Prestons Park Subdivision

Stage E3 Geotechnical Completion Report

CDL Land New Zealand Ltd

Reference: 235361

Revision: 0

2022-11-02

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Document control record

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Document control						aurecon
Report title		Stage E3 Geotechnical Completion Report				
Document code			**Project number**		235361	
File path		Https://aurecongroup.sharepoint.com/sites/235361/5 Deliver Design/Geotechnical/1. Geotechnical Completion Reports/Stage E3/235361 Geotechnical Completion Report Stage E3 Rev0.docx				
Client		CDL Land New Zealand Ltd				
Client contact		Jason Adams	**Client reference**			
Rev	**Date**	**Revision details/status**	**Author**	**Reviewer**	**Verifier** (if required)	**Approver**
A	2022-07-13	For review	C. Scott	J. Muirson		
0	2022-11-02	Issue to Client	C. Scott	J. Muirson		J. Kupec
Current revision		**0**				

Approval			
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Contents

Executive Summary

CDL Land New Zealand Limited is developing Stage E3 of the Prestons Park Subdivision, located on Prestons Road, Christchurch. As part of the work, a geotechnical completion report is required to confirm that the site works have been carried out to the required standard and provide recommendations for building developments. This report describes the earthworks and ground improvement involved with Stage E3 of the Prestons Park Subdivision.

The Client's brief on previous stages of the Prestons Park project was to develop the land to Technical Category 1 (TC1) equivalent performance. Based on Aurecon's geotechnical assessment, Stage E3 comprised ten lots classified as TC2 and eight lots classified as TC1 equivalent prior to earthworks commencing.

Aurecon's role was to monitor the earthworks, fill compaction testing and complete post earthworks quality assurance testing, which comprised Cone Penetration Testing (CPT).

Extensive earthworks predominantly comprising filling have occurred on the site. The quality assurance testing of the engineered earthfill indicates that the earthfill placed within the Stage E3 area has achieved the required compaction levels as per NZS4431:1989.

Following completion of the earthworks and topsoil placement throughout the subdivision, a series of CPTs was carried out to confirm the ground conditions. The purpose of the CPTs was to allow an assessment of the future land performance during large earthquakes and to determine the equivalent Technical Category of the land. The assessment results changed the classification of four lots from TC2 to TC1.

From the monitoring and testing undertaken as part of the development of Stage E3 the following is concluded:

Certificate of Compliance

The standard of bulk earthworks generally meets the earthworks specification and the applicable codes, including NZS4431:1989 (since superseded by the NZS 4431:2022 '*Engineered fill construction for lightweight structures'*).

Building Considerations

General

This report shall not be used for building consent application for buildings on individual lots. Site specific geotechnical investigations, in-line with NZS3604:2011, shall be undertaken at building consent application stage.

TC1 Foundations

For lots identified as TC1, NZS 3604:2011 type foundations are considered suitable. At the time of writing this report, the location and structural form of the future dwelling on the lots are unknown and this recommendation relates to NZS3604:2011 type lightweight timber or steel framed residential buildings only.

TC2 Foundations

For lots identified as TC2, dwellings shall be founded on TC2 type ‘enhanced foundation slabs’ as per Options 2, 3 or 4 from the MBIE Guidelines (2012) Section 5.3 to mitigate the effects of liquefaction induced vertical settlement. Alternatively, a specific design in accordance with MBIE Guidelines Section 5.4 could be undertaken by a suitably qualified chartered professional engineer.

Explanatory Statement

This report shall be read as a whole and our explanatory statement is presented in Section 8.

1 Introduction

1.1 Geotechnical Completion

CDL Land New Zealand Limited are developing Stage E3 of the Prestons Park Subdivision, located on Prestons Road, Christchurch. Stage E3 is a sub-stage within Stage Five of the subdivision. The site works in Stage E3 included bulk earthworks for the development of the lots. As part of this work, a geotechnical completion report is required to certify the site works have been carried out to the required standard and provide recommendations for building developments.

This report has been prepared for CDL Land New Zealand Limited and issued to Christchurch City Council (CCC). It describes the earthworks involved within Stage E3 of the Prestons Park Subdivision (see Figure 1 in Appendix A).

The purpose of this geotechnical completion report is to present the following:

- Summarise information from previous investigations carried out as part of the subdivision consent and detailed design;
- Summarise the ground conditions and liquefaction risk;
- Extent of earthworks on the lots and compliance testing of bulk earthworks;
- Quality assurance of the construction of gravel embankments;
- Quality assurance testing of land for the purposes of technical category assessment;
- Summary of the findings, land technical category and recommendations for building development.

This report has been prepared based on geotechnical data from site observations and compaction testing during and after earthworks construction and ground improvements. All references to cut-fill depths are based on subgrade levels.

This report shall be read as a whole. Our explanatory statement is presented in Section 7.

1.2 Site Description

The Prestons Road subdivision is located on the northern fringes of Christchurch City. The site is made up of a series of adjacent properties forming an irregular and elongated rectangle shape, orientated approximately north to south. The total area of the overall Prestons Subdivision site is approximately 190ha. The site can be separated into two distinct blocks. Prestons North runs from the Lower Styx Road in the north through to Prestons Road in the south. Prestons Park continues from Prestons Road, through to Mairehau Road to the south.

The focus of this geotechnical completion report is on Stage E3 of the Prestons Park Subdivision. Stage E3 incorporates a block in the south east part of the Prestons Park subdivision (see Figure 1 in Appendix A).

2 Pre-Development Geotechnical Work

2.1 Geotechnical Testing

The subdivision consent and detailed geotechnical design for the subdivision included an extensive series of geotechnical investigations. These comprised Cone Penetration Tests (CPT), test pits, groundwater measurements and laboratory testing.

The details of these investigations are presented in the following Aurecon reports:

- *Caldwell Block Subdivision Resource Consent Geotechnical Report,* Revision 0 dated 11 July 2018.
- *Prestons Park Stage Five Gravel Embankment Design*, Revision 0 dated 9 October 2019.

The investigation tests carried out within Stage E3 of the Prestons Park area are presented in Figure 2 in Appendix A.

2.2 Ground Conditions

From the extensive geotechnical investigations, the ground conditions within the Prestons Park Subdivision were defined into various geological areas. The typical ground conditions in the area are presented in Table 1.

Table 1: Typical ground conditions within Stage E3.

Depth to Top of Unit (m)	Depth to Base of Unit (m)	Soil Unit
0	0.3 to 0.4	TOPSOIL.
0.3 to 0.4	3	SAND with minor silt, loose to medium dense.
3	12	SAND with minor silt, medium dense to dense.
12	Not determined	SAND, dense to very dense.

Groundwater levels ranged from 1m to 2.5m below ground level. During the site earthworks the above soil profile and groundwater levels were typically encountered within the area of interest.

2.3 Liquefaction Potential

As part of the geotechnical assessment and detailed design, a liquefaction assessment was carried out. The details of the liquefaction assessments are presented in the above reports. The land categorisation was based on the criteria of Ministry of Business, Innovation and Development (MBIE), Technical Category deformation performance limits are set out in Table 2.

Table 2: Technical category definitions and foundation implications (MBIE, 2012).

Technical Category	Liquefaction Deformation Limits				Likely Implications for House Foundations (Subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15mm	25mm	nil	nil	Standard 3604-like foundation with tied slabs
TC2	50mm	100mm	50mm	100mm	MBIE Enhanced Foundation Solutions
TC3	>50mm	>100mm	>50mm	>100mm	Site Specific Measures – Piles or Ground Improvement

The results from the liquefaction assessment, detailed in the geotechnical report dated 11 July 2018, indicated that the Stage Five of Prestons Park Subdivision can be classified as Technical Category 1 (TC1) and Technical Category 2 (TC2).

3 Subdivision Earthworks

3.1 General

Bulk earthworks for Stage E3 of Prestons were carried out in accordance with the requirements of NZS 4404:2010, "*Code of Practice for Urban Subdivision*" and NZS4431:1989 "*Code of Practice for Earthfill for Residential Development*" (since superseded by the NZS 4431:2022 "*Engineered fill construction for lightweight structures"*). The earthworks typically comprised stripping the site of topsoil, filling using imported pit run gravel or site-won sand, and then replacing topsoil. No excavation to remove in-situ organic material was undertaken as organics were infrequent, typically thin seams if encountered and at depths of greater than 2m.

3.2 Areas of Cut and Fill

Site earthworks within Stage E3 has included predominantly filling in comparison to the site subgrade levels. The fill material comprises site-won sand and pit run gravel overlying a natural sand subgrade. A layer of topsoil overlies the fill material. The extent of filling is shown in Figure 3 in Appendix A.

3.3 Compaction Quality Control Testing

Independent testing of earthfill compaction completed using traditional earthworks techniques was carried out using a Nuclear Densometer (NDM). The acceptance criterion was based on the Prestons Park Subdivision earthworks specification as follows:

- Compaction of fill is to be in accordance with NZS 4431: 1989.
- Compaction standard is 95% Maximum Dry Density (MDD) for all areas of bulk filling, per NZS4402 Test 4.1.3.

Fill materials comprised of site-won sand and imported pit run gravel. Compaction curves for each of the fill materials are presented in Appendix B.

The MDD from the compaction curves were used to determine the level of compaction required for the fill material. A summary of these NDM results is presented in Appendix C and the NDM testing locations are presented in Figure 4 in Appendix A.

On those occasions where quality control testing did not meet the specification, the Contractor was required to rework the fill to achieve the required compaction.

3.4 Compaction Results

The results presented in Appendix C indicate that 95% MDD or greater compaction has been consistently achieved in the areas of bulk fill. Where NDM results indicated the required compaction had not been achieved, the Contractor completed additional compaction effort and conforming NDM results were achieved. From these results and our site observations, we confirm that the earthfill placed within Stage E3 has achieved the required compaction.

4 Gravel Embankments

4.1 Introduction

The construction of the Snelling Drain upgrade running to the east of Stage E3 was identified as being a potential cause of lateral spreading in a large seismic event, even with ground improvement by impact rolling undertaken on previous stages. As the liquefiable layers are typically in the upper 2.5m to 3m depth of the soil profile, it was considered more feasible to remove the liquefiable layers and form a compacted gravel embankment to limit the potential hazard.

Lateral spreading requires the need for a continuous liquefiable layer through to the free face. By removing this continuous liquefiable layer and reinstating with compacted gravel, lateral spreading can be limited or eliminated.

The gravel embankments constructed for the stormwater infrastructure to the north of Stage E3 have been described separately in "*Prestons Subdivision Geotechnical Completion Report, Prestons South Stages W, X and Y*", Revision 0 dated 18 April 2017. Due to the size of the gravel embankments to the north, the lateral spreading risk to the north of Stage E3 has likely been eliminated.

4.2 Gravel Embankment Details

The design of the gravel embankments within Stage Five of Prestons Park Subdivision was undertaken by Aurecon and is presented in *"Prestons Park Stage Five Gravel Embankment Design"*, Revision 0 dated 9 October 2019. The gravel embankments were designed to limit lateral spreading displacements to within TC2 acceptable limits, which are given in Table 2. The purpose of the gravel embankments is to intercept the continuous layer of liquefiable soils adjacent to the free edge (basin or open channel), as lateral spreading requires a continuous liquefiable layer.

Depending on the depth and the extent of liquefiable layers near the free face, the gravel embankment size and depth varied. The gravel embankment design comprised compacted AP65 or pit run gravel with a layer of overlying topsoil. The design shape, extent and location of the gravel embankments is shown in PS-S5-EW-05, which has been included in Appendix D.

4.3 Gravel Embankment Construction

The gravel embankment design required that a well graded sandy gravel material (such as AP65 or approved pit run) was used for the embankment construction. Material used on site comprised of imported, well graded pit run sandy gravel (AP100). The gravel was topped with approximately 300mm of topsoil. The design drawing required that compaction to 98% of MDD for the gravel was achieved, to ensure that the required embankment design parameters were attained.

Site observations by Aurecon Geotechnical and Civil Engineers confirm the gravel embankments have been constructed with imported well graded pit run gravel. In addition, the compaction quality testing discussed in Section 3 indicates that compaction of at least 95% of MDD has been achieved for the sandy gravel embankment fill material. This level of compaction is slightly less than the 98% of MDD specified in the design drawings but based on our site observations, the gravel embankment will meet the minimum design parameters required to achieve the intended performance of the embankments.

A review of as-built earthworks information provided by the civil engineers indicates that the required toe width and depth of the gravel embankment profile has been achieved. The cut slope angle of the gravel embankment sides was not specified, and the contractor was only required to construct the correct toe width and depth. As-built plans for the gravel embankments are provided in Appendix D.

Based on the intended design and the gravel embankment construction, Aurecon considers that the gravel embankments have been constructed appropriately and lateral spreading exceeding TC2 limits adjacent to the Snelling Drain is unlikely. From a lateral spreading perspective, the lots adjacent to Snelling Drain are likely to perform to the level of TC2 equivalent.

5 Post Earthworks CPT

5.1 Introduction

Following completion of the earthworks and topsoil placement throughout Stage E3, a series of CPT tests were carried out to confirm the ground conditions. Areas of Stage E3 which were identified as TC1 in Aurecon's previous assessment were not retested, as the earthworks undertaken would only improve the technical categorisation. As such, post earthworks CPT have been undertaken in the TC2 area on the northern boundary of Stage E3, to confirm if the technical category has improved as a result of the subdivision earthworks. The area tested was chosen as it is outside of the assessed extent of any potential lateral spreading, which is a requirement for a TC1 classification. The post earthworks CPTs are presented in Appendix E and the locations are shown in Figure 5 in Appendix A.

5.2 Liquefaction Assessment

To allow an assessment of the land technical category, a liquefaction assessment has been carried out on the post earthworks CPTs. The liquefaction assessment methodology has been discussed below.

Introduction

As technical categories are derived by liquefaction induced deformation limits, a liquefaction assessment on the post compaction CPTs has been carried out to determine the extent of liquefaction and the induced settlements. To allow CPT testing to be undertaken on the natural sand subgrade, predrilling has been undertaken through the granular pit run fill material. The pit run fill is non-liquefiable by inspection due its density and being located above the groundwater table.

Earthquake Cases

Earthquake induced ground acceleration and sustained shaking, leading to sufficient load cycles, is a requirement and a potential trigger of liquefaction. For this assessment we have reviewed three levels of seismic shaking.

1. Serviceability Limit State (SLS) design level earthquake, as defined by MBIE.
2. Intermediate design level earthquake, as defined by the subdivision consent conditions.
3. Ultimate Limit State (ULS) design level earthquake, as defined by MBIE.

Each of these earthquake cases is discussed in detail below:

Serviceability Limit State (SLS) Earthquake

From the NZGS/MBIE Guidelines (2021), a Peak Ground Acceleration (PGA) of 0.13g has been derived for a SLS event with a Magnitude 7.5 earthquake.

Intermediate Level (Int) Earthquake

Subdivision consent conditions indicate that liquefaction mitigation measures for the subdivision infrastructure shall be designed for a 1 in 150-year return period under the serviceability limit state (SLS) and as defined by NZS1170.5:2004.

Based on NZS1170.5:2004 for an Importance Level 2 (IL2) structure, with an increased Z hazard factor of 0.3, a PGA of 0.2g has been derived for a 1 in 150-year period of return. A Magnitude 7.5 has been used.

Ultimate Limit State (ULS) Earthquake

The NZGS/MBIE Guidelines (2021) recommend a PGA of 0.35g for residential buildings in Christchurch. This PGA value with a magnitude 7.5 earthquake has been adopted for the ULS assessment.

Liquefaction Methodology

In assessing the liquefaction potential, the method of Boulanger and Idriss (2014) has been utilised to assess the potential settlement for each design level event, as per the MBIE Guidelines (2012) for residential properties. The assessment was carried out using an excel spreadsheet developed by Aurecon. The method of Robertson and Wride (1998) with the modified fines content was used to assess the liquefaction potential from the CPT results. The method of Zhang et al (2002) was used for estimating the liquefaction induced settlements from CPT results.

The CPT analysis has been performed to a depth of 10m, as this is the required depth in the MBIE Guidelines for the technical category assessment.

In addition to determining the liquefaction induced reconsolidation settlement, we have assessed the potential for liquefaction induced ground damage based on the Liquefaction Severity Number (LSN), as defined by Tonkin and Taylor (2013). Other ground damage potential methods (such as Ishihara, 1985) were assessed but LSN was considered the more appropriate method. Tonkin & Taylor (T&T) developed the Liquefaction Severity Number (LSN) based on investigation data and observations made following major earthquake events in Christchurch. The LSN number is an index number which qualitatively assesses the effects of liquefaction on a site and on a shallow founded building. The LSN number is calculated by the equation below.

$$LSN = 1000 \int \frac{\varepsilon_v}{z} . dz$$

Where: $\varepsilon_v = \text{volumetric reconsolidation strain}$

$z = \text{depth of liquefaction below ground level}$

The LSN number is likely to be a better index of surface damage than reconsolidation settlement because the LSN number is weighted more heavily by shallow liquefaction and less by liquefaction at depth, which is less likely to affect the ground surface or shallow founded buildings. Reconsolidation settlement places the same weighting on deep liquefaction as shallow liquefaction, even though settlement will have less impact at the ground surface with increasing depth. LSN numbers have been correlated to observed liquefaction effects during recent earthquakes in Christchurch as shown in Table 3.

Table 3: LSN Ranges and Observed Effects (Tonkin and Taylor, 2013).

LSN Range	Predominant Performance
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with sand boils and some structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlement of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services

When compared to the broad descriptions of expected land performance in TC1, TC2 and TC3, as outlined in Section 2.3, the LSN number can be approximately correlated to technical categories as follows:

- TC1 = $LSN_{(ULS)} < 10$
- TC2 = $LSN_{(SLS)} < 20$ and $LSN_{(ULS)} < 30$
- TC3 = $LSN_{(SLS)} > 20$ or $LSN_{(ULS)} > 30$

A groundwater depth of 2.0m below finished earthworks level has been used for the purposes of this liquefaction assessment. Testing information throughout Stage Five indicates the groundwater level is typically greater than 2.0m depth (more likely to be at depths of 2.5m or greater) therefore a conservative groundwater level of 2.0m below ground level has been used for the assessment.

Liquefaction Assessment Results

The results of the liquefaction induced reconsolidation settlement analysis are presented in Table 4. The results for the liquefaction induced ground damage potential (LSN numbers) are presented in Table 5.

Table 4: Liquefaction induced settlements for post earthworks CPTs to 10m depth.

Earthquake Magnitude 7.5, Water Depth 2m, 10m Analysis			
CPT	**SLS Design Event (0.13g)**	**Intermediate Design Event (0.20g)**	**ULS Design Event (0.35g)**
	Settlement (mm)	Settlement (mm)	Settlement (mm)
CPTu301	<5	<5	15
CPTu302	<5	<5	10
CPTu303	<5	<5	30

Table 5: LSN for post earthworks CPTs to 10m depth.

Earthquake Magnitude 7.5, Water Depth 2m, 10m Analysis			
CPTs	**SLS Design Event (0.13g)**	**Intermediate Design Event (0.20g)**	**ULS Design Event (0.35g)**
	LSN	*LSN*	*LSN*
CPTu301	0	0	2
CPTu302	0	0	1
CPTu303	0	0	4

Based on these results, it is considered that part of the TC2 area on the northern boundary of Stage E3 is likely to be TC1 equivalent.

6 Building Development

6.1 Technical Category

Geotechnical testing has been carried out as part of the subdivision development. The testing indicates the lots within Stage E3 are likely to perform to TC1 and TC2 equivalent. The technical category classification of the lots is provided in Figure 6 in Appendix A.

6.2 Earthworks on Building Lots

The extent of earthfill on the lots in Stage E3 is shown on Figure 3 in Appendix A.

The fill areas have been constructed using materials and processes that have been randomly measured by independent testing. The testing shows that the placement of filling is generally in accordance with the specification and relevant standards.

6.3 Soil Suitability Criteria

Section 3 of New Zealand Standard NZS 3604:2011 "*Timber Framed Buildings not requiring specific Engineering Design*" provides several criteria for defining foundation soil suitability for lightweight timber or steel framed residential buildings.

Clauses 3.1.3 and 3.3 of NZS 3604:2011 provide criteria for determining strength and suitability of founding soils. Clauses 3.4.1 and 3.4.2 of NZS 3604:2011 discuss depths to competent founding. For purposes of this report, we have interpreted these clauses as meaning that for sound bearing at depths of 200mm to 600mm, standard shallow type foundations can be utilised. For depths greater than this, specific foundation designs could be used or alternatively excavations can be backfilled to the required level with 10MPa site concrete or compacted hardfill. In line with the Client's brief, Aurecon will be undertaking site specific investigations on each residential lot. We will prepare site specific geotechnical reports addressing the foundation requirements on individual building lots. The testing data for the lot specific investigations will be uploaded to the New Zealand Geotechnical Database. For building consent purposes reports prepared for individual lots shall be used.

6.4 Building Considerations

The recommendations in this report shall not be used for individual building consent applications. Site specific investigations in accordance with NZS 3604:2011 are required.

TC1 Foundations

For lots identified as TC1 we consider NZS 3604:2011 type foundations are suitable. We note that at the time of writing this report, the location and structural form of the future dwelling on the lots are unknown and our recommendations relate to NZS3604:2011 type lightweight timber or steel framed residential buildings only.

TC2 Foundations

For lots identified as TC2 we recommend founding dwellings on TC2 type 'enhanced foundation slabs' as per Option 3 or 4 from the MBIE Guidelines (2012) Section 5.1.3 to mitigate the effects of liquefaction induced vertical settlement. Alternatively, in accordance with MBIE Guidelines Section 5.4 a specific design could be undertaken by a suitably qualified chartered professional engineer.

6.5 Future Earthworks

We do not anticipate that future earthworks will be required on the majority of the lots, however should such work be required the following should be noted.

- All earthworks should be carried out in accordance with the Health and Safety at Work Act 2015 and the Worksafe New Zealand Excavation Safety Good Practice Guidelines, 2016.
- Cuts that exceed 0.6m high around any of the house sites must be retained by a suitable retaining wall designed by a Chartered Professional Engineer.
- We recommend that no more than 450mm of fill is placed on the allotment without detailed engineering design.
- Earthworks (cut and fill) should not be undertaken adjacent to any timber retaining wall, if present.
- Any development where excavations greater than 1.2m in depth are proposed, must be subject to specific investigation and design to confirm these works will have no adverse effect on land stability, infrastructure and/or structures on adjacent lots. Excavations near sensitive structures or near boundaries may require geotechnical engineering input even if shallower than 1.2m.

6.6 Construction Observations

The suitability of foundation conditions must be verified at the time of construction. Foundation inspections by a Building Inspector or a Chartered Professional Engineer who are familiar with this report must be carried out to ensure the adequacy of the foundation subgrade prior to the placement of granular hardfill or the construction of foundations.

7 References

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Tonkin and Taylor (2013) *Liquefaction Vulnerability Study*, Tonkin and Taylor Report 52020.0200/v1.0. February 2013. 52 pages and 14 appendices.

Zhang, Robertson, and Brachman, 2002. *Estimating liquefaction-induced ground settlements from CPT for level ground.* Canadian Geotechnical Journal, Vol. 39, pp.1168 – 1180.

8 Explanatory Statement

This report has been prepared for CDL Land New Zealand Limited. It may be made available to others but only in full. As noted above, it shall not be used by any person as a substitute for specific field observations and testing once house sites are confirmed.

This report has been prepared as part of the development of the Prestons Park Stage E3 Subdivision. It has been prepared to provide the following information:

- To report on the management of the earthworks during construction, including compaction standards of fills.
- To report on the extent of ground improvement and the resulting land technical category.

This report does not remove the responsibility of the Owner / Builder / Building Certifier to satisfy themselves of foundation depth and suitability at the finally selected house location.

Subsurface conditions relevant to construction works should be assessed by experienced Contractors and designers who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes. Subsurface conditions, such as groundwater levels, can change over time. This should be borne in mind, particularly if the report is used after a protracted delay or in wet weather.

It is strongly recommended that any plans and specifications prepared by others and relating to the content of this report, or amendments to the original plans and specifications, are reviewed by Aurecon to verify that the intent of our recommendations is properly reflected in the design. During construction we request the opportunity to review our interpretations if the exposed site conditions are significantly different from those inferred in this report.

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