LATERAL SPREADING ASSESSMENT

Rangitikei Line & Flygers Line, Palmerston North

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Revision:	Rev0
Prepared For:	Flygers Investment Group Limited
Date of Issue:	19 November 2020

Phone +64 9 216 7330
Mobile +64 27 557 7234
Email njacka@tge.co.nz

27D Waipareira Ave, Henderson 0610
PO Box 27294, Glen Eden 0604
Auckland, New Zealand

WWW.TOTALGROUNDENGINEERING.COM

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Executive Summary

Total Ground Engineering Ltd (TGE) have been engaged to carry out supplementary investigations and analysis to support a plan change for the proposed residential subdivision at the intersection of Rangitikei Line and Flygers Line Roads, Palmerston North.

Riley Consultants (Riley)carried out detailed investigations and analyses which identified that the site was subject to liquefaction under the ultimate limit state seismic loads. The surface effects of the liquefaction were considered minor and foundation recommendations were made. However, there was some uncertainty about the depth of groundwater and the subsequent risk and possible extent of lateral spreading and Riley recommended further investigation and analysis of the lateral spreading issue.

TGE have carried out supplementary investigations which confirm the depth of groundwater adopted by Riley Consultants and their analysis of liquefaction triggering and induced settlements. We have analysed the extent of lateral spreading adopting accepted liquefied strength ratios and concluded that lateral spreading is confined to a 55 m wide zone from the centreline of the proposed watercourse. Three options are proposed that prevent lateral spreading from affecting subdivided lots.

This report should be considered supplementary to the original Riley Consultants report.

1. Introduction

Total Ground Engineering Ltd (TGE) have been engaged by Flygers Investment Group Limited (the client) to carry out a supplementary geotechnical investigations and analysis of lateral spreading at Flygers Line Road, Palmerston North. The location of the site is shown in Figure 1.

This report provides supplementary analysis recommended in the Geotechnical Assessment by Riley Consultants (Riley ref 170672-D) prepared to support the proposed re-zoning and residential subdivision of the site. The proposed subdivision comprises realigning the existing drainage system and formation of a multi-lot subdivision. A proposed scheme plan has been provided and is attached in Appendix A.

Figure 1, Locality Plan

The Riley report investigated the geotechnical risks at the site. Riley carried out detailed investigations including cone penetrometer testing to evaluate liquefaction risk. Their analysis indicated that liquefaction was likely under the ultimate limit state loads but the surface damage and likely differential settlement was minor. They concluded that the site was suitable for residential development with provided additional investigation and analysis of lateral spreading was undertaken which would clarify the foundation types which could be adopted across the subdivision (TC2 or TC3).

We have now carried out the additional investigation and analyses to confirm the extent of lateral spreading. We present three options allowing the residential lots to be isolated from the effects of lateral spreading under the ULS event.

This report should be read in conjunction with the Riley Report.

2. Site Description

The site is legally described as Lot 2 DP 389924 and is located approximately 2 km north of the Palmerston North Central Business District. Residential housing and farmland boarder the site with access via the western side of State Highway three, Rangatikei Line.

Currently, the site is used for cropping as shown in Figure 2. The site is near-level to gently-sloping toward the southeast with several natural and manmade shallow drainage channels transecting the site.

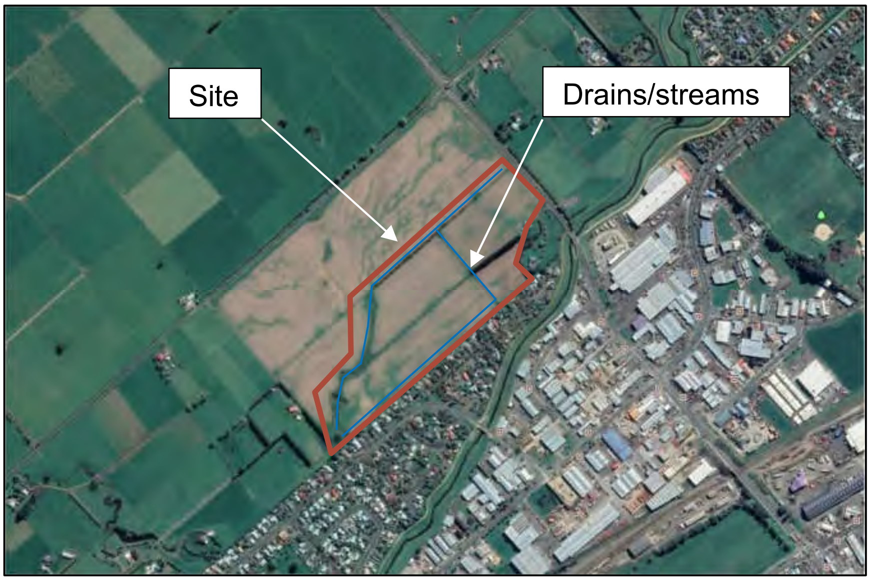


Figure 2, Google Earth image showing approximate extend of development and drainage systems

3. Site geology and regional liquefaction risk

A detailed description of the site geology and subsoil conditions is contained in the Riley Report. We summarise the geological conditions below, however, for a full description of the ground conditions the reader should refer to the Riley Report.

Reference has been made to the New Zealand Geology Web Map on the GNS website, http://data.gns.cri.nz/geology/, accessed 10th November 2020.

The site geology has been mapped as Holocene aged River Deposits (coloured light yellow in Figure 3) bounded to the east of the site by Late Pleistocene river deposits (coloured yellow in Figure 3) These Alluvial Deposits are described as Alluvial gravel, sand, silt, mud and clay with local peat, including modern riverbeds.

Figure 3, Snapshot of NZ Geological Map

GNS Science produced a report titled "*Assessment of liquefaction and related ground failure hazards in Palmerston North, New Zealand*" (GNS Report 2011/108, July 2011) which identifies the site within a broad area encompassing much of suburban Palmerston North in a zone at moderate risk of liquefaction.

4. Investigations and ground conditions

4.1 Original Investigations by Riley

The site was investigated by Riley Consultants Ltd between June 2018 and January 2019 comprising twelve CPTs to refusal at a maximum depth of 6.5m. Three sonic machine boreholes to depths ranging between 10.0m and 15.0m were carried out to investigate the dense gravels below the Holocene sediments.

Fourteen shallow hand augered boreholes where carried out as part of their ground contamination investigation.

The Riley investigation encountered groundwater at levels varying between 0.8m and 4.2m and referred to the GNS report which indicated a groundwater depth of 3m to 4m. For analysis of liquefaction, Riley adopted a conservative estimate of 1m depth.

4.2 Supplementary Investigations by TGE

Liquefaction assessment is sensitive to groundwater level. In order to confirm the groundwater levels, TGE carried out a field investigation on 23 September 2020 comprising the following:

- Three hand augured boreholes and associated in-situ soil testing (i.e. vane shear strength and scala penetrometer testing); and
- Installation of three piezometers for the purpose of ground water monitoring.

The location of the Riley boreholes (black icons) and the TGE hand augers (orange icons) and the location of developed cross sections are shown in Figure 4 extracted from the Test Location Plan attached in Appendix B.

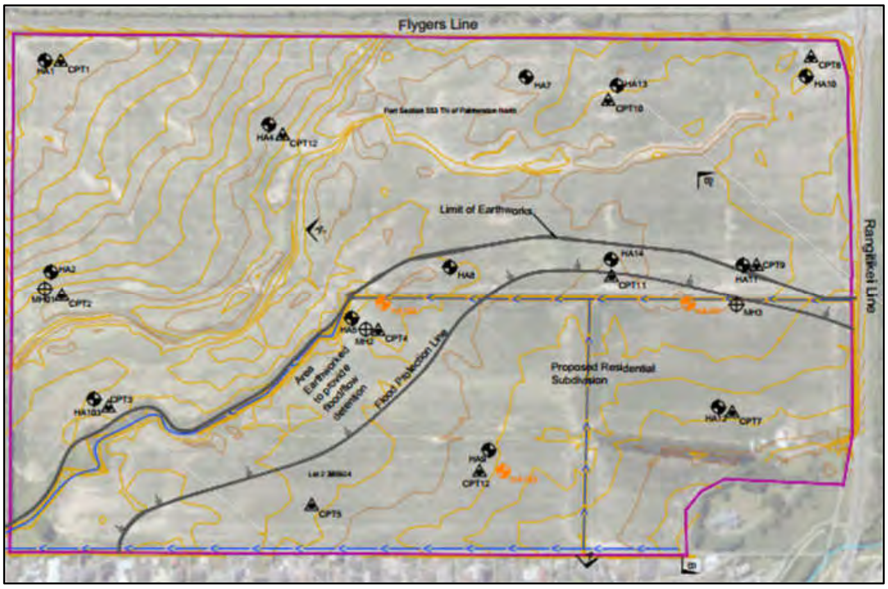


Figure 4, TGE test locations shown as orange icons

Soil conditions were logged by a TGE Engineering Geologist, in accordance with the New Zealand Geotechnical Society's, *Guideline for the Description of Soil and Rock for Engineering Purposes* (2005).

In-situ shear vane tests were carried out at 0.5 m intervals to measure the undrained shear strength of fine-grained cohesive materials. Vane shear tests were carried out in accordance with the New Zealand Geotechnical Society Guideline for handheld shear vane test, (2001). Peak and remoulded shear strength values shown on field logs have been factored in terms of BS1377.

Dynamic Cone Penetrometer (Scala) testing was carried out at selected depths in the boreholes to determine soil density. Scala testing was carried out in accordance with NZS 4402:1988, Test 6.5.2, Dynamic Cone Penetrometer.

Handauger borelogs and scala penetrometer logs are attached in Appendix B.

4.3 Ground Conditions

The subsurface conditions encountered during our field investigation generally comprised a layer of Holocene aged river deposits being stiff to very stiff silts with subordinate fractions of sands and clays interbedded with lenses of medium dense to dense sands, overlying dense to very dense river gravels at depth, in general accordance with the mapped geology and previous field investigations. The geological profile is shown in Figure 5 extracted from cross section A-A' attached in Appendix C.

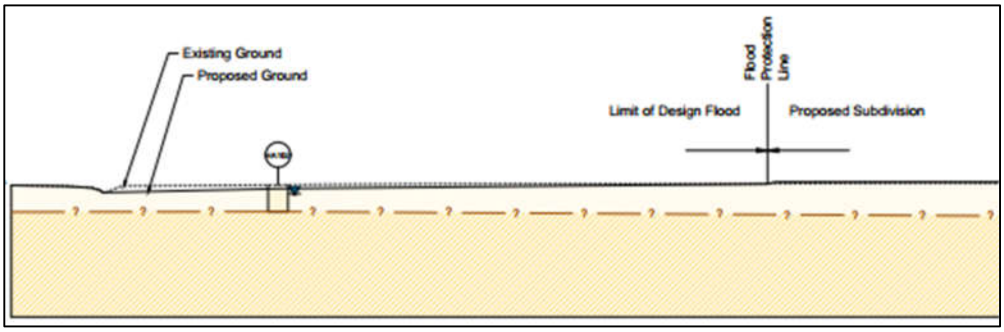


Figure 5, Cross section A-A' showing approx 4.0m-5.0m of silts and sands overlying dense river gravels

A summary of the geological profile is provided below;

Topsoil Topsoil was encountered to a depth of 0.2 m to 0.3 m.

Holocene aged River Deposits Alluvial soils were encountered below topsoil to a depth of 4.0m to 5.0m. These Alluvial soils comprised of stiff to very stiff silts with subordinate fractions of sand and clays, interbedded with layers of fine to medium silty sand to sand. The fine-grained alluvial soils are generally described as slightly to moderately plastic and moist to saturated. Peak vane shear strengths ranged between 69 kPa to greater than 200 kPa within the fine grain cohesive material while Scala penetrometer testing in the non-cohesive material returned values ranging between 3 blows to 29 blows per 100mm penetration, and where generally above 4 blows per 100mm penetration**.**

Scala Penetrometer testing conducted from the base of the hand augers encountered effective refusal at depths between 3.8 m and 5.6 m, inferred to be the contact with dense river gravels at depth.

Groundwater Groundwater was encountered in the augered boreholes on the day of drilling and subsequently measured in the piezometers ranging between 0.85 m and 1.3 m depth.

5. Lateral Spreading Analysis

5.1 Liquefaction

Riley Consultants classified the site as Class D (deep soil site) resulting in a ULS peak ground acceleration of 0.34g. They went on to analyse the risk of liquefaction and concluded that layers of saturated sands and silts in the upper layer of alluvium would liquefy in the ULS event.

Liquefaction Severity Numbers were calculated indicating moderate expression of liquefaction at the surface with sand boils likely and minor differential settlement of structures. Riley considered that residential dwellings with foundations in accordance with MBIE's TC2 category would be appropriate.

Riley used empirical methods to evaluate lateral spread which yielded set-back distances of 100 m from the water-course. Lesser set-backs were considered possible but were contingent on elevating the dwelling foundations to TC3 category. The conclusion was that more in-depth lateral spreading analysis should be carried out.

We concur with the liquefaction analysis methodology and results obtained by Riley and generally concur with their conclusions. We have completed the additional investigations and describe our in-depth analysis of lateral spreading below.

5.2 Lateral Spreading

We have analysed the risk of lateral spread after the ULS event using the slope stability package Slope/w. We have assumed that the upper layer of Holocene alluvial sediments, beneath a 1 m deep groundwater level, liquefies. Olson and Stark (2002) proposed a liquefied strength ratio s_u/σ'_{vo} ranging from 0.05 to 0.12 (Figure 6) with an average of 0.09. For analysis we have conservatively adopted a ratio of $s_u/\sigma'_{vo} = 0.075$.

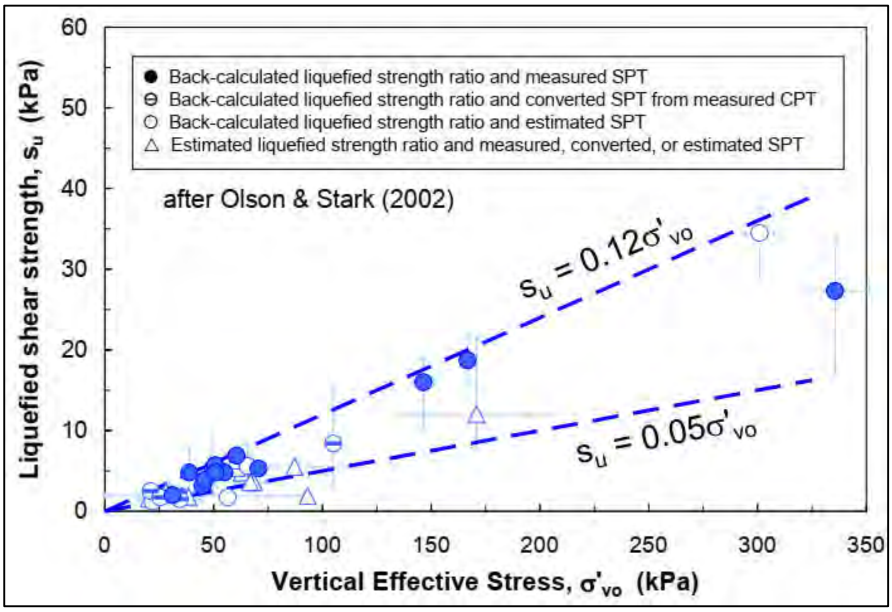
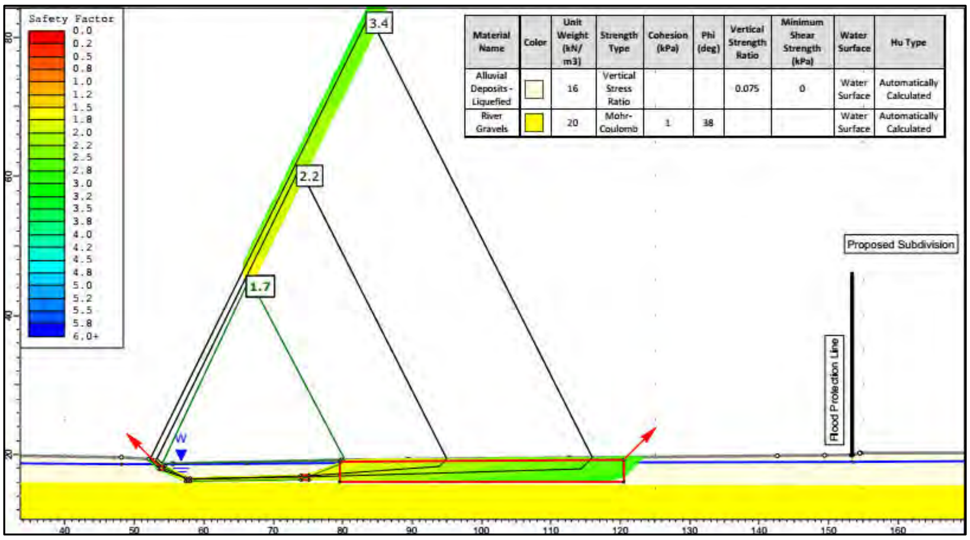


Figure 6. Liquefied strength ratio from back-analysed flow failures.

Figure 7 shows the factor of safety for shallow laterally spreading failure surfaces through the widest section of the proposed channel on Section A-A'.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type
Alluvial Deposits - Liquefied		16	Vertical Stress Ratio			0.075	0	Water Surface	Automatically Calculated
River Gravels		20	Mohr-Coulomb	1	38			Water Surface	Automatically Calculated

Figure 7. Section A-A'. Factor of safety for lateral spreading.

Analysis shows that at Section A-A' where the proposed overland flow channel is broad, and the gradient of the surface is shallow, the factor of safety for lateral spreading exceeds 1.0 and there is little risk of lateral spreading, especially beyond the flood protection line.

At Section B-B' the overland flow channel narrows with a consequently steeper gradient. Figure 8 indicates that lateral spreading would encroach beyond the flood protection line into the subdivision. Adopting a factor of safety of 1.2 as the minimum criteria under ULS seismic loading would result in a building restriction line being imposed within the propose subdivision. We refer to this as Option 1 whereby the lots would need to be reconfigured with a likely reduction in the number of lots, all remaining outside the building restriction line.

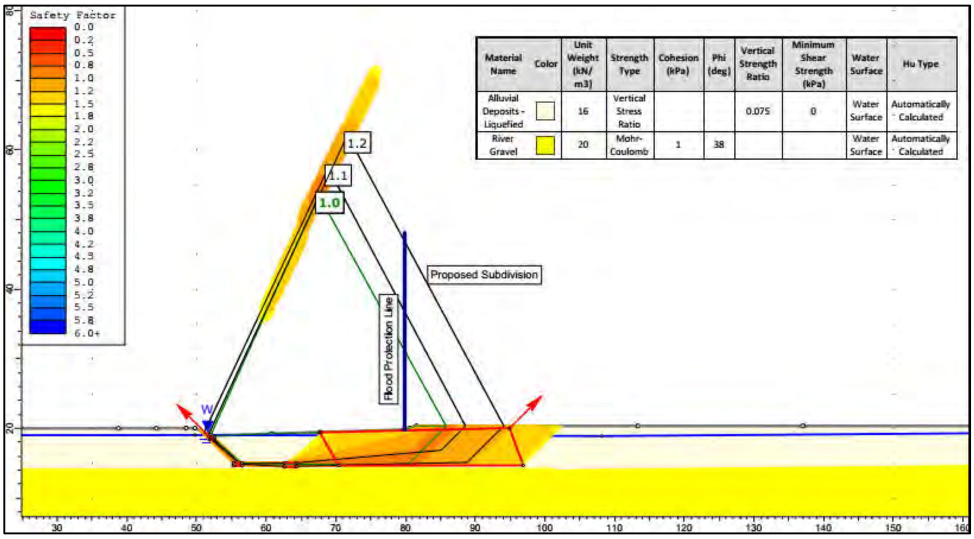


Figure 8. Section B-B'. Lateral Spreading; Option 1.

In order for potential lateral spreading to remain within the flood protection zone, we have widened the overland flow path, reducing the slope gradient until the slip-surface associated with the minimum factor of safety is within the flood zone. Figure 9 shows the results of this scenario which we refer to as Option 2.

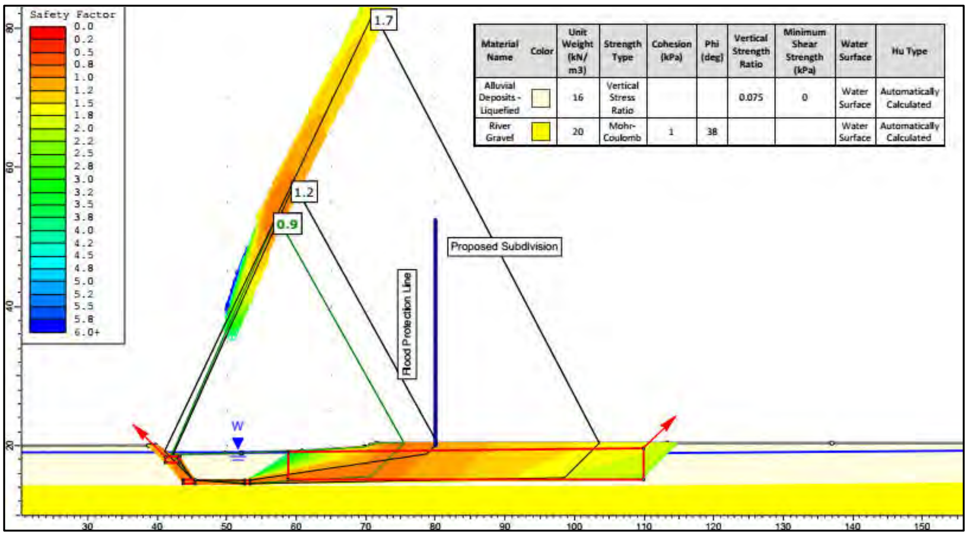


Figure 9. Section B-B'. Lateral Spreading; Option 2.

For Option 3, we have re-analysed the proposed narrow floodpath, with an 8m wide zone of “improved” soil which remains un-liquefied. The improved zone is obscured by the green shaded zone of analysis results shown in Figure 10. The analysis demonstrates that the zone of improved material acts as a shear-key preventing lateral spreading extending into the proposed subdivision.

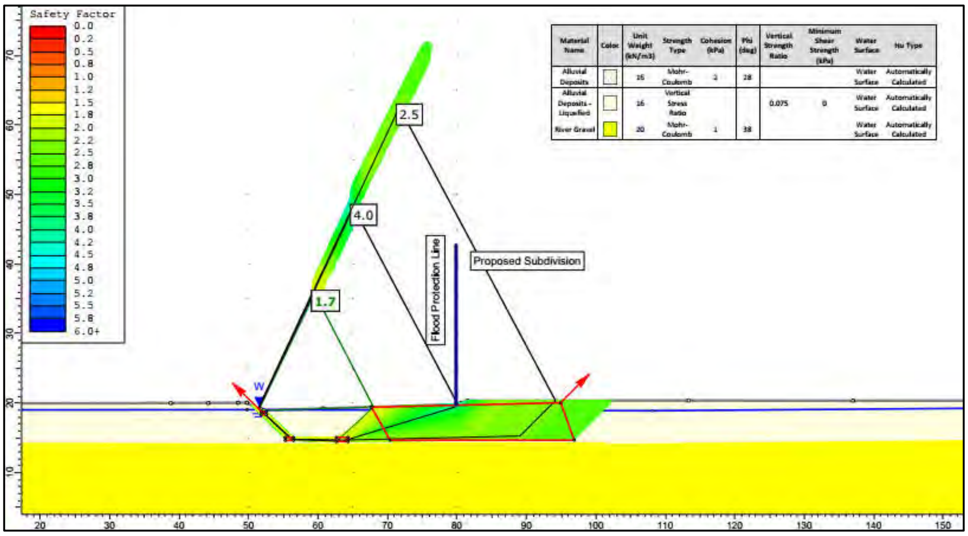


Figure 10. Section B-B'. Lateral Spreading; Option 3.

Options for improving the soil to provide the shear key against lateral spreading are discussed below.

In summary, analysis shows that lateral spreading under the ULS seismic loading encroaches into the proposed subdivision where the overland flow channel becomes narrow to the northeast of the site. We propose three options for mitigating this risk below.

6. Conclusions and Recommendations

Riley Consultants concluded that shallow subsoils at the site could liquefy to depths of approximately 6m under the ULS seismic loading. The effects at the surface would be minor and the site would be equivalent to the TC2 land category adopted by MBIE in Christchurch. However, additional analysis of lateral spreading was recommended.

Our investigations confirm the groundwater levels assumed by Riley Consultants and our analysis indicates that under the current earthworks scheme, Option 1 would comprise a building exclusion line, 55 m from the limit of earthworks as shown in Figure 11.

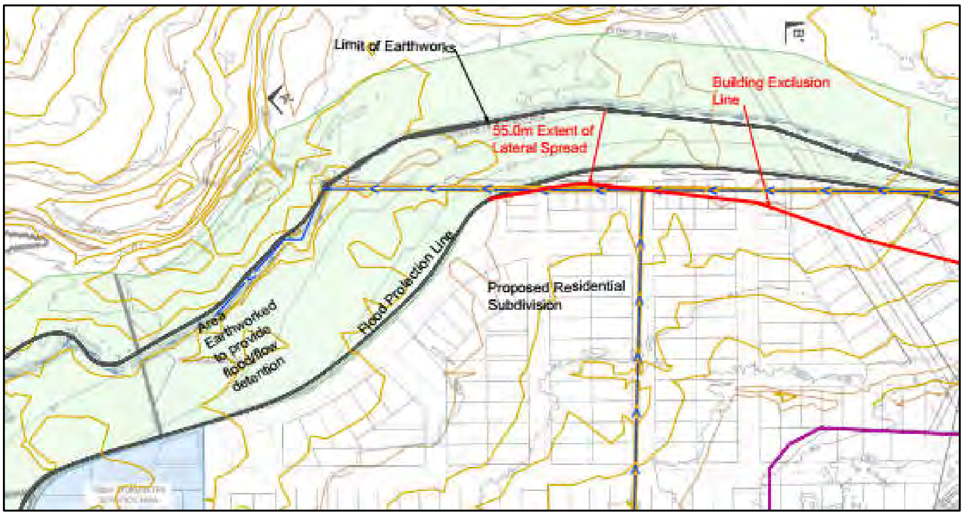


Figure 11. Option 1. Impose Building Restriction Line.

Option 2 would comprise widening the overland flow channel to a minimum width of 55 m from the flood protection line as shown in Figure 12. This would allow the current lot layout to be maintained.

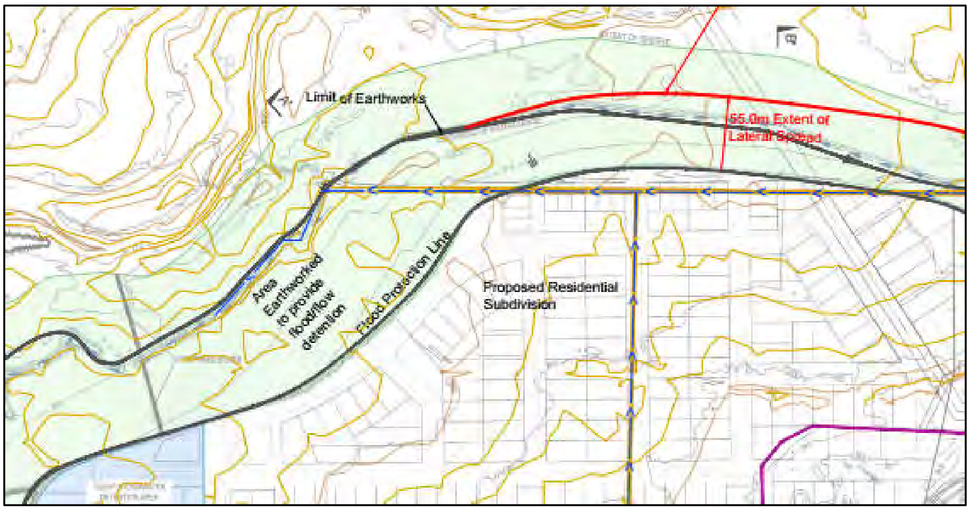


Figure 12. Option 2. Translate extent of earthworks. Maintain lot arrangement.

Figure 13 shows Option 3 comprising an 8 m wide band of ground improvement which would isolate the proposed subdivision from lateral spread by acting as a shear key.

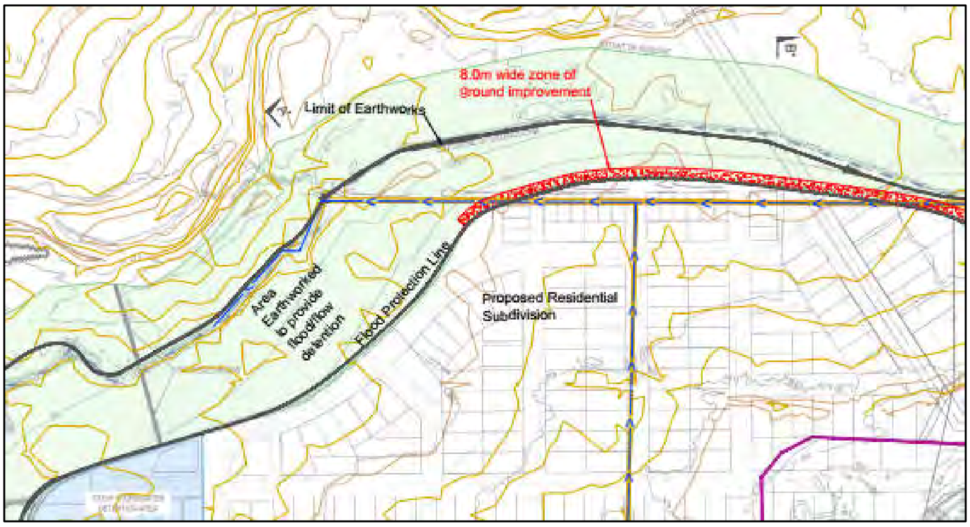


Figure 13. Install ground improvement. Maintain lot arrangement.

For Option 3, there are several methods which could be adopted as follows:

1. Excavate and replace the sediments with river gravels. Temporary stability of the saturated alluvial soils could result in a wide excavation and some excavation trials would be prudent.
2. Dynamic compaction. Densifying the materials could be achieved by heavy dynamic compaction. Square or triangular "rollers" have been used successfully, but trials and testing would be required to demonstrate the effectiveness of this method through the entire column of alluvial sands and silts. There is a high degree of uncertainty attached to this option.
3. Stone columns. Installing stone columns through the alluvial sands and silts, would provide a high-shear composite zone with capacity for high pore pressures to be rapidly relieved by the stone columns.

We trust this report meets your requirements. Please contact the undersigned if you have any questions.

Yours Faithfully

Prepared by:

Jared Healey

Engineering Geologist

BSc(Geology), PGDipSci(Earth Science)

Total Ground Engineering

Reviewed and Authorised by:

Neil Jacka

Principal Geotechnical Engineer

CMEngNZ, CPEng

Total Ground Engineering

Limitation

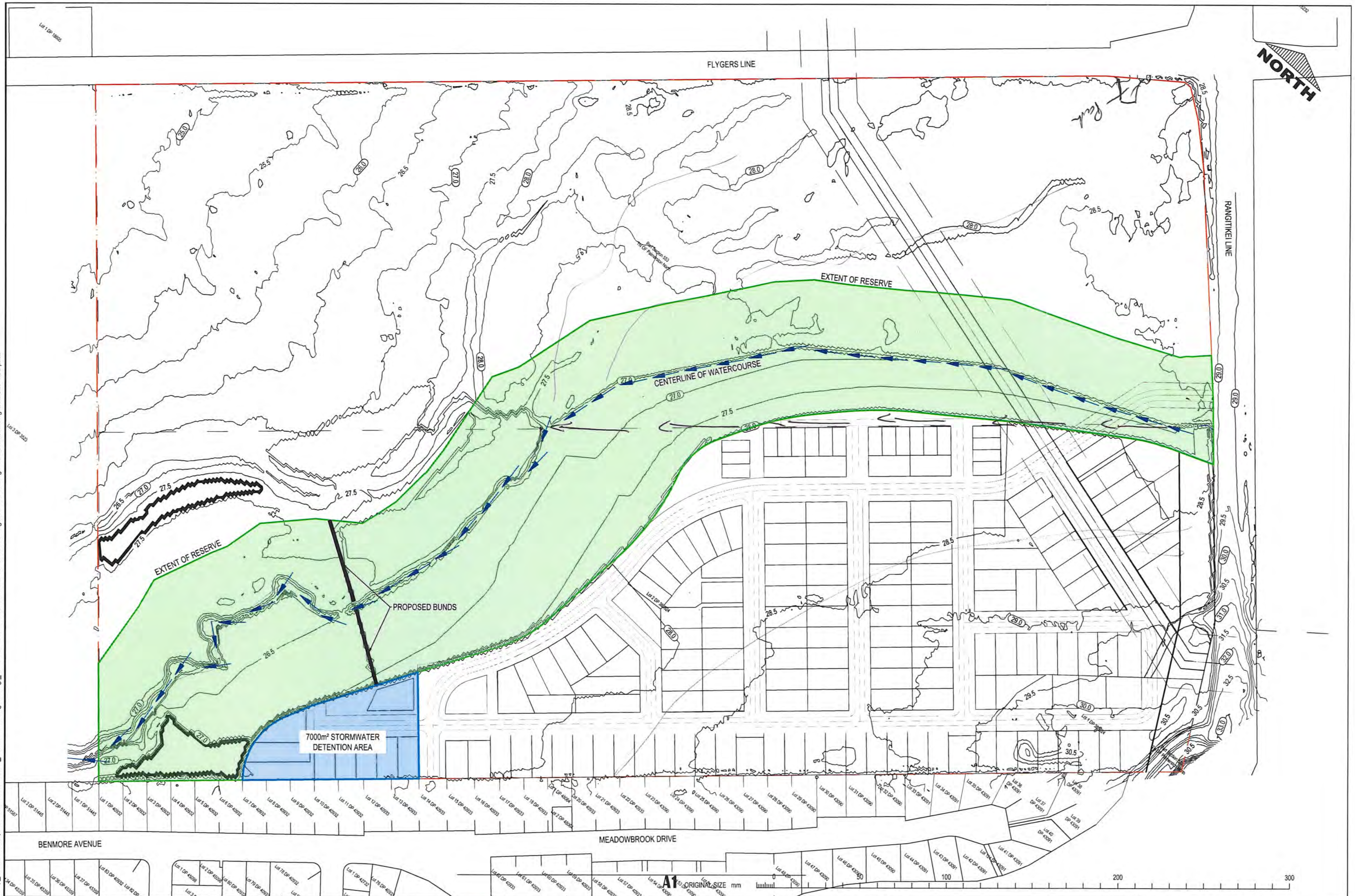
This report has been prepared by Total Ground Engineering for our client's use in accordance with the proposed development plans and agreed scope of work. Any use or reliance by any other person, to which Total Ground Engineering has not given its prior written consent, is at that person's own risk.

The findings, recommendations and comments presented in this report are based on common methods of site investigation. The site investigation has been undertaken at discrete locations and ground conditions away from these locations could vary.

Appendices

Appendix A. Reference Information
Appendix B. Investigation Plan and Borelogs
Appendix C. Geological Sections
Appendix D. Analysis Outputs
Appendix E. Remediation Options

Appendix A
Reference Information



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Rev	Details	Drawn	Date
P1	ISSUED FOR APPROVAL	JWW	08/09/20

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The Contractor shall check all dimensions on site.

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EARTHWORKS DESIGN
FLYGERS LINE
PALMERSTON NORTH

FINISHED GROUND CONTOURS
HIGGINS GROUP

	Initials	Date
Surveyed		
Designed	KBJ	09/20
Drawn	JWW	09/20
Checked	KBJ	09/20
Approved		

DO NOT SCALE, If in doubt ask for dimensions

Scales A1	Scales A3	Job No.
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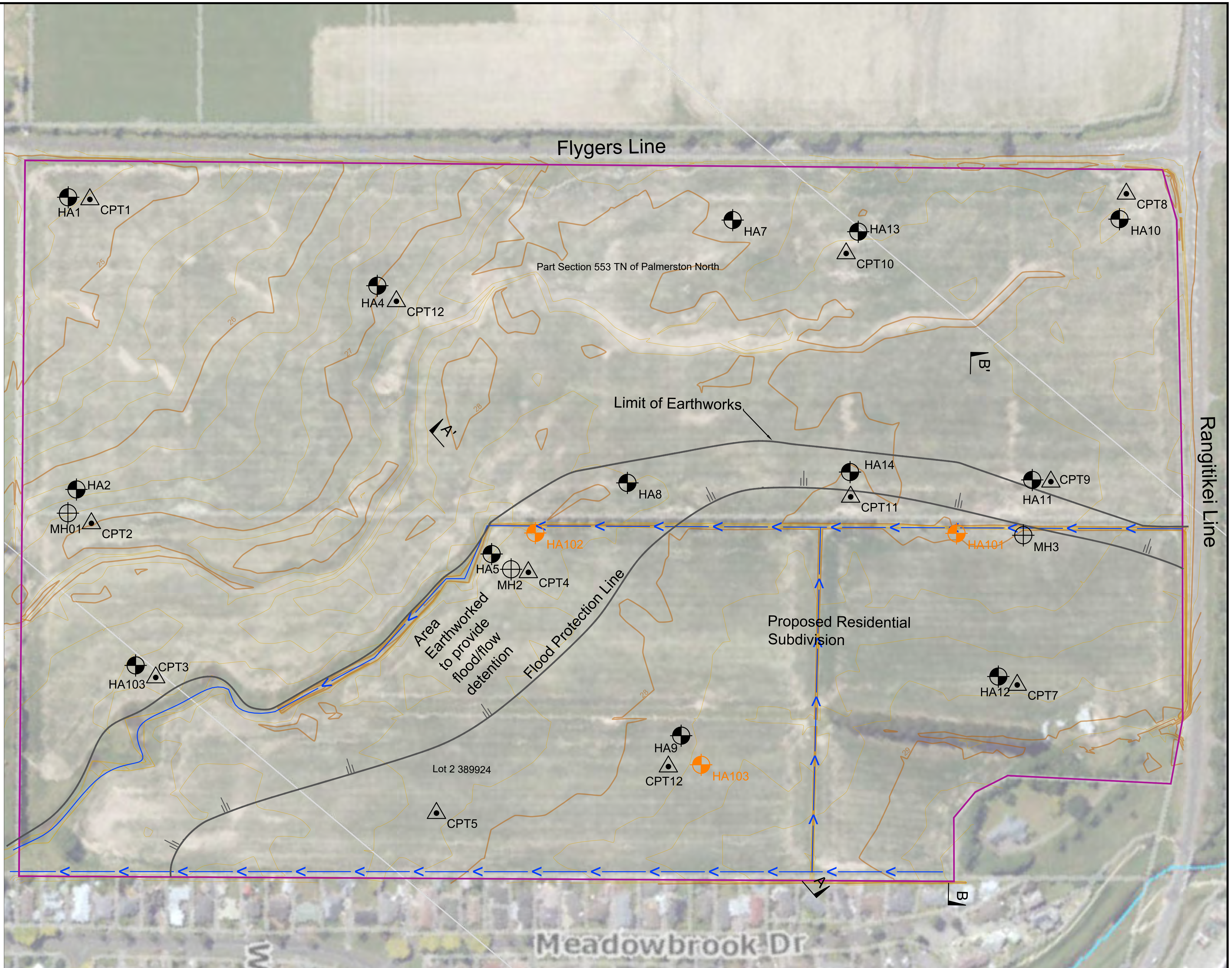
CAD Path/File	Sheet	of	Sheets	Rev.
214115 - Design Contour Plan	1		1	P1

Appendix B
Investigation Plan and Borelogs



KEY:

- HA101 — Total Ground Engineering Ltd. augerhole and Piezometer locations, drilled and installed 29-Oct-2020
- HA1 — Riley Consultants Ltd. augerhole locations, drilled 28 & 29-Jun-2018
- MH1 — GeoTech Drilling NZ Ltd. machine borehole locations, drilled 15&16-Jan-2018
- CPT1 — Geotech Drilling Ltd CPT test locations, tested 19-June-2018
- Open drainage channel/waterway
- Existing boundary
- A A' — Approximate Total Ground Engineering Ltd. cross section locations
- Major contours (1.0m)
- Minor contours (0.25m)
- Flood Protection Line/Limit of Earthworks

NOTES:

Locations of features approximate only

Original sheet size A3

Boundary, Aerial and Contour information on this *Test Location Plan* adapted from Palmerston North City Council Geo-Guide Website (accessed 02-Nov-2020)

AMENDMENTS		
DATE	REV	DESCRIPTION
02/11/2020	A	Report Issue

Check all dimensions and levels on site before commencing construction.

Test Location Plan

Flygers Line Road
PALMERSTON NORTH

TOTAL GROUND ENGINEERING

Physical Address:
27D Waipareira Ave, Henderson, 0610

Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No.	Drawn by:	Date:
J00367/ 1	J Healey	02/Nov/2020
Scale: 1: 2500 (A3)	Checked by: N Jacka	Revision: A
Filename: J00367-Drawings.dwg		

TOTAL GROUND ENGINEERING

Client:	Flygers Investment Group	Augerhole No.	HA101
Project:	Residential Subdivision	Sheet No.	1 of 1
Address:	Flygers Line Road, Palmerston North		

Drill Type:	50mmØ Hand Auger	Project No:	J00367	Logged By:	JH
Drilled By:	JH	Coordinates:	NZTM2000 E1820104.47 N5531754.65	Shear Vane No:	2982
Date Started:	29-Oct-20	Ground Conditions:	Near Level Soil	Calibration Factor:	1.571
Date Finished:	29-Oct-20	Groundwater Level (m):	0.85m (29-Oct-20)	Calibration Date:	18-Sep-20

Soil description in accordance with *Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes*, NZ Geotechnical Society Inc., 2005

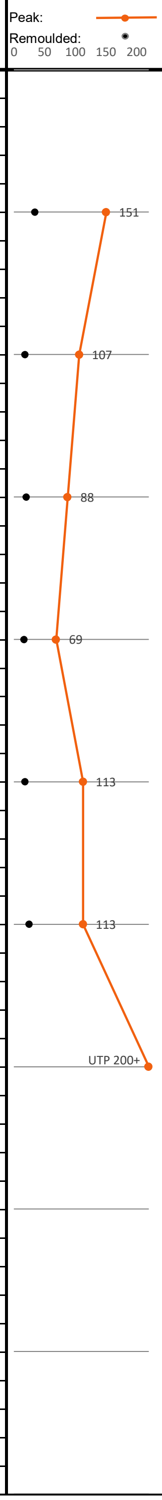
Stratigraphy	Depth (m)	Soil description
TS	0.0–0.2	SILT, trace fine to medium sand, trace clay, brown, firm, moist, non-plastic [TOPSOIL]
HOLOCENE ALLUVIAL DEPOSITS	0.2	SILT, trace to minor clay, trace fine to medium sand, light grey with dark orange streaks, very stiff, moist, slightly plastic [HOLOCENE ALLUVIAL DEPOSITS]
	0.5	some clay, trace fine sand, light grey with trace orange streaks and mottles
	1.2	Fine to medium SAND, trace silt, brownish orange with dark orange bands, loose to medium dense, wet
	1.4	SILT, some clay, minor fine to medium sand, light grey, stiff, wet, moderately plastic
	1.6	some clay to clayey, some decomposed fibrous organic inclusions, light grey with dark brown inclusions
	2.2	50mm bands of decomposed wood
	2.5	some clay, trace fine sand, dark grey, very stiff
	3.5	hard
	3.7	Fine to medium SAND, trace silt, dark grey, medium dense
	3.9	dense
	4.3	very dense
	4.4	dense
	4.8	SILT, minor fine sand, trace clay, dark grey, hard, saturated, non-plastic

Groundwater Level (m): GW = 0.85m (29-Oct-20)

End of Augerhole 5.0m
[TARGET DEPTH]

In-situ Field Testing

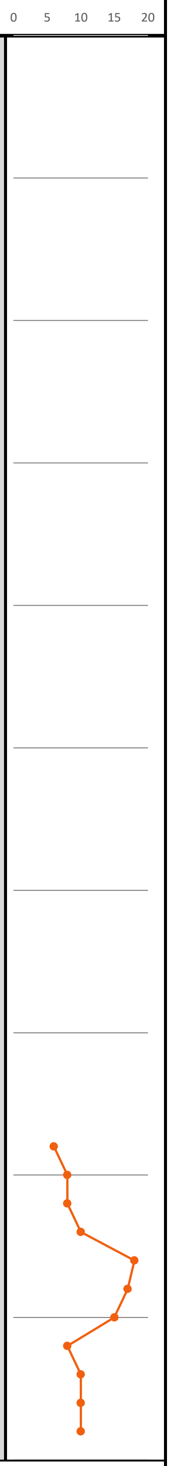
Shear Strength (kPa)



Dynamic Cone (Scala) Penetrometer

Depth (m)	Blow Count
-0.1	
-0.2	
-0.3	
-0.4	
-0.5	
-0.6	
-0.7	
-0.8	
-0.9	
-1.0	
-1.1	
-1.2	
-1.3	
-1.4	
-1.5	
-1.6	
-1.7	
-1.8	
-1.9	
-2.0	
-2.1	
-2.2	
-2.3	
-2.4	
-2.5	
-2.6	
-2.7	
-2.8	
-2.9	
-3.0	
-3.1	
-3.2	
-3.3	
-3.4	
-3.5	
-3.6	
-3.7	
-3.8	
-3.9	6
-4.0	8
-4.1	8
-4.2	10
-4.3	18
-4.4	17
-4.5	15
-4.6	8
-4.7	10
-4.8	10
-4.9	10
-5.0	

Scala Blow Count / 100mm



In-situ field testing in accordance with the following Standards:
Scala Penetrometer Testing: NZS 4402:1988, Test 6.5.2, Dynamic Cone Penetrometer
Shear Vane Testing: Guideline for Hand Held Shear Vane Test, NZGS, August 2001

TOTAL GROUND ENGINEERING

Client:	Flygers Investment Group	Augerhole No.	HA102
Project:	Residential Subdivision	Sheet No.	1 of 1
Address:	Flygers Line Road, Palmerston North		

Drill Type:	50mmø Hand Auger	Project No:	J00367	Logged By:	JH
Drilled By:	JH	Coordinates:	NZTM2000 E1819877.81 N5531574.05	Shear Vane No:	2982
Date Started:	29-Oct-20	Ground Conditions:	Near Level Soil	Calibration Factor:	1.571
Date Finished:	29-Oct-20	Groundwater Level (m):	1.3m (29-Oct-20)	Calibration Date:	18-Sep-20

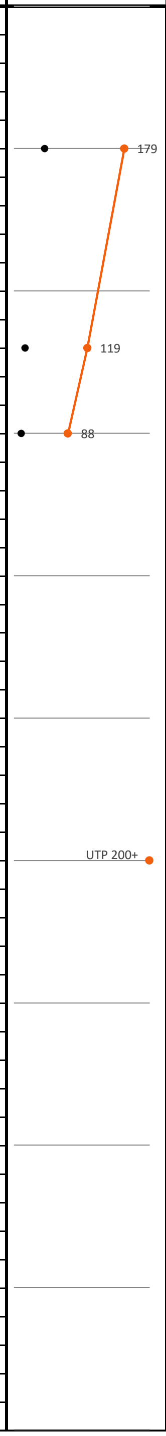
Soil description in accordance with *Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes*, NZ Geotechnical Society Inc., 2005

Stratigraphy	Depth (m)	Soil description
TOPSOIL	0.0–0.3	SILT, trace fine to medium sand, light brown, stiff, moist, non-plastic [TOPSOIL]
HOLOCENE ALLUVIAL DEPOSITS	0.3–0.9	SILT, some clay, trace fine to medium sand, light grey with orange bands and dark orange mottles, very stiff, moist, slightly to moderately plastic [HOLOCENE ALLUVIAL DEPOSITS]
	0.9–1.2	Silty fine to medium SAND, light grey with orange streaks, loose to medium dense, wet
	1.2–1.8	Clayey SILT, trace fine to medium sand, light bluish grey with dark orange streaks, stiff, saturated, moderately plastic
	1.8–2.3	Fine to medium SAND, trace silt, dark grey, medium dense, saturated
	2.3–3.2	SILT, minor clay, minor fine sand, dark grey, stiff, wet, slightly plastic
	2.8	some clay, minor to some decomposed organic inclusions, moderately plastic
	3.2–4.0	Fine to medium SAND, trace silt, dark grey, medium dense, saturated
	4.0	End of Augerhole 4.0m [TOO DENSE TO AUGER]
	5.0	End of Augerhole 5.0m [TARGET DEPTH]

Groundwater Level (m): GW = 1.3m (29-Oct-20)

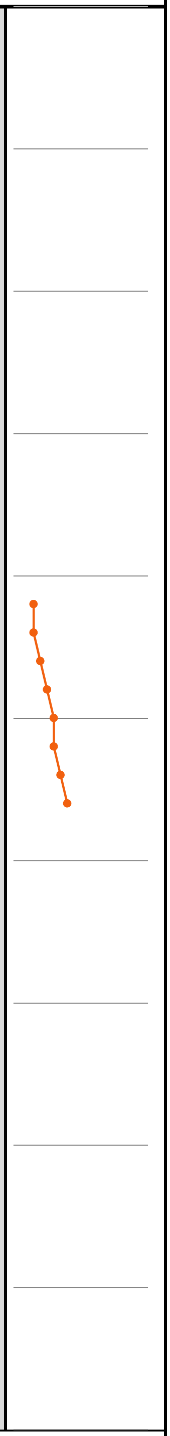
In-situ Field Testing

Shear Strength (kPa) — Peak / Remoulded (0, 50, 100, 150, 200)



Depth (m)	Peak Shear Strength (kPa)
0.5	179
1.2	119
1.5	88
3.0	UTP 200+

Dynamic Cone (Scala) Penetrometer — Scala Blow Count / 100mm (0, 5, 10, 15, 20)



Depth (m)	Blow Count
-0.1	
-0.2	
-0.3	
-0.4	
-0.5	
-0.6	
-0.7	
-0.8	
-0.9	
-1.0	
-1.1	
-1.2	
-1.3	
-1.4	
-1.5	
-1.6	
-1.7	
-1.8	
-1.9	
-2.0	
-2.1	3
-2.2	3
-2.3	4
-2.4	5
-2.5	6
-2.6	6
-2.7	7
-2.8	8
-2.9	
-3.0	
-3.1	
-3.2	
-3.3	
-3.4	21
-3.5	21
-3.6	21
-3.7	24
-3.8	24
-3.9	
-4.0	
-4.1	
-4.2	
-4.3	
-4.4	
-4.5	
-4.6	
-4.7	
-4.8	
-4.9	
-5.0	

In-situ field testing in accordance with the following Standards:

Scala Penetrometer Testing: NZS 4402:1988, Test 6.5.2, Dynamic Cone Penetrometer

Shear Vane Testing: Guideline for Hand Held Shear Vane Test, NZGS, August 2001

TOTAL GROUND ENGINEERING

Client: Flygers Investment Group
Project: Residential Subdivision
Address: Flygers Line Road, Palmerston North

Augerhole No. HA103
Sheet No. 1 of 1

Drill Type:	50mmØ Hand Auger	Project No:	J00367	Logged By:	JH
Drilled By:	JH	Coordinates:	NZTM2000 E1820074.56 N5531533.63	Shear Vane No:	2982
Date Started:	29-Oct-20	Ground Conditions:	Near Level Soil	Calibration Factor:	1.571
Date Finished:	29-Oct-20	Groundwater Level (m):	1.02m (29-Oct-20)	Calibration Date:	18-Sep-20

Soil description in accordance with *Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes*, NZ Geotechnical Society Inc., 2005

Stratigraphy	Depth (m)	Soil description
TOPSOIL	0.0–0.3	SILT, minor fine to medium sand, minor clay, light brown, stiff, moist, slightly plastic [TOPSOIL]
HOLOCENE ALLUVIAL DEPOSITS	0.3–0.8	SILT, minor fine to medium sand, trace clay, light grey with dark orange mottles, stiff, moist, non to slightly plastic [HOLOCENE ALLUVIAL DEPOSITS]
	0.8–3.7	Fine to medium SAND, brown, medium dense, wet
	~1.1	brownish orange
	~1.3	grey, dense
	~2.2	medium dense
	3.7–4.8	SILT, minor clay, minor fine to medium sand, dark grey, very stiff, hard, saturated, slightly plastic
	4.8–4.9	Fine to medium SAND, trace silt, dark grey, very dense, saturated
	4.9–5.0	SILT, minor clay, minor fine to medium sand, dark grey, hard, saturated, slightly plastic

End of Augerhole 5.0m
[TARGET DEPTH]

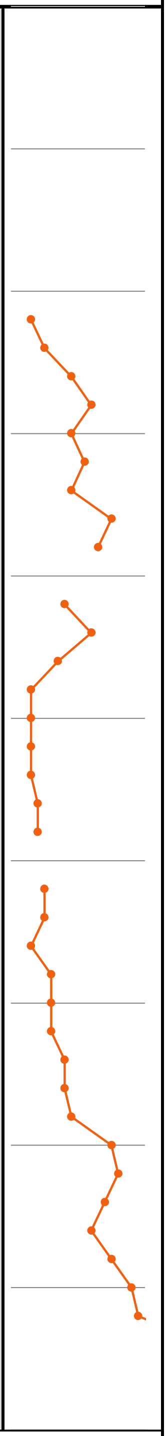
Groundwater Level (m): GW = 1.02m (29-Oct-20)

In-situ Field Testing

Shear Strength (kPa) — Peak / Remoulded (0, 50, 100, 150, 200): 0.5 m — 94

Dynamic Cone (Scala) Penetrometer — Scala Blow Count / 100mm

Depth (m)	Blow Count
-0.1	
-0.2	
-0.3	
-0.4	
-0.5	
-0.6	
-0.7	
-0.8	
-0.9	
-1.0	
-1.1	3
-1.2	5
-1.3	9
-1.4	12
-1.5	9
-1.6	11
-1.7	9
-1.8	15
-1.9	13
-2.0	
-2.1	8
-2.2	12
-2.3	7
-2.4	3
-2.5	3
-2.6	3
-2.7	3
-2.8	4
-2.9	4
-3.0	
-3.1	5
-3.2	5
-3.3	3
-3.4	6
-3.5	6
-3.6	6
-3.7	8
-3.8	8
-3.9	9
-4.0	15
-4.1	16
-4.2	14
-4.3	12
-4.4	15
-4.5	18
-4.6	19
-4.7	29
-4.8	25
-4.9	
-5.0	



In-situ field testing in accordance with the following Standards:
Scala Penetrometer Testing: NZS 4402:1988, Test 6.5.2, Dynamic Cone Penetrometer
Shear Vane Testing: Guideline for Hand Held Shear Vane Test, NZGS, August 2001

Total Ground Engineering Ltd. 27D Waipareira Ave, Henderson, 0610
PO Box 27294, Glen Eden, 0604, Auckland, New Zealand
Phone: +64 9 216 7330
Website: www.totalgroundengineering.com

TOTAL GROUND ENGINEERING

Client: Flygers Investment Group
Project: Residential Subdivision
Address: Flygers Line Road, Palmerston North

Scala Penetrometer Testing

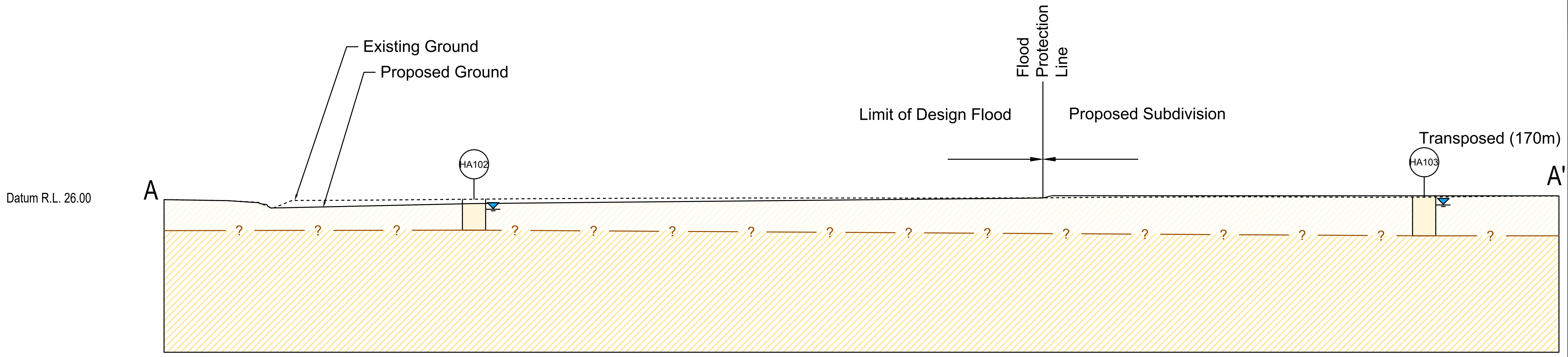
Date tested: 29-Oct-20

Tested By: JH

Test ID	HA101									
Test from (m)	5.0									
Depth (m)	Blows/100mm penetration									
0.1	3									
0.2	3									
0.3	3									
0.4	6									
0.5	23									
0.6	40+									
0.7										
0.8										
0.9										
1.0										
1.1										
1.2										
1.3										
1.4										
1.5										
1.6										
1.7										
1.8										
1.9										
2.0										
Test depth (m)	5.6									

In-situ field testing in accordance with Scala Penetrometer Testing: NZS 4402:1988, Test 6.5.2, Dynamic Cone Penetrometer

Appendix C
Geological Sections



CUT/FILL	0.00	-0.02	-0.86	-0.70	-0.57	-0.54	-0.49	-0.42	-0.33	-0.23	-0.12	-0.05	0.21	0.16	0.13	0.17	0.18	0.09	0.03
EXISTING LEVEL	27.54	27.31	27.45	27.51	27.60	27.68	27.72	27.74	27.75	27.75	27.74	27.77	27.83	27.88	27.91	27.88	27.87	27.95	28.01
PROPOSED LEVEL	27.54	27.29	26.59	26.81	27.04	27.13	27.23	27.33	27.43	27.52	27.62	27.72	28.05	28.05	28.04	28.04	28.04	28.04	28.04
CHAINAGE	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00	130.00	140.00	150.00	160.00	170.00	180.00	190.00	200.00	210.00	220.00

Legend:

HA101 Total Ground Engineering hand augerhole locations

Groundwater Level

Scala penetrometer from base of augerhole

Geologic Unit:

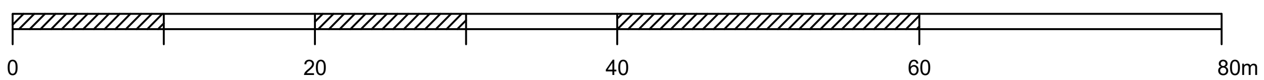
Holocene Alluvial Deposits

River Gravels

KEY:

Proposed Ground

Exisiting Ground



Scale 1: 500

AMENDMENTS		
DATE	REV	DESCRIPTION
06/11/2020	A	Report Issue

Check all dimensions and levels on site before commencing construction.

Cross Section
A - A'
Flygers Line Road
PALMERSTON NORTH

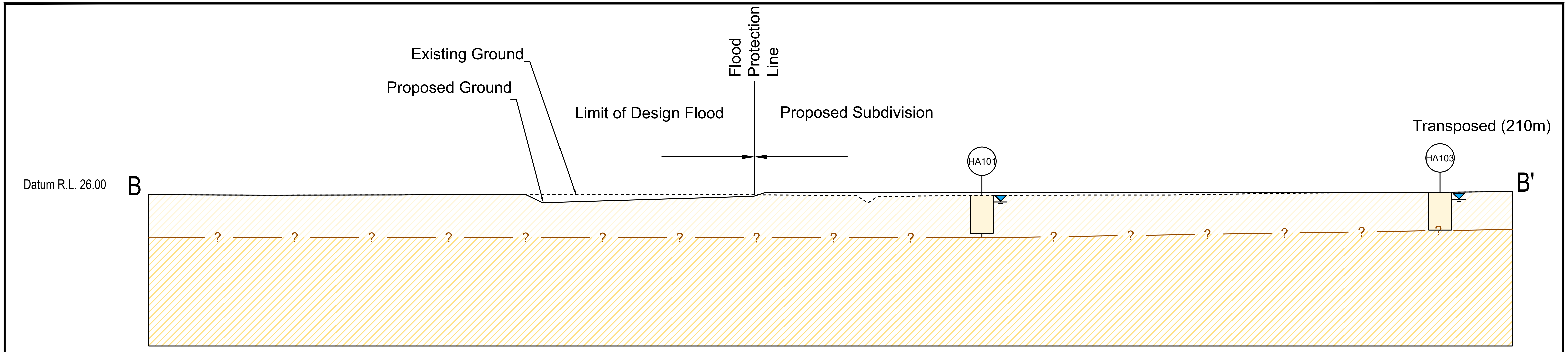
TOTAL GROUND ENGINEERING

Physical Address:
27D Waipareira Ave, Henderson, 0610

Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No. J00367/ 2	Drawn by: J Healey	Date: 06-Nov-2020
Scale: 1: 500 (A3) H:V = 1:1	Checked by: N Jacka	Revision: A
Filename: J00367-Drawings.dwg		



CUT/FILL	0.00	0.00	0.00	0.00	0.00	-0.11	-0.86	-0.57	-0.15	0.41	0.57	0.44	0.38	0.37	0.30	0.15	0.07	0.01	0.00
EXISTING LEVEL	28.15	28.12	28.11	28.13	28.15	28.18	28.19	28.22	28.14	28.08	27.92	28.05	28.11	28.11	28.19	28.34	28.42	28.48	28.56
PROPOSED LEVEL	28.15	28.12	28.11	28.13	28.15	28.06	27.34	27.64	27.99	28.49	28.49	28.49	28.49	28.49	28.49	28.49	28.49	28.49	28.56
CHAINAGE	0.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00	130.00	140.00	150.00	160.00	170.00	180.00

Legend:

HA101 — Total Ground Engineering hand augerhole locations

Groundwater Level

Scala penetrometer from base of augerhole

Geologic Unit:

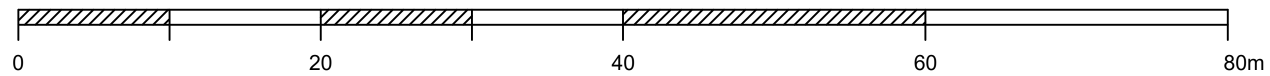
Holocene Alluvial Deposits

River Gravels

KEY:

Proposed Ground

Exisiting Ground



Scale 1: 500

AMENDMENTS		
DATE	REV	DESCRIPTION
09/11/2020	A	Report Issue

Check all dimensions and levels on site before commencing construction.

Cross Section
B - B'
Flygers Line Road
PALMERSTON NORTH

TOTAL GROUND ENGINEERING

Physical Address:
27D Waipareira Ave, Henderson, 0610

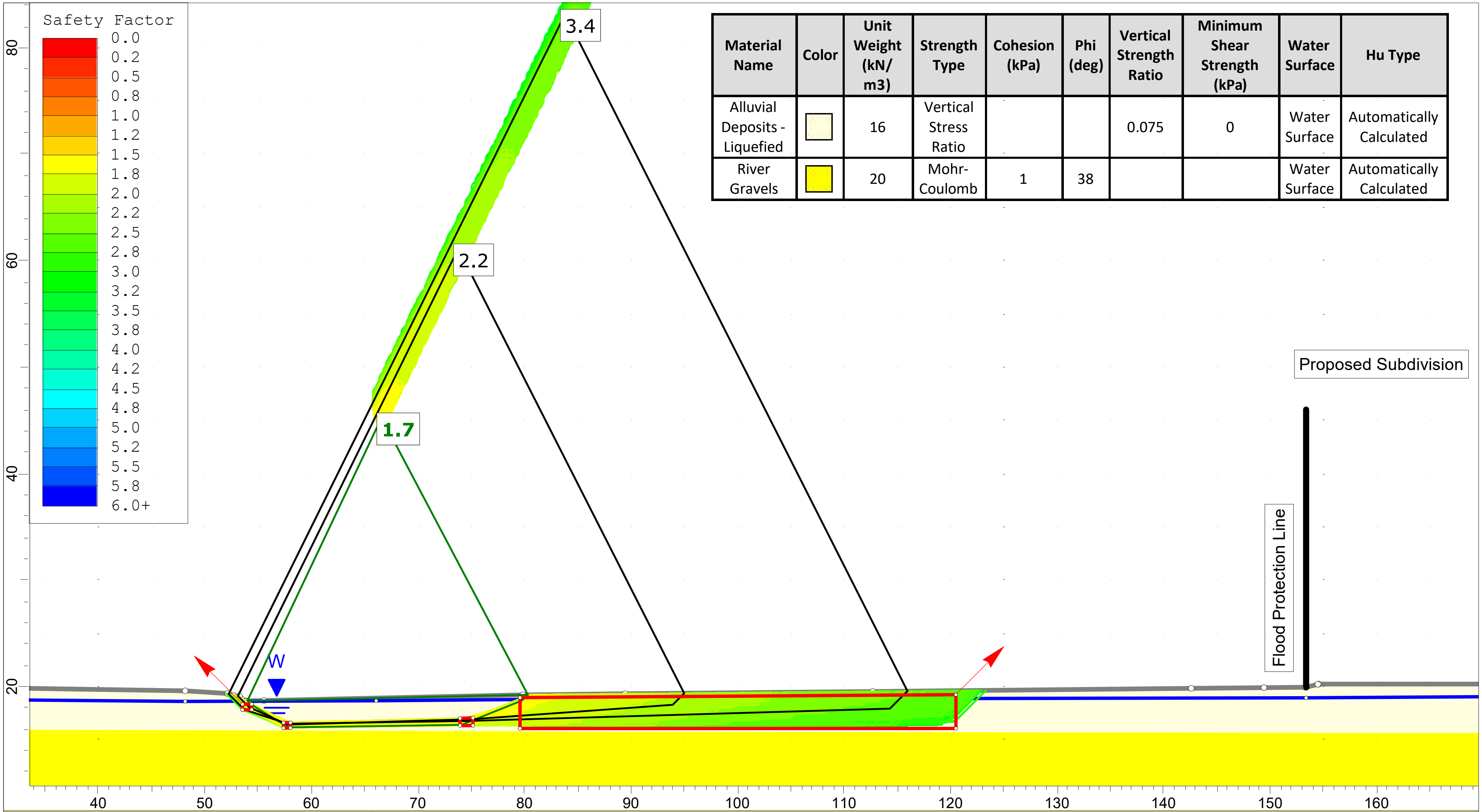
Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No.	Drawn by:	Date:
J00367/ 3	J Healey	09-Nov-2020
Scale: 1: 500 (A3) H:V = 1:1	Checked by: N Jacka	Revision: A

Filename: J00367-Drawings.dwg

Appendix D
Analysis Outputs

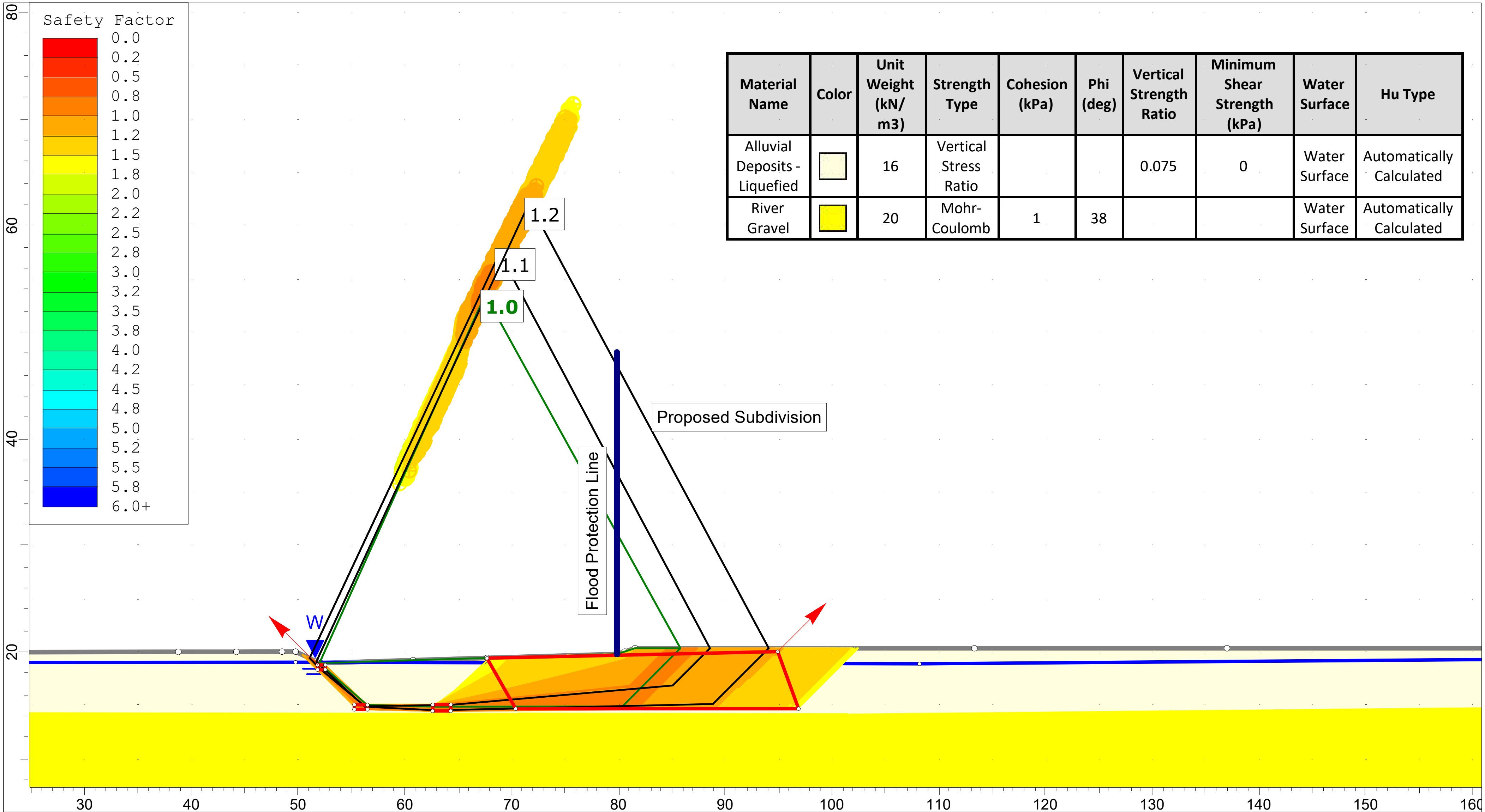


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type
Alluvial Deposits - Liquefied		16	Vertical Stress Ratio			0.075	0	Water Surface	Automatically Calculated
River Gravels		20	Mohr-Coulomb	1	38			Water Surface	Automatically Calculated

TOTAL GROUND ENGINEERING

SLIDEINTERPRET 9.009

Project	Ranitikei Line & Flygers Line - Plan Change		
Group	Proposed Contours A-A'	*Scenario*	Post EQ Liquefaction: Initial Proposal
Drawn By	J Healey	*Company*	Total Ground Engineering Ltd
Date	November 2020	*File Name*	J00367_Section A-A'_r0.slmd

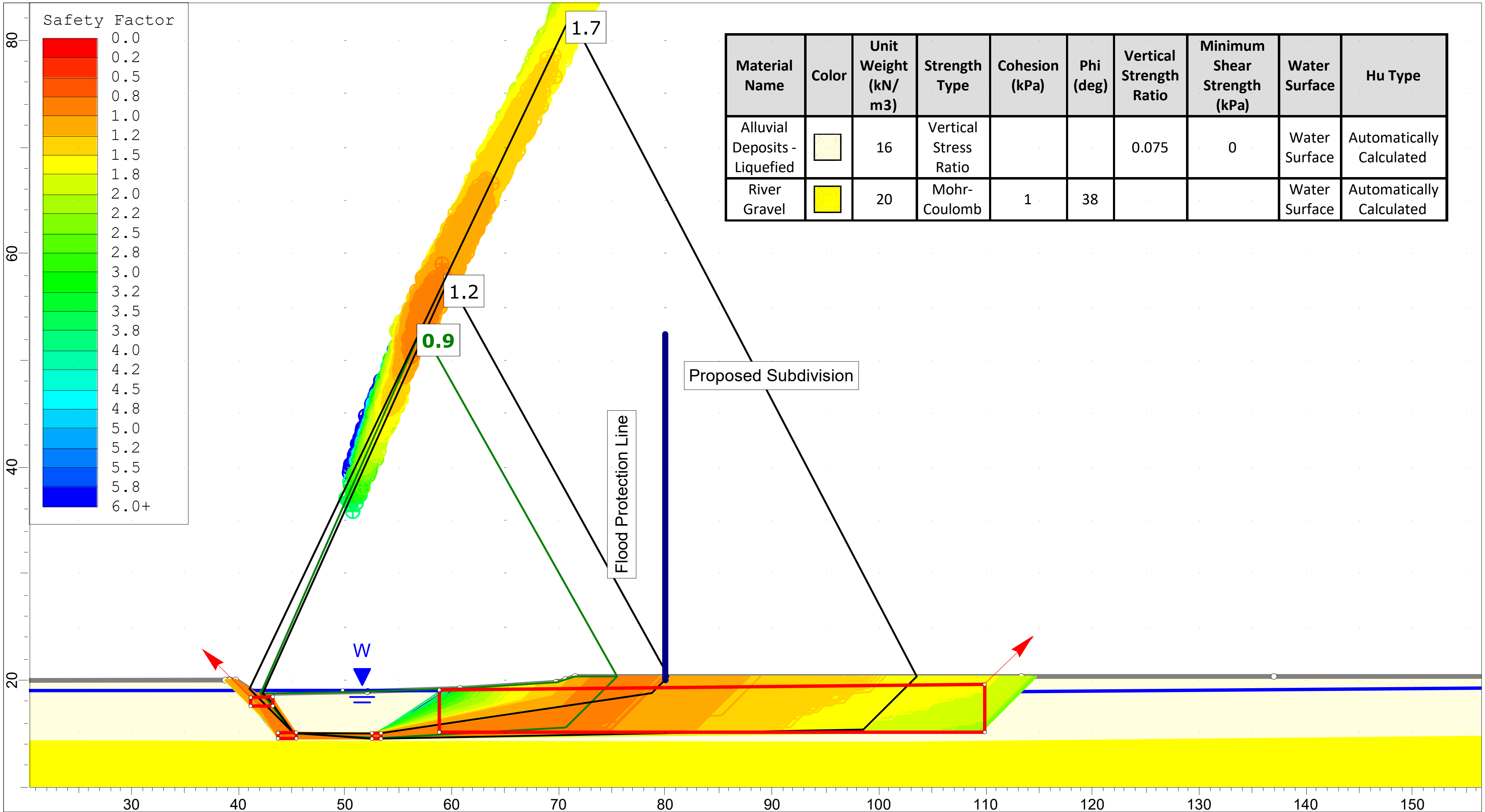


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type
Alluvial Deposits - Liquefied		16	Vertical Stress Ratio			0.075	0	Water Surface	Automatically Calculated
River Gravel		20	Mohr-Coulomb	1	38			Water Surface	Automatically Calculated

TOTAL GROUND ENGINEERING

SLIDEINTERPRET 9.009

Project	Rangitikei Line & Flygers Line - Plan Change
Group	Proposed Countours B-B'
Scenario	Post EQ Liquefaction: Initial Proposal
Drawn By	J Healey
Company	Total Ground Engineering Ltd
Date	November 2020
File Name	J00367_Section_B-B'_r0.slmd

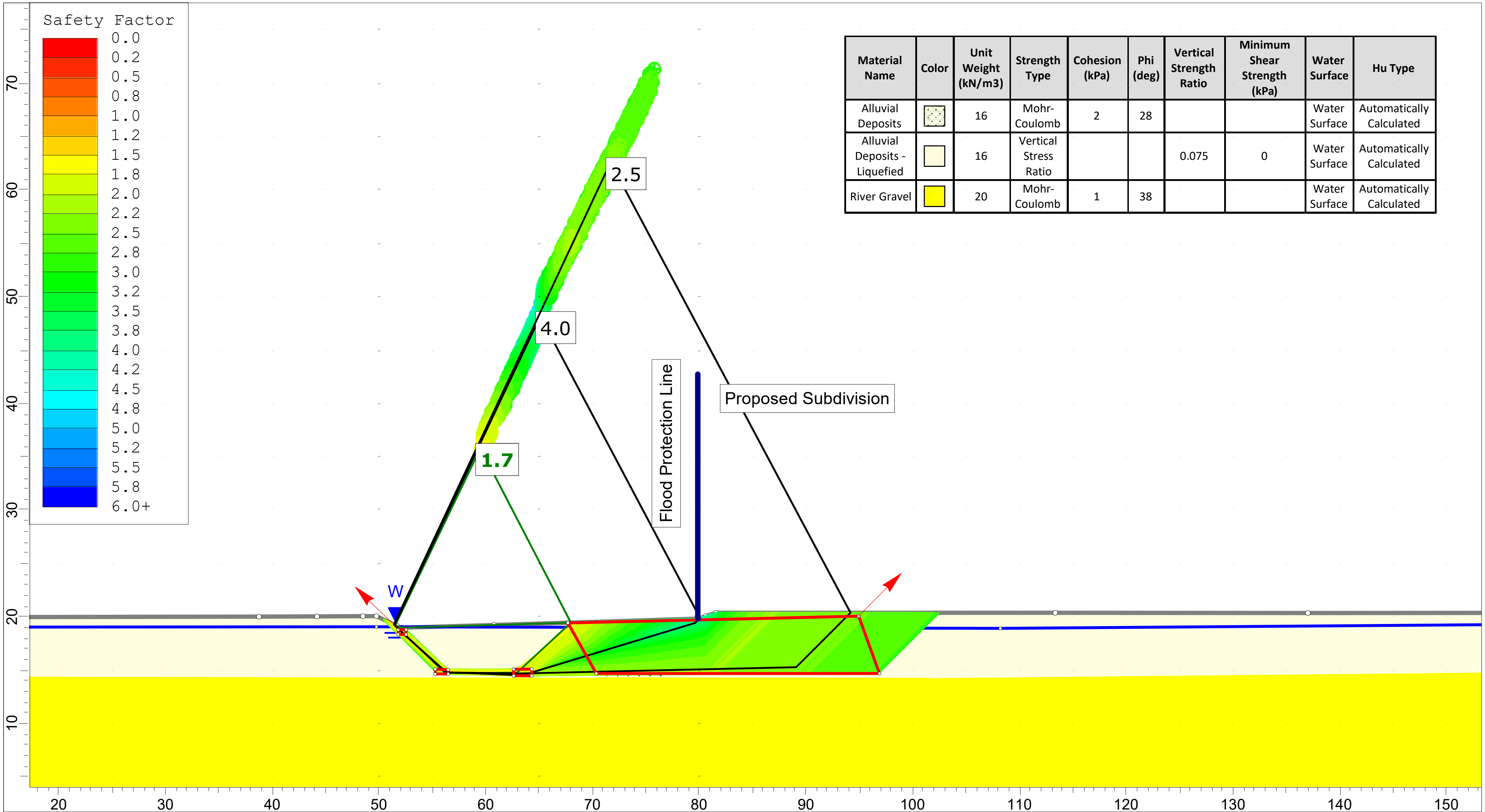


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type
Alluvial Deposits - Liquefied		16	Vertical Stress Ratio			0.075	0	Water Surface	Automatically Calculated
River Gravel		20	Mohr-Coulomb	1	38			Water Surface	Automatically Calculated

TOTAL GROUND ENGINEERING

SLIDEINTERPRET 9.009

Project	Rangitikei Line & Flygers Line - Plan Change		
Group	Remediation Option One Contours_B-B'	*Scenario*	Post EQ Liquefaction: Remediation Option One
Drawn By	J Healey	*Company*	Total Ground Engineering Ltd
Date	November 2020	*File Name*	J00367_Section_B-B'_r0.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type
Alluvial Deposits		16	Mohr-Coulomb	2	28			Water Surface	Automatically Calculated
Alluvial Deposits - Liquefied		16	Vertical Stress Ratio			0.075	0	Water Surface	Automatically Calculated
River Gravel		20	Mohr-Coulomb	1	38			Water Surface	Automatically Calculated

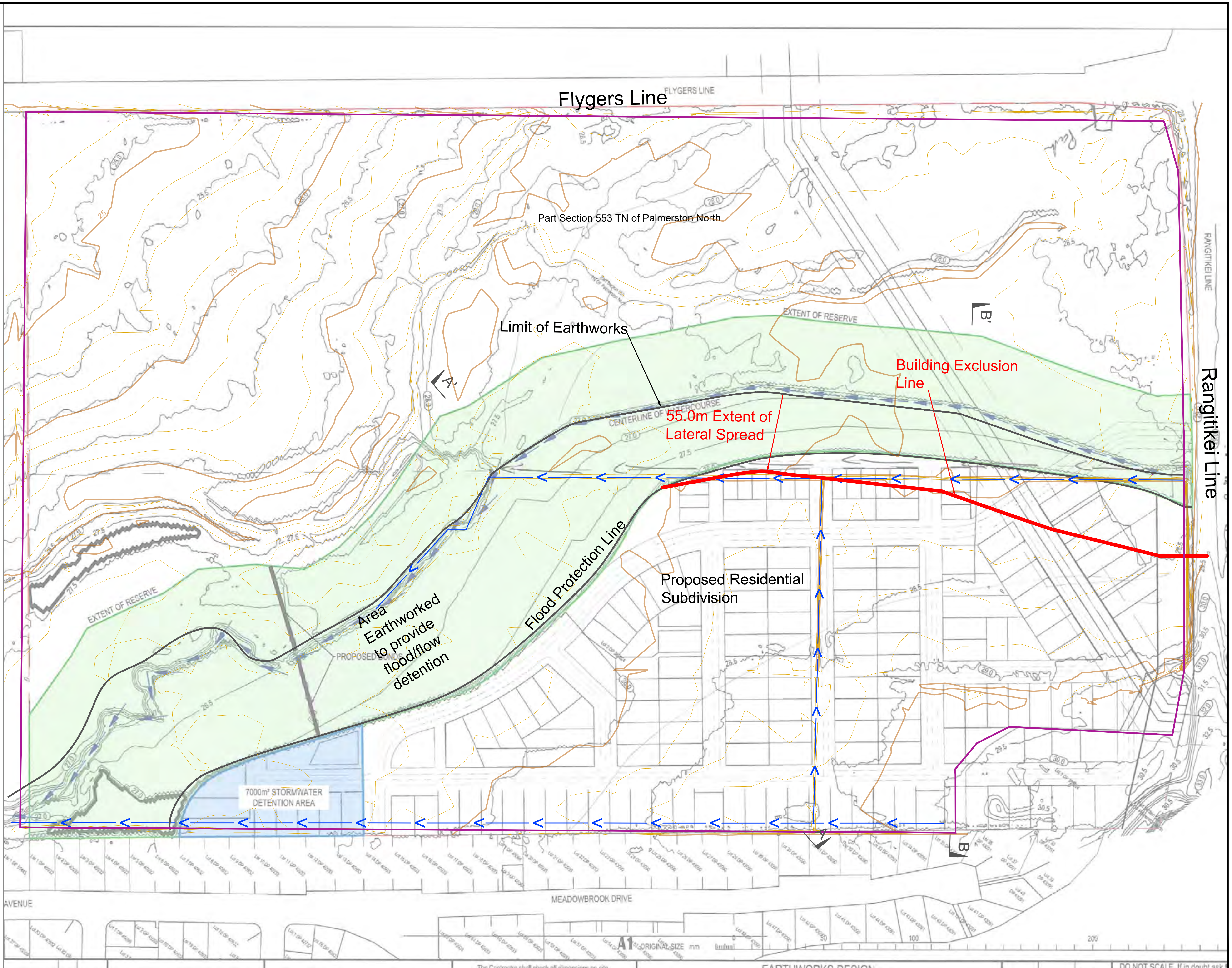
TOTAL GROUND ENGINEERING

SLIDEINTERPRET 9.009

Project	Rangitikei Line & Flygers Line - Plan Change		
Group	Proposed Countours B-B'	*Scenario*	Post EQ Liquefaction: Remediation Option Two
Drawn By	J Healey	*Company*	Total Ground Engineering Ltd
Date	November 2020	*File Name*	J00367_Section_B-B'_r0.slmd

Appendix E
Remediation Options

North



KEY:

- Building Exclusion Line
- Open drainage channel/waterway
- Existing boundary
- Approximate Total Ground Engineering Ltd. cross section locations
- Major contours (1.0m)
- Minor contours (0.25m)
- Flood Protection Line/Limit of Earthworks

NOTES:

Locations of features approximate only

Original sheet size A3

Boundary and Contour information on this *Test Location Plan* adapted from Palmerston North City Council Geo-Guide Website
(accessed 02-Nov-2020)

Location of proposed Earthworks Design adapted from Resonant drawing titled: Finished Ground Contours, Sheet 01, Rev P1, dated Sep/2020

AMENDMENTS		
DATE	REV	DESCRIPTION
12/11/2020	A	Report Issue

Check all dimensions and levels on site before commencing construction.

Initial Proposal : Building Exclusion Line

Flygers Line Road
PALMERSTON NORTH

TOTAL GROUND ENGINEERING

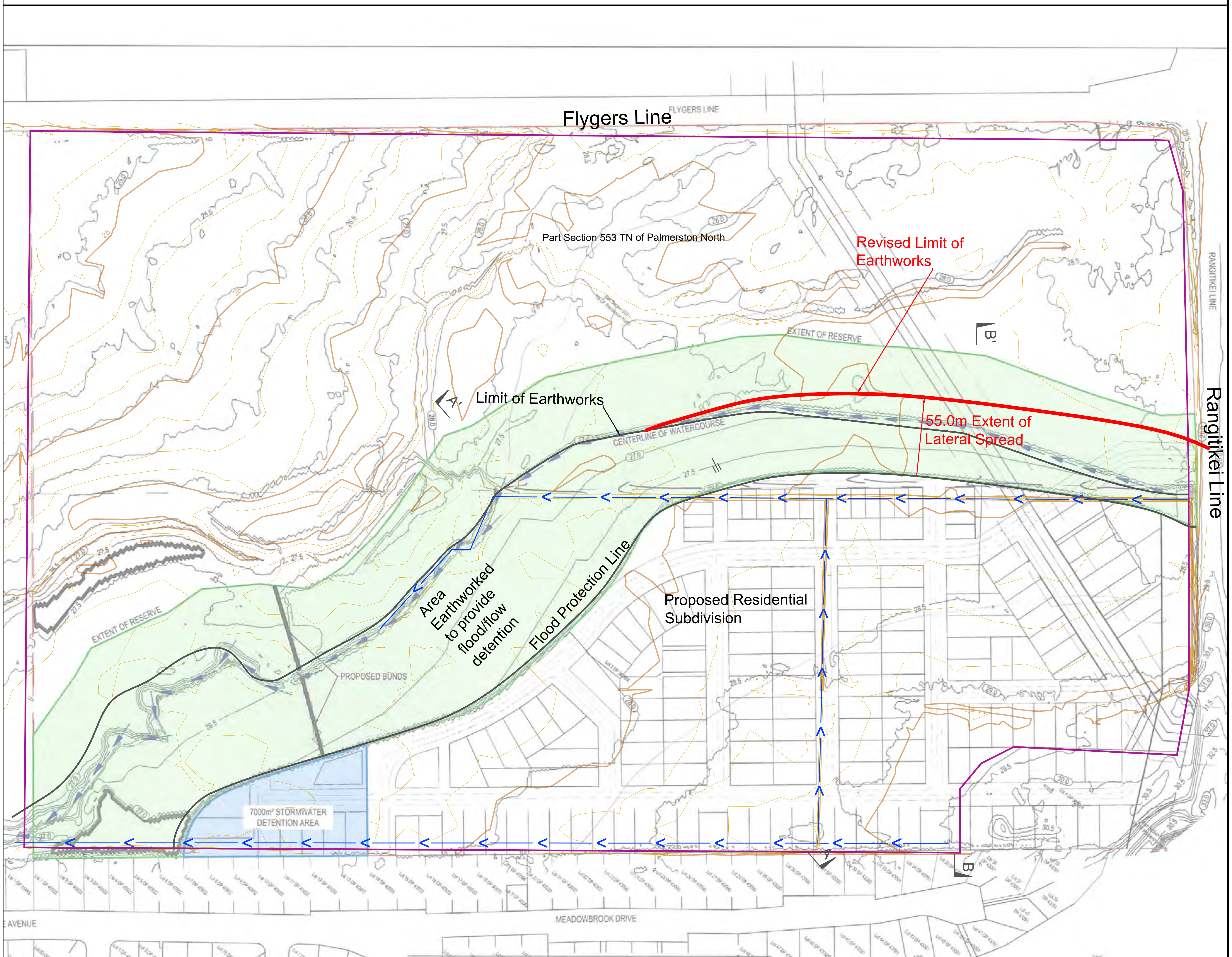
Physical Address:
27D Waipareira Ave, Henderson, 0610

Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No.	Drawn by:	Date:
J00367/ 4	J Healey	12/Nov/2020
Scale:	Checked by:	Revision:
1: 2500 (A3)	N Jacka	A

Filename: J00367-Drawings.dwg



KEY:

- Revised Limit of Earthworks
- Open drainage channel/waterway
- Existing boundary
- A A' Approximate Total Ground Engineering Ltd. cross section locations
- Major contours (1.0m)
- Minor contours (0.25m)
- Flood Protection Line/Limit of Earthworks

NOTES:

Locations of features approximate only

Original sheet size A3

Boundary and Contour information on this *Test Location Plan* adapted from Palmerston North City Council Geo-Guide Website
(accessed 02-Nov-2020)

Location of proposed Earthworks Design adapted from Resonant drawing titled: Finished Ground Contours, Sheet 01, Rev P1, dated Sep/2020

AMENDMENTS		
DATE	REV	DESCRIPTION
12/11/2020	A	Report Issue

Remediation Option 1

Flygers Line Road
PALMERSTON NORTH

TOTAL GROUND ENGINEERING

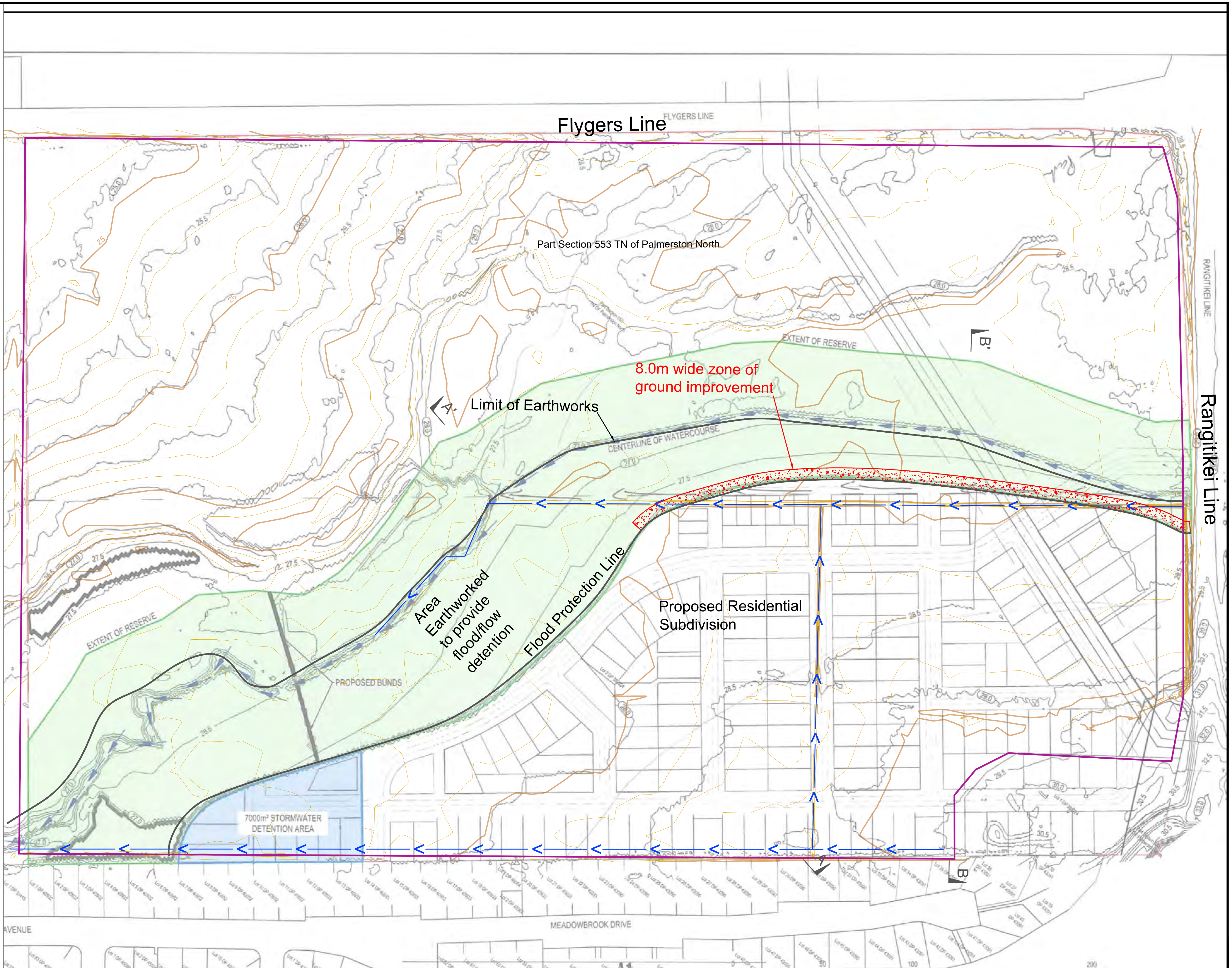
Physical Address:
27D Waipareira Ave, Henderson, 0610

Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No.	Drawn by:	Date:
J00367/ 5	J Healey	12/Nov/2020
Scale: 1: 2500 (A3)	Checked by: N Jacka	Revision: A
Filename: J00367-Drawings.dwg		

North



Notes:

1. Ground improvements could comprise;
   a) Excavate and replace alluvium
   b) Dynamic compaction
   c) Stone columns

KEY:

- Zone of ground improvement
- Open drainage channel/waterway
- Existing boundary
- A A' Approximate Total Ground Engineering Ltd. cross section locations
- Major contours (1.0m)
- Minor contours (0.25m)
- Flood Protection Line/Limit of Earthworks

NOTES:

Locations of features approximate only

Original sheet size A3

Boundary and Contour information on this *Test Location Plan* adapted from Palmerston North City Council Geo-Guide Website (accessed 02-Nov-2020)

Location of proposed Earthworks Design adapted from Resonant drawing titled: Finished Ground Contours, Sheet 01, Rev P1, dated Sep/2020

AMENDMENTS		
DATE	REV	DESCRIPTION
12/11/2020	A	Report Issue

Check all dimensions and levels on site before commencing construction.

Remediation Option 2

Flygers Line Road
PALMERSTON NORTH

TOTAL GROUND ENGINEERING

Physical Address:
27D Waipareira Ave, Henderson, 0610

Postal Address:
PO Box 27294, Glen Eden, 0604
Auckland, New Zealand

Website: www.totalgroundengineering.com

Drawing No.	Drawn by:	Date:
J00367/ 6	J Healey	12/Nov/2020
Scale: 1: 2500 (A3)	Checked by: N Jacka	Revision: A
Filename: J00367-Drawings.dwg		