Geotechnical site investigations, Onoke Lakeside Estate, Lake Ferry

August 2020

for The Jakeman Trust

Project Number 1374

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Contents

Executive summary

Two boreholes and six cone penetration tests were located across the site at Lake Ferry to investigate the potential for liquefaction. Soft alluvial/marine sediments were found between two dense gravel layers. One gravel layer was found near to the surface while the other varied from 5-8m below ground level. No evidence for past liquefaction at the site was observed. Analysis of the CPT data has shown that the liquefaction could affect the soils towards the southern end of the property. However we believe this is unlikely as the soils have a high fines content that is not correctly taken into account with the analysis. Footings for the proposed dwellings should be founded on the upper gravel unit and care must be taken not to over-excavate this layer.

Introduction

Ian R Brown Associates Ltd (IRBA) were engaged by The Jakeman Trust to investigate the ground conditions at the Onoke Lakeside Estate subdivision, Lake Ferry, South Wairarapa (Figure 1).

Investigations were required to assess the potential for liquefaction in this area and to outline suitable foundation design for the proposed housing.

The site is located in an area that has been mapped by GNS Science (2018) as a High Liquefaction Susceptibility Class.

Geological setting

The site is located around 4.5m above sea level and around 100m from the lake shore. The Wairarapa Fault is 12km to the north-west. The site would have been subjected to strong ground shaking during the 1855 earthquake that involved significant displacement along the Wairarapa Fault.

The published geology or the area (GNS) shows the local formation as OIS1 (Holocene) ocean beach deposits, consisting of marine gravel with sand; mud; and beach ridges.

The site is located below eroded limestone hills where fluctuating sea levels have led to embayments and erosional gullys. One such feature is adjacent to the site and has contributed soft silts to the site (Figure 2).

Site investigations

On 27th-28th July 2020, Geotech Drilling (NZ) Ltd drilled two cored boreholes using a rotary drilling rig, Standard penetration tests (SPT’s) were performed at 1.5m intervals down the hole.

Six cone penetration tests (CPT’s) were also undertaken using a track mounted CPT rig fitted with a piezocone (Figure 2). Both boreholes were twinned with CPT’s allowing for direct comparison between the tests.

A UAV was used to photograph the site during. These images were processed using Pix4D (https://www.pix4d.com/), photogrammetric software, to create a 3D model of the site.

Investigation sites were distributed around the property, and were located using georeferenced aerial imagery generated from the UAV flight. The reduced levels of the investigation sites were estimated from Wellington City Council (WCC) LiDAR data.

All investigations were supervised by IRBA staff.

The CPT data were processed using the software package CLiq v.2 (www://geologismiki.gr/).

Robertson's calculation method (Robertson and Wride 1998) was used to infer the soil behaviour from the CPT data (Appendix A).

Image 1&2. Site investigations

Ground conditions

The geology at the site has been confirmed to consist of alluvial soils overlying marine deposits. Historic vertical aerial photographs were examined to investigate any instances of filling of the site and for any evidence of historical liquefaction. The ground surface has been largely unchanged with no evidence of liquefaction observed.

Groundwater was measured in the CPT holes at ~1m below ground level. This could not be directly observed in the boreholes as permeability in the clays was low and the dissipation of water introduced during drilling was slow.

Correlations between the drill holes and the CPT's show that the surficial geology is broadly consistent across the site, with a medium dense gravel layer of ~2m thickness found from 0.5m below ground level. A deeper gravel unit dips towards Lake Ferry from the hills. The environment of deposition also changes with distance from the hills. Finer sediments (clays) are were observed in borehole WGDH376 whereas coarser sediments (sands) were observed in borehole WGDH377.

Soil descriptions are shown on graphic borehole logs in Figures 2-4. Soil behaviour type as assessed by CLiq (Geologismiki 2018), based on the CPT data can be found in Appendix A. These show alternating clays and silts with minor sands.

The silts and clays below the upper gravel unit are very soft-soft. This is demonstrated by very low SPT N values and low cone resistance.

Liquefaction

Liquefaction is a term used to describe the behaviour of low density non-cohesive soils that build up pore water pressure during strong ground shaking. An increase in pore water pressure reduces the strength and stiffness of the soil. If the shaking continues for many cycles, and the soil is not confined, it may flow to the surface and form sand boils. When the earthquake shaking stops, pore water pressures dissipate and strength will gradually be restored.

For liquefaction to occur the soils need to be generally non-cohesive, have a low density, located below the ground water table and within 12m of ground surface. The soil depositional environment is also an important factor with sands deposited in a high energy environment less susceptible than sands and silts deposited in a low energy environment.

Liquefaction analyses have been based on earthquake parameters as recommended by the NZTA Bridge Manual (2018).

$$a_{max} = c_{0,1000}\ R/1.3\ f\ g$$

$$= 0.45\ 1/1.33\ 1.33$$

$$= 0.61g$$

Earthquake magnitude, M_w = 7

This is a 1/500 year, Ultimate Limit State (ULS) earthquake event as required for a building with importance level 2 (IL2).

CLiq has predicted that under these ground shaking conditions, liquefaction may occur at this site (Appendix A). The overall liquefaction potential index (LPI) has been predicted by CLiq to be low for most of the site. An exception to this is the southern area of the site (CPT 1374_1). However there was no borehole associated with this CPT so we are unable to verify the soil structure in that area.

Although soft, it is likely that the fines content of these sediments would prevent the soil in this area from liquefying. We have found at other sites that CLiq does not adequately account for the fines content of the soil, and as a result provides a conservative analysis.

The CPT probe was unable to penetrate beyond the dense gravel layer near to the surface in hole 1374_6 where sands were seen in the borehole. Once again, the relatively high proportion of silt in these sands is likely to prevent them from liquefying.

During our investigations no evidence of past liquefaction was observed.

Discussion

The area does not appear to have been affected by liquefaction during historic strong earthquake shaking. Hancox (2005) showed liquefaction sites inland of Lake Ferry during the 1855 Wairarapa earthquake.

Dellow et al. (2018) refer to sand boils at Lake Ferry during the June 1942 earthquake. We have inspected vertical aerial photograph stereo pairs taken in 1944, and there is no indication of ground disturbance at the site. Sand boils may have occurred in a location where loose sands were near the ground surface and not confined by the surficial soils present at this site.

Some sands and soft sediments are present, and there may be minimal localised liquefaction during an Ultimate Limit State earthquake. The thin sand layers that are present are unlikely to be continuous, and this together with the cover of dense gravels will limit any impact of adverse behaviour of the underlying soils.

The subdivision is expected to be occupied by timber framed dwellings built on shallow concrete foundations and would be at low risk of damage.

This site should be considered as class C, shallow soil sites for NZS 1170.5:2004 with a site period of <=0.6 sec.

References

Dellow, G.D., Perrin, N.D., Ries, W.F. 2018. Liquefaction hazard in the Wellington Region. GNS Science report 2014/16 71 p.

Geologismiki 2018 CLiq Cone penetration test based soil liquefaction software program.

Hancox, G.T. 2005. Landslides and liquefaction effects caused by the 1855 Wairarapa earthquake: then and now. Proceedings of The 1855 Wairarapa Earthquake Symposium. p84 - 94

Lee, J.M, Begg, J.G. (compilers) 2002. Geology of the Wairarapa area. Institute of Geological and Nuclear Sciences 1:250 000 geological map 11. 1 sheet + 66p. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences Limited.

NZS 1170.5:2004 Structural design actions - Part 5: Earthquake actions - New Zealand

NZ Transport Agency 2018 Bridge manual – SP/M/022 3rd edition.

Robertson, P.K, Wride, C.E 1998 Evaluating cyclic liquefaction potential using the cone penetration test. Canadian Geotechnical Journal. Vol. 35, 1998.

Applicability

This report has been prepared for the benefit of The Jakeman Trust with respect to the brief given to Ian R Brown Associates Ltd. It may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Opinions and recommendations contained in this report have been derived from the information and data gathered during the course of our investigations.

No liability is accepted by Ian R Brown Associates Ltd nor by any Director, or any other servant or agent of the company, in respect of the use of this report (or any information contained therein) by any person for any purpose other than that specified in the brief.

Onoke Lakeside Estate
Property outlines
Boreholes
CPT's
Cross-sections
2m topographical contours

Date: 07/2020
Drawn: MKHB
EPSG: 27200

IRBA
GEOLOGICAL ENGINEERING CONSULTANTS

Figure 1. Investigation locations

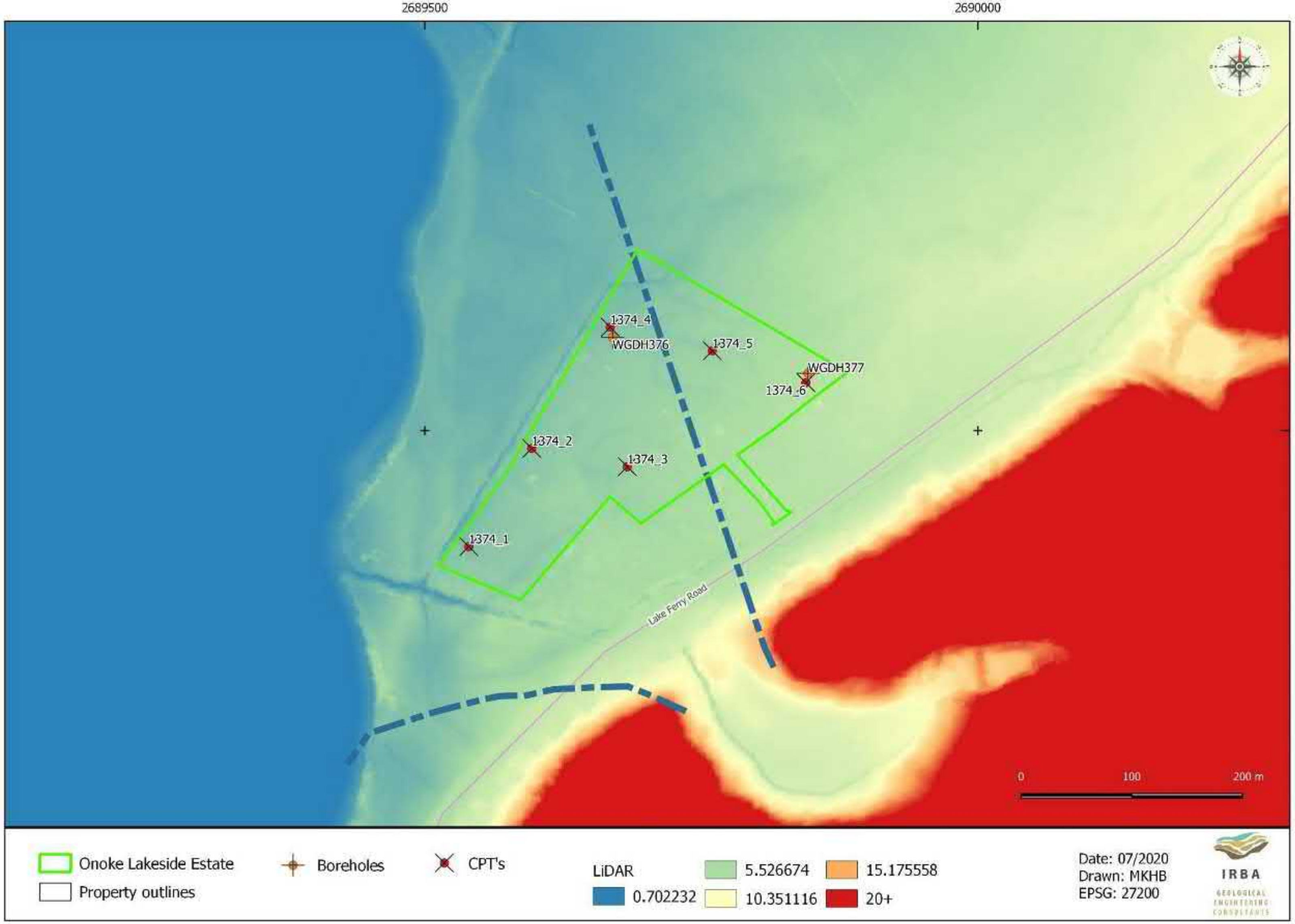

2689500
2690000
5978000
1374_4
WGDH376
1374_5
WGDH377
1374_6
1374_2
1374_3
1374_1
Lake Ferry Road
0
100
200 m
Onoke Lakeside Estate
Property outlines
Boreholes
CPT's
LiDAR
0.702232
5.526674
10.351116
15.175558
20+
Date: 07/2020
Drawn: MKHB
EPSG: 27200
IRBA

Figure 2. Topography

IAN R BROWN ASSOCIATES LTD
Geological Engineering Consultants

GEOTECHNICAL DRILLHOLE LOG

PROJECT:	1374 Lake Ferry Subdivsion			HOLE NO. WGDH376
GRID REF:	2689669E 5978083N	R.L. GROUND:	4.30	
HOLE DIP (angle from horiz):	90	HOLE AZIMUTH:	.0	

Drilling Information / Core Material / Rock Mass Defects / SPT data

METHOD: HOTT / SPT (alternating)

Depth (m): 0 – 10.65

Material Description

- grey brown clayey SILT w/minor sand. v soft, moist
- grey sandy GRAVEL w/some silt, well rounded, fine-coarse, med dense, moist
- grey sandy CLAY w/some gravel, soft, moist
- grey clayey fine SAND, soft-v soft, moist
- grey CLAY w/some sand alternating SAND w/some clay v soft, moist, trace shell
- sandy CLAY w/some silt, v soft, moist, w/some shell fragments
- grey CLAY w/some sand alternating SAND w/some clay v soft, moist, trace shell
- grey CLAY w/some silt, minor sand, v.soft, moist
- gravelly SILT w/some clay, firm, moist
- grey sandy GRAVEL, sub-rounded, coarse-boulders very dense, moist

TOTAL DEPTH 10.65 m

Defect Description / SPT Description

- SPT @ 1.5m 2/3//4/2/2/2 N=10
- SPT @ 3.0m 0/0//0/0/0/1 N=1
- SPT @ 4.5m 0/0//1/0/0/1 N=2
- SPT @ 6.0m 0/0//0/0/0/2 N=2
- SPT @ 7.5m 0/0//0/0/0/2 N=2
- SPT @ 9.0m 15/15//12/16/15/8 N=50+
- SPT @ 10.5m 16/34// N=50+

ROCK WEATHERING
UW - Unweathered
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
CW - Completely weathered

RELATIVE STRENGTH
VS - Very strong
S - Strong
MS - Moderately strong
W - Weak
VW - Very weak
EW - Extremely weak

FRACTURE LOG (cms)

Explanation

LOGGED	MKB	LENGTH	10.65
DATE		CORE BOXES	4
CHECKED		ORIGINAL SCALE 1:	50
APPROVED	IRB	(A3)	
PHOTOGRAPH NUMBERS			
DRILLER	Ewan		
STARTED	2020/07/27	FINISHED	2020/07/28
DRILL	Rotary		
SHEET 1 OF 1.00		DRG NO.	

Figure 3. WGDH376

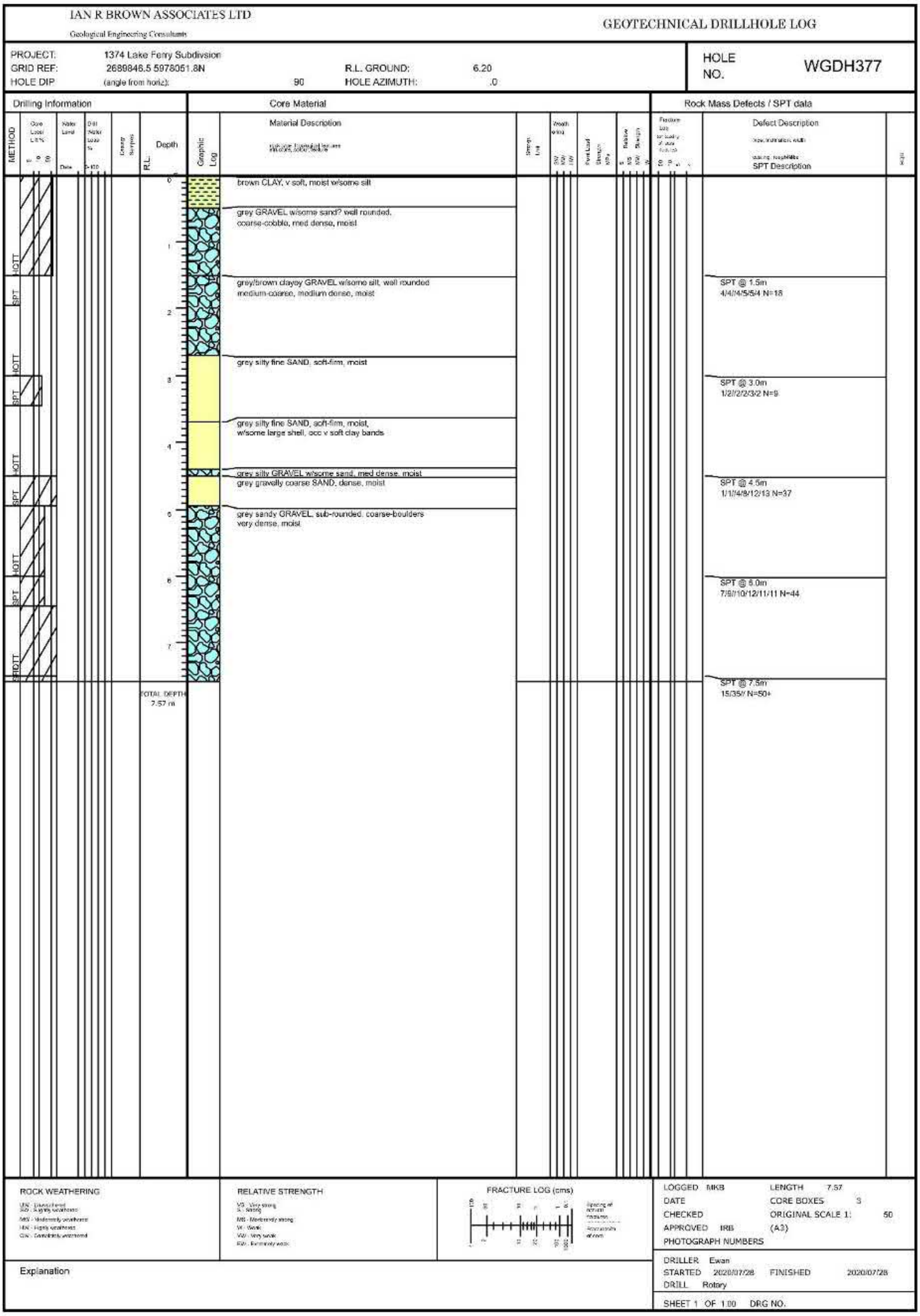


Figure 4. WGDH377

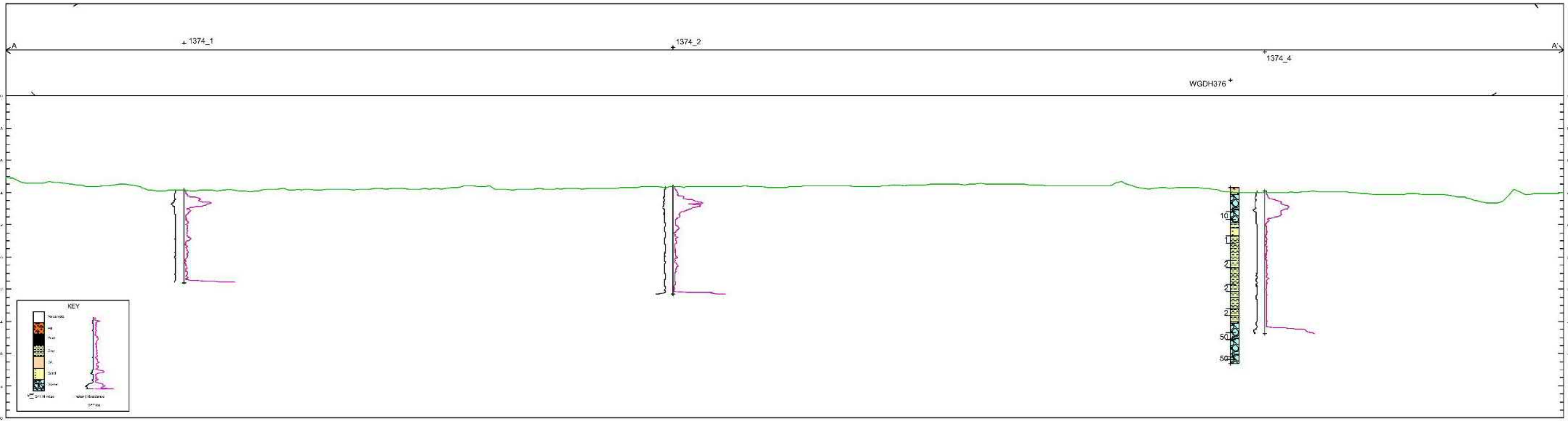


Figure 5. Cross-section A

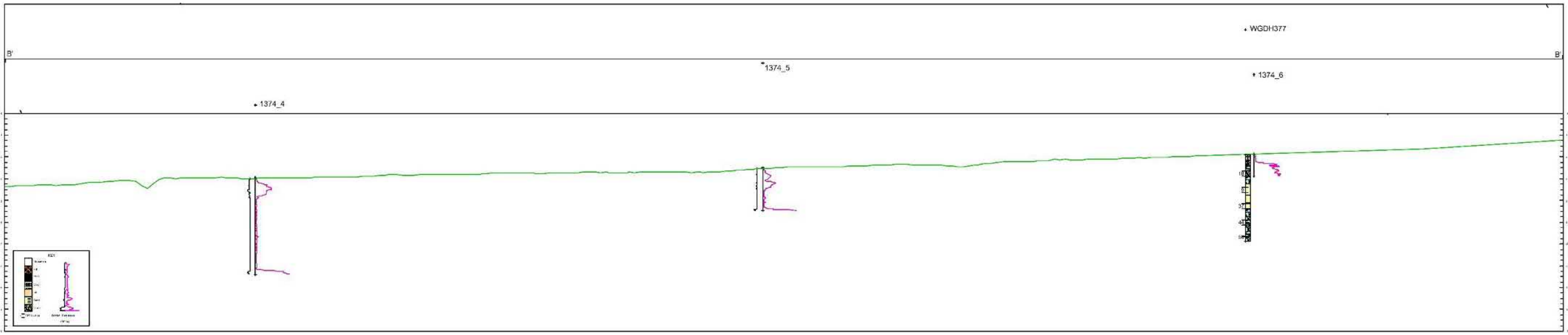


Figure 6. Cross-section B

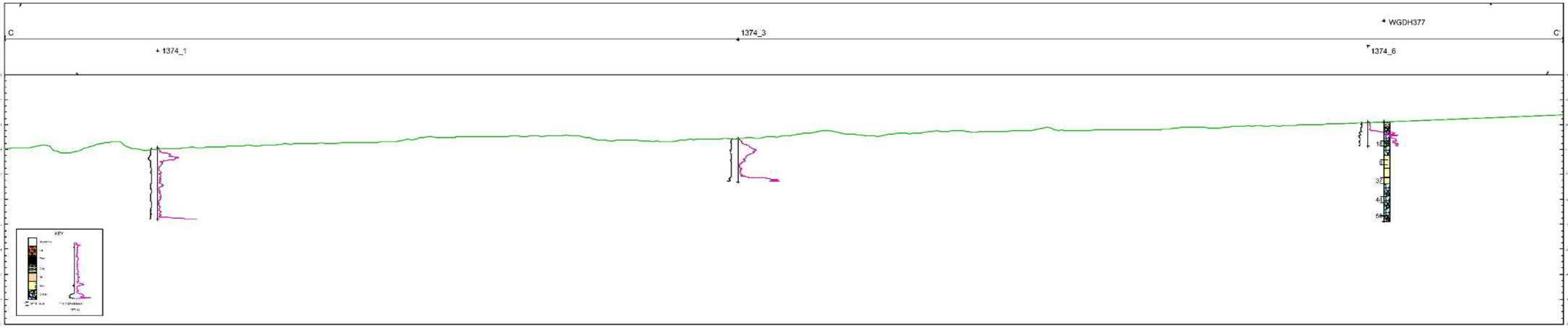
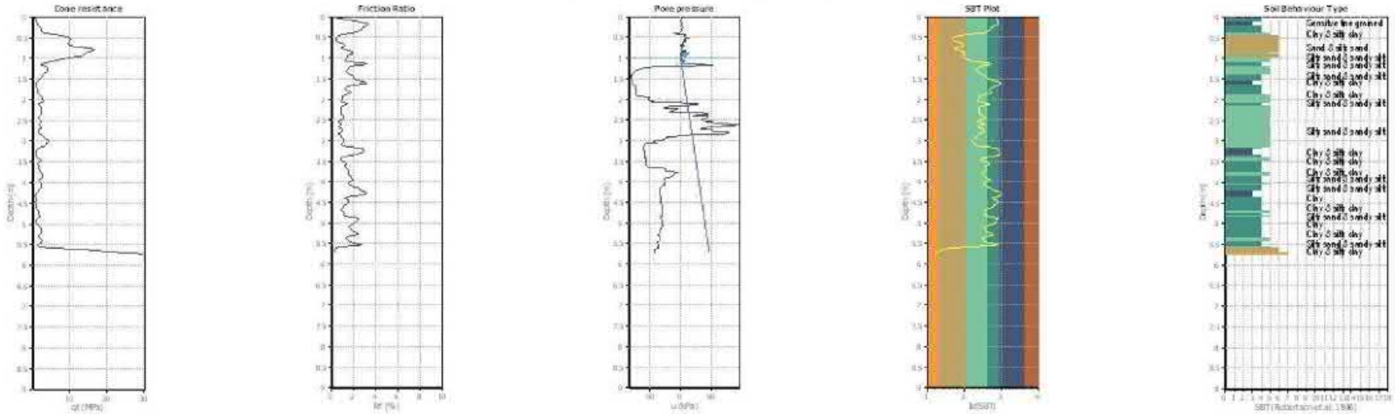


Figure 7. Cross-section

CPT basic interpretation plots



Input parameters and analysis data

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Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No		
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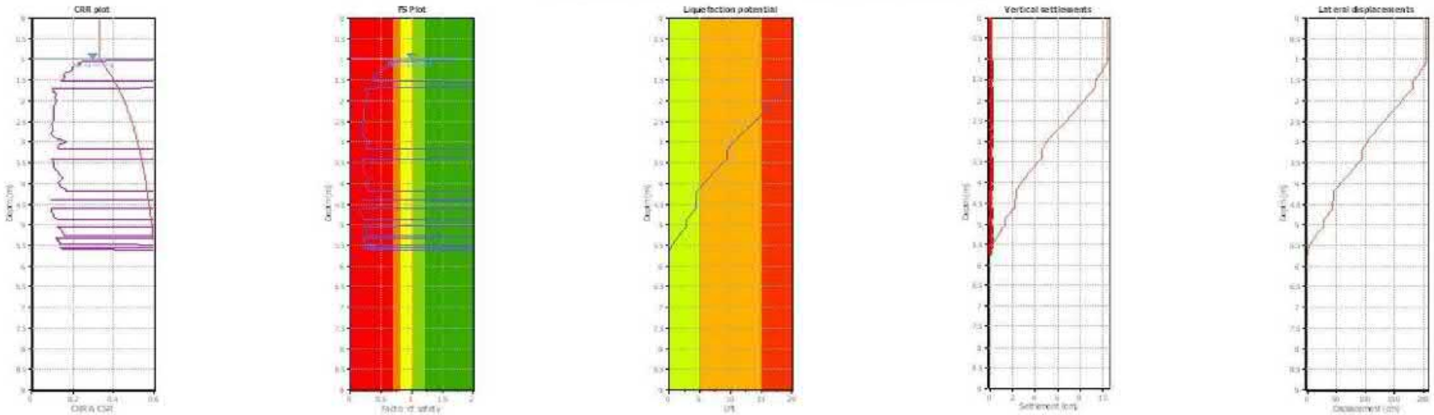
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only		
Peak ground acceleration:	0.61	Use fill:	No	Limit depth applied:	No		
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A		

SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Liquefaction analysis overall plots



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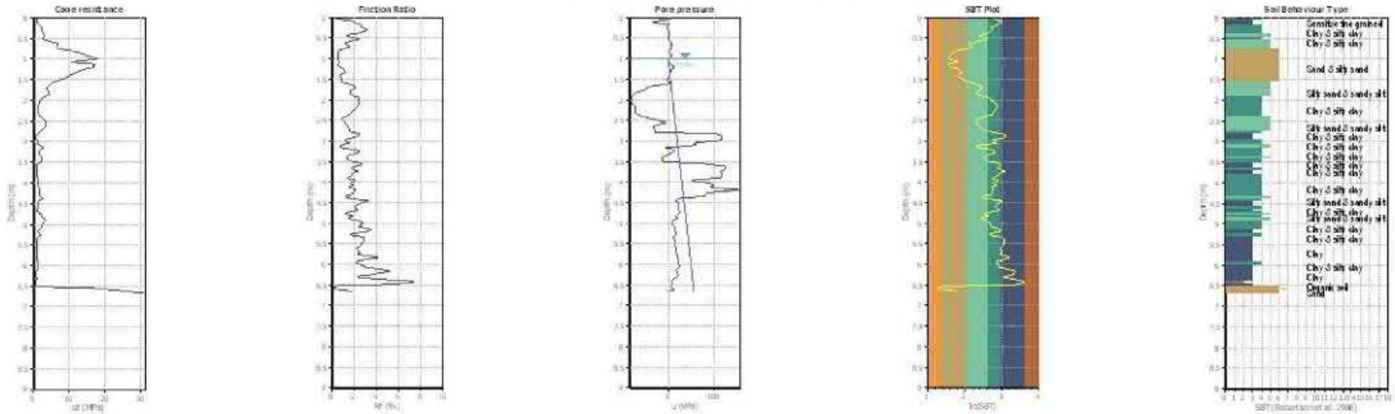
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

CPT basic interpretation plots



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SBT legend

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- 2. Organic material
- 3. Clay to silty clay
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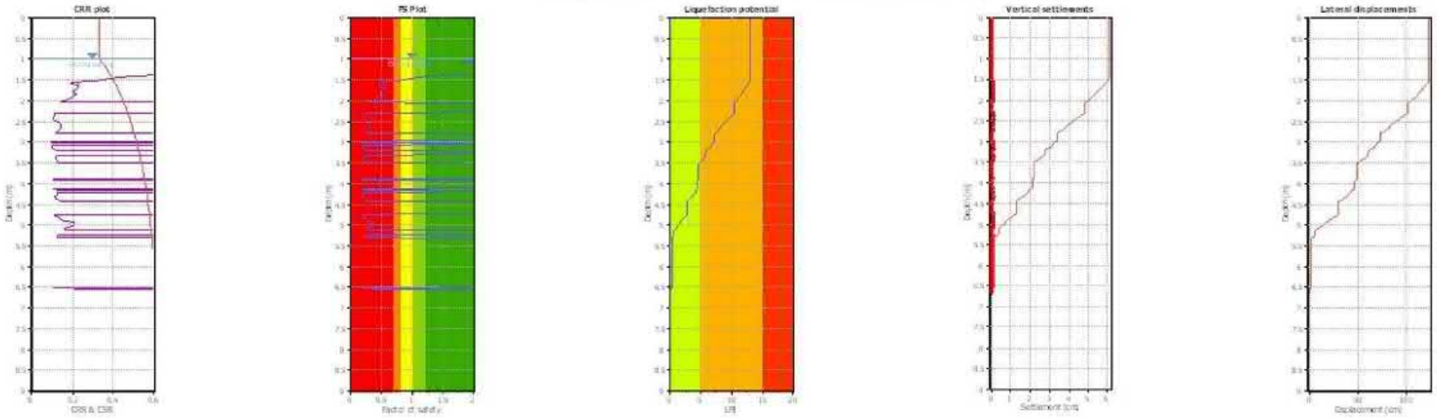
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



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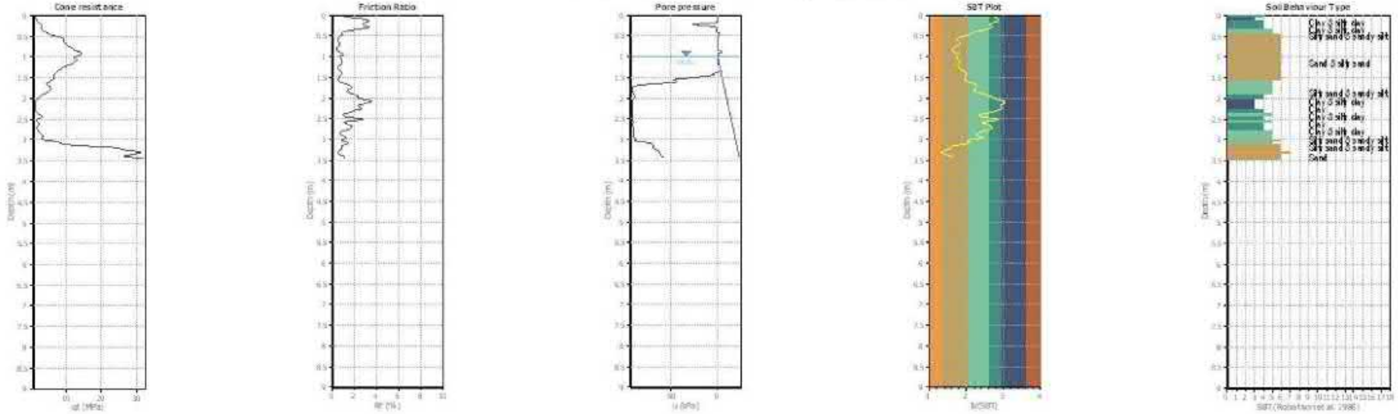

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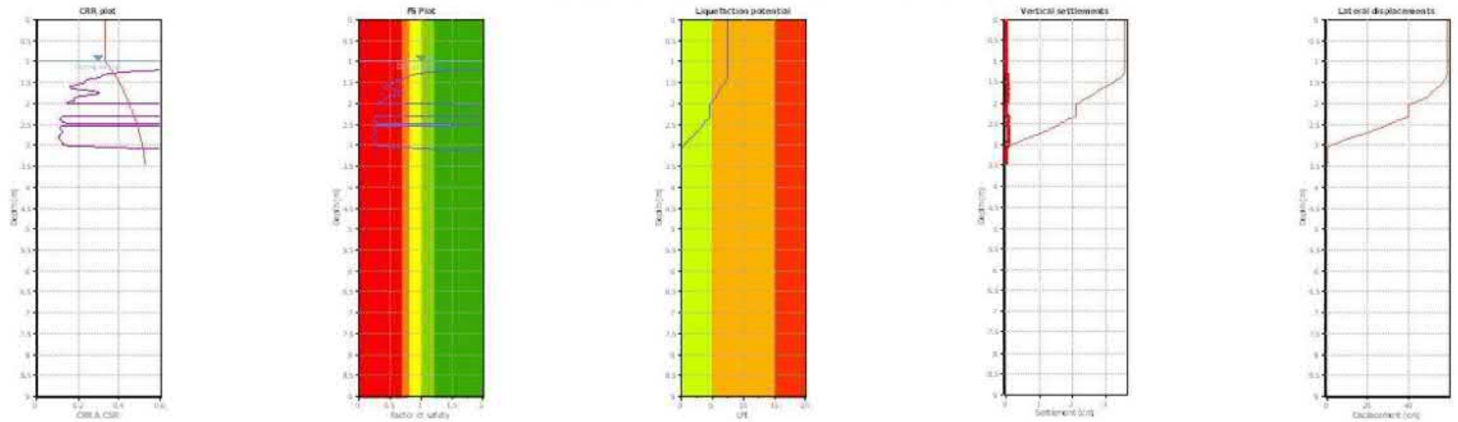

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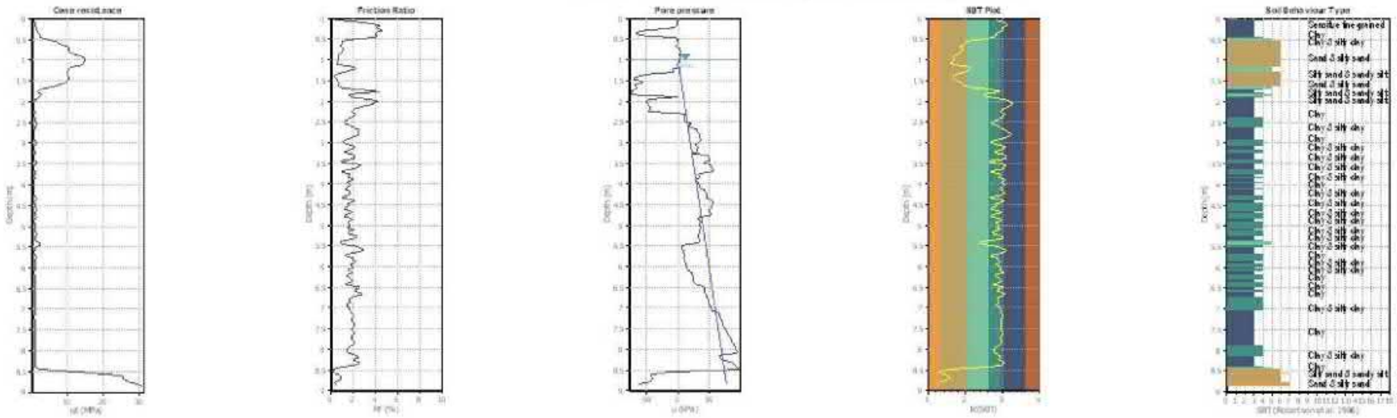

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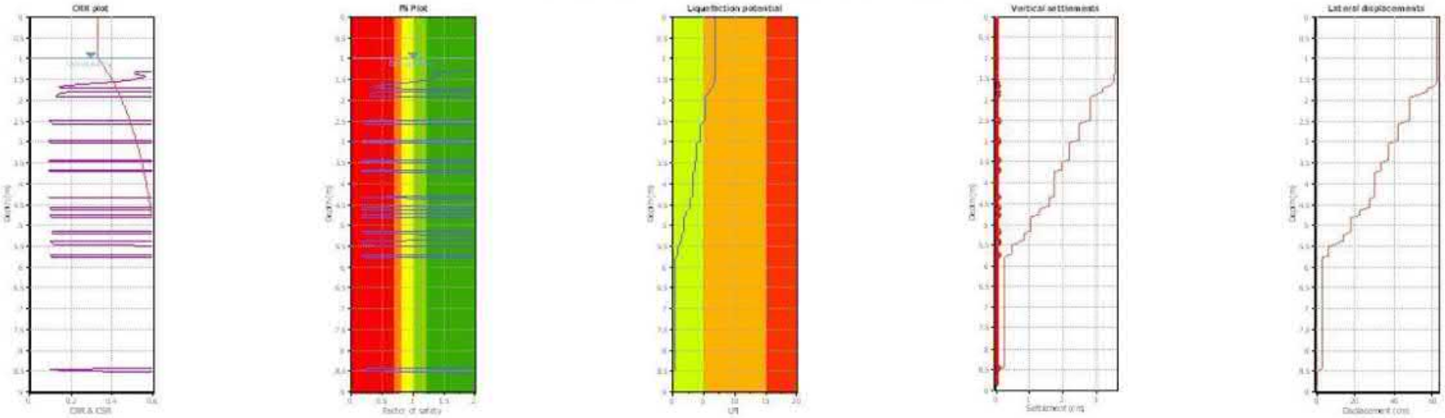

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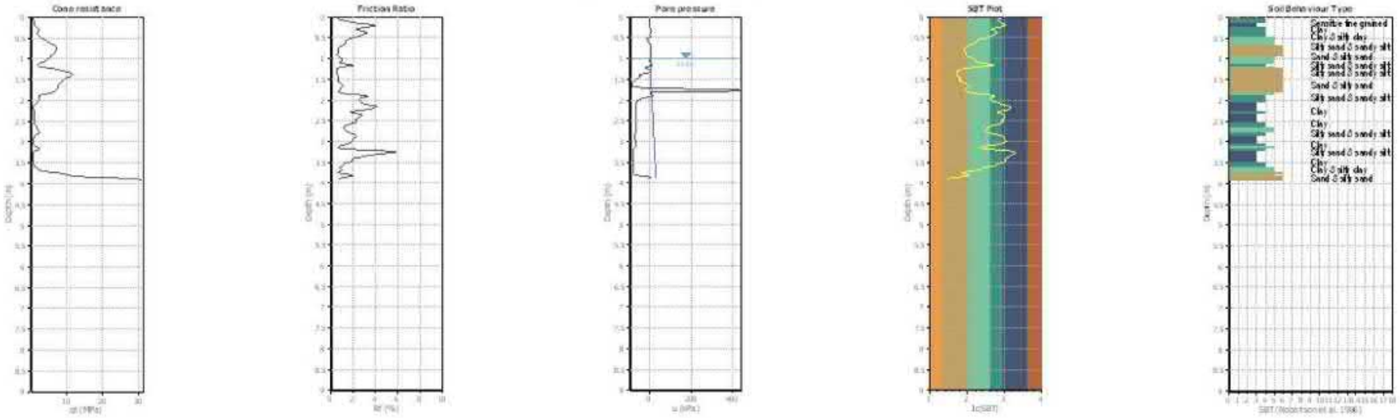

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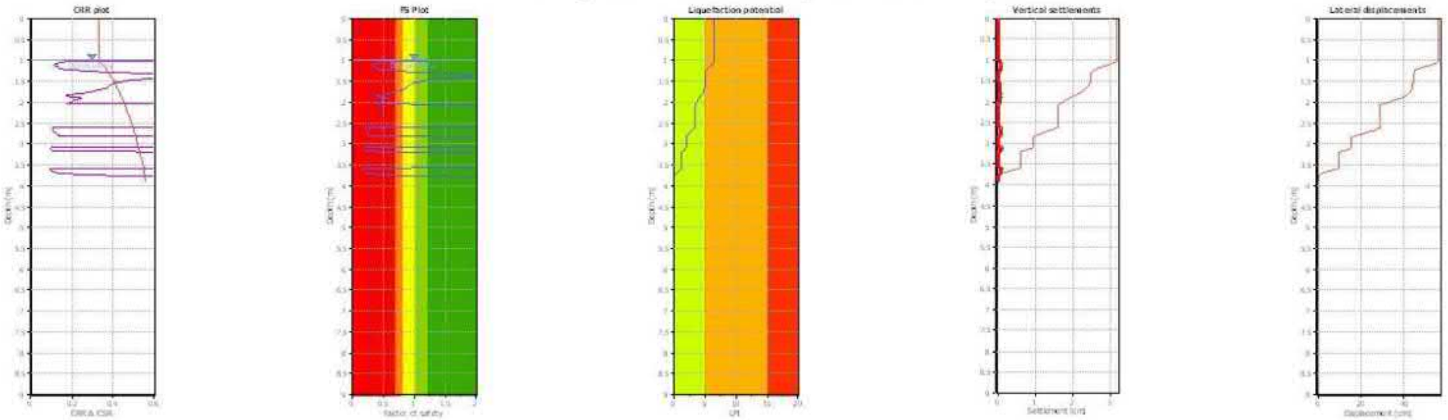
Liquefaction analysis overall plots



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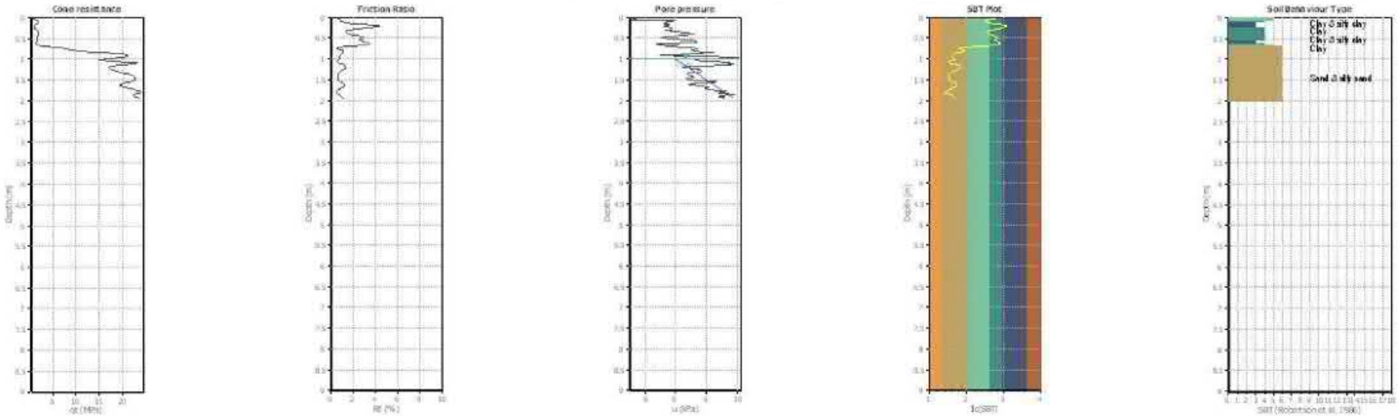

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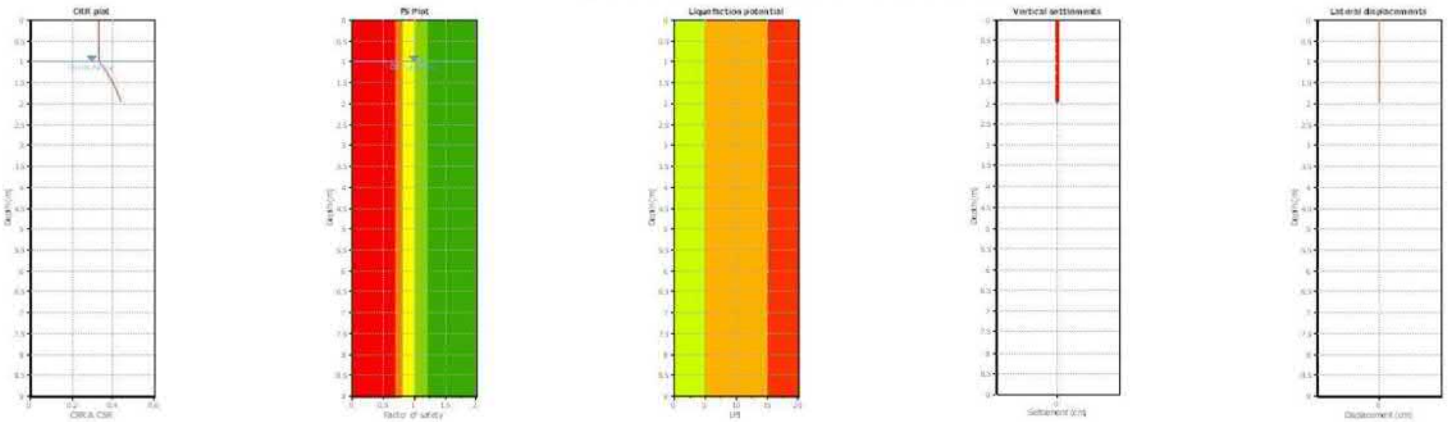
SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.00 m	Fill weight:	N/A		
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No		
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes		
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only		
Peak ground acceleration:	0.61	Use fill:	No	Limit depth applied:	No		
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A		

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

Appendix B

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