grey, well graded, saturated	TEPHRA
5.9			End of borehole at 6.0m depth, no recovery	



Notes: Shear strength lines are indicative only.
Shear strength calibrated and adjusted for plasticity
UTP: Unable to penetrate

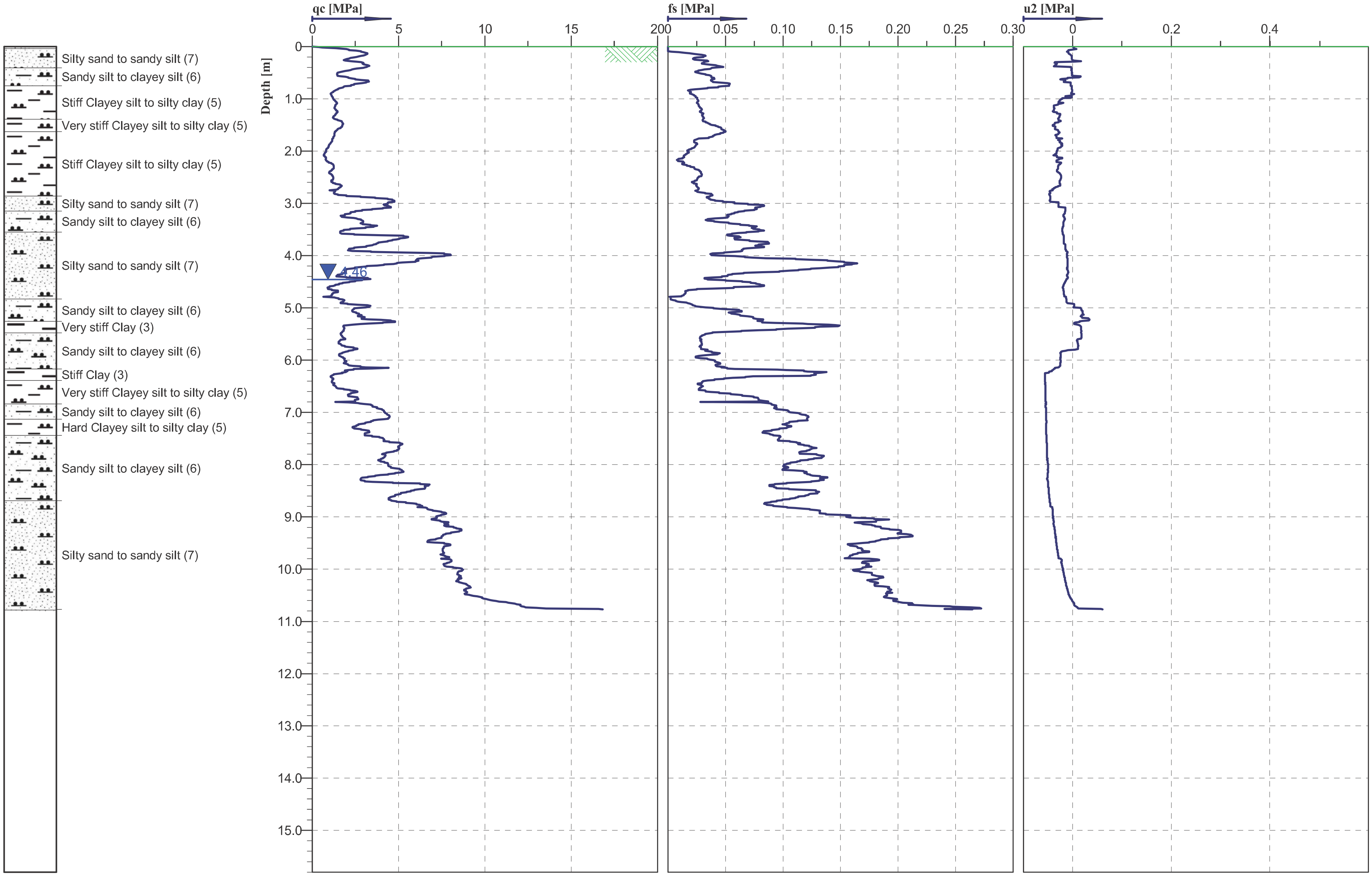


Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891762, N6228835	Ground level: 0.00	Test no: CPT01
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift on 40+ mPa Layer.		File: CPT01.cpt	



Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891762, N6228835	Ground level: 0.00	Test no: CPT01
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift on 40+ mPa Layer.		File: CPT01.cpt	

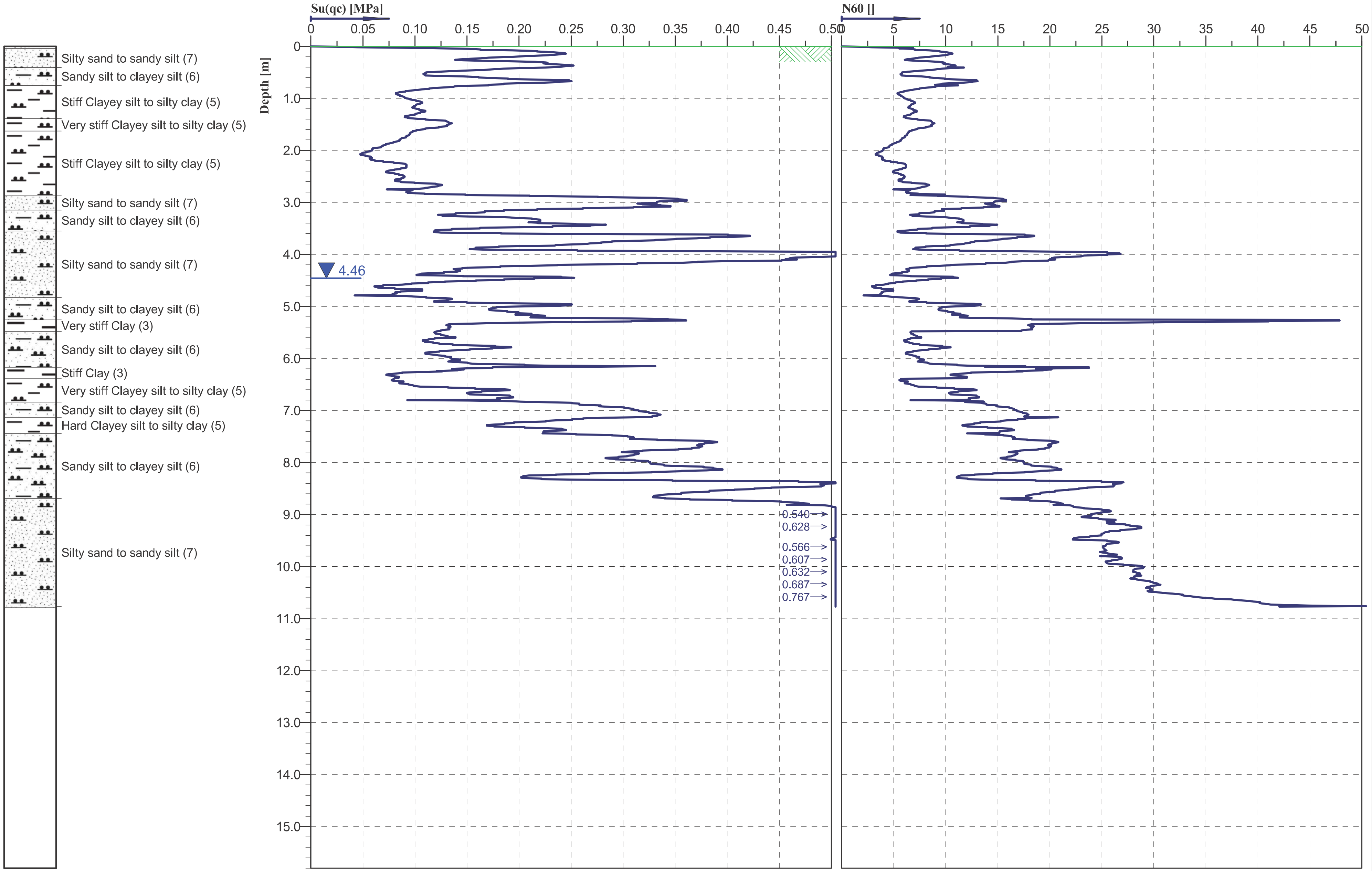


LDE LAND DEVELOPMENT & EXPLORATION LTD.

U2

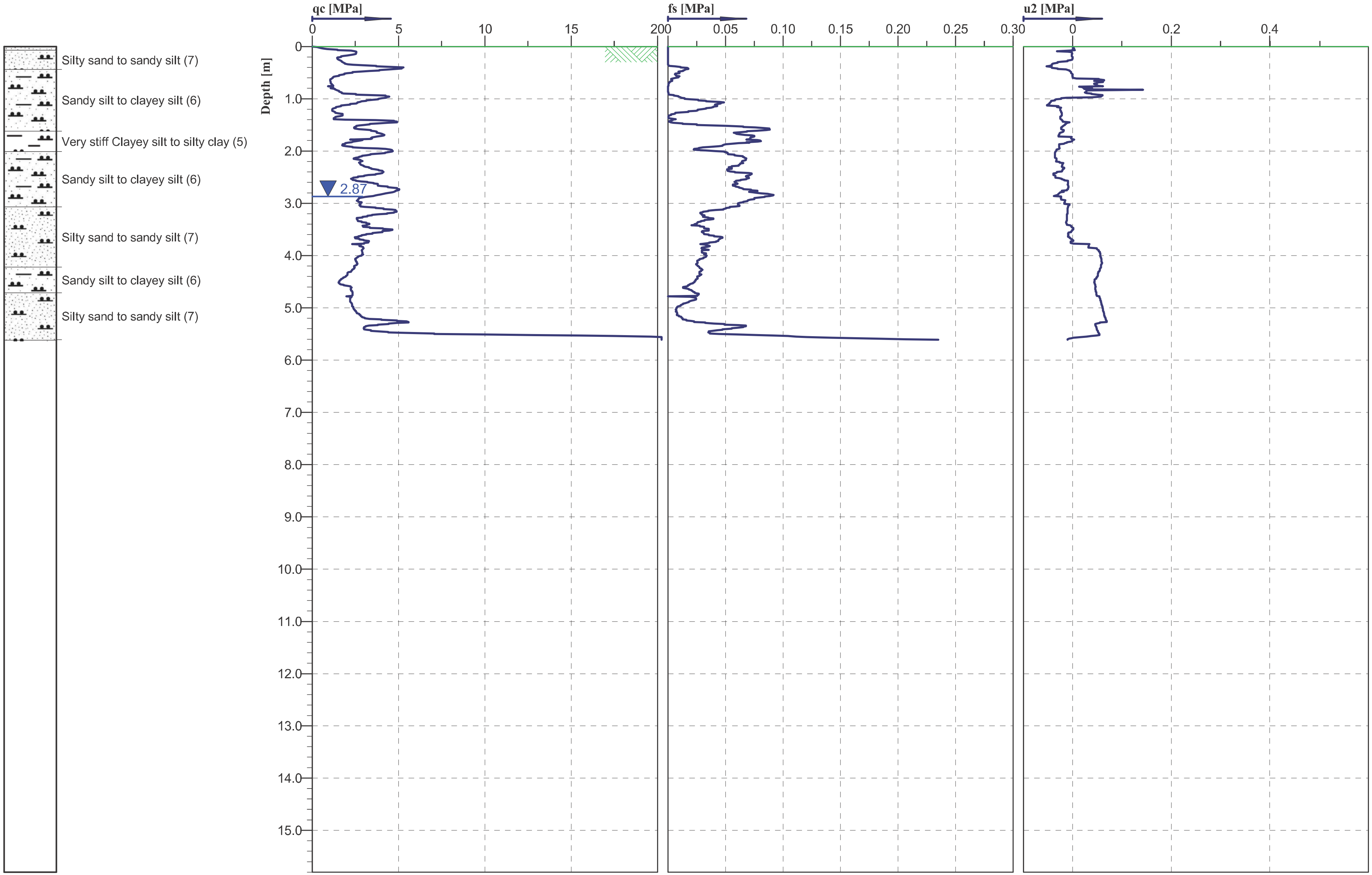
Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891569, N6228909	Ground level: 0.00	Test no: CPT02
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT02.cpt	



Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

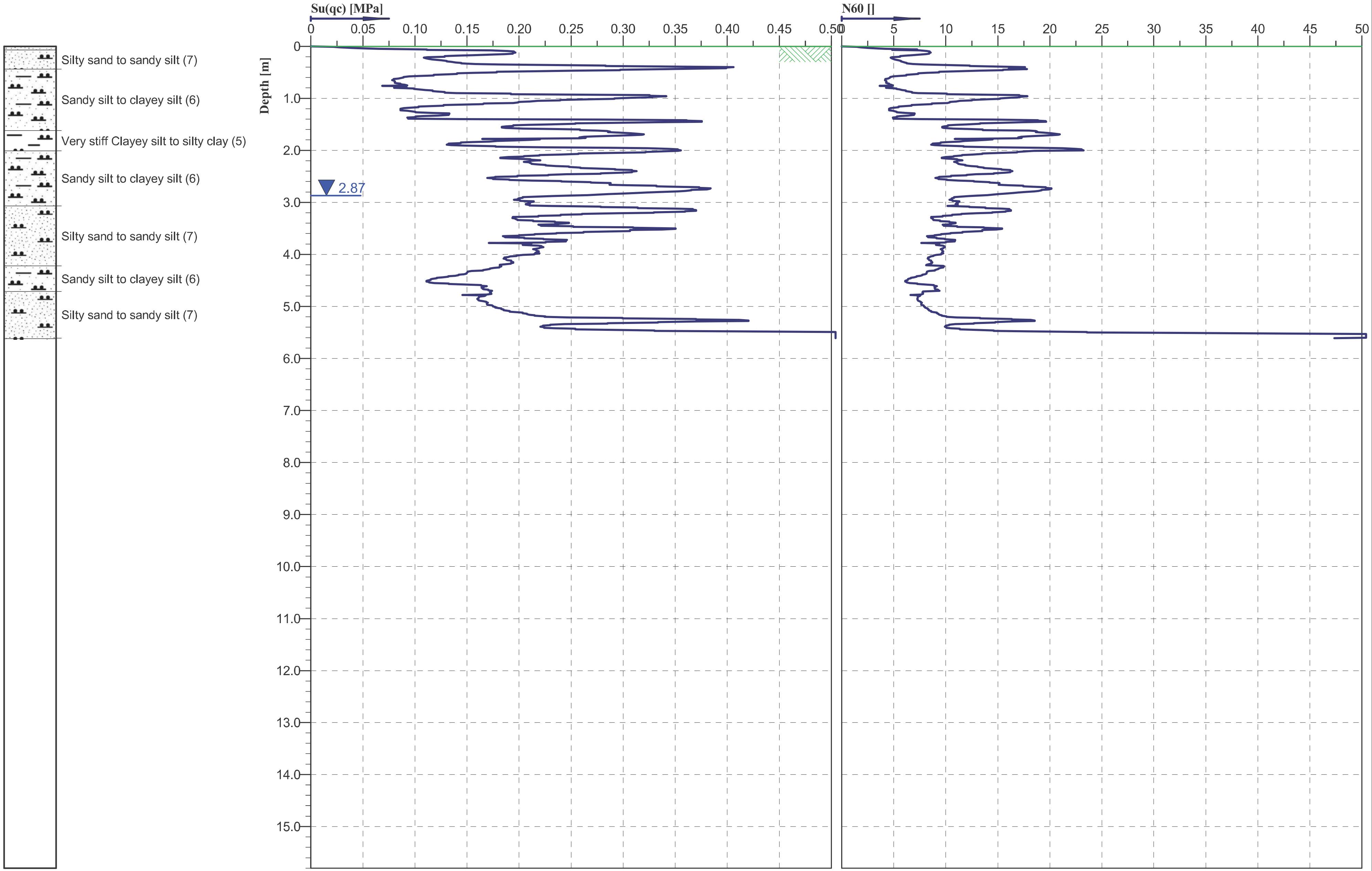
Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891569, N6228909	Ground level: 0.00	Test no: CPT02
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT02.cpt	



U2

Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891783, N6229013	Ground level: 0.00	Test no: CPT03
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT03.cpt	

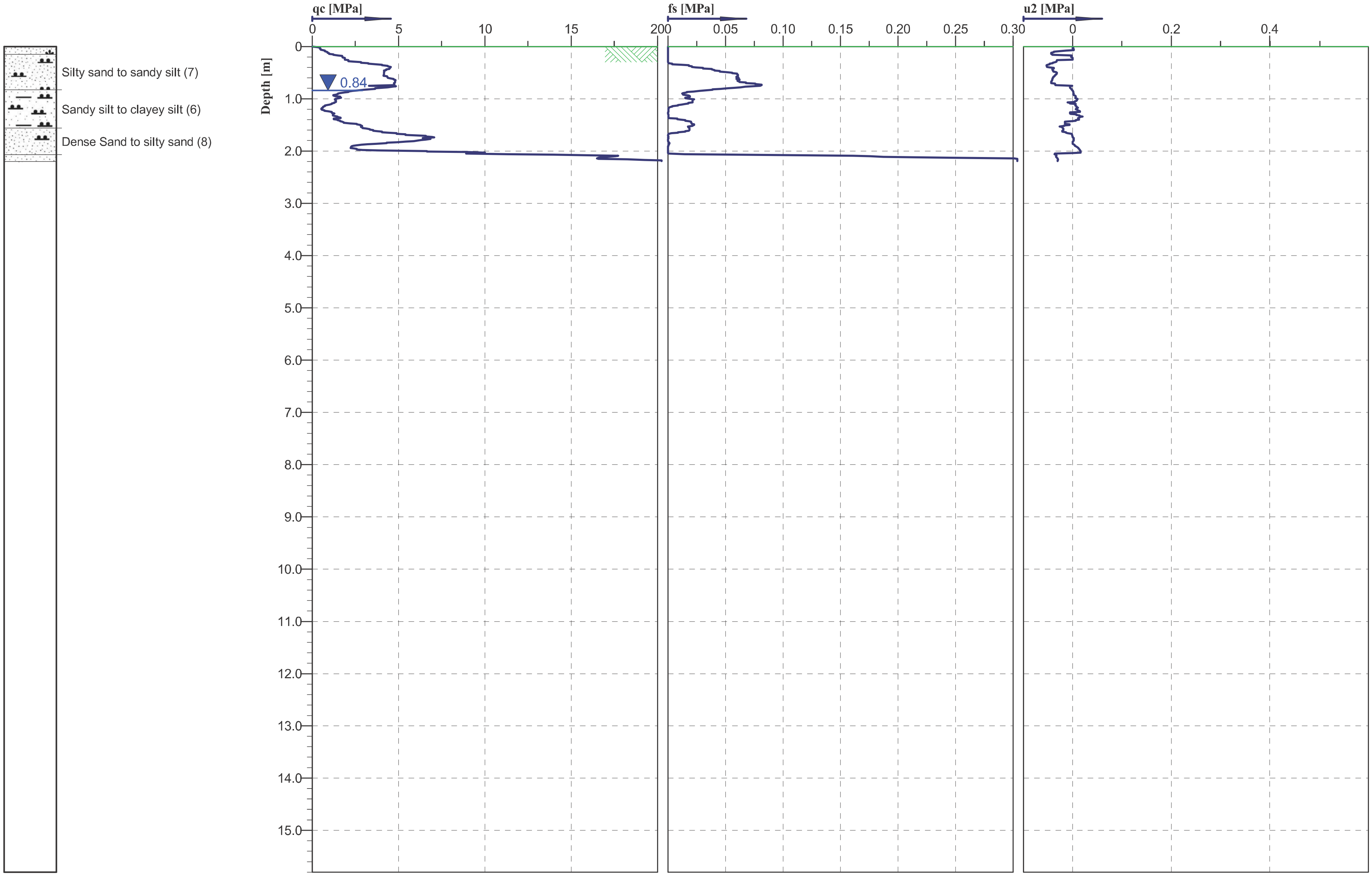


LAND DEVELOPMENT & EXPLORATION LTD.

U2

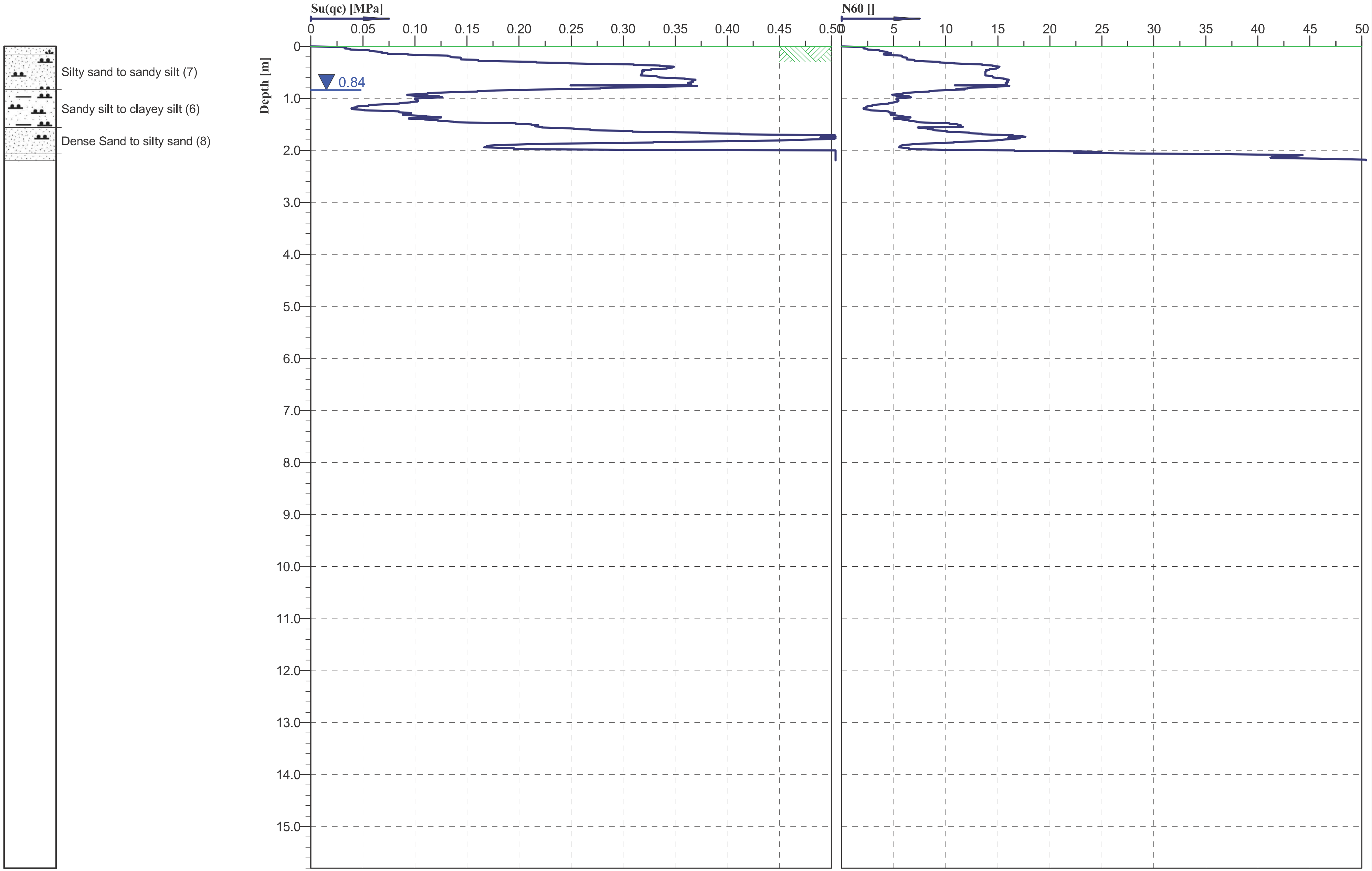
Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891783, N6229013	Ground level: 0.00	Test no: CPT03
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT03.cpt	



Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891796, N6229038	Ground level: 0.00	Test no: CPT04
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT04.cpt	



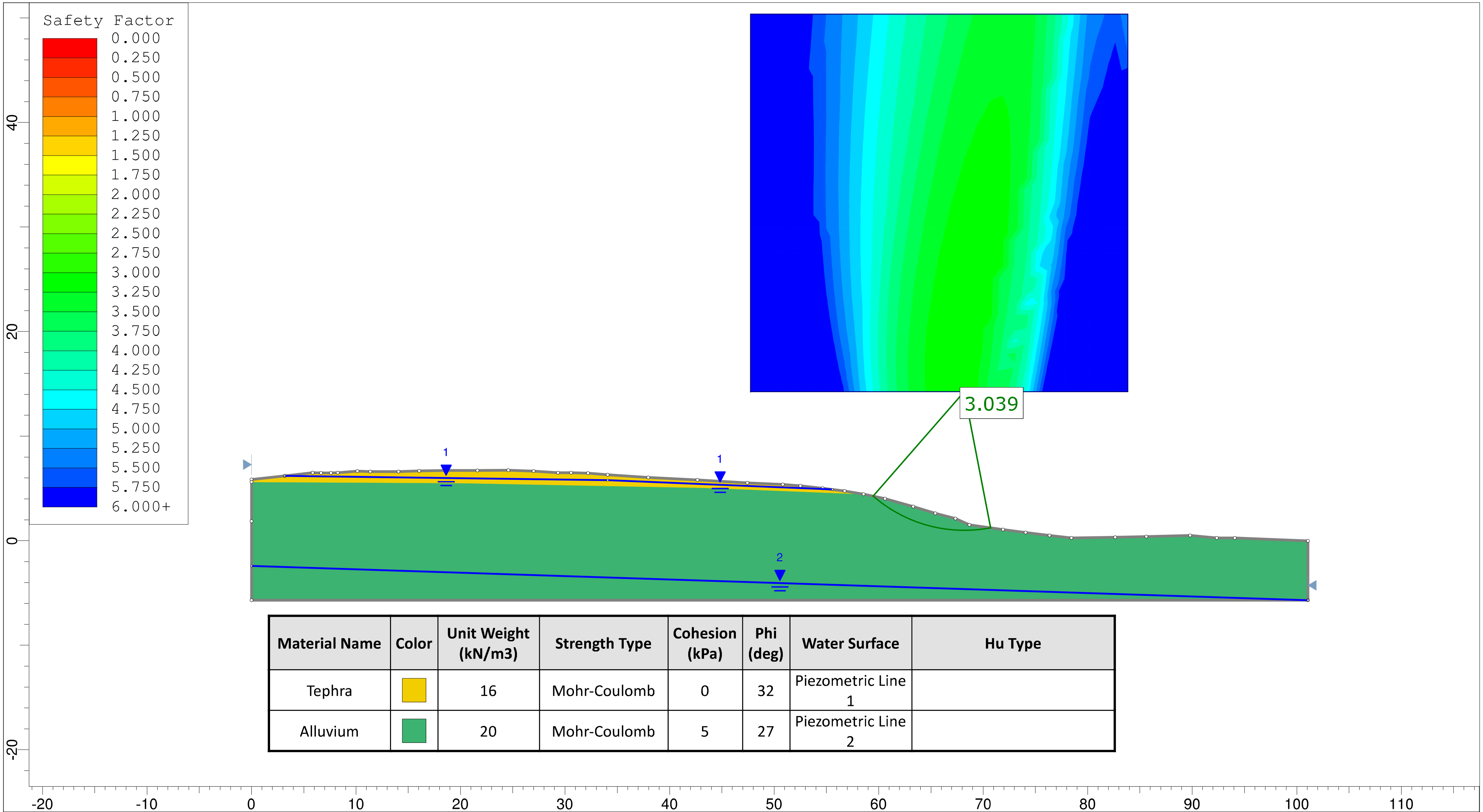
LDE LAND DEVELOPMENT & EXPLORATION LTD.

Cone No: 4614
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Wairoa WWTP, Kopu Road, Wairoa	Position: E2891796, N6229038	Ground level: 0.00	Test no: CPT04
Project ID: 13322	Client: Lowe Environmental Impact Ltd	Date: 21/6/2017	Scale: 1 : 100
Project: Geotechnical Investigation		Page: 1/1	Fig:
Refusal due to rig lift.		File: CPT04.cpt	

Appendix C

Analysis Printouts



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Tephra		16	Mohr-Coulomb	0	32	Piezometric Line 1	
Alluvium		20	Mohr-Coulomb	5	27	Piezometric Line 2	

LAND DEVELOPMENT & EXPLORATION LTD.

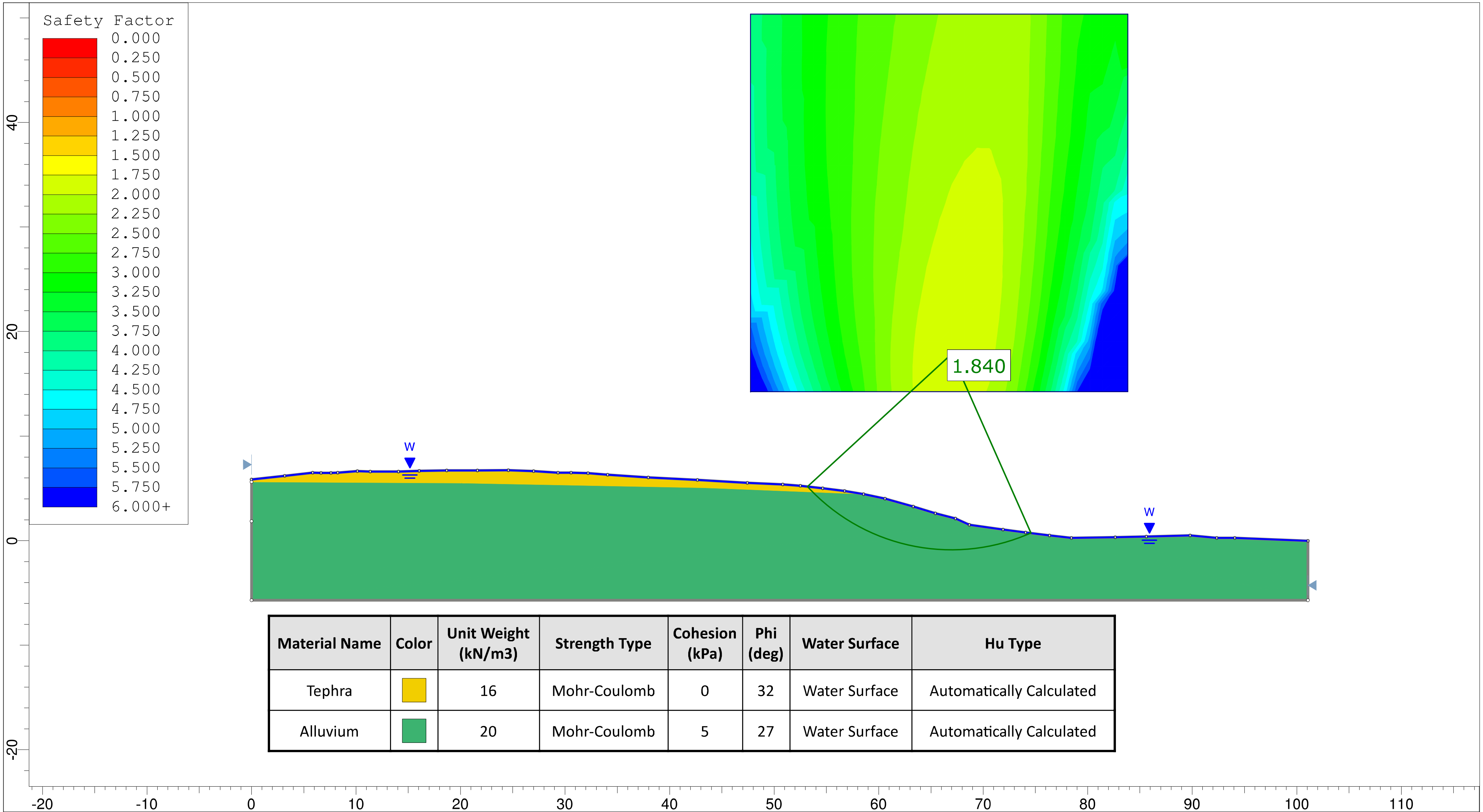
SLIDEINTERPRET 7.017

Project Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa

Analysis Description Existing Southern Terrace Modelled Under Existing Groundwater Conditions

Drawn By A. Mayhead | *Scale* 1:510 | *Company* LDE Ltd

Date 10/07/17 | *File Name*

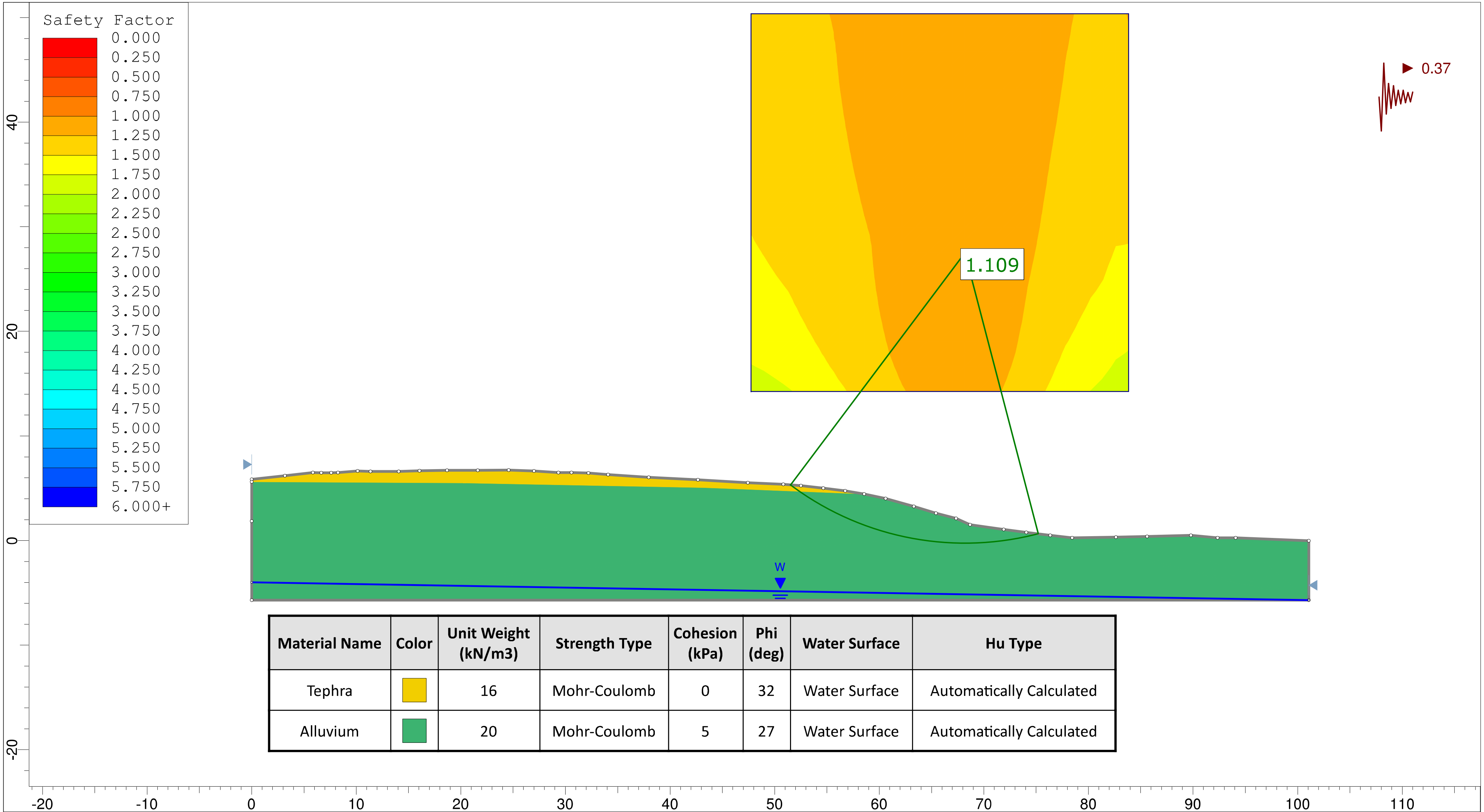


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Tephra		16	Mohr-Coulomb	0	32	Water Surface	Automatically Calculated
Alluvium		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Existing Southern Terrace Modelled Under Extreme Groundwater Conditions
Drawn By	A. Mayhead
Scale	1:510
Company	LDE Ltd
Date	10/07/17
File Name	

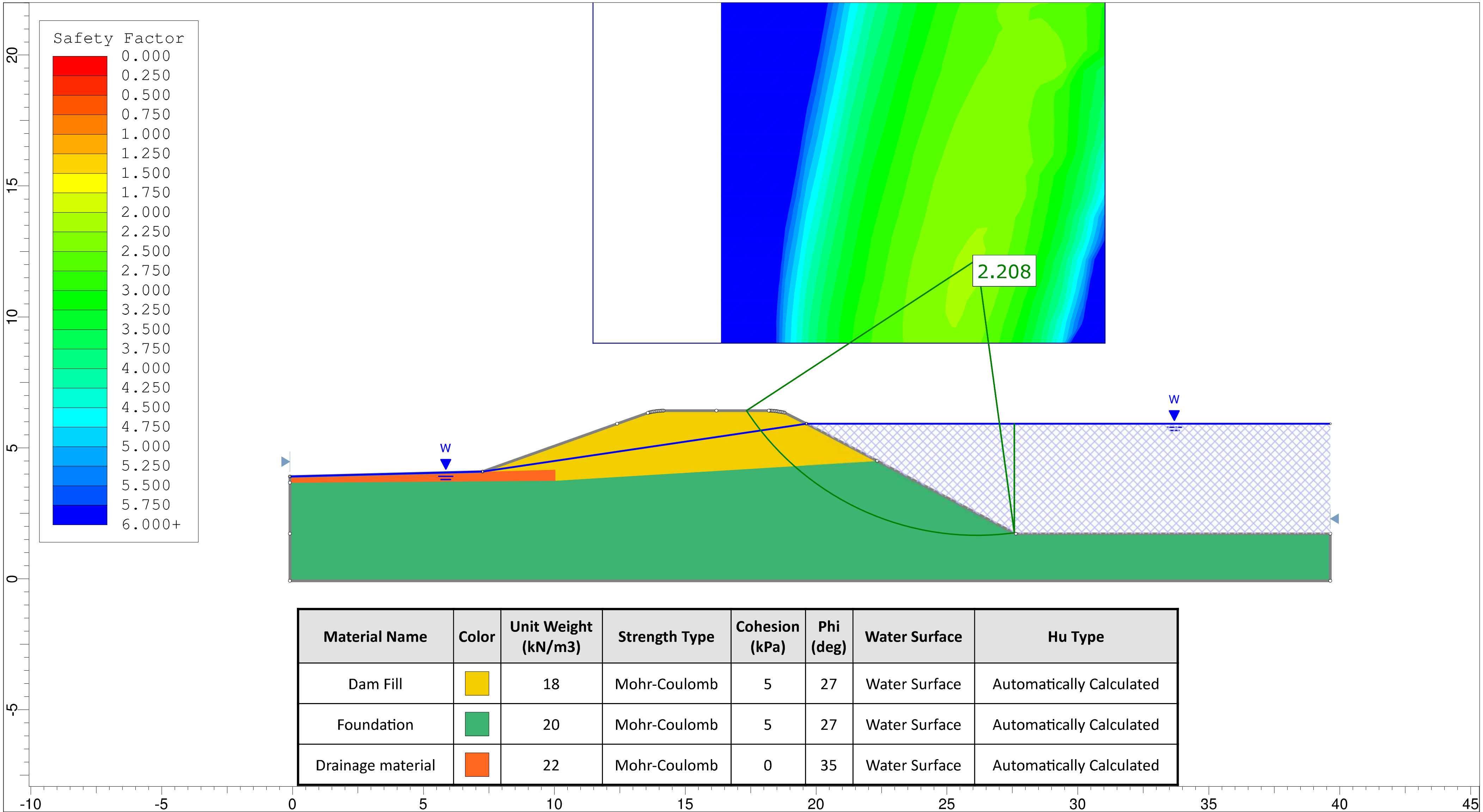


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Tephra		16	Mohr-Coulomb	0	32	Water Surface	Automatically Calculated
Alluvium		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Existing Southern Terrace Modelled Under ULS Seismic Loading
Drawn By	A. Mayhead
Scale	1:510
Company	LDE Ltd
Date	10/07/17
File Name	

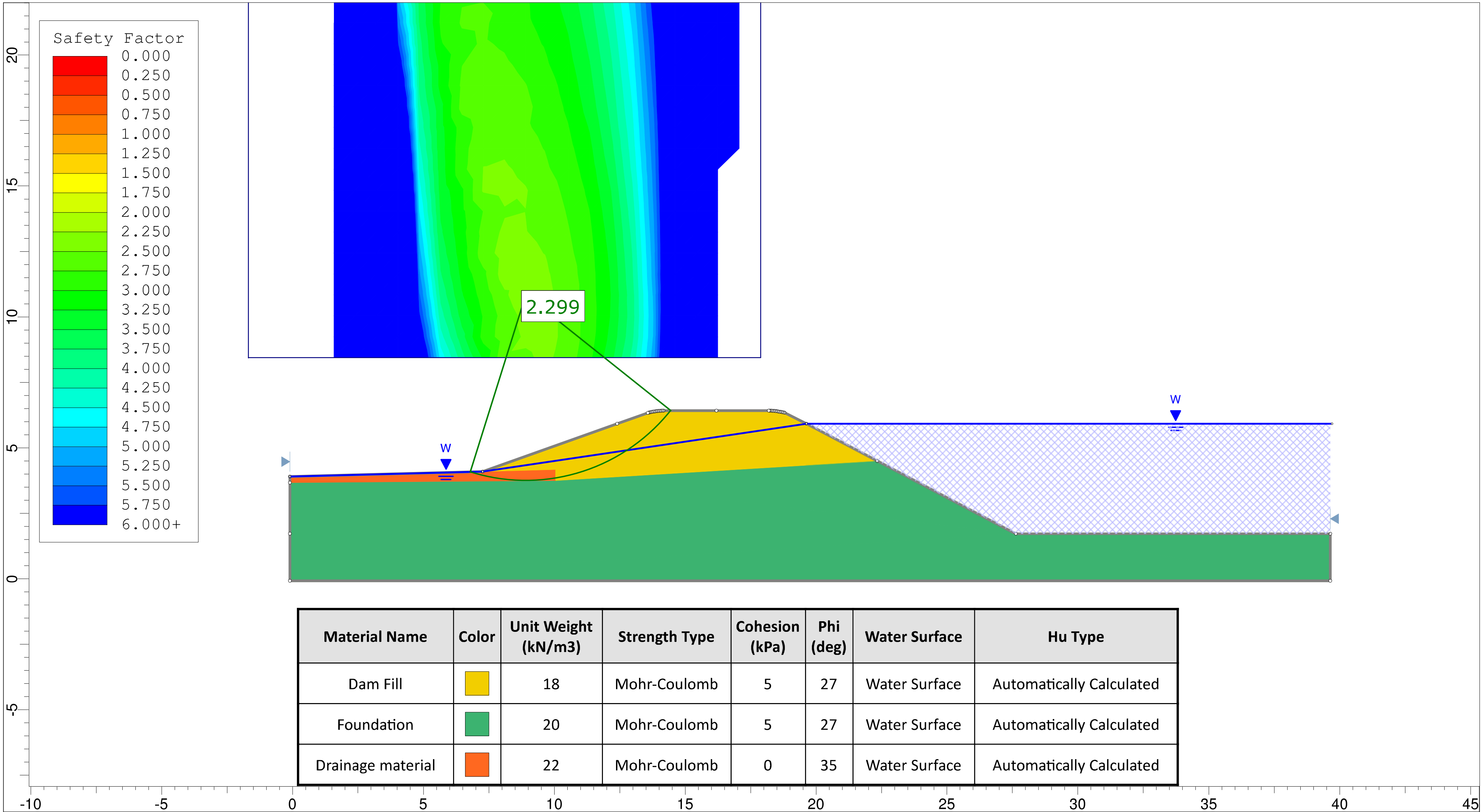


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (internal slope) Modelled Under Design Loading
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

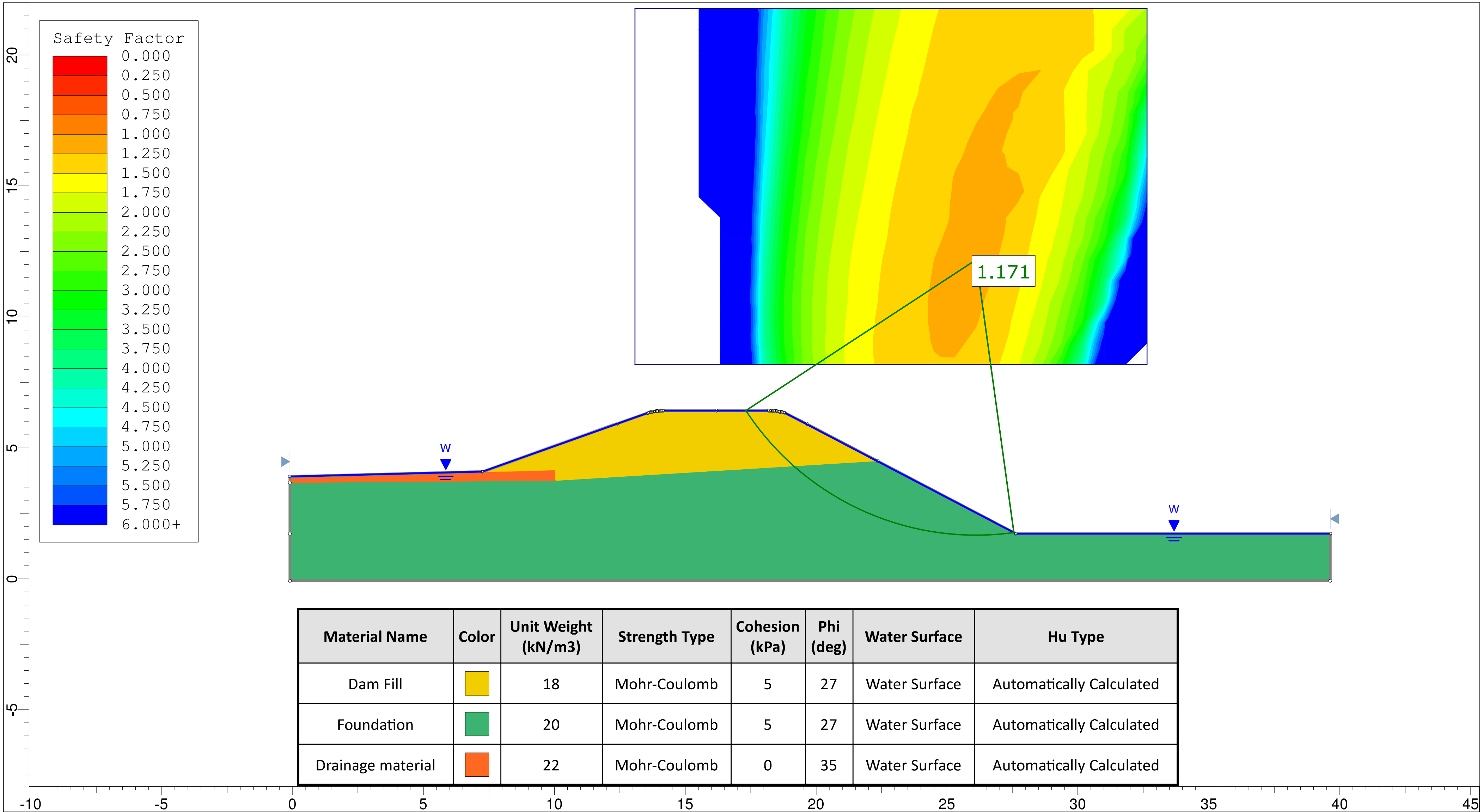


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LDE LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (external slope) Modelled Under Design Loading
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

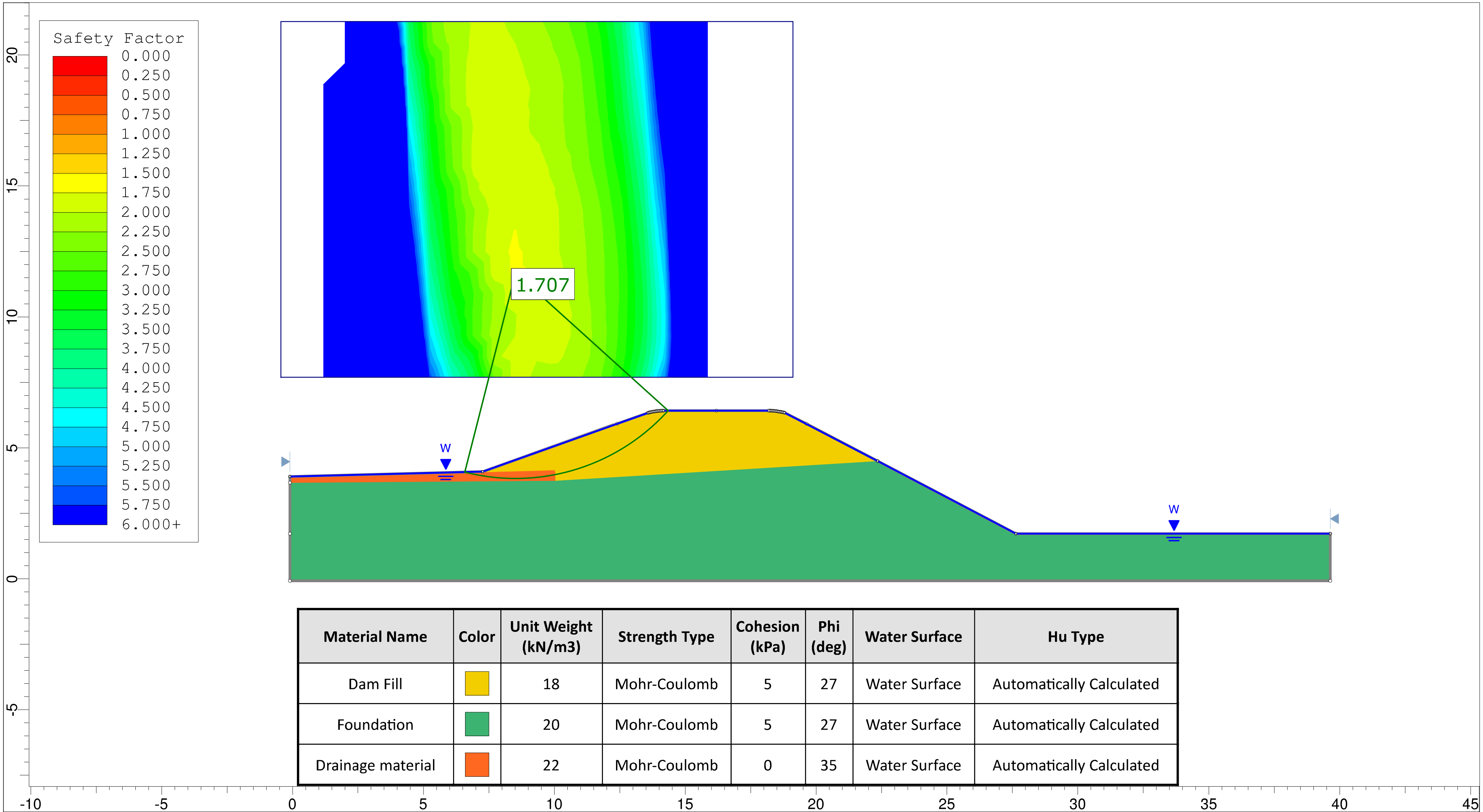


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (internal slope) Modelled Under Extreme Groundwater Conditions
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

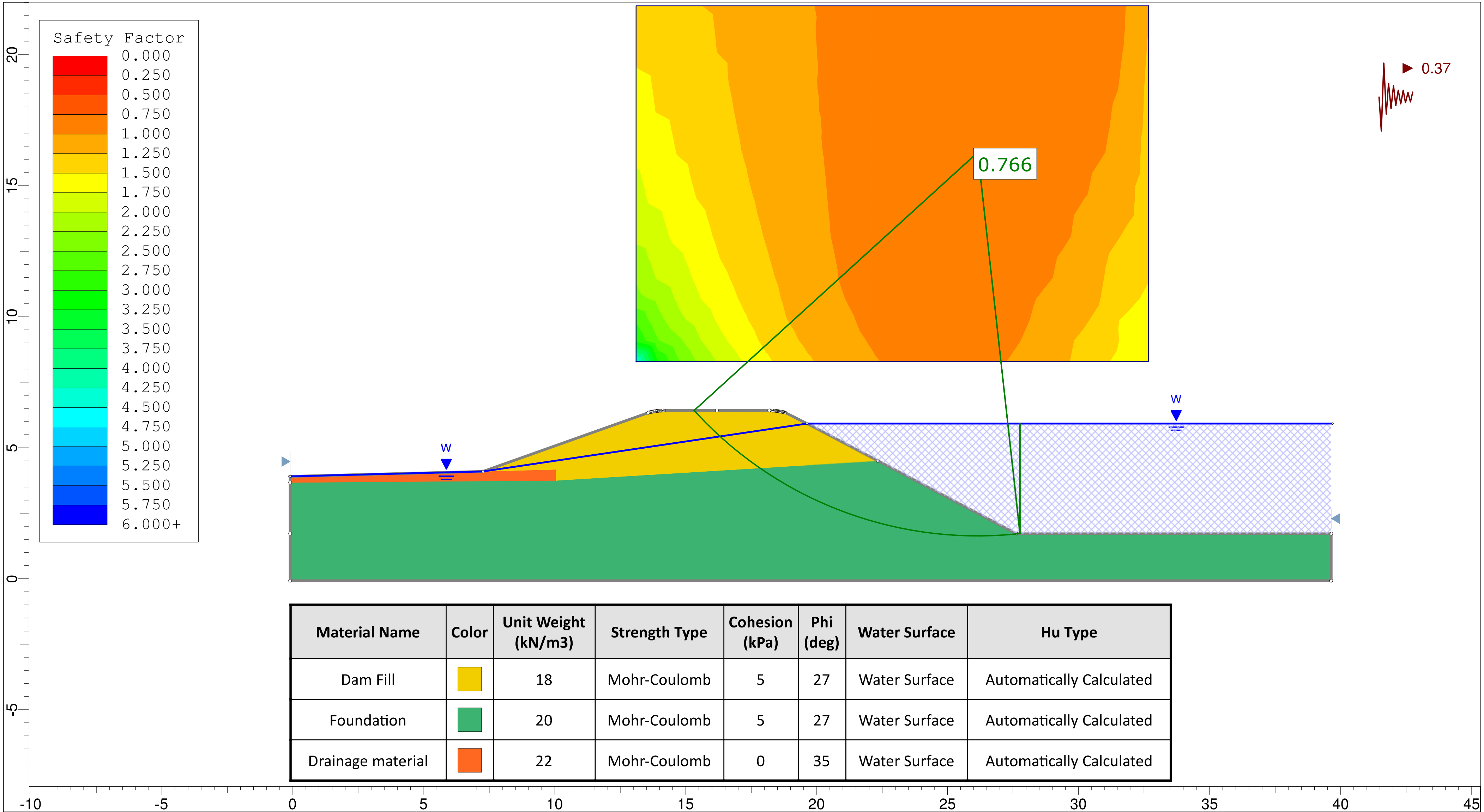


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (external slope) Modelled Under Extreme Groundwater Conditions
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

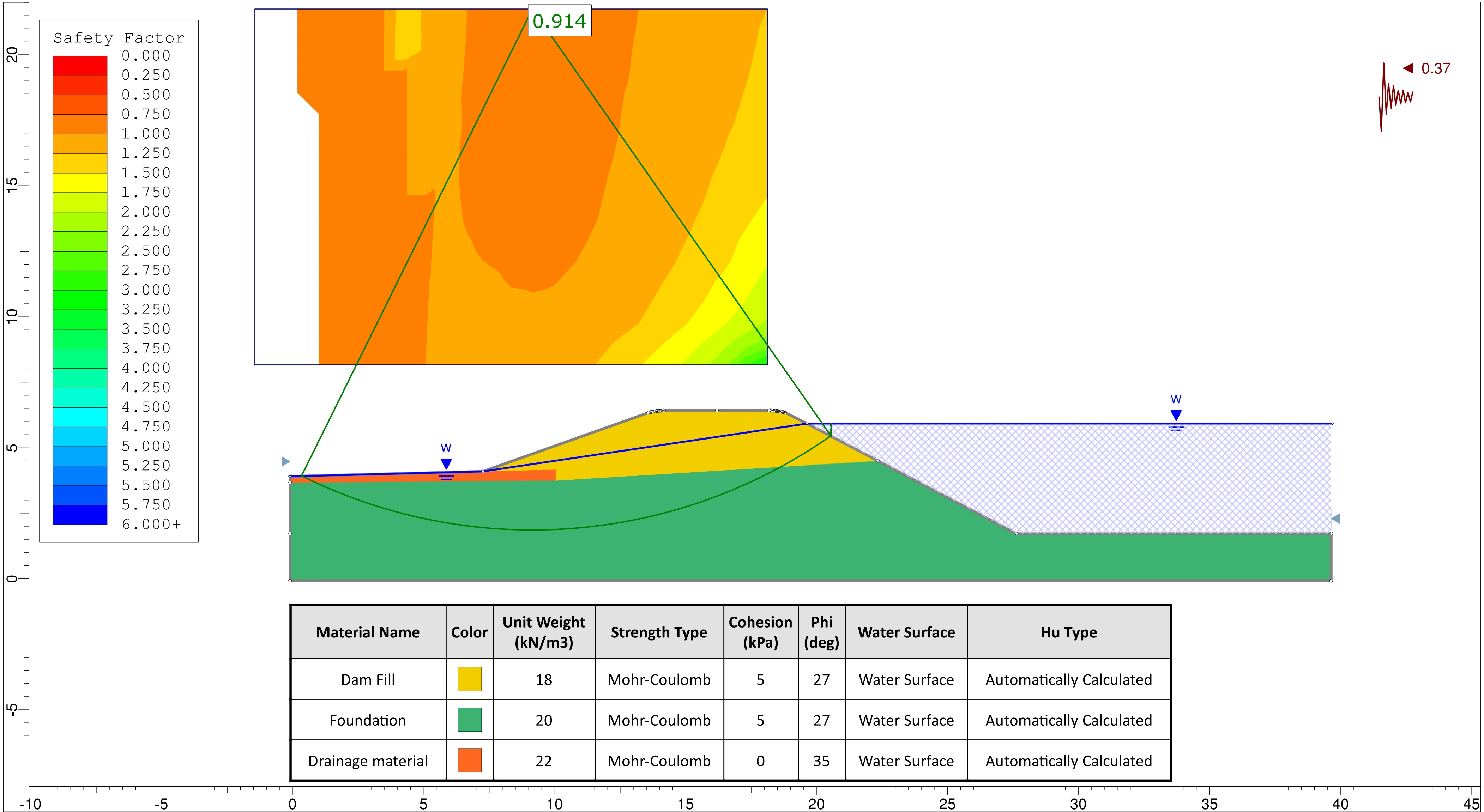


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LDE LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (internal slope) Modelled Under ULS Seismic Loading
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

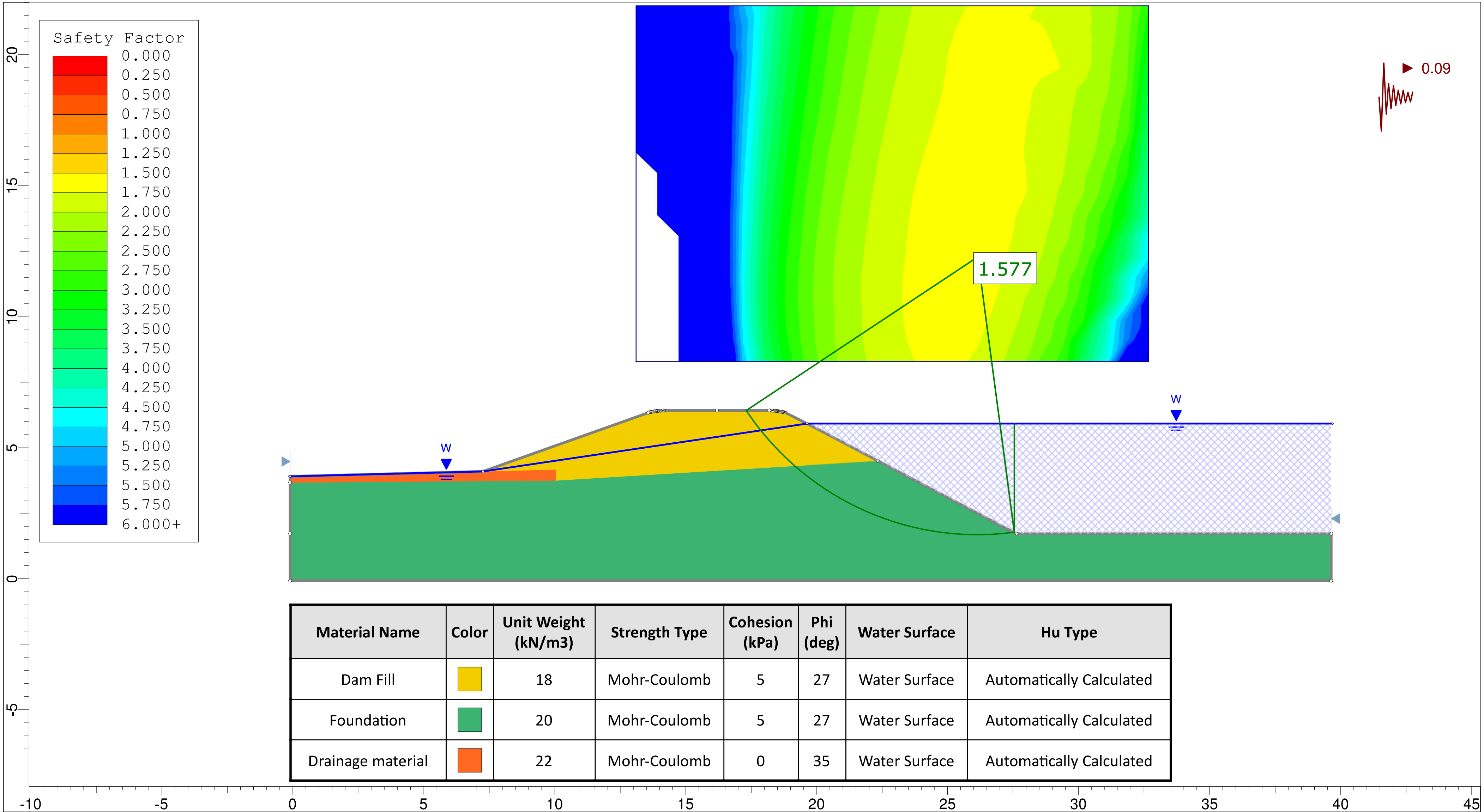
SLIDEINTERPRET 7.017

Project
Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa

Analysis Description
Raised Embankment (external slope) Modelled Under ULS Seismic Loading

Drawn By A. Mayhead | *Scale* 1:204 | *Company* LDE Ltd

Date 10/07/17 | *File Name*

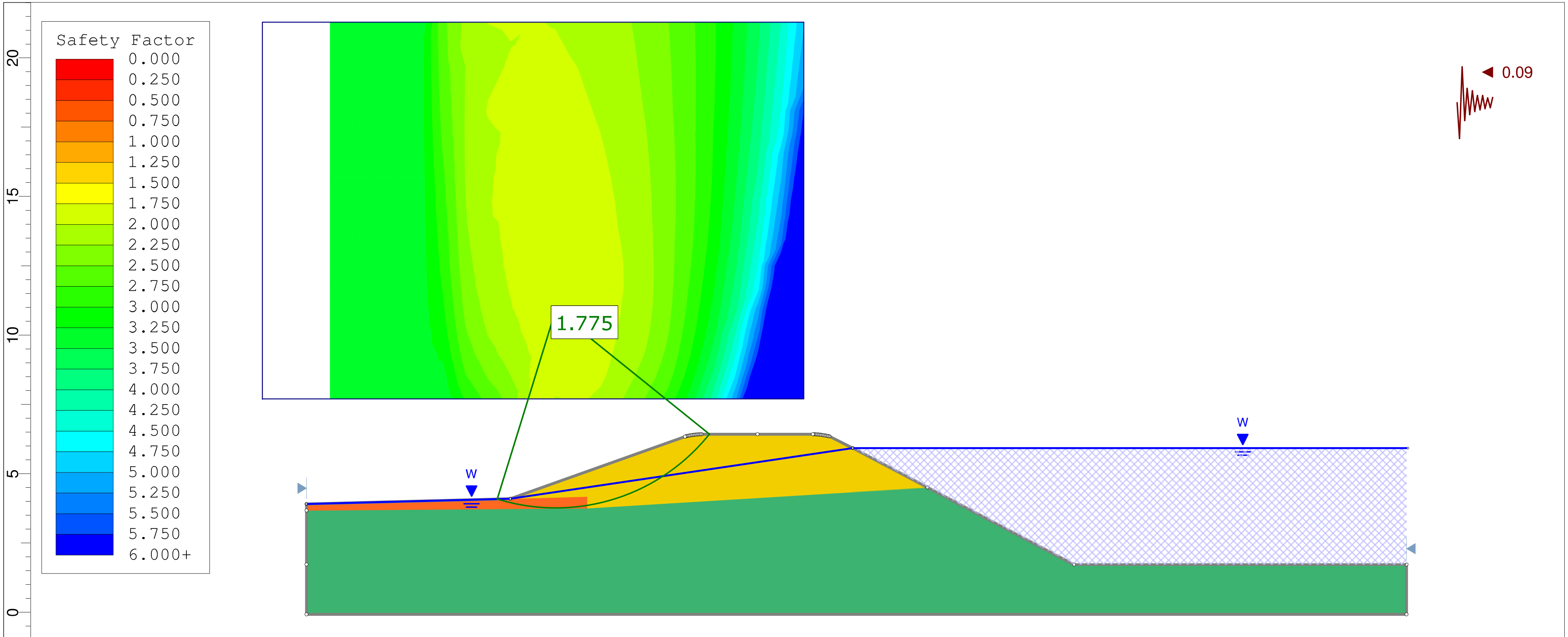


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (internal slope) Modelled Under SLS Seismic Loading
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

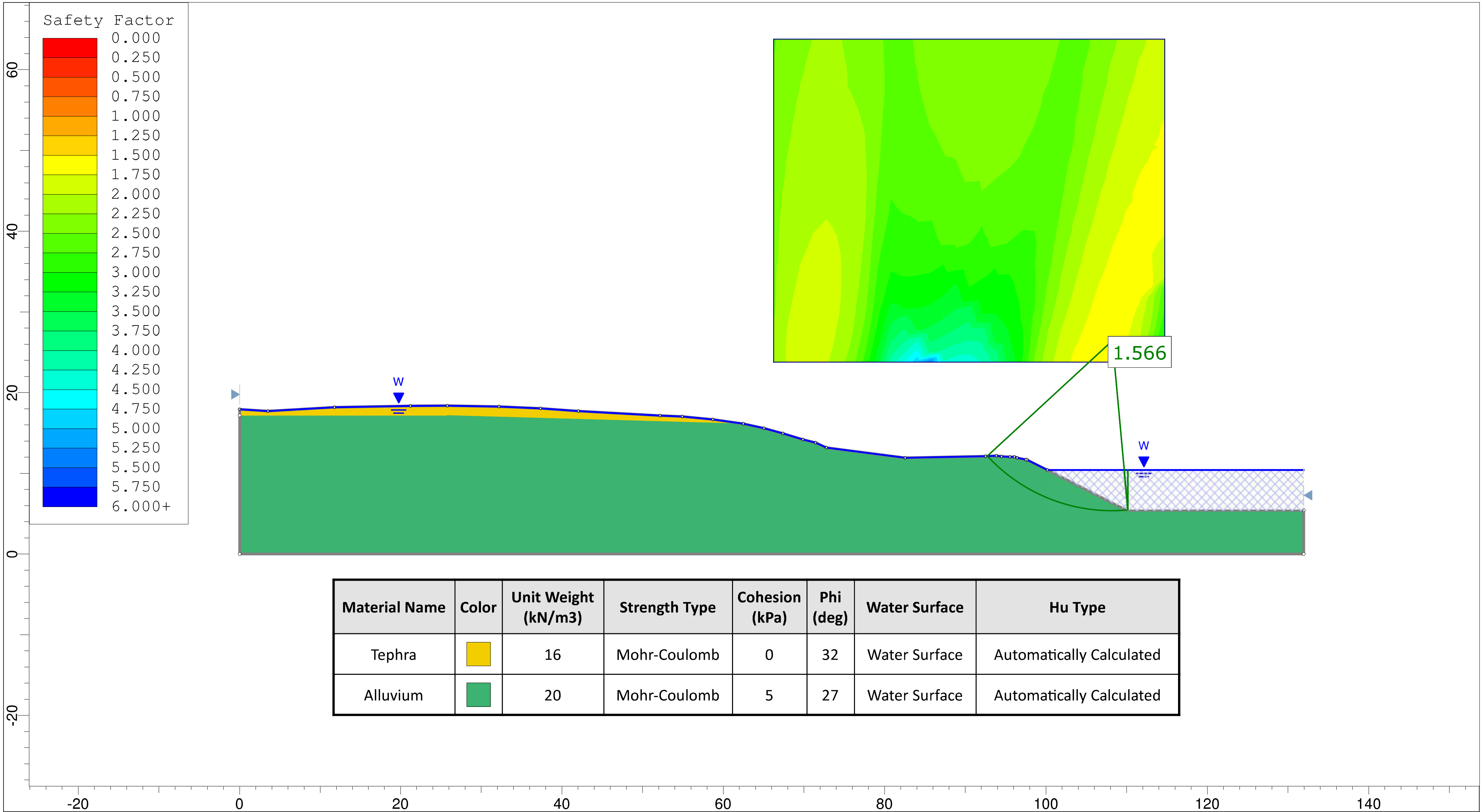


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Dam Fill		18	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Foundation		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated
Drainage material		22	Mohr-Coulomb	0	35	Water Surface	Automatically Calculated

LDE LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Raised Embankment (external slope) Modelled Under SLS Seismic Loading
Drawn By	A. Mayhead
Scale	1:204
Company	LDE Ltd
Date	10/07/17
File Name	

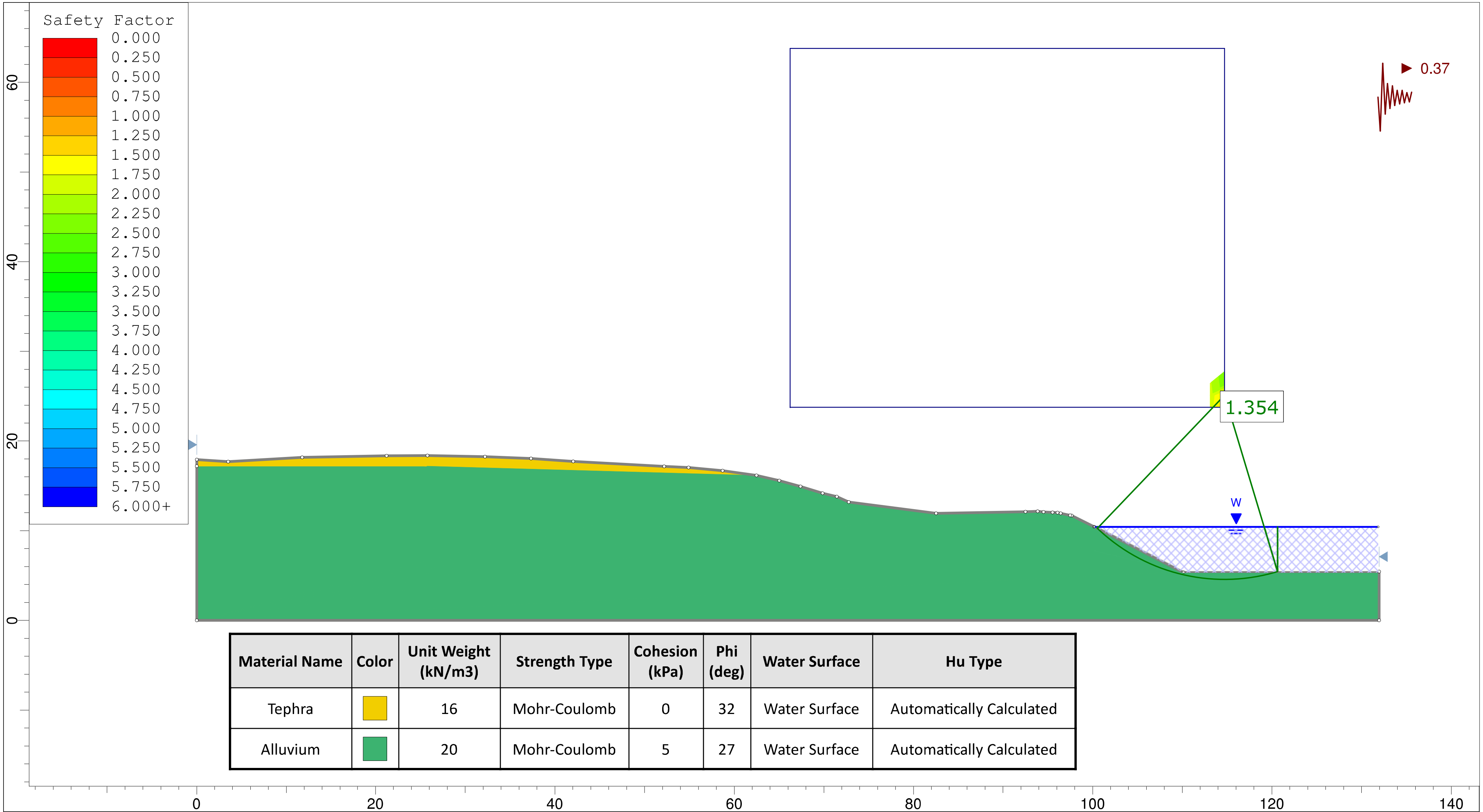


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Tephra		16	Mohr-Coulomb	0	32	Water Surface	Automatically Calculated
Alluvium		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa		
Analysis Description	Effect of Increasing Size of Oxidation Pond on Southern Terrace Modelled Under Extreme Groundwater Conditions		
Drawn By	A. Mayhead	*Scale*	1:661
Company	LDE Ltd		
Date	10/07/17	*File Name*	

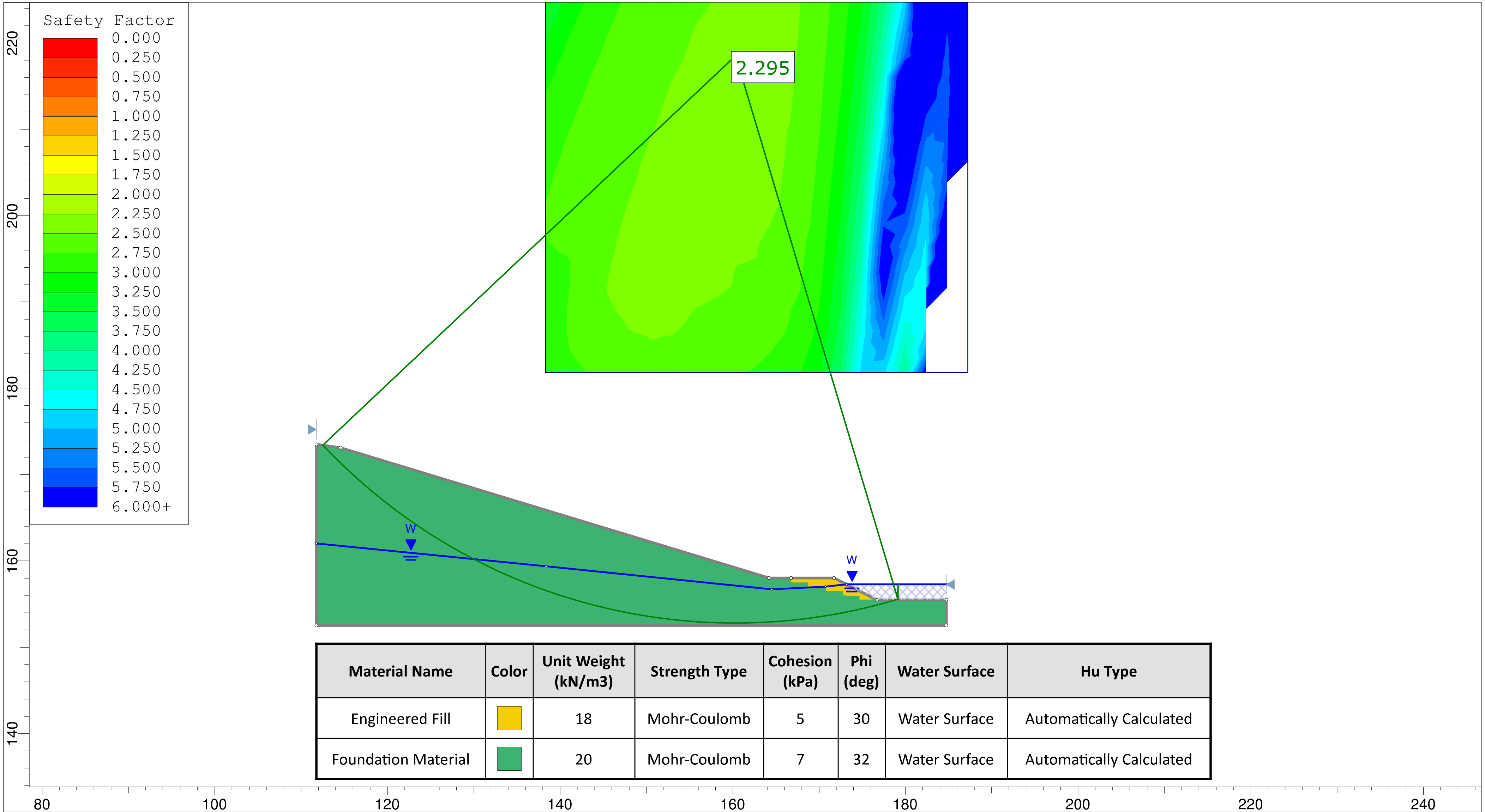


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Tephra		16	Mohr-Coulomb	0	32	Water Surface	Automatically Calculated
Alluvium		20	Mohr-Coulomb	5	27	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa		
Analysis Description	Effect of Increasing Size of Oxidation Pond on Southern Terrace Modelled ULS Seismic Loading		
Drawn By	A. Mayhead	*Scale* 1:595	*Company* LDE Ltd
Date	10/07/17		*File Name*

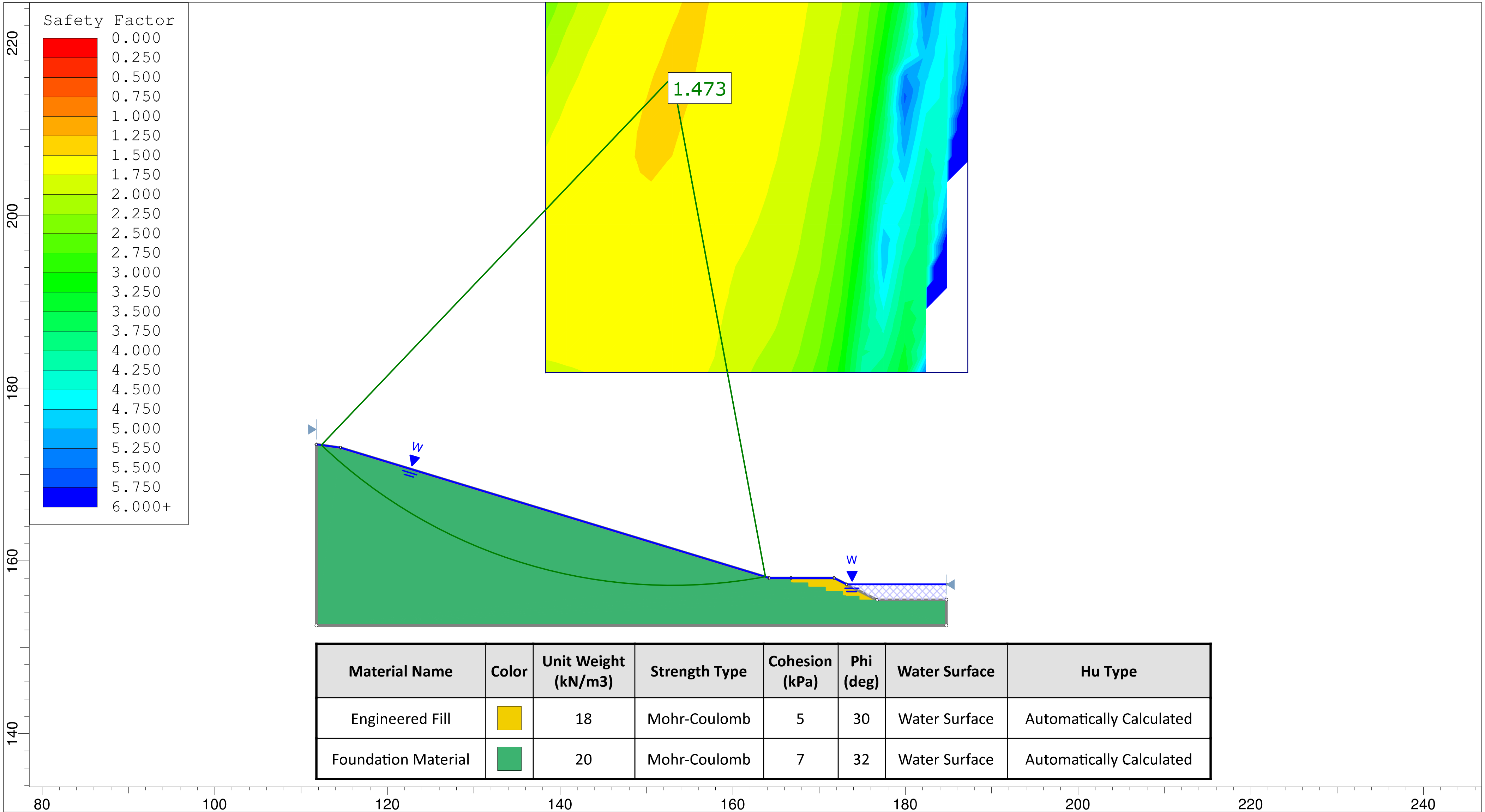


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Engineered Fill		18	Mohr-Coulomb	5	30	Water Surface	Automatically Calculated
Foundation Material		20	Mohr-Coulomb	7	32	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Existing Northern Slope Above Oxidation Pond, Modelled Under Design Groundwater Conditions
Drawn By	A. Mayhead
Scale	1:618
Company	LDE Ltd
Date	10/07/17
File Name	

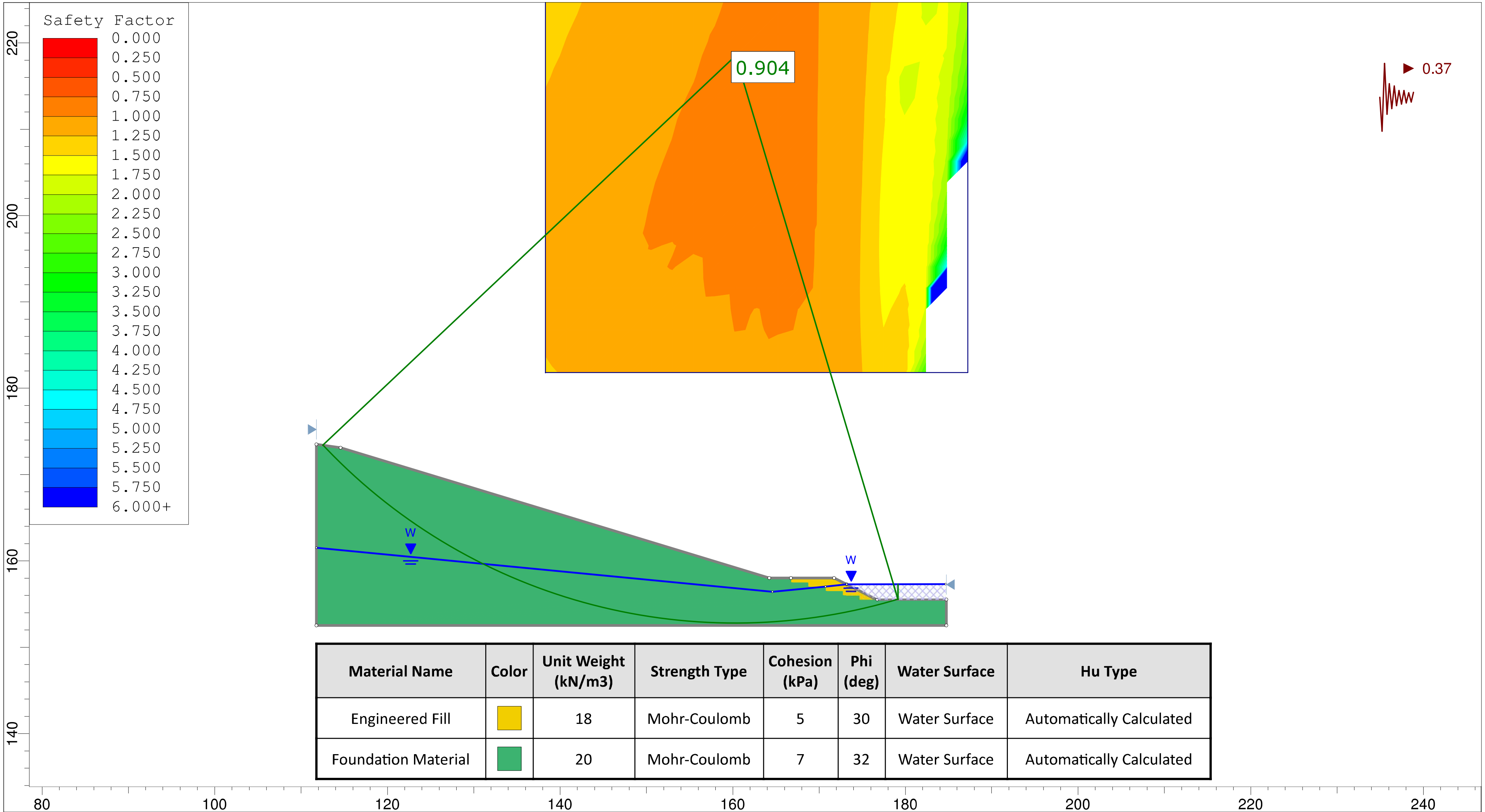


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Engineered Fill		18	Mohr-Coulomb	5	30	Water Surface	Automatically Calculated
Foundation Material		20	Mohr-Coulomb	7	32	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Existing Northern Slope Above Oxidation Pond, Modelled Under Extreme Groundwater Conditions
Drawn By	A. Mayhead
Scale	1:618
Company	LDE Ltd
Date	10/07/17
File Name	



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
Engineered Fill		18	Mohr-Coulomb	5	30	Water Surface	Automatically Calculated
Foundation Material		20	Mohr-Coulomb	7	32	Water Surface	Automatically Calculated

LAND DEVELOPMENT & EXPLORATION LTD.

SLIDEINTERPRET 7.017

Project	Geotechnical Investigation of Wairoa Wastewater Treatment Plant, Part Lot 1 DP 3350, Whakamahia Road, Wairoa
Analysis Description	Existing Northern Slope Above Oxidation Pond, Modelled Under ULS Seismic Loading
Drawn By	A. Mayhead
Scale	1:618
Company	LDE Ltd
Date	10/07/17
File Name	