

26 October 2016

GW Woodend Limited
145 Papanui Road
P O Box 36-511
Christchurch 8146

Issued via email to

Attn: Kerry Watson
Email: Kerry@gwlimited.nz

Two Roads Subdivision Stage 1 - Technical Classification Geotechnical Report

1 Introduction

GW Woodend Limited has recently subdivided a 1.7ha area of rural land into 22 residential lots with associated roading and drainage. This development is Stage 1 of the wider Two Roads residential development and located off Petries Road in Woodend.

A geotechnical subdivision assessment was carried out in 2012 prior to the release of the Ministry of Business, Innovation and Employment (MBIE) Guidelines which provides guidance for geotechnical investigation and classification of subdivisions in the Canterbury Region.

In order to provide an updated Technical Category Classification for the Two Roads Stage 1 development, GW Woodend Limited has engaged Aurecon to carry out additional geotechnical testing and confirm the Technical Category Classification of the site on a lot by lot basis using the latest MBIE Guidelines and methodologies.

Our work was carried out as an extension our existing 30 June 2015 agreement with GW Woodend Limited for the Two Road Woodend Subdivision. Our limitations are presented at the end of this report. This report shall be read as a whole.

This Revision 2 report incorporates minor amendments and clarifications, and supersedes all previous revisions.

2 Geotechnical Testing

Three sets of geotechnical testing have been carried out across the site as follows:

- Kirk Roberts (2012) - Seven CPT tests (CPT001 to 007) were carried out by Kirk Roberts in 2012 for the previous site owner as part of the original subdivision assessment. These tests were undertaken to refusal at depths between 4.5m and 14.8mbgl.
- Elliott Sinclair (2016) - Six CPT tests (CPT01 to 06) carried out by Elliott Sinclair in July 2016 at Lots 5, 9 and 20 to confirm the Technical Category Classification of these three lots only. These tests were all carried out to a depth of 10m.
- Aurecon (2016) – 10 CPT tests (CPT101 to 110) were carried out by Aurecon in two phases. McMillan's Drilling Group carried out five CPT tests (CPT101 to 105) on Lots 16-19 and 21 on the 29 September 2016. Phase 2 by Land Test to carried out an additional five CPT tests (CPT106 to 110) on Lots 2, 6, 7, 13 and 15 on 13 October 2016. The tests were extended to effective refusal or a maximum of 10m depth.

We have used all of the CPT data above in our liquefaction and Technical Category Classification assessments and the CPT test locations are shown on the Figure 1 attached.

3 Ground Conditions

Based on the geotechnical testing to date, the site is underlain by variable interbedded layers of silts and sands with some lenses of organic-silt material and an intermediate sandy-gravel / gravelly-sand layer. This gravelly layer becomes sandier and less dense towards the eastern side of the site.

Groundwater was recorded by Elliott Sinclair at 1.7mbgl during their July 2016 assessment. This matches the groundwater level we encountered during the bulk excavation of the ground remediation works on the adjacent Two Roads Stage 2 area and the stand pipe piezometer installed in the southwest corner of Stage 2 on the northern side of Petries Road. Groundwater is expected to vary seasonally or following periods of drought or heavy precipitation.

4 Liquefaction Hazard Assessment

We have undertaken a liquefaction hazard assessment using the method prescribed in the MBIE Guidelines using both the 2016 Aurecon and the 2012 Kirk Roberts CPT data and reviewed the results of the 2016 Elliott Sinclair assessment which uses the same MBIE methodology as our assessment. Additionally, ground damage has been assessed under the various MBIE design level earthquake events using the Liquefaction Severity Number (LSN) methodology detailed in T&T (2013) and using the method of Ishihara (1985).

Accounting for seasonal variation and the measurement of groundwater during a dry winter period, for design purposes we have assumed a groundwater table at 1.5m depth.

The results of our assessment are summarised in Table 1 appended to this letter. Based upon our assessment there is no distinct geological feature causing higher liquefaction induced settlements (i.e. an old infilled river channel etc.), but the variability in the thickness and density of the sand and silty-sandy soils.

Based upon this assessment and review of Elliott Sinclair's assessments for Lots 5, 9 and 20 we make the following comments:

Lots 1 to 7, 9 to 15, 17, 18, 21 and 22

The calculated liquefaction induced ground deformations are within the limits of a Technical Category 2 (TC2) classification, i.e. minor to moderate ground damage could be expected in a future major seismic event.

Lots 8, 16, 19 and 20

Lots 8, 16, 19 and 20 in their natural form were identified as being noncompliant with the requirements of a TC2 classification based on an indexed liquefaction induced reconsolidation settlement criteria. The wider site is underlain by interbedded silty-sandy soils. However the sand content increases in these lots resulting an increase theoretical reconsolidation settlement in the areas with the higher sand content in the surficial soils.

5 Liquefaction Risk Mitigation

The following liquefaction hazard mitigation is recommended for the site:

Lots 1 to 7, 9 to 15, 17, 18, 21 and 22

No additional liquefaction risk mitigation is required for these lots other than an enhanced TC2 type of foundation system.

Lots 8, 16, 19 and 20

In order to ensure a TC2 classification across the entire site and provide additional seismic resilience we recommend that the 1.2m thick geogrid reinforced gravel ground improvement layer is constructed below and extending at least 1m beyond the building footprint of new houses. The ground improvement works have been based upon *Type G1d Shallow Densified Crust Treatment* option presented in Section 15 of the MBIE (2012) Guidelines. With this ground improvement implemented a TC2 foundation system can be used at these sites. An indicative cross section of this capping layer is appended to this report.

6 Foundation Recommendations

The following foundation recommendations are made for residential houses to be built at the site:

Lots 1 to 7, 9 to 15, 17, 18, 21 and 22 – Natural Ground

With Lots 1 to 7, 9 to 15, 17, 18, 21 and 22 TC2 foundation are required as outlined in Section 5 of the MBIE (2012) Guidelines. In accordance with the Guidelines standard shallow lot specific shallow geotechnical investigations are required during the detailed house design to assess the lot specific ground conditions and bearing capacity values. These shallow investigations should be undertaken by the designer of the house foundation to confirm appropriate foundation types and shallow bearing capacities.

Lots 8, 16, 19 and 20 – Capping Layer

With Lots 8, 16, 19 and 20 it is recommended the houses are:

- Founded directly onto the underlying gravel capping layer utilising the 200kPa bearing capacity TC2 type enhanced slab foundations (Options 2 to 4 in Section 5.3.1 of the MBIE Guidelines), or a suspended timber floor (based upon the recommendations in Section 5.3.2 of the MBIE Guidelines / NZS3604:2011) with the design pro rata to use 200kPa bearing capacity.
- To provide the best seismic resilience houses should:
 - Be formed from conventional one to two storey residential construction
 - Single storey only if heavy cladding and roofing is used
 - Up to two storeys if light to medium weight cladding and roofing is used.
 - The structural form should be restricted to timber frame (or light weight cold-rolled steel equivalent).

These foundations systems can be founded directly onto the underlying gravel. With the enhanced raft foundation options all topsoil and silty-sandy soil should be removed below the entire house footprint and if required replaced with compacted hardfill (95% of maximum dry density).

Due to the presence of the geogrid reinforcement within the gravel, and the capping function that the geogrid reinforced gravel raft preforms, penetrations through the geogrid must be avoided. Houses build in these lots should not have basements protruding through the

capping layer. Underfloor hydraulic services and conduits (wastewater, stormwater etc.), where possible should be designed in such a way that they do not penetrate through the geogrid reinforcement either and stay within the upper 900mm of the reinforced gravel layer.

7 References

Aurecon, 2015. *Gladstone Road Subdivision Geotechnical Subdivision Report, Revision 1* - dated 28 August 2015. Aurecon New Zealand Limited, Christchurch, New Zealand.

Boulanger R.W. and Idriss, I.M. (2014). *CPT and SPT Based Liquefaction Triggering Procedures, Center for Geotechnical Modelling*. Report No. UCD/CGM-14/01

Ishihara. (1985). *Stability of natural deposits during earthquakes*. Proceedings, 11th International Conference on Soil Mechanics and Foundation engineering, Vol 1, pp. 321-376.

MBIE, 2012. *Repairing and rebuilding houses affected by the Canterbury earthquakes*. Ministry of Business, Innovation and Employment, Wellington, New Zealand.

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

8 Limitations

We have prepared this report in accordance with the brief as provided. The contents of the report are for the sole use of the Client and no responsibility or liability will be accepted to any third party. Data or opinions contained within the report may not be used in other contexts or for any other purposes without our prior review and agreement.

The recommendations in this report are based on data collected at specific locations and by using suitable investigation techniques. Only a finite amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it must be appreciated that actual conditions could vary from the assumed model.

Subsurface conditions relevant to construction works should be assessed by contractors 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.

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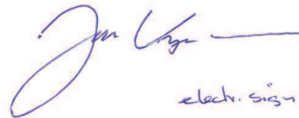
This conclusions in this report draws on investigations, analysis and conclusions from various investigations stages and numerous reports. For specific details please refer to the above mentioned references or contact the writers.

If you have any queries regarding the content of this letter, please do not hesitate to contact the undersigned.

Yours sincerely



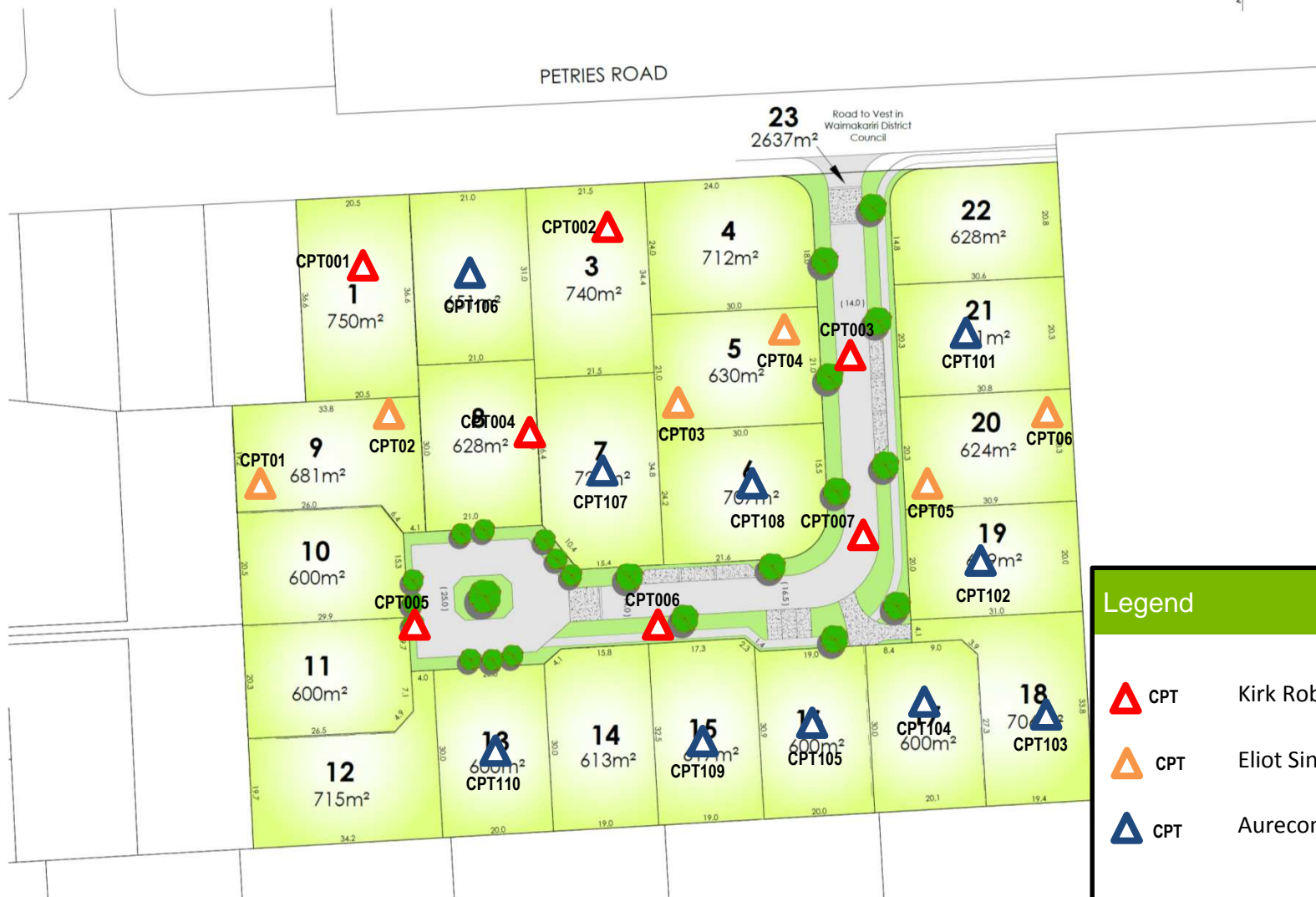
Tim Mitchell
Geotechnical Engineer



Dr Jan Kupec
Technical Director – Ground Engineering

Enc:

- Figure 1 – CPT Test Location Plan
- Figure 2 – Geogrid Capping Layer Detail
- Table 1 – Liquefaction Assessment Results



Legend	
	CPT Kirk Roberts 2012 CPT
	CPT Eliot Sinclair 2016 CPTu
	CPT Aurecon 2016 CPTu

CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

TITLE

CPT TEST LOCATION PLAN

NTS

A4

BY

BACKGROUND IMAGE FROM DAVIE LOVELL SMITH
DRAWING NO. C17796

T. MITCHELL

APPROVED

D. MAHONEY

DATE

26 OCTOBER 2016

FIGURE No.

PROJECT

WBS

TYPE

DISC

NUMBER

REV

FIGURE

FIGURE 1

PROJECT

TWO ROAD SUBDIVISION

248126

001

FIG

TRA

01

B



REINFORCED GRAVEL RAFT BACKFILL NOTES

1. COMPACTED REINFORCED GRAVEL RAFT BACKFILL MATERIAL SHALL BE CAP40, CAP65 OR CRUSHED RECYCLED CONCRETE TO AP65 GRADING WITH AT LEAST TWO BROKEN FACES (NOT PIT RUN/RIVER RUN) COMPACTED TO 95% MAXIMUM DRY DENSITY AT ±2% OF OPTIMUM WATER CONTENT. FILL GRADING SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
2. THE CONTRACTOR SHALL PROVIDE THE ENGINEER AT LEAST 48 HOURS NOTICE PRIOR TO COMMENCEMENT OF FILLING A 20kg REPRESENTATIVE SAMPLE OF THE CAP40 OR CAP 65 MATERIAL TO BE USED. THE CONTRACTOR SHALL ALSO PROVIDE PARTICLE SIZE DISTRIBUTION TEST, COMPACTION TEST AND BROKEN FACE PERCENTAGE TEST RESULTS FROM A REPRESENTATIVE SAMPLE TESTED IN AN INDEPENDENT LABORATORY. THE TEST RESULTS SHALL BE PROVIDED PRIOR TO THE PLACEMENT OF ANY FILL ON SITE. THE TEST SAMPLE SHALL BE TAKEN FROM SITE OR QUARRY STOCKPILE WITHIN 30 DAYS OF SITE WORKS.
3. A MINIMUM LOOSE THICKNESS OF 150mm OF FILL SHALL BE PLACED OVER GEOGRIDS PRIOR TO OPERATING TRACKED CONSTRUCTION EQUIPMENT OVER THEM. CARE SHOULD BE TAKEN NOT TO OVERWORK THE SUBGRADE OR TO CAUSE WEAVING WHEN COMPACTING INITIAL LAYER OF GRAVEL.
4. PLACEMENT AND COMPACTION OF THE FILL SHALL BE COMPLETED IN STAGES BY PLACING LAYERS OF COMPACTED GRAVEL, FOLLOWED CLOSELY BY THE PLACEMENT OF GEOGRIDS. THE FILL SHALL BE COMPACTED TO 95% OF MODIFIED COMPACTION IN ACCORDANCE WITH NZS 4402:1986, TEST 4.1.3. TESTING IS REQUIRED ON EACH LIFT OF AGGREGATE.
5. HARDFILL SHALL BE PLACED IN LAYERS NOT EXCEEDING 200mm MAXIMUM THICKNESS.
6. THE GRAVEL SHALL HAVE A GRADING THAT FALLS WITHIN CCC CIVIL ENGINEERING STANDARD SPECIFICATION GRADING CURVES FOR "CCC AP65" OR "CCC STABILISED AP40" WHEN TESTED IN ACCORDANCE WITH NZS 4407:1991 TEST 3.8.1 (WET SIEVING).
7. THE CRUSHED RECYCLED CONCRETE SHALL HAVE A GRADING THAT FALLS WITHIN THE CCC CIVIL ENGINEERING STANDARD SPECIFICATION GRADING CURVES WHEN TESTED IN ACCORDANCE WITH NZS 4407:1991 TEST 3.8.1 (WET SIEVING).

EXCAVATION AND FOUNDATION REQUIREMENTS

1. EXCAVATION IS REQUIRED FOR CONSTRUCTION OF THE GRAVEL RAFT. THE DETAILS PROVIDED ON THE DRAWINGS SHOW NET FINISHED CONSTRUCTION PROFILES. THE CONTRACTOR SHALL ESTABLISH THE METHODS OF EXCAVATION NEEDED, THE PLANT REQUIREMENT AND GENERAL SEQUENCING OF CONSTRUCTION TO MAINTAIN A STABLE AND SAFE CONDITION INCLUDING SAFE SLOPES.
2. ALL TEMPORARY EXCAVATIONS AND CONSTRUCTION ACTIVITY SHALL COMPLY WITH THE OCCUPATIONAL SAFETY AND HEALTH GUIDELINES.
3. ANY SOFT GROUND, LOW STRENGTH OR ORGANIC MATERIAL ENCOUNTERED AT SUBGRADE LEVEL SHALL BE REMOVED AND REPLACED WITH COMPACTED GRANULAR FILL REFER TO THE GEOTECHNICAL REPORT FOR ANTICIPATED GROUND CONDITIONS.
4. THE CONTRACTOR SHALL TAKE APPROPRIATE MEASURES TO KEEP EXCAVATIONS DRY AND STABLE UNTIL CONSTRUCTION OF GRANULAR BACKFILL IS COMPLETE.
5. WHERE MATERIAL IS USED AS ENGINEERED BACKFILL BENEATH GRAVEL RAFT, THE BACKFILL SHALL BE COMPACTED TO 95% OF MAXIMUM DRY DENSITY BASED ON MODIFIED COMPACTION (NZS4402:1986, TEST 4.1.3)

GEOGRID REINFORCEMENT

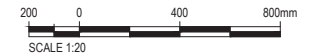
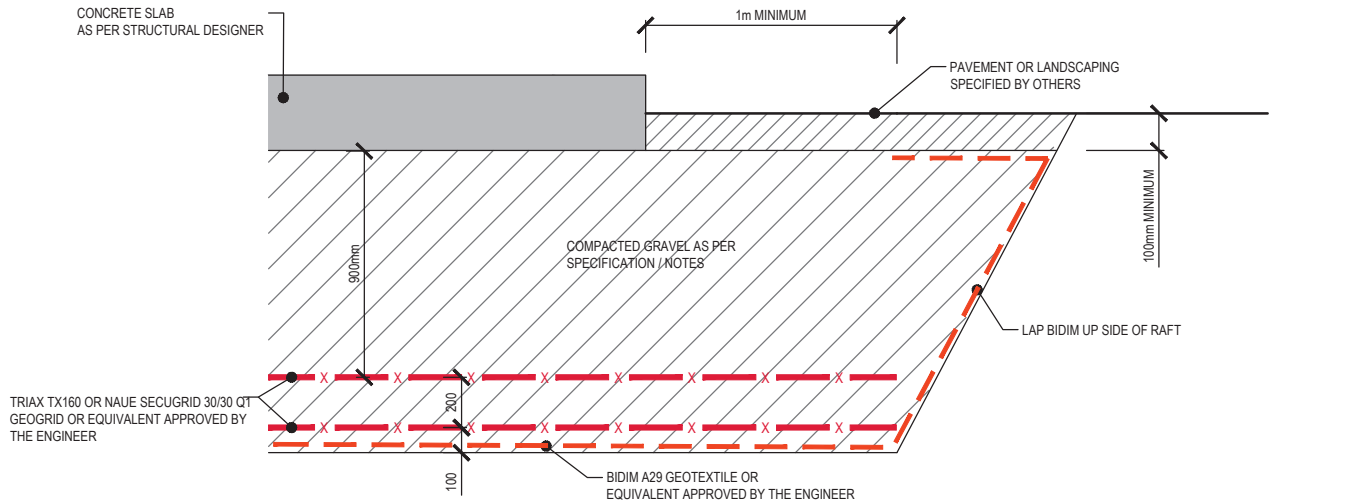
1. REINFORCING GEOGRID TO BE TRIAX TX160 OR NAUE SECUGRID 30/30 Q1 GEOGRID OR EQUIVALENT APPROVED BY THE ENGINEER.
2. LAYERS OF GEOGRID SHALL BE LAID IN ALTERNATING PERPENDICULAR ORIENTATION (i.e. EACH LAYER OF GEOGRID SHALL BE LAID PERPENDICULAR TO THE LAYER BELOW).
3. GEOGRIDS SHALL BE LAID TO THE MANUFACTURER'S SPECIFICATION WITH MIN. LAP OF 500mm UNLESS CONFIRMED OTHERWISE BY MANUFACTURER.
4. THE CONTRACTOR SHALL PROVIDE ALL NECESSARY QA/QC DOCUMENTATION FOR ALL GEOGRIDS INCORPORATED INTO PERMANENT WORKS.
5. ALL GEOTEXTILE AND GEOGRIDS SHALL BE HANDLED AND STORED IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATION AND GOOD PRACTICE. ALL GEOTEXTILES SHALL BE PROTECTED FROM DEGRADATION BY UV LIGHT.
6. ALL GEOTEXTILES AND GEOGRIDS SHALL BE LAID ON A FLAT SURFACE AND APPROPRIATELY TENSIONED PRIOR TO PLACEMENT OF FILL. THE GEOTEXTILE AND GEOGRID SHALL REMAIN TENSIONED DURING GRAVEL PLACEMENT AND COMPACTION.

SERVICES

1. ALL SERVICES SHALL BE AT LEAST 100mm ABOVE GEOGRIDS.

DEWATERING

1. IF GROUNDWATER IS ENCOUNTERED IN THE EXCAVATION THE GEOTECHNICAL ENGINEER SHALL BE CONTACTED TO UNDERTAKE AN INSPECTION BEFORE ANY DEWATERING IS UNDERTAKEN.
2. ANY DEWATERING POINTS SHALL BE LOCATED OUTSIDE THE BUILDING FOOTPRINT. DEWATERING METHOD, EITHER WELL POINTS OR SUMP PUMP, TO BE CONFIRMED BY CONTRACTOR AND AGREED WITH GEOTECHNICAL ENGINEER.



File name: \\AURECON\INFO\SHARES\NCH\PROJECTS\248126\CADD\DRG\CG-01\248126-000.DWG; CG-01.A.DWG
 Plot Date: 26/10/2016 4:22:51 p.m. Office: NZCHD



REV	DATE	REVISION DETAILS	APPROVED
A	20/10/2016	ISSUE TO CLIENT	J KUPEC
B	26/10/2016	ISSUE TO CLIENT - MINOR AMENDMENTS	J KUPEC

SCALE	AS SHOWN
SIZE	A3
DRAWN	T MITCHELL
DESIGNED	D MAHONEY
CHECKED	J KUPEC

NOT FOR CONSTRUCTION	
APPROVED	DATE
J KUPEC	26/10/2016

PROJECT	TWO ROADS STAGE 1				
TITLE	TC3 GRAVEL CAPPING LAYER				
DRAWING No.	PROJECT No.	WBS	TYPE	DISC	NUMBER
248126	248126	0000	DRG	CG	0001

Table 1 – Liquefaction Hazards Assessment Results

	Test	Test Depth	SLS-a			SLS-b			ULS			Technical Category
			Settlement	Surface Expression		Settlement	Surface Expression		Settlement	Surface Expression		
				Indexed	Ishihara		LSN	Indexed		Ishihara	LSN	
Kirk Roberts 2012	CPT001	10.5m	1mm	No	1	4mm	No	1	17mm	No	9	TC1
	CPT002	14m	7mm	No	3	18mm	No	2	46mm	No	16	TC2
	CPT003	10m	36mm	No	12	60mm	No	10	104mm	Yes	33	TC3
	CPT004	14.8m	53mm	No	18	81mm	Yes	17	94mm	Yes	25	TC3
	CPT005	5m	2mm	No	2	8mm	No	1	28mm	No	13	TC2*
	CPT006	5m	1mm	No	1	5mm	No	1	8mm	No	3	TC2*
	CPT007	7m	10mm	No	7	6mm	No	6	39mm	No	13	TC2*
Aurecon 2016	CPT101	10m	6mm	No	5	21mm	No	4	57mm	Yes	23	TC2
	CPT102	10m	45mm	No	22	89mm	Yes	19	112mm	Yes	36	TC3
	CPT103	10m	20mm	No	10	42mm	No	8	78mm	Yes	26	TC2
	CPT104	10m	25mm	No	13	51mm	No	11	94mm	Yes	33	TC2
	CPT105	10m	50mm	No	13	70mm	No	12	107mm	Poss	31	TC3
Aurecon 2016	CPT106	10m	17mm	No	5	28mm	No	4	54mm	Poss	16	TC2
	CPT107	10m	14mm	No	7	34mm	No	5	68mm	Yes	22	TC2
	CPT108	10m	24mm	No	6	47mm	No	5	100mm	Yes	29	TC2
	CPT109	10m	15mm	No	10	37mm	No	9	71mm	Yes	25	TC2
	CPT110	10m	20mm	No	7	33mm	No	6	56mm	Yes	18	TC2
Elliott Sinclair 2016	CPT01	10m	6mm		2	45mm		6	47mm		14	TC2
	CPT02	10m	38mm		9	66mm		20	90mm		28	TC2/3**
	CPT03	10m	5mm		2	22mm		11	45mm		19	TC2
	CPT04	10m	40mm		9	64mm		18	85mm		26	TC2/3**
	CPT05	10m	33mm		7	64mm		17	82mm		21	TC2/3
	CPT06	10m	55mm		11	87mm		23	107mm		29	TC3

Notes:

* Due to the CPT refusing on very dense sandy-gravelly material and the limited settlements in the upper 5-7m these tests have been assessed as TC2

** Classified TC2 equivalent by Elliott Sinclair due to depth of liquefiable layers.