GEOSOLVE

GEOTECHNICAL

WATER
RESOURCES

PAVEMENTS

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Geotechnical Report for Private Plan Change

8 Brodie Avenue, Arrowtown

Report prepared for:

Arrowsouth Properties Limited

Report prepared by:

GeoSolve Limited

Distribution:

Arrowsouth Properties Limited

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1	12/06/2025	Client issue	ELH	FAW
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GEOTECHNICAL WATER RESOURCES PAVEMENTS

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1 Introduction

1.1 General

This report presents the results of a geotechnical investigation and assessment carried out by GeoSolve Limited (GeoSolve) in order to provide comment on subsoil conditions, natural hazards and geotechnical inputs in support of a private plan change application to Council.

Photo 1.1 – Looking southeast across the land subject to private plan change.

The investigations were carried out for Arrowsouth Properties Limited in accordance with GeoSolve's proposal dated 7 April 2025, which outlines the scope of work and conditions of engagement.

1.2 Development

We understand the proposed development comprises a private plan change to change the property designation to a lower density residential zone.

Figure 1, Appendix A illustrates the land subject to private plan change and Figures 2a and 2b, Appendix A illustrates a cross-section ground model.

2 Site Description, Topography and Surface Drainage

The subject property is legally described as, Lot 103 DP 535793 and is located on the southern outskirts of the Arrowtown Township, as shown in Figure 2.1 below.

Figure 2.1 – Subject site location (yellow pin) in relation to Arrowtown (Image Source: Google Earth).

The property is accessed from Brodie Avenue to the northwest and McDonnell Road to the southwest. The property is bounded by McDonnell Road to the southwest, farmland to the south and developed residential properties from the northwest to the northeast.

The property is currently undeveloped and being used as farmland with a public walking track running northwest to southeast through the property. Vegetation comprises grass and riparian native planting.

A small watercourse is located in the middle of the property running northwest to southeast.

The northeast boundary lies along the top of a southwest facing outwash terrace. The property then slopes moderately towards the southwest grading out to a gently slope towards the watercourse. The southwest half of the site is gently sloping to sub-horizontal with minor ground undulations. A schist rock outcrop is located in the south corner of the property.

Previously placed uncontrolled fill is located across the proposed private plan change area. The approximate extent of the fill areas is shown in Appendix A, Figure 1.

3 Geotechnical Investigations

An engineering geological site assessment has been undertaken with confirmatory subsurface investigations. GeoSolve visited the subject property on 22 and 23 April and 7 and 8 May 2025, undertaking geotechnical investigations comprising:

- Eleven test pits with associated Scala penetrometer tests (TPs 1-11) which were advanced to a maximum depth of 3.9 m.
- Seven cone penetrometer tests (CPTs 1-7) advanced to a maximum depth of 9.93 m, to assess liquefaction potential and the relative density of the subsoils.
- Three soakage pits (SPs 1-3) which were advanced to a maximum depth of 1.6 m below ground level (bgl) to undertake soakage testing, assess the relative permeability and soakage potential of the subsoils.

Test pit and CPT locations and logs are contained in Appendix A and B respectively.

4 Subsurface Conditions

4.1 Regional Geology

The site is located in the Wakatipu basin, a feature formed predominantly by glacial advances. Published references indicate the last glacial event occurred in the region between 10,000 and 20,000 years ago. Glaciations have left deposits of glacial till, glacial outwash and lake sediment over ice–scoured bedrock. Post glacial times have been dominated by the erosion of the bedrock and glacial sediment, with deposition of alluvial deposits by local watercourses and lacustrine sediment during periods of high lake levels.

No known active fault traces are present at the site or in the immediate vicinity. A significant seismic risk exists in this region from rupture of the Alpine Fault, located 80 km northwest from Queenstown along the West Coast of the South Island. There is a high probability that an earthquake with an expected magnitude of over M_W 8 will occur along the Alpine Fault in the next 50 years.

4.2 Stratigraphy

The subsurface soils observed during the site investigations across the gently sloping areas (TPs 1-8) typically comprise:

- 0.2-0.35 m of **topsoil**, overlying;
- 0.3-1.1 m of **uncontrolled fill** or 0.3 m of **buried topsoil**, overlying;
- 0.45-1.05 m of **alluvial silt** or 0.35-0.6 m of **loess**, overlying;
- 0.8-3.0 m of **alluvial deposits** (interbedded silt and sand), overlying;
- 0.3-2.6 m + of **alluvial sand**, overlying;
- 0.4-1.55 m + of **alluvial gravel**, overlying;
- 0.1 m + of **schist bedrock**.

Investigations along the northeast slopes of the proposed plan change area (TPs 9-11) typically comprised:

- 0.25 m of **topsoil** or 0.7-0.8 m of **uncontrolled fill**, overlying;
- 0.55-2.2 m + of **colluvium**, overlying;

- 1.0 m of **outwash sand** (TP 9), overlying;
- 0.2-0.6 m + of **schist bedrock** (TPs 10 and 11).

Geologic cross-sections for the site are shown in Appendix A, Figures 2a and 2b. Investigation locations and more detailed geotechnical description of soils is provided in the test pit logs contained in Appendix A and B, respectively.

4.3 Groundwater

Groundwater was observed in TPs 1-8, northeast and southwest of the watercourse that runs through centre of the property, between depths of 0.9-2.9 m bgl during the site investigations. The soils observed were dry to saturated in condition. Perched groundwater may develop at the contact between the schist bedrock and overlying soils during times of heavy or extended periods of rainfall.

5 Natural Hazards

5.1 Seismic

A severe seismic risk is present in the region and appropriate allowance should be made for seismic loading during detailed design of any proposed building, foundations or retaining walls.

5.2 Slope Stability

No deep seated, recent or active slope instability of the soils along the northeastern slopes was observed during the site walkover, and no known risks are present on the Queenstown Lakes District Council (QLDC) natural hazard planning maps.

The outwash terrace slope northeast of the ‘Indicative Residential Development Boundary’ is moderately to steeply inclined with a maximum slope angle of approximately 34°, sloping in a southwest direction. Based on the inferred geology of the terrace and observations during site investigations the slope is stable in its current condition. It is understood; the private plan change does not enable any building on the slope.

Instability of the terrace slope during a moderate to large seismic event is possible. Slope stability assessment including additional site investigations along the ‘Indicative Residential Development Boundary’ and sloping ground to the northeast is recommended during subdivision planning and design to confirm lot boundaries, building platform locations and associated remedial works, if required, to develop the land.

Specific engineering design will be required to assist subdivision layout and building platform location confirmation.

5.2.1 Alluvial Fan

No alluvial fan hazard has been identified at the site, and none are indicated on the QLDC natural hazards planning maps.

5.3 Liquefaction Analysis

5.3.1 Design Earthquakes

Three earthquake scenarios have been assessed in accordance with NZS1170 – Structural Design Actions[1] for Importance Level 2 structures with a 50-year design life.

Peak horizontal ground accelerations and effective magnitudes were taken from Table A1 in Appendix A of Module 1: Overview of the guidelines – Earthquake geotechnical engineering practice. Table 5.1 summarises the scenarios considered. The MBIE NZGS Module 1 design earthquakes are an interim hazard until results of the national seismic hazard update are made available for use.

Table 5.1 – Earthquake accelerations and effective magnitudes for liquefaction assessment

Scenario	Performance Requirements	Annual Probability of Exceedance	Peak Horizontal Ground Acceleration (PGA)	Effective Magnitude
Serviceability Limit State (SLS)	*Avoid damage that would prevent the structure being used as originally intended without repair.*	1/25	0.1 g	6.5
Intermediate State (INT)	*No specific requirements unless a more resilient structure is desired.*	1/100	0.32 g	6.5
Ultimate Limit State (ULS)	*Avoid collapse of the structural system.*	1/500	0.41 g	6.5

5.3.2 Liquefaction Summary

The following analysis has been carried out:

- Analysis was undertaken on the CPT soundings using Boulanger & Idriss (2014)[2] to calculate factor of safety against liquefaction and Zhang et al (2002)[3] to calculate liquefaction-induced reconsolidation settlement. As no laboratory testing has been undertaken in this analysis, a soil classification index (Ic) cut off of 2.6 and a fines correction coefficient (Cfc) of 0 has been adopted.
- Groundwater levels have been adopted, based on the static groundwater level observed in the test pits adjacent to CPT tests.
- Lateral spreading has been assessed quantitatively based on topography, calculated liquefiable layers and comments in the MBIE (2017) and MBIE/NZGS Module 3 guidelines[4].

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[1] NZS1170-5 (2004) Structural Design Actions, Part 5: Earthquake Actions – New Zealand.

[2] Boulanger, R.W. & Idriss, I.M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Department of Civil & Environmental Engineering, University of California.

[3] Zhang, G., Robertson, P.K., Brachman, R.W.I. (2002). Estimating liquefaction-induced ground settlements from CPT for level ground.

[4] New Zealand Geotechnical Society, Ministry of Business, Innovation & Employment (2021). Earthquake geotechnical engineering practice; Module 3. Identification, assessment and mitigation of liquefaction hazards. ISBN 978-0-947524-48-7 (Online)

The liquefaction analysis indicates the following:

- No liquefaction is calculated for the SLS design earthquakes.
- Liquefaction is calculated in the Intermediate and ULS design earthquake. Earthquake reconsolidation settlements of between 0 to 160 mm is calculated for the ULS design earthquake.
- The liquefaction is calculated between 1.5 and 9 m, with a liquefaction severity number (LSN) of between 0-40 calculated (L0-4, Insignificant to Severe).
- Based on the MBIE Guidance (2015), the proposed private plan change area ranges between MBIE TC1 to TC3 sites.
- Lateral spreading is not likely based on the thickness of the depth of liquefiable layers and topography.
- Liquefaction at the site is “triggered” at a PGA of around 0.14g which has an AEP of 50 years (note 500 year is the IL2, 50 year design life ULS earthquake event).

A detailed discussion of the process of liquefaction and the various considerations can be found in Appendix C, which also contains the full liquefaction analysis results from CPT’s.

6 Preliminary Engineering Considerations

6.1 General

The proposed development is expected to be achievable from a geotechnical perspective. Ground conditions will range across the property. Further investigation and assessment will be required during the subdivision design phase. Preliminary considerations are provided in the sections below.

The preliminary recommendations and opinions contained in this report are based upon ground investigation data obtained at discrete locations and historical information held on the GeoSolve database. The nature and continuity of subsoil conditions away from the investigation locations is inferred and cannot be guaranteed.

6.2 Excavations

Excavations can be readily achieved across the site area.

If deep excavations are required within the buildable area along the northeast slope, specific geotechnical investigation and assessment are recommended to confirm appropriate temporary and permanent batter angles, any retaining requirements and to assess slope stability.

Deep excavations across the property will need to consider groundwater. Dewatering or other groundwater related construction methodology may be required for deep excavations.

The subsurface soils will be relatively easy to excavate by conventional methods; however, schist bedrock rock is expected to be at shallow depths along the northeastern slopes.

We recommend that the excavations should be inspected by a geotechnical practitioner during earthworks construction.

6.3 Foundations

No specific lot boundaries are confirmed at the time of plan change reporting as these are a matter for subdivision consent, and investigations were widely spaced. Based on liquefaction testing the private plan change area ranges from MBIE TC1 to TC3 categories. Lot specific testing is recommended to determine the specific technical category.

Across the property the natural soils underlying topsoil and uncontrolled fill will provide a reduced bearing capacity with respect to ‘good ground’ in accordance with NZS3604:2011. Increased foundation bearing is expected to be available at depth on sand and gravel materials and schist rock.

TC1 lots can use standard ground improvement methods and standard foundations, raft foundations or specific engineering design (SED) to allow for the reduced bearing capacity. Foundation solutions for TC2 lots are detailed in the MBIE Guidance (2012) Part A and options for TC3 lots are detailed in MBIE Guidance (2015) Part C. Viable foundation solutions are available across the property.

Specific foundation design, or deeper foundations may be required where construction close to sloping ground is proposed.

7 Preliminary Soakage Assessment

The location and method of the stormwater disposal is unconfirmed at this stage; therefore, the results and recommendations below are preliminary only.

Soakage testing was completed to assess the suitability of the ground conditions for stormwater disposal. Soakage testing was undertaken within SPs 1-3 at depths of between 1.3-1.6 m depth within alluvial sand.

Soakage testing was performed by introducing water from a water cart until the water level of the pit reached the designated testing level. Inflow was then ceased, and the time taken for the water level to drop was recorded, i.e., a falling head test. Testing was then repeated to ensure saturated conditions were achieved and until consistent readings had been achieved for each test.

The groundwater level was encountered during test pitting; therefore, the regional groundwater level will likely influence the long-term infiltration rate.

7.1 Permeability Analysis

Results from the field soakage testing have been analysed to determine indicative infiltration rates which are provided below in Table 7.1.

Table 7.1: Calculated Infiltration Rates

Test	Test Depth (m)	Soil type at testing level and test subsoil	Unfactored infiltration rate*	Testing situation*[1]
SP1	1.3	Silty SAND	1 mm/hr	Falling head test in soil, Quality level 3
SP2	1.6	Silty SAND	0 mm/hr	Falling head test in soil, Quality level 3
SP3	1.5	Silty SAND	3 mm/hr	Falling head test in soil, Quality level 3

*Does not include a factor of safety to account for loss of soakage performance over time. A factor of safety is to be calculated by the soak pit designer at the detailed design stage.

*[1] Information provided to allow selection of the correct partial factor of safety (F_u) for uncertainty in input data as per Table 4-7 of the proposed 2022 amendments to the QLDC COP[5].

8 Summary

The geotechnical site investigations and analysis have determined that there are no geotechnical constraints or reasons for the rezoning not to be granted.

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[5] Queenstown Lakes District council (2020), Land Development & Subdivision Code of Practice (2022 proposed amendments)

9 Applicability

This report has been prepared for the sole use of our client, Arrowsouth Properties Limited, with respect to the particular brief and on the terms and conditions agreed with our client. It may not be used or relied on (in whole or part) by anyone else, or for any other purpose or in any other contexts, without our prior review and written agreement.

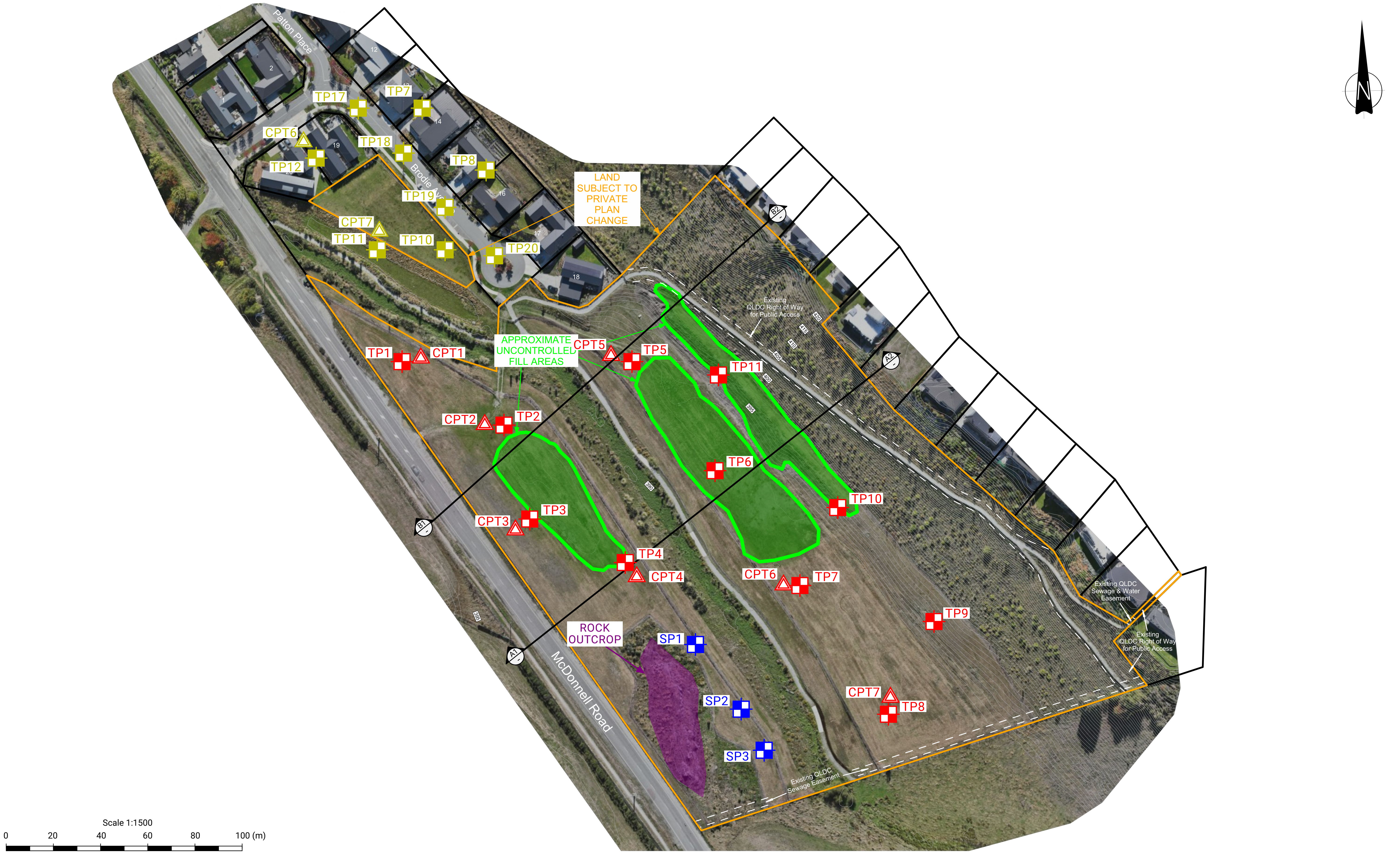
Investigations have been undertaken at discrete locations in accordance with the brief provided. It must be appreciated that the nature and continuity of subsoil conditions away from the investigation locations cannot be guaranteed.

Report prepared and Reviewed for GeoSolve Ltd by:

……………………..………..……………	……………………..………..……………
Emma Hutchinson	Fraser Wilson
Engineering Geologist	Senior Engineering Geologist

Appendices: **Appendix A – Site Plan & Cross-Sections**
Appendix B – Investigation Data
Appendix C – Liquefaction Analysis

Appendix A: Site Plan & Cross-sections



Key

△CPT1 = Cone Penetrometer Test

🟥TP1 = Test Pit

🟩 = Approximate area of Uncontrolled fill

🟦TP1 = Soakage Test

△ = Cross-section location and facing

🟨TP1 = Historic Test Pit and CPTs

CADFILE:	Sketch 1.xar	DRAWN	ELH	05/2025
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	ELH	06/2025
PROJECT No:	170605.02	APPROVED	FAW	06/2025

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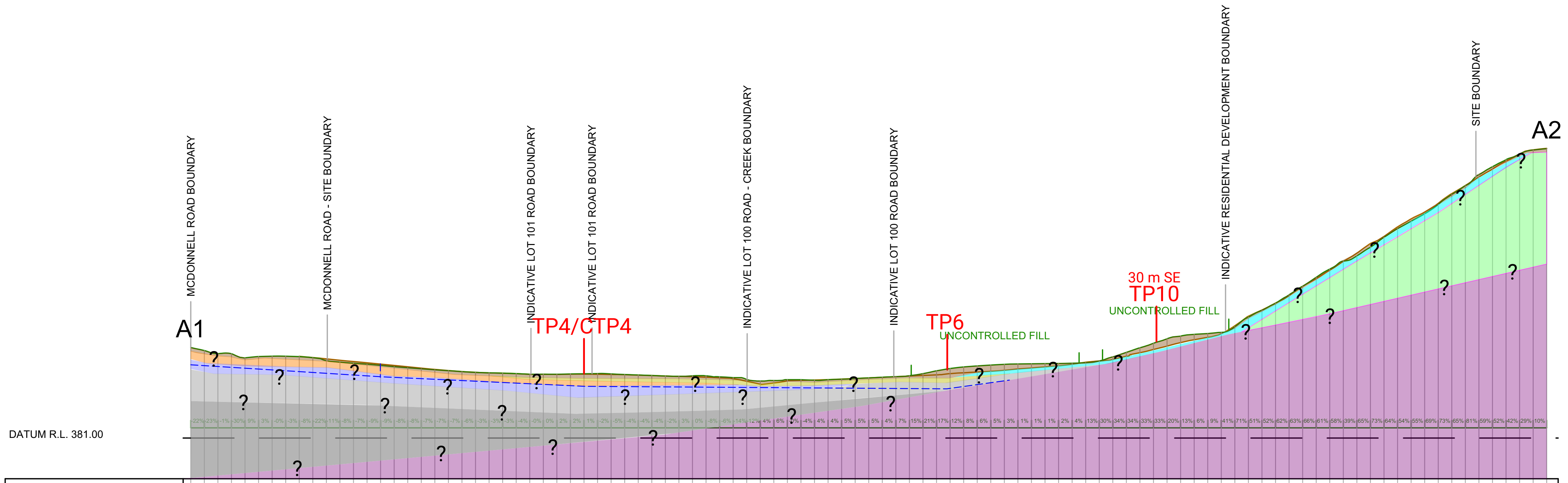
Arrowsouth Properties Ltd
Geotechnical Assessment
McDonnell Road, Arrowtown
Site Investigation Plan

FIG No: APPENDIX A, FIGURE 1

REV. 1



UPDATED / EXISTING UAV SURFACE LEVELS	394.3	393.9	393.4	393.4	392.8	393.0	393.1	393.1	393.0	392.8	392.4	392.2	392.0	391.9	391.7	391.5	391.4	391.2	391.1	390.9	390.8
PREVIOUS LIDAR SURFACE LEVELS									393.0	392.9	392.7	392.5	392.3	392.1	391.9	391.7	391.5	391.3	391.1	390.9	390.8
APPROX. DIFFERENCE CUT(-) / FILL(+)									-0.0	-0.0	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.0	-0.0
CHAINAGE	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0	40.0

UPDATED / EXISTING UAV SURFACE LEVELS	390.7	390.6	390.6	390.5	390.4	390.4	390.4	390.4	390.5	390.5	390.5	390.4	390.3	390.2	390.1	390.1	390.2	390.2	390.0	389.9	389.6
PREVIOUS LIDAR SURFACE LEVELS	390.7	390.6	390.6	390.5	390.4	390.4	390.4	390.4	390.4	390.4	390.4	390.3	390.3	390.2	390.1	390.1	390.0	390.0	389.9	389.7	389.4
APPROX. DIFFERENCE CUT(-) / FILL(+)	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.0	-0.0	0.0	0.1	0.2	0.1	0.2	0.3
CHAINAGE	42.0	44.0	46.0	48.0	50.0	52.0	54.0	56.0	58.0	60.0	62.0	64.0	66.0	68.0	70.0	72.0	74.0	76.0	78.0	80.0	82.0

UPDATED / EXISTING UAV SURFACE LEVELS	389.4	389.5	389.6	389.6	389.5	389.6	389.7	389.8	389.9	390.0	390.0	390.2	390.5	390.9	391.2	391.5	391.6	391.8	391.9	391.9	391.9
PREVIOUS LIDAR SURFACE LEVELS	388.9	389.1	389.4	389.5	389.6	389.6	389.7	389.8	389.9	390.0	390.0	390.1	390.2	390.3	390.5	390.6	390.7	390.8	391.0	391.2	391.3
APPROX. DIFFERENCE CUT(-) / FILL(+)	0.5	0.4	0.2	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	0.9	0.9	0.9	0.7	0.6
CHAINAGE	84.0	86.0	88.0	90.0	92.0	94.0	96.0	98.0	100.0	102.0	104.0	106.0	108.0	110.0	112.0	114.0	116.0	118.0	120.0	122.0	124.0

UPDATED / EXISTING UAV SURFACE LEVELS	392.0	392.0	392.0	392.1	392.4	393.0	393.6	394.3	395.0	395.6	396.0	396.3	396.4	396.6	397.4	398.8	399.8	400.9	402.1	403.4	404.7
PREVIOUS LIDAR SURFACE LEVELS	391.5	391.6	391.9	392.2	392.4	392.6	393.1	393.6	394.0	394.5	395.1	395.5	395.8	396.4	397.6	399.0	399.9	400.9	402.0	403.4	404.5
APPROX. DIFFERENCE CUT(-) / FILL(+)	0.5	0.4	0.2	-0.1	0.0	0.4	0.6	0.7	0.9	1.1	1.0	0.8	0.6	0.2	-0.2	-0.1	-0.0	-0.0	0.1	0.0	0.2
CHAINAGE	126.0	128.0	130.0	132.0	134.0	136.0	138.0	140.0	142.0	144.0	146.0	148.0	150.0	152.0	154.0	156.0	158.0	160.0	162.0	164.0	166.0

UPDATED / EXISTING UAV SURFACE LEVELS	405.9	407.1	407.8	409.1	410.6	411.9	412.9	414.1	415.4	416.9	418.2	419.8	421.0	422.0	422.9	423.4	423.6
PREVIOUS LIDAR SURFACE LEVELS	405.7	407.0	408.2	409.7	410.7	412.1	413.3	414.3	415.6	417.0	418.2	419.5	420.6	421.8	422.8	423.5	423.7
APPROX. DIFFERENCE CUT(-) / FILL(+)	0.2	0.0	-0.4	-0.5	-0.1	-0.3	-0.4	-0.3	-0.1	-0.1	-0.0	0.3	0.3	0.2	0.1	-0.0	-0.0
CHAINAGE	168.0	170.0	172.0	174.0	176.0	178.0	180.0	182.0	184.0	186.0	188.0	190.0	192.0	194.0	196.0	198.0	200.0

CROSS SECTION A

SCALE. HORIZ = 1:750 VERT = 1:750

Scale 1:750

Key

🟫 = Topsoil/Uncontrolled Fill
🟨 = Loess
🟧 = Alluvial Silt
🟦 = Alluvial Sand

🟦 = Colluvium
🟥 = Alluvial Deposits
⬜ = Alluvial Gravel
🟩 = Outwash Deposits

🟪 = Schist Bedrock
🟩 = Outwash Sand
⬛ = Alluvial sand and gravel
------ = Groundwater Level

CADFILE:	Sketch 1.xar	DRAWN	ELH	05/2025
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	ELH	06/2025
PROJECT No:	170605.02	APPROVED	FAW	06/2025

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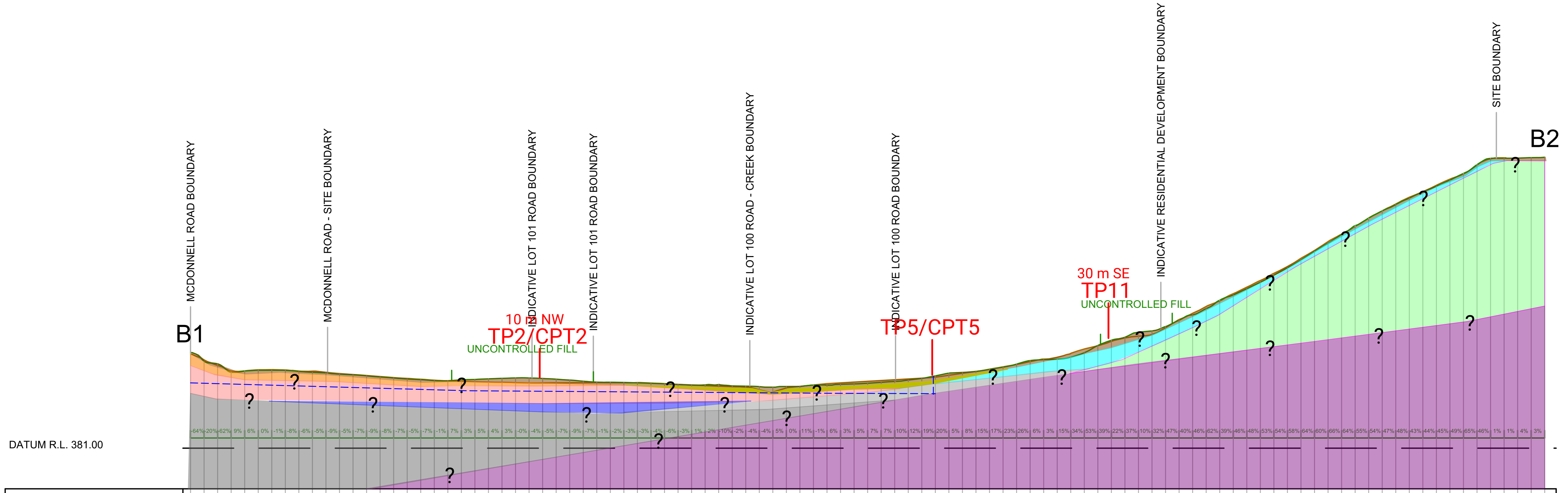
Geotechnical Assessment
McDonnell Road, Arrowtown
Cross Section A1-A2

FIG No: APPENDIX A, FIGURE 2a
REV. 1



UPDATED / EXISTING UAV SURFACE LEVELS	395.1	393.8	393.4	392.2	392.4	392.5	392.5	392.5	392.3	392.2	392.1	391.9	391.8	391.7	391.5	391.4	391.2
PREVIOUS LIDAR SURFACE LEVELS	394.9	394.0	393.2	392.4	392.4	392.6	392.6	392.5	392.4	392.4	392.2	392.0	391.9	391.7	391.6	391.4	391.3
APPROX. DIFFERENCE CUT(-) / FILL(+)	0.2	-0.2	0.2	-0.2	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.1	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1
CHAINAGE	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0

UPDATED / EXISTING UAV SURFACE LEVELS	391.1	391.0	391.0	391.1	391.1	391.2	391.3	391.4	391.4	391.3	391.2	391.1	390.9	390.7	390.7	390.7	390.6
PREVIOUS LIDAR SURFACE LEVELS	391.2	391.0	390.9	390.9	390.8	390.8	390.7	390.7	390.6	390.6	390.6	390.6	390.7	390.7	390.7	390.7	390.7
APPROX. DIFFERENCE CUT(-) / FILL(+)	-0.1	-0.1	0.0	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.5	0.4	0.2	0.1	0.1	0.1	-0.0
CHAINAGE	34.0	36.0	38.0	40.0	42.0	44.0	46.0	48.0	50.0	52.0	54.0	56.0	58.0	60.0	62.0	64.0	66.0

UPDATED / EXISTING UAV SURFACE LEVELS	390.6	390.5	390.4	390.3	390.3	390.4	390.2	390.2	390.1	390.0	390.1	390.1	390.3	390.3	390.4	390.5	390.6
PREVIOUS LIDAR SURFACE LEVELS	390.6	390.5	390.4	390.3	390.2	390.2	390.1	390.0	389.6	389.3	389.9	390.1	390.3	390.5	390.6	390.8	390.9
APPROX. DIFFERENCE CUT(-) / FILL(+)	-0.0	-0.0	-0.0	0.0	0.1	0.2	0.1	0.1	0.5	0.7	0.2	-0.0	-0.0	-0.2	-0.2	-0.3	-0.3
CHAINAGE	68.0	70.0	72.0	74.0	76.0	78.0	80.0	82.0	84.0	86.0	88.0	90.0	92.0	94.0	96.0	98.0	100.0

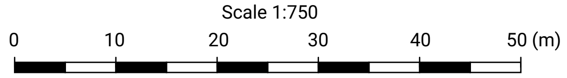
UPDATED / EXISTING UAV SURFACE LEVELS	390.7	390.8	391.1	391.3	391.7	392.1	392.2	392.3	392.6	393.0	393.4	393.9	394.1	394.1	394.4	395.1	396.2
PREVIOUS LIDAR SURFACE LEVELS	391.0	391.1	391.2	391.3	391.5	391.8	392.0	392.3	392.7	393.0	393.4	393.8	394.2	394.4	395.0	395.6	396.1
APPROX. DIFFERENCE CUT(-) / FILL(+)	-0.3	-0.3	-0.2	-0.0	0.2	0.3	0.1	0.0	-0.0	-0.0	0.1	0.2	-0.1	-0.3	-0.6	-0.6	0.0
CHAINAGE	102.0	104.0	106.0	108.0	110.0	112.0	114.0	116.0	118.0	120.0	122.0	124.0	126.0	128.0	130.0	132.0	134.0

UPDATED / EXISTING UAV SURFACE LEVELS	396.9	397.4	398.1	398.3	399.0	399.9	400.7	401.6	402.8	403.6	404.5	405.5	406.5	407.6	408.8	410.1	411.2
PREVIOUS LIDAR SURFACE LEVELS	396.8	397.3	397.5	397.8	398.8	400.0	400.9	401.9	402.8	403.8	404.8	405.8	406.8	407.8	409.0	410.2	411.5
APPROX. DIFFERENCE CUT(-) / FILL(+)	0.2	0.1	0.6	0.5	0.2	-0.1	-0.2	-0.3	0.1	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.1	-0.2
CHAINAGE	136.0	138.0	140.0	142.0	144.0	146.0	148.0	150.0	152.0	154.0	156.0	158.0	160.0	162.0	164.0	166.0	168.0

UPDATED / EXISTING UAV SURFACE LEVELS	412.6	413.8	414.9	416.0	417.0	417.9	418.8	419.7	420.6	421.6	422.9	423.8	423.8	423.8	423.9	423.9
PREVIOUS LIDAR SURFACE LEVELS	412.6	413.7	415.0	416.0	417.0	418.0	418.9	419.8	420.7	421.5	422.8	423.7	423.9			
APPROX. DIFFERENCE CUT(-) / FILL(+)	-0.0	0.1	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	0.1	0.1	-0.1			
CHAINAGE	170.0	172.0	174.0	176.0	178.0	180.0	182.0	184.0	186.0	188.0	190.0	192.0	194.0	196.0	198.0	200.0

CROSS SECTION B

SCALE. HORIZ = 1:750 VERT = 1:750



Key

🟫 = Topsoil/Uncontrolled Fill	🟦 = Colluvium	🟪 = Schist Bedrock
🟨 = Loess	🟥 = Alluvial Deposits	🟩 = Outwash Sand
🟧 = Alluvial Silt	⬜ = Alluvial Gravel	⬛ = Alluvial sand and gravel
🟦 = Alluvial Sand	🟩 = Outwash Deposits	- - - - - = Groundwater Level

CADFILE:	Sketch 1.xar	DRAWN	ELH	10/2025
SCALE (AT A3 SIZE):	AS SHOWN	DRAFTING CHECKED	MDP	10/2025
PROJECT No:	250	APPROVED	FAW	10/2025

GEOSOLVE
ENGINEERING CONSULTANTS
GEOTECHNICAL
WATER RESOURCES
PAVEMENTS

Arrowsouth Properties Ltd
Geotechnical Assessment
McDonnell Road, Arrowtown
Cross Section B1-B2

FIG No:
APPENDIX A, FIGURE 2b

REV.
1

Appendix B: Investigation Data

TEST PIT LOG

HOLE NO.: TP01

JOB NO.: 170605.02

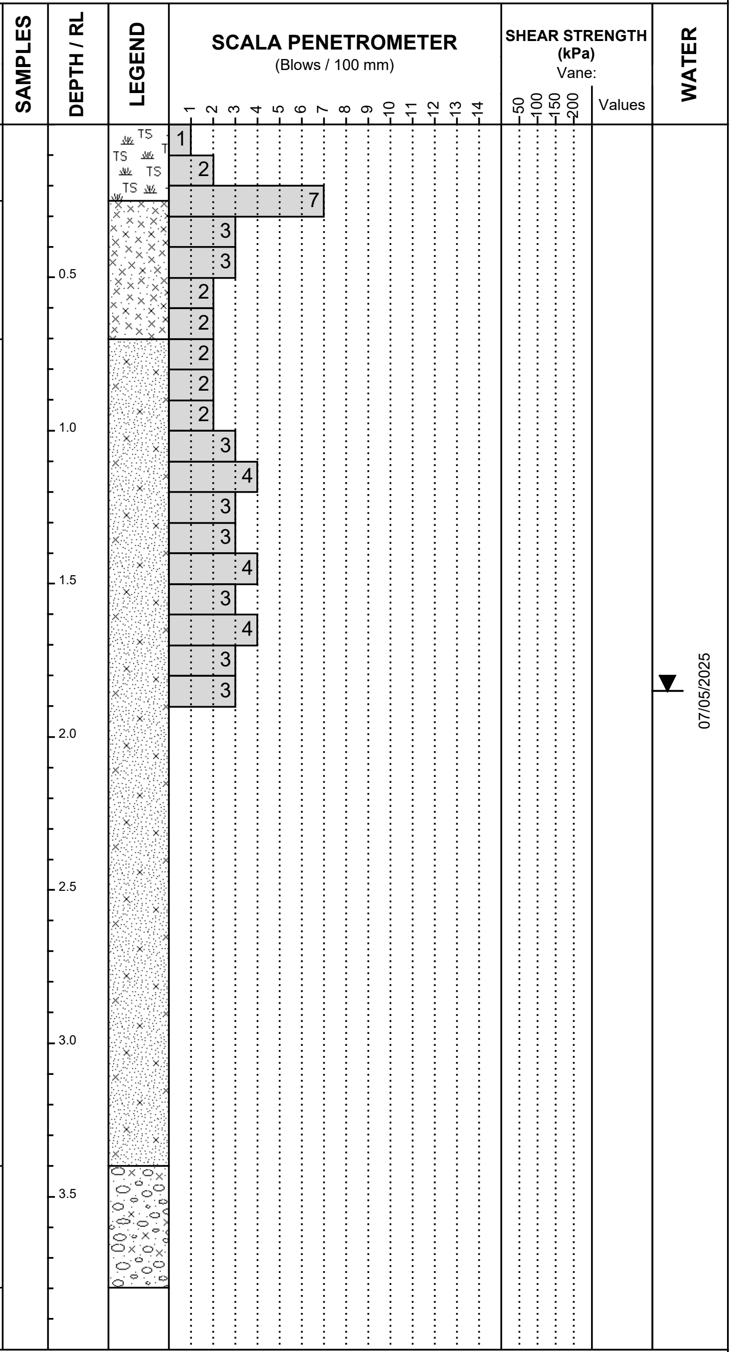
CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2

SITE LOCATION: McDonnell Road, Arrowtown
COORDINATES:
LOCATION METHOD: Map or aerial photograph
ELEVATION: Existing ground level

CONTRACTOR: Earthwork Central
EQUIPMENT: 5T Excavator
ACCURACY: ± 3 m
OPERATOR: Tony

START DATE: 07/05/2025
END DATE: 07/05/2025
LOGGED BY: JAS
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	
TOPSOIL	Organic SILT, dark grey. Soft to firm, moist, a trace of rootlets.	0.25 m
ALLUVIAL SILT	Sandy SILT, light grey, massive. Stiff, moist, sand, fine.	0.70 m
ALLUVIAL DEPOSITS	Interbedded silty fine to medium SAND to sandy SILT, dark grey, laminated. Loose to medium dense/stiff, moist to saturated, mottled orange micaceous dilatant.	3.40 m
ALLUVIAL GRAVEL	Silty sandy fine to coarse GRAVEL, grey. Loose to medium dense, saturated, gravel, subangular; sand, fine to coarse.	3.80 m
	End Of Hole: 3.80 m	



PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

TEST PIT LOG

HOLE NO.: TP02

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025
LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Organic SILT, dark grey. Stiff, moist, a trace of rootlets.		0.20 m	TS
ALLUVIAL SILT	Sandy SILT, light grey, massive. Firm to stiff, moist, sand, fine.		0.60 m	
ALLUVIAL DEPOSITS	Interbedded silty fine to medium SAND to sandy SILT, dark grey, laminated. Loose to medium dense/stiff, moist to saturated, mottled orange micaceous dilatant.		3.60 m	
ALLUVIAL SAND	Fine to coarse SAND, grey. Loose, saturated.		3.90 m	
	End Of Hole: 3.90 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows
0.0–0.1	3
0.1–0.2	3
0.2–0.3	2
0.3–0.4	3
0.4–0.5	3
0.5–0.6	2
0.6–0.7	1
0.7–0.8	2
0.8–0.9	2
0.9–1.0	1
1.0–1.1	3
1.1–1.2	4
1.2–1.3	4
1.3–1.4	4
1.4–1.5	4
1.5–1.6	4
1.6–1.7	4
1.7–1.8	3
1.8–1.9	4

SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER ▼ 07/05/2025

PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 9/05/2025 11:05:05 am

TEST PIT LOG

HOLE NO.: TP03

CLIENT: Arrowsouth Properties Ltd

PROJECT: ArrowsouthSubdivisionStage2

JOB NO.: 170605.02

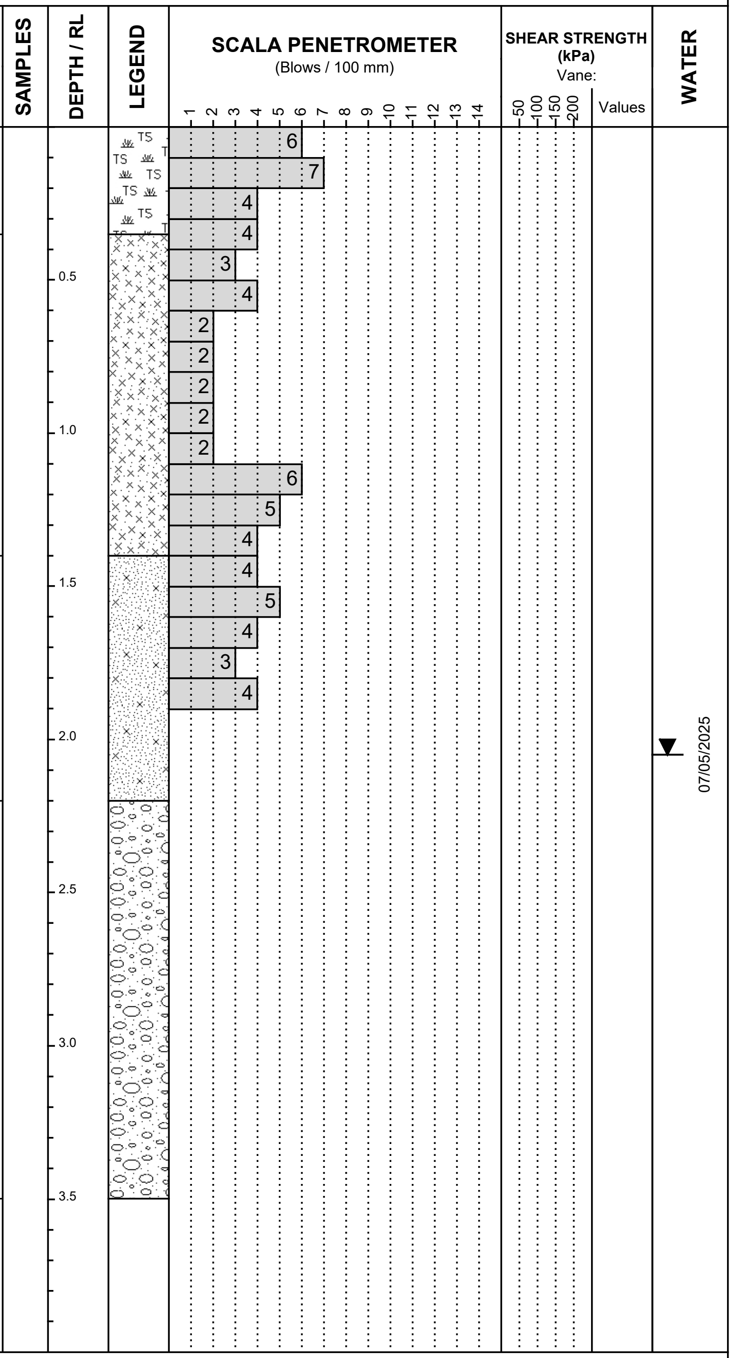
SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025

COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025

LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS

ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic SILT, dark grey. Stiff to very stiff, dry, a trace of rootlets. 0.35 m
ALLUVIAL SILT	Sandy SILT, light brown and light grey, massive. Stiff, moist, sand, fine. 1.40 m
ALLUVIAL DEPOSITS	Interbedded silty fine to medium SAND to sandy SILT, grey, laminated. Loose to medium dense/stiff, moist to wet, mottled orange micaceous dilatant. 2.20 m
ALLUVIAL GRAVEL	Sandy fine to coarse GRAVEL with some cobbles and a trace of boulders, grey. Medium dense, saturated, gravel, subangular to rounded; sand, fine to coarse; boulders up to 400 mm diameter.. 3.50 m
	End Of Hole: 3.50 m



PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

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GEOSOLVE ENGINEERING CONSULTANTS

TEST PIT LOG

HOLE NO.: TP04

JOB NO.: 170605.02

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2

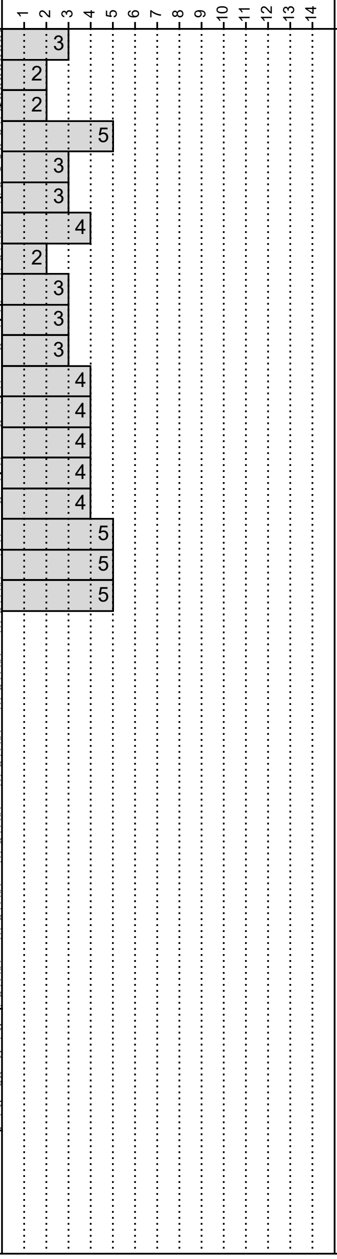
SITE LOCATION: McDonnell Road, Arrowtown
COORDINATES:
LOCATION METHOD: Map or aerial photograph
ELEVATION: Existing ground level

CONTRACTOR: Earthwork Central
EQUIPMENT: 5T Excavator
ACCURACY: ± 3 m
OPERATOR: Tony

START DATE: 07/05/2025
END DATE: 07/05/2025
LOGGED BY: JAS
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
UNCONTROLED FILL	Gravelly fine to coarse SAND, brown, massive. Loose to medium dense, moist, gravel, fine to coarse, subangular. 0.25 m		
BURIED TOPSOIL	Organic SILT, dark grey, massive. Stiff, moist, a trace of rootlets. 0.55 m		0.5
LOESS	Silty fine SAND, light brown, massive. Medium dense, moist, bioturbated weathered. 0.90 m		
ALLUVIAL SILT	Sandy SILT, grey, massive. Stiff, moist, sand, fine. 1.70 m		1.0 1.5
ALLUVIAL SAND	Interbedded silty fine to medium SAND to SAND, dark grey, laminated. Loose to medium dense, wet, mottled orange micaceous dilatant. 3.20 m		2.0 2.5 3.0
ALLUVIAL GRAVEL	Sandy fine to coarse GRAVEL, grey and brown. Medium dense, saturated, gravel, subangular; sand, fine to coarse; iron staining. 3.60 m		3.5
	End Of Hole: 3.60 m		

SCALA PENETROMETER (Blows / 100 mm)



SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER ▼ 07/05/2025

PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

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TEST PIT LOG

HOLE NO.: TP05

CLIENT: Arrowsouth Properties Ltd

PROJECT: ArrowsouthSubdivisionStage2

JOB NO.: 170605.02

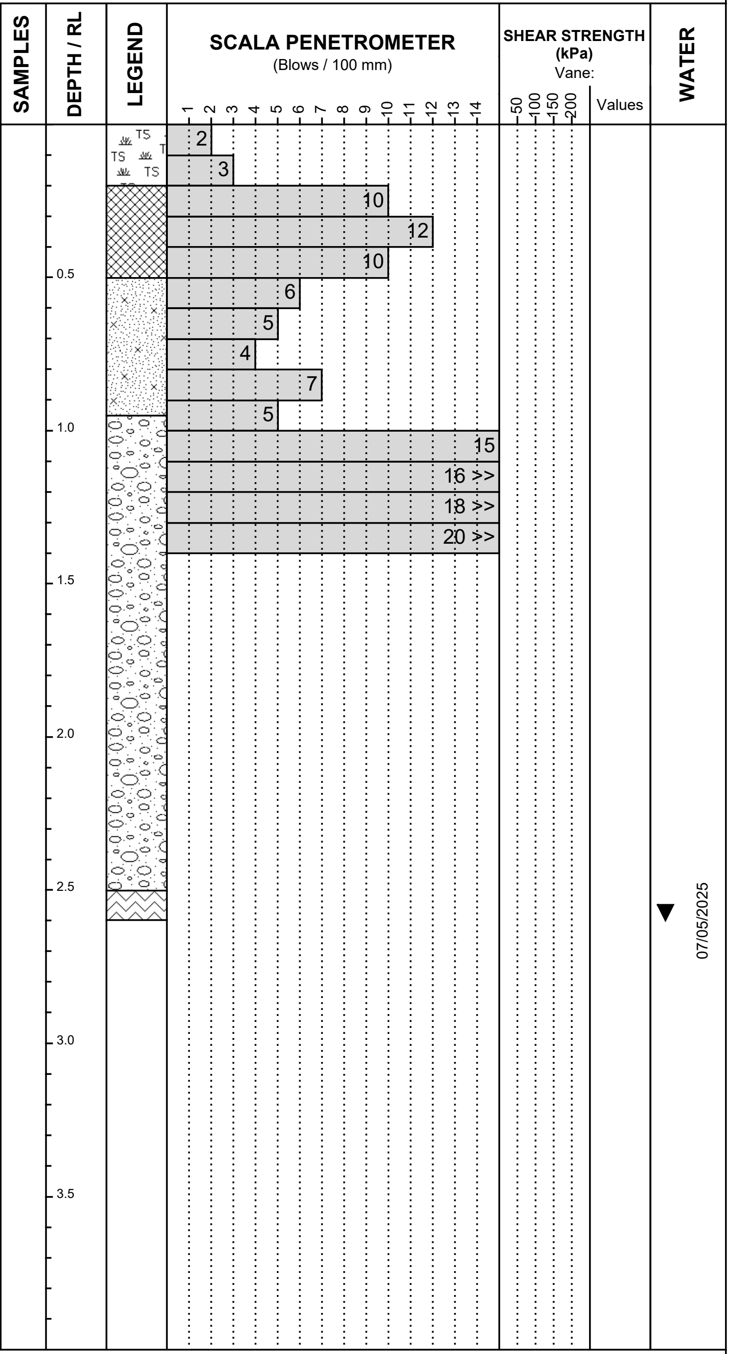
SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025

COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025

LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS

ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	
TOPSOIL	Organic SILT, dark brown. Stiff, dry.	0.20 m
UNCONTROLED FILL	Silty fine SAND with minor organic SILT, dark grey, massive. Dense, dry, a trace of rootlets.	0.50 m
LOESS	Silty fine SAND, light brown, massive. Medium dense, moist, bioturbated weathered.	0.95 m
ALLUVIAL GRAVEL	Sandy fine to coarse GRAVEL with minor cobbles and a trace of boulders, grey, bedded. Medium dense, moist, gravel, subangular to rounded; sand, fine to coarse; boulders up to 400 mm diameter..	2.50 m
SCHIST BEDROCK	Slightly weathered, dark grey, PELITIC SCHIST. Moderately strong, foliated.	2.60 m
	End Of Hole: 2.60 m	



PHOTO(S)

REMARKS

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 9/05/2025 11:05:20 am

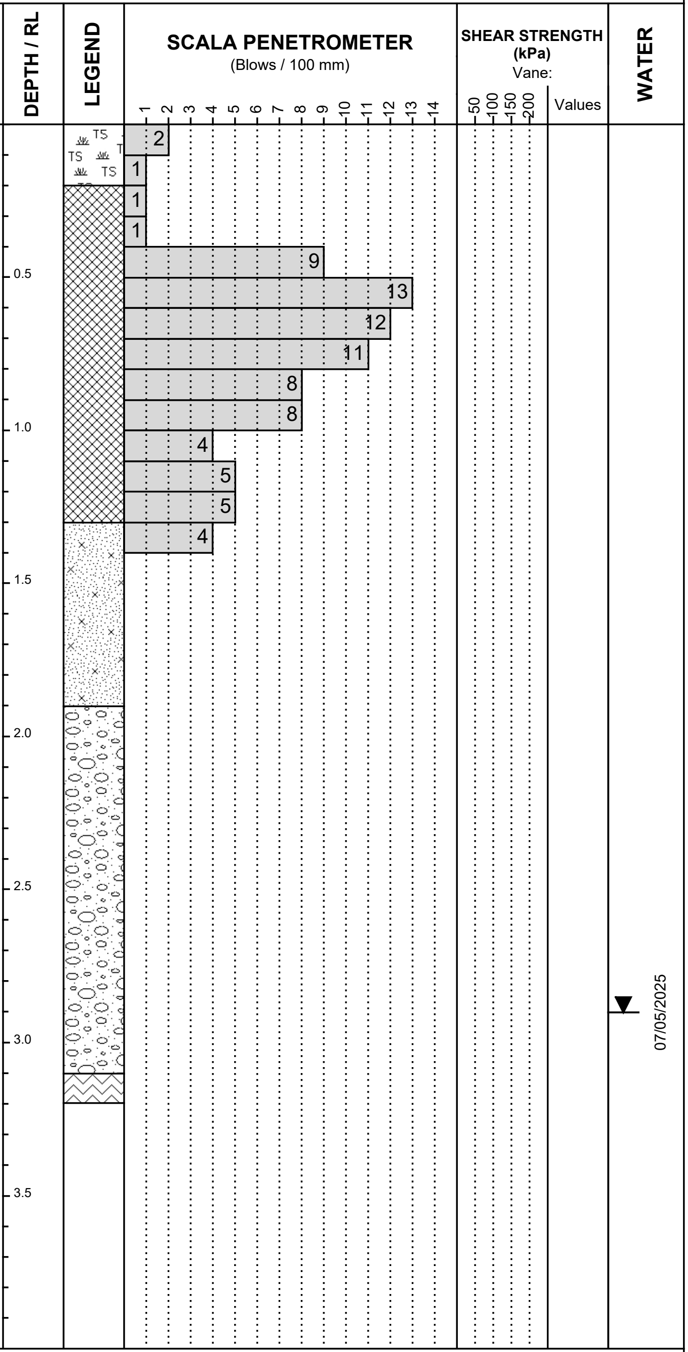
TEST PIT LOG

HOLE NO.: TP06

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025
LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES
TOPSOIL	Organic SILT, dark brown. Firm to stiff, dry. 0.20 m	
UNCONTROLED FILL	Silty fine SAND with minor organic SILT and organic debris, a trace of gravel, cobbles and boulders, grey and brown, massive. Medium dense to dense, dry, gravel, fine to coarse, angular to rounded; boulders up to 600mm diameter. 1.30 m	
LOESS	Silty fine SAND, light brown, massive. Medium dense, dry, bioturbated weathered. 1.90 m	
ALLUVIAL GRAVEL	Sandy fine to coarse GRAVEL with minor cobbles and a trace of boulders, grey and brown, bedded. Medium dense, moist, gravel, subangular to rounded; sand, fine to coarse; boulders up to 600 mm diameter.. 3.10 m	
SCHIST BEDROCK	Slightly weathered, dark grey, PELITIC SCHIST. Moderately strong, foliated. 3.20 m	
	End Of Hole: 3.20 m	



PHOTO(S)

REMARKS

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

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TEST PIT LOG

HOLE NO.: TP07

CLIENT: Arrowsouth Properties Ltd

PROJECT: ArrowsouthSubdivisionStage2

JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025

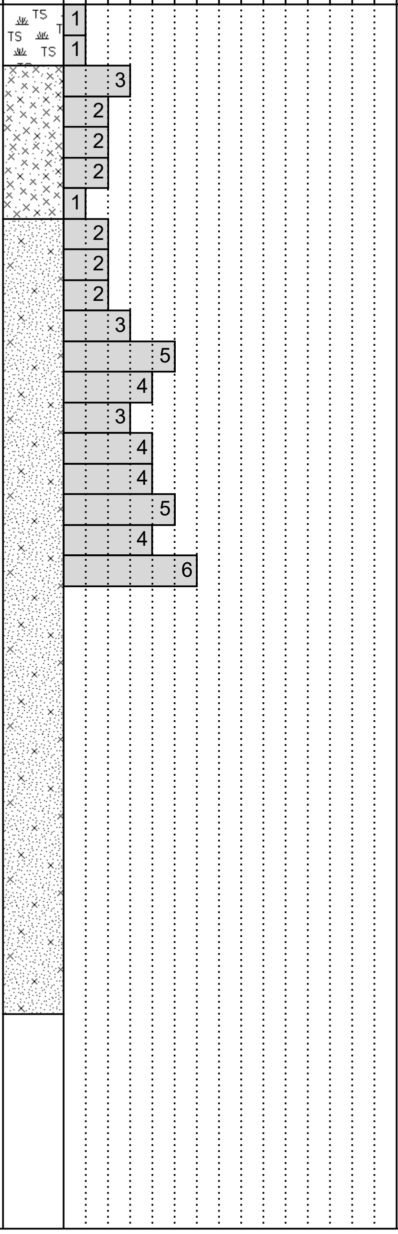
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025

LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS

ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	WATER
TOPSOIL	Organic SILT, dark brown. Soft to firm, moist. 0.20 m			
ALLUVIAL SILT	Sandy SILT, grey, massive. Firm to stiff, moist, sand, fine. 0.70 m		0.5	
ALLUVIAL SAND	Silty fine to medium SAND, dark grey, laminated. Loose to medium dense, moist to saturated, becoming wet at 1.1m bgl, mottled orange micaceous dilatant. 3.30 m		1.0 1.5 2.0 2.5 3.0	▼ 07/05/2025
	End Of Hole: 3.30 m		3.5	

SCALA PENETROMETER (Blows / 100 mm)



SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 9/05/2025 11:05:30 am

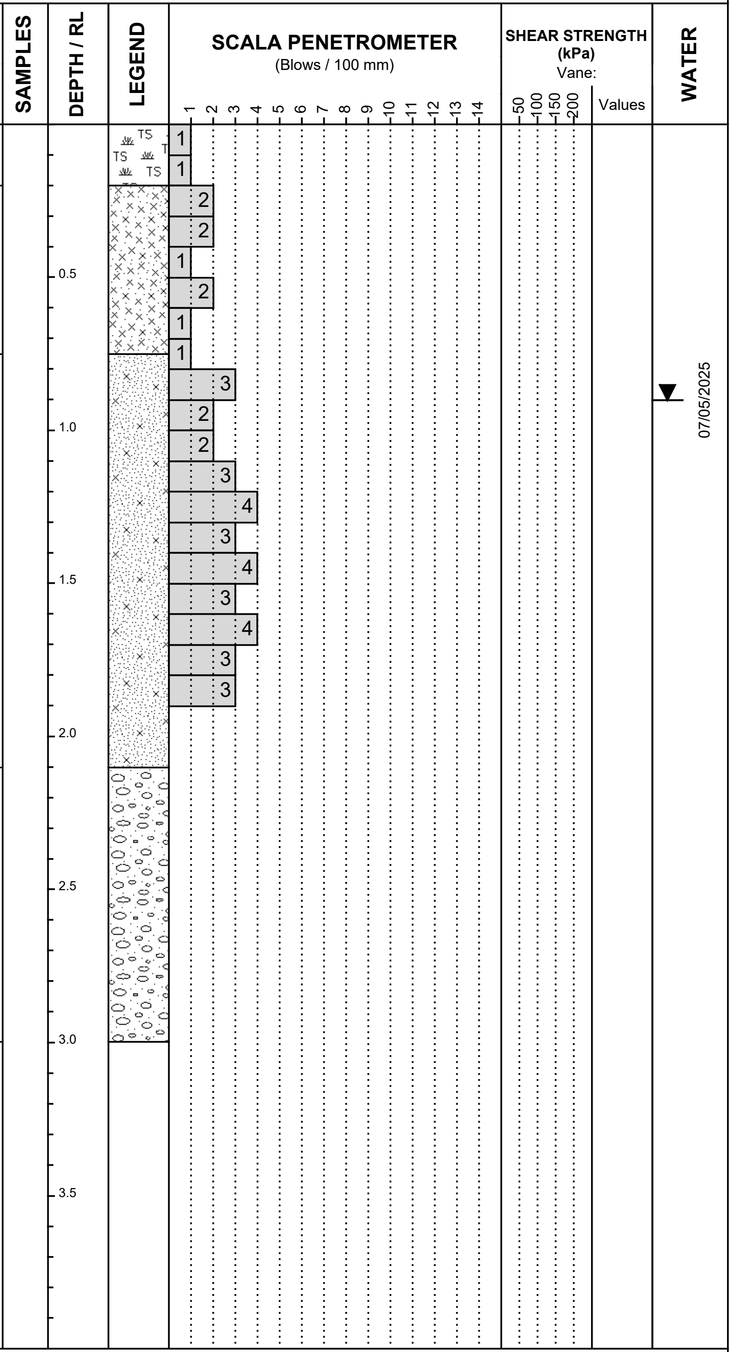
TEST PIT LOG

HOLE NO.: TP08

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025
LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	
TOPSOIL	Organic SILT, dark brown. Soft to firm, moist.	0.20 m
ALLUVIAL SILT	Sandy SILT, grey, massive. Firm, moist.	0.75 m
ALLUVIAL SAND	Silty fine to medium SAND, dark grey, bedded. Loose to medium dense, wet to saturated, lens of gravelly fine to medium SAND at 1.5 m bgl, mottled orange micaceous dilatant.	2.10 m
ALLUVIAL GRAVEL	Interbedded sandy fine to medium GRAVEL and silty fine to coarse SAND, grey and brown, bedded. Loose to medium dense, saturated, gravel, subangular; iron staining.	3.00 m
	End Of Hole: 3.00 m	



PHOTO(S)

REMARKS

The test pit walls collapsed below the groundwater table

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

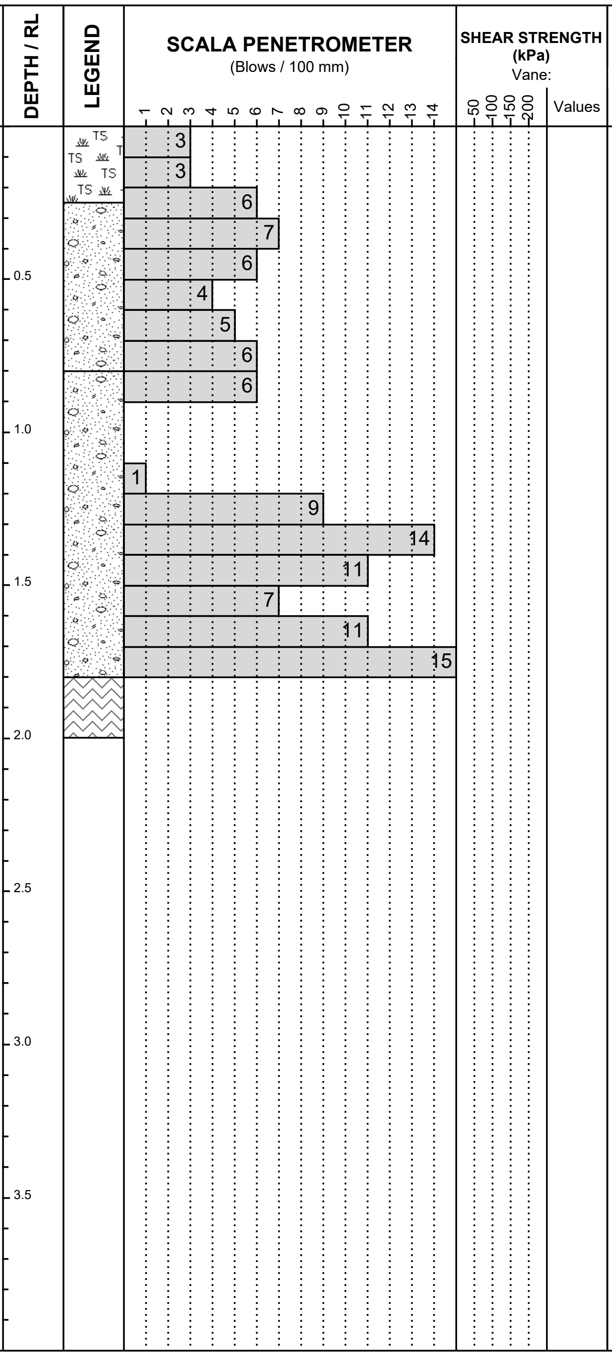
TEST PIT LOG

HOLE NO.: TP09

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025
LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	WATER
TOPSOIL	Organic SILT, dark brown. Firm to stiff, dry. 0.25 m		Groundwater Not Encountered
COLLUVIUM	Gravelly fine to coarse SAND with a trace of cobbles, light brown, bedded. Medium dense, dry, gravel, fine to medium, subangular to rounded. 0.80 m		
OUTWASH SAND	Gravelly fine to coarse SAND, light grey, bedded. Medium dense, dry, gravel, fine to coarse, subrounded to rounded. 1.80 m		
SCHIST BEDROCK	Slightly weathered, dark grey, PELITIC SCHIST. Moderately strong, foliated. 2.00 m		
	End Of Hole: 2.00 m		



PHOTO(S)

REMARKS

No groundwater observed.

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

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TEST PIT LOG

HOLE NO.: TP10

CLIENT: Arrowsouth Properties Ltd

PROJECT: ArrowsouthSubdivisionStage2

JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown

CONTRACTOR: Earthwork Central

START DATE: 07/05/2025

COORDINATES:

EQUIPMENT: 5T Excavator

END DATE: 07/05/2025

LOCATION METHOD: Map or aerial photograph

ACCURACY: ± 3 m

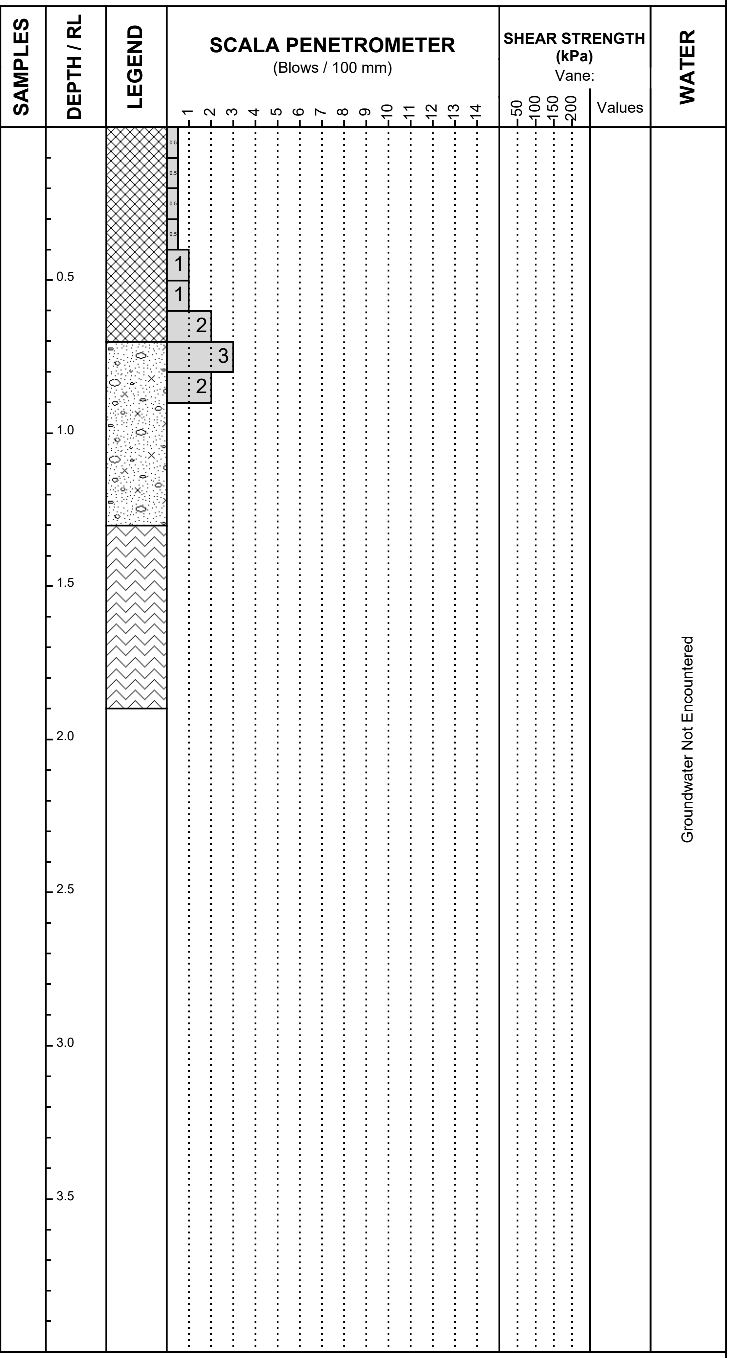
LOGGED BY: JAS

ELEVATION: Existing ground level

OPERATOR: Tony

CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
UNCONTROLED FILL	Organic SILT with minor gravel, dark brown. Soft to firm, moist, gravel, fine to coarse, subangular to rounded. 0.70 m
COLLUVIUM	Silty gravelly fine to coarse SAND, light brown, bedded. Medium dense, moist, gravel, fine to coarse, subangular to rounded. 1.30 m
SCHIST BEDROCK	Slightly weathered, dark grey, PELITIC SCHIST. Weak to moderately strong, foliated. 1.90 m
	End Of Hole: 1.90 m



PHOTO(S)

REMARKS

No groundwater observed.

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 9/05/2025 11:05:51 am

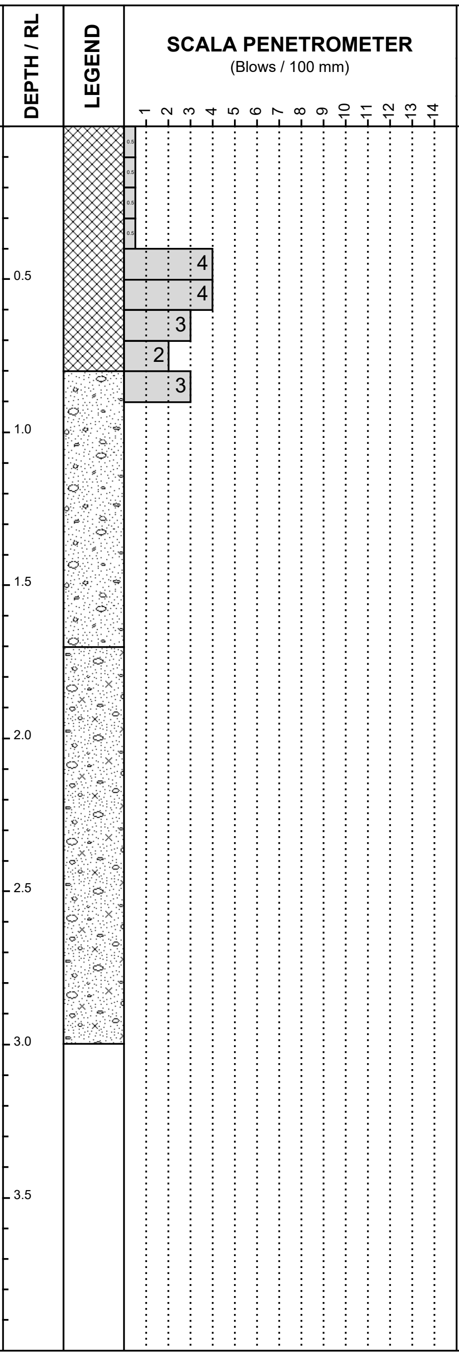
TEST PIT LOG

HOLE NO.: TP11

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthwork Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 5T Excavator
END DATE: 07/05/2025
LOCATION METHOD: Map or aerial photograph
ACCURACY: ± 3 m
LOGGED BY: JAS
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 09/05/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	WATER
UNCONTROLED FILL	Organic SILT with minor gravel, dark grey. Very soft to firm, moist, gravel, fine to medium, subangular to rounded.		0.80 m	Groundwater Not Encountered
COLLUVIUM	Gravelly fine to coarse SAND, light brown, bedded. Medium dense, moist, gravel, fine to medium, subangular to rounded.		1.70 m	
	Silty gravelly fine to coarse SAND with a trace of cobbles and boulders, grey, bedded. Medium dense, moist, gravel, fine to coarse, subangular to rounded; boulders up to 600mm diameter.		3.00 m	
	End Of Hole: 3.00 m			



SHEAR STRENGTH (kPa)
Vane:
50 100 150 200
Values

PHOTO(S)

REMARKS

No groundwater observed.

WATER

▼	Standing Water Level
▷	Out flow
◁	In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 9/05/2025 11:05:55 am

TEST PIT LOG

HOLE NO.: SP01

CLIENT: Arrowsouth Properties Ltd

PROJECT: ArrowsouthSubdivisionStage2

JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown

CONTRACTOR: Earthworks Central

START DATE: 07/05/2025

COORDINATES:

EQUIPMENT: 6 T Excavator

END DATE: 07/05/2025

LOCATION METHOD: GIS\Web map viewer

ACCURACY: ± 3 m

LOGGED BY: WF

ELEVATION: Existing ground level

OPERATOR: Tony

CHECKED DATE: 06/06/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 0 mm) 1 2 3 4 5 6 7 8 9 10 11 12 13 14	SHEAR STRENGTH (kPa) Vane: 50 100 150 200	Values	WATER
TOPSOIL	Organic SILT, dark brown.		0.30 m	TS				Groundwater Not Encountered
ALLUVIAL SILT	SILT, brown. Soft, moist.		0.70 m	× × ×				
ALLUVIAL SAND	Silty fine SAND, grey, mottled brown, orange, loosely laminated. Loose, moist.		1.30 m	⁘				
	End Of Hole: 1.30 m							

Depth scale: 0.5, 1.0, 1.5

PHOTO(S)

REMARKS

WATER

- ▼ Standing Water Level
- ▷ Out flow
- ◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/06/2025 12:58:16 pm

TEST PIT LOG

HOLE NO.: SP02

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthworks Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 6 T Excavator
END DATE: 07/05/2025
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 3 m
LOGGED BY: WF
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 06/06/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 0 mm) 1 2 3 4 5 6 7 8 9 10 11 12 13 14	SHEAR STRENGTH (kPa) Vane: 50 100 150 200	Values	WATER
TOPSOIL	Organic SILT, dark brown. 0.20 m			TS				Groundwater Not Encountered
ALLUVIAL SILT	SILT, brown. Soft, moist. 0.60 m		0.5	×				
ALLUVIAL SAND	Silty fine SAND, grey, mottled brown, orange, loosely laminated. Loose, moist. 1.60 m		1.0 1.5					
	End Of Hole: 1.60 m							

PHOTO(S)

REMARKS

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/06/2025 12:58:22 pm

TEST PIT LOG

HOLE NO.: SP03

CLIENT: Arrowsouth Properties Ltd
PROJECT: ArrowsouthSubdivisionStage2
JOB NO.: 170605.02

SITE LOCATION: McDonnell Road, Arrowtown
CONTRACTOR: Earthworks Central
START DATE: 07/05/2025
COORDINATES:
EQUIPMENT: 6 T Excavator
END DATE: 07/05/2025
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 3 m
LOGGED BY: WF
ELEVATION: Existing ground level
OPERATOR: Tony
CHECKED DATE: 06/06/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 0 mm) 1 2 3 4 5 6 7 8 9 10 11 12 13 14	SHEAR STRENGTH (kPa) Vane: 50 100 150 200	Values	WATER
TOPSOIL	Organic SILT with some gravel and a trace of cobbles, dark brown. Gravel, fine to coarse, angular. 0.30 m			TS				Groundwater Not Encountered
ALLUVIAL SILT	SILT, brown. Soft, moist. 0.60 m		0.5					
ALLUVIAL SAND	Silty fine SAND, grey, mottled brown, orange, loosely laminated. Loose, moist. 1.50 m		1.0 1.5					
	End Of Hole: 1.50 m							

PHOTO(S)

REMARKS

WATER

▼ Standing Water Level
▷ Out flow
◁ In flow

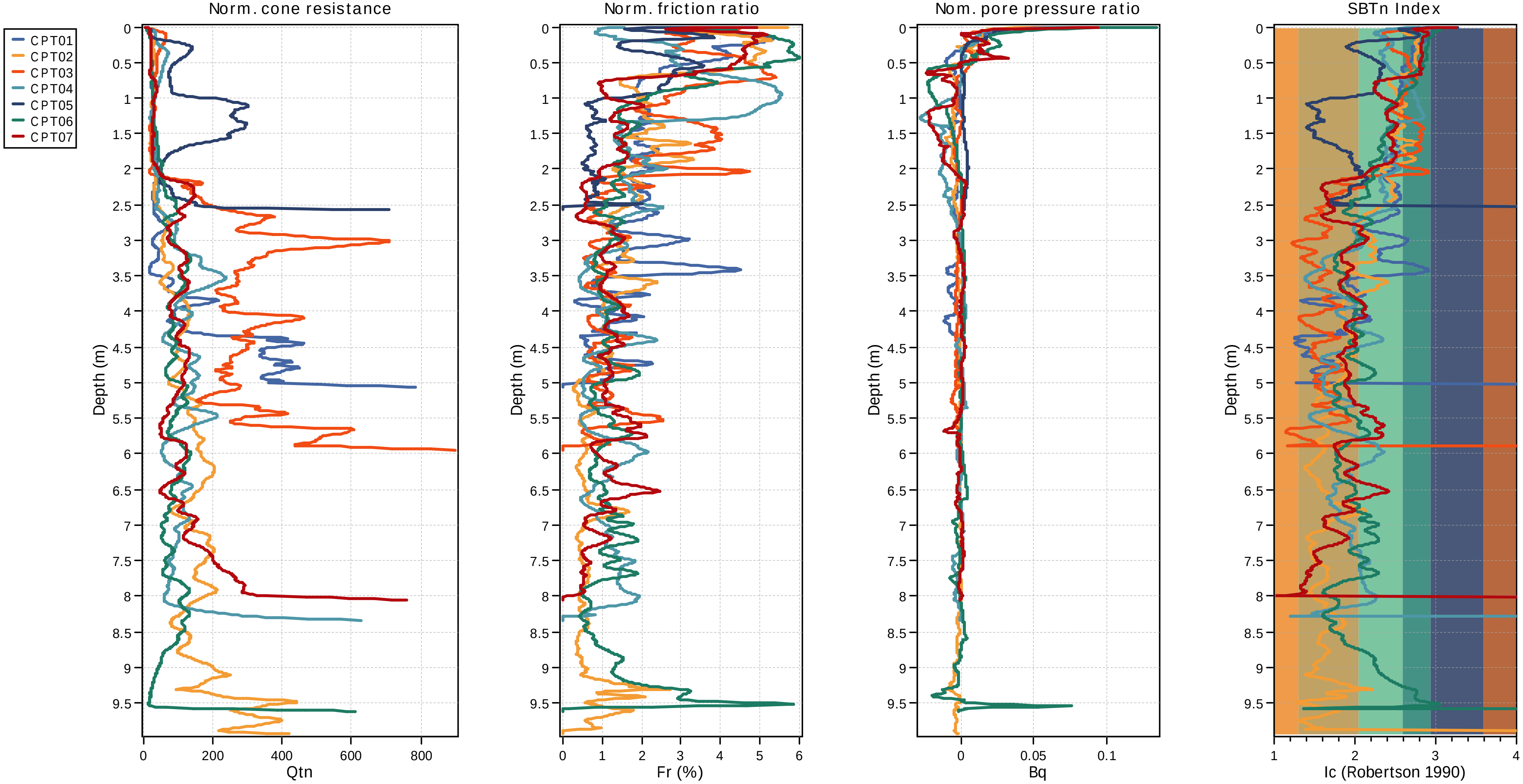
Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/06/2025 12:58:29 pm

Appendix C: Liquefaction Analysis

SLS

Project:

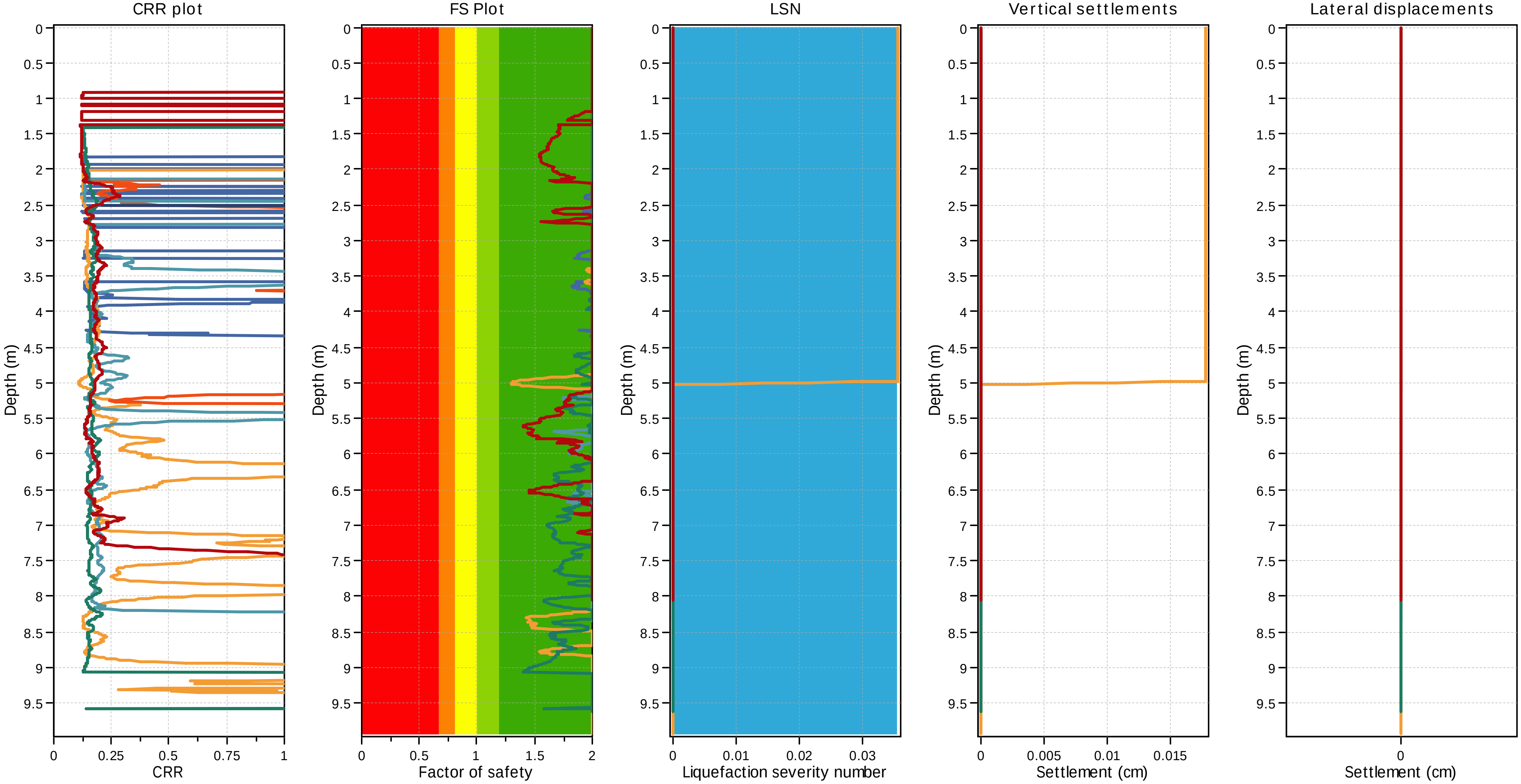
Overlay Normalized Plots



SLS

Project:

Overlay Cyclic Liquefaction Plots

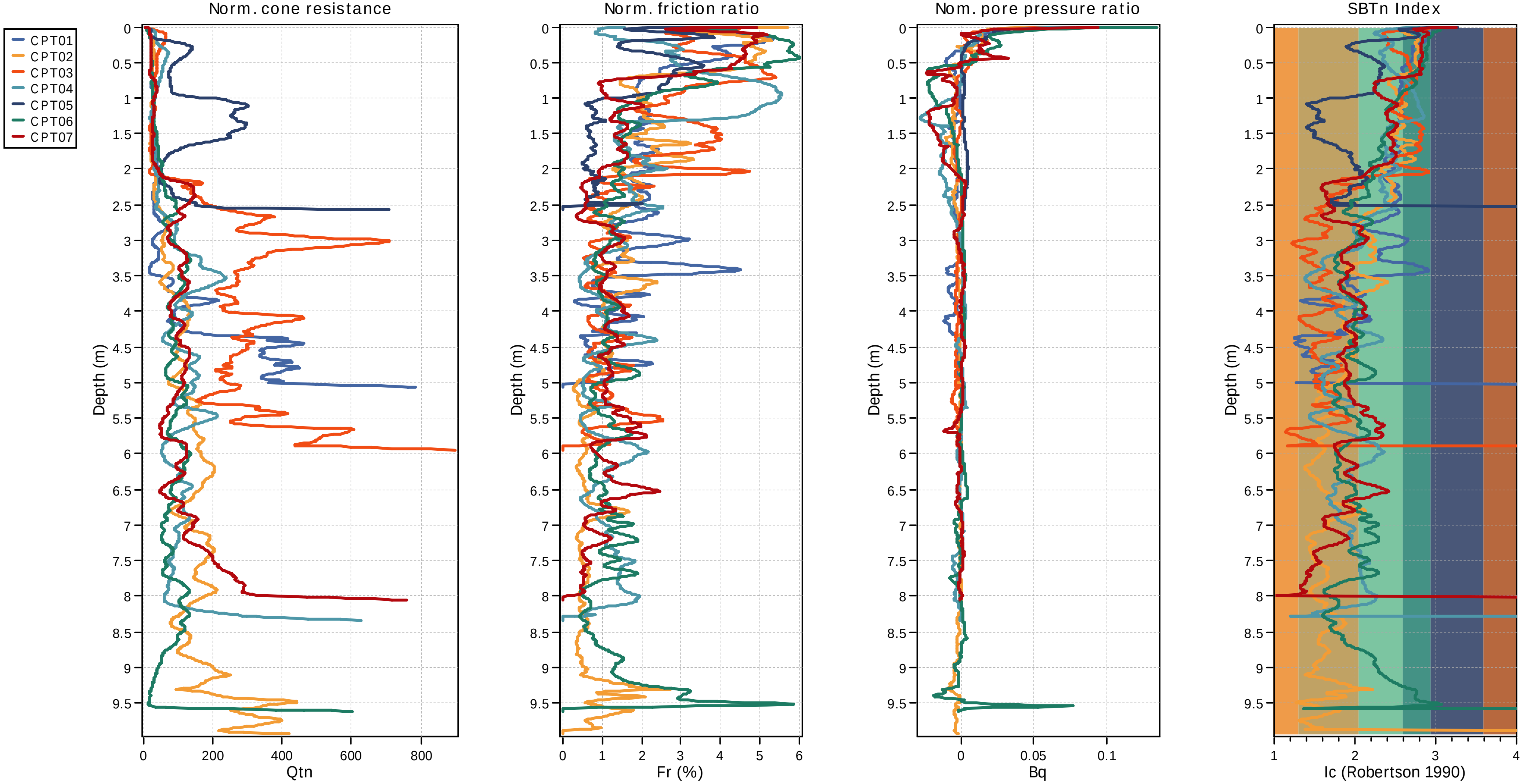


ULS

GeoLogismiki
Geotechnical Engineers
Merarhias 56
http://www.geologismiki.gr

Project:

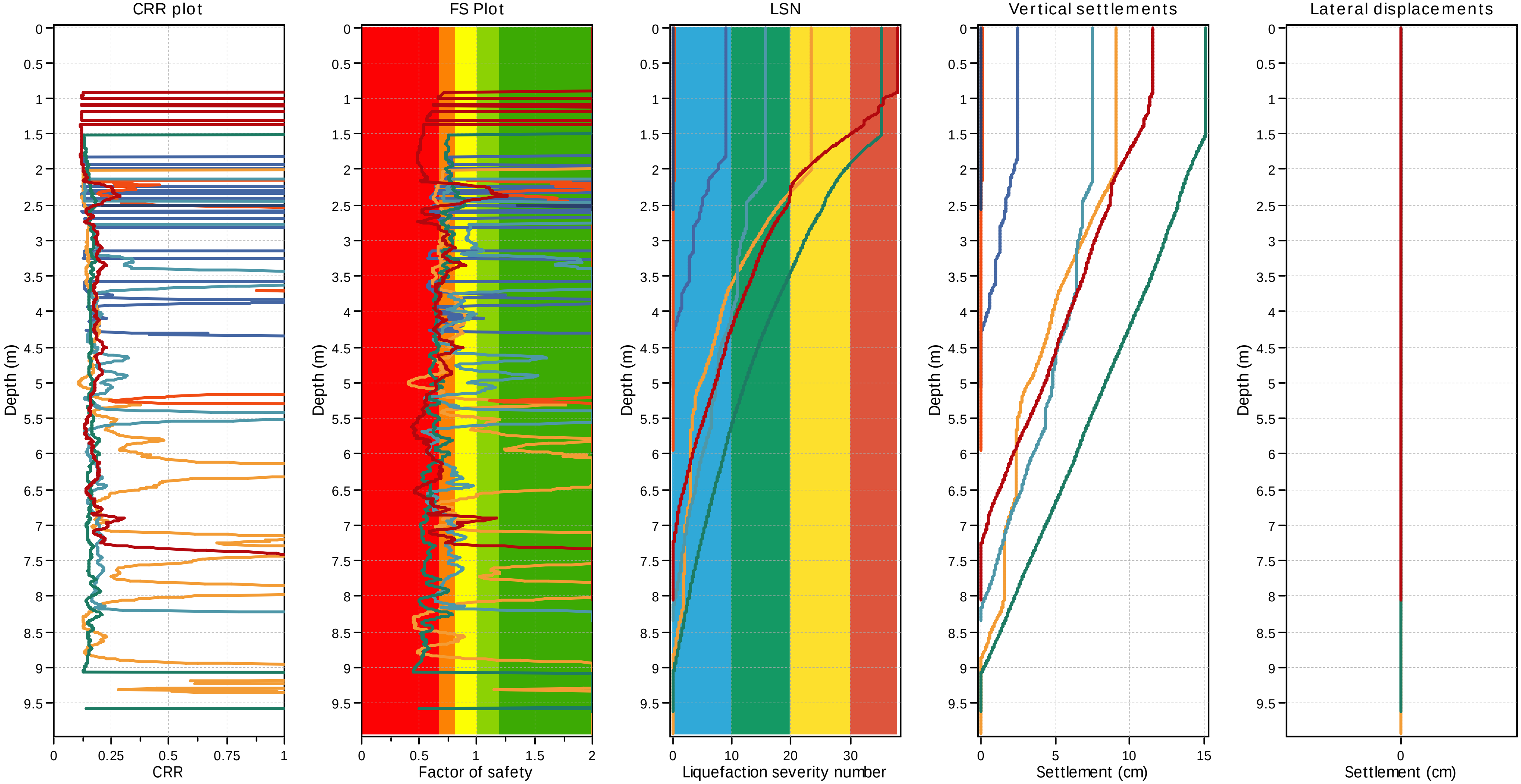
Overlay Normalized Plots



ULS

Project:

Overlay Cyclic Liquefaction Plots



Appendix C - Liquefaction Analysis

General

Liquefaction occurs when susceptible, saturated soils attempt to move to a denser state under cyclic shearing. In this report, liquefaction is defined as when pore pressures rise to reach the overburden stress. When this occurs, the following effects can happen at flat sites:

- loss of strength;
- ejection of material under pressure to the ground surface; and
- post-liquefaction volumetric densification as the materials reconsolidate.

In addition, sloping sites or sites with a 'free face' may experience lateral spreading or movement.

Liquefaction Susceptibility

Soils susceptible to liquefaction have the following characteristics:

- Saturated. Below the ground water level;
- Have "sand like" behaviour[6]; and
- Are in loose or medium dense condition.

Soils which are susceptible to liquefaction require a certain level of earthquake shaking (trigger) to cause them to liquefy. Denser soils require more intense and/or longer duration of shaking (higher trigger) than less dense soil.

Analysis Method

Liquefaction analyses were undertaken on the test data using the Boulanger & Idriss (2014)[7] deterministic method.

Assessment of Consequences of Liquefaction

The following can be assessed to estimate the consequences of liquefaction at this site:

- Crust thickness
- Liquefaction severity index
- Free field settlements
- Lateral spread

Crust Thickness

The non-liquefiable upper layer of soils (crust) provides some protection against ground surface damage as a result of liquefaction. The thicker the crust, the less ground surface damage is expected with significant protection provided by thicknesses of more than 5 m.

Empirical correlations have been developed by Ishihara[7] to quantify the thickness of non-liquefiable crust required to prevent the formation of sand boils resulting from the liquefaction of underlying soil layers. These correlations indicate that for a given thickness of liquefiable soil, as the peak ground acceleration increases a greater thickness of non-liquefiable soil is required to prevent liquefaction damage from manifesting on the surface.

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[6] "Geotechnical earthquake engineering practice: Module 1 Guideline for the identification, assessment and mitigation of liquefaction hazards", Rev 0, July 2010. New Zealand Geotechnical Society. This document states that soil with: Fc <30%, or; Fc >30% and PI < 7% (where Fc= percent passing a 0.075mm sieve and PI=plasticity index) is considered as "sand-like" and is susceptible to liquefaction.

[7] Ishihara, K. (1985). "Stability of natural deposits during earthquakes," Theme lecture, Proc. 11th Int. Conf. On Soil Mechanics and Foundation Engineering, San Francisco, 2, 321-376pp.

Liquefaction Severity Number

Liquefaction severity number (LSN) is a single value which can be calculated from a liquefaction assessment considering the thickness density and depth of liquefiable layers and the intensity of earthquake shaking. Based on observations of ground surface damage in Christchurch an indicative correlation has been developed between ground surface damage from liquefaction and LSN as described below.

As the LSN increases, so does the risk of severe effects on the land and structure. In general, the following surface effects are considered likely at sites with various LSN values.

Table 1C - Liquefaction Severity Number[8]

	Effects from excess porewater pressure and liquefaction	Characteristic LSN	Characteristics of liquefaction and its consequences
L0	Insignificant	< 10	No significant excess pore water pressures (no liquefaction)
L1	Mild	5 – 15	Limited excess pore water pressures; negligible deformation of the ground and small settlements.
L2	Moderate	10 – 25	Liquefaction occurs in layers of limited thickness (small proportion of the deposit, say 10 percent or less) and lateral extent; ground deformation results in relatively small differential settlements.
L3	High	15 – 35	Liquefaction occurs in significant portion of the deposit (say 30 percent to 50 percent) resulting in transient lateral displacements, moderate-to-large differential movements, and settlement of the ground in the order of 100 mm to 200 mm.
L4	Severe	> 30	Complete liquefaction develops in most of the deposit resulting in large lateral displacements of the ground, excessive differential settlements and total settlement of over 200 mm.
L5	Very severe		Liquefaction resulting in lateral spreading (flow), large permanent lateral ground displacements and/or significant ground distortion (lateral strains/stretch, vertical offsets and angular distortion).

Free Field Settlements

This describes the settlement of ground not occupied by a building, occurring due to dissipation of excess pore water pressure generated during earthquake shaking. Where appropriate, we have estimated reconsolidation settlement of any potentially liquefiable layers using the methodology recommended by Idriss & Boulanger (2014)[7].

A component of building settlement may also occur due to yield of any liquefied founding soils. This component of settlement is very difficult to predict and depends on the interaction of the building and the soil it is founded on.

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[8] New Zealand Geotechnical Society [NZGS] and Ministry of Business, Innovation and Employment [MBIE] (2021). Earthquake geotechnical engineering practice in New Zealand. Module 3: Identification, assessment and mitigation of liquefaction hazards. Rev 1.