14 March 2017 Our Ref: 47003 - Rev 1

Julius Long
Structex Harvard Ltd
248 Montreal Street,
Christchurch, NZ
Email: JLong@structex.co.nz

RE: 80 BYRON STREET, SYDENHAM
GEOTECHNICAL LETTER FOR PROPOSED EXTENSION

Dear Mr Julius Long

1.0 INTRODUCTION

Engineering Design Consultants Ltd (EDC) has been engaged to provide a brief geotechnical investigation and soil bearing assessment for the proposed extension of the western warehouse building at 80 Byron Street in Sydenham, henceforth referred to as 'the site'. The new single storey extension will be used as offices.

1.1 Site Identification

The site's legal description is Lot 1 DP 449853. The property is rectangular, covers an area of 1280m² and is located on the south side of Byron Street in Sydenham, as shown below on Figure 1:

Figure 1: Site Location

1.2 Proposed Extension

The client has provided an extension drawing set, drafted by Architectural Design Group (ADG) Ltd (Ref: 5996; January 2017) for the proposed offices.

These drawings indicate that the proposed extension is to be situated near the northwest corner of the existing west building, as shown on Figure 1 above. The drawings also indicate that the extension is approximately 13m long (north-south), 7.8m wide (east-west) and one-storey. The foundation is proposed to be a concrete slab and is to be tied into the existing buildings concrete slab.

A copy of the proposed extension drawings is attached in Appendix A.

2.0 NEARBY GEOTECHNICAL INVESTIGATION

The site owner has supplied a geotechnical report completed for the property at 83 Byron Street (approx. 40m northeast of extension; see Figure 1) by Engco Consulting Engineers (Ref: 16363) in January 2017. The following is a summary of relevant information:

- Engco undertook 2 No. Cone Penetration Tests (CPT') and 2 No. Hand Augers (HA's) across the site. The HA's indicated that the shallow ground profile consists gravel fill to 0.3m below ground level (bgl), underlain by clayey silt to 2.0m bgl.
- Groundwater was not encountered during the HA's.
- Estimated '*Free-Field*' index (upper 10m) ground settlements, based on the on-site CPT's, range between 60mm and 90mm under SLS 2 (0.19g 6.0Mw) earthquake conditions and 90mm to 115mm under ULS earthquake conditions. Very little settlement is anticipated in the upper 4.5m under SLS or ULS conditions.
- The risk of lateral spreading as a result of liquefaction is considered low and the risk of lateral stretch is considered to within the MBIE minor to moderate category (less than 200mm).
- Due to the liquefaction risk, conventional shallow foundations are not recommended.
- A piled foundation is considered a viable solution for a single-storey warehouse building. It is anticipated that piles would need to be founded at 12.5m bgl. The CPT's indicated that the soil layer between 12m and 16m begl has sufficient bearing capacity (>15MPa) and thickness for deep piles.

Based on the level of estimated settlement from the Engco on-site CPT's, the ground performance in a future earthquake event would be considered equivalent of CERA Technical Category 3 (TC3) if the site were residential.

The Engco geotechnical report is available upon request.

3.0 DESK BASED INFORMATION

3.1 Historical Imagery

Historical aerial imagery indicates that the site was residential in 1941, with two dwellings located in the northern half of the property (not covering location of the current building). Between 1941 and 1994 the site was subject to several developments, none of which were in the area of the proposed extension. By 1994 the site appeared as it does currently (March 2017).

3.2 Historical Land Use

The Environment Canterbury (ECan) Listed Land Use Register (LLUR) holds all known information about Hazardous Activities or Industries (HAIL) that have historically (and/or currently) taken place on the site or within the vicinity of the site.

The ECan LLUR indicates that a known HAIL activity has not occurred on the site, however there are two properties identified on the LLUR within 50m as follows:

- 71 Byron Street, located approximately 45m northwest of the site. This portion of land has been listed for 'F4 – Motor Vehicle Workshops'. The impacts of this HAIL activity have not been investigated as the activity is on-going.
- A small portion of land in the northeast corner of 83 Byron Street, located approximately 45m northeast of the site has been listed for 'A17 – Storage tanks or drums for fuel, chemicals or liquid waste'. This HAIL activity was investigated in 2011 during decommissioning and soil testing results indicated that hydrocarbons were present in the soil, though the level of contamination was below industrial/commercial guideline values.

These nearby HAIL activities are considered unlikely to present a geotechnical constraint for the proposed extension.

The ECan LLUR is attached in Appendix B.

3.3 New Zealand Geotechnical Database

3.3.1 CERA Technical Classification

The site is located in an un-zoned CERA area as it is non-residential.

3.3.2 Geology and Hydrology

The GNS Geological QMap shows the site as being located on '*Modern river floodplain/low-level degradation terrace. Un-weathered, variably sorted, gravel/sand/silt/clay*'. Nearby geological investigation data suggests that the ground profile in vicinity of site (~50m northwest) consists 0.8m of fill, underlain by silt with occasional sand to 4.5m bgl and fine to medium sand from 4.5m to at least 15.0m begl.

The GNS 'Depths to Water Table' maps indicate that the mean depth of groundwater is generally 0.0m – 2.0m bgl in the area of the site. The EQC 'Event Specific Depths to

Water Table' maps indicate that the depth to groundwater was generally closer to 1.0m – 2.0m bgl for each of the major 2010/2011 earthquakes.

3.3.3 Seismic

The EQC 'Vertical Ground Movements' map indicates that the area of the might have subsided between 100mm and 200mm following the 2010/2011 Canterbury Earthquake Sequence.

The EQC 'Horizontal Ground Movements' map indicates that the area of the site may have experienced 170mm of lateral movement in a south-westerly direction. However this amount of movement is highly consistent for the surrounding area.

EDC has reviewed post-earthquake aerial photos taken for the 2010/2011 Canterbury Earthquake sequence. No liquefaction ejecta was evident on-site or on surrounding areas following any of the major earthquakes during the 2010/2011 Canterbury Earthquake Sequence. Additionally, EQC did not observe any ground cracks on-site or within the surrounding area following the 2010/2011 earthquakes.

Estimated Peak Ground Accelerations (PGA's) for the site, based on a model by Bradley et al, indicate that the site experienced a median PGA of 0.33g during the February 2011 event (greatest shaking at the site) and therefore, the site can be considered 'sufficiently tested' to a Serviceability Limit State (SLS) earthquake event, but not to an Ultimate Limit State (ULS) earthquake. It is noted that the site was not 'sufficiently tested' during any of the other 2010/2011 earthquakes.

It is understood that damage to the existing building from the earthquakes was light and limited.

3.4 Seismic Subsoil Classification

Based on the above, a seismic subsoil classification 'Class D –Deep or Soft Soil', as defined in NZS 1170.5 is considered appropriate for the site.

3.5 Flooding

The Christchurch City Council (CCC) has indicated that the site is located within a District Plan Flood Management Area (FMA) and therefore a Finished Floor Level (FFL) of 14.39m RL is required for new building at the site. LiDAR information indicates that the average ground level at the site is 13.82m RL, approximately 0.6m below the required FFL.

4.0 INTRUSIVE WORKS

4.1 Rational

Due to the relatively small footprint of the proposed extension and the lack of earthquake related ground damage at and within vicinity of the site, it was considered that two shallow intrusive holes would be adequate to gain an understanding of the ground conditions and that deep investigation/liquefaction analysis was not necessary.

4.2 Investigation

EDC visited the site on 03 March 2017 to undertake the shallow intrusive investigation to determine the subsoil conditions.

Two exploratory holes comprising a Hand Auger (HA) and Scala Penetrometer (SC) were undertaken at either end of the proposed extension footprint, as indicated below on Figure 2:

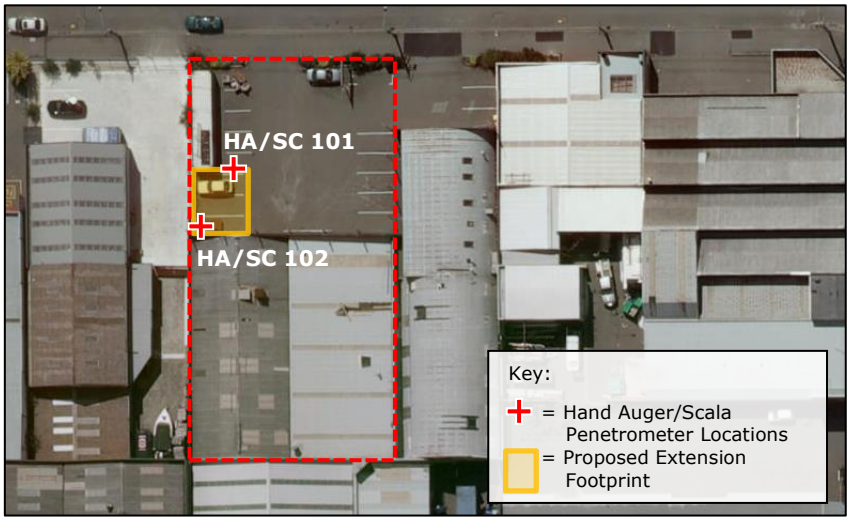

Figure 2: Intrusive Investigation and Extension Locations

Both HA's were drilled to the target depth of 3.2m below existing ground level (begl). SC 101 extended to its target depth of 3.9m begl and SC 102 extended to its target depth of 2.9m begl.

4.3 Ground Summary

Table 1 below is a summary of the ground profile encountered during EDC's HA's:

General Depth Range (begl)	Ground Description	Density/ Consistency	Water Content
Surface to 0.025m	Asphalt	-	-
0.025m to 0.40m/0.50m	FILL – Fine to coarse sandy gravel with occasional cobbles (hardfill)	Medium dense	-
0.4m to 0.65m/0.75m	FILL - Dark grey organic silt with occasional ash and fine sand	Soft to firm	Moist to wet

General Depth Range (begl)	Ground Description	Density/ Consistency	Water Content
0.65m to 2.50m	Light grey mottled orange clayey SILT	Firm to stiff	Moist to wet. Saturated from 1.8m/1.9m
2.50m to at least 3.20m	Bluish grey fine to medium sandy SILT	Firm	Saturated

Table 1: Summary of Ground Profile

Groundwater was encountered at 1.8m begl in HA 101, rising to 1.6m begl after one hour. Groundwater was encountered at 1.9m begl in HA 102.

A 150mm diameter plastic pipe was encountered at 0.9m depth in HA 102. Additionally, the natural soil below 1.0m at the location of HA 102 had a greenish colour and produced a slight hydrocarbon smell. It was not clear if the two changes in the soil are related.

A copy of the exploratory hole logs are attached in Appendix C.

4.4 Geotechnical Ultimate Bearing Capacity

The Scala Penetrometer results have been assessed for the approved bearing strata using a correlation between Scala blowcount and allowable bearing capacity by Stockwell, 1977. Using this correlation, the Scala Penetrometer results indicate that the Geotechnical Ultimate Bearing Capacities (UBC) shown in Table 2 can be assumed:

Soil Type	UBC (kPa)
Fill	150
Natural Silt (upper 3.0m)	300

Table 2: Available UBC

A copy of the Geotechnical UBC graph is attached in Appendix D.

5.0 CONCLUSIONS & RECOMMENDATIONS

No historical activities have been identified that are likely to present geotechnical constraints for the proposed extension.

It is understood that damage to the existing building from the earthquakes was light and limited.

A geotechnical report for the adjacent land to the north indicates estimated '*Free-Field*' index ground settlements of between 60mm and 90mm under 'worst case' SLS earthquake conditions and 90mm to 115mm under ULS earthquake conditions.

The risk of lateral spreading as a result of liquefaction is considered low and the risk of lateral stretch is considered to within the MBIE minor to moderate category (less than 200mm).

Notwithstanding the above, estimated Peak Ground Accelerations (PGA's) for the site, indicate that during the February 2011 event (greatest shaking at the site) the site was considered 'sufficiently tested' to a Serviceability Limit State (SLS) earthquake event. Following this event no liquefaction ejecta was evident on-site or on surrounding areas.

The liquefaction analysis for the adjacent site indicates that little settlement is anticipated in an SLS or ULS event in the upper 4.5m despite a groundwater of 0.5m being used in the analysis. Based on this and the lack of significant earthquake damage from the Canterbury Earthquake Sequence it is considered that shallow foundation types are suitable for the proposed lightweight building extension.

The GNS 'Depths to Water Table' maps indicate that the mean depth of groundwater is generally 0.0m – 2.0m bgl in the area of the site. The EDC HA's indicated groundwater to be at approximately 1.6m depth.

EDC's HA's encountered a consistent soil profile comprising: 25mm asphalt, hardfill to approximately 0.45m depth, fill comprising dark grey organic silt to approximately 0.7m depth, firm to stiff silt to at least 3.2m depth.

The Scala Penetrometer results indicate the following Geotechnical Ultimate Bearing Capacities (UBC) can be assumed:

Soil Type	UBC (kPa)
Fill	150
Natural Silt (upper 3.0m)	300

The Christchurch City Council (CCC) has indicated that the site is located within a District Plan Flood Management Area (FMA) and therefore a Finished Floor Level (FFL) of 14.39m RL is required for new building at the site. LiDAR information indicates that the average ground level at the site is 13.82m RL, approximately 0.6m below the required FFL.

6.0 RECOMMENDATIONS

Based on the CCC floor level requirements to mitigate flood risk it is recommended that an assessment of the design implications for the extension is undertaken by the architect and structural engineer for the project.

It is understood that the preferred foundation for the proposed extension is a slab on grade. This is considered a suitable foundation type. The proposed extension is understood to be light weight (distributed load of less than 15kPa). The fill encountered on the site is hardfill to 0.5m over 0.25m thick organic silt fill. Settlement of the topsoil is considered unlikely to be significant (<10mm) if the foundation loads were above the organic fill. In view of this it is considered that the slab foundation can found above the organic fill, on the basis that the assumed distributed load of <15kPa is correct. A UBC of 150kPa should be assumed for design. A 300mm thick layer of compacted AP65 should be placed beneath the concrete slab. A layer of geotextile (Bidim A19 or equal) should be placed on the base and sides of the excavation. A layer of geogrid (Cirtex Duragrid 30/30 or equal) should be placed over the geotextile.

The foundation should be designed by a Chartered Professional Engineer.

The gravel hardfill should extend laterally a distance beyond the building footprint that is equal to the depth of gravel. Over excavation will not be possible along the southern and western sides of the excavation due to the site boundary and the existing building. As such, a Chartered Structural Engineer should design the new section of slab to suitably tie into the existing slab and cantilever along the western side.

It is recommended that services (particularly drainage) are not located below the new foundation. All services in the area of the new foundation should therefore be identified (such as the pipe identified at HA 102) and re-aligned (if required) as part of the final design.

It is not likely that dewatering of the excavation will be required.

Advice from a suitably qualified Geotechnical Engineer should be sought if ground conditions different to those encountered in the intrusive investigation are observed during foundation construction works.

Any filling work should be undertaken in accordance with NZS 4431:1989 Code of Practice for Earthfill for Residential Development and MBIE Module 5A: Specification of ground improvement for residential properties in the Canterbury region (MBIE & NZGS, 2015). Validation testing of the compacted gravel should be undertaken and signed off by a suitably experienced Geotechnical Engineer.

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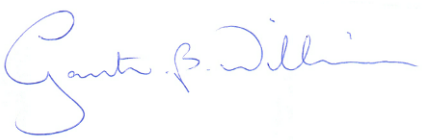

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LIMITATIONS

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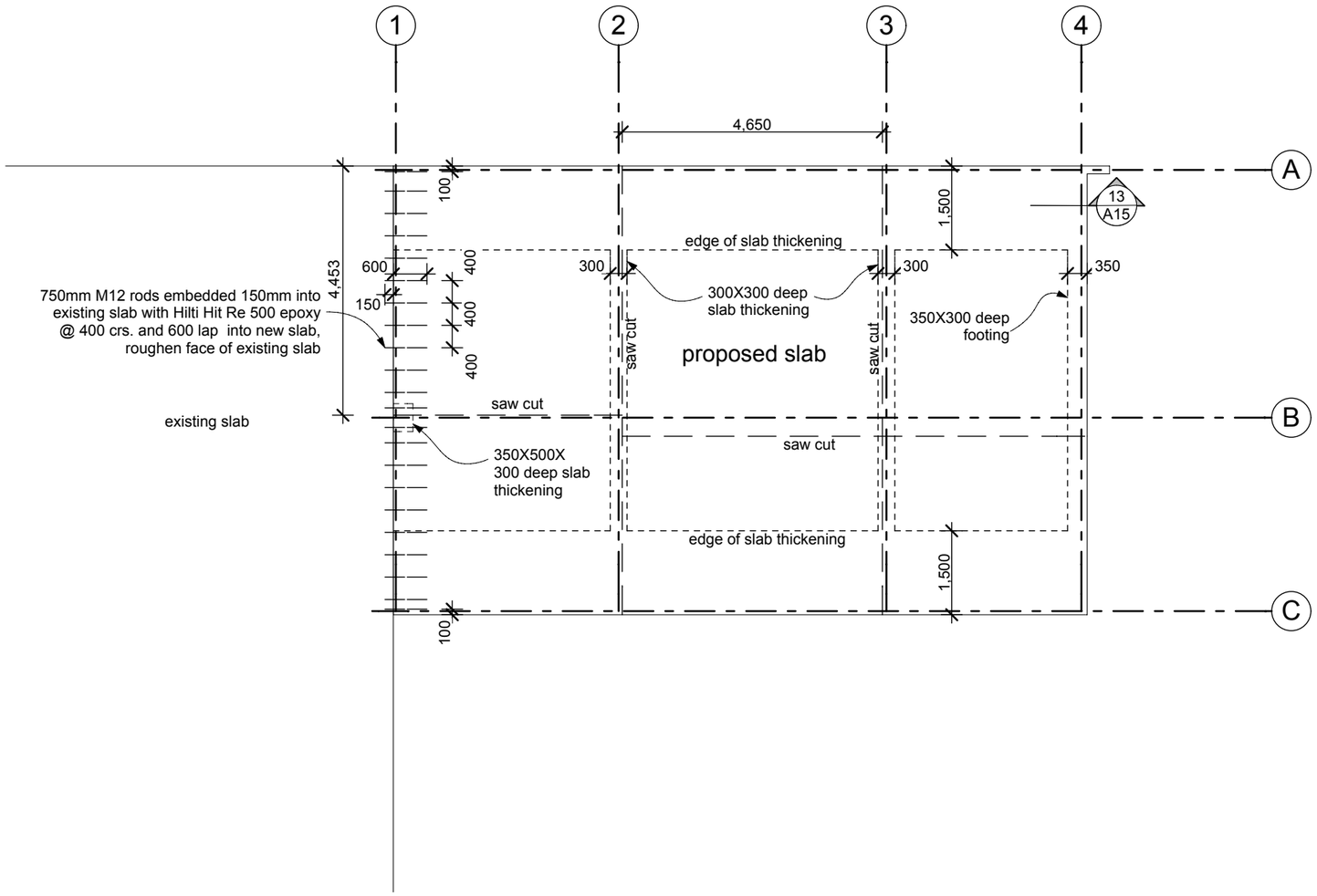
The recommendations and opinions contained in this letter are based on our visual reconnaissance of the site, information from geological maps and upon data from the field investigation as well as the results of in situ testing of soil. Inferences are made about the nature and continuity of subsoils away from and beyond the exploratory holes which cannot be guaranteed. The descriptions detailed on the exploratory hole logs are based on the field descriptions of the soils encountered.

Appendices:
Appendix A – Proposed Extension Drawing Set by Architectural Design Group (ADG) Ltd (Ref: 5996)
Appendix B – Environment Canterbury Listed Land Use Register
Appendix C – Exploratory Hole Logs
Appendix D – Geotechnical Ultimate Bearing Capacity Graph

Appendices should be read in conjunction with letter and this letter should not be considered complete without them.

APPENDIX A

Proposed Extension Drawing Set by Architectural Design Group (ADG) Ltd (Ref: 5996)



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Proposed Additions
80 Byron Street
Christchurch
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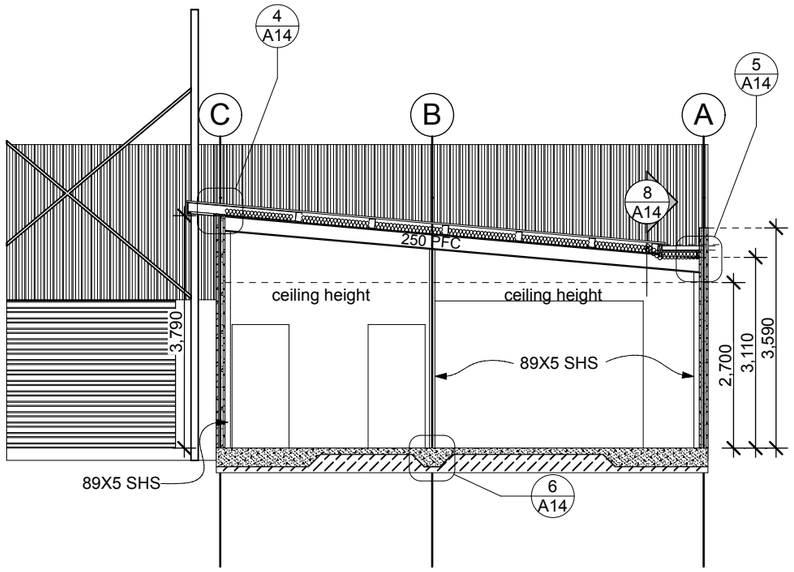
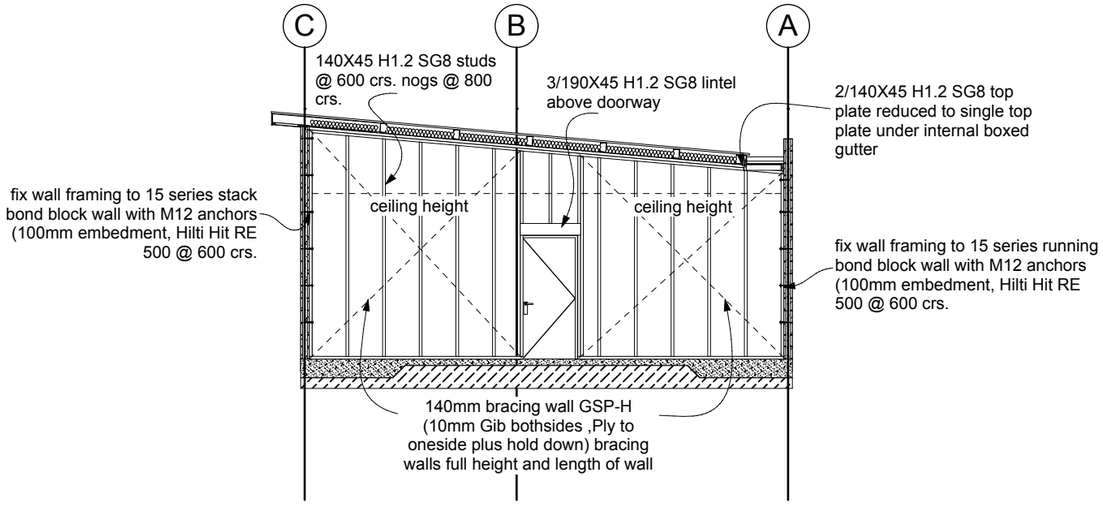
Drawing:	Foundation Plan
Scale at A3:	1:100
Date:	January 2017
Job no:	5996

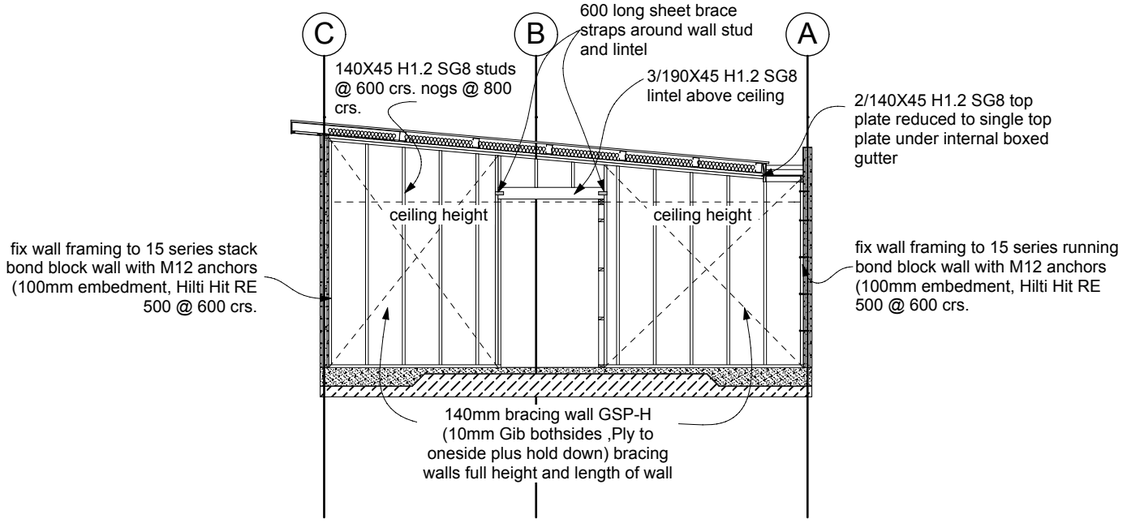
Issue: 1
Sheet no.
A9
of sheets



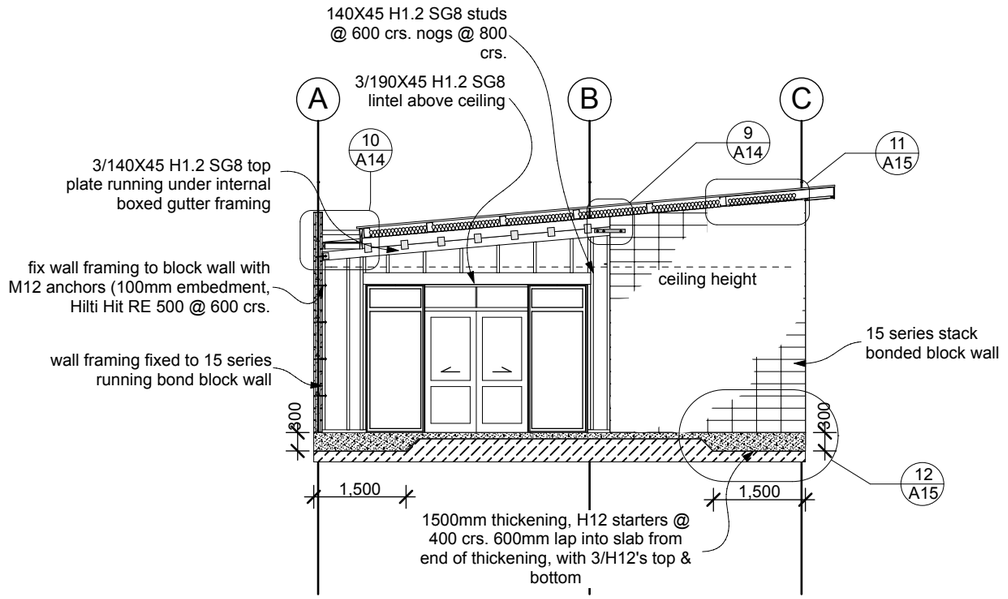
Gridline 1 Cross Section



Gridline 2 Cross Section



Gridline 3 Cross Section



Gridline 4 Cross Section

NOTE:
15 series block walls on grids A & C

- H12's @ 400 crs. verticals
- D16's @ 200 crs. horizontal in 3 courses by roof connection.
- H12's @ 400 crs. horizontal rest of wall.

wall framing to NZS 3604:2011

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Drawing:	Gridline Cross Sections
Scale at A3:	1:100
Date:	January 2017
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Issue: 1
Sheet no.
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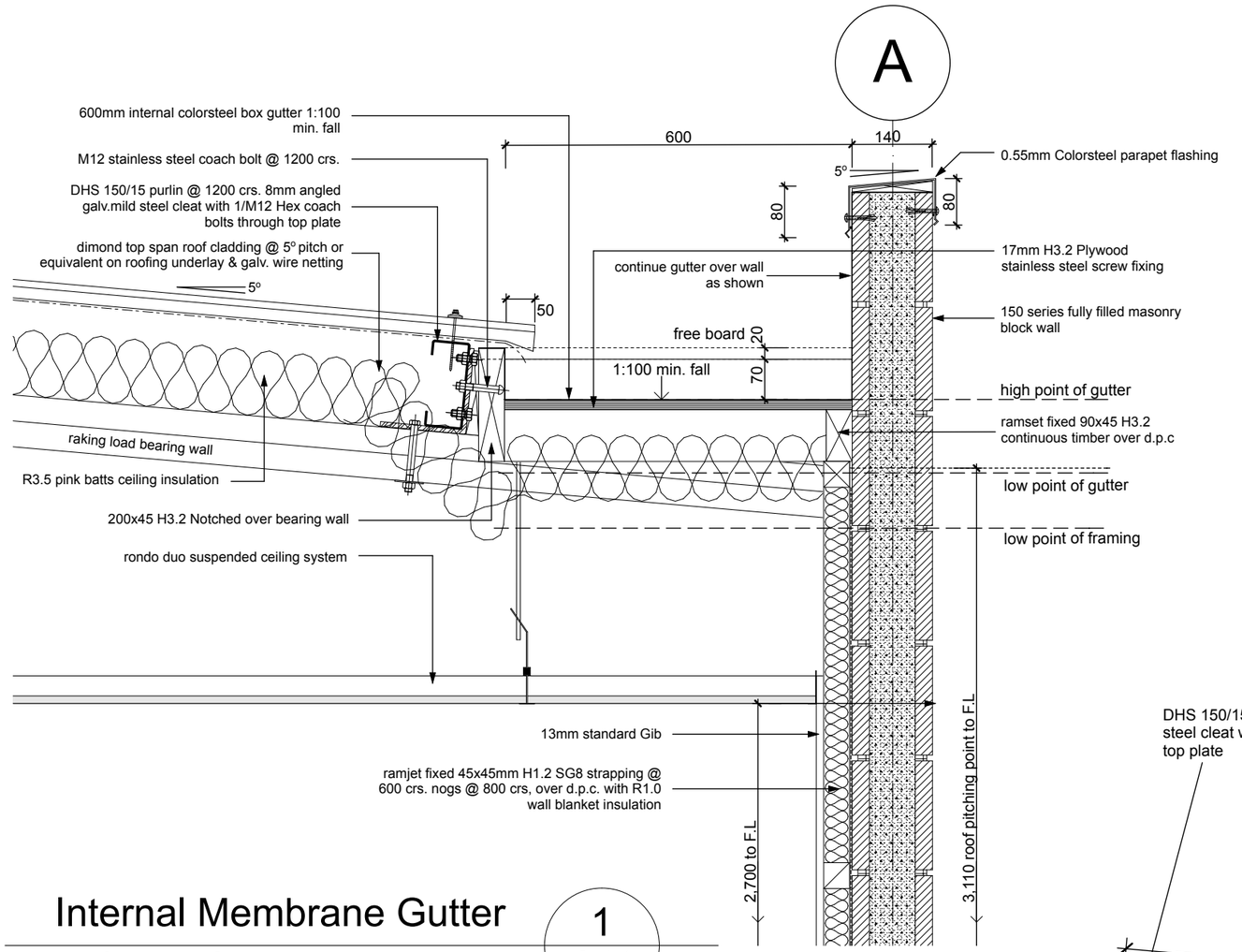
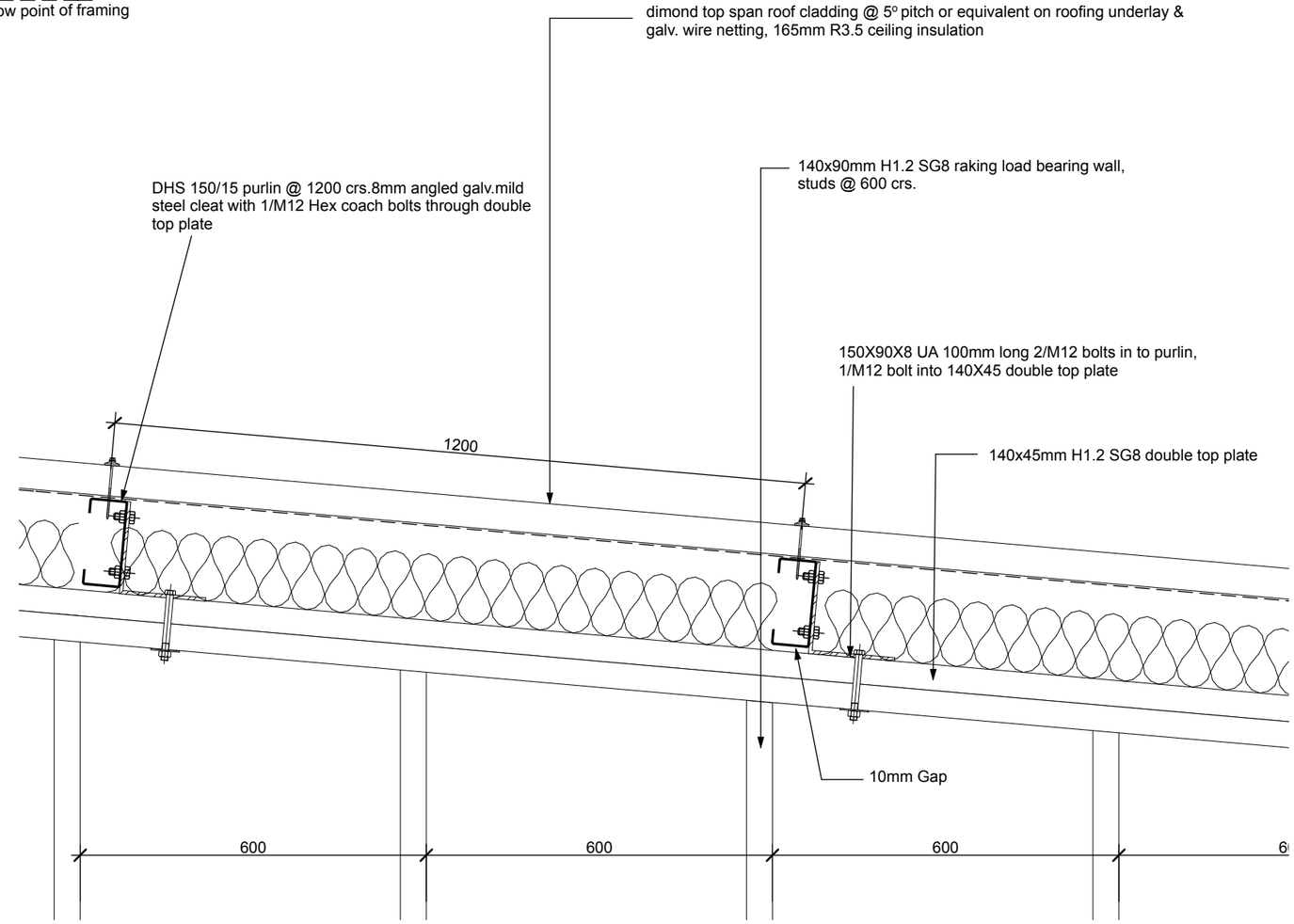


Internal Membrane Gutter Cross Sectional Detail

1
A11



150 DHS Purlin Connection Cross Sectional Detail

2
A11

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Scale at A3:	1:10
Date:	January 2017
Job no:	5996

Issue: 1
Sheet no.
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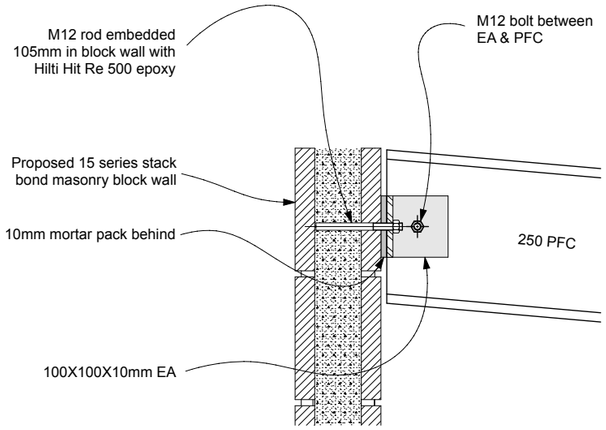
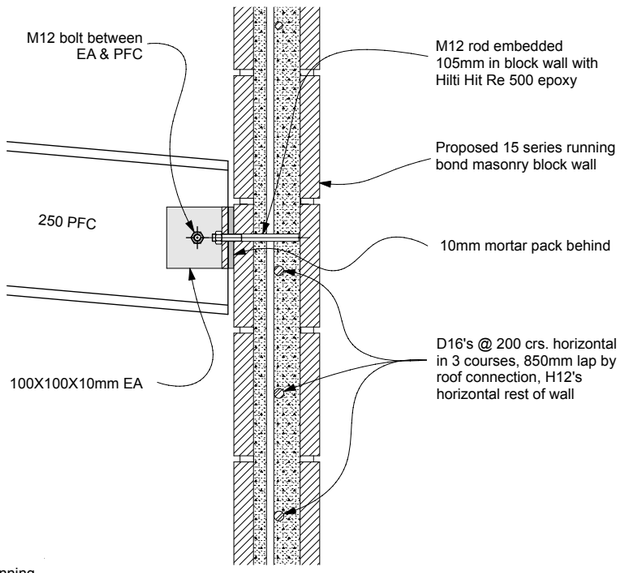
of sheets



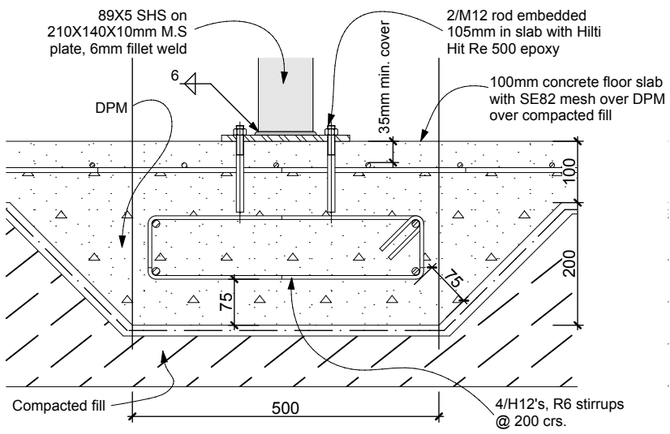
Grids 1 & C PFC To Block Connection

Cross Sectional Detail — 4 / A12



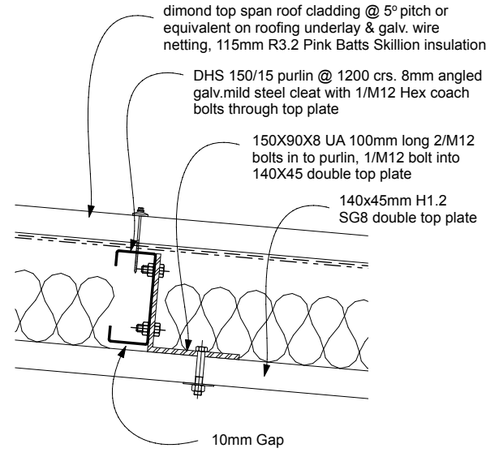
Grids 1 & A PFC To Block Connection

Cross Sectional Detail — 5 / A12



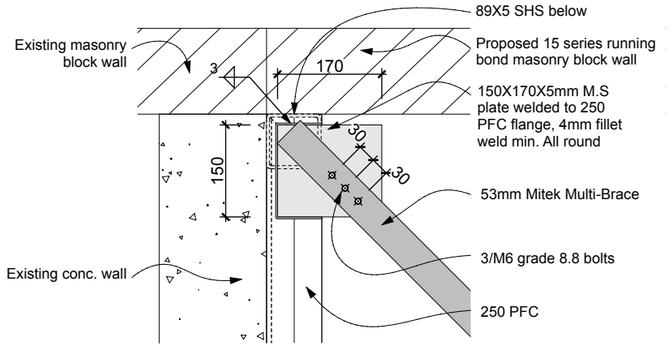
Grids 1 & B Slab Thickening

Cross Sectional Detail — 6 / A12



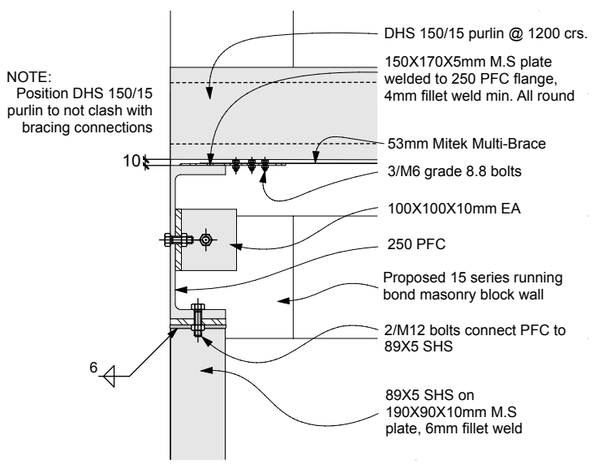
Typical Purlin Cleat

Cross Sectional Detail — 3 / A11



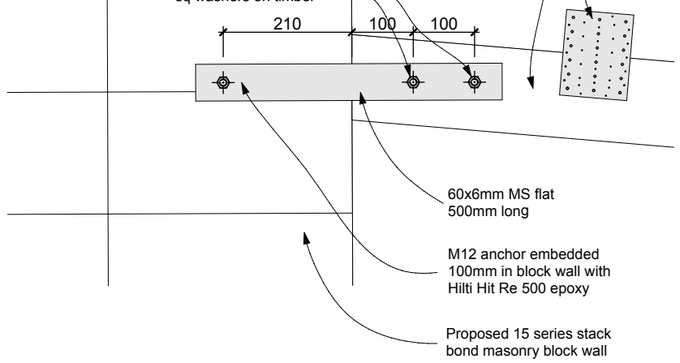
Grids 1 Roof Brace To PFC Connection

Plan Detail — 7 / A17



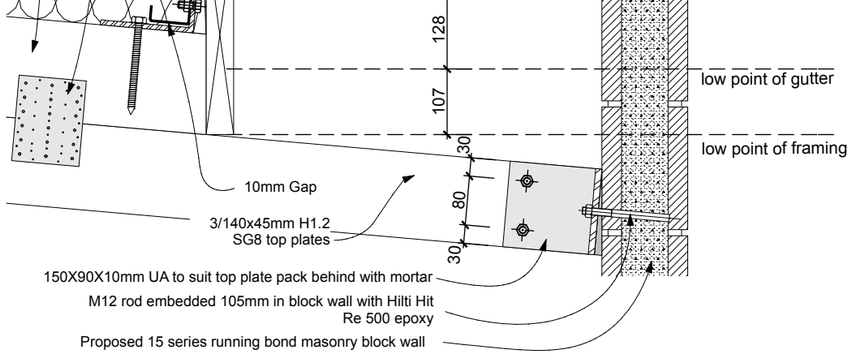
Grids 1 Roof Brace To PFC Connection

Section Detail — 8 / A12



Grids 4 Wall Tie Connection

Section Detail — 9 / A12



Grids 4 Wall Tie Connection

Section Detail — 10 / A12

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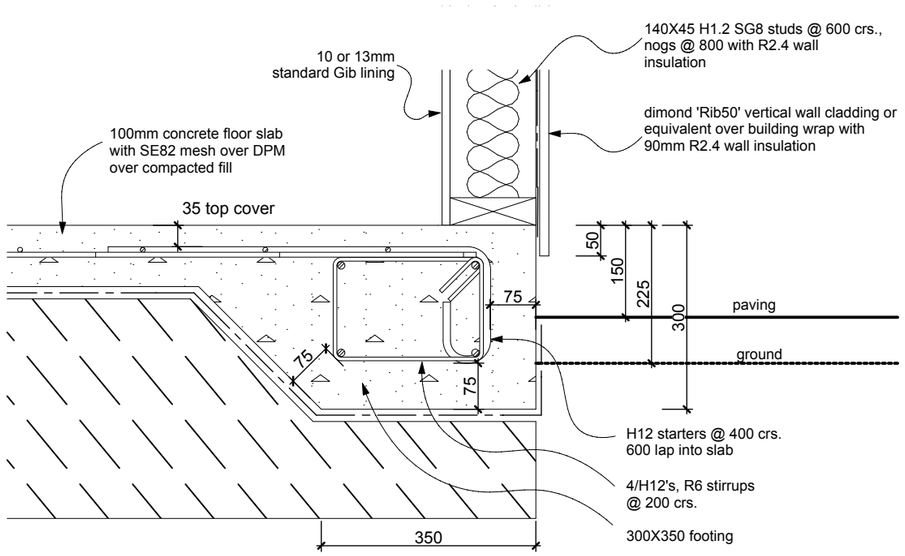
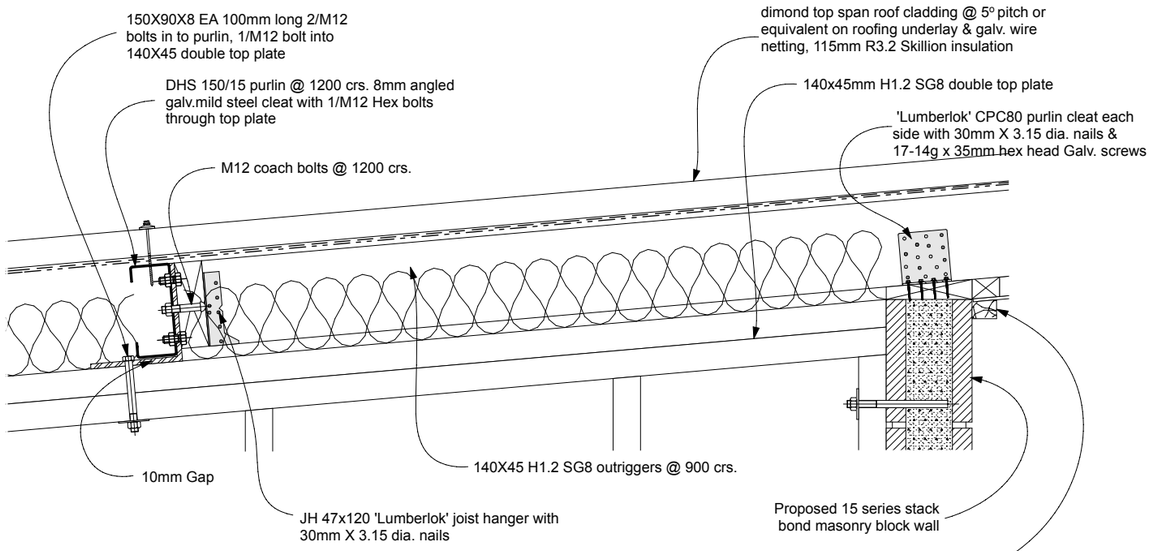
Drawing:	Architectural Details
Scale at A3:	1:10
Date:	January 2017
Job no:	5996

Issue: 1
Sheet no. A14
of sheets



Grid 4 Slab Foundation
Section Detail

13
A9



Grid C Outrigger connections
Section Detail

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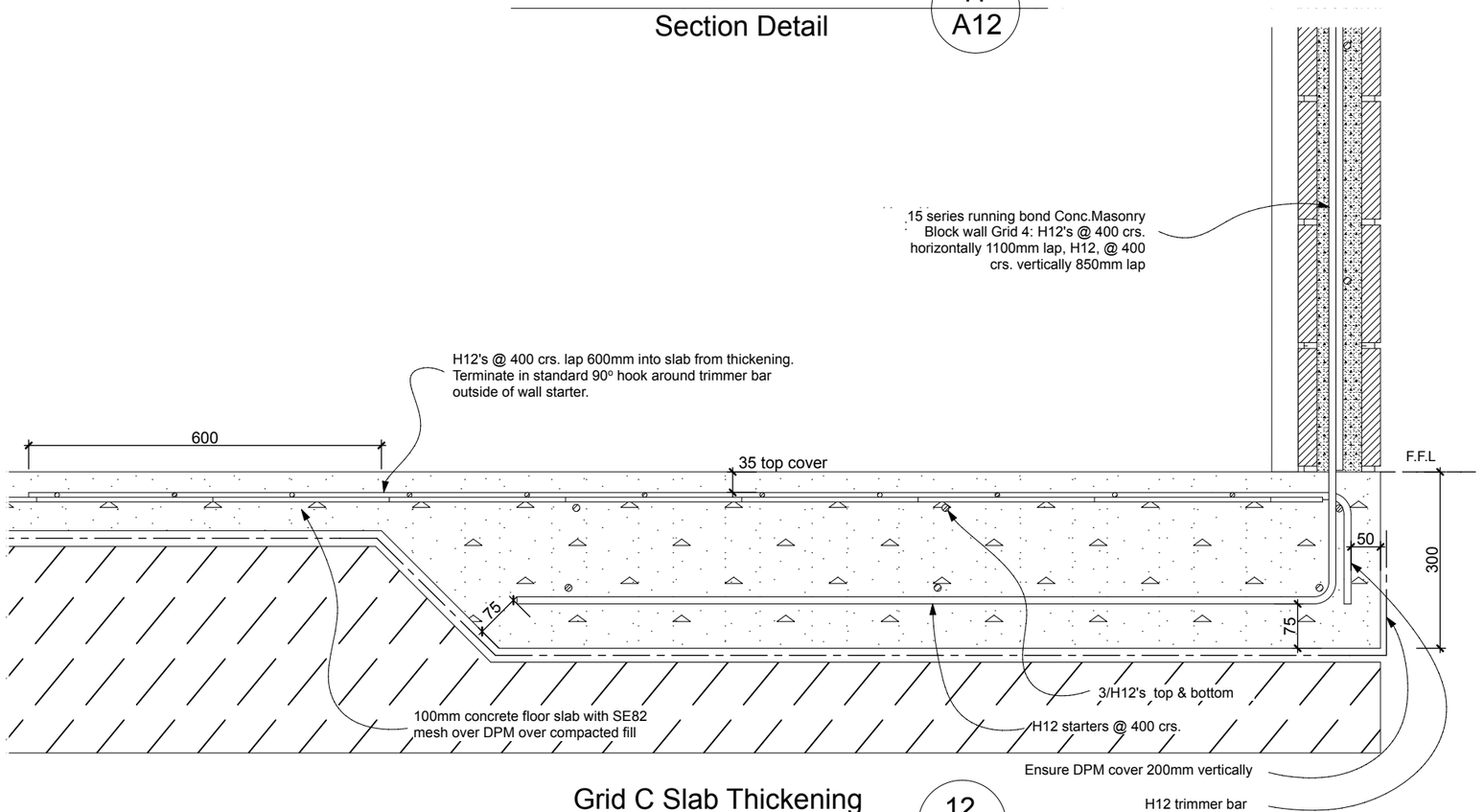
A12



Grid C Slab Thickening
Section Detail

12
A12

Architectural Design Group
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Drawing:	Architectural Details
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Issue: 1
Sheet no.
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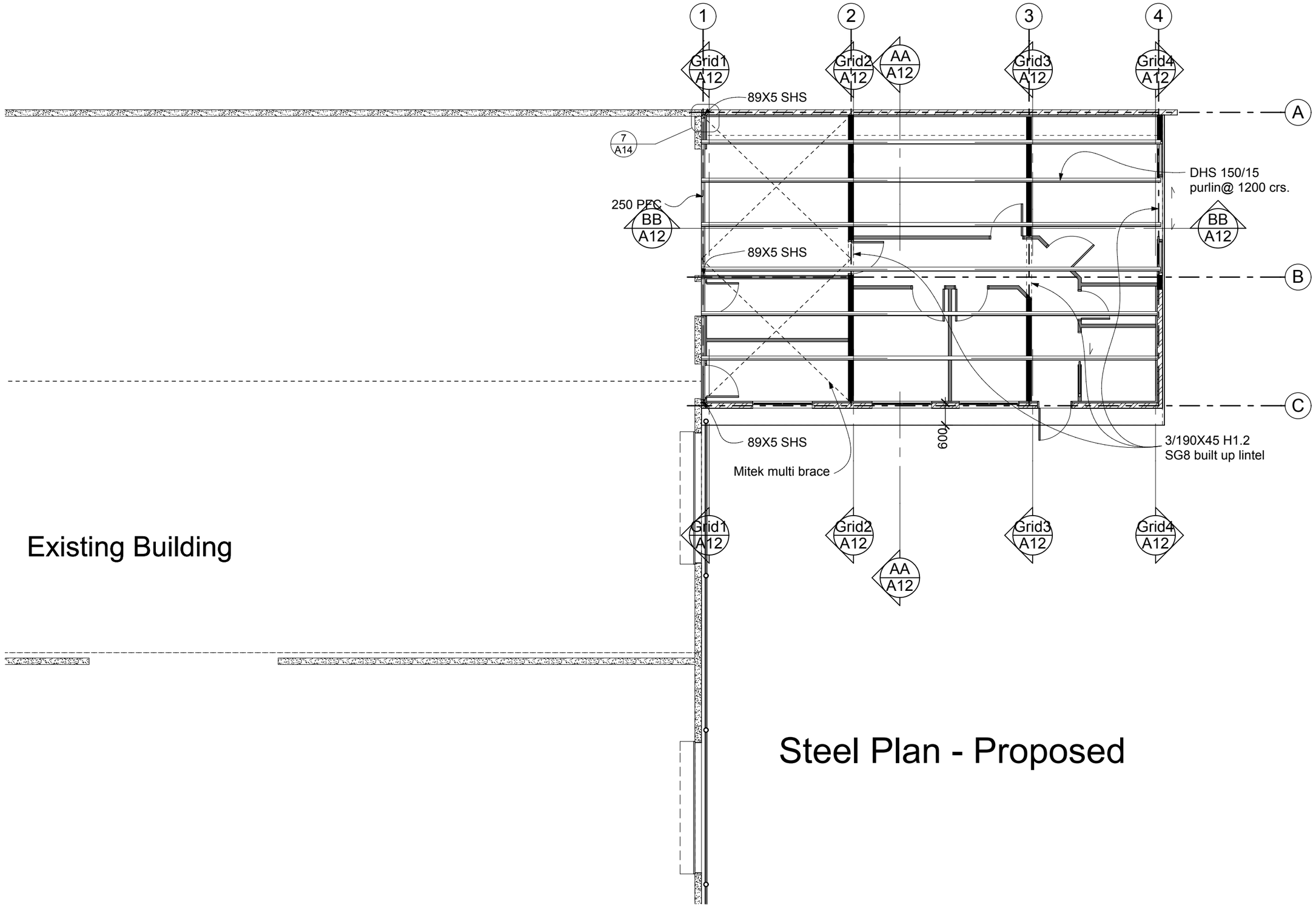
of sheets



Steel Plan - Proposed

Architectural Design Group
A DIVISION OF WALKER COMMERCIAL SERVICES LTD
ADG
t/f 07 578 2899
e adg_architecture@xtra.co.nz
p PO Box 70131 Fraser Cove
Tauranga 3155
office 31 Fifteen Ave , Tauranga

Proposed Additions
80 Byron Street
Christchurch
For Clip & Climb

Drawing:	Steel Work Setout Plan
Scale at A3:	1:100
Date:	January 2017
Job no:	5996

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Sheet no.
A17
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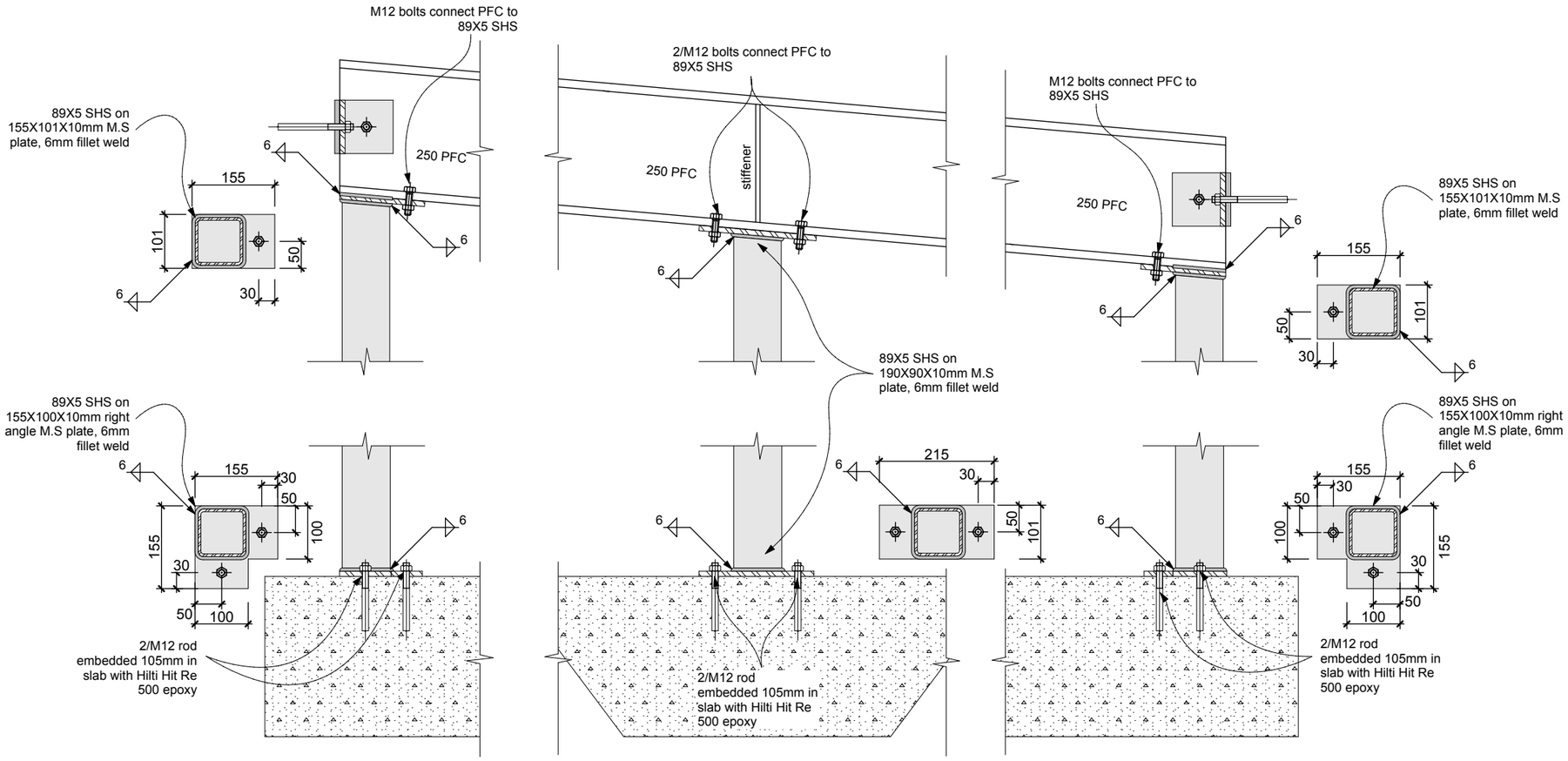

Gridline 1 Steel Details

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For Clip & Climb

Drawing:	Grid 1 Steel Details
Scale at A3:	1:10
Date:	January 2017
Job no:	5996

Issue: 1
Sheet no.
A18
of sheets

APPENDIX B

Environment Canterbury Listed Land Use Register

ENGCO
Consulting Engineers

GEOTECHNICAL REPORT FOR PROPOSED COMMERCIAL BUILDING

83 BYRON ST, SYDENHAM, CHRISTCHURCH

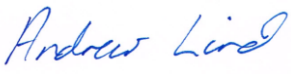
Project Reference No: 16363

Prepared for: Spaghetti Junction Ltd

Date: 11/11/2016

Office: 03 366 7955 Email: office@engco.co.nz www.engco.co.nz Heathcote House, Level 1, 596 Ferry Road, Woolston, Christchurch 8023

Project Summary				
Report Title		Geotechnical Report		
ENGCO Project No		16363		
Client		Spaghetti Junction Ltd		
Rev	**Date**	**Details**	**Prepared by**	**Approver**
0	25/11/2016	Draft for review	Ragulan Kanapathippillai	
1	30.01.2017	For Consent	Ragulan Kanapathippillai	AL

Approval			
Action	**Name**	**Title**	**Signature**
Prepared by	Ragulan Kanapathippillai	Geotechnical Engineer	
Reviewed by	Dave Brierley	Technical Director CPEng No 225268	
Authorised by	Andrew Lind	Director CPEng No. 1019507	

Contents

1 INTRODUCTION

The Engineering Company Limited (ENGCO) was requested by Spaghetti Junction Ltd, to undertake a geotechnical assessment for the proposed warehouse building with offices at 83 Byron Street, Sydenham, Christchurch. Refer to Figure 1 for a plan of the proposed development area. This report evaluates the surface and subsurface conditions of the site and provides preliminary geotechnical recommendations for the proposed building foundations, with reference to Ministry of Business, Innovation and Employment (MBIE) Guidance, and building codes, as appropriate.

Our scope of works included the following:

- Desktop study of relevant, publicly available geotechnical and geological publications;
- Organizing deep geotechnical investigation, comprising Piezocone Penetration Tests (CPTu), Dynamic Cone Penetrometers (DCP) and Hand Augers (HA);
- An assessment of liquefaction potential for the site;
- Preparation of this report, outlining our findings on the ground conditions and including geotechnical advice on foundation conditions and ground remediation if necessary;
- Preliminary foundation recommendations for the proposed warehouse building;

2 SITE DETAILS

2.1 Site description

The site 83 Byron Street, Sydenham is located approximately 1.5k southeast of Christchurch city centre. The vacant site is surrounded by commercial buildings. At the time of our investigation, the site was cleared, the contour was generally flat and the site was occupied by a number of containers.

2.2 MBIE land zoning

The site is classified as a non-residential site and the current liquefaction severity land classification for this site, according to Canterbury Earthquake Recovery Authority (CERA) maps, is "**N/A-Urban Non-Residential".** A plan of the site location is provided in Figure 2.

2.3 Regional Geology and Seismicity

The geological map of the area indicates that the site has surface geology consisting of *"Dominantly alluvial sand and silt overbank deposits*".

2.4 Flood hazard

Ground levels have changed across Christchurch as a result of the Canterbury earthquake sequence. Minimum floor elevation requirements for any rebuild at the site should be confirmed with the Christchurch City

Council to inform the design and construction processes. At the time of writing this report, there was no publically available information regarding the final floor level for the commercial building development proposed.

2.5 Hazardous Activities and Industries List

The ECAN contaminated land registry indicates that the site contained an underground storage tank which was removed in 2011. It should be noted that contaminated land assessment is outside the scope of this report.

2.6 Liquefaction and Lateral Spreading

2.6.1 Observed performance

A site walkover was performed by ENGCO on 31st October 2016. During the inspection, there was no evidence of any earthquake-induced land deformation remaining onsite. A summary of our desktop assessment and site walkover is provided below;

The "EQC Liquefaction Interpreted from Aerial Photography" map layers indicate that the property is located within an area where moderate to severe liquefaction was observed, following the June 2011 earthquake, and minor liquefaction was observed following the December 2011 earthquake. No liquefaction was observed following the September 2010 or February 2011 Earthquake.

The "EQC Liquefaction and Lateral Spreading Observations" map indicates no ground cracking or ejected liquefied material were reported at the site, following the February 2011 earthquake event. The road observation indicates no ejected liquefied material observed, after the June 2011 earthquake.

The "EQC Observed Ground Crack Locations" map indicates there were no ground cracks observed near the site, following the February 2011 earthquake.

3 FIELDWORK SUMMARY

3.1 Site Investigation

On behalf of ENGCO, Land Test Ltd carried out two Piezocone Penetration Tests (CPTu), four Dynamic Cone Penetrometer Tests (DCPs) and two Hand Augur Tests (HAs) on 31st October 2016. In addition, another CPT test was carried out on 15th November 2016. These deep investigations were carried out under the supervision of ENGCO's Engineer. The results of both deep and shallow investigations are summarized in Table 1.

Table 1: Location and Depth of Investigations

Test No	Investigations Type	Depth (m)
1	Piezocone Penetration Tests (CPTu 1)	15m bgl
2	Piezocone Penetration Tests (CPTu 2)	15m bgl
3	Dynamic Cone Penetrometer (DCP1& HA1)	2.0m bgl
4	Dynamic Cone Penetrometer (DCP2 & HA2)	2.0m bgl
5	Dynamic Cone Penetrometer (DCP3)	2.0m bgl
6	Dynamic Cone Penetrometer (DCP4)	2.0m bgl

The locations of the DCP, HA and CPTu tests are shown on Figure 3, and the results are attached in Appendix 2.

3.2 Shallow Ground Condition

The shallow ground conditions encountered during the investigation have been interpreted from the HAs and DCPs. The subsurface conditions encountered are considered to be generally consistent with published geological information.

The inferred shallow ground condition from specific Hand Augers (HA) are provided in Table 2.

Table 2: Inferred soil profile from Test Pits

HA1	HA2	Summary of Soil Type
0 to 0.3m bgl	0 to 0.3m bgl	Sandy GRAVEL (FILL)
0.3 to 2.0m bgl	0.3 to 2.0m bgl	Clayey SILT

3.3 Groundwater Regime

Groundwater was not encountered during the shallow investigation at this site, in October 2016. The GNS ground water elevation model indicates that the water table may vary between 0.0m and 1.0m bgl at this site. It should be noted that the ground water level may vary, seasonally.

For liquefaction analysis purposes, an in-situ groundwater depth of 2.0m bgl and a design groundwater level of 0.5m bgl were adopted.

3.4 Site subsoil class

In accordance with NZS1170.5, Section 3.1.3, site subsoil classification "*Class D – Deep or soft soil* sites" may be assumed for this site.

3.6 Deep Ground Condition

Based on the existing geotechnical information, the site-specific geotechnical investigation undertaken by ENGCO and the review of published information, the following ground model for the site has been inferred, as outlined in Table 3.

Table 3: Inferred geological model

Soil Layer	Depth range(m bgl)	Soil Description
Layer 1	0.0 to 6.0	Clay & silty clay
Layer 2	0.6 to 16.5	Sand & silty sand
Layer 3	16.5 to 24.5	Clay & silty clay, Silty sand & sandy silt
Layer 4	24.5 to 24.7	Silty sand & sandy silt, Gravel

4 EARTHQUAKE- INDUCED GROUND DEFORMATION

4.1 Predicted vertical deformation

Assessment of earthquake-induced ground deformation at the site has been carried out in accordance with MBIE Guidance, using proprietary liquefaction assessment software. The derivation of the procedures has been based on a conservative approach to give estimates of deformation that may be experienced in the earthquake scenarios at a free-field site, i.e. one with no building present, and not subject to lateral spreading. The results of this analysis are summarized in Table 4.

Table 4: Estimated Total "Free-Field "Ground Surface Settlement from CPT and BH results

Earthquake Scenario	Moment Magnitude (Mw)	Peak Ground Acceleration(PGA,(m/s^2))	Settlement to tested depth (mm)	MBIE "Index Value"(settlement in Upper 10m) (mm)
SLS1	7.5	0.13	65 - 90	55 - 80
SLS2	6.0	0.19	75 - 100	60 - 90
ULS	7.5	0.35	155 - 165	90 - 115

The liquefaction assessment results are provided in Appendix 2.

The analysis results indicates that a non-liquefiable soil layer is located between 3.0m bgl and 7.0m bgl, under ULS conditions.

4.2 Assessed lateral deformation

Following the procedure outlined in Section 12.2 of the MBIE Guidance, an assessment of the global lateral movement of the site and lateral stretch across the site has been undertaken and the results are outlined in Table 5.

Table 5: Assessed lateral deformation at the site

Assessed global lateral movement category of the site	Minor to moderate (less than 300mm)
Assessed lateral stretch category of the site	Minor to moderate (less than 200mm)

Based on the Canterbury Geotechnical database (CGD) horizontal ground movement data, the site is categorized as being subject to minor to moderate global lateral movement. Site observations and subsequent analyses show that the site has been 'sufficiently tested at SLS' to a significant degree, and that a minor global lateral movement category is appropriate for this site.

We consider the risk of lateral spreading, as a result of liquefaction at this site, to be low, as there are no major cracks due to earthquake events (based on desktop studies). We consider that the risk of lateral stretch is in the minor to moderate category as there were no significant ground cracks identified at the site.

5 FOUNDATION RECOMMENDATION FOR THE DEVELOPMENT

5.1 Design considerations

At the time of preparation of this report, the anticipated foundation loads from the proposed structures were not known to ENGCO, but have been assumed to be based on a single level, heavyweight warehouse building. Due to the liquefaction risk at this site, conventional shallow foundations are not recommended.

A specifically designed, piled foundations is a viable solution for the proposed building. The piles would need to be founded at a depth of 12.5m bgl. It should be noted that pile driving operations can cause vibration to adjacent buildings and suitable pile installation methods should be considered for the pile driving, including the potential use of screw piles. The piled foundation solution would require minimal excavation, as the structural loads would be transferred through the piles. It should be noted that the soil layer between 12m and 16m bgl has sufficient bearing capacity (>15MPa) and thickness, to resist superstructure loads, under SLS earthquake conditions.

The design of the building structure and foundations must be carried out to ensure that, as a minimum, SLS and ULS Building Code performance requirement are fulfilled (e.g. low probability of causing loss of amenity through undue deformation, for SLS events, and low probability of rupturing, becoming unstable, losing equilibrium or collapsing, for ULS events).

6. Construction Observation

6.1 Pavement Areas

It is generally advisable that any un-engineered fill or unsuitable material be removed from under any pavement areas, prior to construction, and replaced with compacted granular fill. However, based upon our assessment, the density of existing soils may be adequate for the support of access ways.

6.2 Underground Services

Flexible connections should be constructed where all service drains and ducts enter/exit the concrete floor slabs. Service trench backfill within 1.5m of the buildings is to comprise well graded crushed stone aggregate (i.e. CAP 20), compacted from the surface only.

6.3 Storm water

Concentrated storm water flows from all impermeable areas must be collected and carried in sealed pipes to the Council system. Uncontrolled storm water flows must not be allowed to run onto or saturate the ground so as to adversely affect foundation performance, both statically and during future seismic activity (liquefaction potential and liquefaction induced settlement are both increased with a higher groundwater table, resulting from uncontrolled disposal of storm water).

7 Limitations and Restrictions on Building Consents

7.1 Construction of building on land subject to natural hazards

In terms of Section 71 of the Building Act 2004, Christchurch City Council has an obligation to consider the following matters, and to refuse consent unless satisfied that measures have been or will be taken to remedy identified hazards:

- Erosion, including surface and subsurface erosion, associated with water and wind;
- Falling debris, including rockfall that could impact the site from upslope sources;
- Subsidence, which involves the removal of underlying support by natural or artificial means;
- Slippage, which is defined as the downslope transfer of materials by sliding and/or flowage;
- Inundation, including flooding, overland flow, storm surge, tidal effects, and ponding.

Provided adequate stormwater drainage is in place, erosion is not considered an issue at this site.
As the site is situated on the flat, falling debris is not an issue. Due to the moderate to high potential for soils to liquefy at ULS levels of seismic shaking beneath the site, minor to moderate subsidence could occur during an earthquake event. Provided a foundation system per the recommendations of this report (Section 5.0) is constructed, we consider the proposed foundation system will comply with MBIE industrial building guidance performance criteria. There are no other potential subsidence and/or settlement processes that could

adversely affect the foundation system. The site is far removed from any free edge or major waterway. In terms of slippage, lateral movement is considered to be consistent with the minor category during a ULS seismic event. ENGCO is satisfied that there are no geotechnical issues pertaining to Section 71 of the Building Act 2004 that cannot be addressed by appropriate foundation design and drainage on the site.

8 REFERENCES

1) Ministry of Business, Innovation and Employment (MBIE) 2012. Repairing and rebuilding houses affected by the Canterbury earthquakes. Ministry of Business, Innovation and Employment. Available from: http://www.building.govt.nz/guidance-on-repairs-after-earthquake.

2) Ministry of Business, Innovation and Employment (MBIE) 2014. Clarifications and updates to the Guidance 'Repairing and rebuilding houses affected by the Canterbury earthquakes'. Issue 7.

3) Forsyth, P.J.; Barrell, D.J.A; Jongens, R. 2008: Sheet 16 - Geology of the Christchurch Area 1:250,000. Institute of Geological and Nuclear Sciences, Lower Hutt.

4) http://llur.ecan.govt.nz

5) Canterbury Geotechnical Database. EQC Liquefaction Interpreted from Aerial Photography. Map layer CGD0200 – 11 Feb 2013

6) Canterbury Geotechnical Database. EQC Liquefaction and Lateral Spreading Observations. Map layer CGD0300 – 11 Feb 2013

7) Canterbury Geotechnical Database. EQC Observed Ground Crack Locations. Map layer CGD0400 – 23 Jul 2012

8) van Ballegooy, S., Wentz, F. J. & Boulanger, R. W. 2015c. Evaluation of a CPT-based liquefaction procedure at regional scale. Soil Dynamics and Earthquake Engineering, Special Issue: Liquefaction in New Zealand and Japan

9) Boulanger, R. W. & Idriss, I. M. 2014. CPT and SPT based liquefaction triggering procedures. (Report No. UCD/CGM-14/01). Center for Geotechnical Modelling, Department of Civil and Environmental Engineering, University of California, Davis, CA

10) Robertson and Wride, 1998. Evaluating cyclic liquefaction potential using the cone penetration test. Canadian Geotechnical Journal, Vol. 35, pp. 442 – 459

11) Zhang, G., Robertson, P. K., & Brachman, R. W. I. (2002). Estimating liquefaction induced ground

settlements from CPT for level ground, Canadian Geotechnical Journal, 39, 1168–80

12) Ministry of Business, Innovation and Employment (MBIE) 2015. Repairing and rebuilding houses affected by the Canterbury earthquakes - Section 15.3 Updated guidance on site ground improvement, Christchurch.

9 LIMITATIONS

9.1 General

This report, prepared by ENGCO, at the request of our Client, is exclusively for our Client's use, is not to be relied upon by any other person, and is strictly limited to the matters herein.

No responsibility or liability to any third party is accepted for any loss or damages whatsoever arising out of the use of or reliance on this report by any third party, outside of our Client. Nor may the report be used for any other property than the one specified.

The report and its contents are not to be quoted or published without ENGCO's consent.

9.2 Geotechnical

The conclusions of the report are based on the interpretation of a limited number of tests at specific locations, and information gathered from nearby sites and other sources. It shall not be relied upon for any other purpose. The reliance by other parties on the information or opinions contained in this report shall, without our prior review and agreement in writing, be at such parties' sole risk. ENGCO will not accept liability for global stability issues on this site where investigation on a single lot could not reasonably assess the global stability issues.

During excavation and construction, the site should be examined by a Geotechnical Engineer to judge whether the exposed subsoils are compatible with the inferred conditions. It is possible that the nature of the exposed subsoils may require further investigation and the modification of the design based on this report. In any event, it is essential that ENGCO is notified if there is any variation in subsoil conditions from those described in the report, as it may affect the design parameters recommended in the report. There is no investigation, which is thorough enough to preclude the presence of materials at the site, which presently, or in the future, may be considered hazardous.

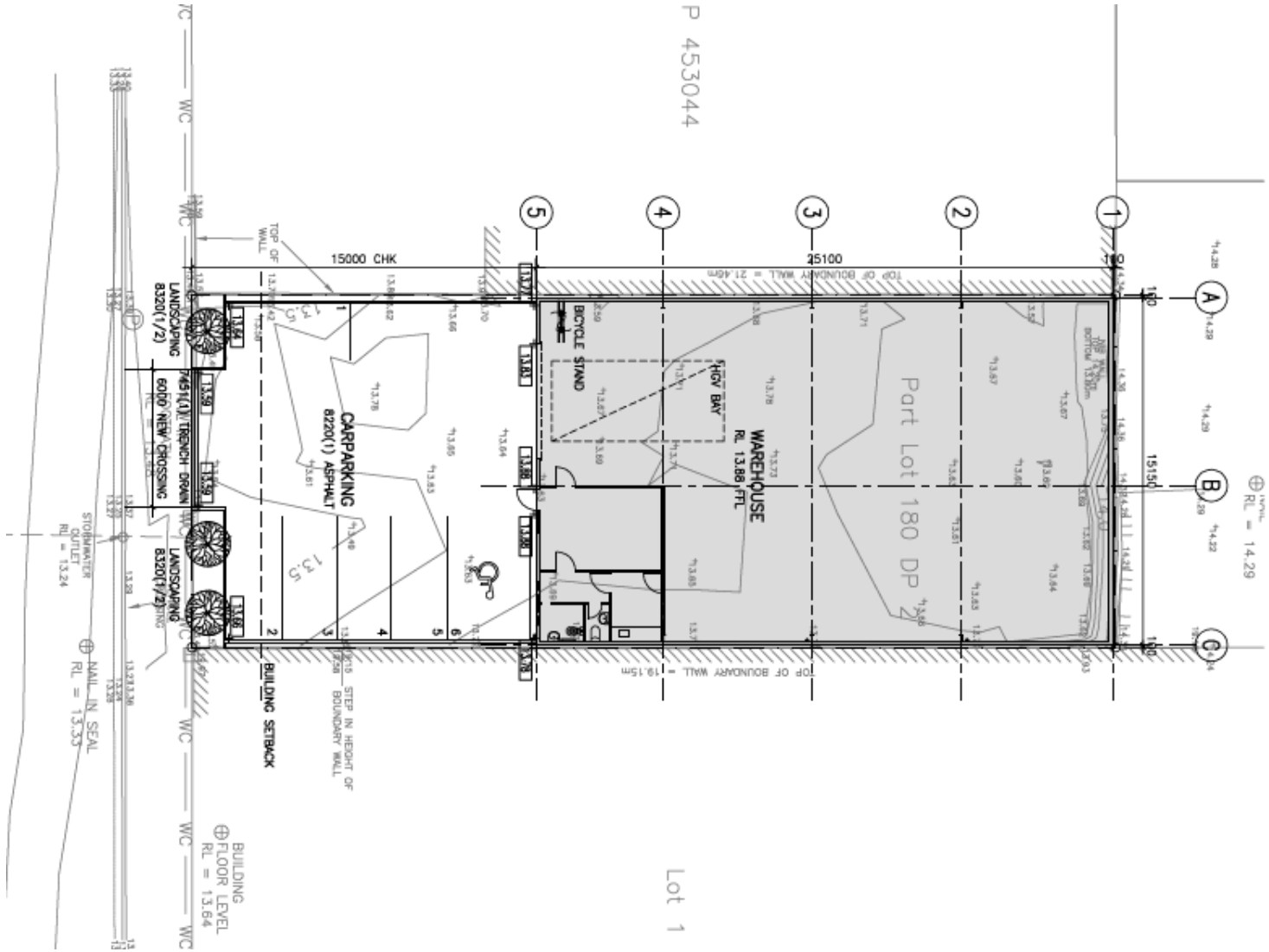
Should you require any further information, please contact the ENGCO office on 03 366 7955

Appendix 1

Figure 1- Site location plan

Figure 2- Site Location plan Showing MBIE Technical Category Map

Figure 3- Field Investigation Location



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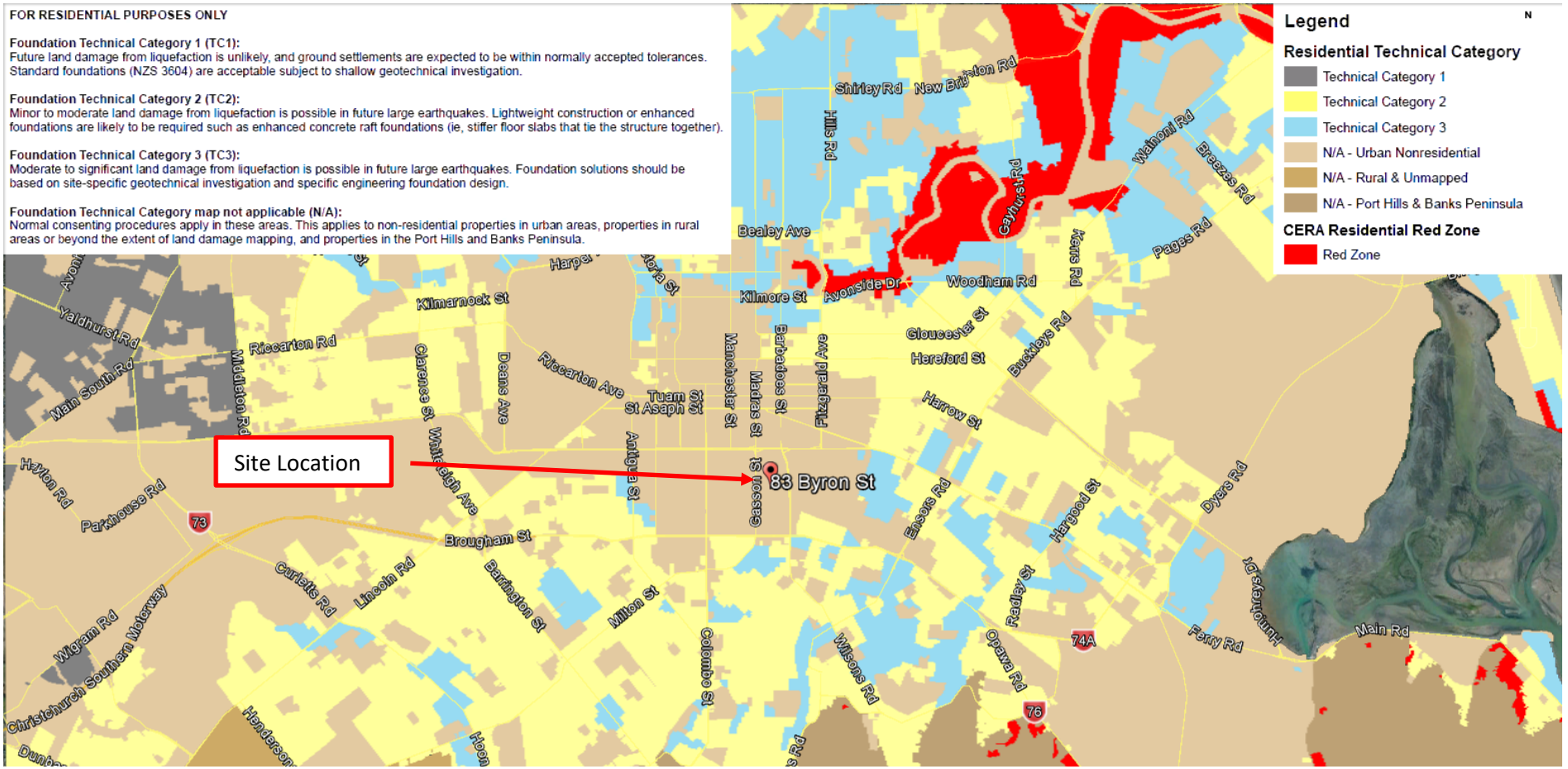
	Project No	16363			Reference	N/A



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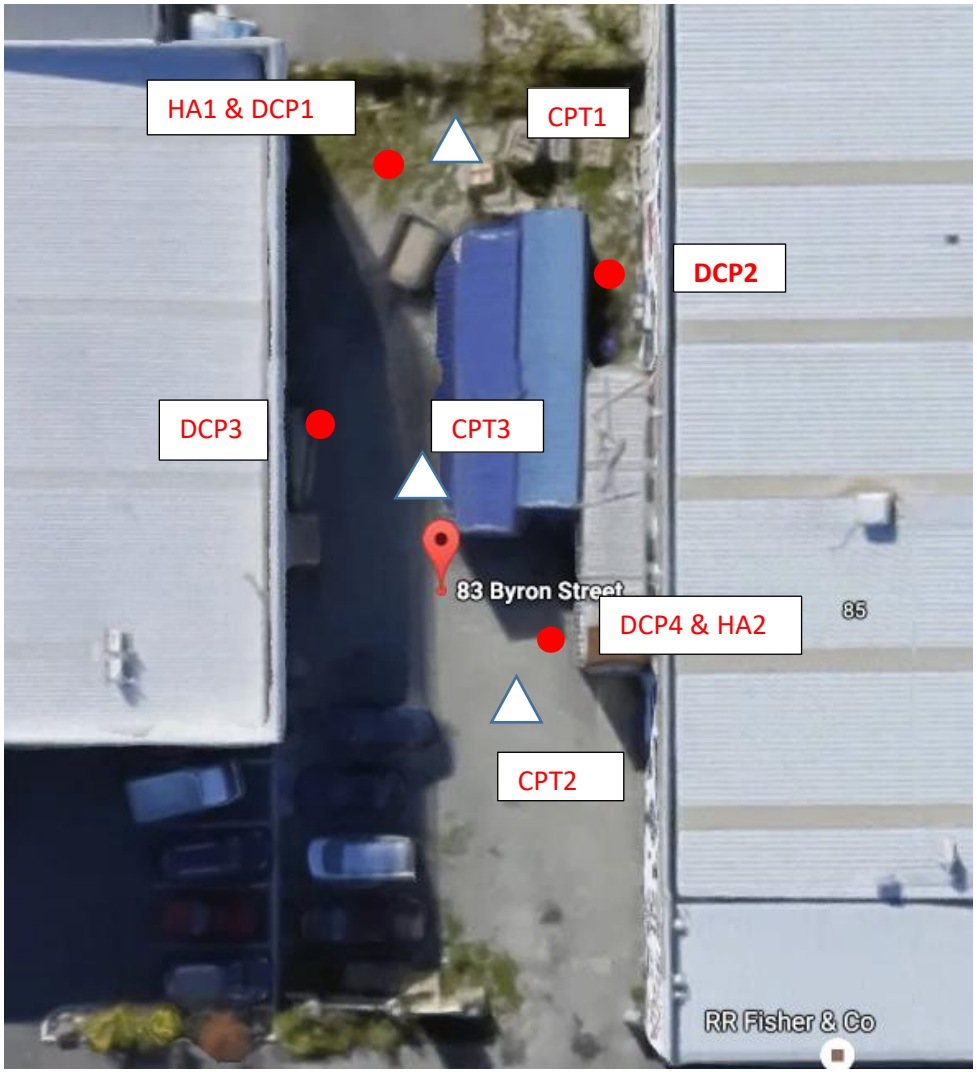


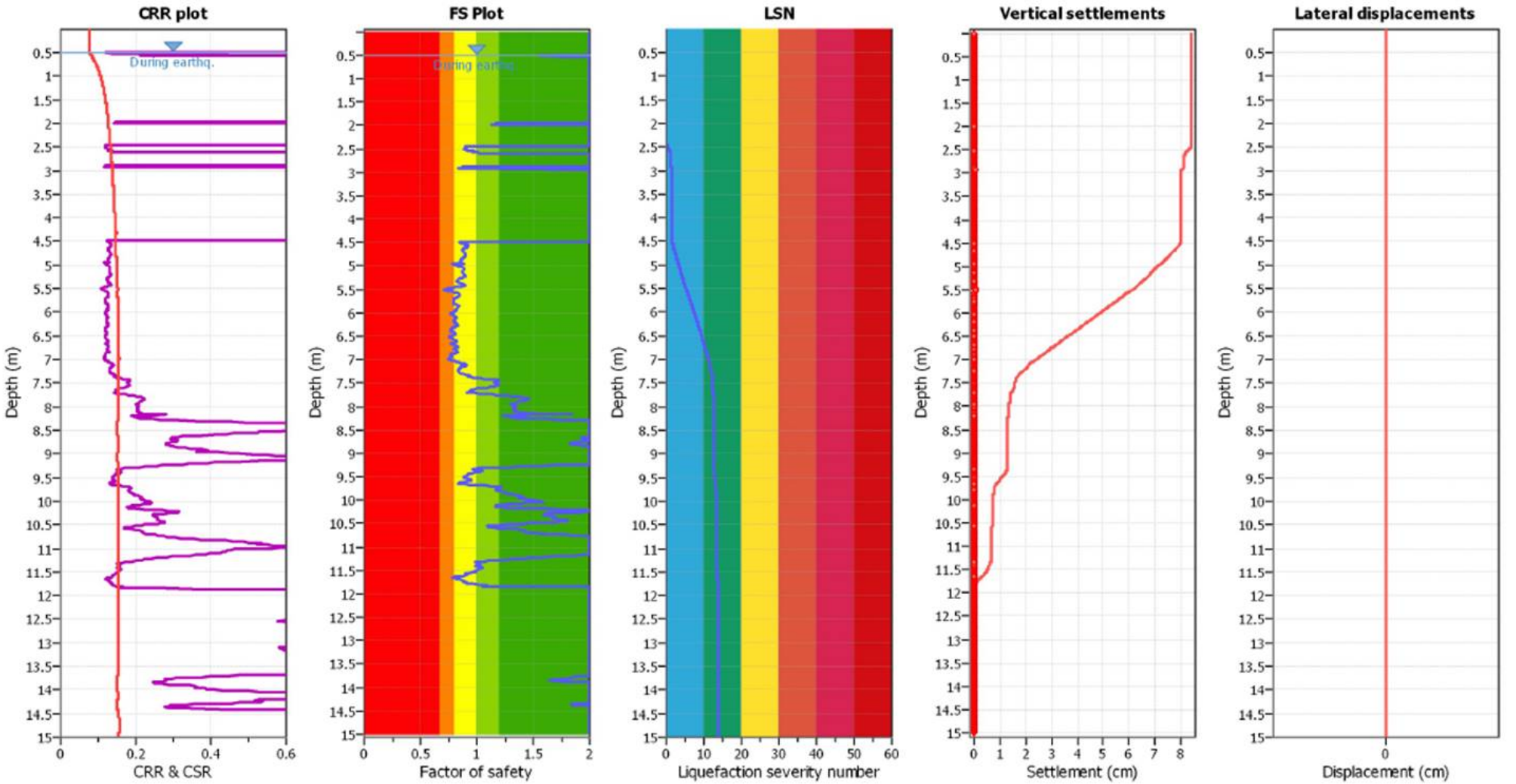
ENGCO Consulting Engineers	Figure	3	Date	23/11/2016	Title	Field Investigation Locations
	Project No	16363			Reference	N/A

ENGCO
Consulting Engineers

Appendix 2

Liquefaction Assessment Results

Liquefaction analysis overall plots



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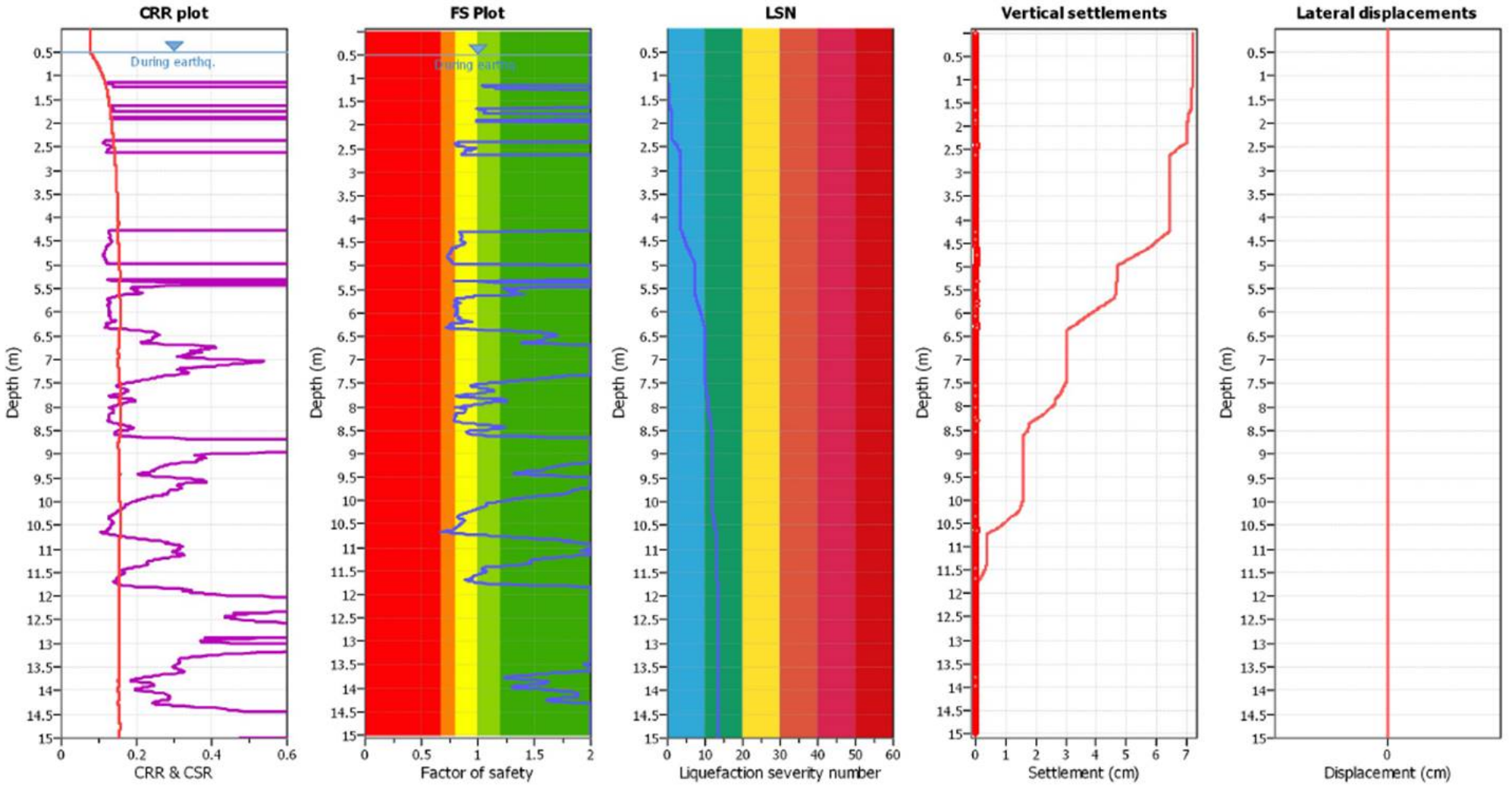
F.S. color scheme

- 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

LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Liquefaction analysis overall plots



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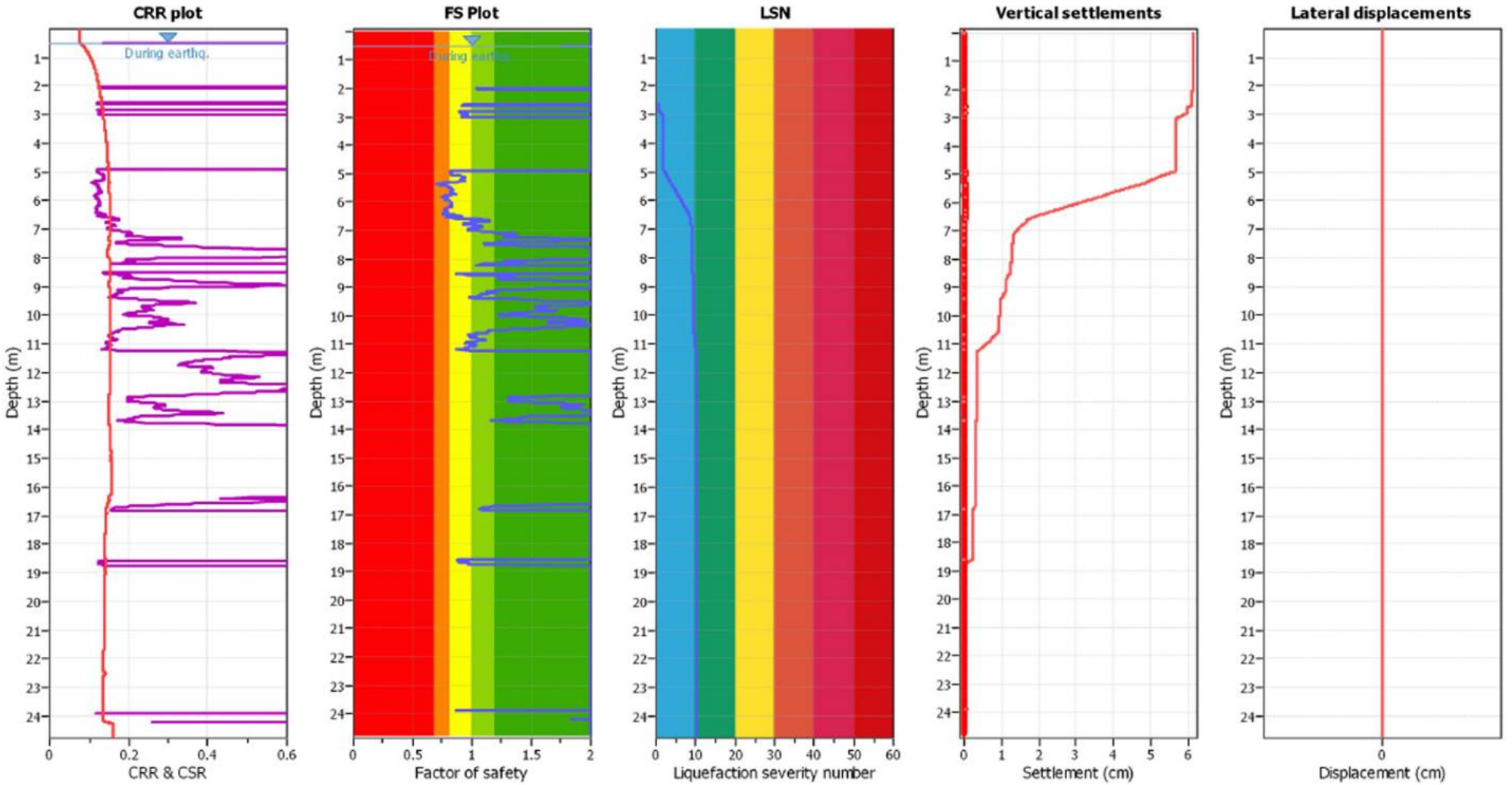

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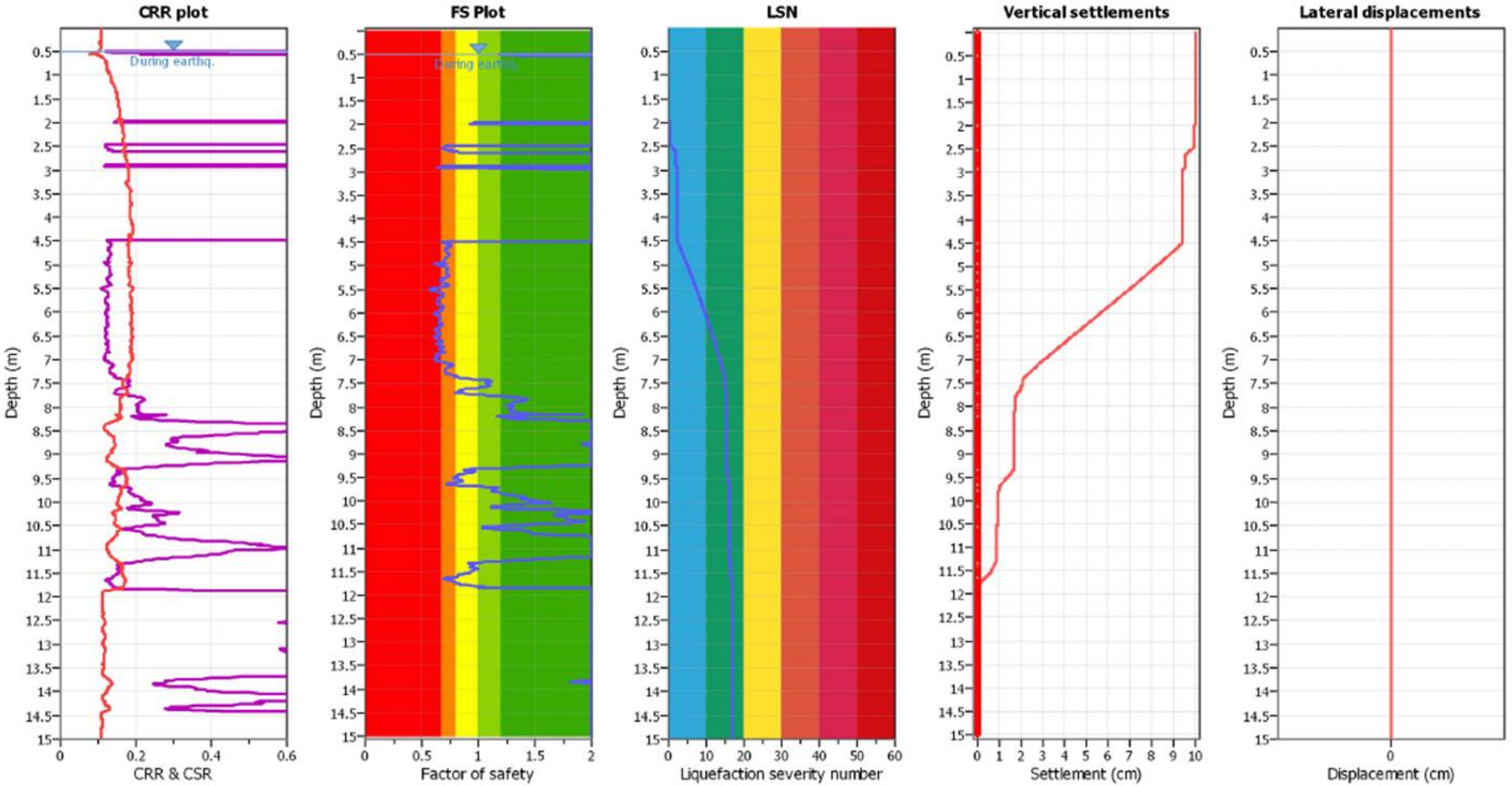

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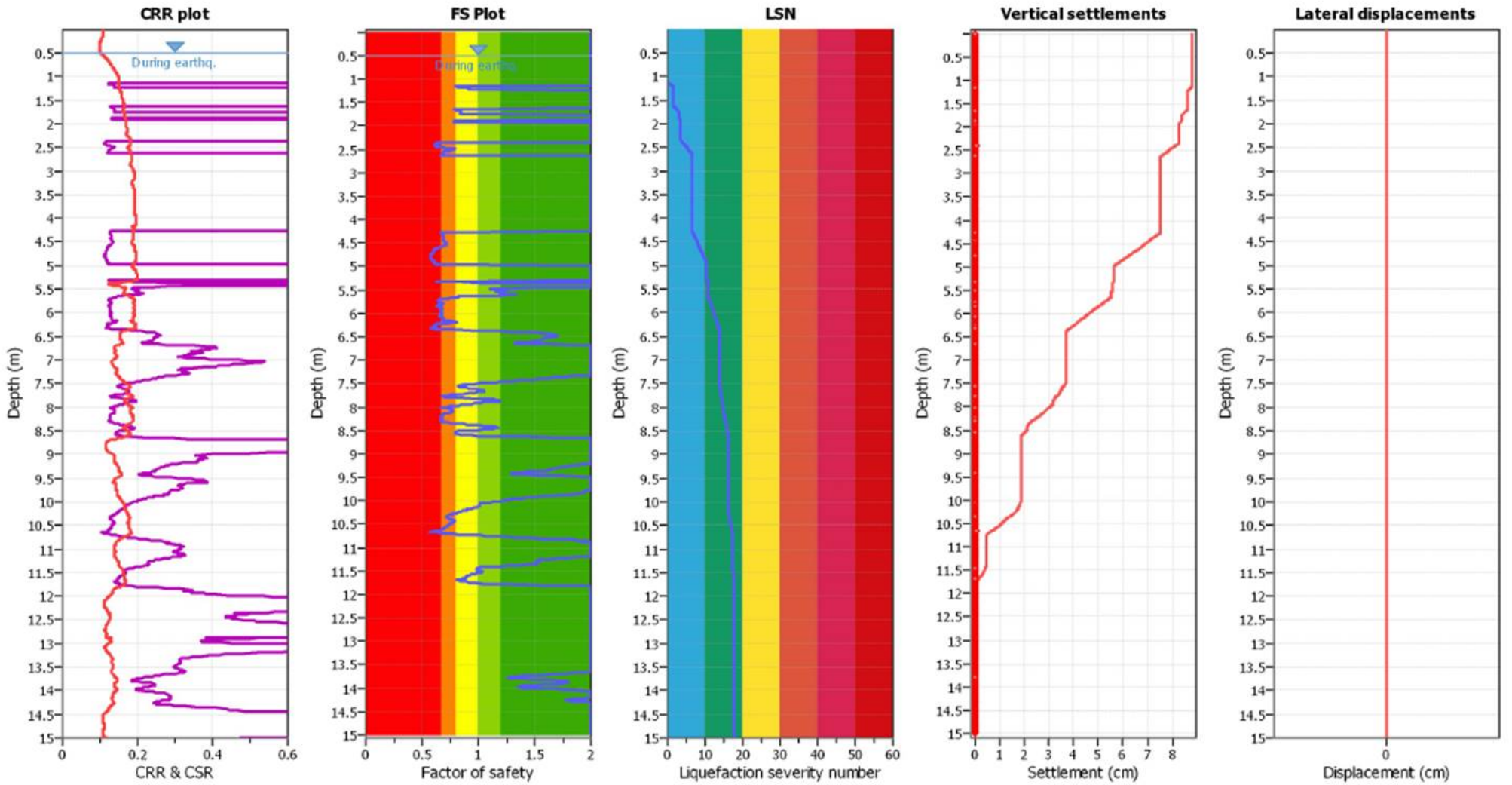

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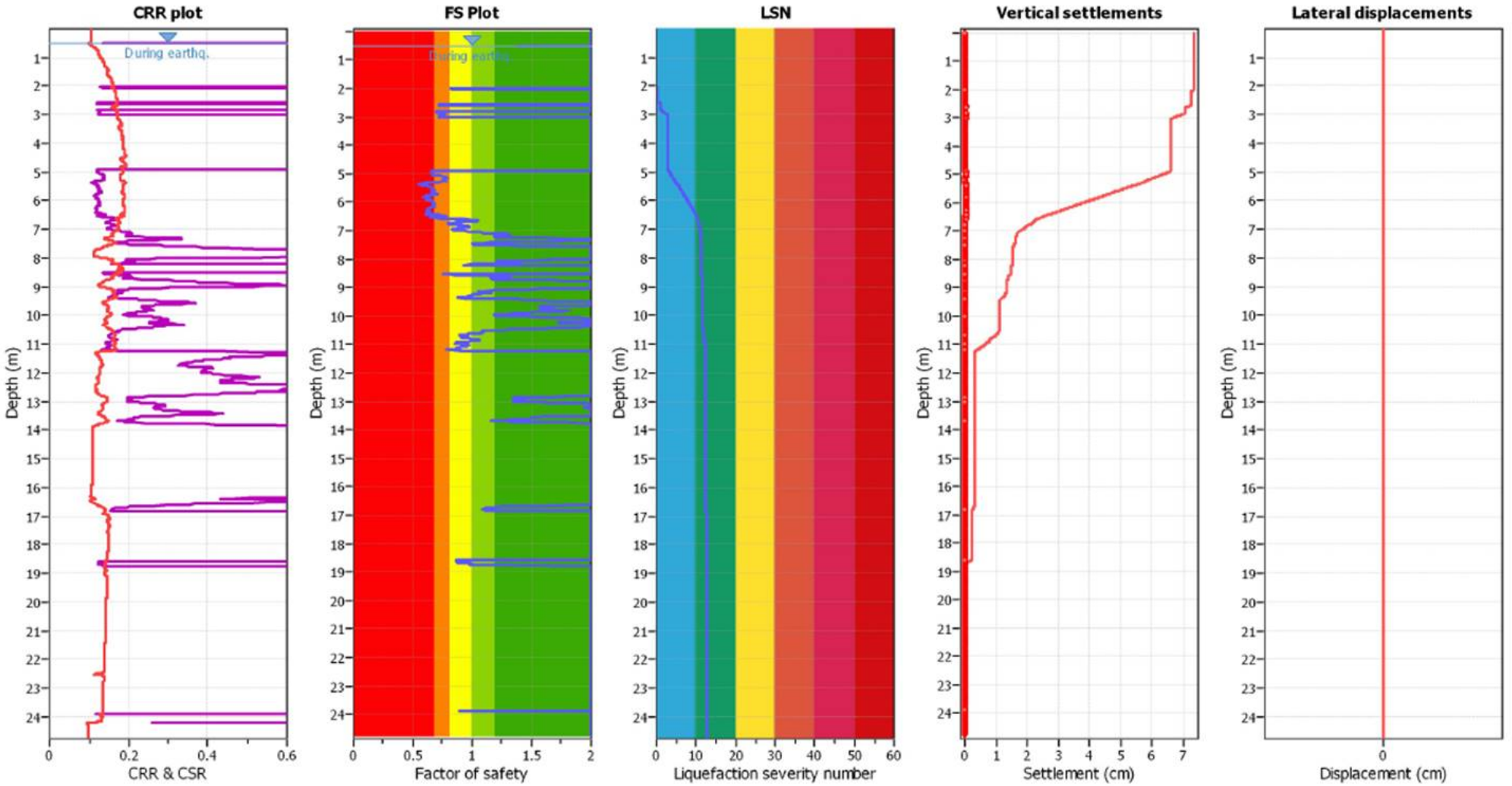


Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.00 m	Fill height:	N/A	Limit depth:	N/A

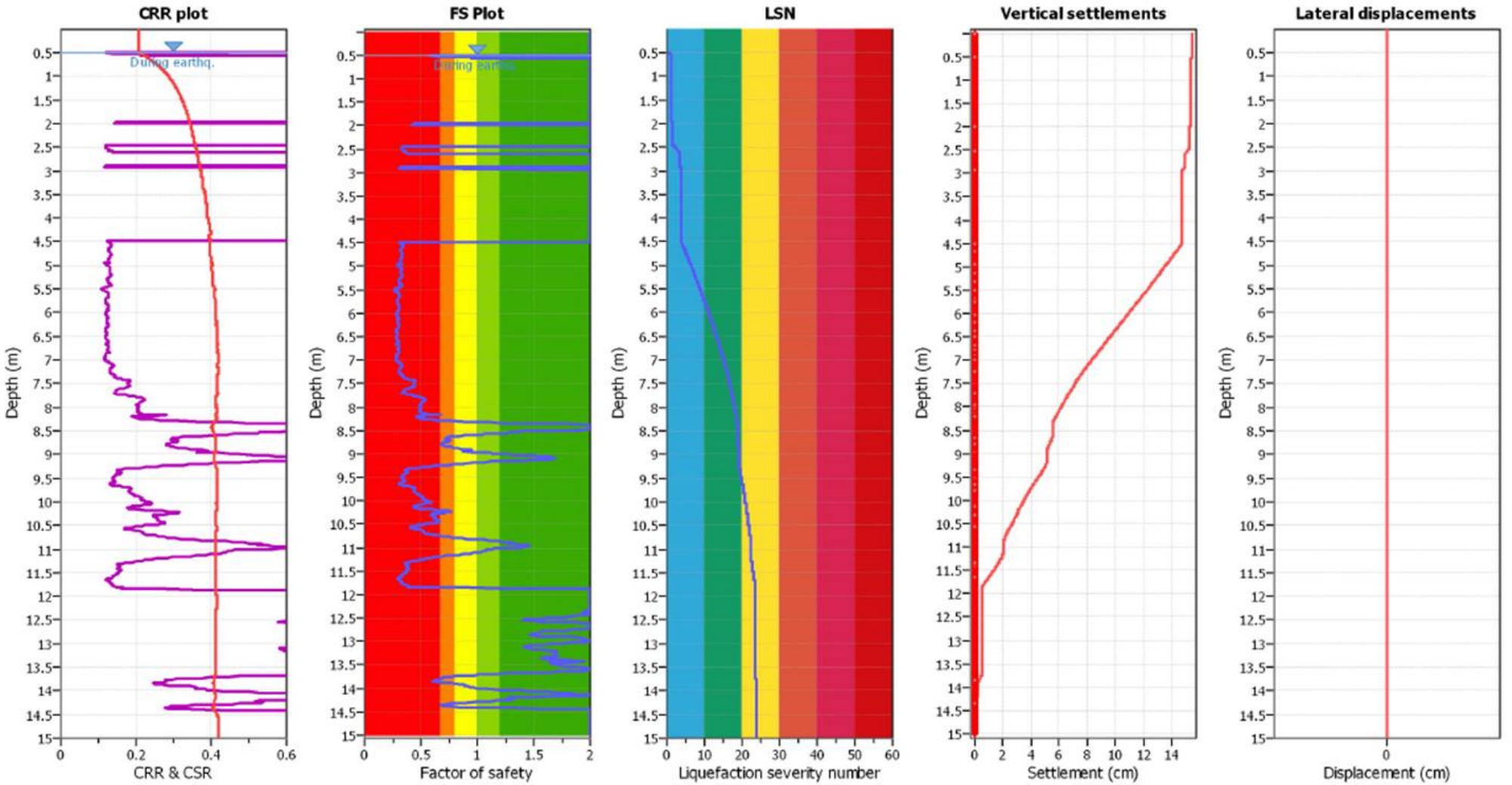
F.S. color scheme

- 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

LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.00 m	Fill height:	N/A	Limit depth:	N/A

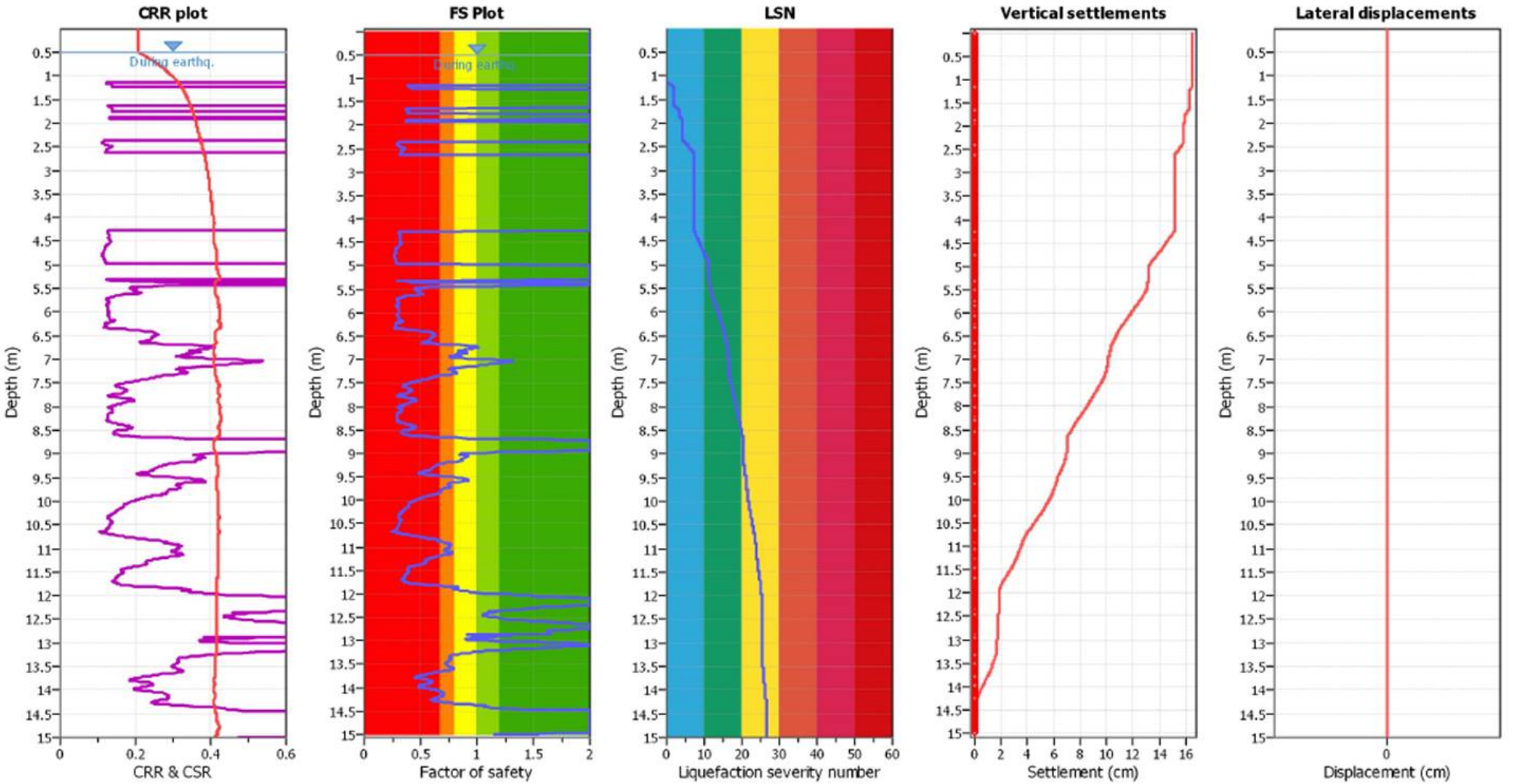
F.S. color scheme

- 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

LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
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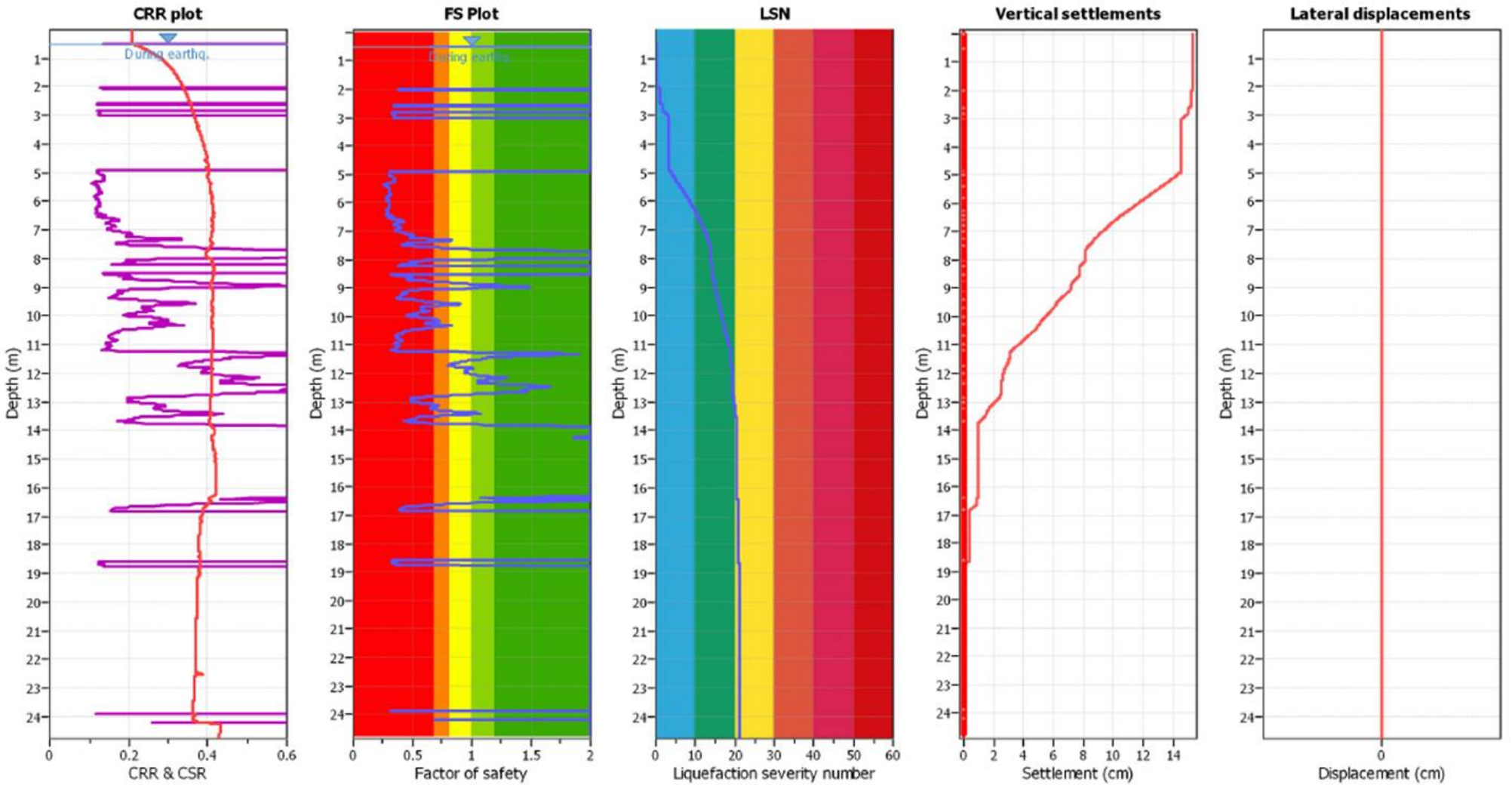
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.00 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
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LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

ENGCO
Consulting Engineers

Appendix 3

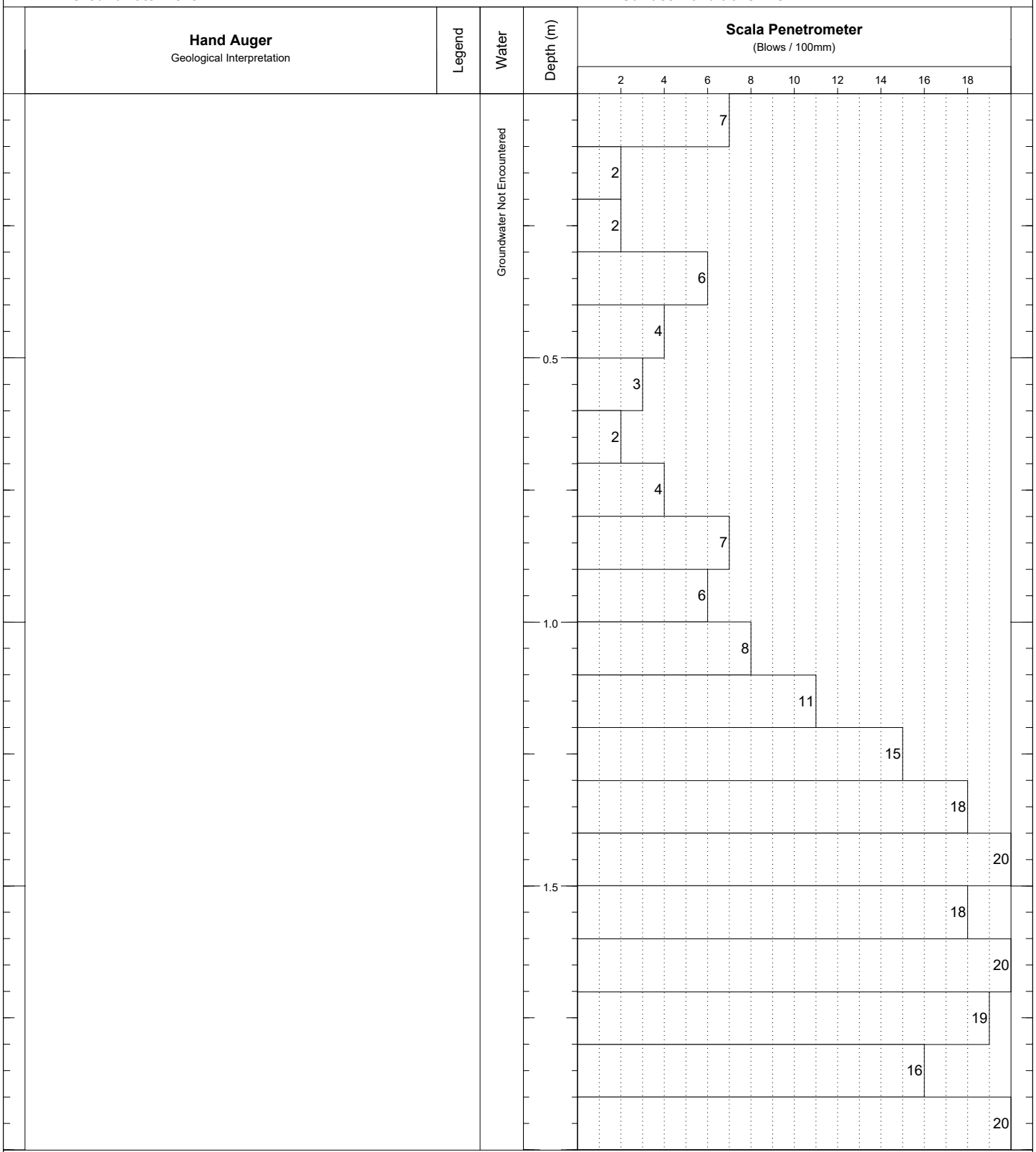
Shallow Geotechnical Investigation Results

HAND AUGER & SCALA LOG

Job Number:	16412
Client:	ENGCO
Project:	83 Byron Street
Test Label:	DCP02

Site Location: 83 Byron Street, Christchurch
Test Date: 31/10/2016
Coordinates: -43.542160, 172.644481 (WGS84)
Groundwater Level: Not encountered

Operator: Logan Allan
Logger: Jozef Knottenbelt
Hole Depth: 2m
Surface Conditions: Grass



Remarks
Testing carried out to New Zealand Standard 4402:1986 (Test 6.5.2.1988)

HAND AUGER & SCALA LOG

Job Number: 16412

Client: ENGCO

Project: 83 Byron Street

Test Label: DCP03

Site Location: 83 Byron Street, Christchurch

Test Date: 31/10/2016

Coordinates: -43.542241, 172.644351 (WGS84)

Groundwater Level: Not encountered

Operator: Logan Allan

Logger: Jozef Knottenbelt

Hole Depth: 2m

Surface Conditions: Gravel

Hand Auger
Geological Interpretation

Legend

Water

Depth (m)

Scala Penetrometer
(Blows / 100mm)

2 4 6 8 10 12 14 16 18

Groundwater Not Encountered

0.5

1.0

1.5

6
17
8
2
5
4
4
4
7
6
10
11
11
12
12
13
11
8

Remarks

Testing carried out to New Zealand Standard 4402:1986 (Test 6.5.2.1988)

HAND AUGER & SCALA LOG

Job Number: 16412

Client: ENGCO

Project: 83 Byron Street

Test Label: HA01/SP01

Site Location: 83 Byron Street, Christchurch

Test Date: 31/10/2016

Coordinates: -43.542137, 172.644341 (WGS84)

Groundwater Level: Not encountered

Operator: Logan Allan

Logger: Jozef Knottenbelt

Hole Depth: 2m

Surface Conditions: Grass

Hand Auger (Geological Interpretation)	Depth (m)
Sandy Gravely SILT; with minor tiles and trace brick, dark brown/black, medium dense to very dense, damp, grey clasts(rounded)	
Sandy SILT; blue/grey with orange mottles, dense, damp, low plasticity	
SILT; black with orange mottles, loose, damp, moderate plasticity	0.5
clayey SILT; green/blue, medium dense, damp, high plasticity	
clayey SILT; grey/blue with orange mottles, medium dense, damp, high plasticity	
clayey SILT; grey/blue with orange mottles, medium dense to dense, wet, high plasticity	1.0
clayey SILT; grey/blue, medium dense, wet, high plasticity	1.5
clayey SILT; grey/blue, medium dense, saturated, high plasticity,	

Legend

Water: Groundwater Not Encountered

Scala Penetrometer (Blows / 100mm)

Depth (m)	Blows / 100mm
	6
	8
	28 >>
	9
	3
0.5	3
	6
	6
	6
	5
1.0	6
	6
	10
	9
	7
1.5	7
	7
	6
	6
	7

Remarks

Testing carried out to New Zealand Standard 4402:1986 (Test 6.5.2.1988)

17A Gasson Street, Sydenham, Christchurch 8023, New Zealand 0800 TESTER (837837) www.landtest.co.nz

Hole Depth: 2m

Created: 1/11/2016 9:47:22 AM

HAND AUGER & SCALA LOG

Job Number: 16412

Client: ENGCO

Project: 83 Byron Street

Test Label: HA02/DCP04

Site Location: 83 Byron Street, Christchurch

Test Date: 31/10/2016

Coordinates: -43.542315, 172.644489 (WGS84)

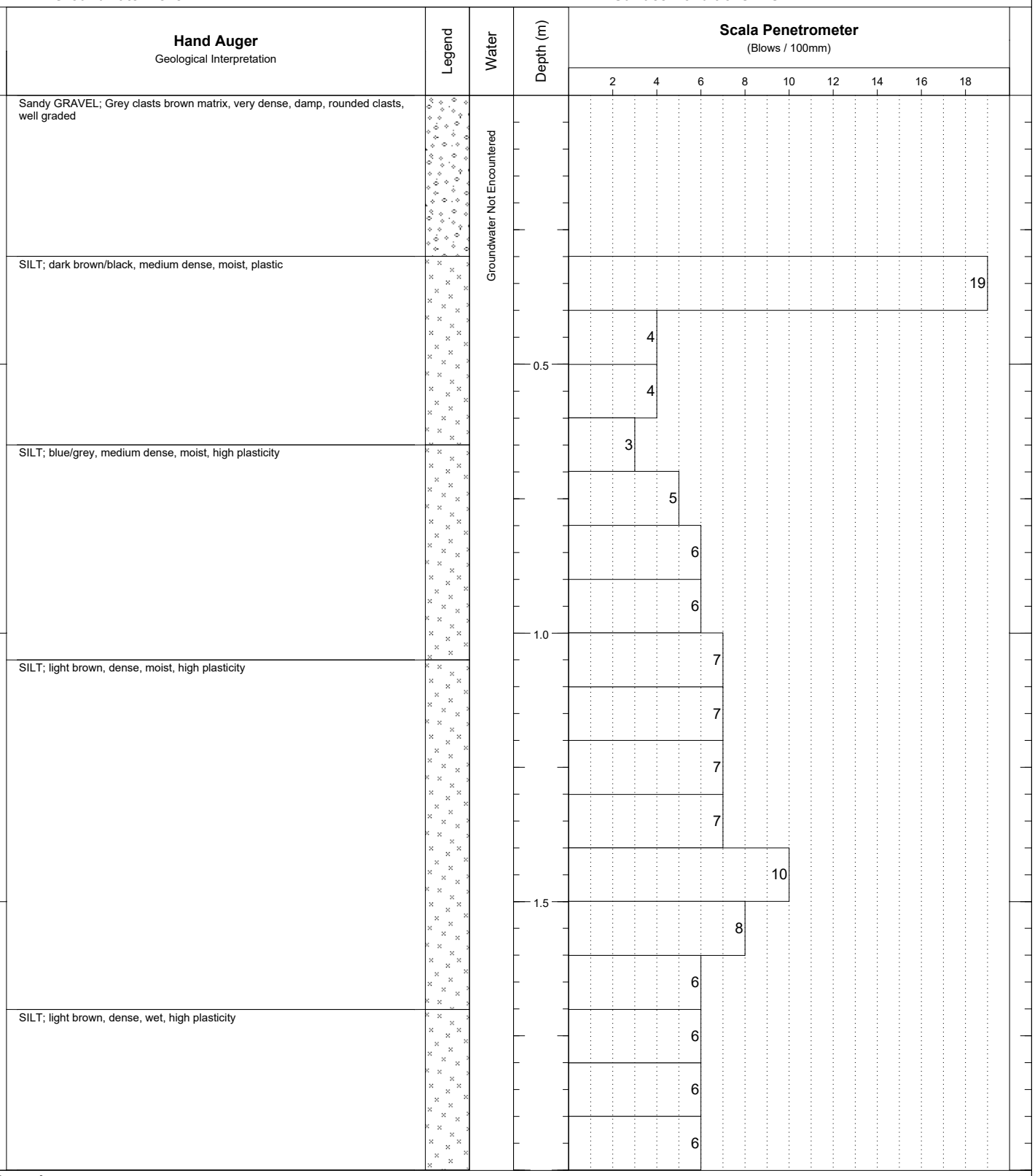
Groundwater Level: Not encountered

Operator: Jozef Knottenbelt

Logger: Logan Allan

Hole Depth: 2m

Surface Conditions: Gravel



Remarks

Testing carried out to New Zealand Standard 4402:1986 (Test 6.5.2.1988)

Scalar prehole to 0.3m

17A Gasson Street, Sydenham, Christchurch 8023, New Zealand 0800 TESTER (837837) www.landtest.co.nz

Hole Depth: 2m

Created: 1/11/2016 9:47:57 AM