Appendix D: Laboratory Test Results

Babbage Geotechnical Laboratory

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68 Beach Road
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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

20th July 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH01-23 7.15 - 7.41m

Borehole No: MH01-23 Sample No: Sample 1 Depth: 7.15 – 7.41m

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 50kPa, 100kPa or 200kPa when being sheared.

Direct Shear Test Procedure

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 50kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 100kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 200kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

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TESTING LABORATORY
№ 126

All tests reported herein have been performed in accordance with the laboratory’s scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

Babbage Geotechnical Laboratory	Job No: 63282#L		
	Reg No: 2766	Report No:	63282#L/SB Milldale Stage 7 MH01-23 7.15 - 7.41m
	PROJECT:	MILLDALE STAGE 7	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	***Tested By:***	WEC	July 2023
Version:	7	***Compiled By:***	WEC	19-Jul-23
Issued By:	W. Campton	***Checked By:***	JF	20-Jul-23

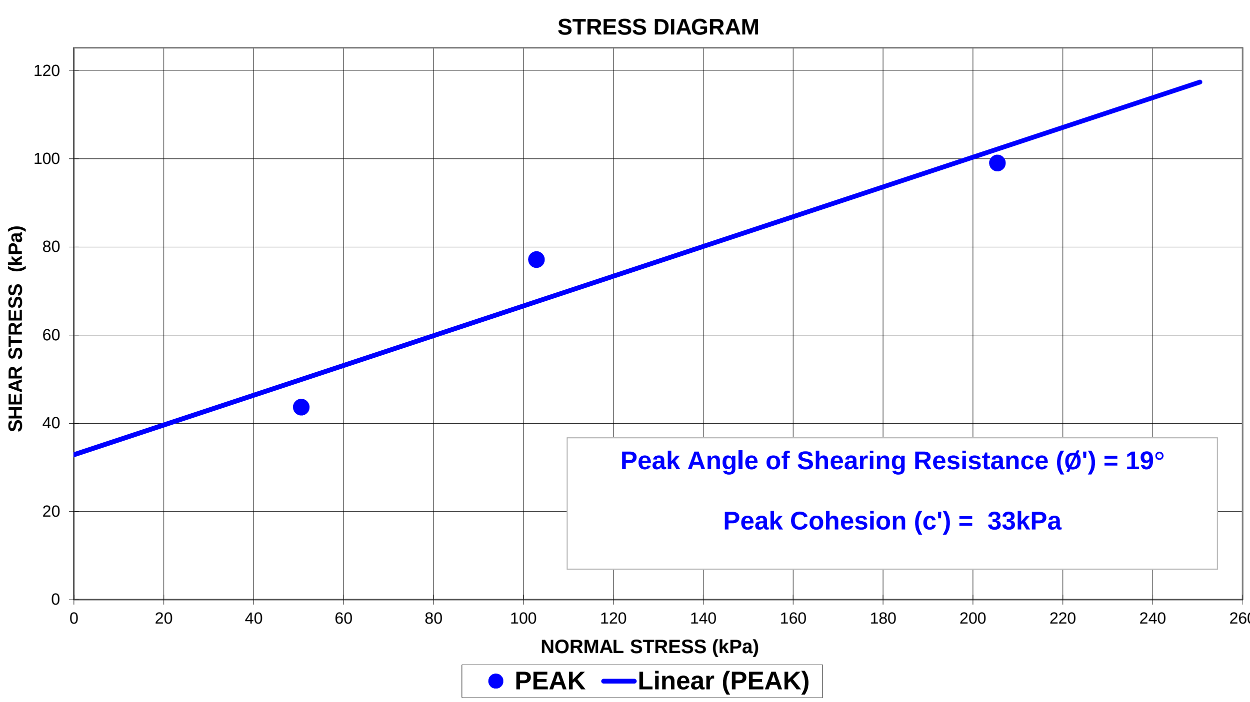
Borehole No: **MH01-23** **Sample No:** **Sample 1** **Depth:** **7.15 - 7.41m**

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE, very weak, greenish grey.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.54	25.0	**50.6**	**0.058**	**43.6**	**0.856**	**0.012**
SHEAR CYCLE 2 - FAILURE VALUES						
1.52	24.8	**102.9**	**0.023**	**77.1**	**1.010**	**0.011**
SHEAR CYCLE 3 - FAILURE VALUES						
1.53	25.2	**205.5**	**0.063**	**99.0**	**1.148**	**0.010**



BGL Babbage Geotechnical Laboratory

Job No:	63282#L		
Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH01-23 7.15 - 7.41m
PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	***Tested By:***	WEC	July 2023
Version:	7	***Compiled By:***	WEC	19-Jul-23
Issued By:	W. Campton	***Checked By:***	JF	20-Jul-23

Borehole No: **MH01-23** **Sample No:** **Sample 1** **Depth:** **7.15 - 7.41m**

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	24.884	24.318	24.688
Height of Solids	(Hs)	14.544	14.361	14.476
Initial Water Content	(%)	25.0	24.8	25.2
Initial Bulk Density	(t/m^3)	1.93	1.90	1.92
Initial Dry Density	(t/m^3)	1.54	1.52	1.53
Dry Mass of sample	(g)	108.902	107.529	108.390
Initial Void Ratio	(e1)	0.719	0.741	0.727
Void Ratio after Consolidation	(e2)	0.711	0.693	0.705
Void Ratio after Shearing	(e3)	0.715	0.695	0.701

Peak Cycles - Failure Values

Rate of Strain	(set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure	(actual)	(mm/minute)	0.012	0.011	0.010

Ratio of Vertical Strain/Horizontal Strain		0.068	0.023	0.055
Vertical Deformation at Failure	(mm)	0.058	0.023	0.063

Horizontal Displacement	(mm)	**0.856**	**1.010**	**1.148**
Normal Stress	(kPa)	**50.6**	**102.9**	**205.5**
Peak Shear Stress	(kPa)	**43.6**	**77.1**	**99.0**

	PEAK
Angle of Shearing Resistance - ∅'	**19°**
Cohesion - c'	**33 kPa**

Babbage Geotechnical Laboratory

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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

24th July 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH01-23 14.00 – 14.25m

Borehole No: MH01-23 **Sample No: Sample 2** **Depth: 14.00 – 14.25m**

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 100kPa, 200kPa or 400kPa when being sheared.

<u>Direct Shear Test Procedure</u>

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 100kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 200kPa normal stress and then sheared at a set rate of 0.024mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 400kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

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Nº 126

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BGL Babbage Geotechnical Laboratory	Job No: 63282#L		Page 3 of 4
	Reg No: 2766	Report No:	63282#L/SB Milldale Stage 7 MH01-23 14.00 - 14.25m
	PROJECT:	MILLDALE STAGE 7	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	***Tested By:***	WEC	July 2023
Version:	7	***Compiled By:***	WEC	24/07/2023
Issued By:	W. Campton	***Checked By:***	JF	24/074/2023

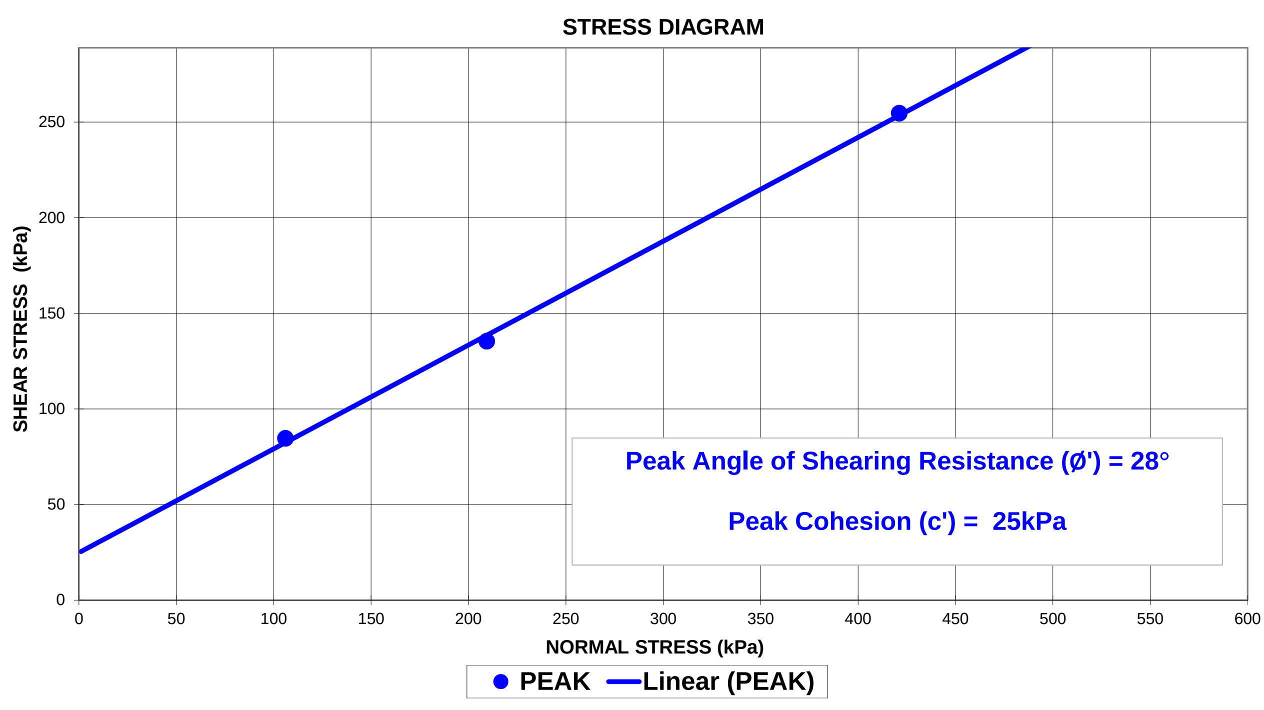
Borehole No: **MH01-23** **Sample No:** **Sample 2** **Depth:** **14.00 - 14.25m**

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: **SILTSTONE, very weak, grey, sheared & slickensilded.**
(not IANZ endorsed)

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.49	26.4	**106.1**	**0.066**	**84.6**	**2.394**	**0.014**
SHEAR CYCLE 2 - FAILURE VALUES						
1.53	25.5	**209.4**	**0.124**	**135.3**	**2.007**	**0.011**
SHEAR CYCLE 3 - FAILURE VALUES						
1.49	25.7	**421.2**	**0.153**	**254.5**	**2.365**	**0.009**



BGL Babbage Geotechnical Laboratory	Job No:	63282#L			
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH01-23 14.00 - 14.25m	
	PROJECT:	MILLDALE STAGE 7			

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	***Tested By:***	WEC	July 2023
Version:	7	***Compiled By:***	WEC	24/07/2023
Issued By:	W. Campton	***Checked By:***	JF	24/074/2023

Borehole No: MH01-23 **Sample No: Sample 2** **Depth: 14.00 - 14.25m**

SHEAR CYCLES

		1	*2*	*3*
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	24.109	23.991	23.909
Height of Solids	(Hs)	14.020	14.420	14.033
Initial Water Content	(%)	26.4	25.5	25.7
Initial Bulk Density	(t/m^3)	1.88	1.92	1.87
Initial Dry Density	(t/m^3)	1.49	1.53	1.49
Dry Mass of sample	(g)	104.978	107.973	105.076
Initial Void Ratio	(e1)	0.783	0.734	0.781
Void Ratio after Consolidation	(e2)	0.720	0.664	0.704
Void Ratio after Shearing	(e3)	0.724	0.655	0.693

Peak Cycles - Failure Values

Rate of Strain	(set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure	(actual)	(mm/minute)	0.014	0.011	0.009

Ratio of Vertical Strain/Horizontal Strain		0.028	0.062	0.065
Vertical Deformation at Failure	(mm)	0.066	0.124	0.153

Horizontal Displacement	(mm)	**2.394**	**2.007**	**2.365**
Normal Stress	(kPa)	**106.1**	**209.4**	**421.2**
Peak Shear Stress	(kPa)	**84.6**	**135.3**	**254.5**

	PEAK
Angle of Shearing Resistance - ∅'	**28°**
Cohesion - c'	**25 kPa**

Babbage Geotechnical Laboratory

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Level 4
68 Beach Road
Auckland 1010
P O Box 2027
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Telephone 64-9-367 4954
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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

Attention: **MELISSA CAMPBELL**

27th July 2023

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH02-23 2.85 – 3.00m

Borehole No: MH02-23 Sample No: Sample 3 Depth: 2.85 – 3.00m

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 50kPa, 100kPa or 200kPa when being sheared.

Direct Shear Test Procedure

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 50kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 100kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 200kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

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№ 126

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BGL Babbage Geotechnical Laboratory	Job No:	63282#L		
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH02-23 2.85 - 3.00m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	**Tested By:**	WEC	July 2023
Version:	7	**Compiled By:**	WEC	26/07/2023
Issued By:	W. Campton	**Checked By:**	JF	27/07/2023

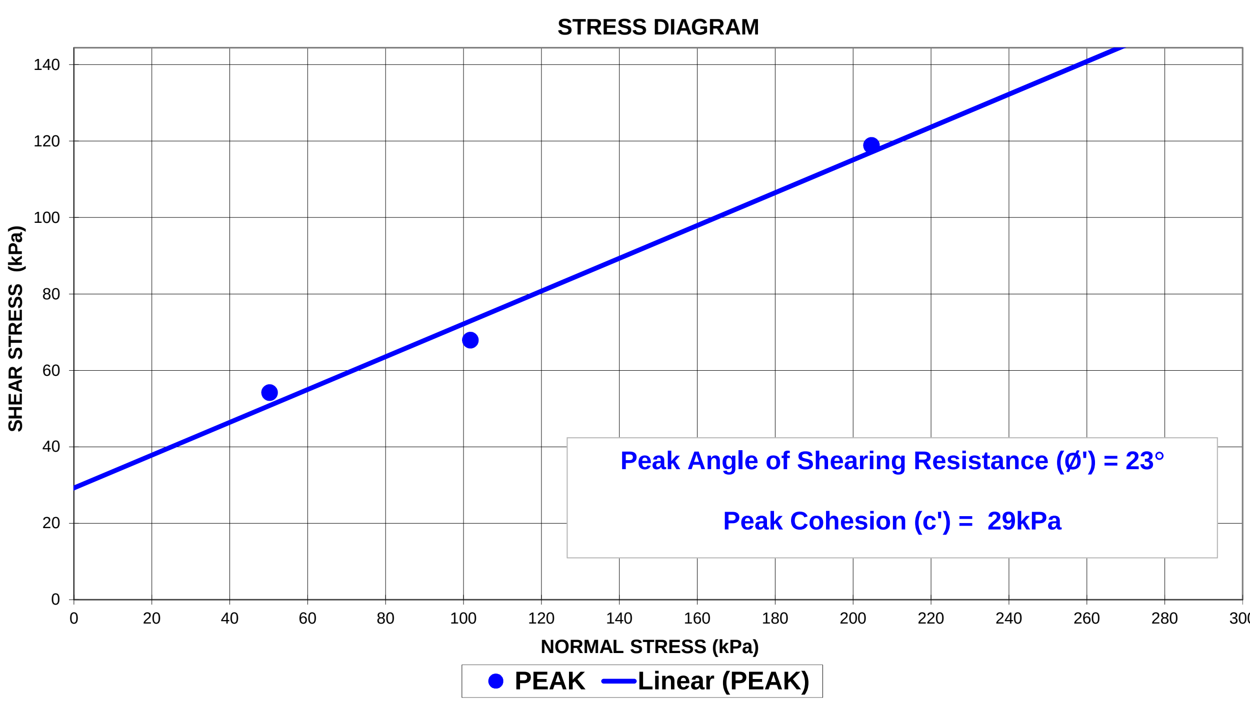
Borehole No: MH02-23 **Sample No:** Sample 3 **Depth:** 2.85 - 3.00m

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE with thin sandstone bands, very weak, sheared, grey.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.45	30.1	50.2	0.080	54.2	0.484	0.009
SHEAR CYCLE 2 - FAILURE VALUES						
1.49	27.0	101.8	0.021	67.9	0.512	0.008
SHEAR CYCLE 3 - FAILURE VALUES						
1.46	29.4	204.8	0.082	118.8	0.986	0.009



Babbage Geotechnical Laboratory

Job No:	63282#L				
Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH02-23 2.85 - 3.00m		
PROJECT:	MILLDALE STAGE 7				
Issue Date:	Nov 2022	Tested By:	WEC	July 2023	
Version:	7	Compiled By:	WEC	26/07/2023	
Issued By:	W. Campton	Checked By:	JF	27/07/2023	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Borehole No: MH02-23 **Sample No:** Sample 3 **Depth:** 2.85 - 3.00m

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	25.033	25.003	24.762
Height of Solids	(Hs)	13.710	14.021	13.777
Initial Water Content	(%)	30.1	27.0	29.4
Initial Bulk Density	(t/m^3)	1.89	1.89	1.89
Initial Dry Density	(t/m^3)	1.45	1.49	1.46
Dry Mass of sample	(g)	102.658	104.985	103.161
Initial Void Ratio	(e1)	0.823	0.783	0.815
Void Ratio after Consolidation	(e2)	0.826	0.783	0.797
Void Ratio after Shearing	(e3)	0.832	0.782	0.791

Peak Cycles - Failure Values

Rate of Strain (set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure (actual)	(mm/minute)	0.009	0.008	0.009
Ratio of Vertical Strain/Horizontal Strain		0.164	0.042	0.083
Vertical Deformation at Failure	(mm)	0.080	0.021	0.082
Horizontal Displacement	(mm)	**0.484**	**0.512**	**0.986**
Normal Stress	(kPa)	**50.2**	**101.8**	**204.8**
Peak Shear Stress	(kPa)	**54.2**	**67.9**	**118.8**

	PEAK
Angle of Shearing Resistance - ∅'	**23°**
Cohesion - c'	**29 kPa**

Babbage Geotechnical Laboratory

Babbage Geotechnical Laboratory
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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

1st August 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH03-23 5.65 – 5.90m

Borehole No: MH03-23 Sample No: Sample 4 Depth: 5.65 – 5.90m

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 75kPa, 200kPa or 400kPa when being sheared.

<u>Direct Shear Test Procedure</u>

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 75kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 200kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 400kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

ACCREDITED IANZ TESTING LABORATORY № 126

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BGL Babbage Geotechnical Laboratory	Job No:	63282#L	Page 3 of 4
	Reg No:	2766	Report No: 63282#L/SB Milldale Stage 7 MH03-23 5.65 - 5.90m
	PROJECT:	MILLDALE STAGE 7	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date: Nov 2022	***Tested By:***	WEC	July 2023
Version: 7	***Compiled By:***	WEC	31/07/2023
Issued By: W. Campton	***Checked By:***	JF	1/08/2023

Borehole No: **MH03-23** **Sample No:** **Sample 4** **Depth:** **5.65 - 5.90m**

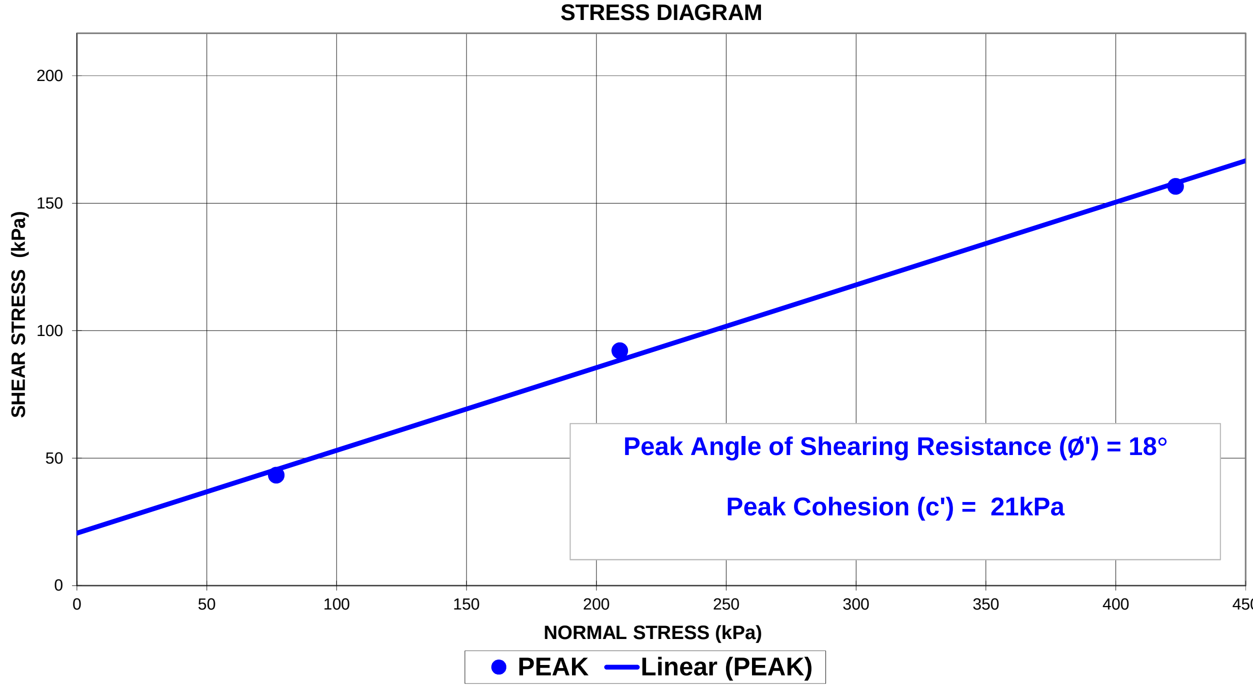
Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE, very weak, highly to completely weathered, mottled greenish grey, light grey & orangish brown, shiny smooth surfaces, hard brown chert inclusions, slightly moist.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.63	22.7	76.8	0.005	43.3	0.653	0.011
SHEAR CYCLE 2 - FAILURE VALUES						
1.60	24.3	209.0	0.101	92.1	1.930	0.013
SHEAR CYCLE 3 - FAILURE VALUES						
1.69	22.1	423.1	0.173	156.5	2.565	0.012

STRESS DIAGRAM



BGL Babbage Geotechnical Laboratory	Job No:	63282#L		Page 4 of 4
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 5.65 - 5.90m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY	Issue Date:	Nov 2022	Tested By:	WEC	July 2023
	Version:	7	Compiled By:	WEC	31/07/2023
BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test	Issued By:	W. Campton	Checked By:	JF	1/08/2023

Borehole No: MH03-23 **Sample No:** Sample 4 **Depth:** 5.65 - 5.90m

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	23.913	24.790	23.600
Height of Solids	(Hs)	15.351	15.101	15.931
Initial Water Content	(%)	22.7	24.3	22.1
Initial Bulk Density	(t/m^3)	2.00	1.99	2.06
Initial Dry Density	(t/m^3)	1.63	1.60	1.69
Dry Mass of sample	(g)	114.943	113.070	119.285
Initial Void Ratio	(e1)	0.629	0.656	0.569
Void Ratio after Consolidation	(e2)	0.558	0.642	0.481
Void Ratio after Shearing	(e3)	0.558	0.635	0.471

Peak Cycles - Failure Values

Rate of Strain	(set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure	(actual)	(mm/minute)	0.011	0.013	0.012

Ratio of Vertical Strain/Horizontal Strain		0.008	0.052	0.067
Vertical Deformation at Failure	(mm)	0.005	0.101	0.173

Horizontal Displacement	(mm)	**0.653**	**1.930**	**2.565**
Normal Stress	(kPa)	**76.8**	**209.0**	**423.1**
Peak Shear Stress	(kPa)	**43.3**	**92.1**	**156.5**

	PEAK
Angle of Shearing Resistance - ∅'	**18°**
Cohesion - c'	**21 kPa**

BGL
Babbage Geotechnical Laboratory

Babbage Geotechnical Laboratory
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68 Beach Road
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P O Box 2027
New Zealand
Telephone 64-9-367 4954
E-mail wec@babbage.co.nz

Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

2nd August 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH03-23 7.20 - 7.50m

Borehole No: MH03-23 Sample No: Sample 5 Depth: 7.20 – 7.50m

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 75kPa, 150kPa or 300kPa when being sheared.

Direct Shear Test Procedure

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 75kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 150kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 300kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of $2.65 t/m^3$ was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

ACCREDITED IANZ TESTING LABORATORY Nº 126

All tests reported herein have been performed in accordance with the laboratory’s scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

BGL Babbage Geotechnical Laboratory	Job No:	63282#L		
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 7.20 - 7.50m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	*Tested By:*	WEC	July 2023
Version:	7	*Compiled By:*	WEC	2/08/2023
Issued By:	W. Campton	*Checked By:*	JF	2/08/2023

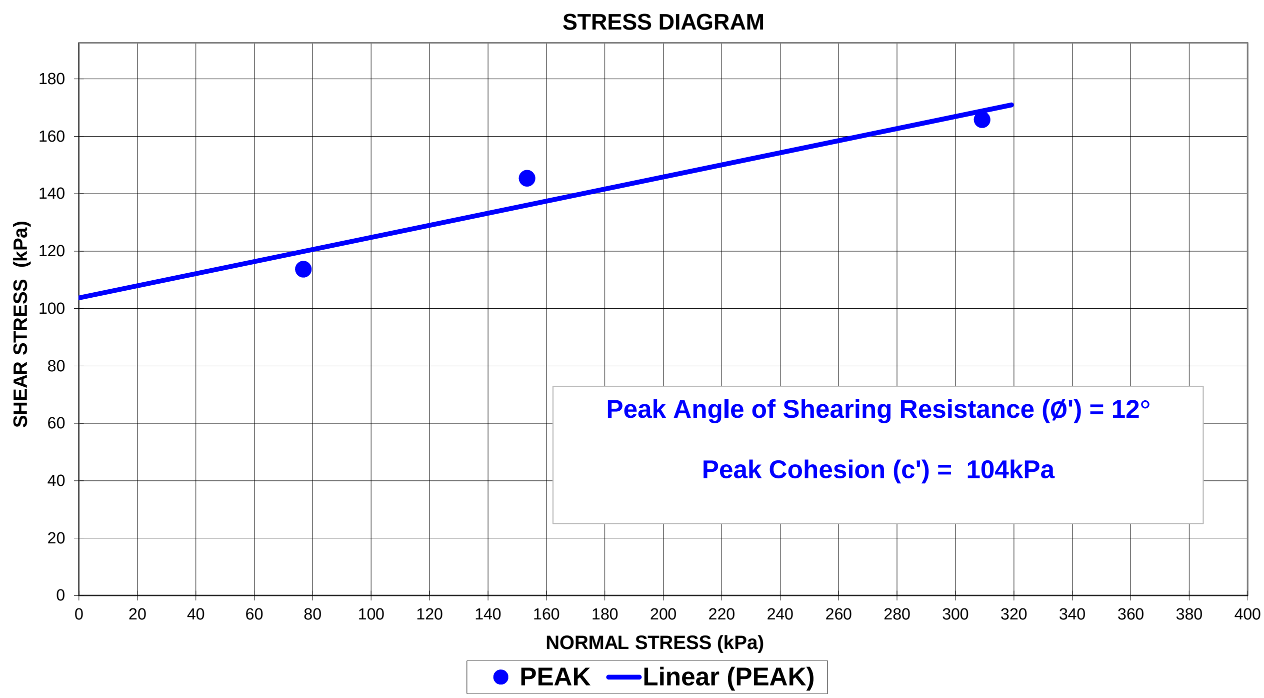
Borehole No: **MH03-23** **Sample No:** **Sample 5** **Depth:** **7.20 - 7.50m**

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE, extremely weak to very weak, moderately to highly weathered, banded grey & reddish brown, cemented siltstone gravel inclusions, banding set up perpendicular to direction of shear.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.82	18.6	76.9	0.089	113.7	0.695	0.008
SHEAR CYCLE 2 - FAILURE VALUES						
1.81	17.8	153.4	0.054	145.3	0.867	0.007
SHEAR CYCLE 3 - FAILURE VALUES						
1.81	18.3	309.2	0.008	165.8	1.358	0.009



BGL Babbage Geotechnical Laboratory	Job No:	63282#L		
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 7.20 - 7.50m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY					
	Issue Date:	Nov 2022	Tested By:	WEC	July 2023
	Version:	7	Compiled By:	WEC	2/08/2023
BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test	Issued By:	W. Campton	Checked By:	JF	2/08/2023

Borehole No: MH03-23 **Sample No: Sample 5** **Depth: 7.20 - 7.50m**

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	25.117	23.692	24.853
Height of Solids	(Hs)	17.131	17.061	17.084
Initial Water Content	(%)	18.6	17.8	18.3
Initial Bulk Density	(t/m^3)	2.15	2.13	2.14
Initial Dry Density	(t/m^3)	1.82	1.81	1.81
Dry Mass of sample	(g)	128.275	127.747	127.921
Initial Void Ratio	(e1)	0.459	0.465	0.463
Void Ratio after Consolidation	(e2)	0.466	0.389	0.455
Void Ratio after Shearing	(e3)	0.471	0.392	0.455

Peak Cycles - Failure Values

Rate of Strain (set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure (actual)	(mm/minute)	0.008	0.007	0.009
Ratio of Vertical Strain/Horizontal Strain		0.128	0.062	0.006
Vertical Deformation at Failure	(mm)	0.089	0.054	0.008
Horizontal Displacement	(mm)	**0.695**	**0.867**	**1.358**
Normal Stress	(kPa)	**76.9**	**153.4**	**309.2**
Peak Shear Stress	(kPa)	**113.7**	**145.3**	**165.8**

	PEAK
Angle of Shearing Resistance - ∅'	**12°**
Cohesion - c'	**104 kPa**

BGL
Babbage Geotechnical Laboratory

Babbage Geotechnical Laboratory
Level 4
68 Beach Road
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Telephone 64-9-367 4954
E-mail wec@babbage.co.nz
P O Box 2027
New Zealand

Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Attention: **MELISSA CAMPBELL**

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

8th August 2023

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH03-23 16.95 – 17.20m

Borehole No: MH03-23 **Sample No: Sample 6** **Depth: 16.95 – 17.20m**

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 150kPa, 300kPa or 500kPa when being sheared.

Direct Shear Test Procedure

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine.

Once set up in the shear box, the first sample was consolidated to approximately 150kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

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The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 300kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 500kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

ACCREDITED IANZ TESTING LABORATORY
№ 126

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Babbage Geotechnical Laboratory	Job No:	63282#L		Page 3 of 4
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 16.95 - 17.20m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY	Issue Date:	Nov 2022	Tested By:	WEC	August 2023
	Version:	7	Compiled By:	WEC	8/08/2023
BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test	Issued By:	W. Campton	Checked By:	JF	8/08/2023

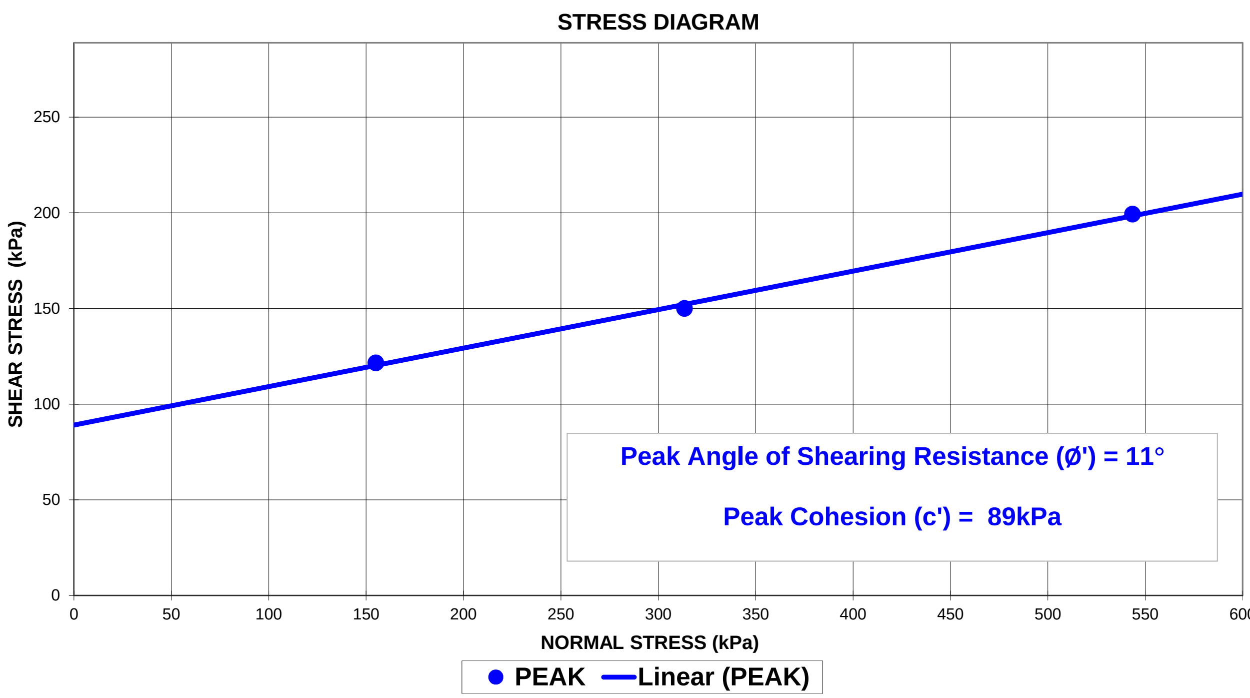
Borehole No: MH03-23 **Sample No:** Sample 6 **Depth:** 16.95 - 17.20m

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE, extremely weak, highly to completely weathered, weakly cemented, light greenish grey with reddish brown bands, weathered highly plastic clays, slightly moist.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.83	18.8	155.0	0.032	121.6	1.367	0.010
SHEAR CYCLE 2 - FAILURE VALUES						
1.78	19.2	313.5	0.228	150.0	1.997	0.011
SHEAR CYCLE 3 - FAILURE VALUES						
1.76	19.3	543.4	0.443	199.3	3.406	0.012



BGL Babbage Geotechnical Laboratory	Job No:	63282#L		Page 4 of 4
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 16.95 - 17.20m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY	Issue Date:	Nov 2022	Tested By:	WEC	August 2023
	Version:	7	Compiled By:	WEC	8/08/2023
BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test	Issued By:	W. Campton	Checked By:	JF	8/08/2023

Borehole No: **MH03-23** **Sample No:** **Sample 6** **Depth:** **16.95 - 17.20m**

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	24.878	24.613	24.191
Height of Solids	(Hs)	17.251	16.795	16.580
Initial Water Content	(%)	18.8	19.2	19.3
Initial Bulk Density	(t/m^3)	2.17	2.12	2.10
Initial Dry Density	(t/m^3)	1.83	1.78	1.76
Dry Mass of sample	(g)	129.170	125.754	124.150
Initial Void Ratio	(e1)	0.449	0.489	0.508
Void Ratio after Consolidation	(e2)	0.442	0.466	0.459
Void Ratio after Shearing	(e3)	0.444	0.452	0.432

Peak Cycles - Failure Values

Rate of Strain (set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure (actual)	(mm/minute)	0.010	0.011	0.012
Ratio of Vertical Strain/Horizontal Strain		0.023	0.114	0.130
Vertical Deformation at Failure	(mm)	0.032	0.228	0.443
Horizontal Displacement	(mm)	**1.367**	**1.997**	**3.406**
Normal Stress	(kPa)	**155.0**	**313.5**	**543.4**
Peak Shear Stress	(kPa)	**121.6**	**150.0**	**199.3**

	PEAK
Angle of Shearing Resistance - ∅'	**11°**
Cohesion - c'	**89 kPa**

Babbage Geotechnical Laboratory

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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

10th August 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH03-23 17.20 - 17.50m

Borehole No: MH03-23 **Sample No: Sample 7** **Depth: 17.20 – 17.50m**

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 150kPa, 300kPa or 500kPa when being sheared.

Direct Shear Test Procedure

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine. As per your instructions, all of the three tested samples were set up orientated with respect to a faint, sub-horizontal plane of weakness in the core (i.e. the direction of shear was parallel with the "dip" direction of the plane of weakness.

Once set up in the shear box, the first sample was consolidated to approximately 150kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 300kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 500kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of $2.65t/m^3$ was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

ACCREDITED TESTING LABORATORY
№ 126

All tests reported herein have been performed in accordance with the laboratory’s scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

BGL Babbage Geotechnical Laboratory	Job No:	63282#L	
	Reg No:	2766	Report No: 63282#L/SB Milldale Stage 7 MH03-23 17.20 - 17.50m
	PROJECT:	**MILLDALE STAGE 7**	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	***Tested By:***	WEC	August 2023
Version:	7	***Compiled By:***	WEC	10/08/2023
Issued By:	W. Campton	***Checked By:***	JF	10/08/2023

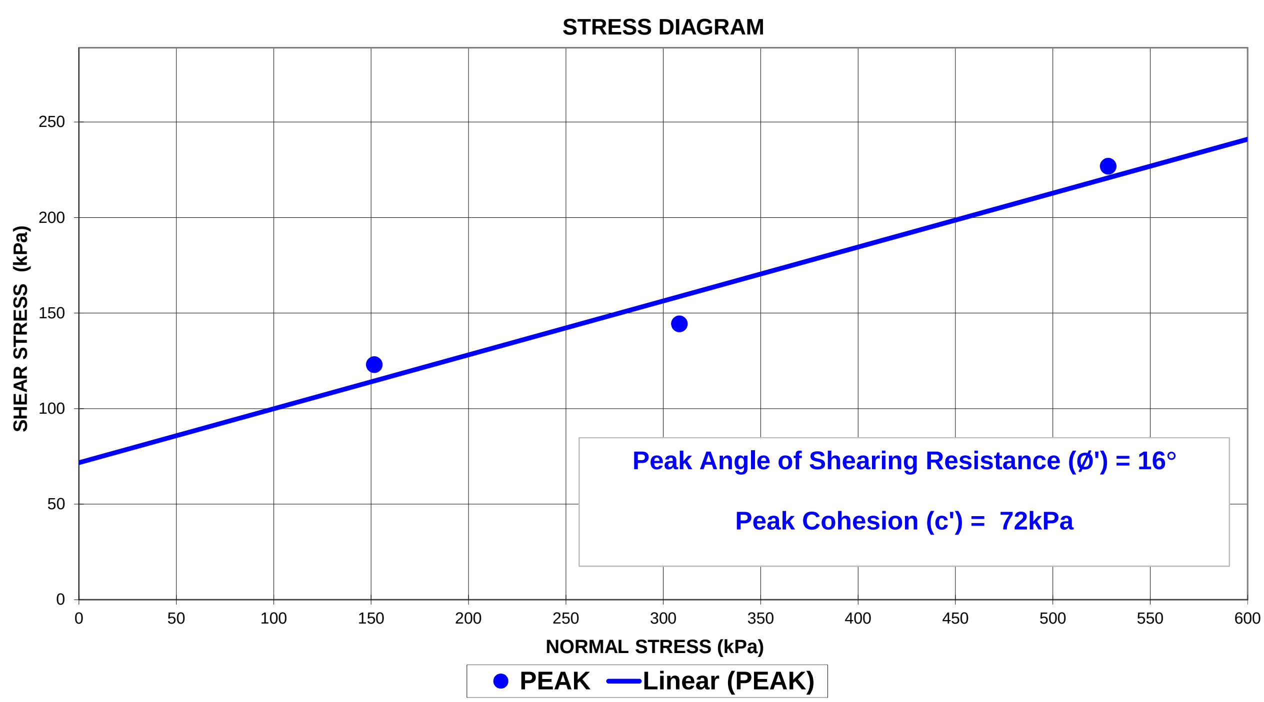
Borehole No: **MH03-23** **Sample No:** **Sample 7** **Depth:** **17.20 - 17.50m**

Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed) **SILTSTONE, very weak, highly weathered, mottled red & greenish grey, slightly moist, occasional weakly cemented siltstone inclusions.**

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.79	18.2	**151.7**	**0.128**	**122.9**	**1.031**	**0.009**
SHEAR CYCLE 2 - FAILURE VALUES						
1.78	19.8	**308.3**	**0.120**	**144.3**	**1.236**	**0.009**
SHEAR CYCLE 3 - FAILURE VALUES						
1.78	18.6	**528.4**	**0.295**	**226.7**	**2.457**	**0.010**



BGL Babbage Geotechnical Laboratory	Job No:	63282#L		Page 4 of 4
	Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH03-23 17.20 - 17.50m
	PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY	Issue Date:	Nov 2022	Tested By:	WEC	August 2023
	Version:	7	Compiled By:	WEC	10/08/2023
BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test	Issued By:	W. Campton	Checked By:	JF	10/08/2023

Borehole No: MH03-23 **Sample No:** Sample 7 **Depth:** 17.20 - 17.50m

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	24.750	24.565	24.415
Height of Solids	(Hs)	16.875	16.809	16.747
Initial Water Content	(%)	18.2	19.8	18.6
Initial Bulk Density	(t/m^3)	2.11	2.14	2.11
Initial Dry Density	(t/m^3)	1.79	1.78	1.78
Dry Mass of sample	(g)	126.355	125.859	125.399
Initial Void Ratio	(e1)	0.481	0.487	0.493
Void Ratio after Consolidation	(e2)	0.467	0.461	0.458
Void Ratio after Shearing	(e3)	0.474	0.454	0.440

Peak Cycles - Failure Values

Rate of Strain	(set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure	(actual)	(mm/minute)	0.009	0.009	0.010
Ratio of Vertical Strain/Horizontal Strain			0.124	0.097	0.120
Vertical Deformation at Failure		(mm)	0.128	0.120	0.295
Horizontal Displacement		(mm)	**1.031**	**1.236**	**2.457**
Normal Stress		(kPa)	**151.7**	**308.3**	**528.4**
Peak Shear Stress		(kPa)	**122.9**	**144.3**	**226.7**

	PEAK
Angle of Shearing Resistance - ∅'	**16°**
Cohesion - c'	**72 kPa**

BGL
Babbage Geotechnical Laboratory

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Please reply to: W.E. Campton

CMW Geosciences Ltd.
PO Box 300 206
Albany
Auckland 0752

Job Number: 63282#L
BGL Registration Number: 2766
Checked by: JF

14th August 2023

Attention: **MELISSA CAMPBELL**

DIRECT SHEAR (SHEAR BOX) TESTING

Dear Melissa,

Re: MILLDALE STAGE 7

Your Reference: AKL2022-0138
Report Number: 63282#L/SB Milldale Stage 7 MH04-23 7.12 - 7.31m

Borehole No: MH04-23 Sample No: Sample 8 Depth: 7.12 – 7.31m

The following report presents the results of Direct Shear Testing at BGL of a weathered rock sample delivered to this laboratory on the 5th of July 2023. Test results are summarised in the following pages. Test standards used were:

Water Content:	NZS4402:1986:Test 2.1
Direct Shear Test of Soils Under Consolidated Drained Conditions:	BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Three peak shear stress values were obtained from three separate samples taken from the rock core sample. Each sample was subjected to a normal stress of either 100kPa, 200kPa or 400kPa when being sheared.

<u>Direct Shear Test Procedure</u>

The sample for the first cycle was trimmed into the shear box ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge was then used to trim the sample flat in the ring. The sample was then set up in the shear box machine. As per your instructions, all of the three tested samples were set up orientated with respect to the sub-linear colour banding of the core (i.e. the direction of shear was parallel with the banding).

Once set up in the shear box, the first sample was consolidated to approximately 100kPa normal stress. The rate of shearing to use was determined from the equation: $t_f = 50t_{50}$ (where t_f = the total estimated elapsed time to failure in minutes and t_{50} = the time required in minutes for the sample to achieve 50% consolidation under the normal stress), and an estimation of the displacement distance to failure in mm. The sample was then sheared at a set rate of 0.016mm/minute until a "peak shear stress" value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The sample for the second cycle was then prepared as in cycle 1 and set up in the shear box. This sample was consolidated to approximately 200kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 2 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

Finally, the sample for the third cycle was prepared and set up in the shear box as previously described. This sample was consolidated to approximately 400kPa normal stress and then sheared at a set rate of 0.016mm/minute until the cycle 3 “peak shear stress” value was obtained. Once complete, the sample was dried out in a soils drying oven to determine the water content.

The three peak values are plotted on a graph of shear stress vs. normal stress on page 3.

Note that a solid density value of 2.65t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report.

Please note that the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Key Technical Person
Laboratory Manager
Babbage Geotechnical Laboratory

ACCREDITED IANZ TESTING LABORATORY
Nº 126

All tests reported herein have been performed in accordance with the laboratory’s scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

Babbage Geotechnical Laboratory

Job No:	63282#L		
Reg No:	2766	Report No:	63282#L/SB Milldale Stage 7 MH04-23 7.12 - 7.31m
PROJECT:	MILLDALE STAGE 7		

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date:	Nov 2022	*Tested By:*	WEC	August 2023
Version:	7	*Compiled By:*	WEC	14/08/2023
Issued By:	W. Campton	*Checked By:*	JF	14/08/2023

Borehole No: MH04-23 **Sample No:** Sample 8 **Depth:** 7.12 - 7.31m

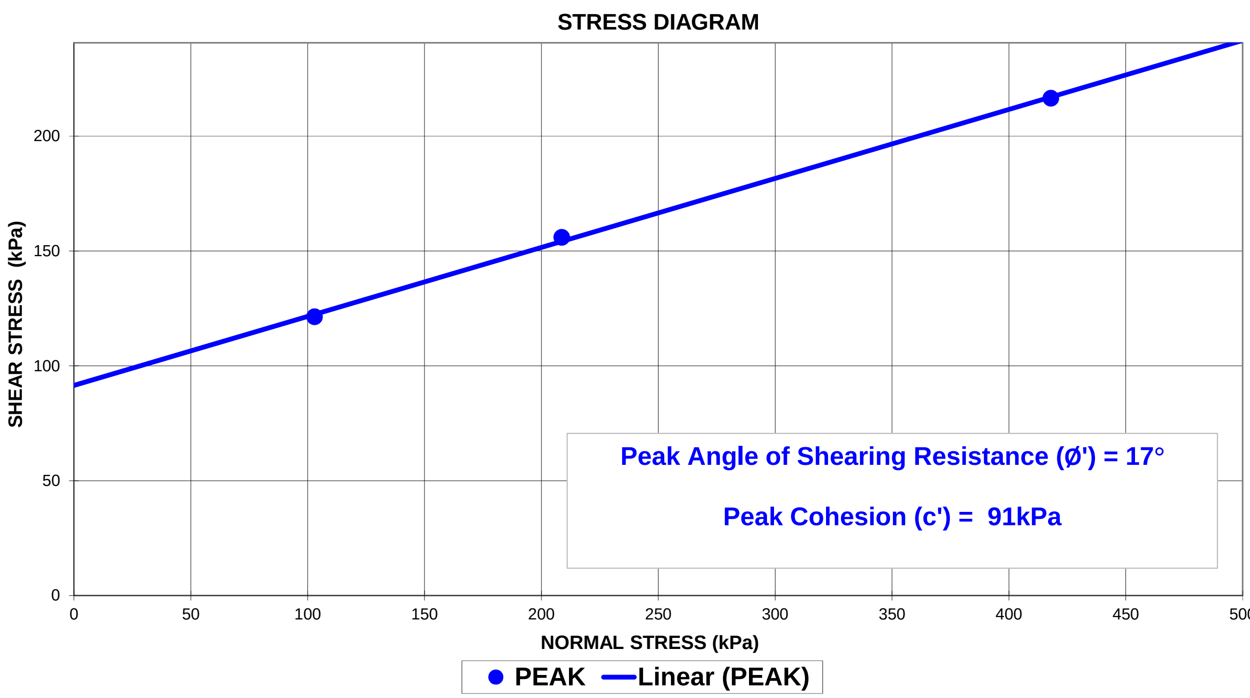
Sample History / Preparation: Core sample trimmed into shear box ring in small increments.

Sample Type: ~~block / push-tube / recompacted /~~ rock core

Sample Description: (not IANZ endorsed)

SILTSTONE, very weak, occasional weakly cemented inclusions, light greenish grey with red laminations, slightly moist.

Initial Dry Density (t/m^3)	Initial Moisture Content (%)	Normal Stress (kPa)	Normal Displacement (mm)	PEAK Shear Stress (kPa)	Displacement at Failure (mm)	Average Rate of Displacement (mm/minute)
SHEAR CYCLE 1 - FAILURE VALUES						
1.73	20.5	103.0	0.099	121.3	1.033	0.009
SHEAR CYCLE 2 - FAILURE VALUES						
1.75	20.0	208.8	0.068	155.9	1.878	0.011
SHEAR CYCLE 3 - FAILURE VALUES						
1.78	19.7	418.0	0.166	216.5	2.021	0.009



BGL Babbage Geotechnical Laboratory	Job No: 63282#L		
	Reg No: 2766	Report No: 63282#L/SB Milldale Stage 7 MH04-23 7.12 - 7.31m	
	PROJECT:	MILLDALE STAGE 7	

SHEAR TEST SUMMARY

BGL IN-HOUSE TEST METHOD NUMBER 1: Direct Shear Test

Issue Date: Nov 2022	***Tested By:***	WEC	August 2023
Version: 7	***Compiled By:***	WEC	14/08/2023
Issued By: W. Campton	***Checked By:***	JF	14/08/2023

Borehole No: MH04-23 **Sample No: Sample 8** **Depth: 7.12 - 7.31m**

SHEAR CYCLES

		1	2	3
Solid Density of Soil Particles (assumed)	(t/m^3)	2.65	2.65	2.65
Initial Sample Thickness	(mm)	25.00	25.00	25.00
Initial Sample Diameter	(mm)	59.98	59.98	59.98
Thickness After Consolidation	(mm)	24.987	24.896	24.704
Height of Solids	(Hs)	16.328	16.504	16.772
Initial Water Content	(%)	20.5	20.0	19.7
Initial Bulk Density	(t/m^3)	2.09	2.10	2.13
Initial Dry Density	(t/m^3)	1.73	1.75	1.78
Dry Mass of sample	(g)	122.256	123.576	125.585
Initial Void Ratio	(e1)	0.531	0.515	0.491
Void Ratio after Consolidation	(e2)	0.530	0.509	0.473
Void Ratio after Shearing	(e3)	0.536	0.504	0.463

Peak Cycles - Failure Values

Rate of Strain (set)	(mm/minute)	0.016	0.016	0.016
Mean Rate of Strain at Failure (actual)	(mm/minute)	0.009	0.011	0.009
Ratio of Vertical Strain/Horizontal Strain		0.096	0.036	0.082
Vertical Deformation at Failure	(mm)	0.099	0.068	0.166
Horizontal Displacement	(mm)	**1.033**	**1.878**	**2.021**
Normal Stress	(kPa)	**103.0**	**208.8**	**418.0**
Peak Shear Stress	(kPa)	**121.3**	**155.9**	**216.5**

	PEAK
Angle of Shearing Resistance - ∅'	**17°**
Cohesion - c'	**91 kPa**

Appendix E: Geotechnical Risk Register

	CLIENT: Fulton Hogan Land Development Ltd	DESIGNER: MJC
CMW Geosciences — Great People | Practical Solutions	PROJECT: PROPOSED MILLDALE STAGES 10/11/12/13 DEVELOPMENT WAINUI EAST	CHECKED: CR
		JOB NO: AKL2024-0257
	TITLE: GEOTECHNICAL RISK REGISTER	DATE: 24/03/2025
		ISSUED FOR: GIR

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Assessed	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
1	Earthquake	Seismicity	NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in New Zealand, Module 1: Overview of the Guidelines Structural design actions - Part 0: General principles, NZS1170.0:2002 Structural design actions - Part 5: Earthquake actions - New Zealand, NZS1170.5:2004	Entire Site	Site subsoil class = Class B or C due to the variance in depth of rock across the site. ULS PGA = 0.19g							
		Fault Rupture	GNS Science, New Zealand Active Faults Database, retrieved from https://data.gns.cri.nz/af/	Entire Site	Nearest active fault = Wairoa North Fault, approximately 60km from the site. Recurrence interval rate unknown.	1	5	5	Mitigation not required.	1	5	5
		Liquefaction	NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 1: Overview of the Guidelines NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 3: Identification, assessment and mitigation of liquefaction hazards Refer to Auckland Council GIS website for liquefaction hazard maps	Entire Site	Liquefaction anaylsis carried out for CPTs across the site - refer Appendix G for calculation package including methodology and detailed results. In respect to the MBIE Module 3 Liquefaction Performance Levels, the site is rated as mild with liquefaction severity numbers ranging from 1-8, with ULS settlements being a maximum of 30mm. Based on our results, the site is expected to experience negligible liquefaction induced settlement.	1	5	5	Mitigation not required.	1	5	5
		Lateral Spread	NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 3: Identification, assessment and mitigation of liquefaction hazards MBIE (2012) Repairing and rebuilding houses affected by the Canterbury earthquakes, Part A: Technical Guidance	Entire Site	No lateral spread anticapted, liquifable layers are limited to thin, discontinuous lenses and does not pose a credible failure mechanism in the slope stability analysis.	1	5	5	Mitigation not required.	1	5	5
		Cyclic Softening	NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice in NZ, Module 3: Identification, assessment and mitigation of liquefaction hazards	Alluvium	Cyclic softening not anticipated, refer to Appendix G for details	1	5	5	Mitigation not required.	1	5	5
2	Slope Instability / Landslide	Global Instability	Auckland Council (2023), The Auckland Code of Practice for Land Development and Subdivision, Chapter 2: Earthworks and Geotechnical, Version 2	Entire site	Target Min. FOS = 1.5, 1.3 and 1.0 for prevailing, worst credible and seismic conditions. Results show that the proposed landforms generally achieve the target factors of safety for Stages 10 and 11. The exception is a proposed retaining wall near the stream. Results show that proposed landforms for Stages 12 and 13 do not achieve target factors of safety. Significant remediation is required. Refer Appendix F for calculation package and detailed results.	4	5	20	Remediation design includes the use of shear keys and reinforced earth slopes with significant engineered fill buttresses. Refer Appendix F for calculation package and detailed results. Remediation plans are shown on Drawings 17 and 18 with typical details on Drawing 25.	2	5	10
		Soil Creep		Entire Site	Soil creep anticipated on fill slopes steeper than 1V:3H and natural slopes steeper than 1V:5H within upper 1.0m of ground surface	4	4	16	Use of reinforced earth slopes for slopes greater than 1V:3H. Typical detail shown on Drawing 25 with locations shown on the Woods Retaining Wall Plans.	2	4	8

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Assessed	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
		Cut / Fill Batter Stability		Entire site	Cut batters proposed in Stages 12/13 do not achieve target factors of safety as noted in Global Stability above. Refer Appendix F for calculation package and detailed results.	4	5	20	Remediation design includes the use of shear keys and reinforced earth slopes with significant engineered fill buttresses. Refer Appendix F for calculation package and detailed results. Remediation plans are shown on Drawings 17 and 18 with typical details on Drawing 25.	2	5	10
		Stream bank instability and erosion		Slopes adjacent to stream in Stages 10/11	Fill placement above meandering stream on Stages 10/11 requires proposed retaining wall on Stage 10 (Section A). This does not meet factory of safety requirements. Refer to calculation package in Appendix F. Significant fills near the stream need to also consider bearing capacity failure during construction, refer to settlement Appendix H.	3	5	15	Retaining walls along stream banks must consider global stability. If factors of safety arent met (such as Section A), deeper palisade piles may be used. As noted in Appendix H - bearing capacity failure due to excess pore pressure may occur in underlying alluvium due to fill placement near stream. Construction methodology must consider this and monitoring / instrumentation may be required.	1	5	5
3	Problematic Soils	Pumice Soil Exposure	N/A	Not in this geological setting								
		Rockmass Exposure	N/A	Areas of large cuts.	Earthworks will expose Northland Allochthon weathered rock at design subgrade level. Bedrock unit with open defects have high rates of permeability and are susceptible to rapid weathering thereby contributing to land instability.	4	4	16	Earthworks management such as capping materials with a 0.85m thick cohesive engineered fill which is less permeable.	1	4	4
		Expansive Soils	MBIE (2021) Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 Structure, Amendment 20 NZS 3604:2011 NZS 4402:1998 Test 2.1, 2.4 and 2.6 Fraser Thomas Ltd, Brown, B.J., Goldsmith, P.R., Shorten, J.P.M. & Henderson, L (2003) Soil Expansivity in the Auckland Region. BRANZ, Study Report SR 120	Entire Site	Testing on previous stages of the development in these soils and engineered fills created from these soils indicates that they are typically moderately to highly expansive (AS2870)	4	5	20	Testing to be carried out on final surface prior to submission of the Geotechnical Completion Report. Specific foundation design to be undertaken by structural engineer in accordance with AS2870 or NZBC B1/AS1 (site class to be determined on a lot by lot basis).	2	5	10
		Sensitive Soils	NZGS Field Description of Soil and Rock (NZGS, 2005)	Entire site	Not anticipated in this geology. Soils have high clay content and not anticipated to be sensitive.	2	3	6	No mitigation required	2	3	6
		Acid Sulphate Soils	Roberts, R.C. & McConchie, J. (2017) Preliminary assessment of the acid sulphate soils hazard in the Auckland region Proc. 20th NZGS Geotechnical Symposium. Dear, S-E., Ahern, C. R., O'Brien, L. E., Dobos, S. K., McElnea, A. E., Moore, N. G. & Watling, K. M. (2014) Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines.	Not in this geological setting								
		Collapsible / Dispersible Soils	N/A	Entire site	Not anticipated in this geology. Soils have high clay content and not anticipated to be collapsable/ dispersable							
		Uncontrolled Fill	N/A	Entire Site	Potential for uncontrolled fill to be discovered during earthworks where previous stockpiles or historical farm fills, embankments or building platforms are encountered.	3	5	15	Uncontrolled fill is to be excavated and replaced during construction.	1	5	5

CMW Geosciences Great People | Practical Solutions	CLIENT: Fulton Hogan Land Development Ltd	DESIGNER:	MJC
	PROJECT: PROPOSED MILLDALE STAGES 10/11/12/13 DEVELOPMENT WAINUI EAST	CHECKED:	CR
		JOB NO:	AKL2024-0257
	TITLE: GEOTECHNICAL RISK REGISTER	DATE:	24/03/2025
		ISSUED FOR:	GIR

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Assessed	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
		Contamination	Ministry for the Environment (2021) Contaminated land management guidelines	Entire Site	Contamination assessment not undertaken by CMW.							
4	Settlement	Compressible Soils	Mesri G, Kwan Lo D, Feng T (1994) Settlement of Embankments on Soft Clays, Chapter of Vertical and Horizontal Deformation of foundations and Embankments, A.T.Yeung & G.Y.Felio, ASCE, New York, 8-56 Mesri G, Ajlouni N (2007) Engineering Properties of Fibrous Peats, Journal of Getotechnical and Geoenvironmental Engineering, Vol. 133:7. ASCE	Fills over alluvial soils	Primary (t90) settlements of 10mm to 140mm predicted. Post-construction settlements of 5 to 55mm predicted. Differential settlements likely to be within NZ Building Code limits provided sufficent time is left for construction settlements to occur prior to commencement of lot sign off and building development. CPT17-24 in Stage 12 shows settlements >50mm, this warrants further investigation. Refer to calculation package in Appendix H. Northland Allochthon materials are considered generally incompressible due to their age and stiffness.	2	5	10	Mitigation generally not required, however settlement monitoring is recommended during construction to confirm the estimated magnitudes in Appendix H. Preliminary settlement monitoring plans are shown on Drawings 21 and 22. Further investigation required in the area around CPT17-24 in Stage 12.	1	5	5
		Bearing Capacity	MBIE (2021) Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 Structure, Amendment 20, B1/VM4	Entire site	Bearing capacity assessment shows preliminary geotechnical ultimate bearing capacity (GUBC) of 300kPa is available in both cut and fill areas with corresponding settlements of <50mm anticipated over design life.	1	5	5	A preliminary geotechnical ultimate bearing capacity (GUBC) of 300kPa should be available for shallow strip and pad foundations constructed within both the natural cut ground and engineered fill areas, subject to the short axis of those footings measuring no greater than 2.5m in plan. This is to be confirmed by shallow hand augers in cut areas as part of Geotechnical Completion Reporting.	1	5	5
		Effects of Dewatering	Somerville, S.H. (1988) Report 113: Control of groundwater for temporary works, CIRIA C113	Cut areas	Groundwater drawdown is being assessed by others. Boundary effects to be assessed once known.			0				0
		Settlement Behind Retaining Wall – Boundary Effects		No cut walls propsoed on boundaries.	Not assessed							
		Tomos	N/A	Entire Site	Existence of tomos reported by the farmer. None found during our investigations.	1	4	4	Review during stripping inspections, backfill if encountered.	1	4	4
5	Erosion	Cut Batters	N/A	Enitre site	Cut batters of up to 1V:2H indicated on Woods plans. Cut batters within Mangakahia and Hukerenui units likely subject to ongoing erosion / frittering.	3	4	12	Addressed as part of the Global Instability mitigation design. Refer Drawing 25. All slopes greater than 1V:2H will be geogrid reinforced. Restrictions will be applied above and below the reinforced earth batters in the Geotechnical Completion Report to protect the geogrid reinforcement.	1	4	4
		Fill Batters	N/A	Entire site	Engineered fill batters of up to 1V:2H indicated on Woods plans. Fill batters at these gradients likely to require surface management	3	4	12	Addressed as part of the Global Instability mitigation design. Refer Drawing 25. Restrictions will be applied above and below the reinforced earth batters in the Geotechnical Completion Report to protect the geogrid reinforcement.	1	4	4
		Coastal Regression	Roberts, R., N Carpenter and P Klinac (2020). Predicting Auckland's exposure to coastal instability and erosion, Auckland Council, technical report, TR2020/021 Auckland Council GeoMaps (Climate Impact overlay) TCC Mapi (Coastal Hazard Erosion Overlay)	Entire site	Site some 1km away from the Auckland Council ACSIE lines	1	5	5	Mitigation shouldn't be required.	1	5	5

CMW Geosciences Great People | Practical Solutions	CLIENT:	Fulton Hogan Land Development Ltd	DESIGNER: MJC
	PROJECT:	PROPOSED MILLDALE STAGES 10/11/12/13 DEVELOPMENT WAINUI EAST	CHECKED: CR
			JOB NO: AKL2024-0257
	TITLE:	GEOTECHNICAL RISK REGISTER	DATE: 24/03/2025
			ISSUED FOR: GIR

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Assessed	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
6	Groundwater	Groundwater Impacts	Auckland Council, Auckland Unitary Plan operative in part (2016) - Section E7	Groundwater Assessment carried out by Williamson Water & Land Advisory.								
7	Geothermal activity	Formation of geysers, hot springs, fumaroles, mud pools	Auckland Council GeoMaps (Geothermal overlay)	Not in this geological setting								
8	Sedimentation	Rockfall, Debris Inundation	MBIE & NZGS (2016) Rockfall: Design considerations for passive protection structures	No source areas expected								
9	Flooding	Flooding, inundation	Auckland Council GIS		Assessed by others							
10	Construction Risks	Excavatability	Transit New Zealand (1997) Specification for Earthworks Construction TNZ F/1:1997	Entire site	Given the fabric of the Mangakahia and Hukerenui units that will be encountered, excavation is expected to be readily achieved with normal earthworks plant. The Mahurangi Limestone unit may be encountered in the lower regions of Stages 12/13 which may be classified as R2 Rock.	3	3	9	Specialist ripping plant or a rock breaker may be required. Provision in contract and budget. Consider additional investigations.	3	3	9
		Sediment Retention Ponds	N/A	Enitre Site - as required	Temporary sediment retention ponds are proposed, however location not currently known. Global stability conditions could be compromised by cuts in Hukerenui Mudstone.	4	3	12	Geotechnical engineer to have input on pond locations with respect to stability/seepage potential, structural design including key and compaction specifications, observation of subgrade conditions, earthfill and QA testing of embankment materials. When decommissioning temporary sediment ponds, all water softened material in the bases and sides of the ponds shall be removed and undercut to the satisfaction of the Geotechnical Engineer. Backfilling of temporary ponds shall be to the compaction standard for general filling unless otherwise specified.	1	3	3
		Stockpile locations	N/A	Enitre Site - as required	Locations currently not known. Global stability conditions could be compromised by placement of stockpiles on Hukerenui Mudstone slopes.	4	3	12	The location of all temporary stockpiles must be approved by the Geotechnical Engineer prior to placement. Where stockpiles cannot be avoided above sloping ground they should be placed over a wide area with the height restricted under the direction of the Geotechnical Engineer.	1	3	3
		Bearing Capacity Failure		Areas of alluvial soils	Rapid filling on alluvial soils could trigger a bearing capacity type failure.	3	5	15	Mitigation of bearing capacity failure risk is primarily undertaken as part of the earthworks planning and execution. The primary considerations are: Placing fill evenly across the site and in planned lifts. Restrictions on the speed of placing fill-in areas with thick, soft alluvium layers. Staging of the fill placement to allow for excess pore pressures to dissipate	2	5	10

CMW Geosciences Great People | Practical Solutions	CLIENT: Fulton Hogan Land Development Ltd	DESIGNER:	MJC
	PROJECT: PROPOSED MILLDALE STAGES 10/11/12/13 DEVELOPMENT WAINUI EAST	CHECKED:	CR
		JOB NO:	AKL2024-0257
	TITLE: GEOTECHNICAL RISK REGISTER	DATE:	24/03/2025
		ISSUED FOR:	GIR

Item	Geotechnical Hazard	Description	Relevant Standards*/Guidance Documents	Area Assessed	Assessment Outcome	Existing Risk of Damage to Land / Structures			Mitigation Measure	Residual Risk of Damage to Land / Structures		
						Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
		Land Instability as a Result of General Works		Entire site	Dependent on construction methodology and programme.	4	4	16	Avoid: - unplanned removal of slope toe support via excavation - over-steepening batters - loading upslope of excavations. Ensure: - Critical works follow agreed methodology and construction recommendations Consider: -staging critical excavations to limit areas of exposure - ceasing works during and immediately following significant rainfall - benching / battering requirements - control of surface water above excavations - covering steep batters with polythene - regular inspections for signs of movements	2	4	8
11	Safety in Design	Boundary instability / inability to batter normally	N/A									
		Temporary batter slope	N/A	Construction and Safety in Design (SiD) risks will be completed during detailed design for the final remedial geotechnical design.								
		Hole collapse	N/A									
		Service lines (overhead or underground)	N/A									
		Excavation collapse	N/A									

*Refer to SAI Global to access relevant Standards

Appendix F: Slope Stability Design Memo

CMW Geosciences
Great People | Practical Solutions

Slope Stability

Site Address	Milldale Fast Track	Report Number	AKL2024-0257
Client	Fulton Hogan Land Development Ltd	Date	31/01/25
Prepared by	Sasiruban Loganathan		
Reviewed & Authorised by	Chris Ritchie		

1 DESIGN CRITERIA

The stability of cut batters and fill embankments under a range of design conditions is expressed in terms of a factor of safety, which is defined as the ratio of forces resisting failure to the forces causing failure. The following performance standards are recommended for slope stability assessment:

Slope Stability Factor of Safety Criteria	
Condition	Required Factor of Safety
Normal Groundwater Condition	1.5
Extreme (worst credible) groundwater condition	1.3
Seismic condition for ULS PGA	1.0

2 DESIGN PARAMETERS

Geotechnical Design Parameters				
Unit Description	γ (kN/m^3)	c´ (kPa)	ϕ´ (deg)	S_u (kPa)
Engineered Fill (proposed)	18	8	28	100
Tauranga Group Alluvium (Stream)	17	5	26	60
Tauranga Group Alluvium (Ridge)	17	8	26	80
Residual Northland Allochthon	18	5	28	60
Transitional Hukerenui Mudstone	18	8	12	95
Hukerenui Mudstone	21	20	28	S-N Function*
Transitional Undifferentiated Mangakahia	18	8	21	55
Undifferentiated Mangakahia Rock Mass	21	20	28	S-N Function*
Mahurangi Limestone	19	10	40	-

Notes: γ = soil unit weight (conservative value determined from CPT correlations / typical published values for similar soil types)
c´ = effective cohesion (conservative industry accepted value)
ϕ´ = effective friction angle (conservative industry accepted value/back analysis)
S_u = undrained shear strength
S-N Function* = Shear / Normal Function (Applied for Seismic Cases to limit failure surfaces to reasonable depths)

3 METHODOLOGY

Slope stability analyses were undertaken using the Morgenstern-Price method of slices under both circular and translational failure mechanisms using the proprietary software SLIDE Version 6.

- 12 kPa of load was applied for Lots and Roads.
- A shear normal function was applied to Hukerenui Mudstone and Undifferentiated Mangakahia Roak Mass in seismic cases to approximately model its in-situ behaviour.
- The Ru method was utilized to model groundwater across all units. The parameters for each unit under different groundwater conditions are as follows:

  Tauranga Alluvium and Residual Northland Allochthon:

  - Ru = 0.2 under normal groundwater conditions.
  - Ru = 0.4 under extreme groundwater conditions.

  Transitional Hukerenui and Transitional Mangakahia:

  - Ru = 0.05 under normal groundwater conditions.
  - Ru = 0.2 under extreme groundwater conditions.

  Hukerenui Mudstone, Undifferentiated Mangakahia Rock Mass, and Mahurangi Limestone:

  - Ru = 0 under both normal and extreme groundwater conditions.
- Liquefaction is disregarded in the seismic cases because it is limited to thin, discontinuous lenses and does not pose a credible failure mechanism in the slope stability analysis.

4 INITIAL RESULTS

Slope stability analyses were undertaken on Sections A-A to L-L (see Figure 1 & 2)

Results are appended to this memo and are summarised below for the proposed landform.

Slope Stability Analysis Results			
Section	Slope Stability Minimum Factor of Safety		
	Normal	Extreme	Seismic
A-A	1.4	1.1	1.9
B-B	1.5	1.3	2.2
C-C	2.7	2.2	1.1
D-D	1.9	1.7	1.1

E-E	2.6	2.2	1
F-F	1.5	1.4	2.1
G-G	0.8	0.7	1.2
H-H	0.9	0.7	1.7
I-I	1.0	0.9	1.2
J-J	0.9	0.8	1.5
K-K	0.8	0.7	1.2
L-L	1.8	1.4	1

5 PRELIMINARY SLOPE STABILITY MANAGEMENT

Significant remedial works, in the form of shear keys and/or engineered fill buttresses excavated into the Transitional Hukerenui has been modelled, see Figure 3 shows outputs of these for each section where required.

Results of these analyses are presented below:

Slope Stability Analysis Results – Post Remedial Works				
Section	Remedial Works	Slope Stability Minimum Factor of Safety		
		Prevailing	Transient	Seismic
A-A	Retaining Wall with Palisade Action (1.5m Retained Height at the southern boundary)	1.6	1.4	1.9
G-G	Shear Key and Engineered Fill Buttress For Upper RE Slope Fill Buttress – 26m wide and 13.6m high formed at 1V:2H Shear Key – 19.5 wide and 5.0m deep into Transitional Mangakahia	1.6	1.3	1.5
H-H	Shear Key and Engineered Fill Buttress for Upper RE Slope Fill Buttress – 17m wide and 9m high formed at 1V:2H Shear Key – 17m wide base, 5m into Transitional Hukerenui	1.6	1.5	1.7
I-I	Shear Key and Engineered Fill Buttress For Upper RE Slope Fill Buttress – 13m wide and 5.5m high formed at 1V:2H Shear Key – 10m wide and 6m deep into Transitional Hukerenui Shear Key and Engineered Fill Buttress for mid slope Fill Buttress – 8m wide and 4m deep formed at 1V:2H	1.5	1.3	1.2
	Shear Key – 10m wide and 4.5m deep into Transitional Hukerenui			
J-J	Shear Key and Engineered Fill Buttress For Upper RE Slope Fill Buttress – 20.5m wide and 10m high formed at 1V:2H Shear Key – 14m wide and 7m deep into Transitional Hukerenui Shear Key and Engineered Fill Buttress for Lower slope Fill Buttress – 11 wide and 6m high formed at 1V:2H Shear Key – 11.5 wide and 2m deep into Transitional Hukerenui	1.7	1.5	1.5
K-K	Retaining Wall with palisade action for upper cut-slope. Mid RE Slope Shear Key -12m wide base, 4.5m deep into Northland Allochthon /Transitional Hukerenui.	1.5	1.3	1.2

Refer to *Drawings 17 and 18* for preliminary remediation layout plans and *Drawing 25* for typical remediation details.

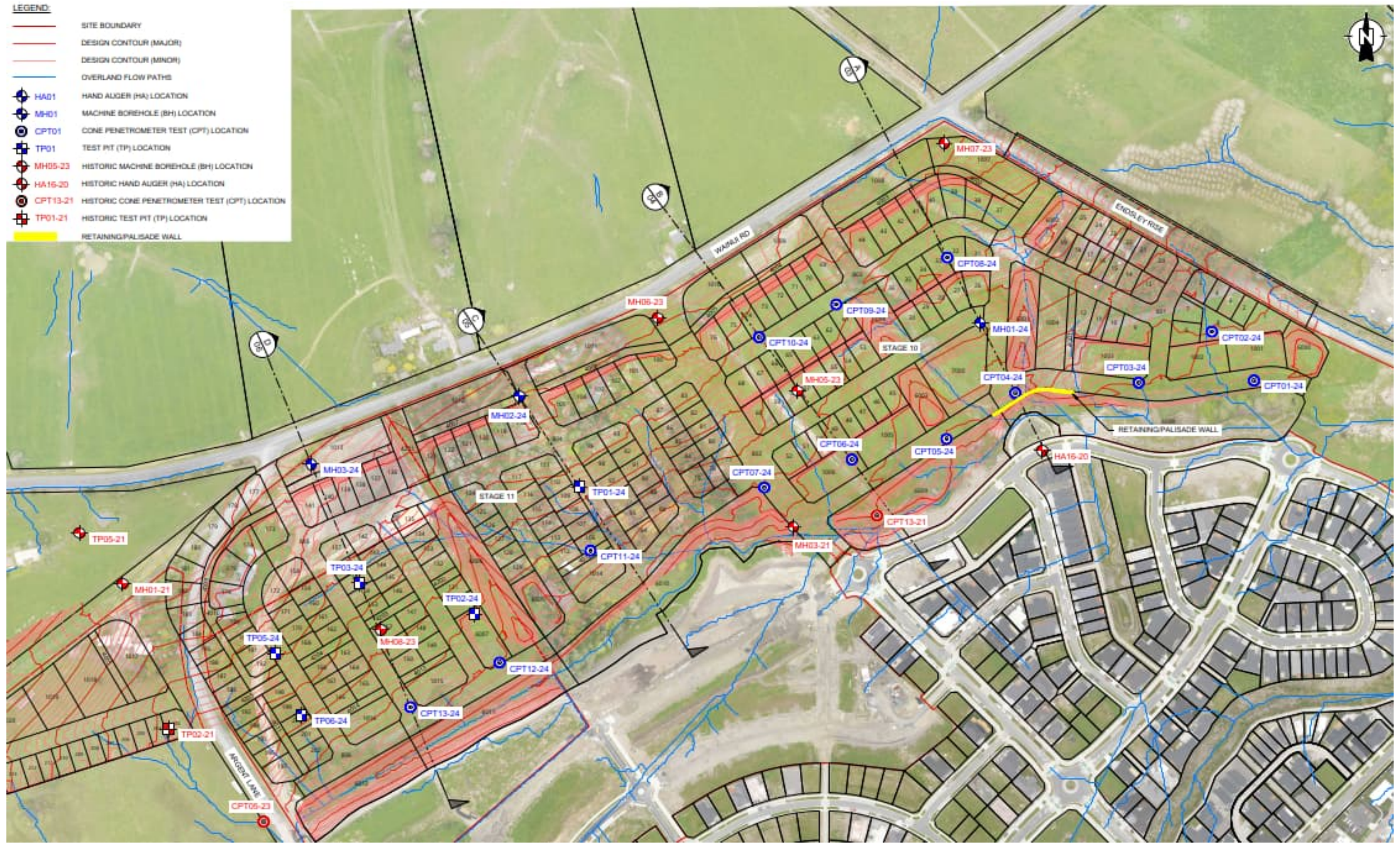


Figure 1: Slope Stability Sections (Stage 10/11)

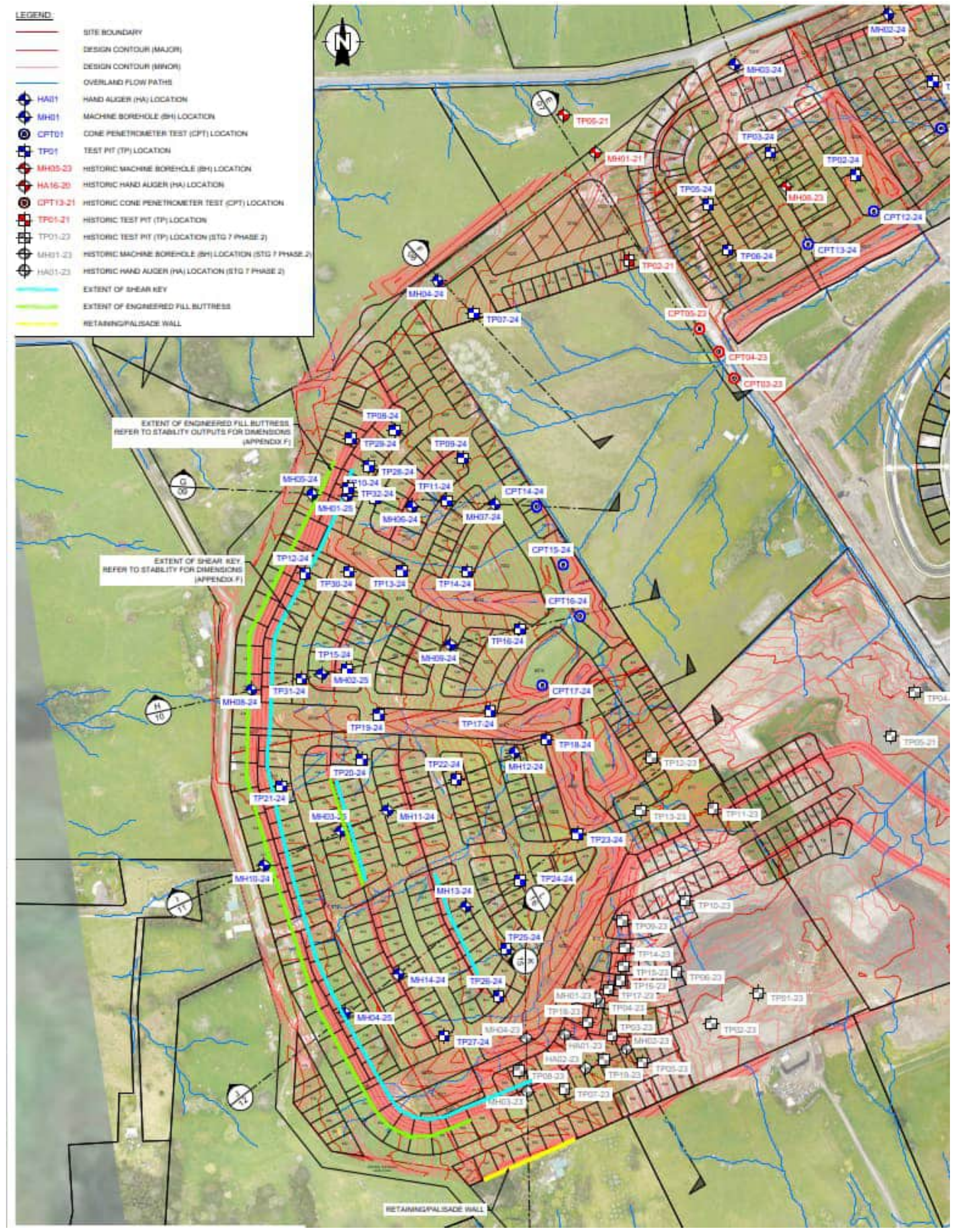
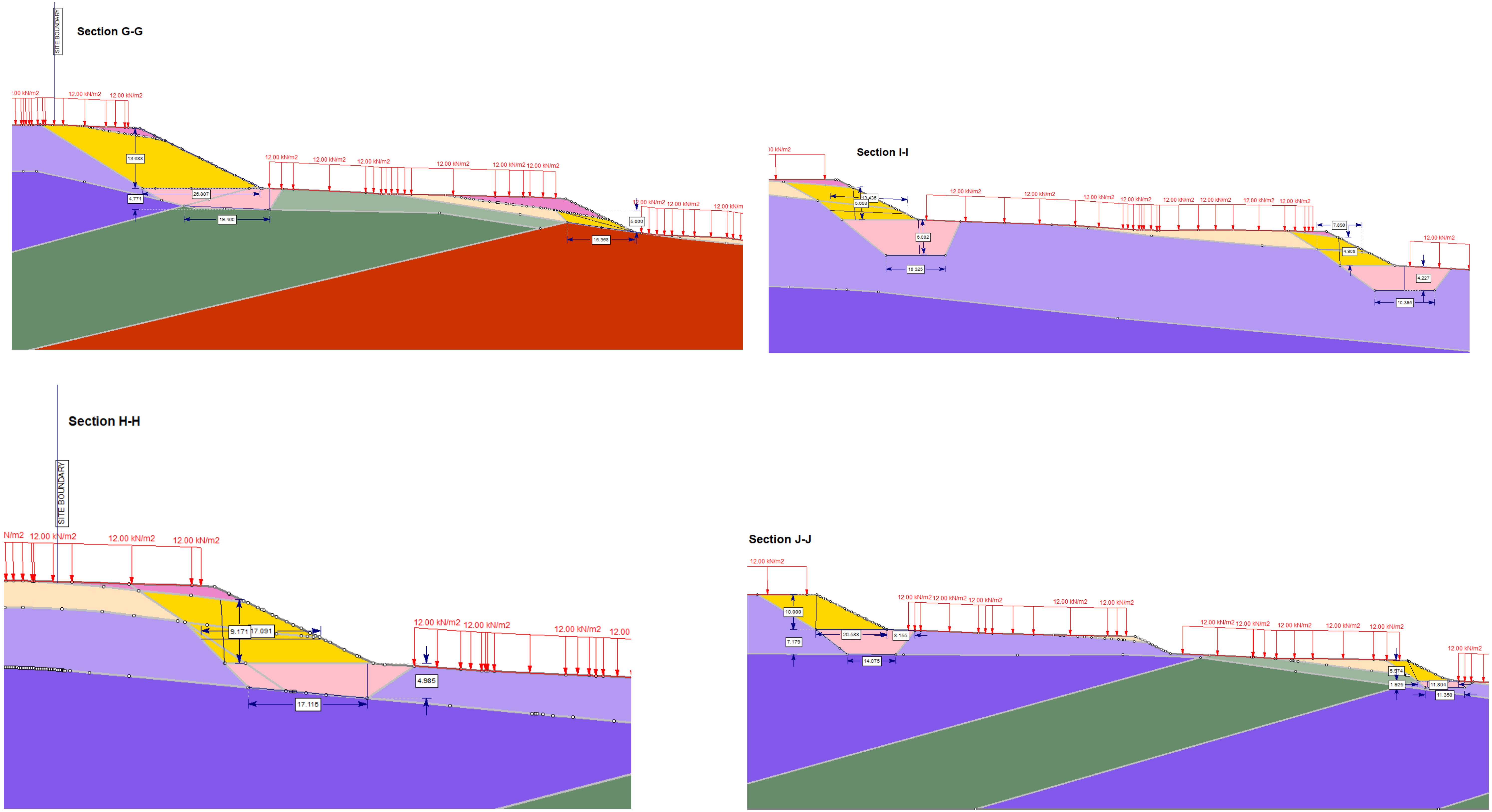
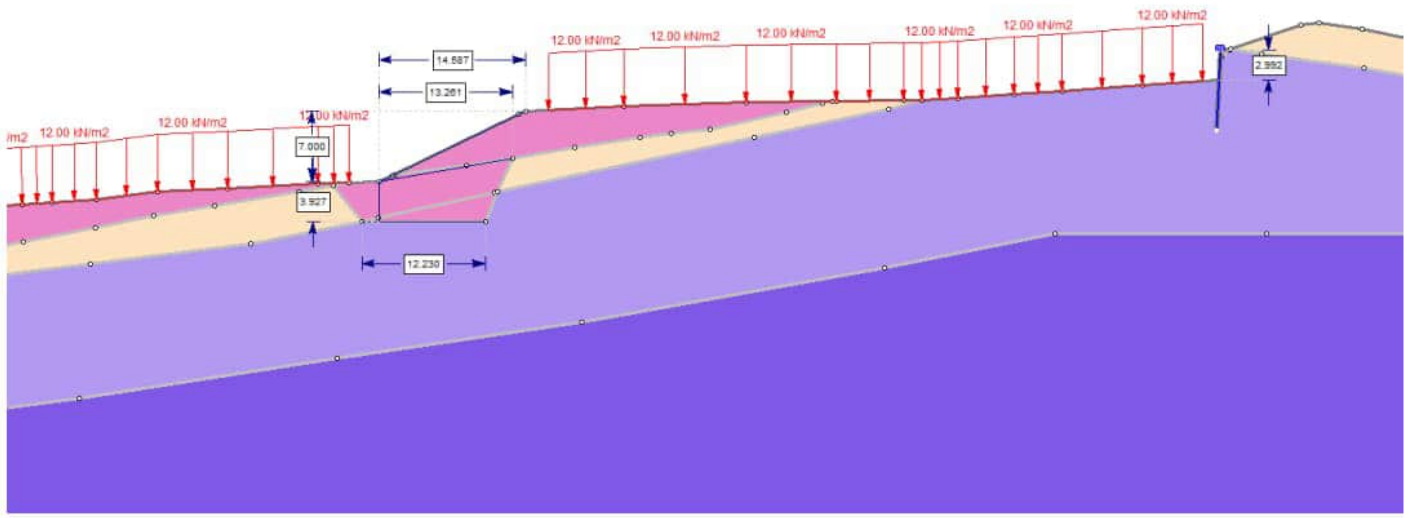


Figure 2: Slope Stability Sections (Stage 12/13)

Figure 3: Remediation outputs, Shear Keys (pink) and Buttress Fill (Yellow) are shown.



Section K-K



12.00 kN/m2
12.00 kN/m2
12.00 kN/m2
12.00 kN/m2
12.00 kN/m2
12.00 kN/m2
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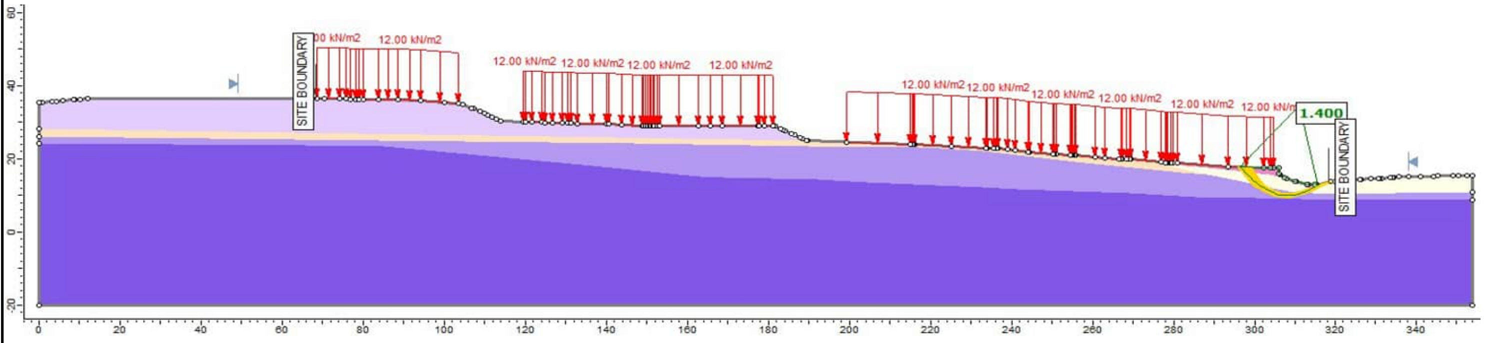
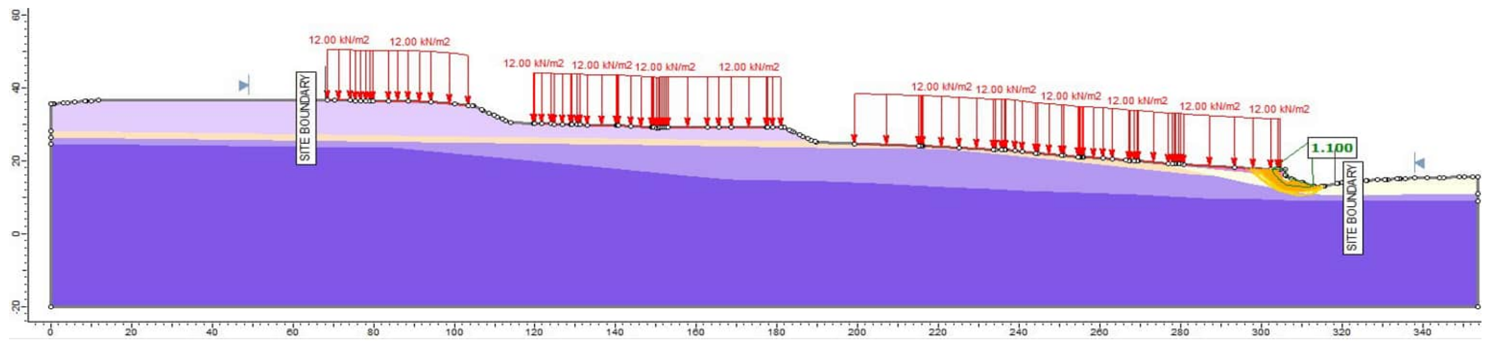
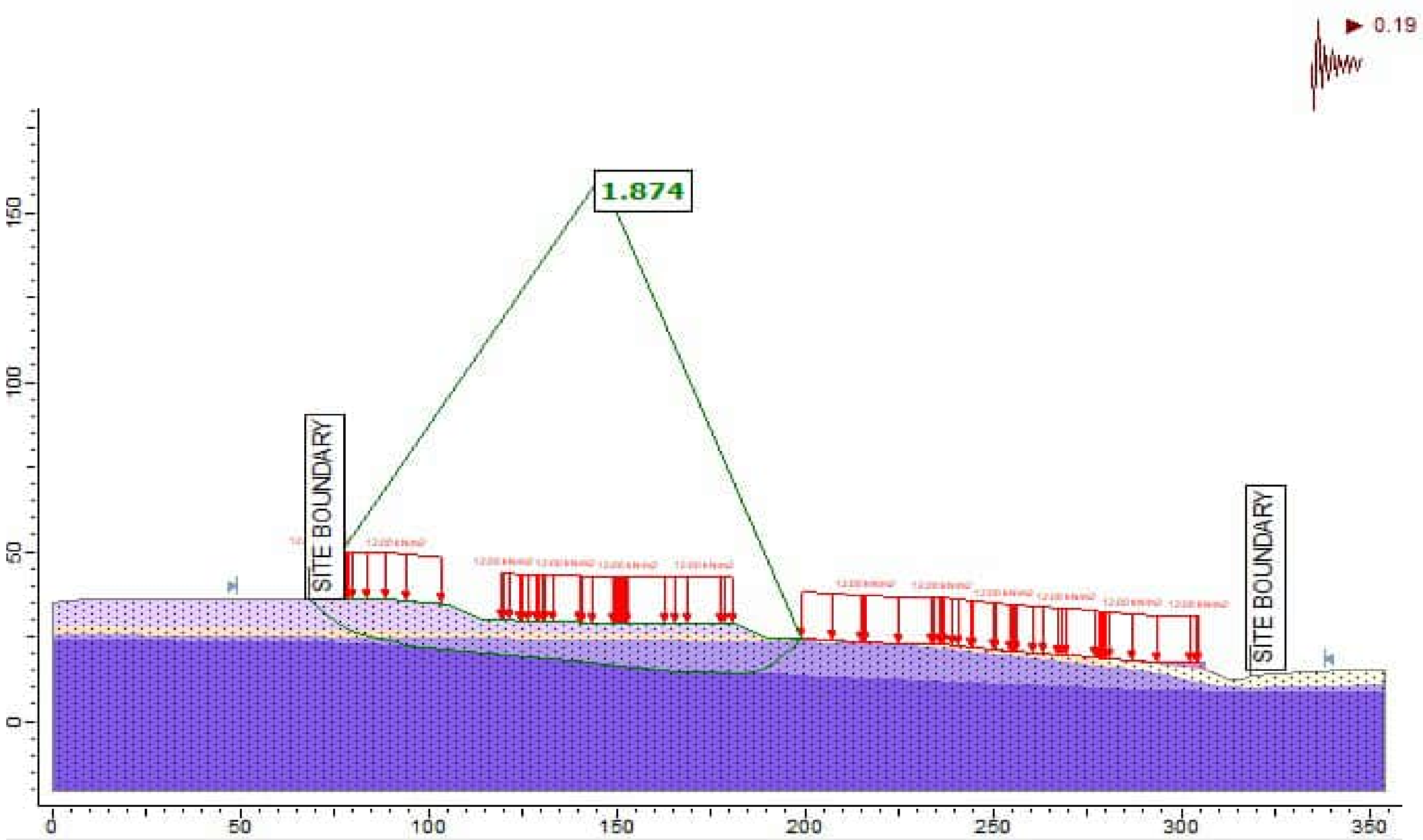
13.261
7.000
3.927
12.230
2.992





Normal Groundwater Conditions

Transient Groundwater Conditions



Seismic Event

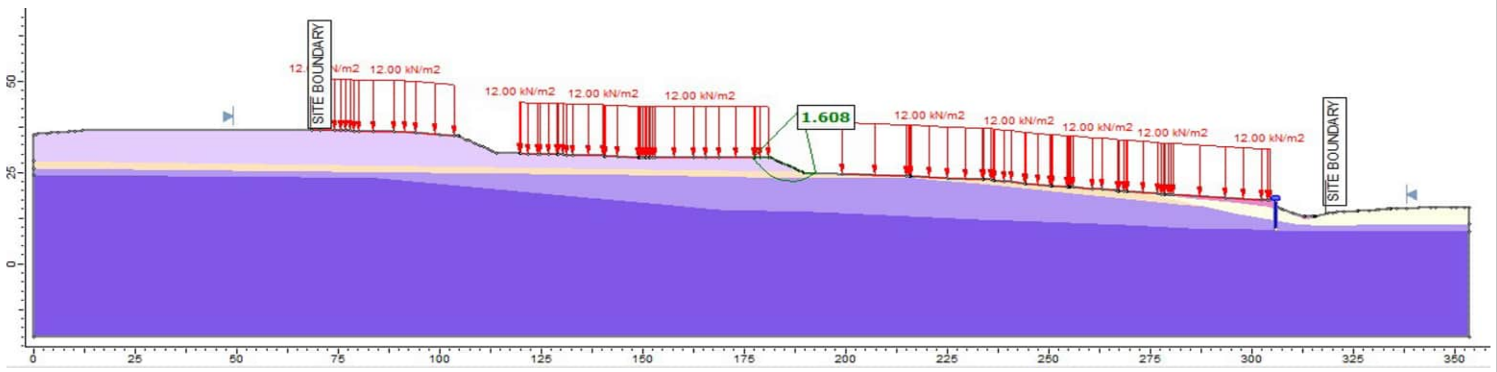
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

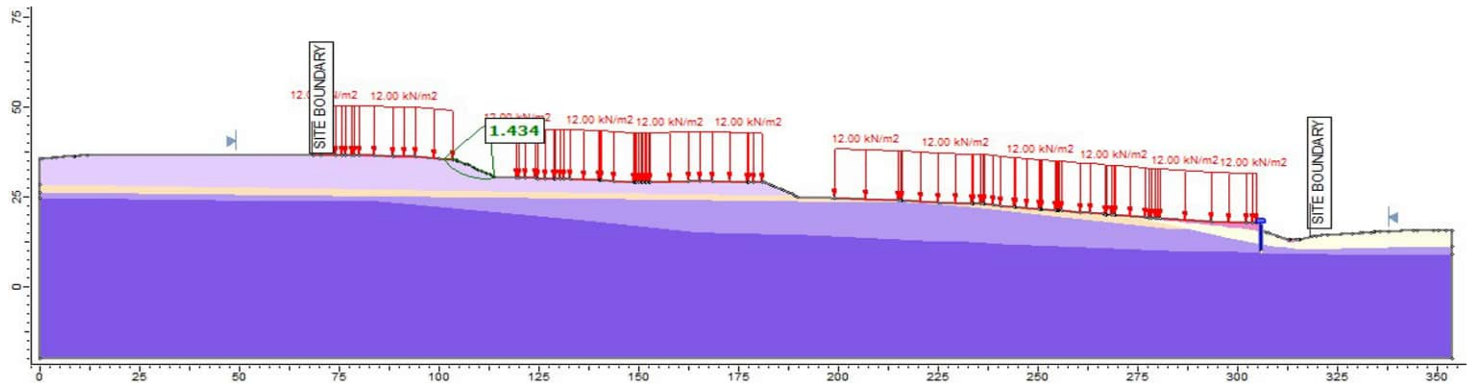
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Ridge) UD		17	Undrained	80	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

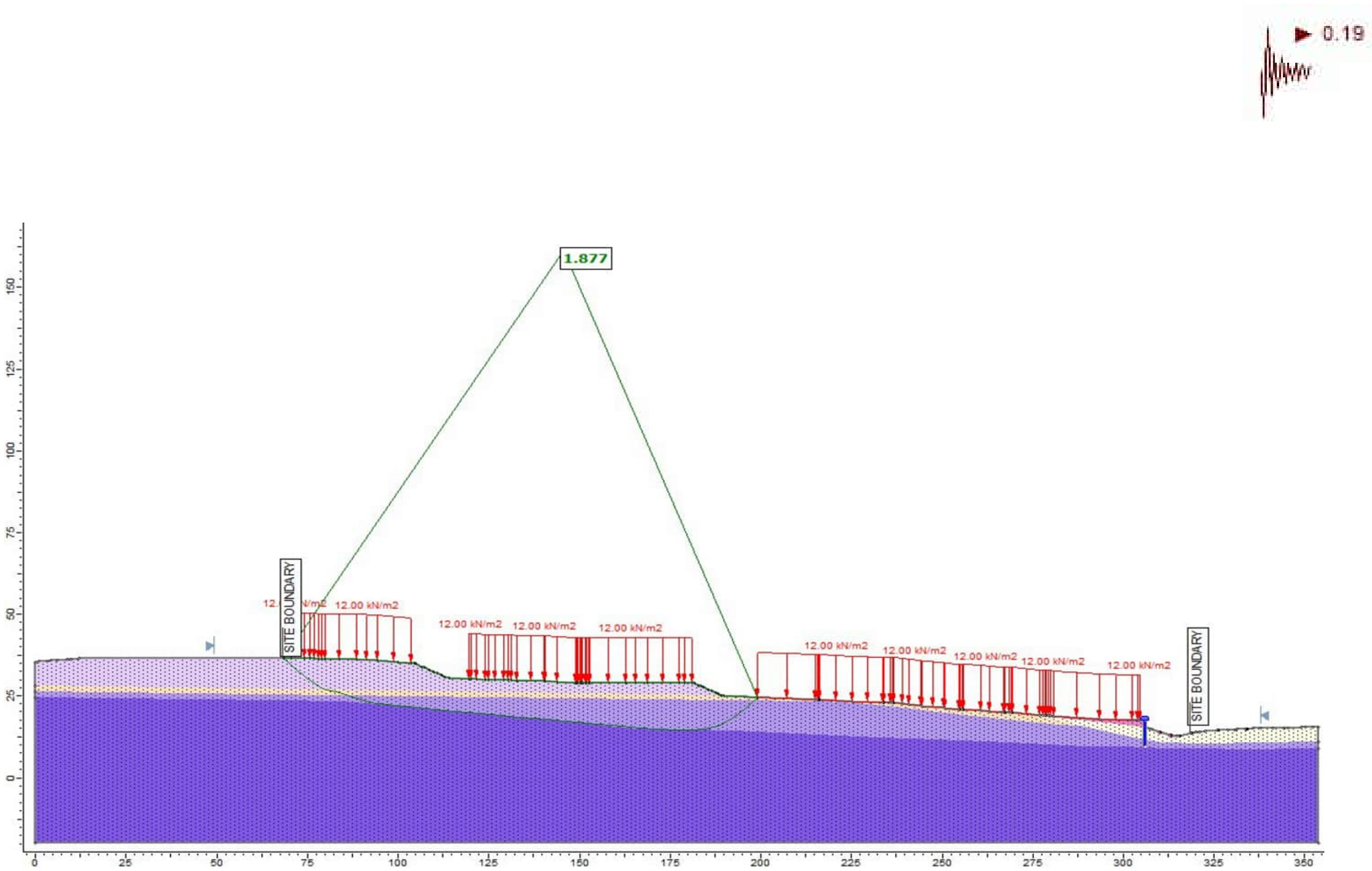
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section A - Proposed	*Date* 11/12/2024	*Drawing* STAB 01



Normal Groundwater Conditions

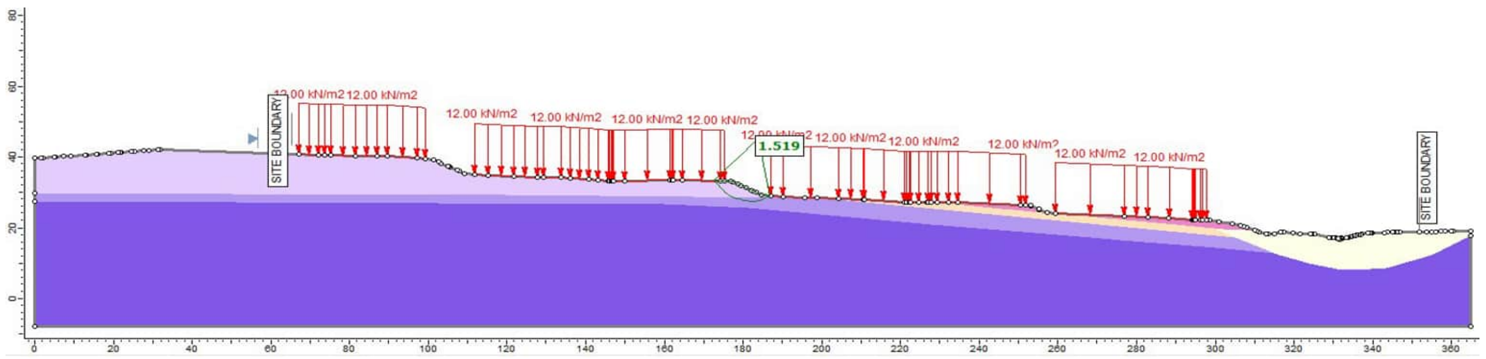


Transient Groundwater Conditions

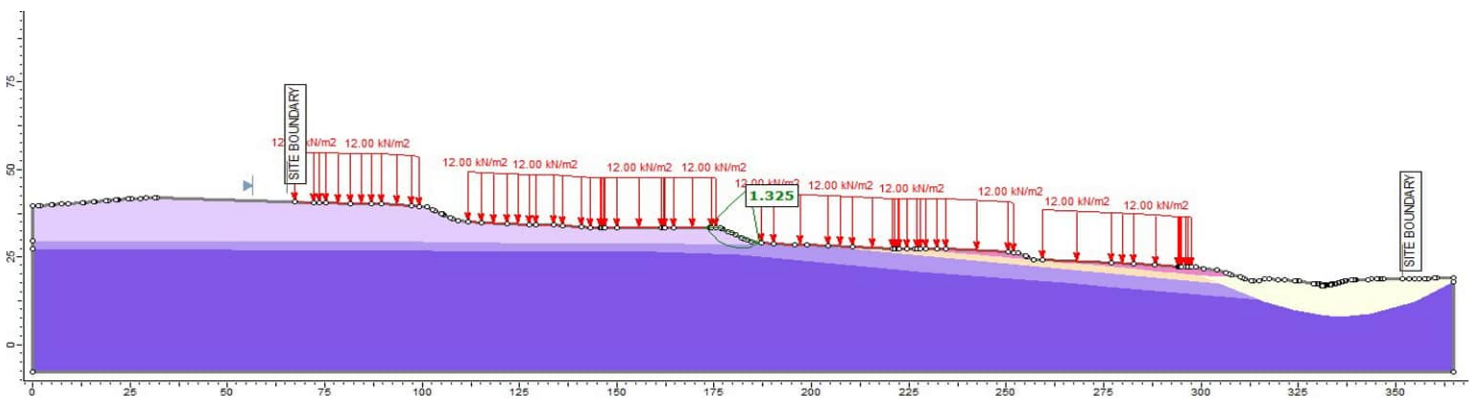


Seismic Event

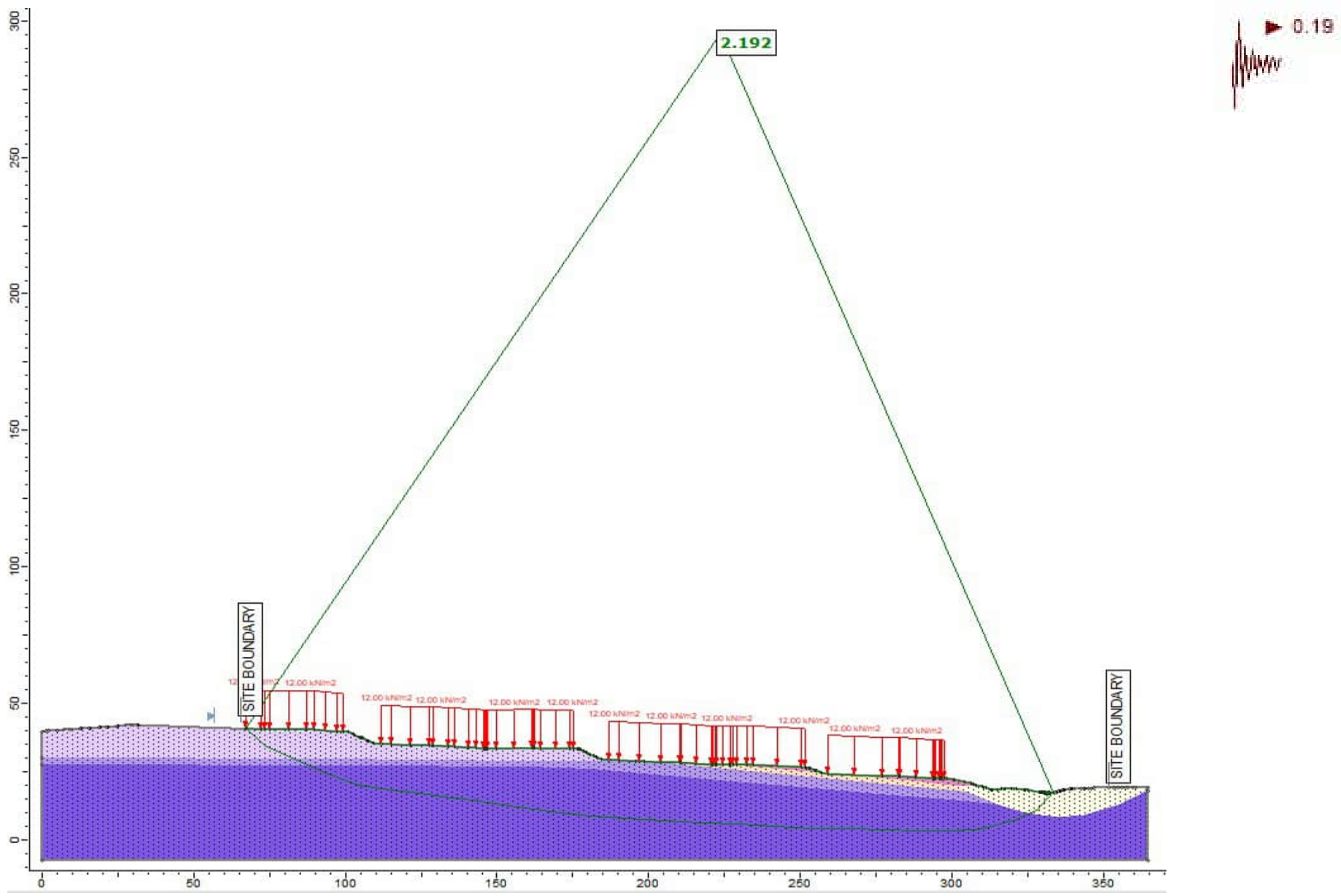
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2021-0161
	Title Section A - Proposed with Remediation (Retaining Walls)	*Date* 11/12/2024	*Drawing* STAB 01a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

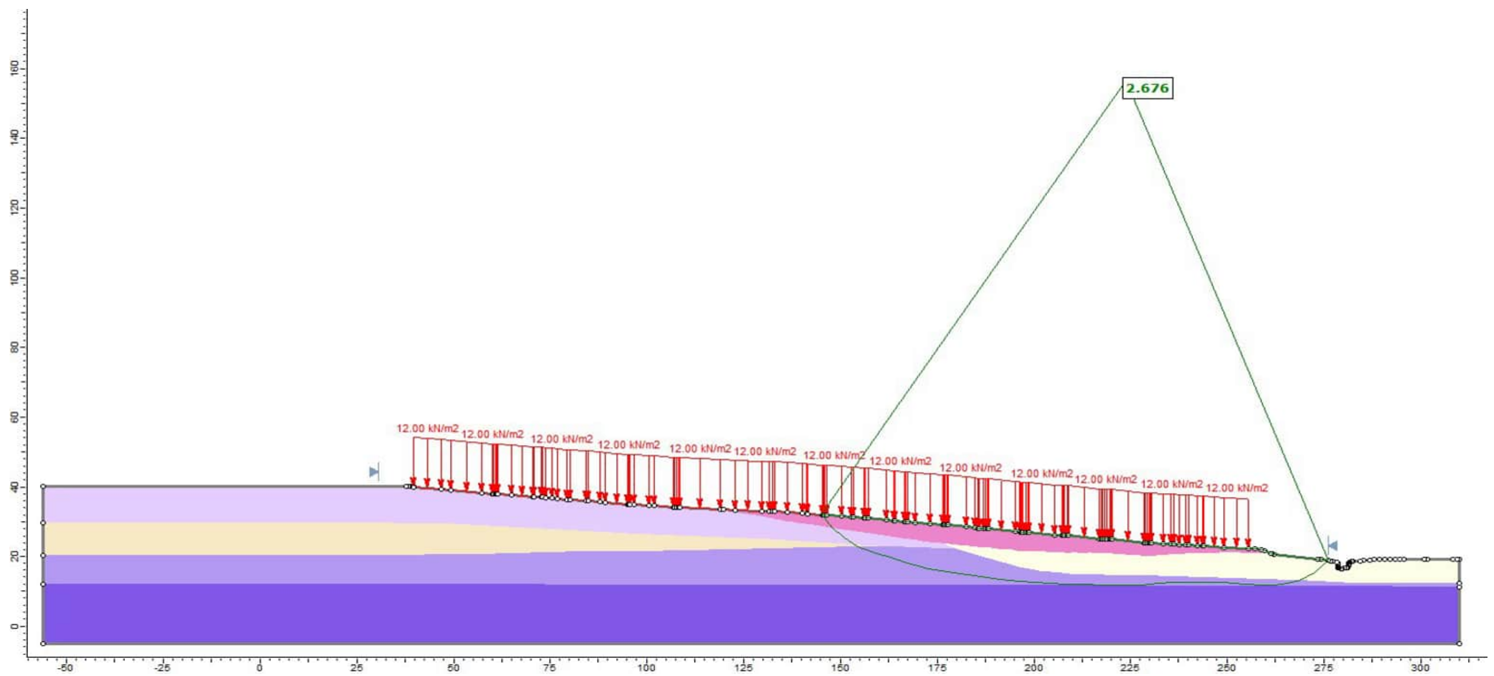
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

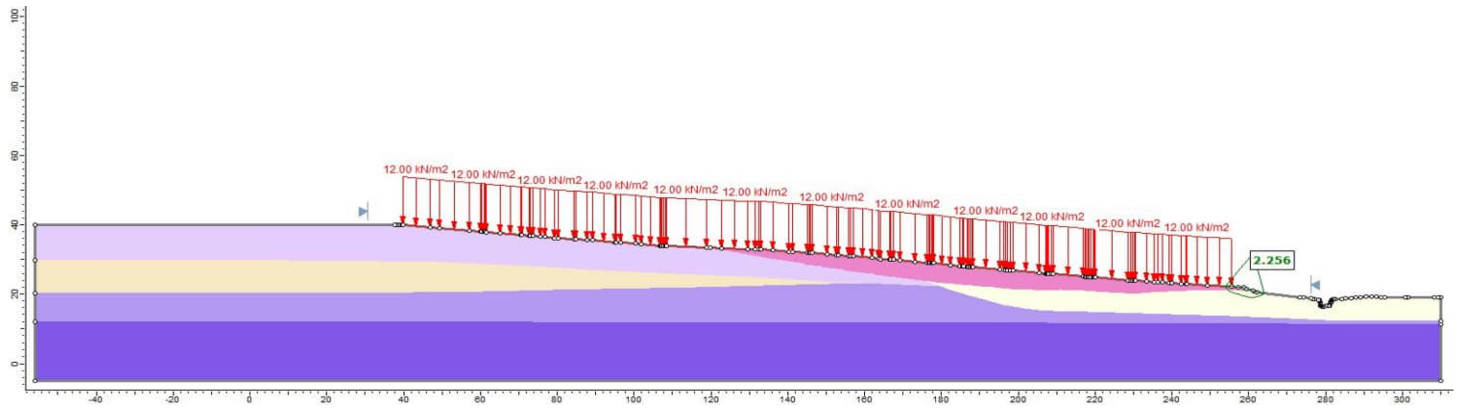
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Tauranga Group Alluvium UD		17	Undrained	60	0	Constant		None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Ridge) UD		17	Undrained	80	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

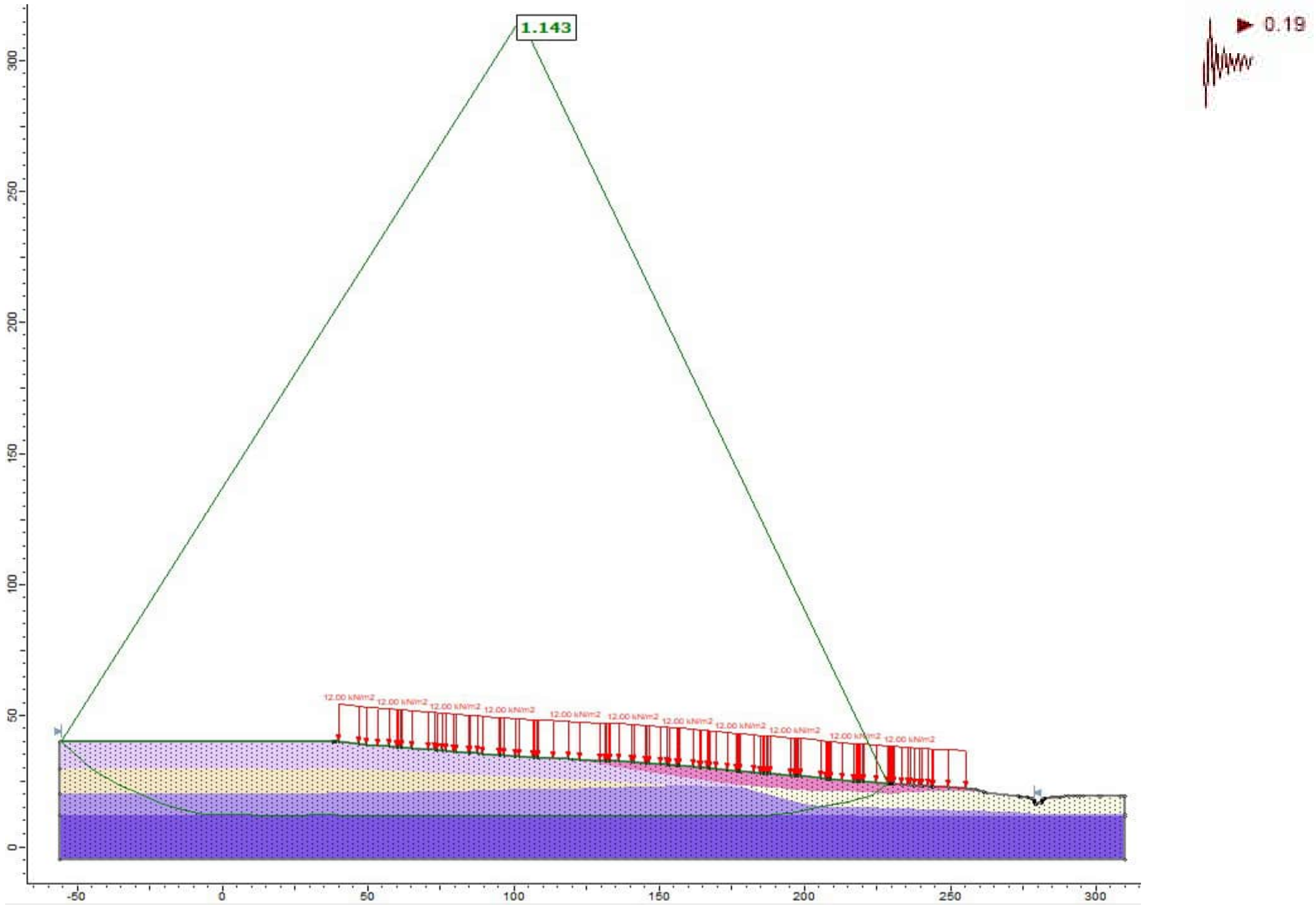
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section B - Proposed	*Date* 11/12/2024	*Drawing* STAB 02





Normal Groundwater Conditions

Transient Groundwater Conditions



Seismic Event

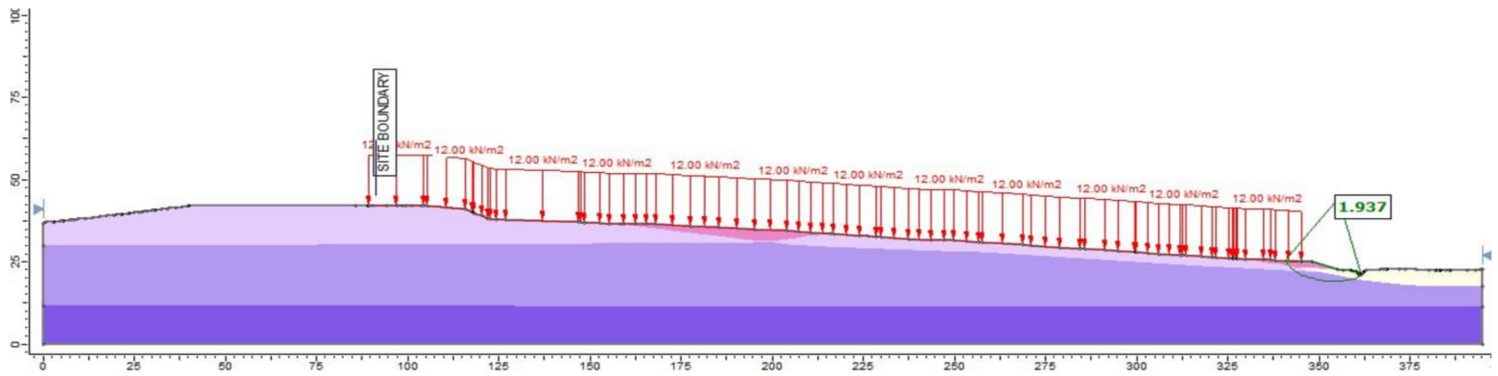
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Colluvium		17	Mohr-Coulomb	5	26	None	0.2
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

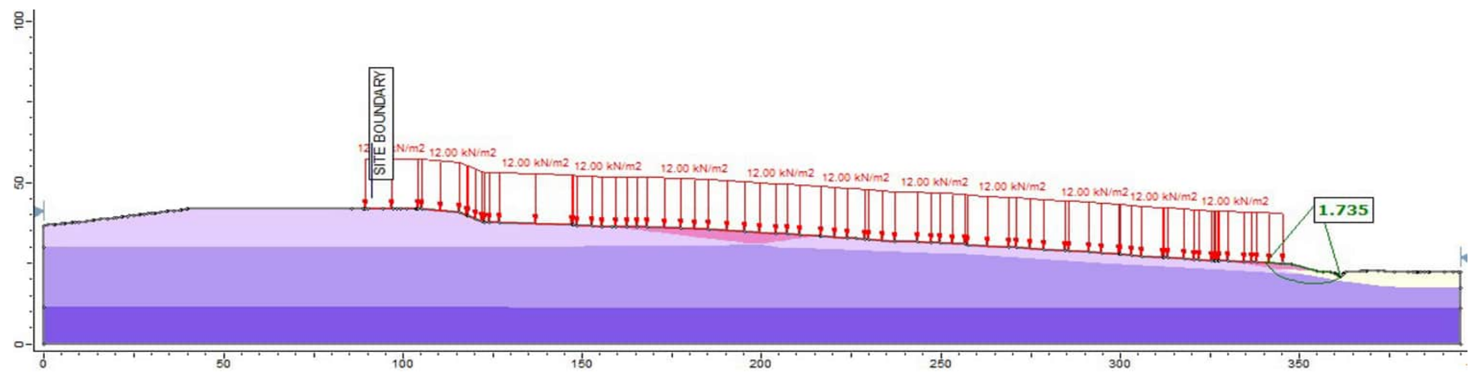
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Colluvium		17	Mohr-Coulomb	5	26	None	0.4
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Tauranga Group Alluvium UD		17	Undrained	60	0	Constant		None	0
Colluvium UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Ridge) UD		17	Undrained	80	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section C - Proposed	*Date* 11/12/2024	*Drawing* STAB 03





Normal Groundwater Conditions

Transient Groundwater Conditions

Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Tauranga Group Alluvium (Ridge)		17	Mohr-Coulomb	8	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Ridge) UD		17	Undrained	80	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

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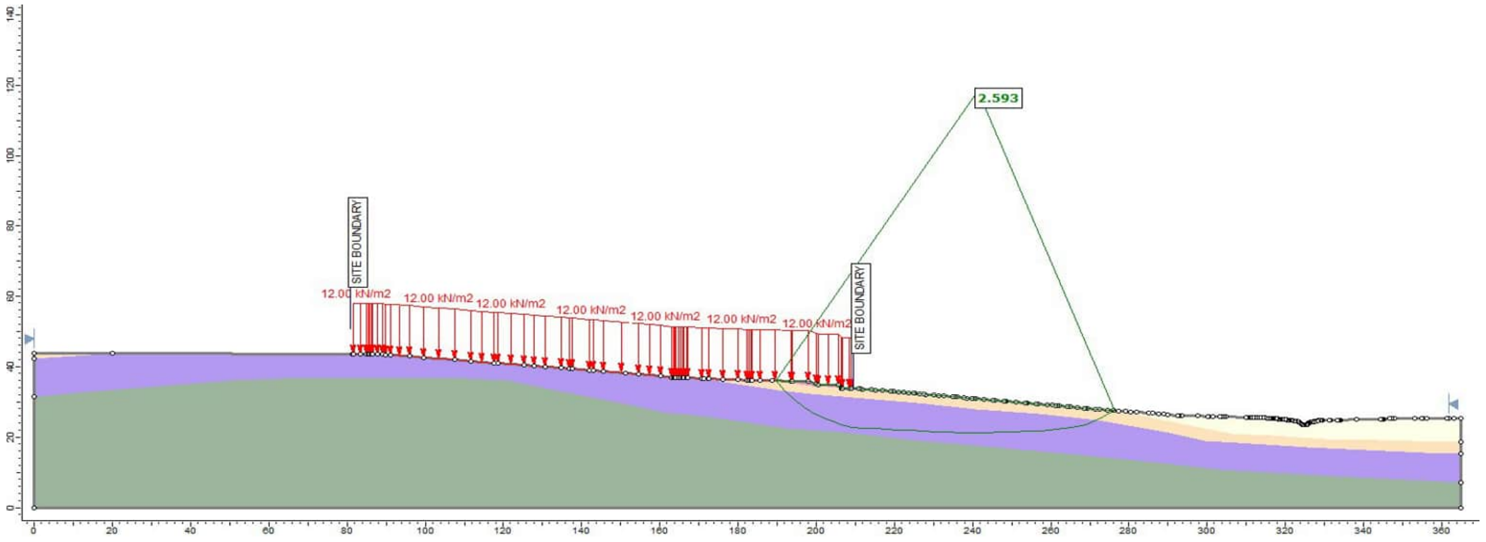
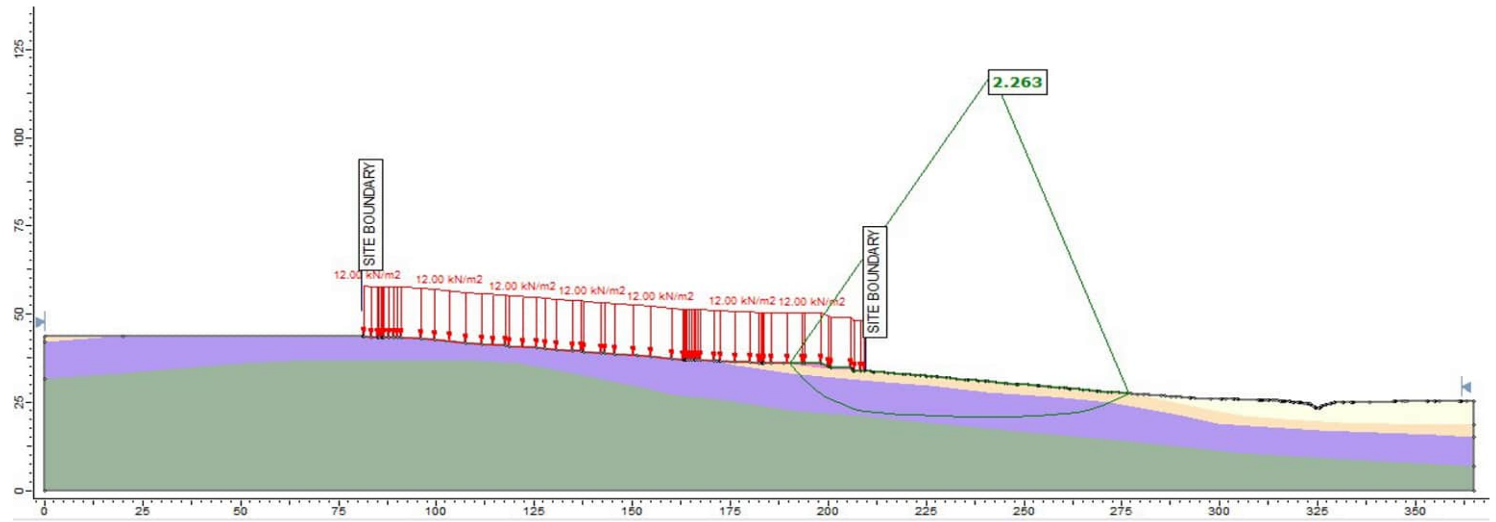
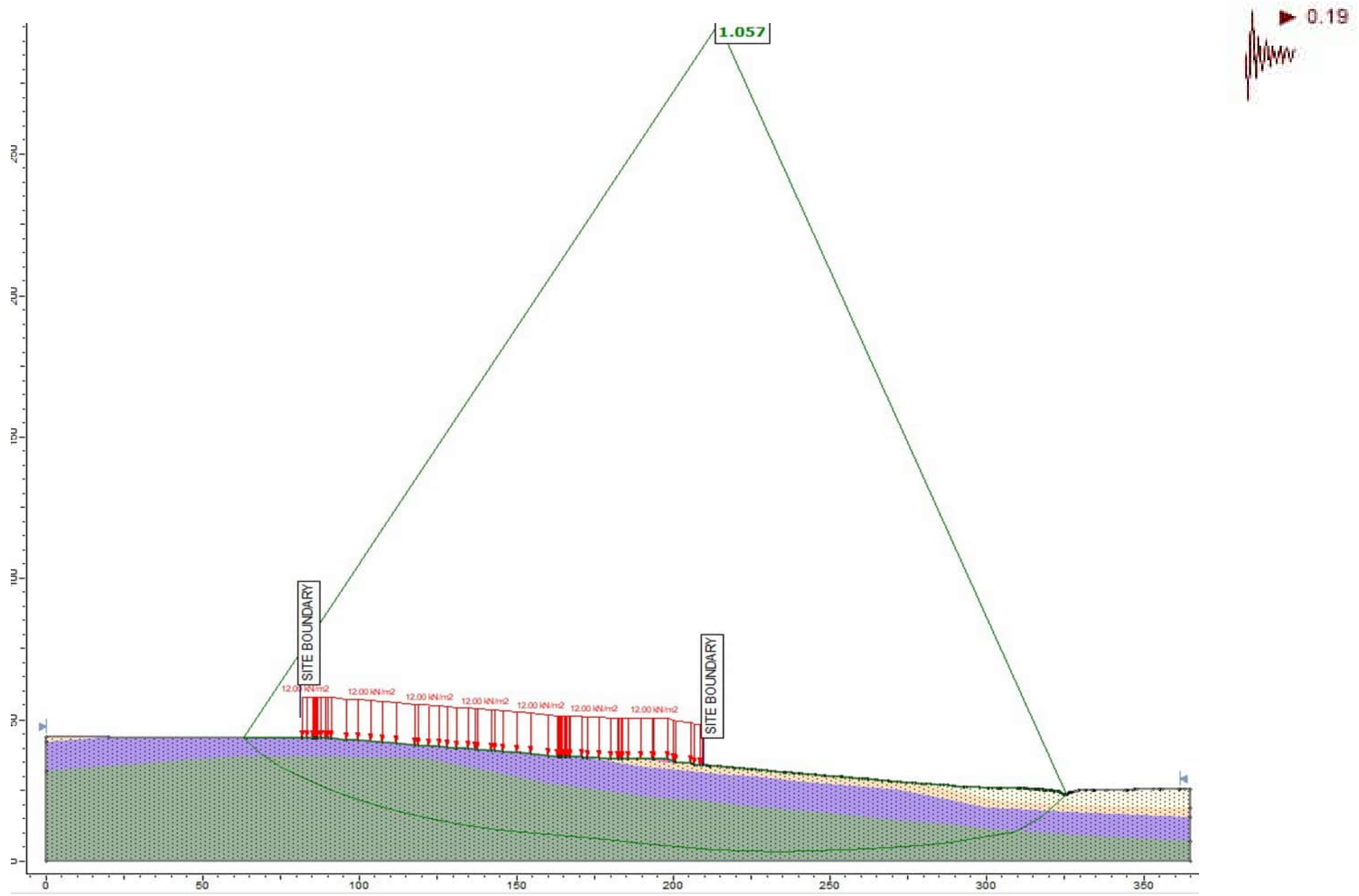
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section D - Proposed	*Date* 11/12/2024	*Drawing* STAB 04



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Transitional Mangakahia		18	Mohr-Coulomb	8	21	None	0.05
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Transitional Mangakahia		18	Mohr-Coulomb	8	21	None	0.2
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Transitional Mangakahia UD		18	Shear/Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

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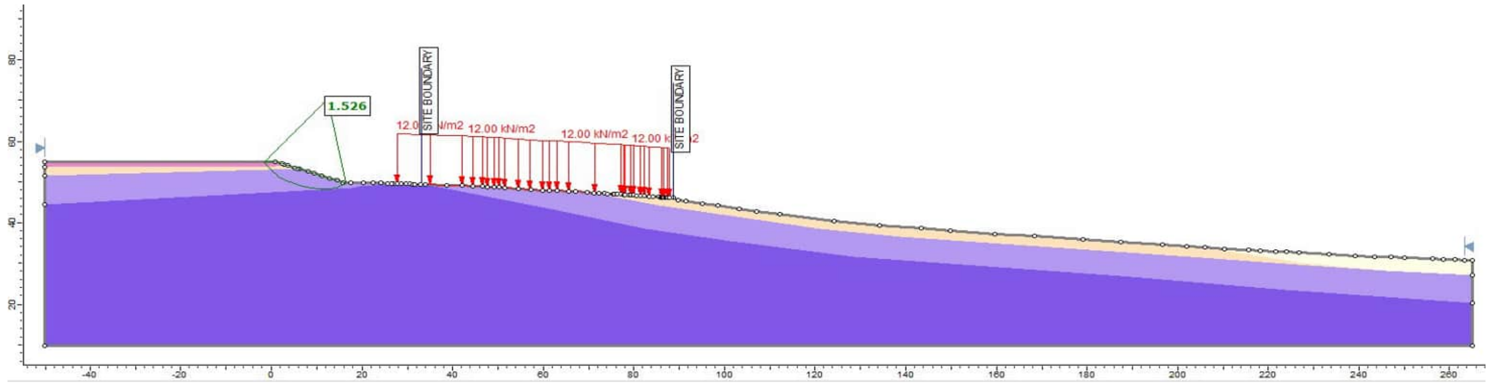
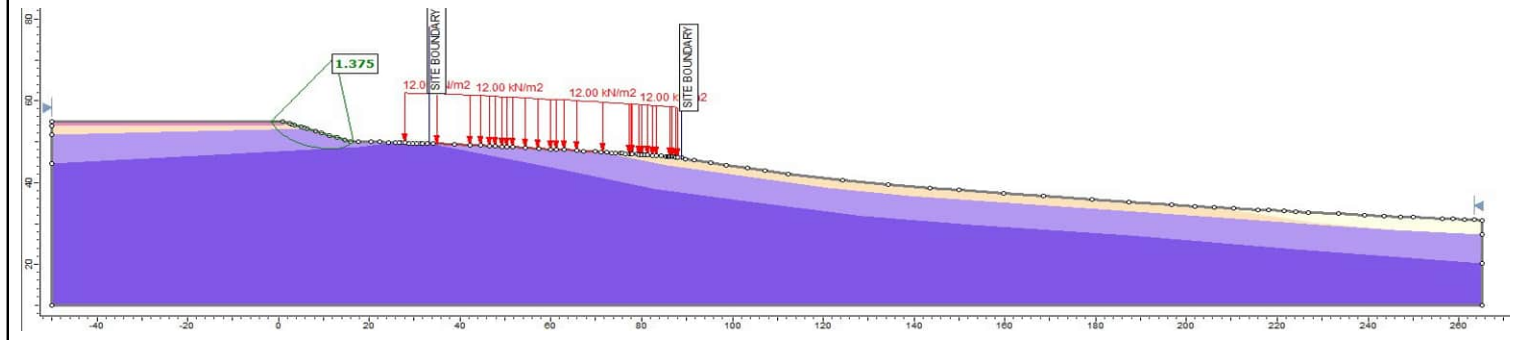
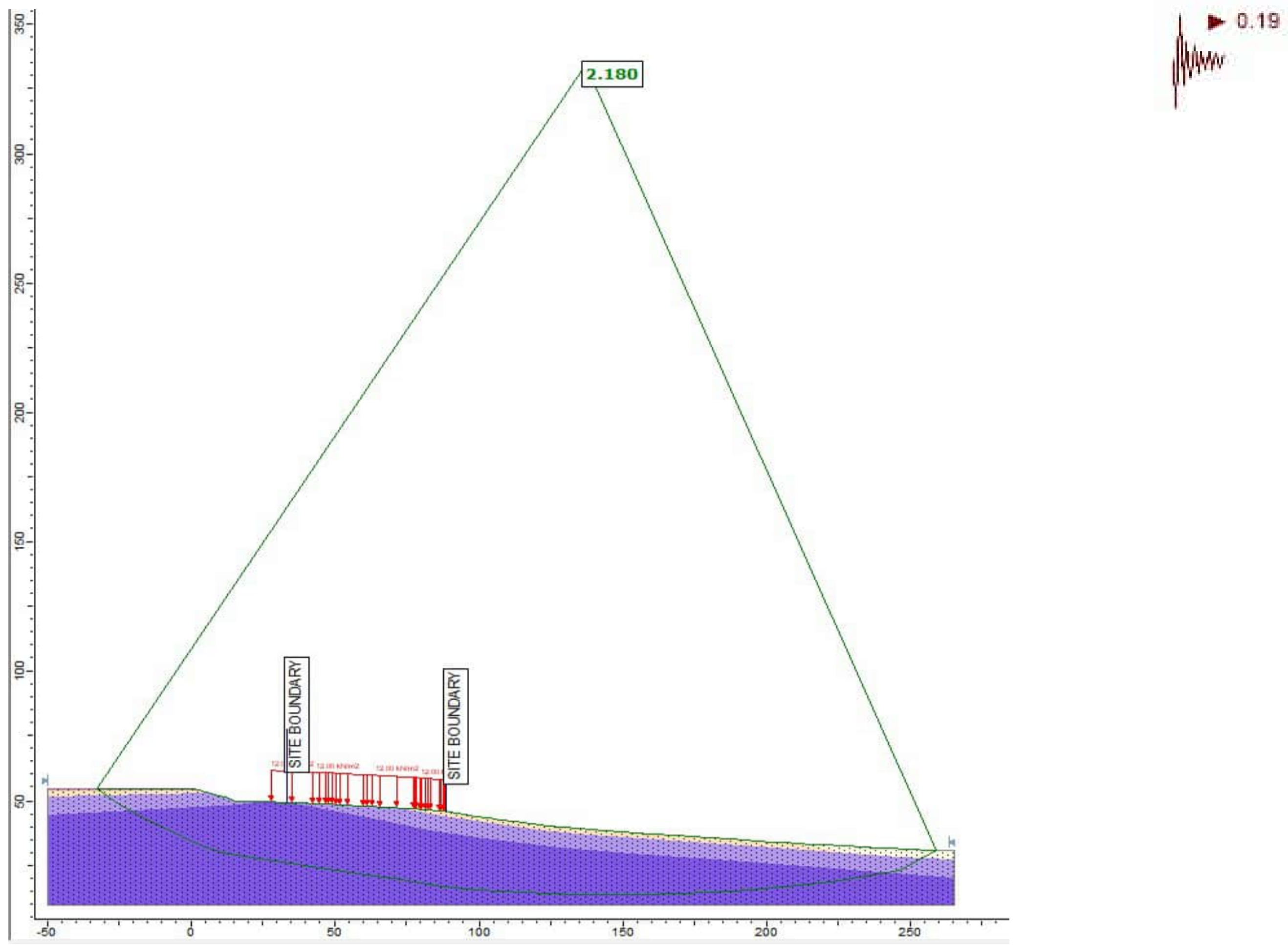
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section E - Proposed	*Date* 11/12/2024	*Drawing* STAB 05



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

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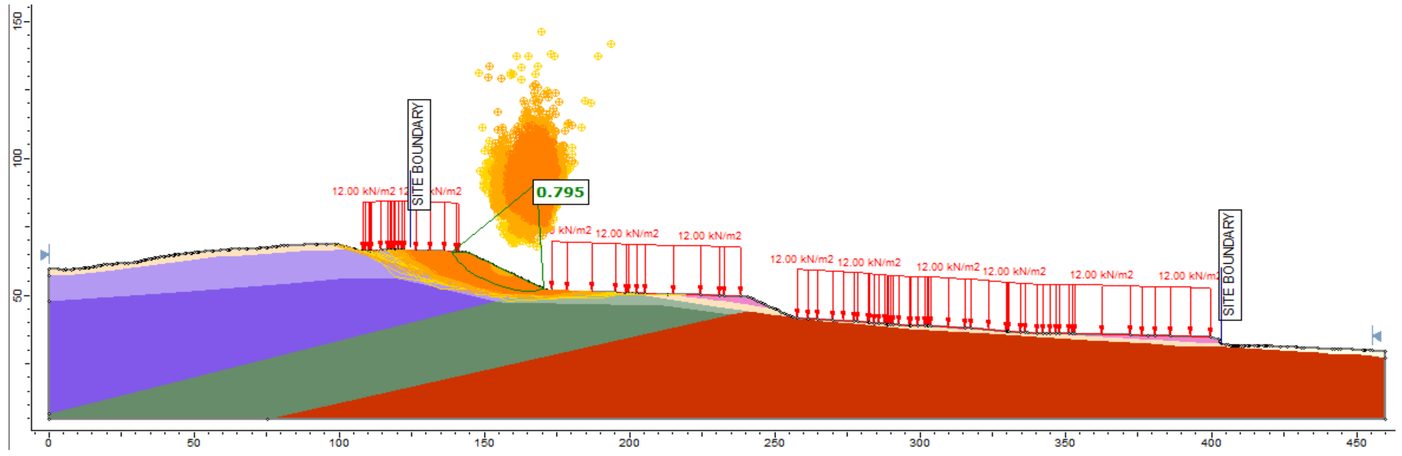
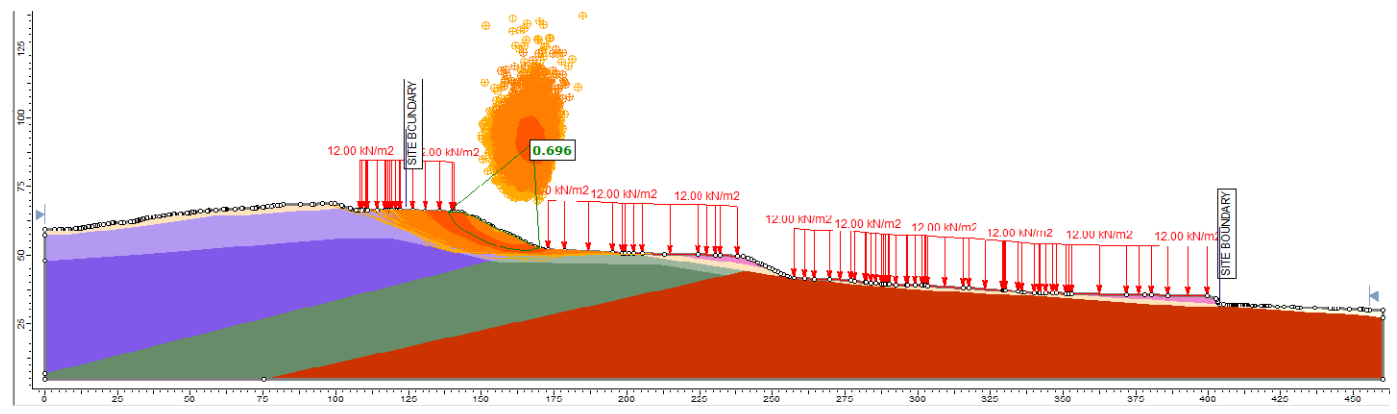
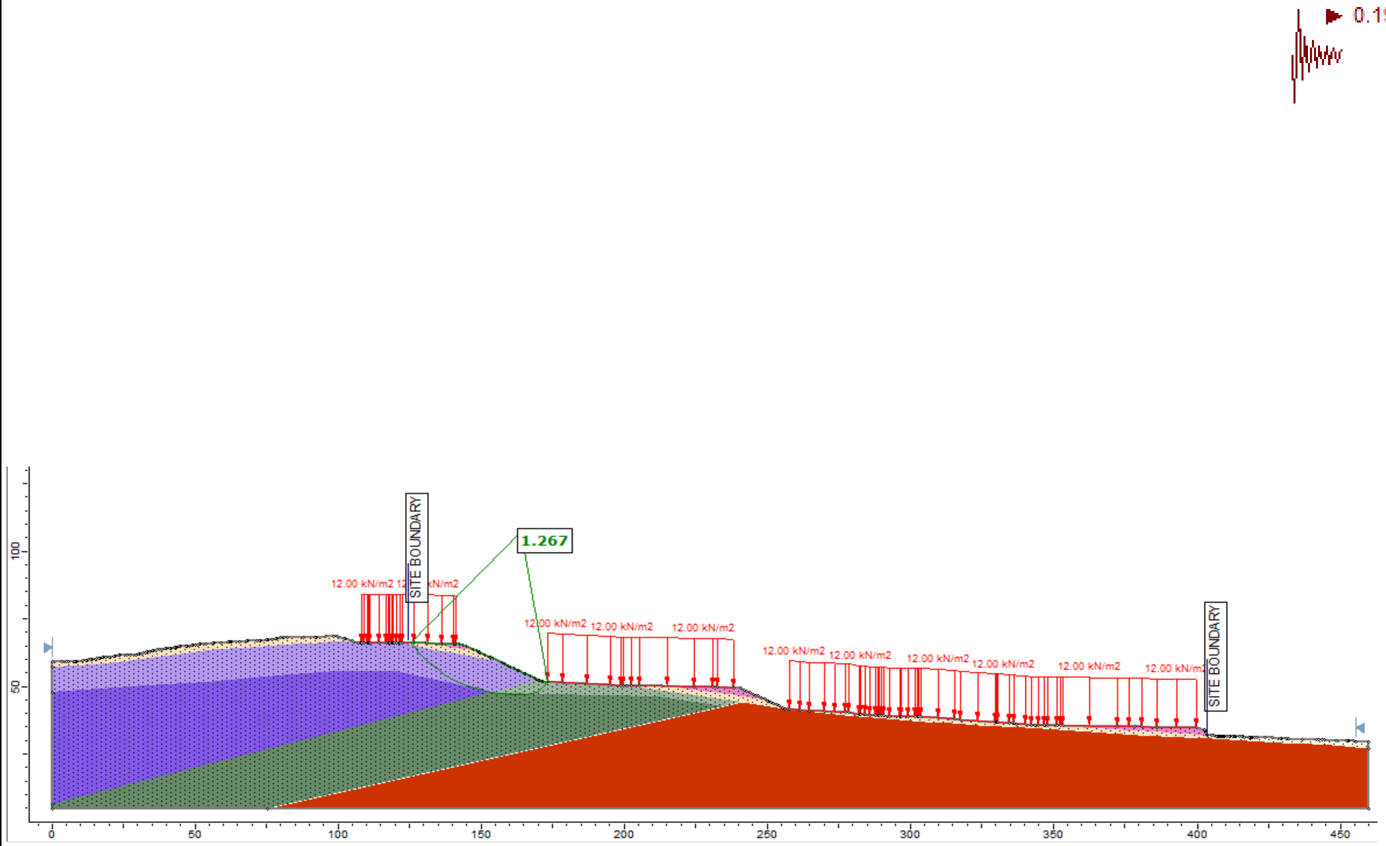
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section F - Proposed	*Date* 11/12/2024	*Drawing* STAB 06



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

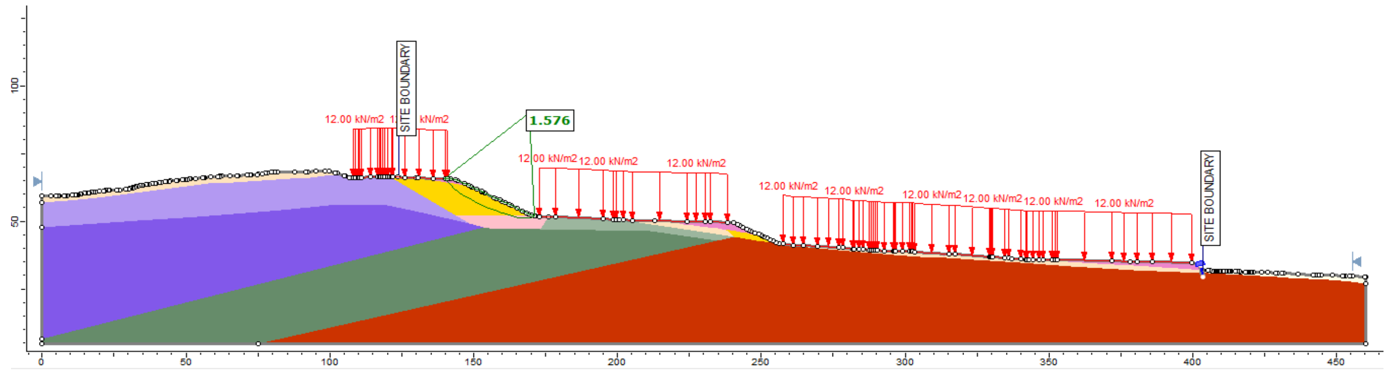
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.2
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

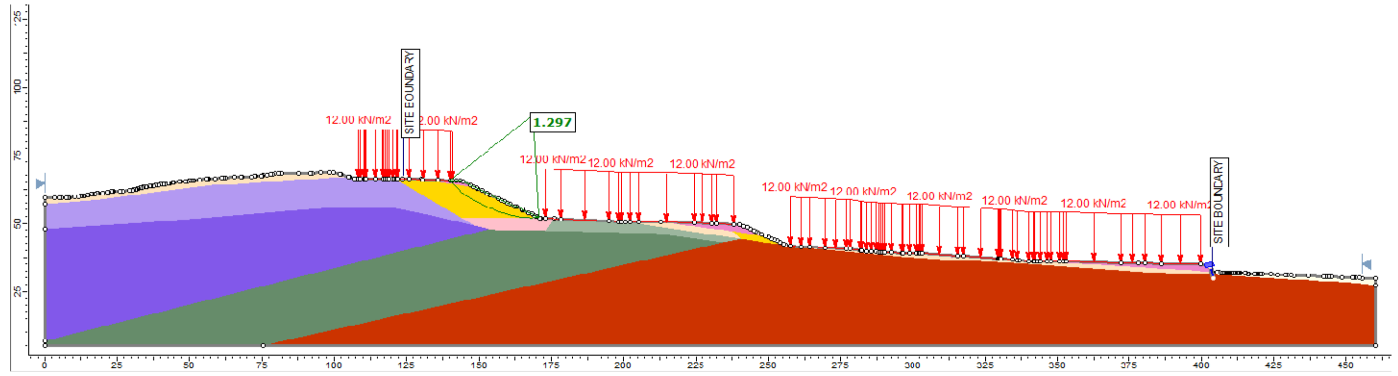
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/Normal Function	Water Surface	Ru Value
Mahurangi Limestone		19	Mohr-Coulomb	10	40			None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

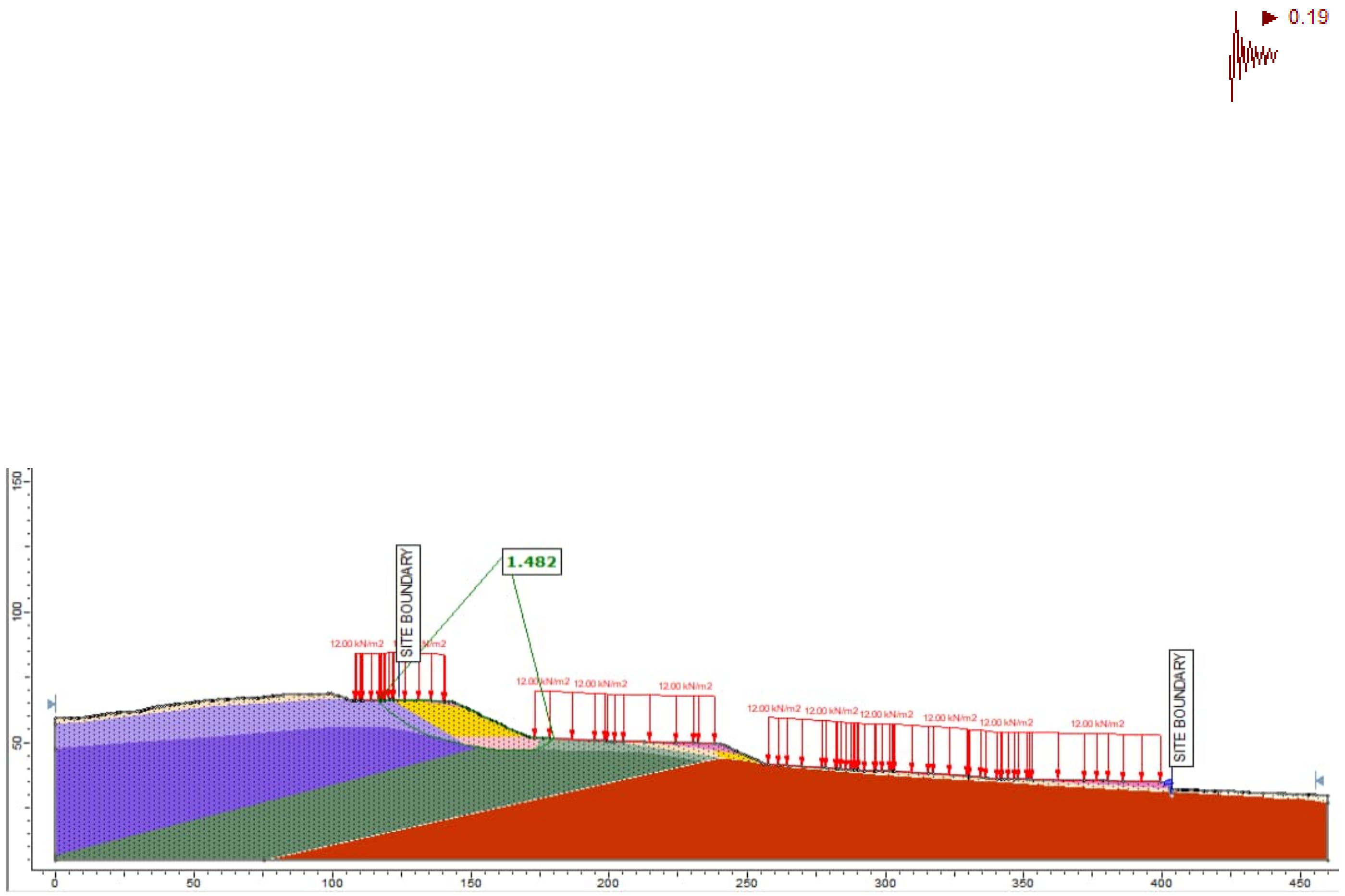
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section G - Proposed	*Date* 3/02/2025	*Drawing* STAB 07



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Mahurangi Limestone		19	Mohr-Coulomb	10	40			None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0
Shear Key_UD		18	Undrained	100	0	Constant		None	0
Buttress Fill_UD		18	Undrained	100	0	Constant		None	0

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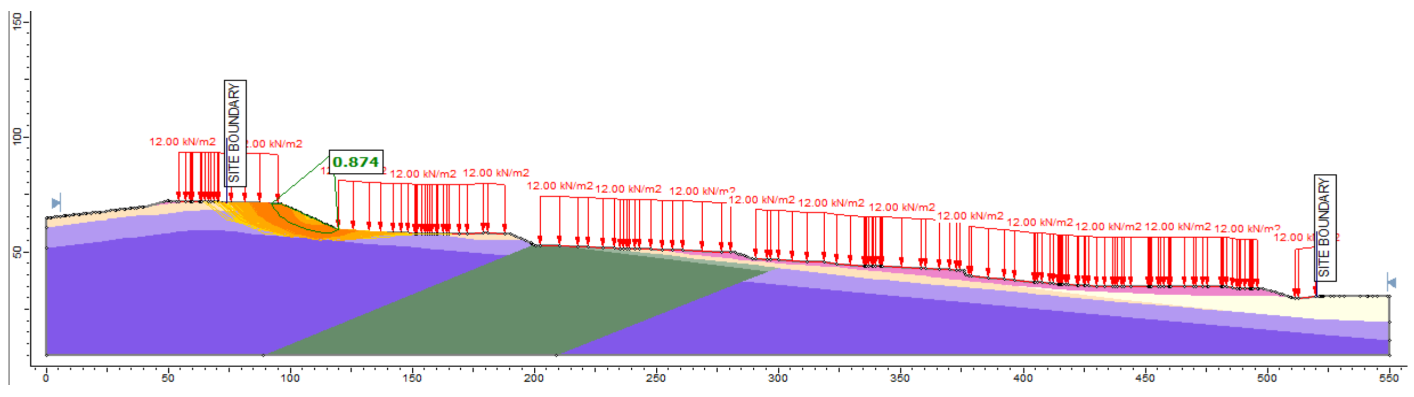
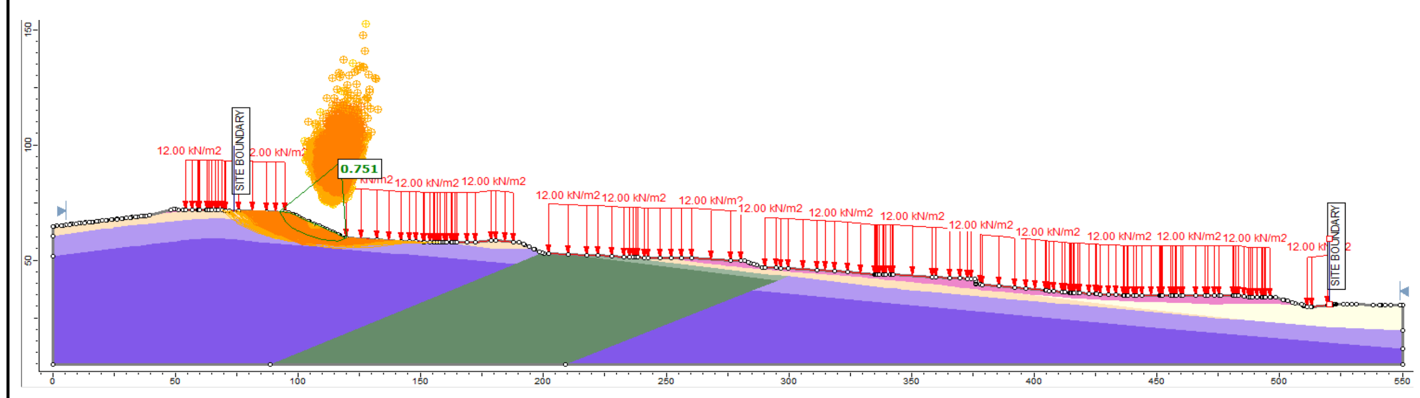
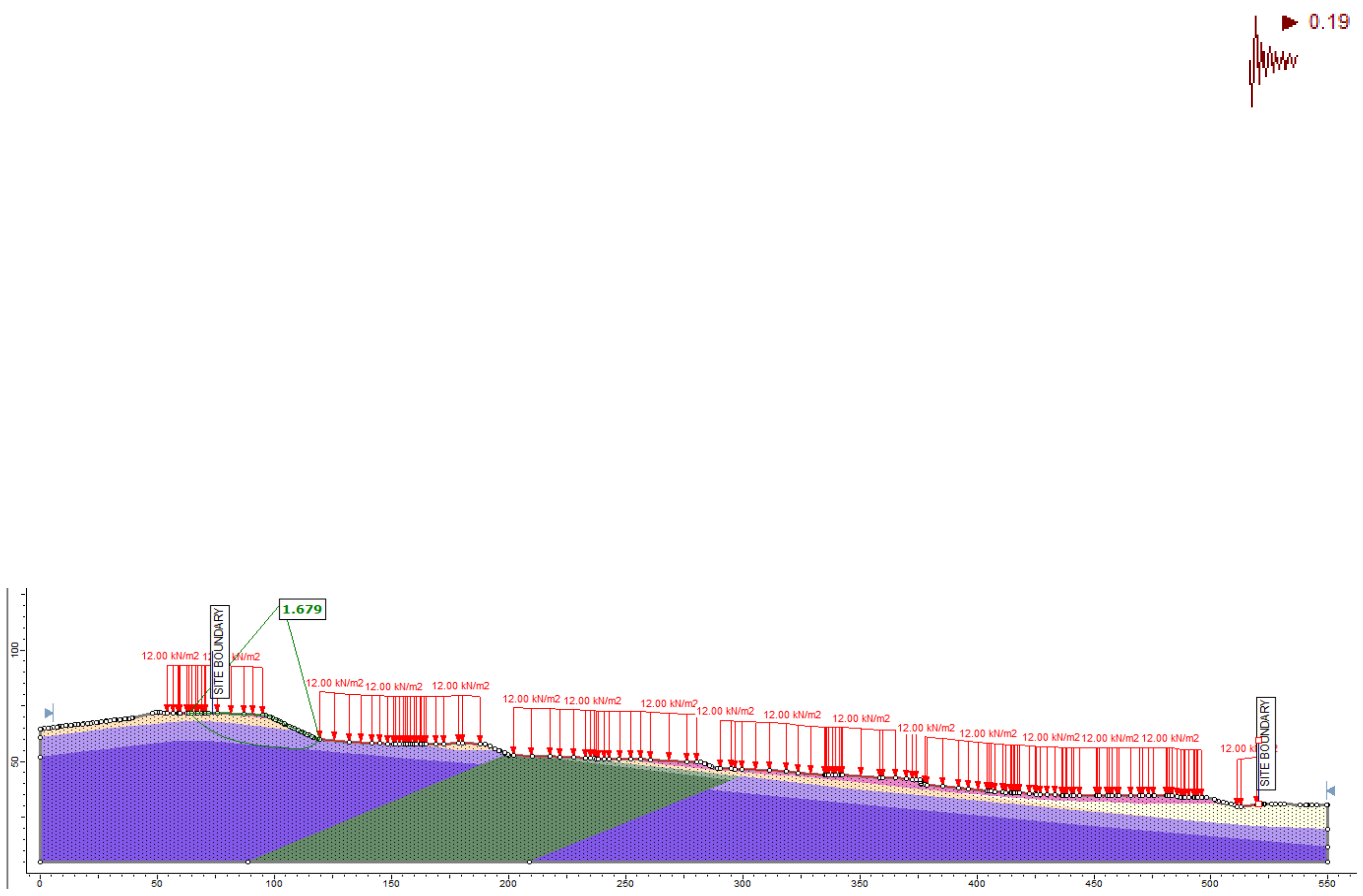
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section G - Proposed with Remediation (Shear Key & Buttress fill)	*Date* 3/02/2025	*Drawing* STAB 07a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.2
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

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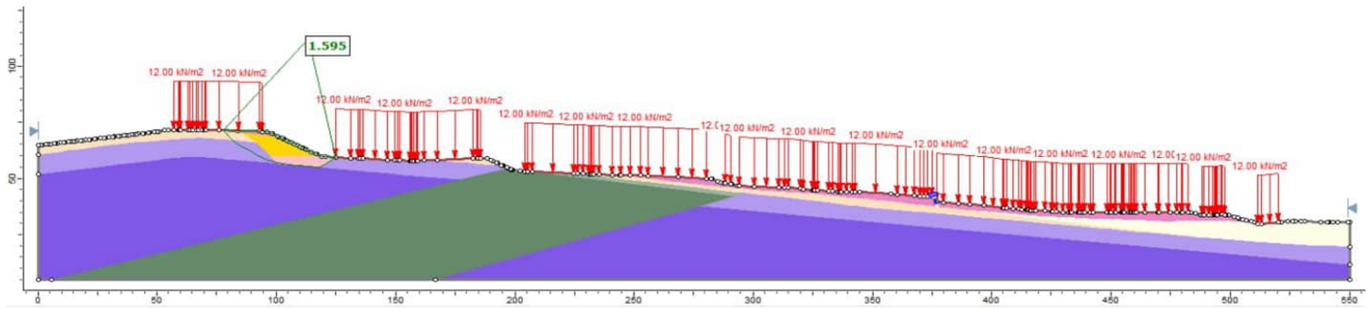
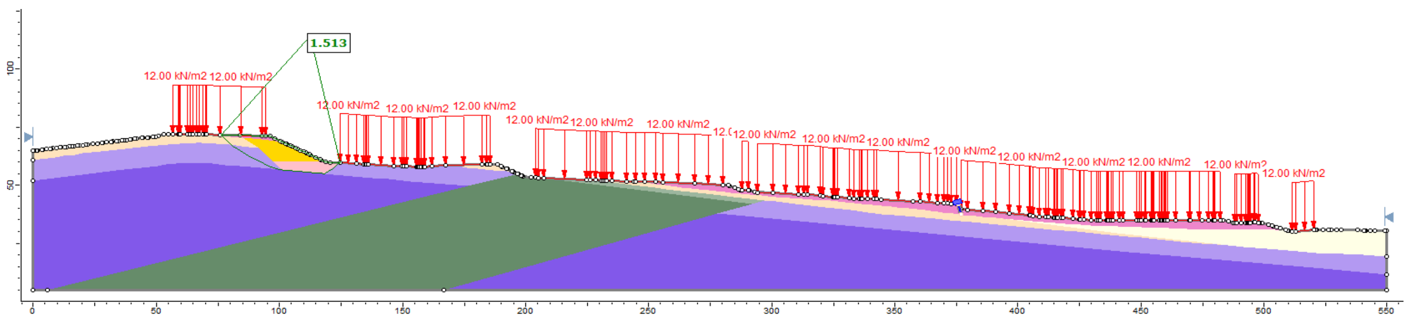
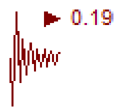
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section H - Proposed	*Date* 3/02/2025	*Drawing* STAB 08

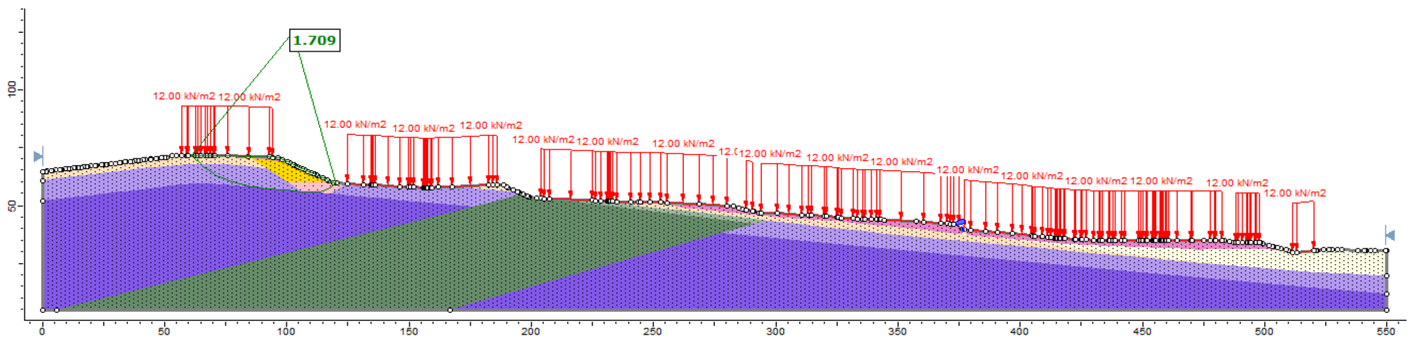


Normal Groundwater Conditions



Transient Groundwater Conditions





Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui MudstoneUD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated MangakahiaRock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0
Shear Key_UD		18	Undrained	100	0	Constant		None	0
Buttress Fill _UD		18	Undrained	100	0	Constant		None	0

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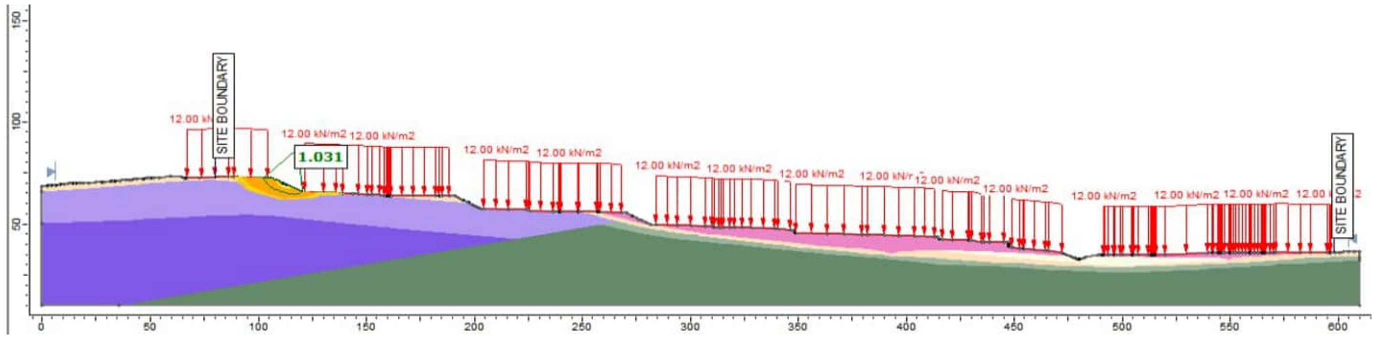
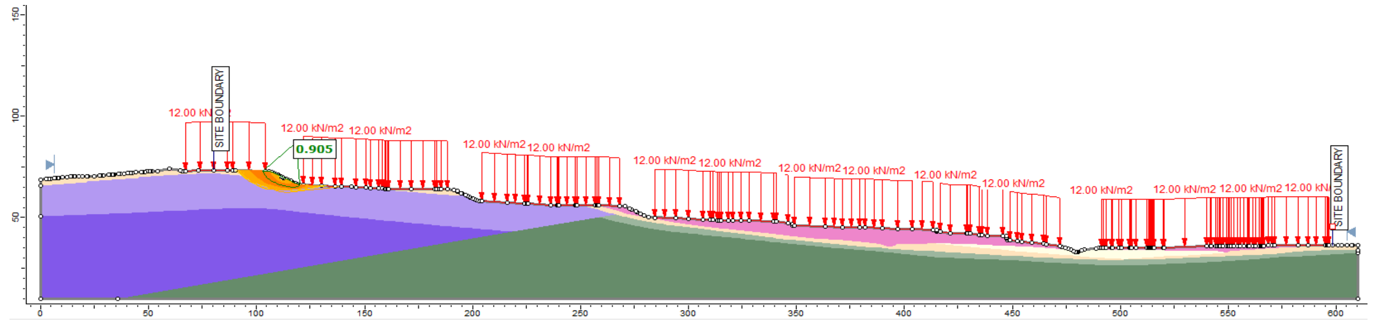
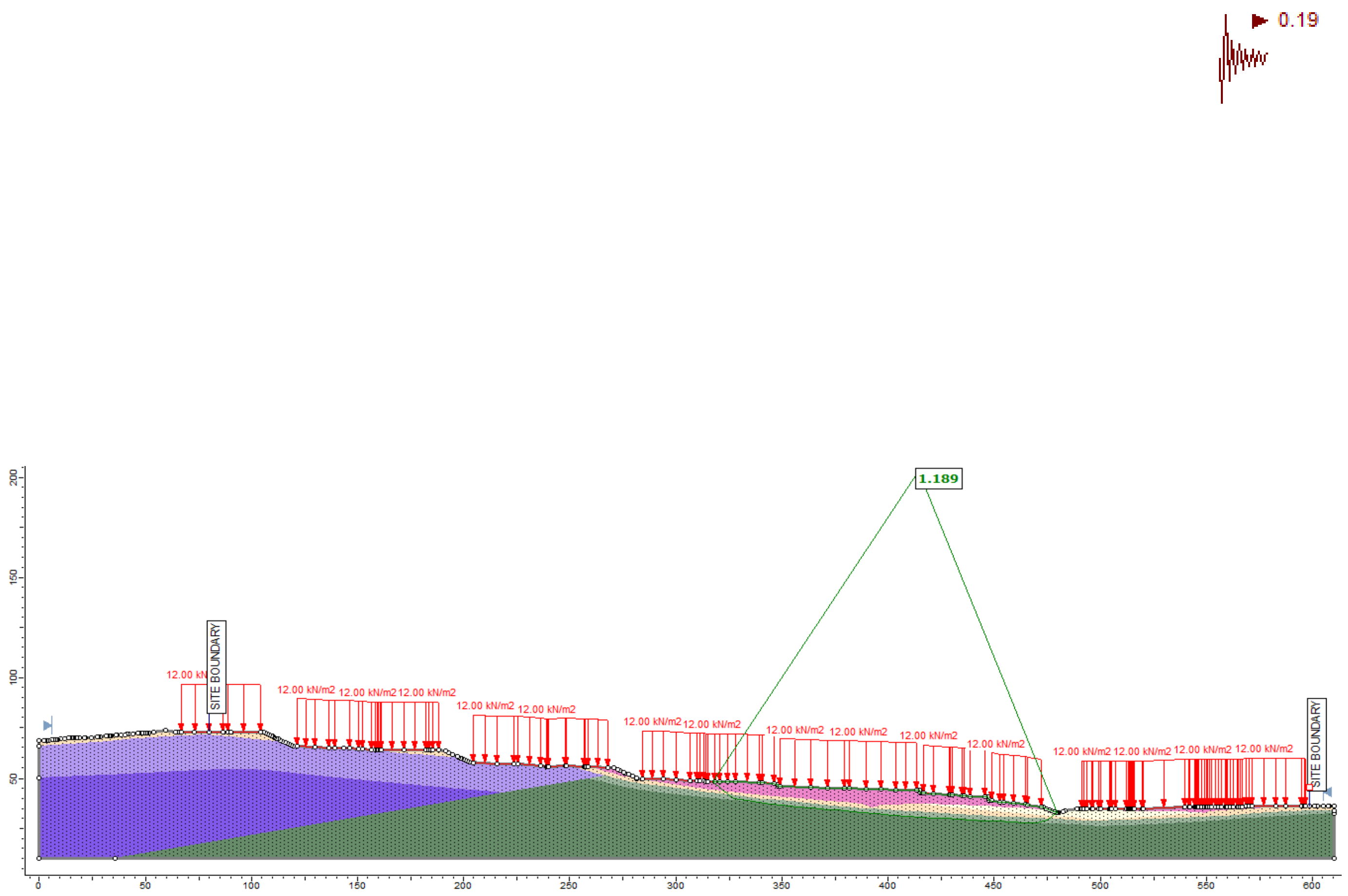
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non -circular	*Project No.* AKL2024-0257
Title Section H - Proposed with Remediation (Shear Key & Buttress fill)	*Date* 3/02/2025	*Drawing* STAB 08a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

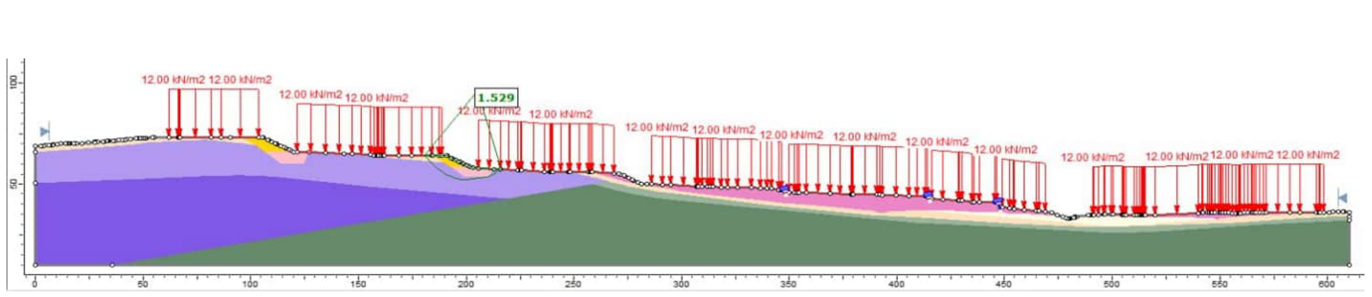
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

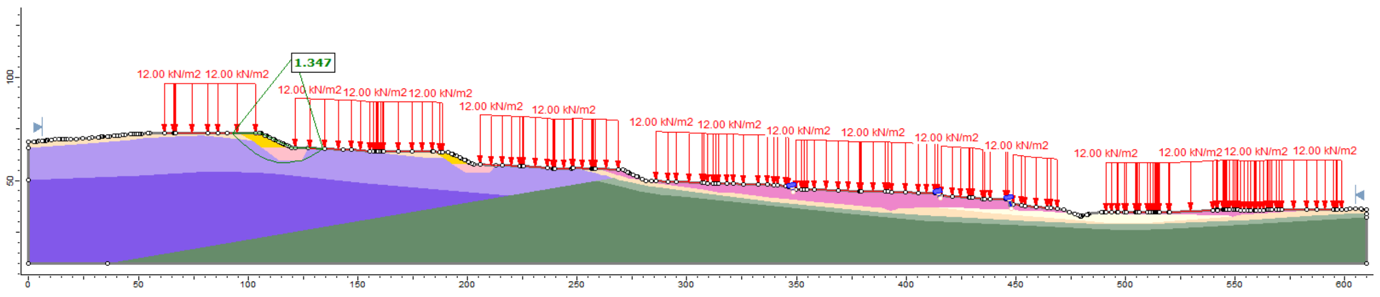
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.2
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Parameters

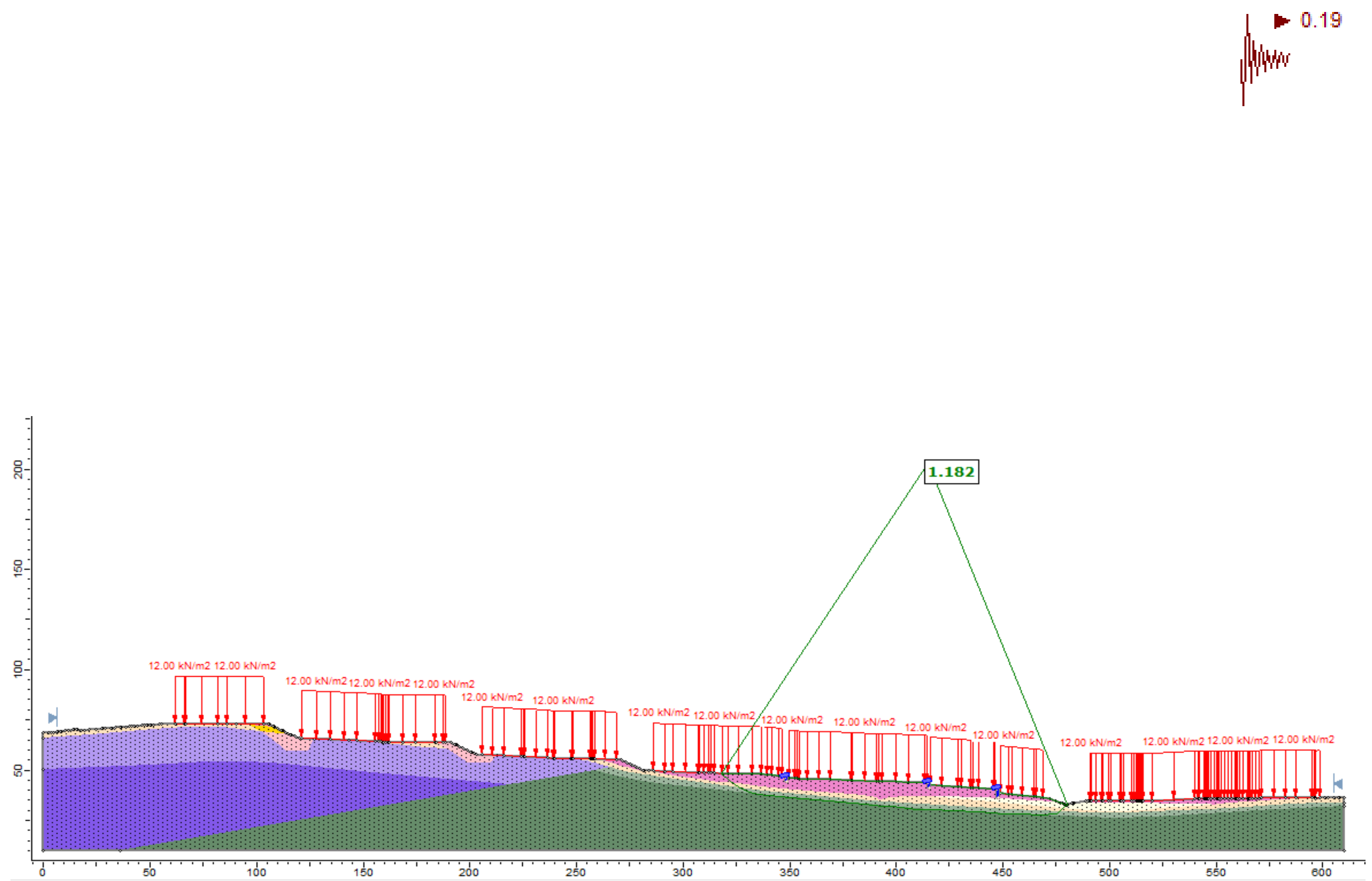
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section I - Proposed	*Date* 3/02/2025	*Drawing* STAB 09



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Fill Buttress		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Tauranga Group Alluvium (Stream) UD		17	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0
Shear Key_UD		18	Undrained	100	0	Constant		None	0
Fill Buttress_UD		18	Undrained	100	0	Constant		None	0

CMW Geosciences
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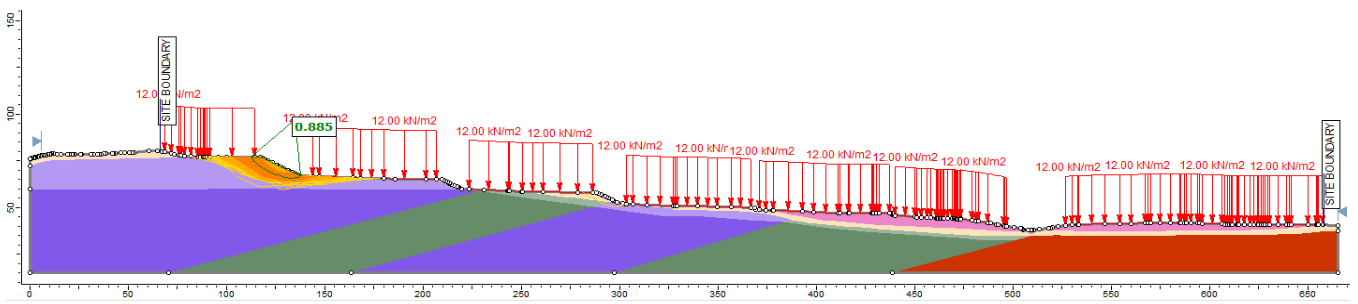
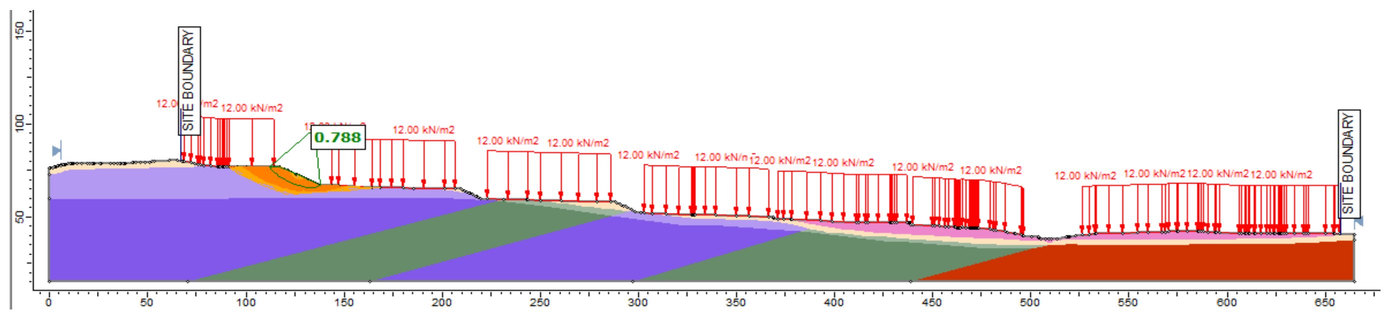
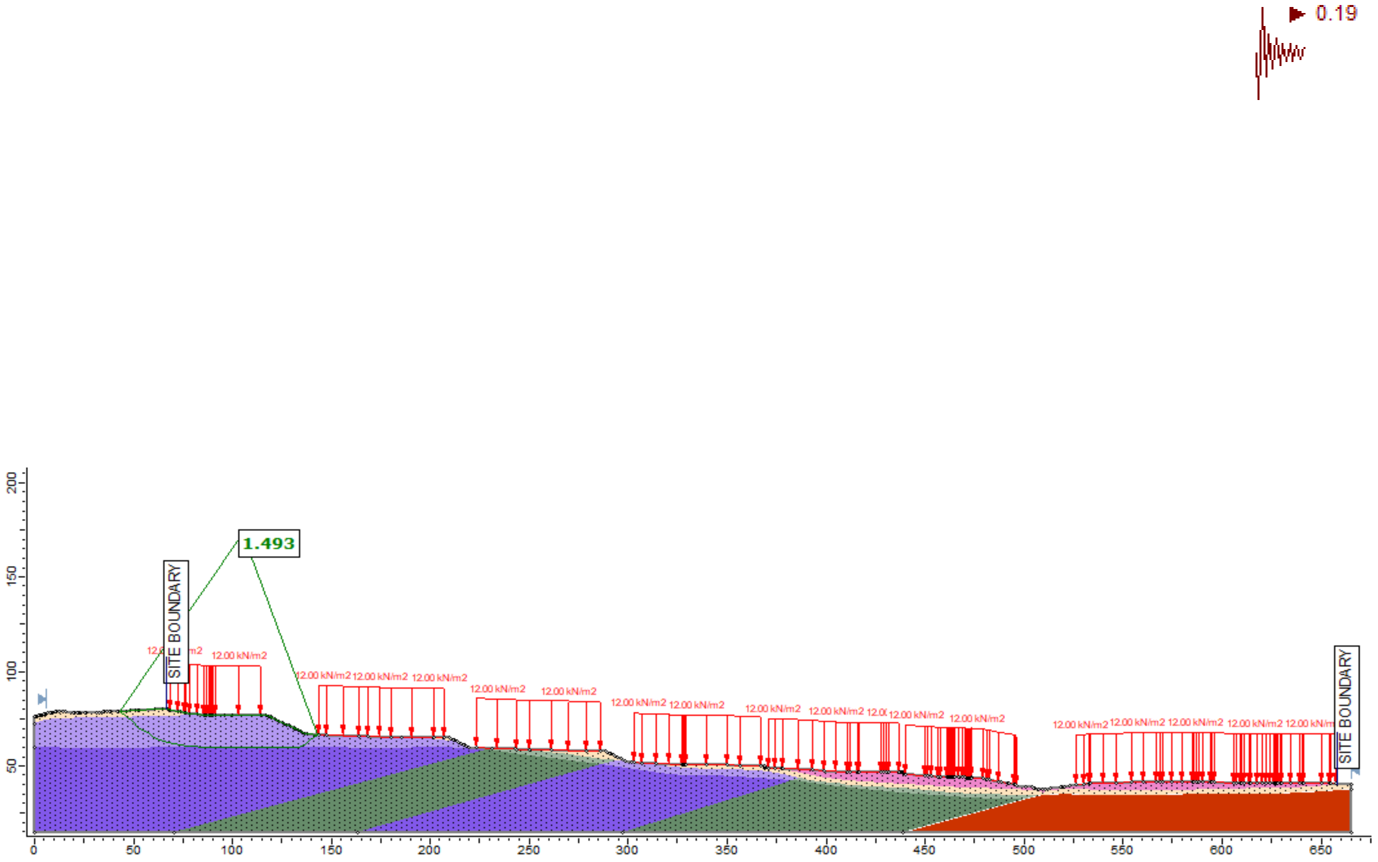
Project	Analysis	Project No.
MILLDALE FAST TRACK APPLICATION	Circular	AKL2024-0257
Title	**Date**	**Drawing**
Section I - Proposed with Remediation Proposed with Remediation (Shear Key & Buttress fill)	3/02/2025	STAB 09a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.2
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.2
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight(kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Mahurangi Limestone		19	Mohr-Coulomb	10	40			None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

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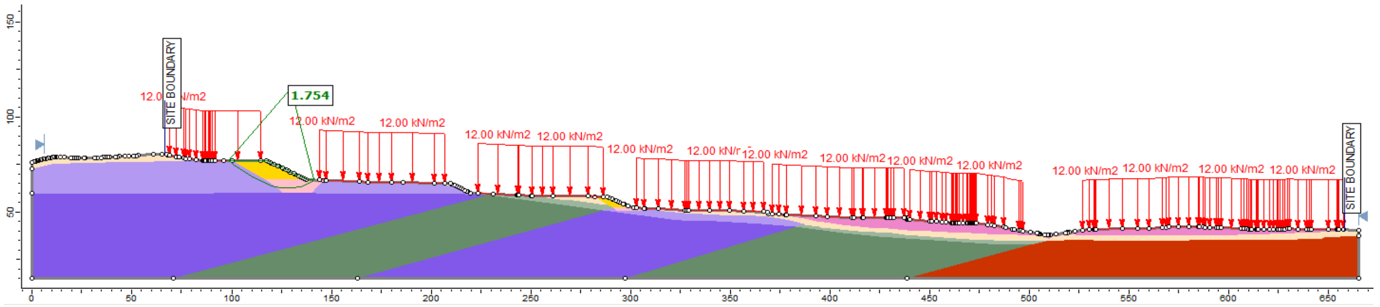
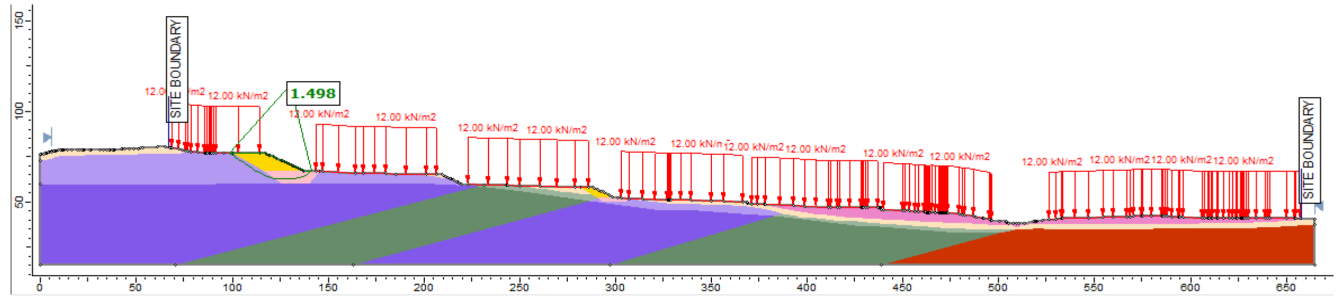
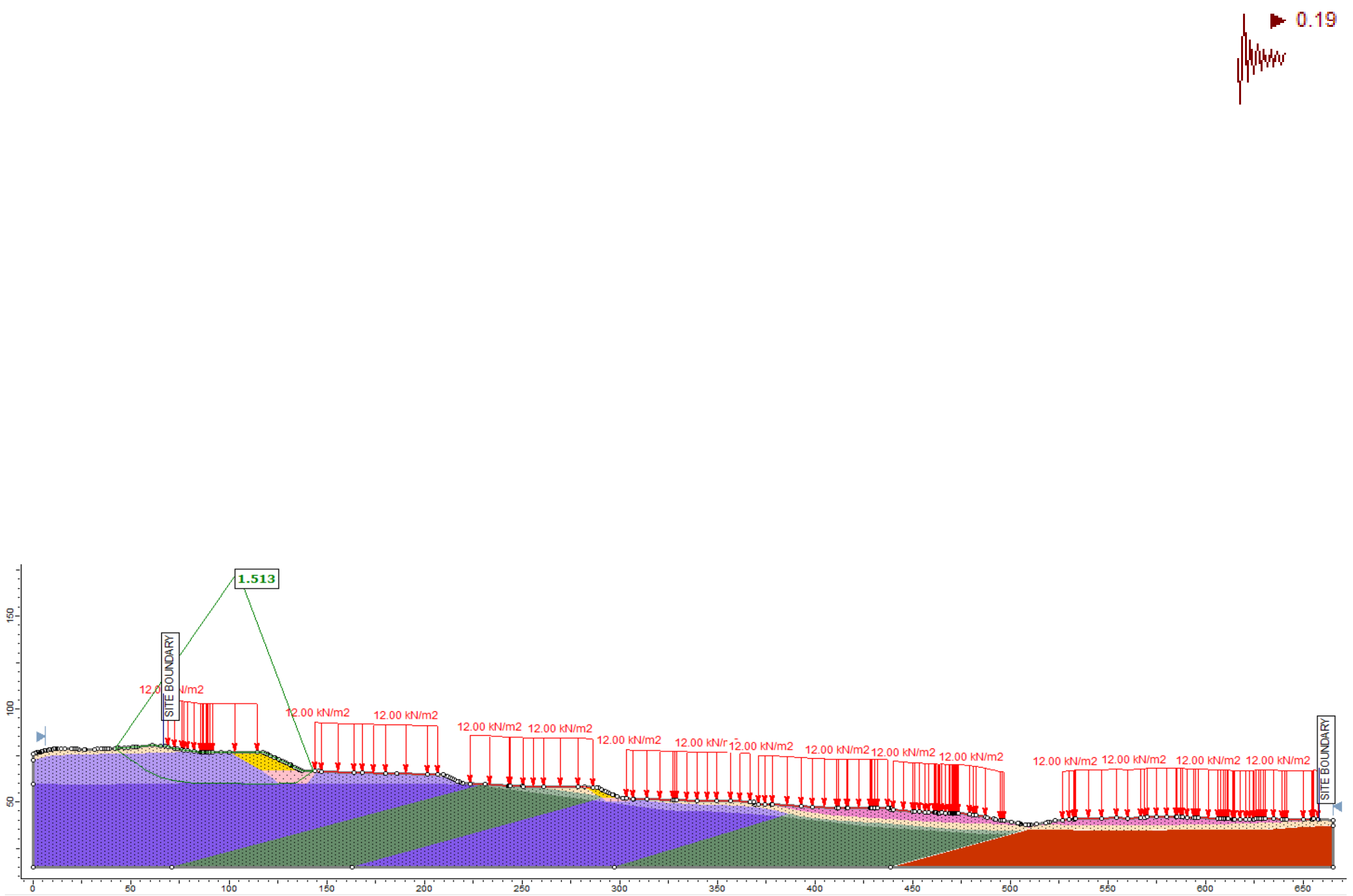
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section J - Proposed	*Date* 3/02/2025	*Drawing* STAB 10



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Tauranga Group Alluvium (Stream)		17	Mohr-Coulomb	5	26	None	0.2
Transitional Hukerenui Mudstone		18	Mohr-Coulomb	8	12	None	0.05
Hukerenui Mudstone		21	Mohr-Coulomb	20	28	None	0
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Mahurangi Limestone		19	Mohr-Coulomb	10	40	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0
Shear Key		18	Mohr-Coulomb	8	28	None	0
Buttress Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Mahurangi Limestone		19	Mohr-Coulomb	10	40			None	0
Residual Northland Allocthon UD		18	Undrained	60	0	Constant		None	0
Transitional Hukerenui Mudstone UD		18	Undrained	95	0	Constant		None	0
Hukerenui Mudstone UD		18	Shear/ Normal Function				User Defined 1	None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0
Shear Key UD		18	Undrained	100	0	Constant		None	0
Buttress Fill UD		18	Undrained	100	0	Constant		None	0

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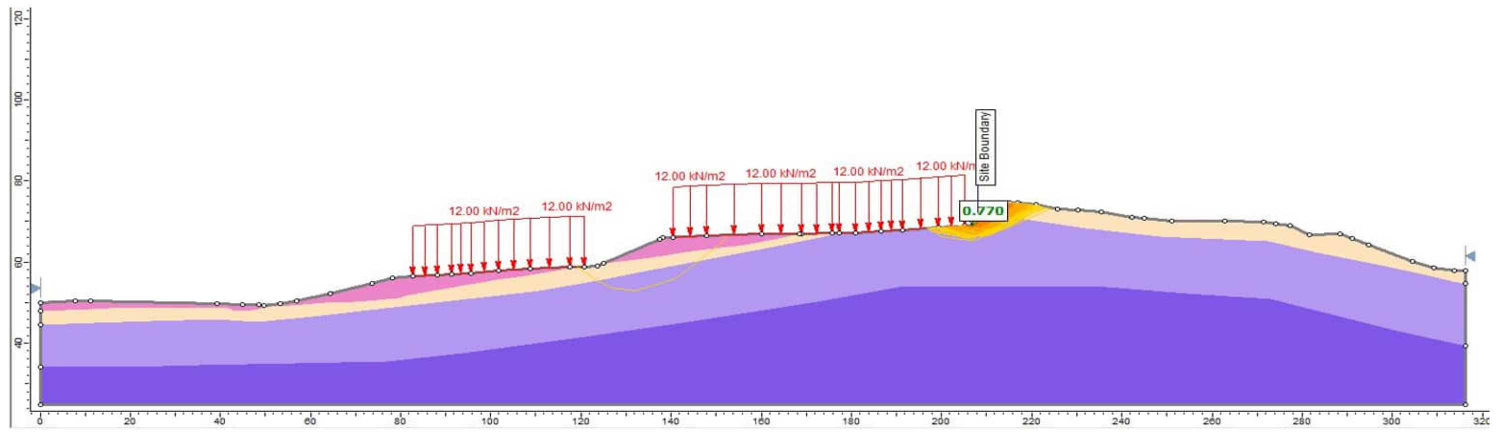
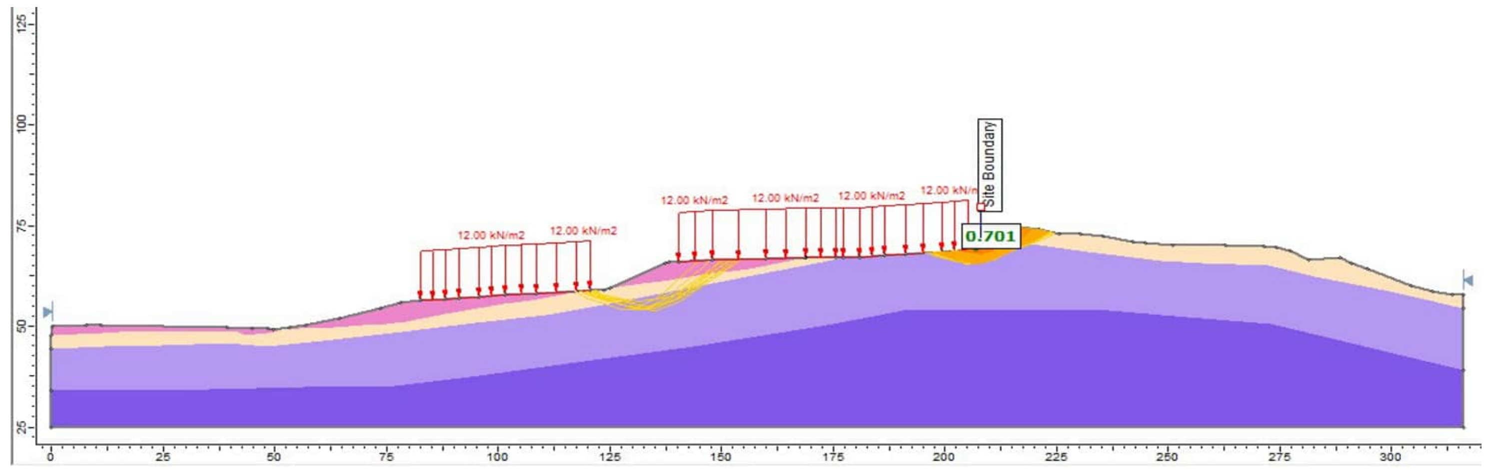
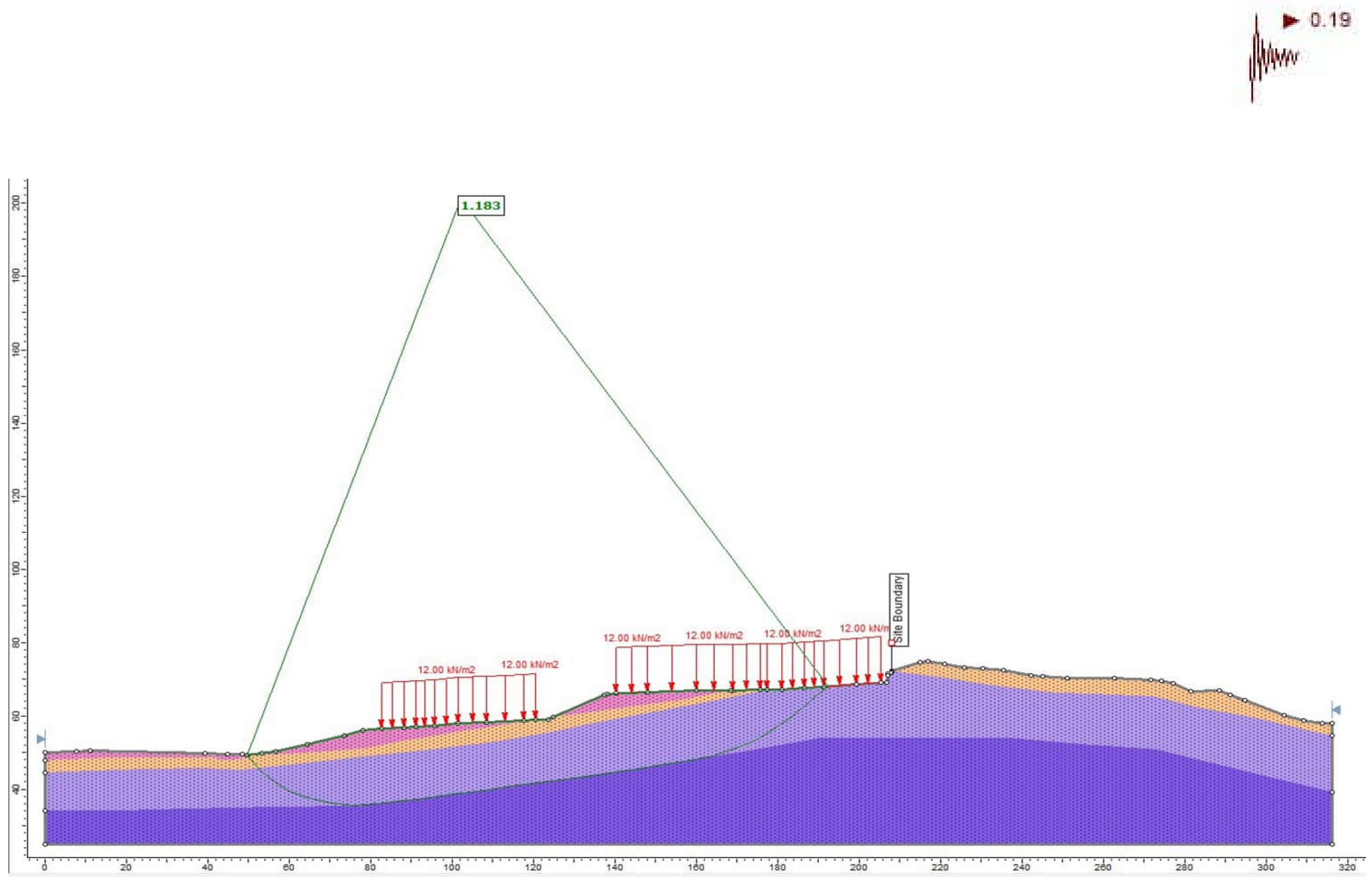
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Circular	*Project No.* AKL2024-0257
Title Section J - Proposed with Remediation Proposed with Remediation (Shear Key & Buttress fill)	*Date* 3/02/2025	*Drawing* STAB 10a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Ru Value
Residual Northland Allochthon		18	Mohr-Coulomb	5	28	0.2
Transitional Hukereui Mudstone		18	Mohr-Coulomb	8	12	0.05
Hukernui Mudstone		21	Mohr-Coulomb	20	28	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Ru Value
Residual Northland Allochthon		18	Mohr-Coulomb	5	28	0.4
Transitional Hukereui Mudstone		18	Mohr-Coulomb	8	12	0.2
Hukernui Mudstone		21	Mohr-Coulomb	20	28	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Ru Value
Proposed Engineered Fill		18	Mohr-Coulomb	8	28			0.2
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		0
Residual Northland Allochthon UD		18	Undrained	60	0	Constant		0
Transitional Hukereui Mudstone UD		18	Undrained	95	0	Constant		0
Hukernui Mudstone UD		20.5	Shear/ Normal Function				User Defined 1	0

Parameters

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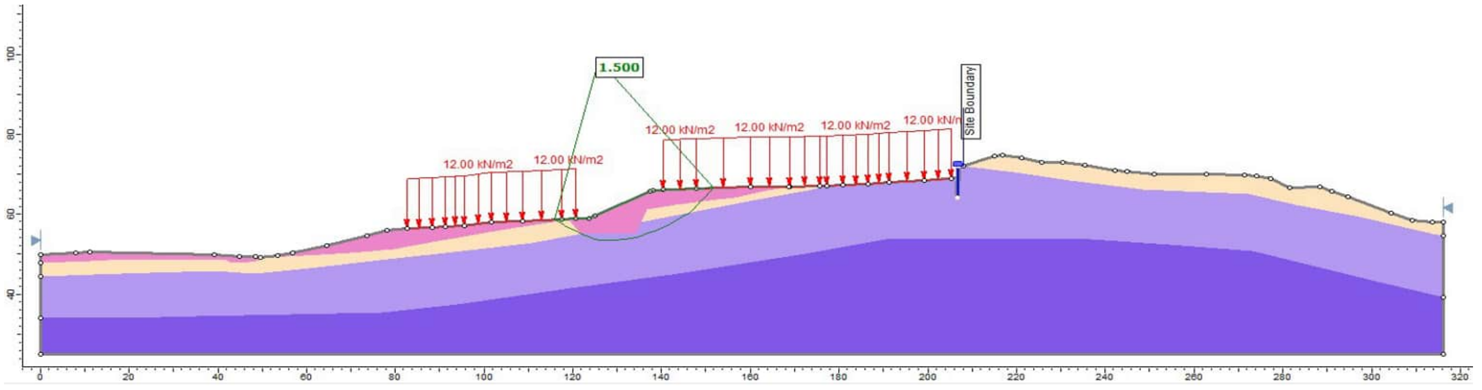
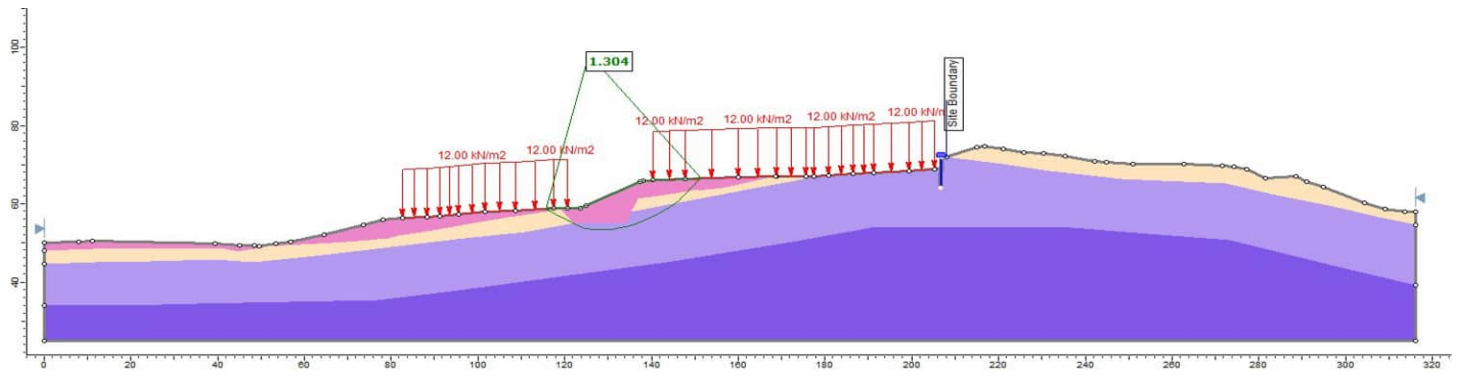
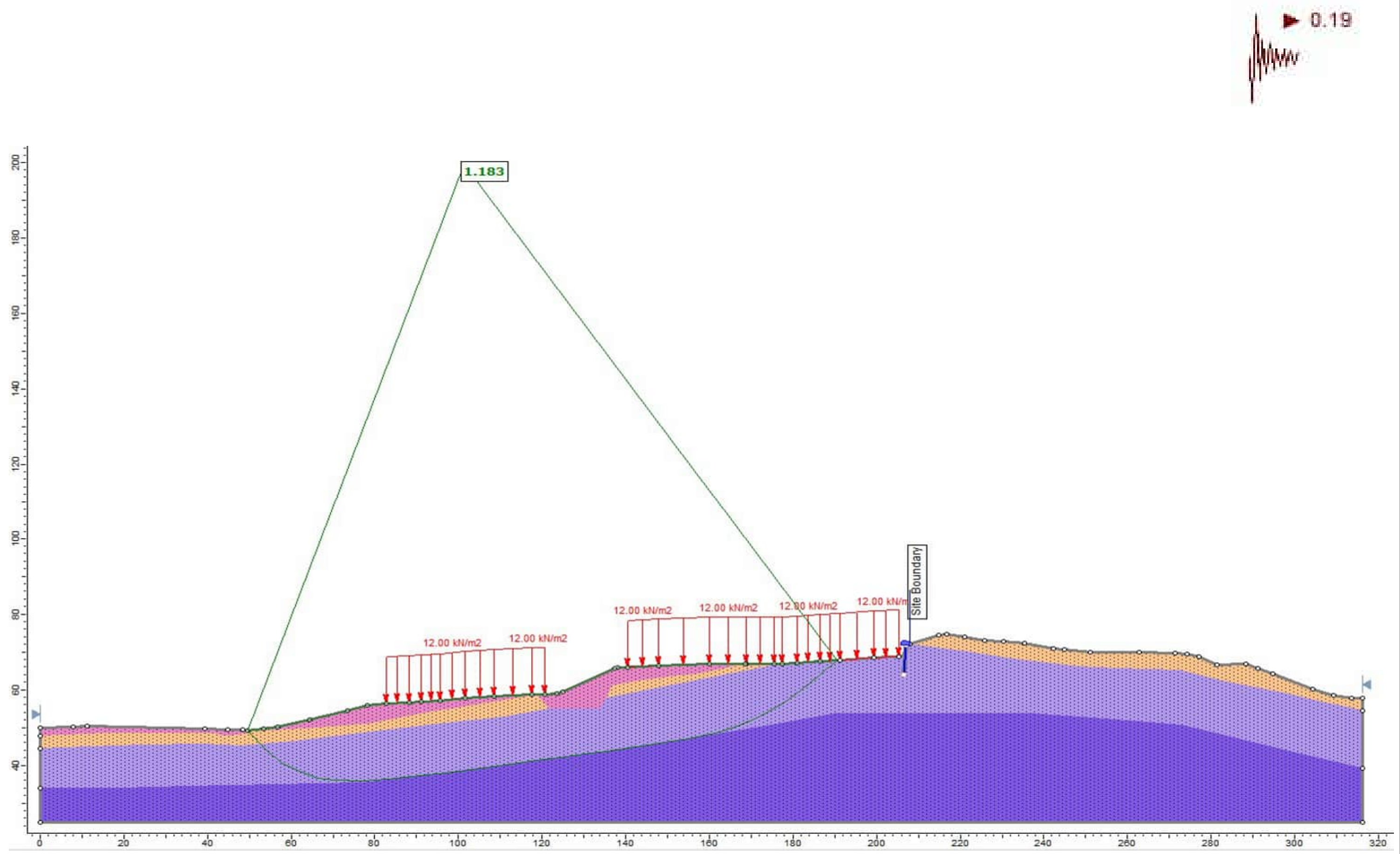
Project MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
Title Section K - Proposed	*Date* 16/12/2024	*Drawing* STAB 11





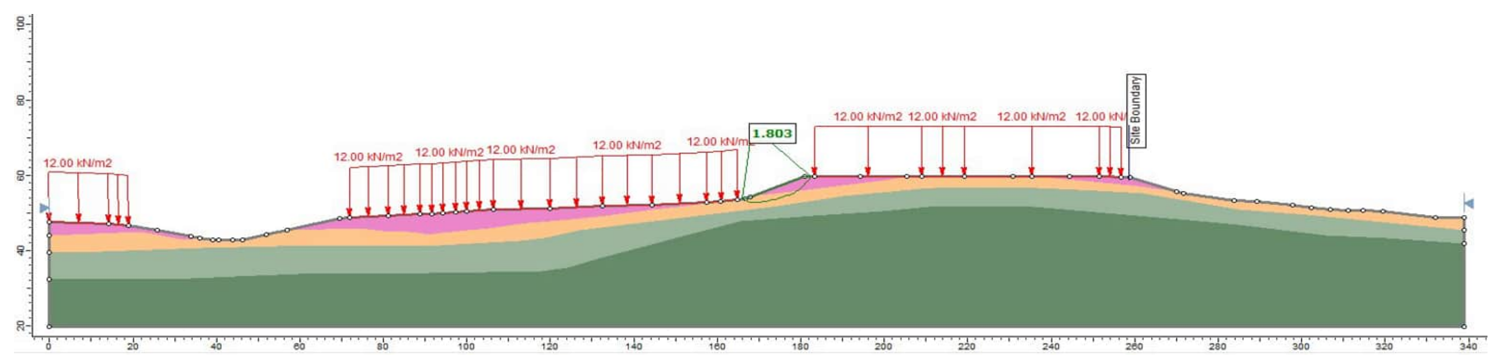
Normal Groundwater Conditions

Transient Groundwater Conditions

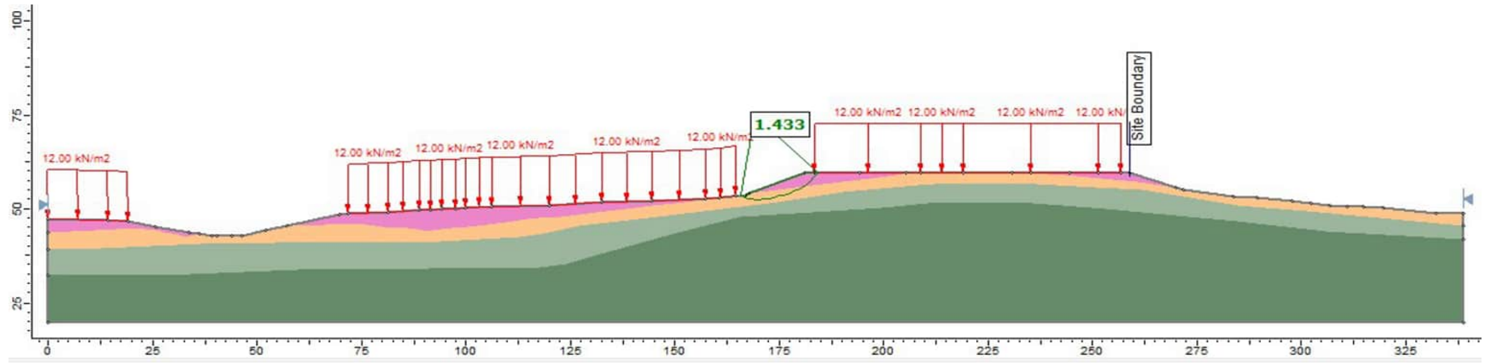


Seismic Event

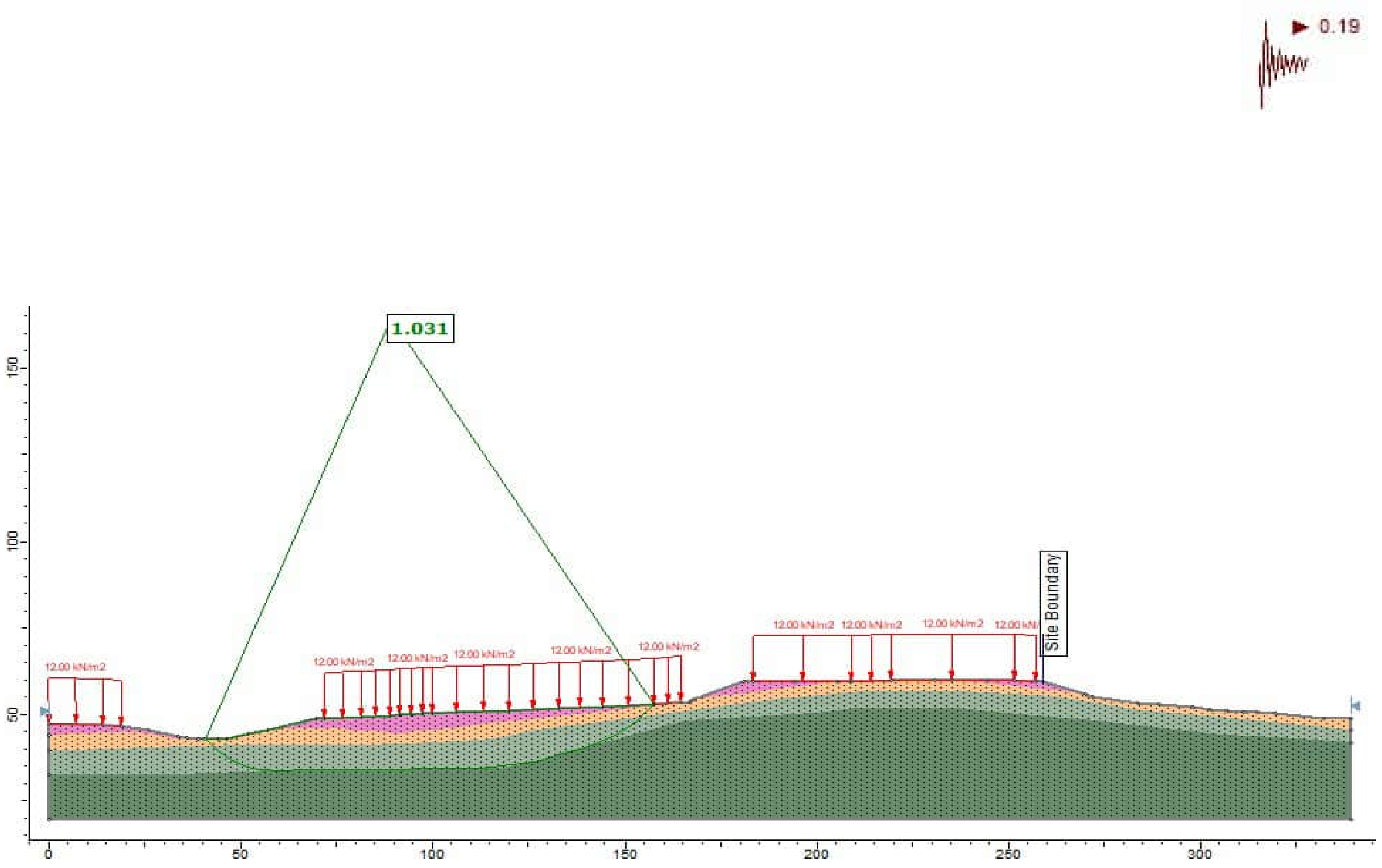
CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Circular	*Project No.* AKL2021-0161
	Title Section K - Proposed with Remediation (Shear Key and Retaining Wall)	*Date* 16/12/2024	*Drawing* STAB 11a



Normal Groundwater Conditions



Transient Groundwater Conditions



Seismic Event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.2
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.05
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Water Surface	Ru Value
Residual Northland Allocthon		18	Mohr-Coulomb	5	28	None	0.4
Mangakahia Transitional		18	Mohr-Coulomb	8	21	None	0.2
Undifferentiated Mangakahia Rock Mass		21	Mohr-Coulomb	20	28	None	0
Proposed Engineered Fill		18	Mohr-Coulomb	8	28	None	0.2

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (°)	Cohesion Type	Shear/ Normal Function	Water Surface	Ru Value
Residual Northland Allochthon UD		18	Undrained	60	0	Constant		None	0
Mangakahia Transitional UD		18	Undrained	55	0	Constant		None	0
Undifferentiated Mangakahia Rock Mass UD		21	Shear/ Normal Function				User Defined 1	None	0
Proposed Engineered Fill UD		18	Undrained	100	0	Constant		None	0

Parameters

CMW Geosciences Great People | Practical Solutions	*Project* MILLDALE FAST TRACK APPLICATION	*Analysis* Non-Circular	*Project No.* AKL2024-0257
	Title Section L - Proposed	*Date* 16/12/2024	*Drawing* STAB 12

Appendix G: Liquefaction and Cyclic Softening Design Memo

Liquefaction & Cyclic Softening

Site Address	Milldale Fast Track	Report Number	AKL2024-0257
Client	Fulton Hogan Land Development Ltd	Date	10/12/24
Prepared by	Sasiruban Loganathan		
Reviewed & Authorised by	Chris Ritchie		

LIQUEFACTION

1.1 Design Criteria

General performance levels for liquefied deposits are presented below (as obtained from MBIE Module 3):

PERFORMANCE LEVEL	EFFECTS FROM EXCESS PORE WATER PRESSURE AND LIQUEFACTION	CHARACTERISTICS OF LIQUEFACTION AND ITS CONSEQUENCES	CHARACTERISTIC F_L, LPI
L0	Insignificant	No significant excess pore water pressures (no liquefaction).	$F_L > 1.4$ LPI=0 LSN <10
L1	Mild	Limited excess pore water pressures; negligible deformation of the ground and small settlements.	$F_L > 1.2$ LPI = 0 LSN = 5 – 15
L2	Moderate	Liquefaction occurs in layers of limited thickness (small proportion of the deposit, say 10 percent or less) and lateral extent; ground deformation results relatively small in differential settlements.	$F_L \approx 1.0$ LPI < 5 LSN 10 – 25
L3	High	Liquefaction occurs in significant portion of the deposit (say 30 percent to 50 percent) resulting in transient lateral displacements, moderate differential movements, and settlement of the ground in the order of 100mm to 200mm.	$F_L < 1.0$ LPI = 5 – 15 LSN = 15 – 35
L4	Severe	Complete liquefaction develops in most of the deposit resulting in large lateral displacements of the ground, excessive differential settlements and total settlement of over 200mm.	$F_L << 1.0$ LPI > 15 LSN > 30
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).	

[1] Earthquake Geotechnical Engineering Practice, Module 3: Identification, assessment and mitigation of liquefaction hazards", (November 2021)
[2] Repairing and Rebuilding House affected by the Canterbury Earthquakes", (December 2012)

1.2 Methodology

In accordance with MBIE/NZGS guidance[1], the liquefaction susceptibility of the soils at this site was assessed with respect to compositional (soil fabric and density) criteria, based on the following assumptions:

- Saturated soils below an assessed seasonal average groundwater level at the existing surface level were modelled as being susceptible to liquefaction.
- In accordance with MBIE/NZGS guidance[1] and in the absence of site-specific shear wave velocity measurements, no aging / strength gain factor has been applied.
- Soils are also classified with respect to their grain size and plasticity to assess liquefaction susceptibility. For this project, a cut-off threshold soil behaviour type index value (I_c) of 2.6 was used to distinguish between liquefiable (I_c>2.6) and non-liquefiable (I_c<2.6) soils.
- Specific liquefaction analyses were undertaken for an IL2 structure, using the software package CLiq using the Boulanger and Idriss (2014) method. The cyclic stress ratio (CSR), being a function of the earthquake magnitude for the design return period event, was compared to the cyclic resistance ratio (CRR), being a function of the CPT cone resistance (q_c) and friction ratio (F_r).
- Free-field liquefaction induced settlements were determined in accordance with Zhang et al. (2002). With respect to liquefaction response, consideration was given to a 10m cut-off depth to estimate index settlements as per MBIE[2] guidance (foundation technical categories). These were compared to liquefaction settlement estimates over the full depth range of the CPTs with a depth weighting factor ranging from 1 at the ground surface to 0 at 18m depth applied to the volumetric strains (e_v) in accordance with Cetin et al (2009)[3].

1.3 Results

Results are appended to this memo and are summarised below:

- In respect to the MBIE Module 3 Liquefaction Performance Levels, the site is rated as mild with liquefaction severity numbers ranging from 1-8. AKL2024-0257_CPT12 and AKL2021-0014_CPT13 are the exceptions where the calculated liquefaction severity number is greater than 40, however AKL2021-0014_CPT13 is an area where no lots are proposed and AKL2024-0257_CPT12. All of the predicted liquefaction at AKL2024-0257_CPT12 is in the Hukerenui Mudstone, which is considered extremely unlikely, and can be investigated during further testing.
- ULS settlements are a maximum of 30mm, with SLS settlements not expected.
- Based on our results, the site is expected to perform relatively well with negligible liquefaction induced settlement.

Liquefaction Analyses Results		
CPT No.	SLS Settlement (mm)	Total[2] ULS Settlement (mm)
CPT01-2024	< 5	< 5
CPT02-2024	< 5	< 5
CPT03-2024	< 5	< 5
CPT04-2024	< 5	< 5
CPT05-2024	< 5	< 5

[3] Cetin, K., Bilge, H., Wu, J., Kammerer, A., and Seed, R. (2009). Probabilistic Model for the Assessment of Cyclically Induced Reconsolidation (Volumetric) Settlements, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 135(3), pp. 387-398.

CPT06-2024	< 5	<10
CPT07-2024	< 5	<10
CPT08-2024	< 5	<10
CPT09-2024	< 5	<10
CPT10-2024	< 5	<10
CPT11-2024	< 5	15
CPT12-2024	< 5	30
CPT13-2024	< 5	<10
CPT14-2024	< 5	<5
CPT15-2024	< 5	<5
CPT16-2024	< 5	<10
CPT17-2024	< 5	<10

Note: All settlements and depths based on existing ground profile.

[2]Total ULS settlements are based on the full depth of the CPT trace with a depth weighting factor applied.

2 CYCLIC SOFTENING

The fine-grained alluvium, while not liquefiable due to its high plasticity, may be susceptible to some strength loss, referred to as cyclic softening, during a ULS seismic event.

Cyclic softening analyses of those soils was carried out in accordance with Boulanger[4] and Idriss[5], however no cyclic softening of the fine-grained soils is anticipated.

[4] Boulanger, R.W. and Idriss. I. M. (2007) Evaluation of Cyclic Softening in Silts and Clays, Journal of Geotechnical and Environmental Engineering, Vol 133, Issue 6.

[5] Idriss, I. M. and Boulanger, R. W. (2008) Soil Liquefaction During Earthquakes. Monograph 12, Earthquake Engineering Research Institute.

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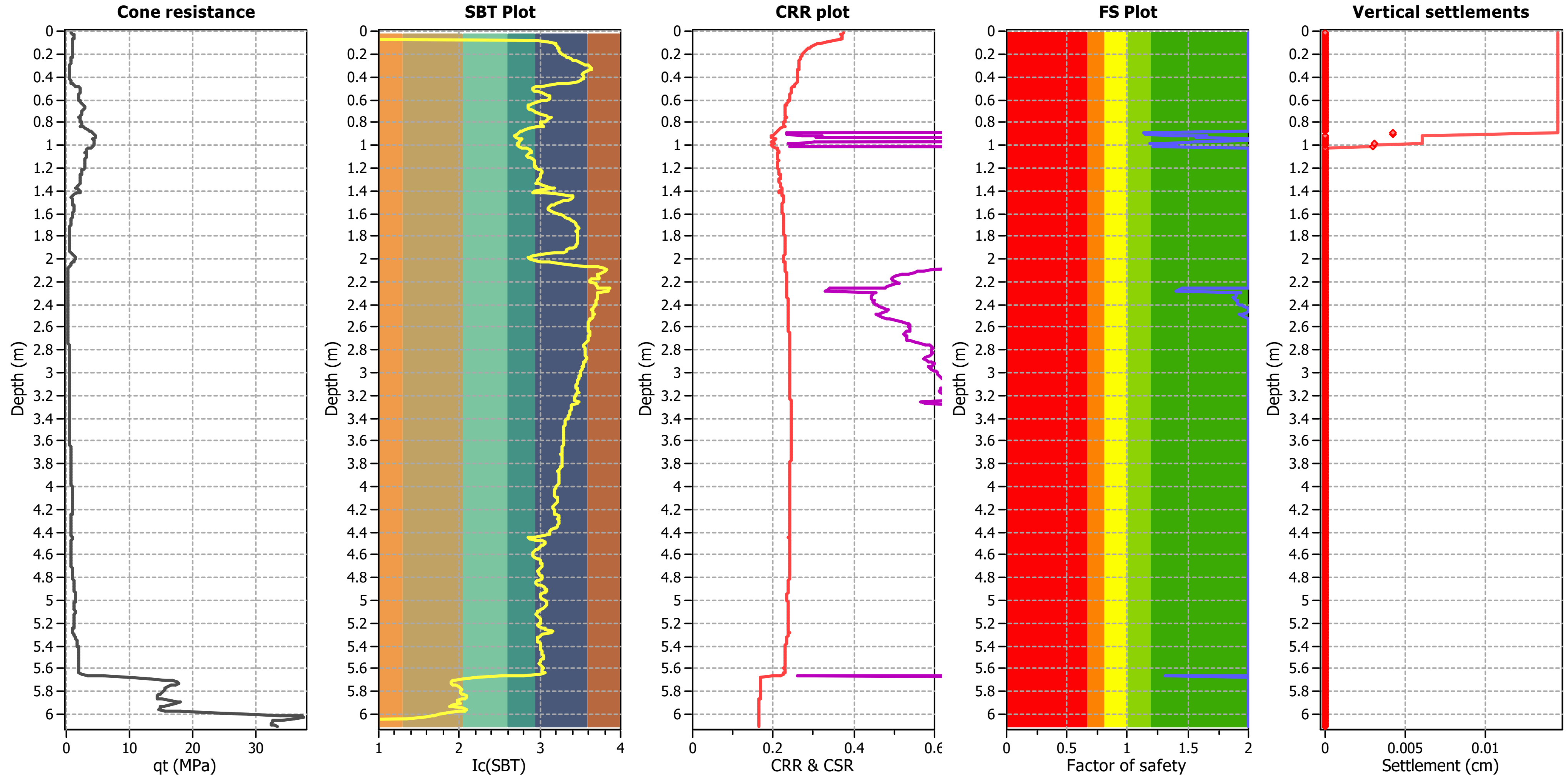
Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL-2024-0257_CPT01
Total depth: 6.11 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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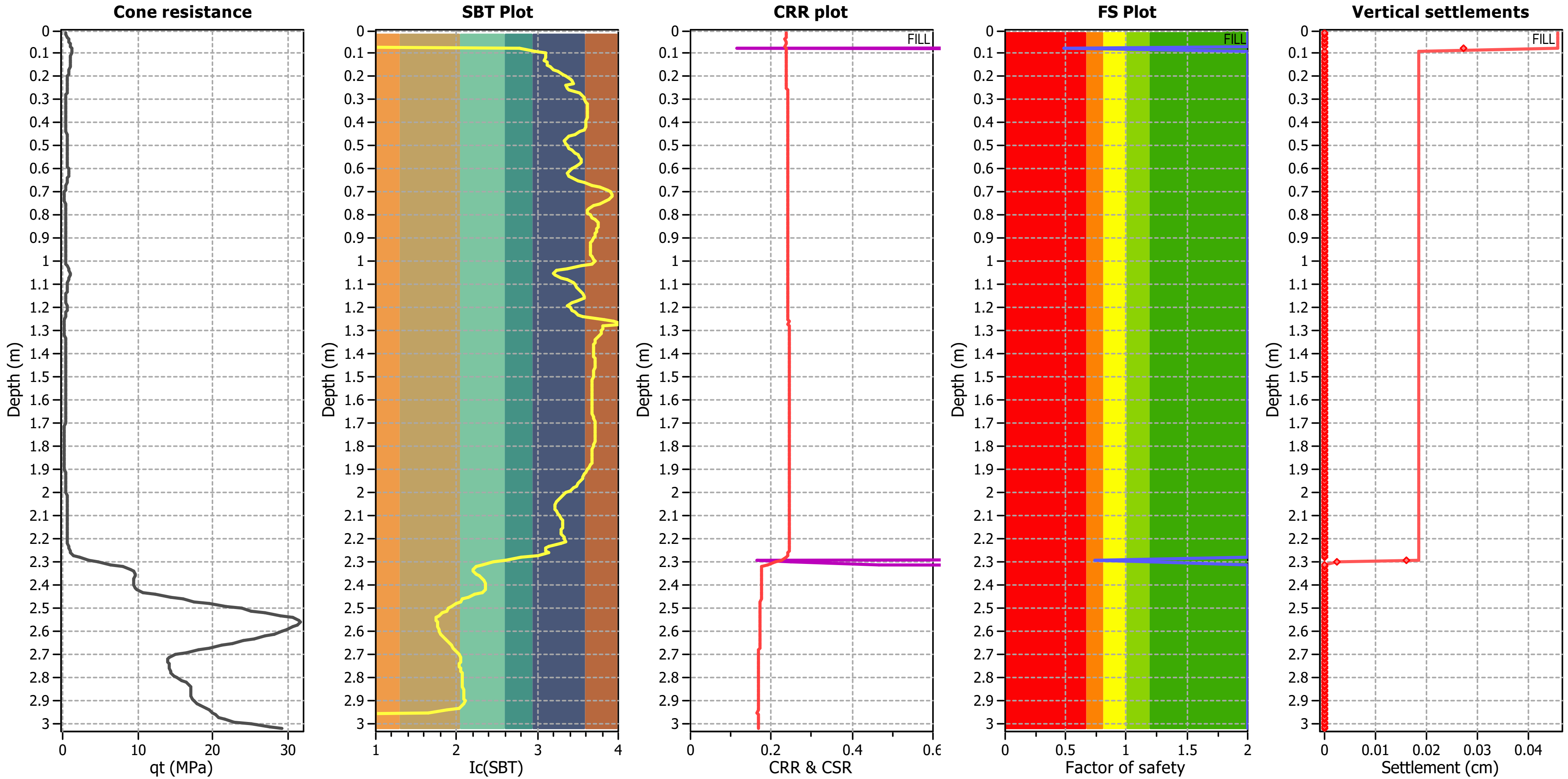
Project: Milldale Fast Track
Location: Wainui East

CPT: AKL2024-0257_CPT02
Total depth: 3.02 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	1.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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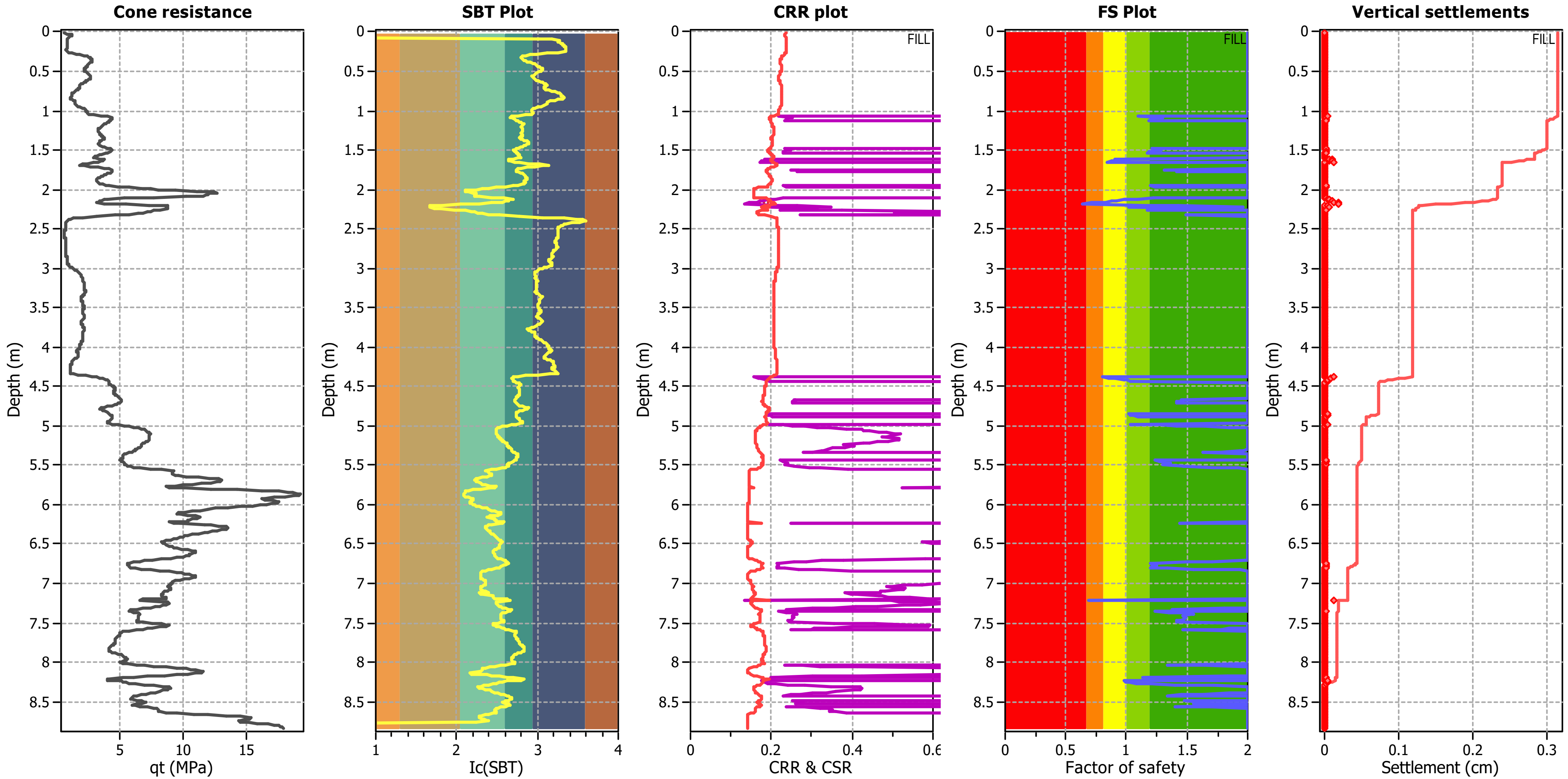
Project: **Milldale Fast Track**

Location: **Wainui East**

CPT: AKL2024-0257_CPT03

Total depth: 8.84 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	1.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m^3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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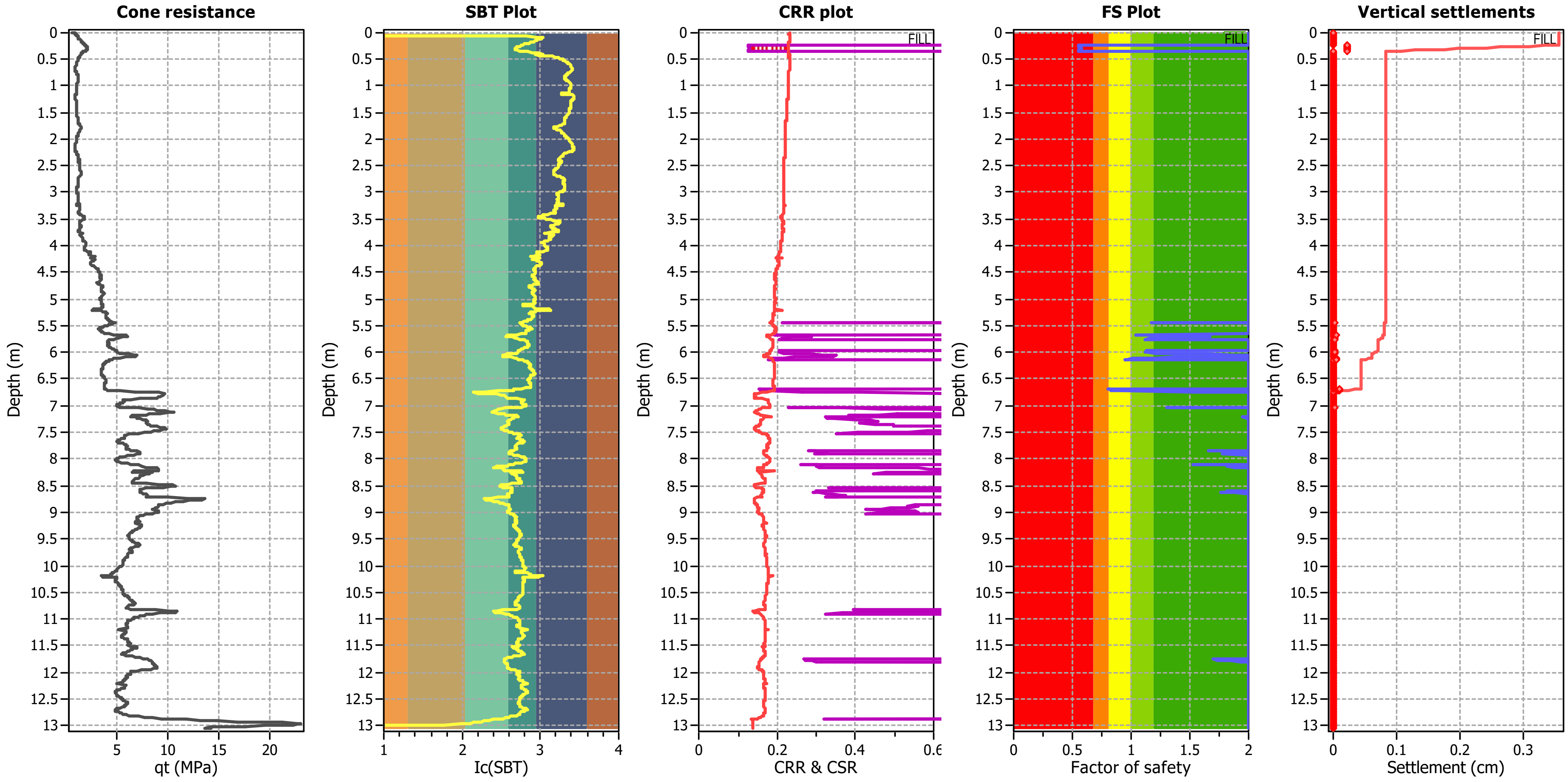
Project: **Milldale Fast Track**

Location: **Wainui East**

CPT: AKL2024-0257_CPT04

Total depth: 13.05 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	1.30 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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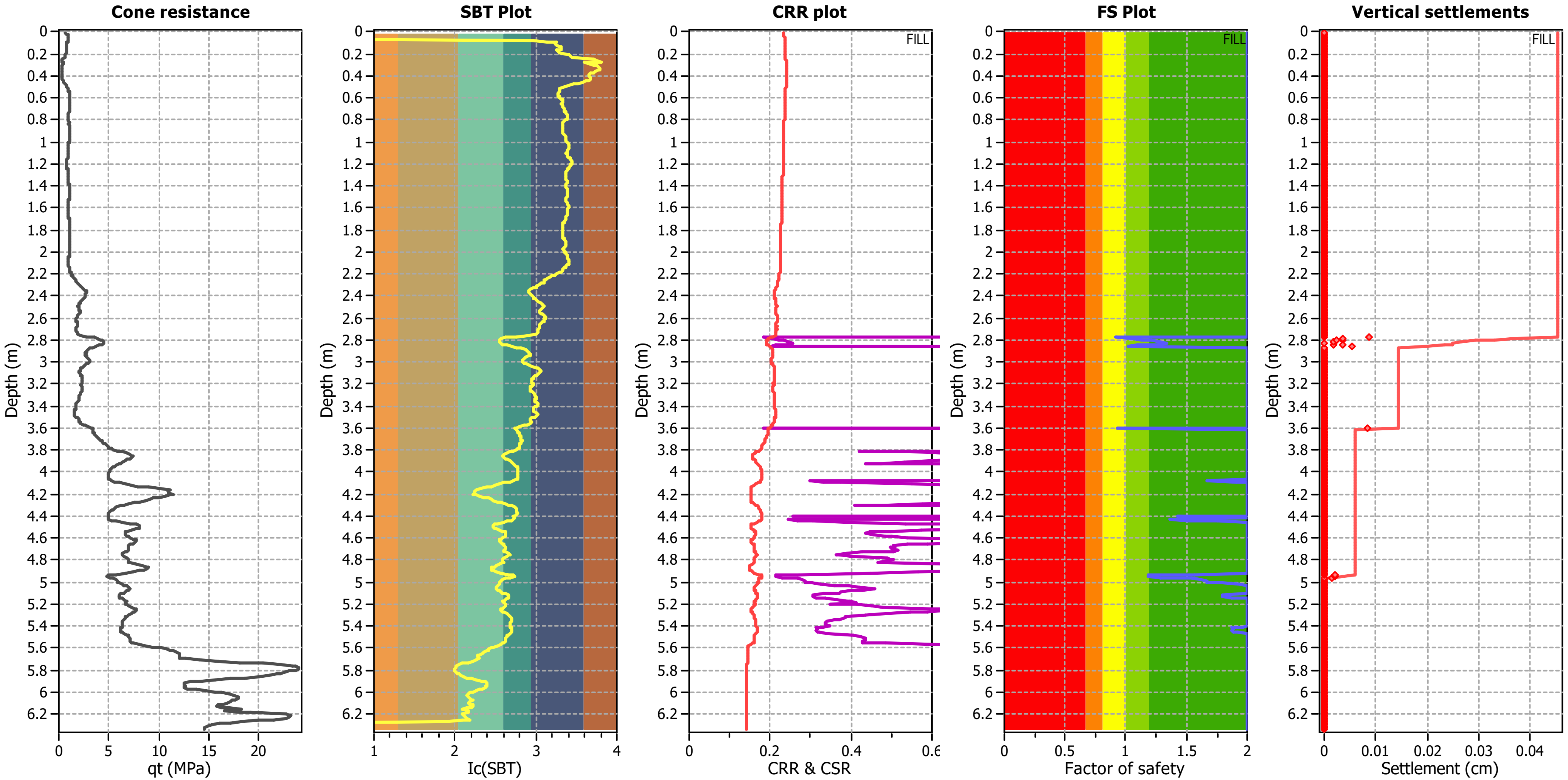
Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT05
Total depth: 6.34 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	1.00 m		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

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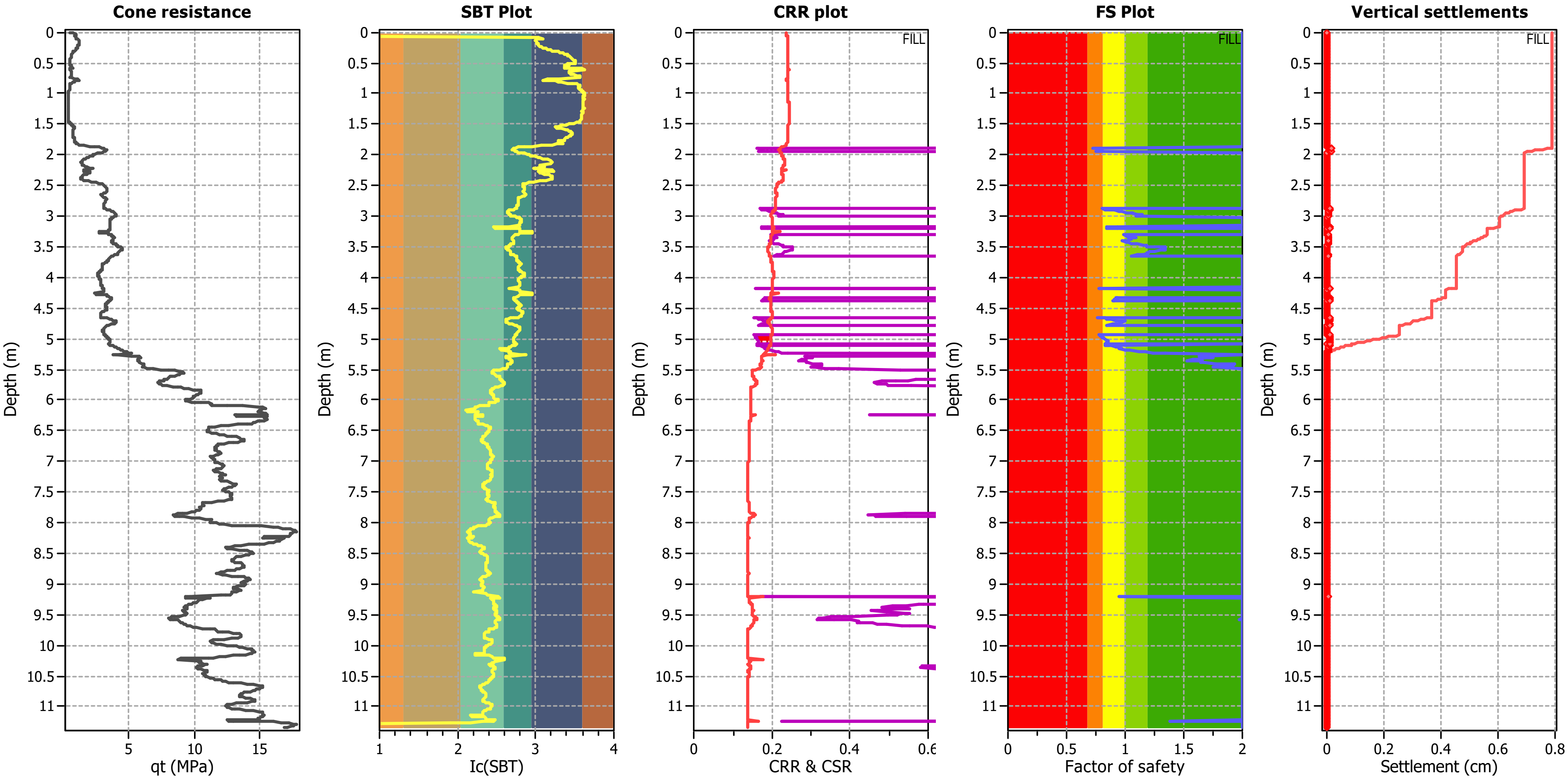
Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT06
Total depth: 11.34 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	0.60 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m³	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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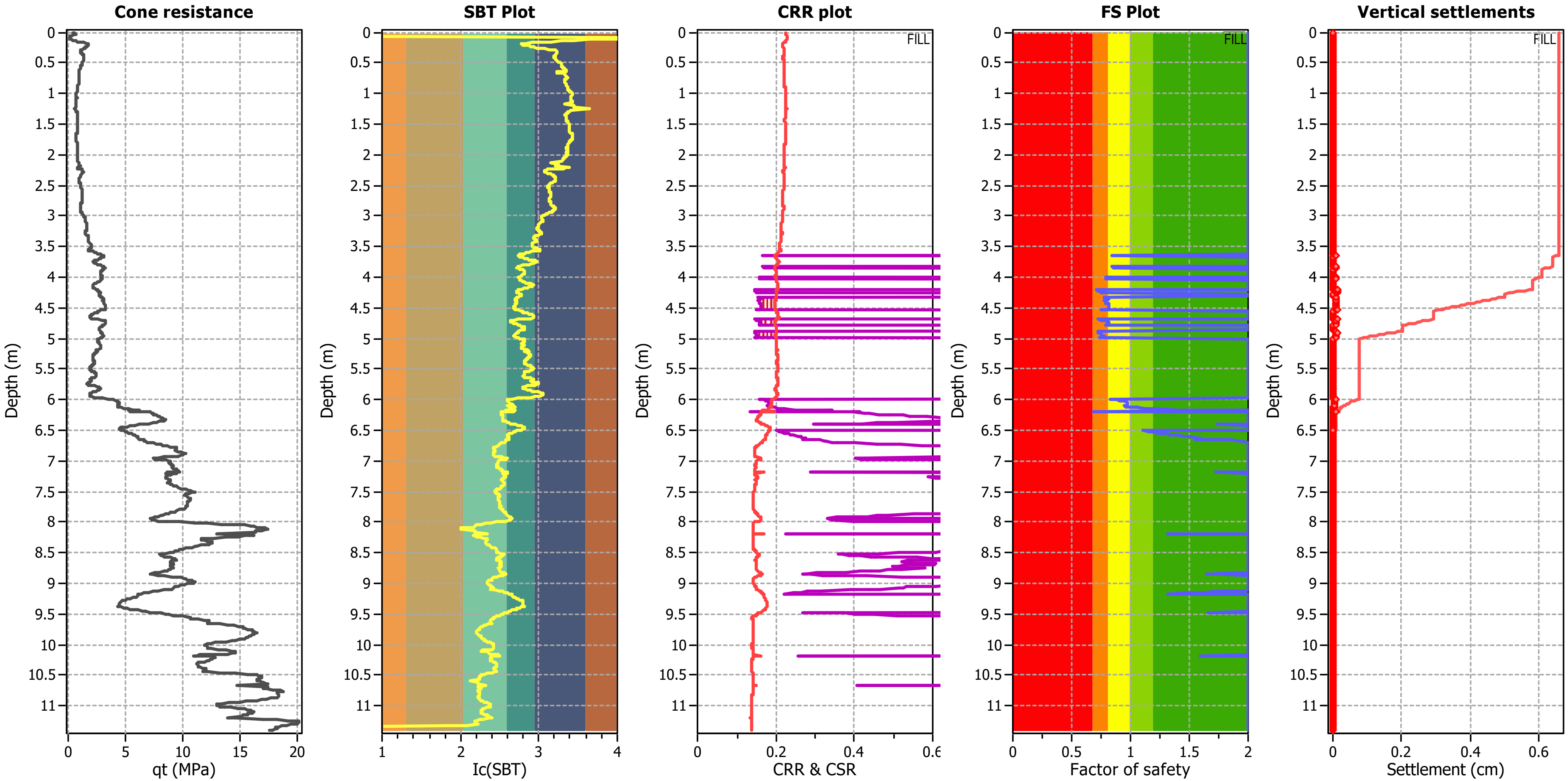
Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT07
Total depth: 11.40 m



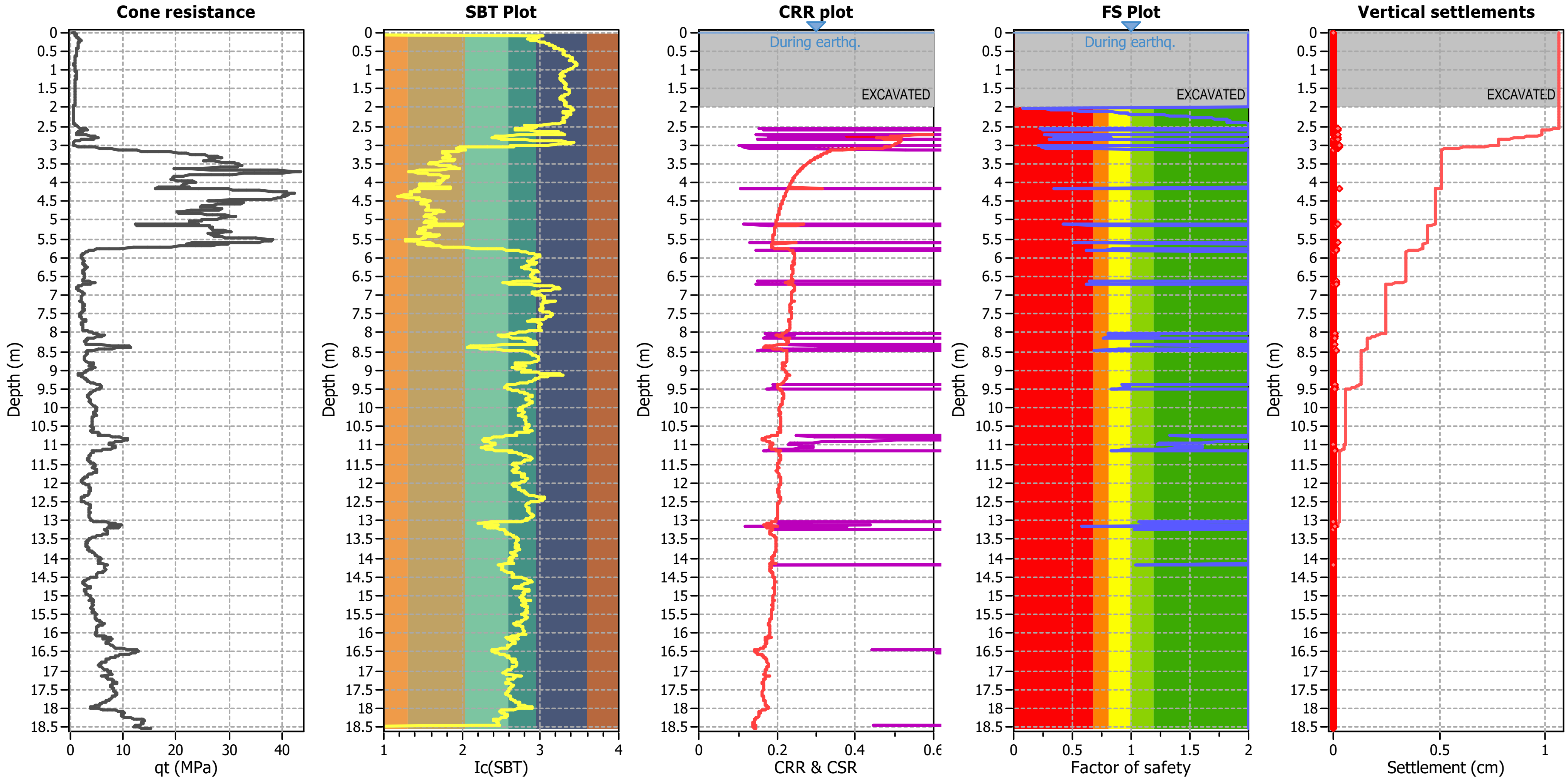
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	4.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT08
Total depth: 18.54 m



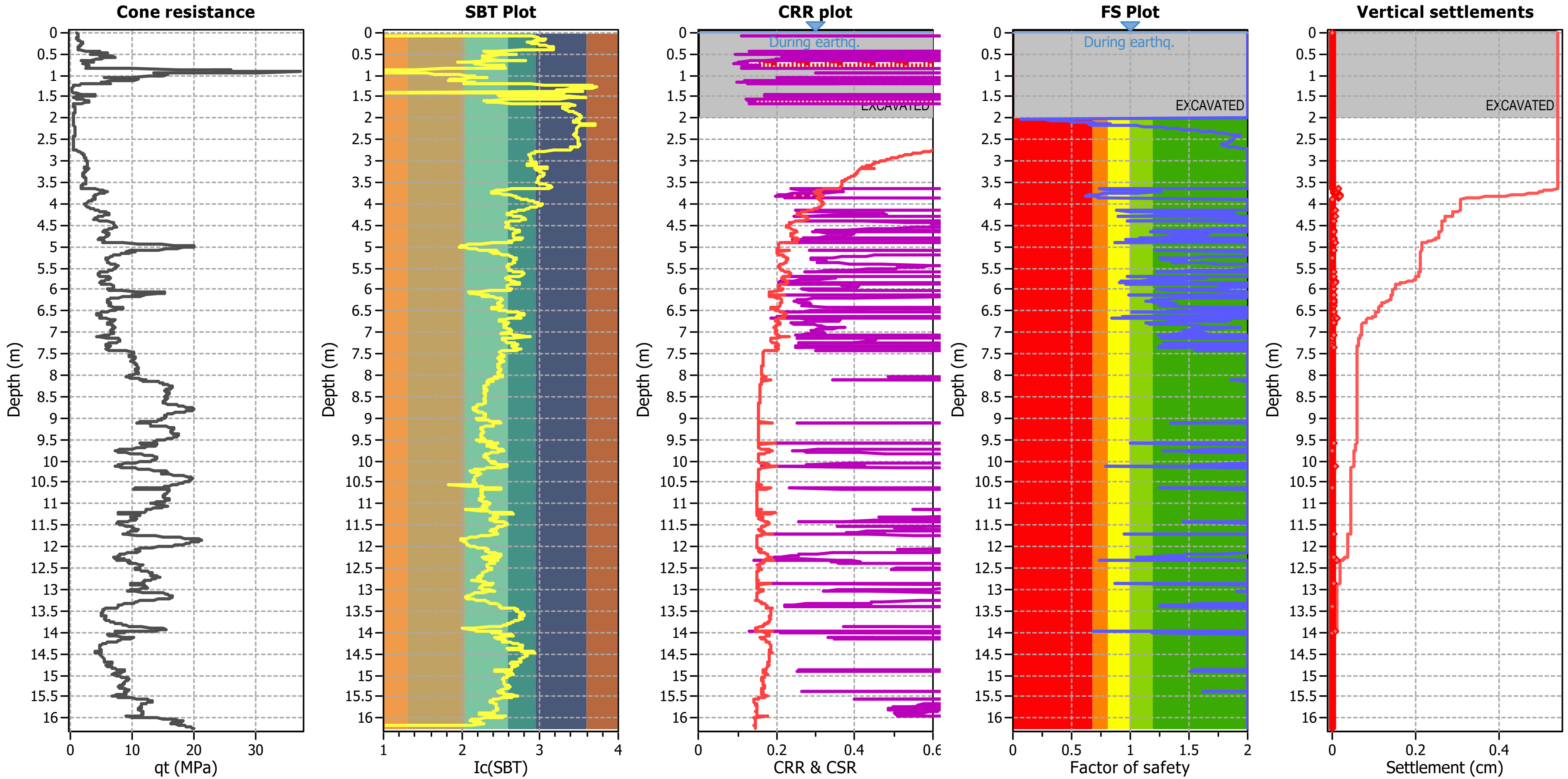
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Excavation:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Excavation depth:	2.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Footing load:	0.00 kPa	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT09
Total depth: 16.24 m



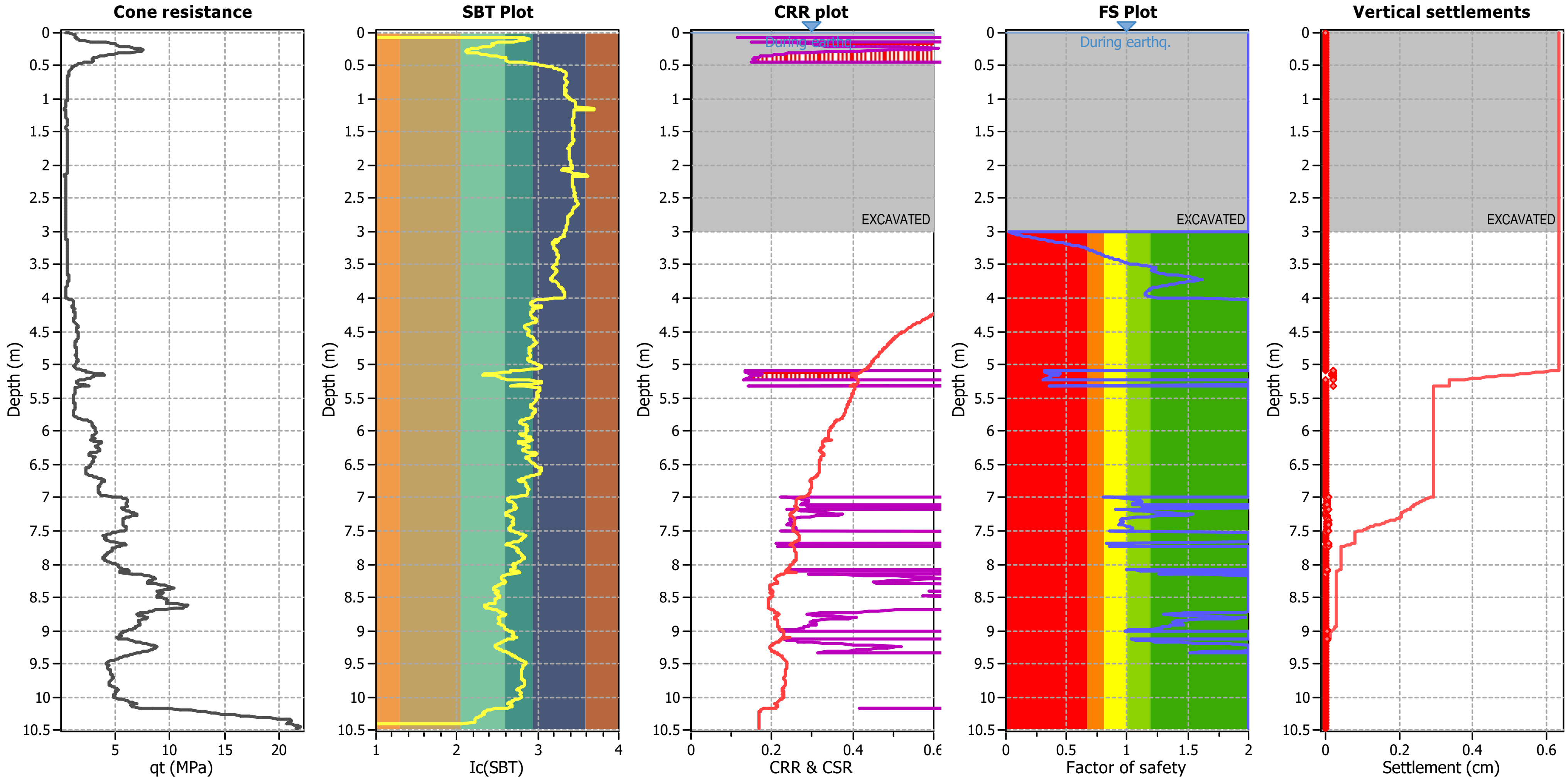
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Excavation:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Excavation depth:	2.00 m		
Points to test:	Based on Ic value	Average results interval:	3	Footing load:	0.00 kPa	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT10
Total depth: 10.47 m



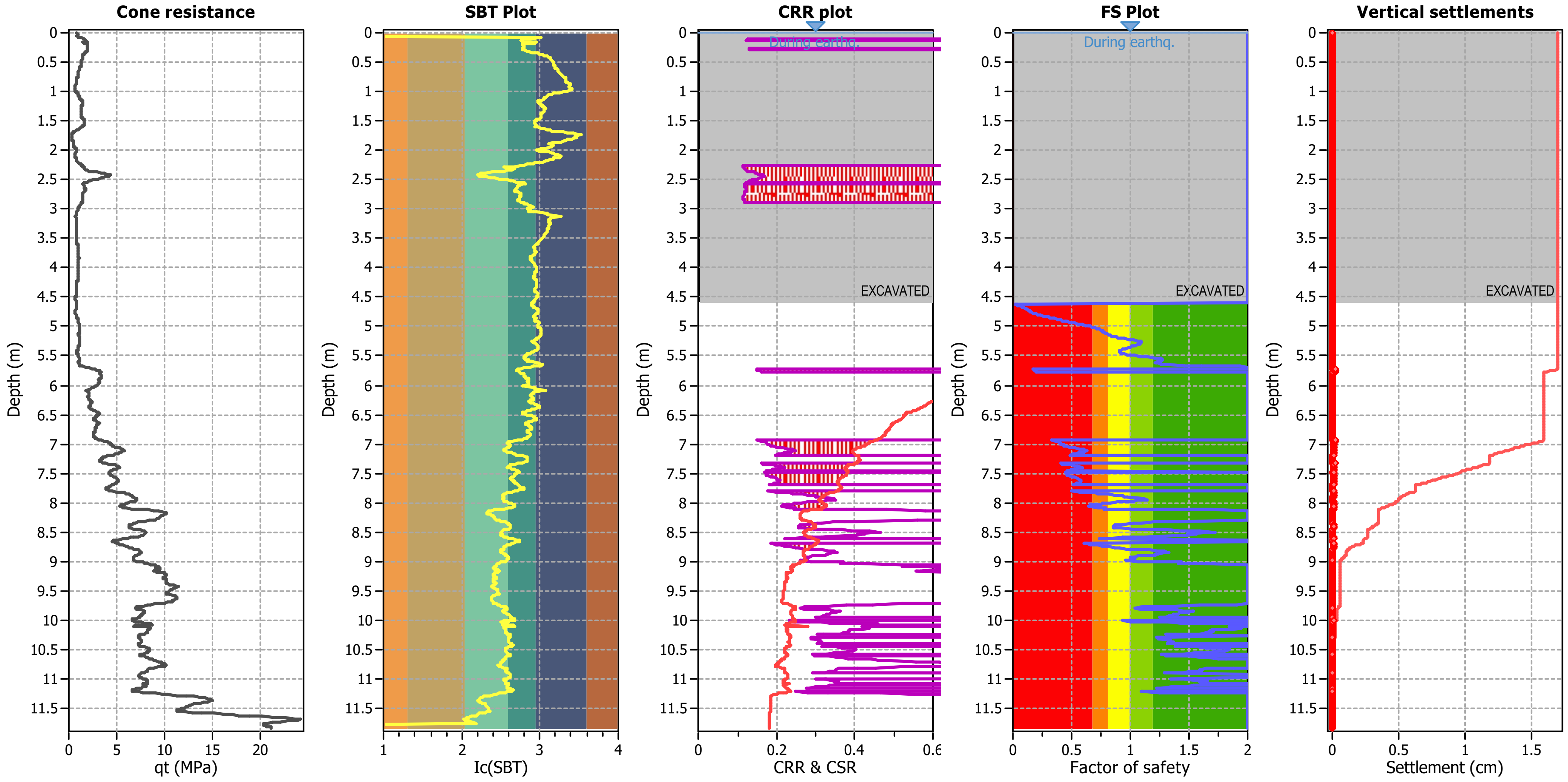
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Excavation:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Excavation depth:	3.00 m		
Points to test:	Based on Ic value	Average results interval:	3	Footing load:	0.00 kPa	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT11
Total depth: 11.83 m



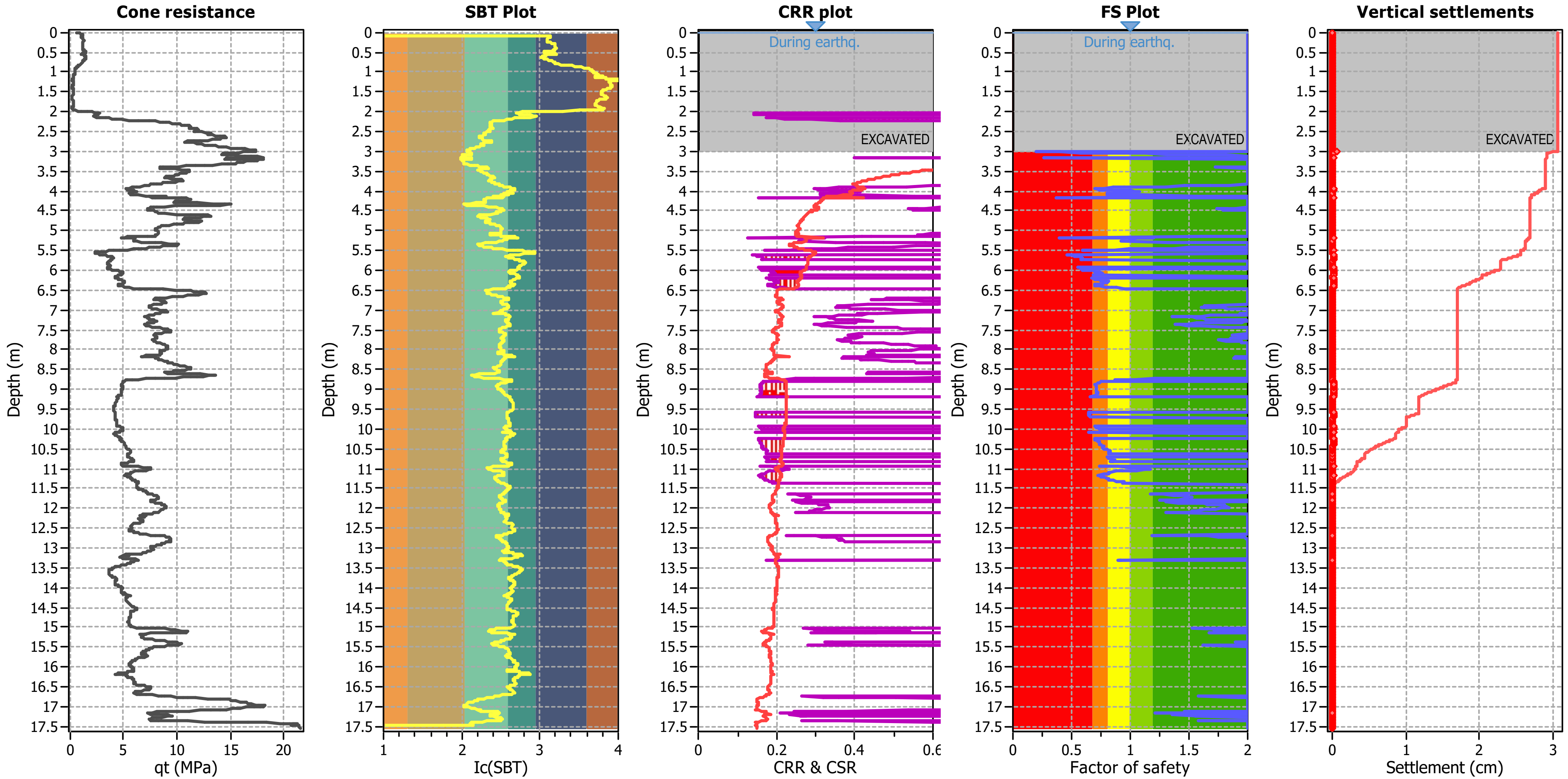
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Excavation:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Excavation depth:	4.60 m		
Points to test:	Based on Ic value	Average results interval:	3	Footing load:	0.00 kPa	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT12
Total depth: 17.55 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Excavation:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Excavation depth:	3.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Footing load:	0.00 kPa	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

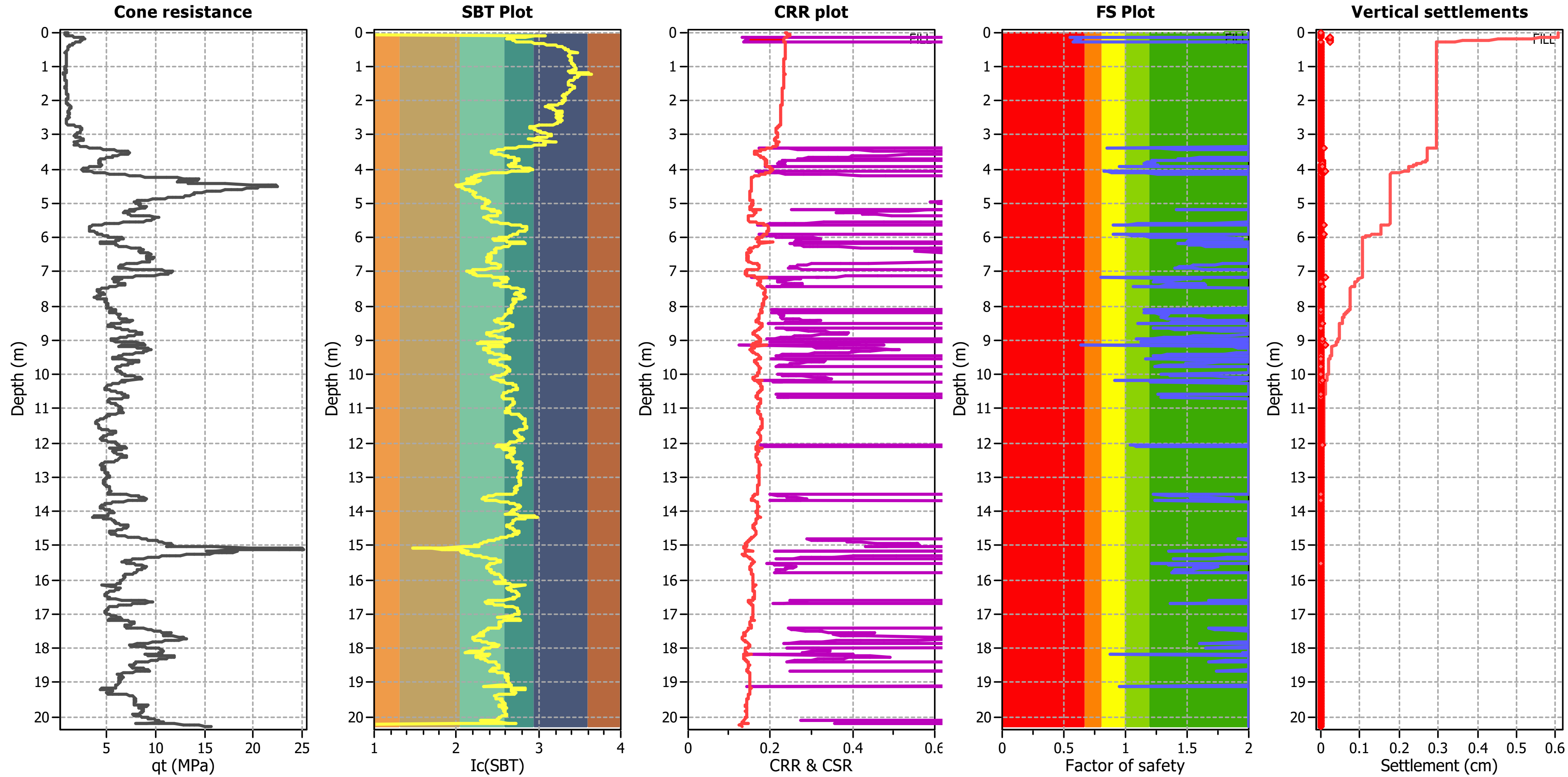
https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**

Location: **Wainui East**

CPT: AKL2024-0257_CPT13

Total depth: 20.29 m



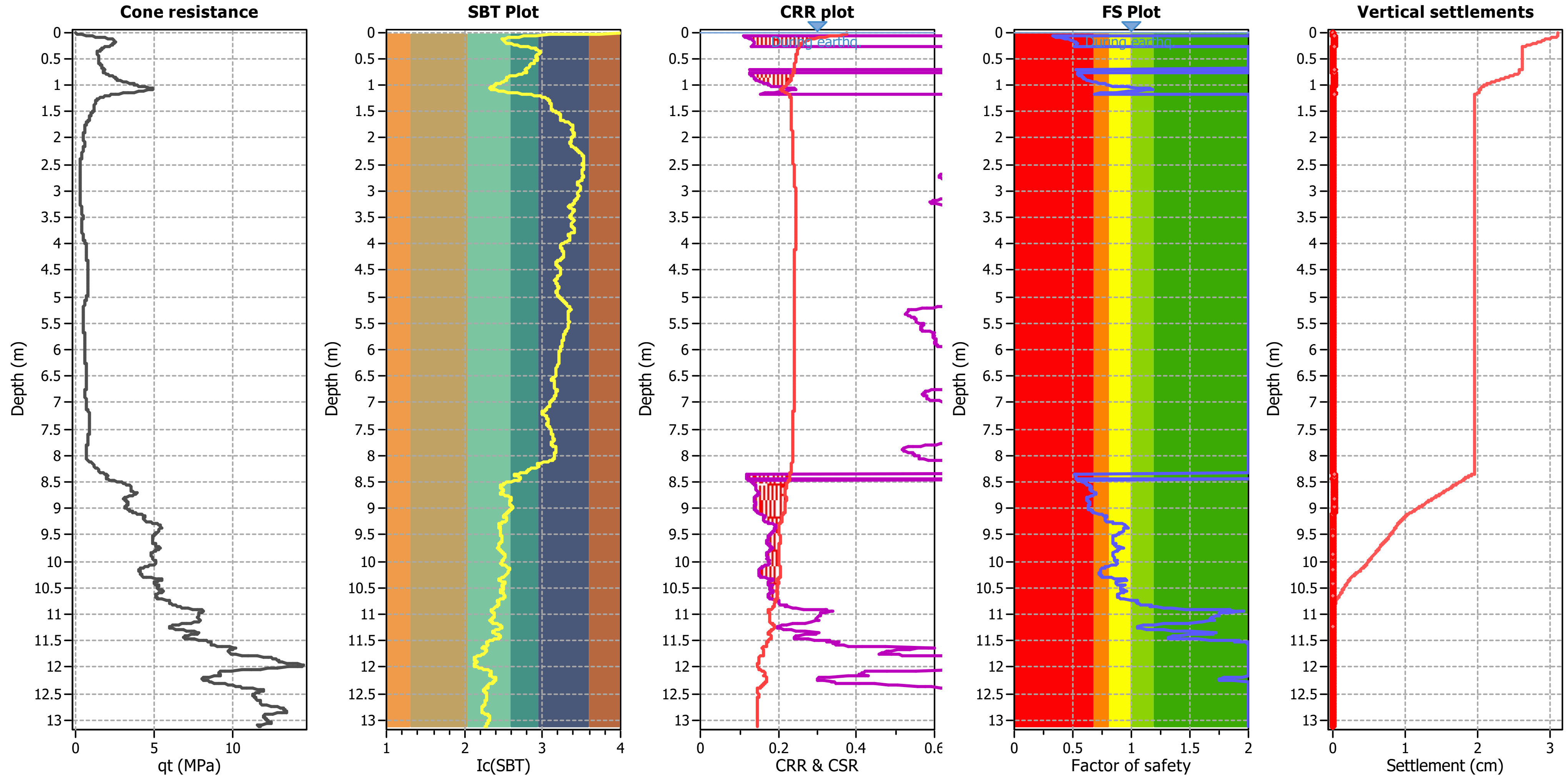
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	0.30 m		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m^3	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2021-0014_CPT13
Total depth: 13.12 m



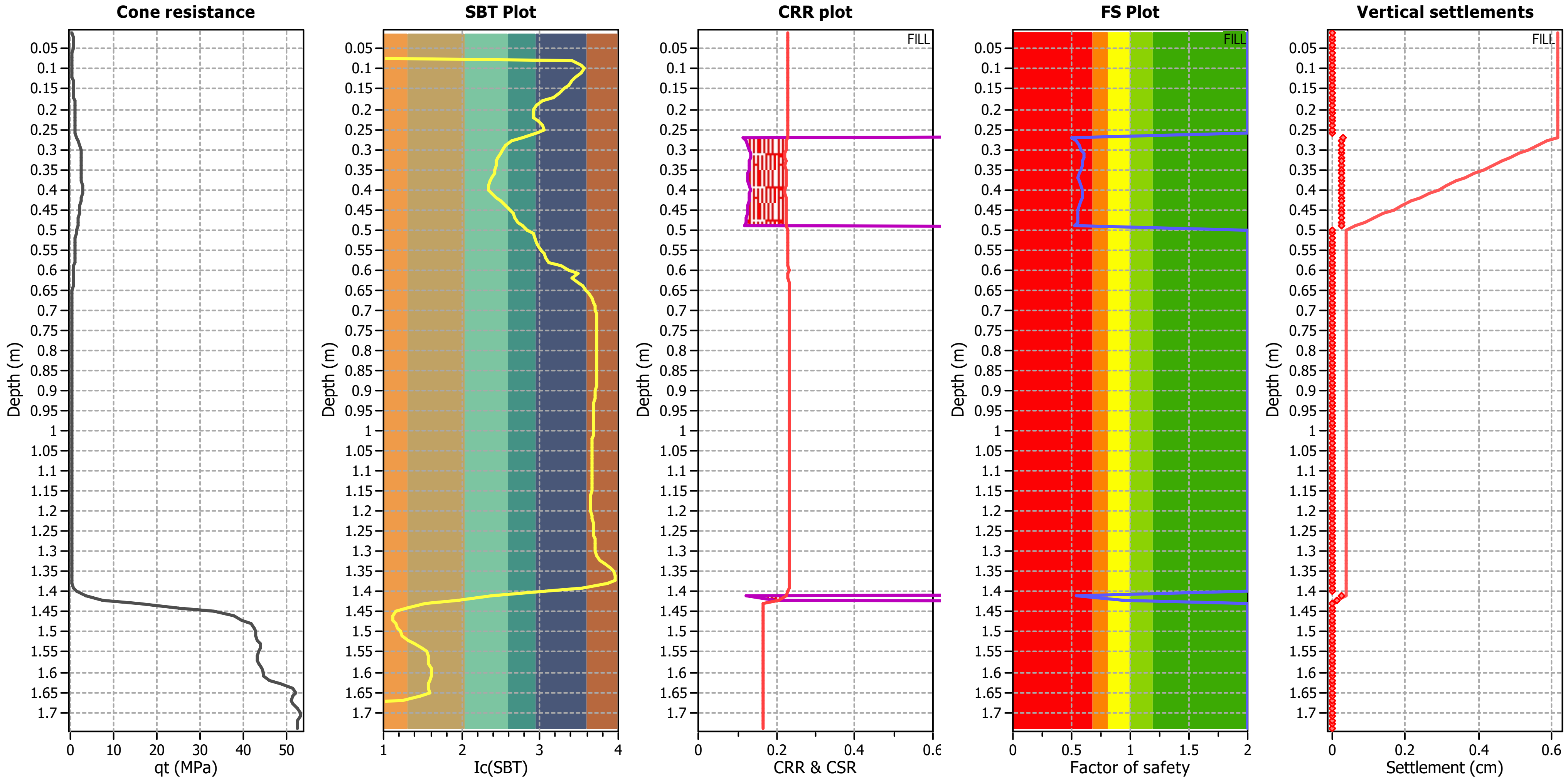
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT14
Total depth: 1.74 m



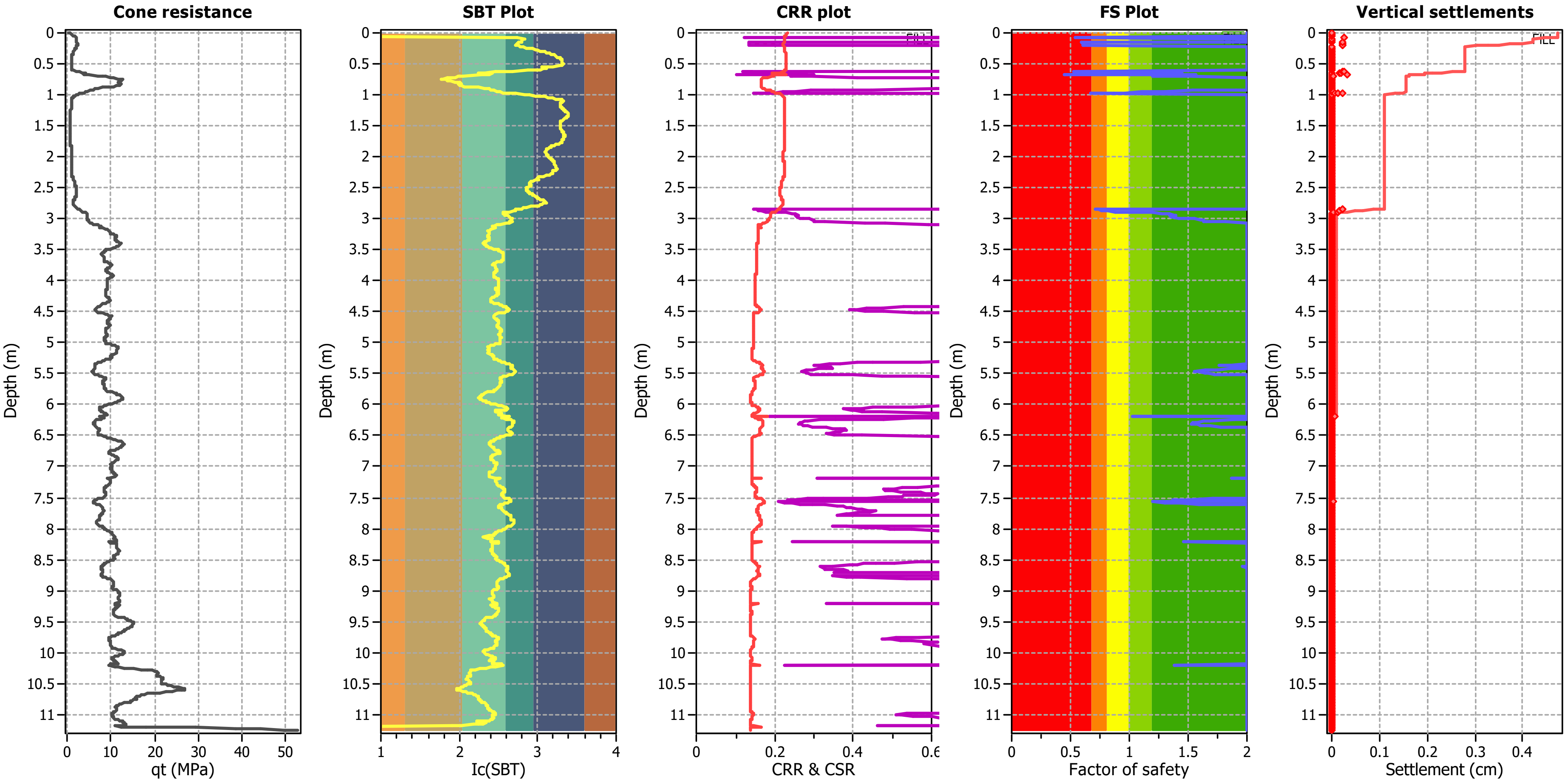
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	2.50 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT15
Total depth: 11.25 m



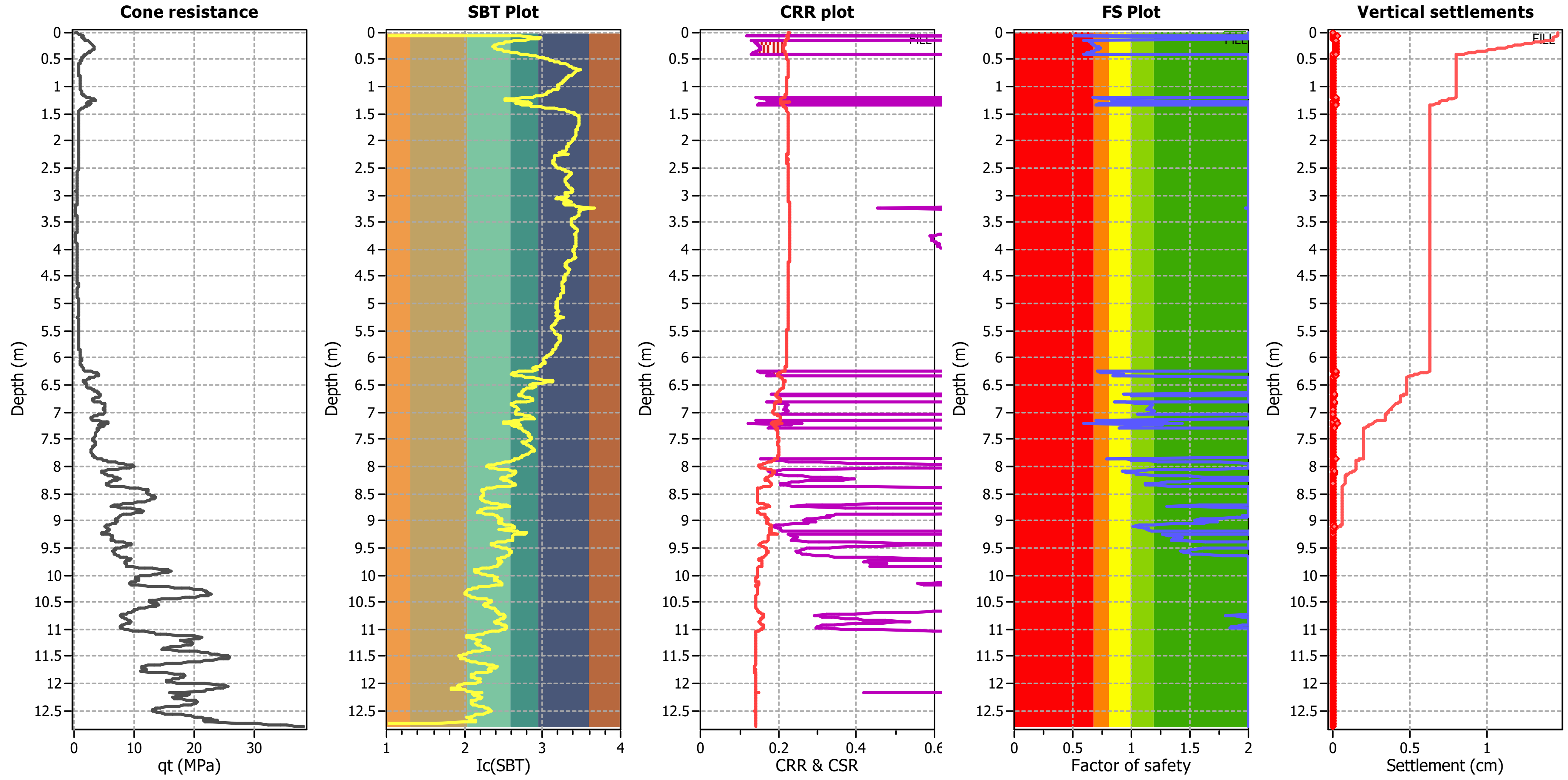
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	2.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m3	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT16
Total depth: 12.79 m



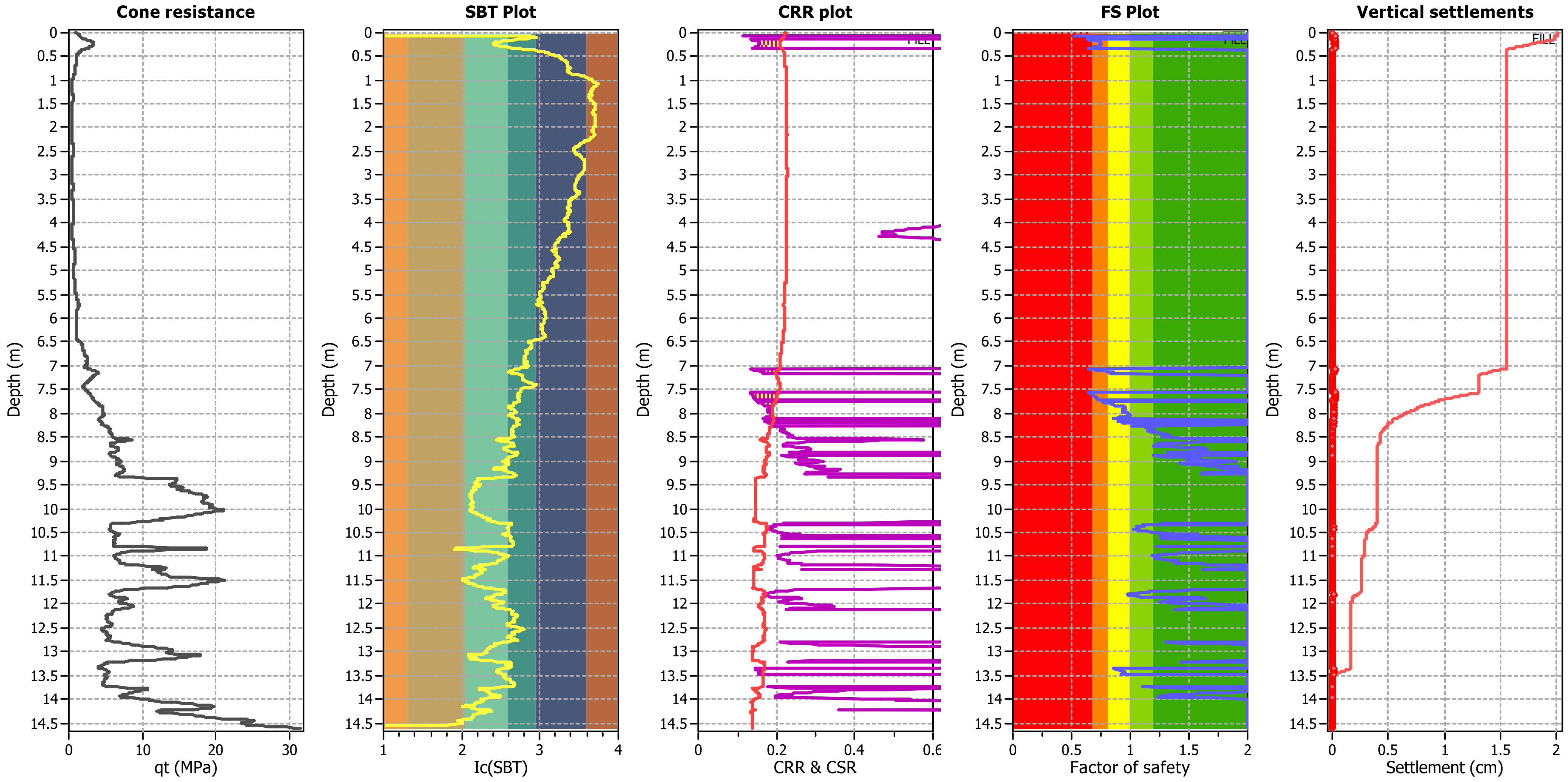
Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior	
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	3.00 m	applied:	.
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m³	Limit depth applied:	No
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	N/A
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

CMW Geosciences

https://www.cmwgeosciences.com/

Project: **Milldale Fast Track**
Location: **Wainui East**

CPT: AKL2024-0257_CPT17
Total depth: 14.61 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	Yes	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.00 m	Fill height:	4.00 m	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	18.00 kN/m³	Limit depth:	N/A
Earthquake magnitude M_w:	6.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

Appendix H: Static Settlement Design Memo

Static Settlement

Site Address	Milldale Fast Track Application	Report Number	AKL2024-0257
Client	Fulton Hogan Land Development Ltd	Date	10/12/24
Prepared by	Sasiruban Loganathan		
Reviewed & Authorised by	Chris Ritchie		

1.0 INTRODUCTION

The purpose of this design verification is to provide a broad estimate of construction and post-construction settlement magnitudes and rates at the site and to provide recommendations on potential remedial works required to address static settlement issues. It is anticipated that this is a general screening exercise and detailed settlement assessments will be required on a stage-by-stage basis.

The area(s) assessed herein are depicted on the plans prepared by Woods as:

- Stages 10 and 11 with a maximum proposed fill depth of 5 m.
- Stages 12 and 13 with a maximum proposed fill depth of 8 m.

2.0 METHODOLOGY

2.1 Static Settlement Assessment

Proposed fill embankments and potential future building loads will induce settlements within the underlying subsoils.

Preliminary load induced settlement analysis was undertaken using the software CPeT-IT, with primary settlements calculated according to the following formula:

$$S_p = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

Where: $\Delta\sigma_v$ = change in effective stress
M_{CPT} = constrained modulus from CPT
Δz = change in depth

Secondary creep settlements were calculated according to the following equation:

$$S_c = C_\alpha \cdot \Delta z \cdot \log\left(\frac{t}{t_p}\right)$$

Where: C_α = coefficient of secondary compression
t_p = duration of primary consolidation (6 months assumed)
t = duration of design life (50 years)

3.0 RESULTS

3.1 Static Settlements

Estimated static settlements are summarised as follows:

Table 1: Estimated Fill Induced Static Settlements

CPT No.	Soft Soil Thickness (m)	Fill Height (m)	Construction Settlement (t_{90} mm)	Post Construction Settlement (mm)
CPT01-24	5.6	0.3	10	40
CPT02-24	2.3	1	20	20
CPT03-24	5.1	1	10	15
CPT04-24	7	2	30	20
CPT05-24	3.8	1	10	15
CPT06-24	5.5	0	-	15
CPT07-24	6.5	4	70	25
CPT08-24	3	Cut (-2)	-	10
CPT09-24	4.2	Cut (-2)	-	0
CPT10-24	7	Cut (-3)	-	5
CPT11-24	8	5	90	35
CPT12-24	2	Cut (-3)	-	5
CPT13-24	3.4	Cut (-1)	-	10
*CPT14-24	1.5	2.5	25	11
CPT15-24	3.2	2	20	12
CPT16-24	6.5	3	80	40
CPT17-24	7	4	140	55

Notes:
Post construction settlements made up of secondary creep + remaining 10% fill induced consolidation + widespread development load induced consolidation (assumed to be 20kPa).
Embankment construction using available borrow materials (unit weight = 18kN/m^3) assumed. Greater settlements will occur if using imported rockfill or sand.
*CPT14-24 is terminated at 1.8m

The post-construction settlement estimates generally do not exceed 50mm and are therefore suitable for building development, provided sufficient time is left for construction settlements to occur prior to building development.

The exception is CPT17-24 which is situated within a gully on Stage 12A. is recommended that further investigation is carried out within this area to further assess the settlement potential of this gully.

3.2 Time Rate of Settlement

- The ground model presents a maximum compressible silt/ clay layer thickness of 8.2m
- In most cases, the compressible layer is underlain by low permeability silt, clays and rock that will present only 1-way drainage.

- Previous settlement monitoring on Earthworks 2A and Earthworks 6 (adjacent to stage 9) suggest that T90 consolidation is achieved between 9 months and 1 year.

3.3 Settlement Criteria

We consider that the settlement criteria at completion of the earthworks is achievement of t90 construction settlements or post construction settlements of less than 50mm (based on a 50 year design life) at the monitored settlement locations.

The percentage of consolidation will be estimated using curve fitting Asaoka plots based on observed settlement magnitudes. There may be variation from the estimated construction settlements listed above. Details on monitoring are included in Section 5 below.

Based on the precited post construction settlements (which includes a widrespread future development load of 20kPa) noted in Table 1, settlement mitigation is not expected to be required, provided sufficent time is left between bulk filling and release of lots.

4.0 CONSIDERATION OF BEARING CAPACITY FAILURE

Mitigation of bearing capacity failure risk is primarily undertaken as part of the earthworks planning and execution. The primary considerations are:

- Placing fill evenly across the site and in planned lifts.
- Restrictions on the speed of placing fill-in areas with thick, soft alluvium layers.
- Staging of the fill placement to allow for excess pore pressures to dissipate.
- Surcharge proximity to slopes.

Consideration of a geosynthetic-based reinforcement across areas where deep, soft alluvium combined with deep fills are present to increase the bearing capacity.

It is recommended that the constructability programme including proposed heights of fills, their locations and the timing of their placement is reviewed by the geotechnical engineer with the contractor prior to the commencement of the works. Further slope stability and bearing capacity analysis may be required prior to the placement of fill to ensure it is undertaken in a controlled manner. This is particularly important in Stage 11A highlighted on Figure 1.

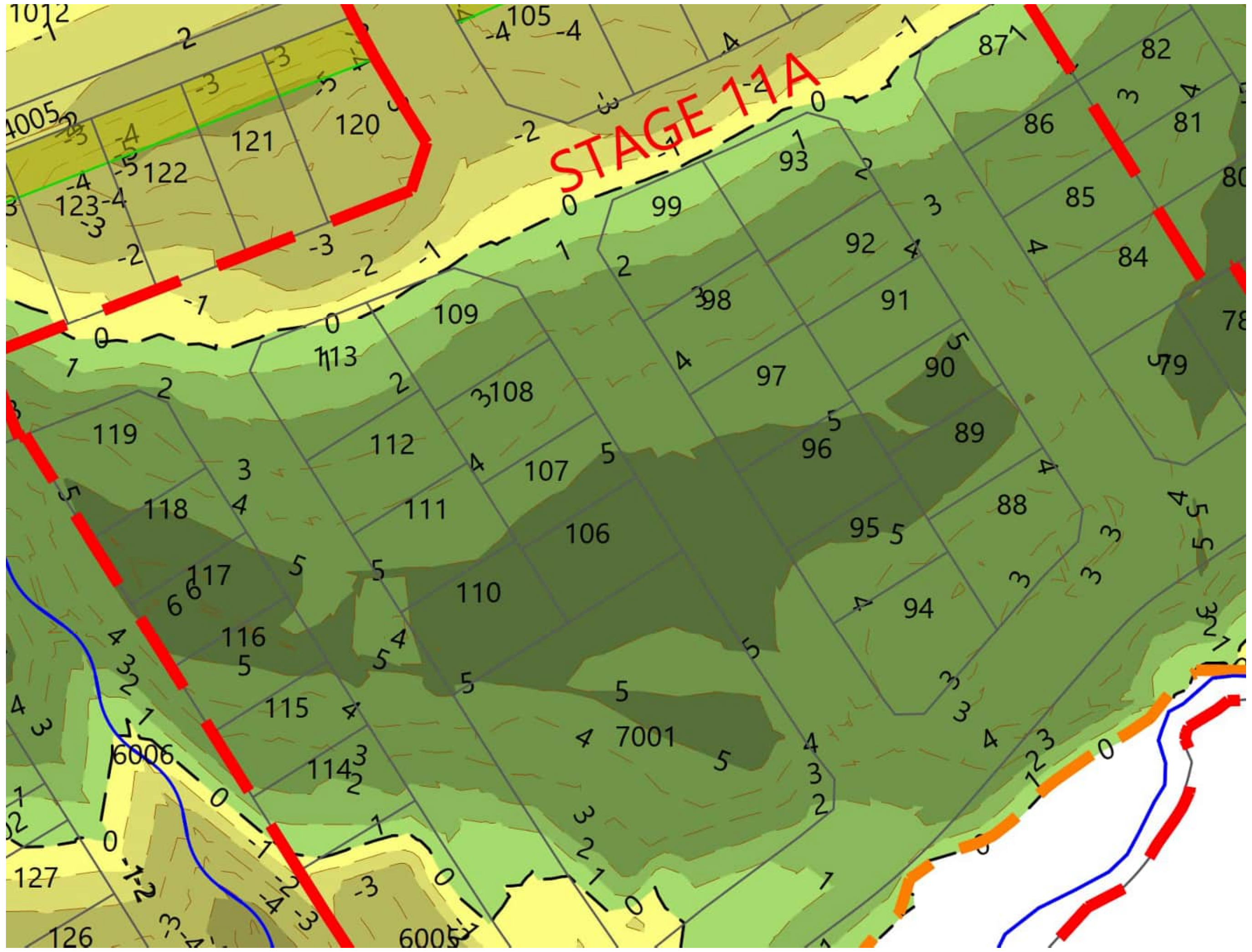
5.0 SETTLEMENT MONITORING

The above settlement magnitude and time rate estimates are based on CPT settlement estimations. As there will inevitably be some variation in soil composition and resulting settlement profiles from one location to the next and the magnitude of assumptions made, it is imperative that settlement monitoring is undertaken during construction to back analyse consolidation settlement parameters to update settlement predictions and to confirm that the settlement criteria noted in Section 3.3 has been achieved prior to release of the lots. Results are to BE included in the Geotechnical Completion Reports for respective stages

For this project it is recommended that surface settlement plates, placed over the ground surface prior to filling, are used to assess total settlement magnitudes and provide a cost-effective robust monitoring technique. Recommended settlement marker locations are shown on *Drawing 21-22* these are selected based on fill heights and the position of CPT data to undertake back analysis. A typical detail for a settlement marker is presented in *Drawing 23*.

Additional settlement marker locations are likely to be proposed following further investigation.

Figure 1: Stage 11A Gully Fill Near the Stream

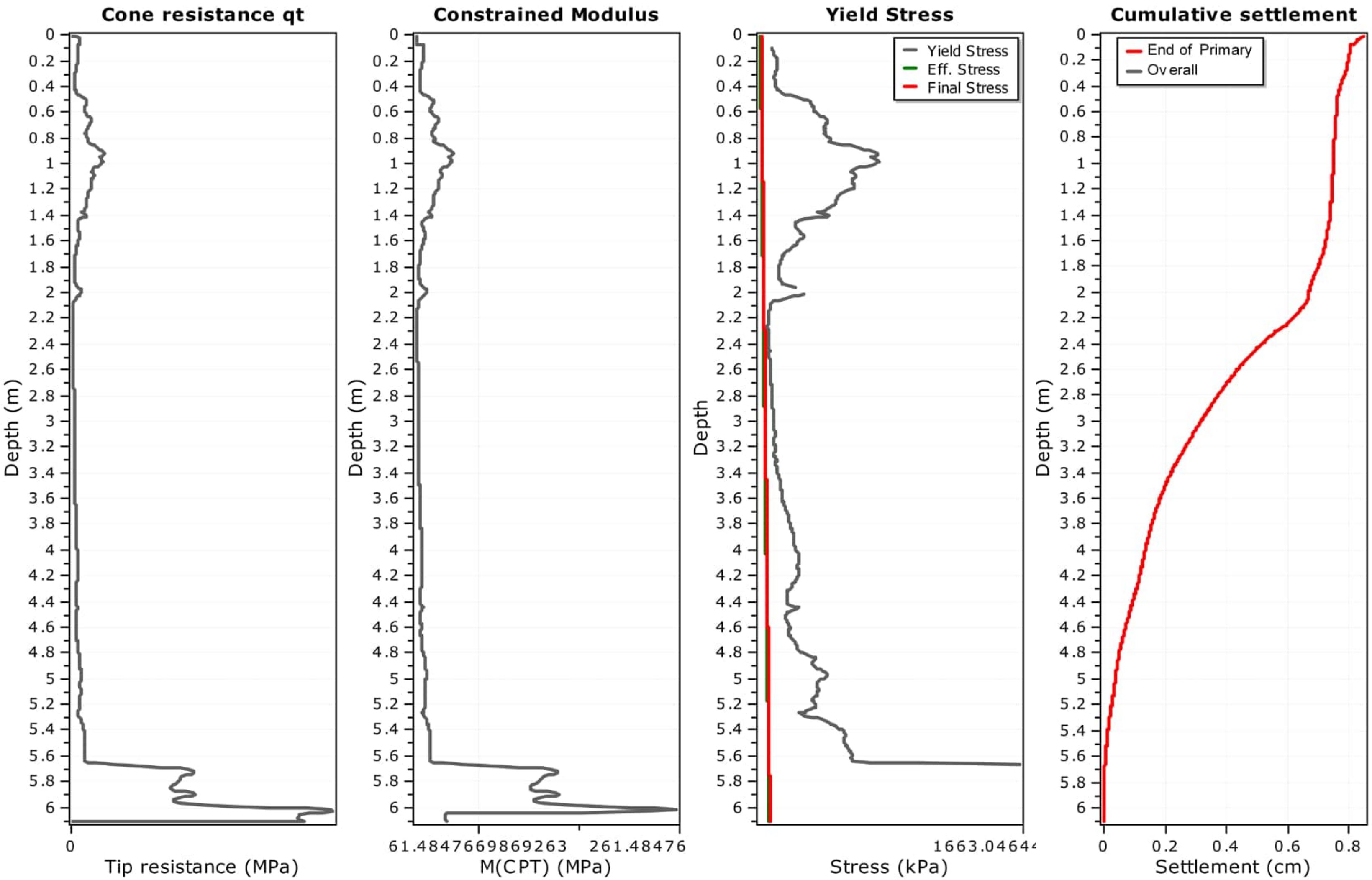


6.0 GROUND IMPROVEMENT OPTIONS

A number of options are available for remediating static settlements if additional investigations encounter further soft ground, these include:

- Preload and surcharge, with or without wick drains. This method has extensively used throughout the development
- Undercut of soft ground and replacement with engineered fill.
- Use of light weight fills for embankments such as pumice sand.
- Use of ground improvement columns such as rigid inclusions, rammed aggregate piers or similar.

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 5.40 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

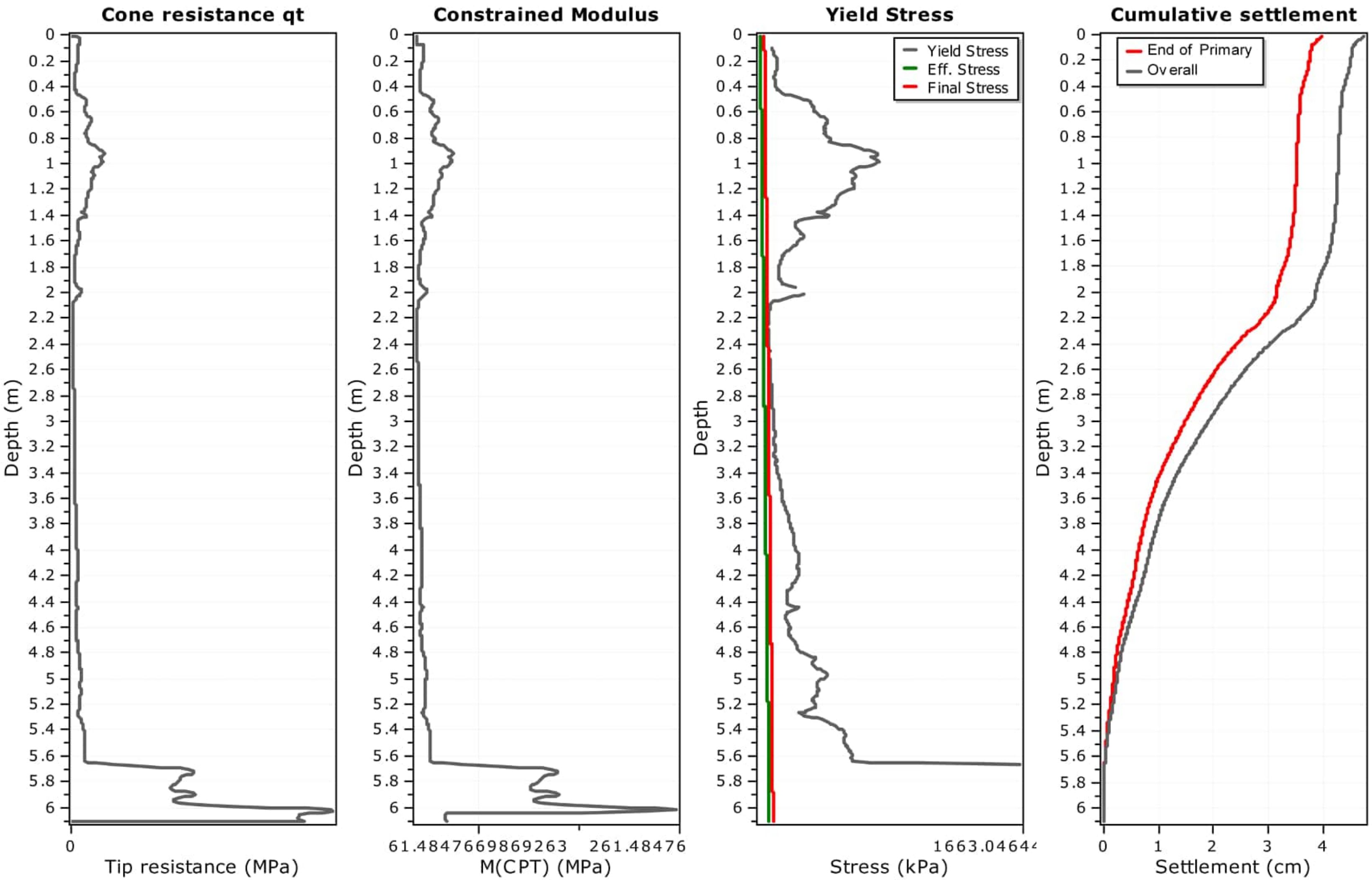
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 25.40 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

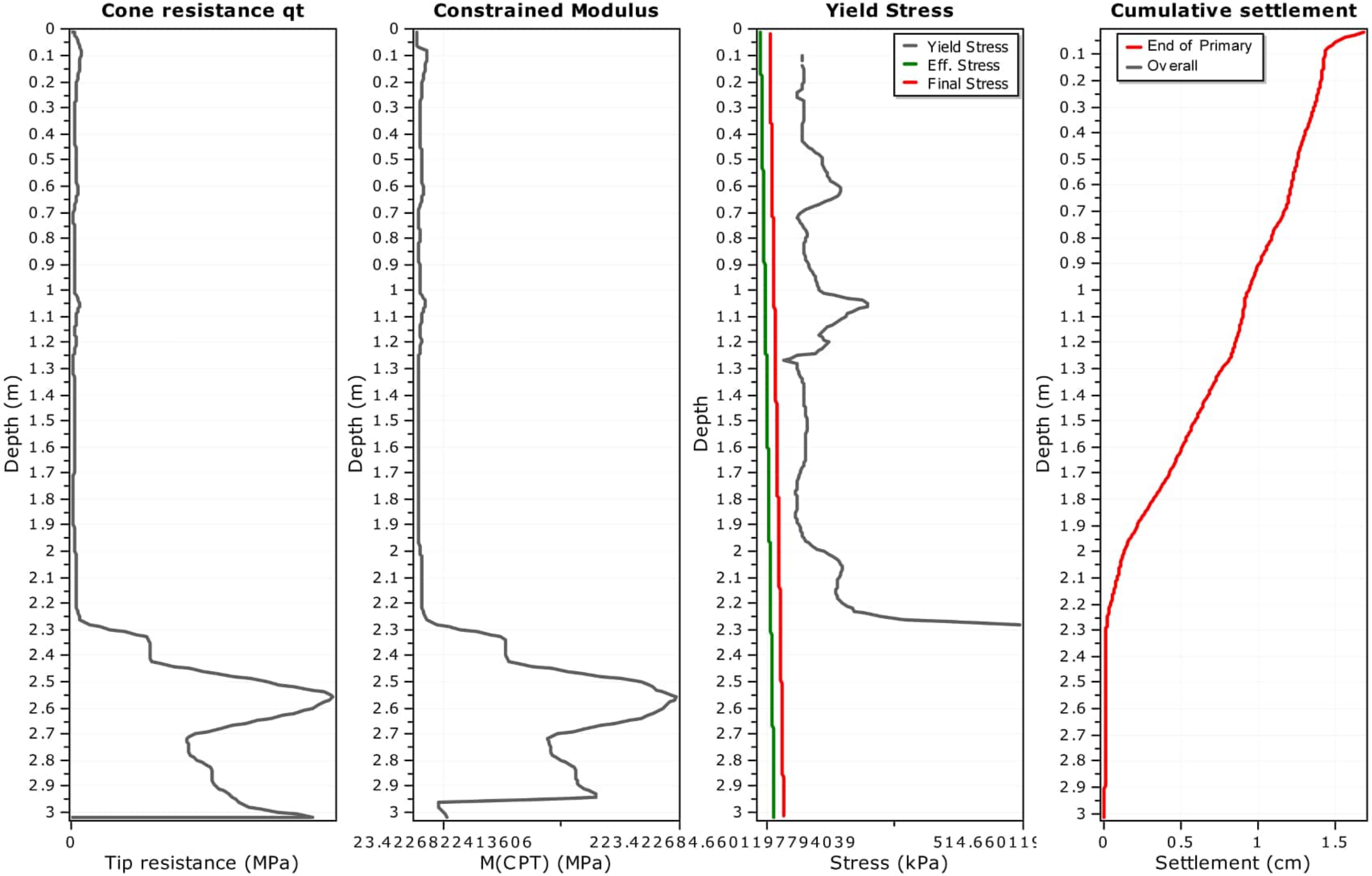
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT02

Total depth: 3.02 m, Date: 20/11/2024

Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

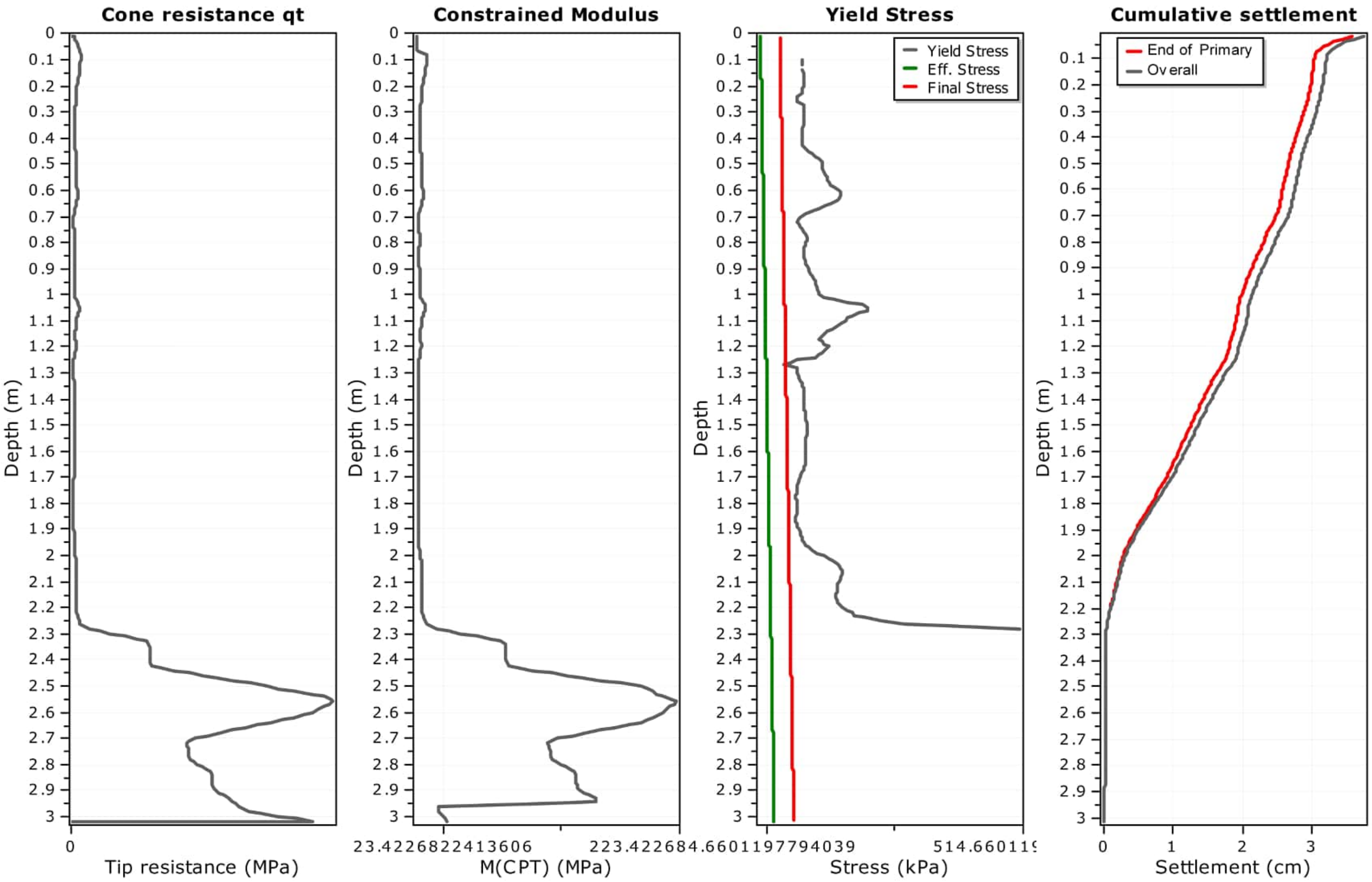
Project:

Location:

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 38.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

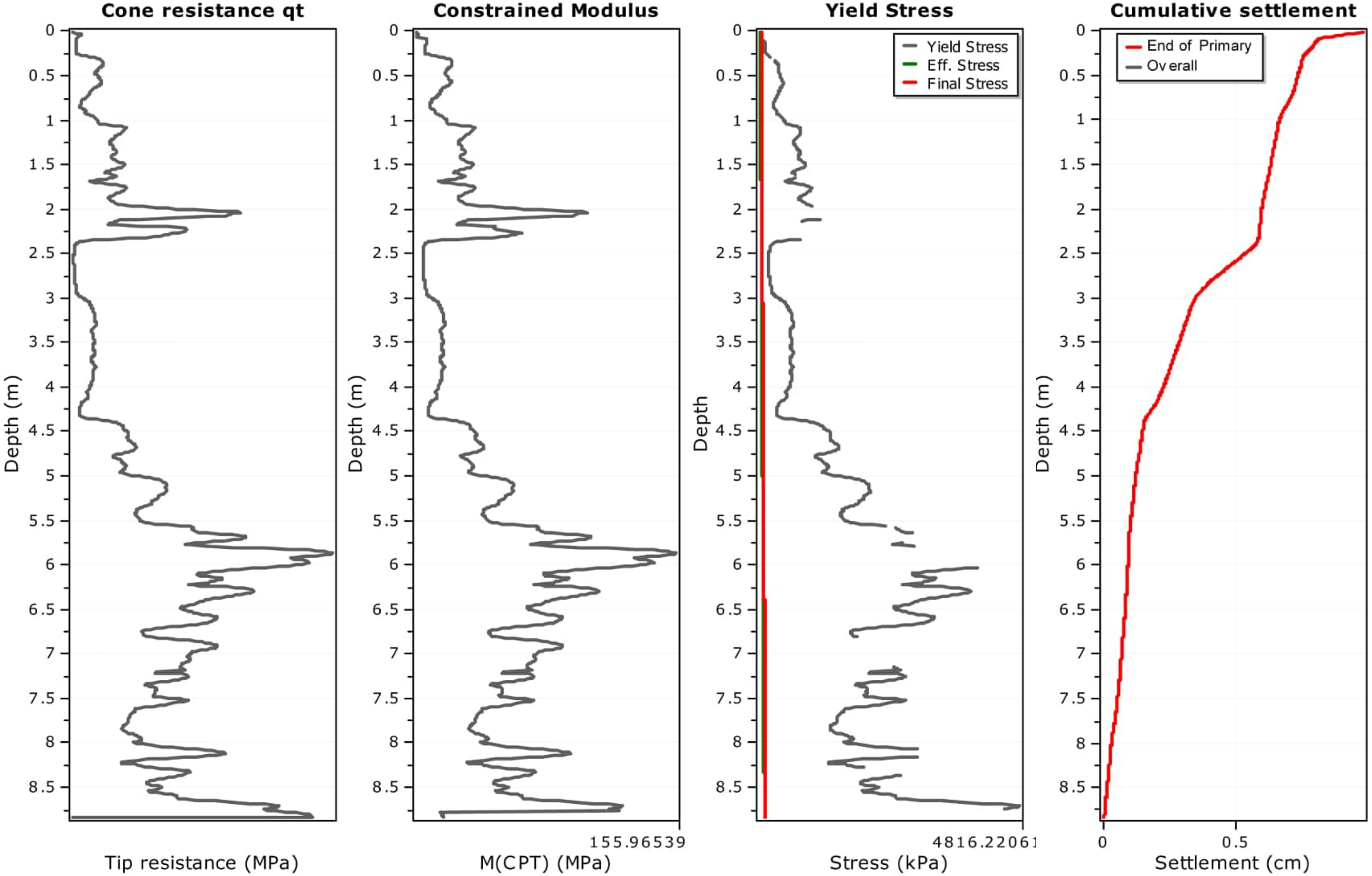
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

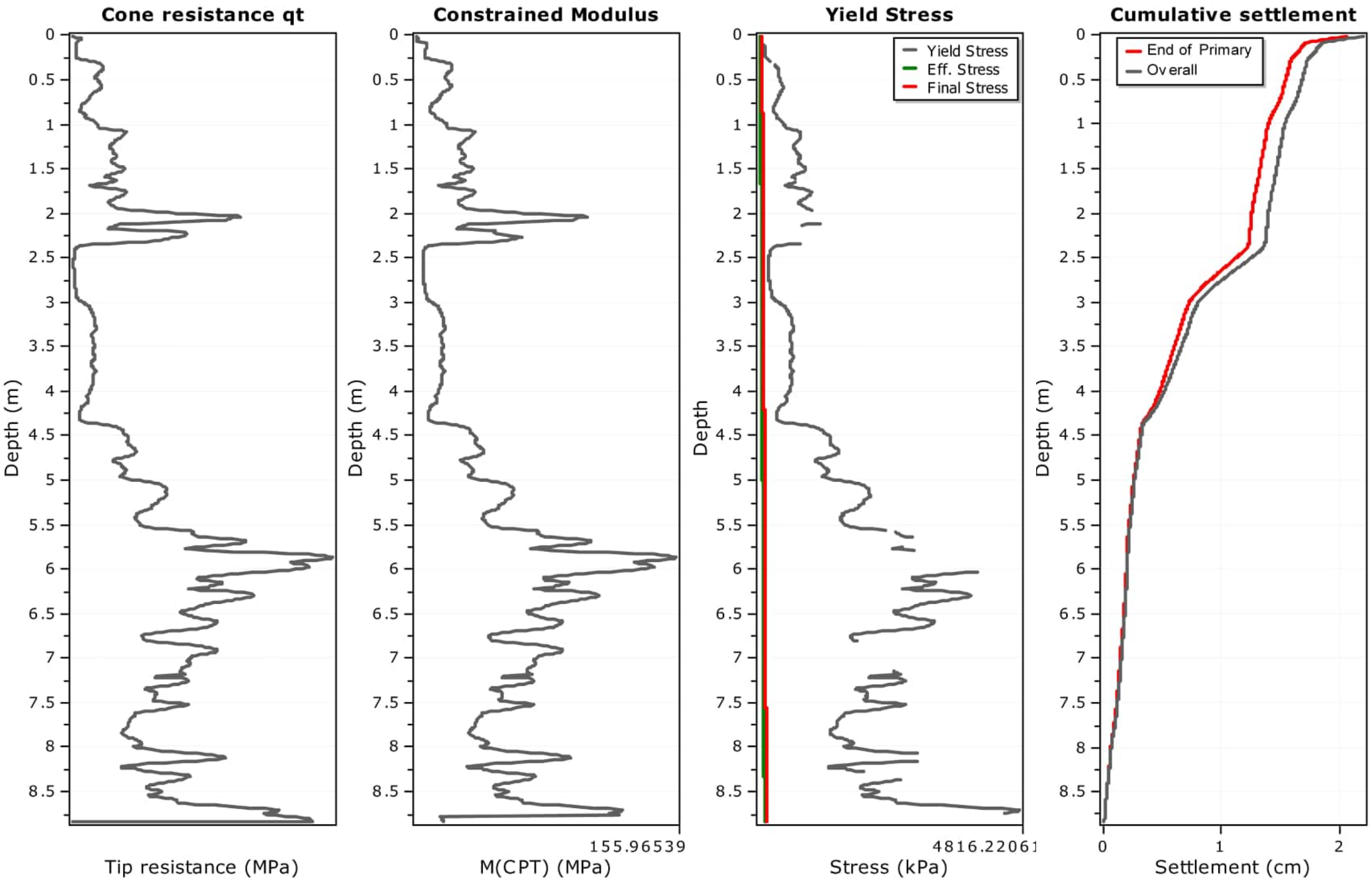
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 38.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

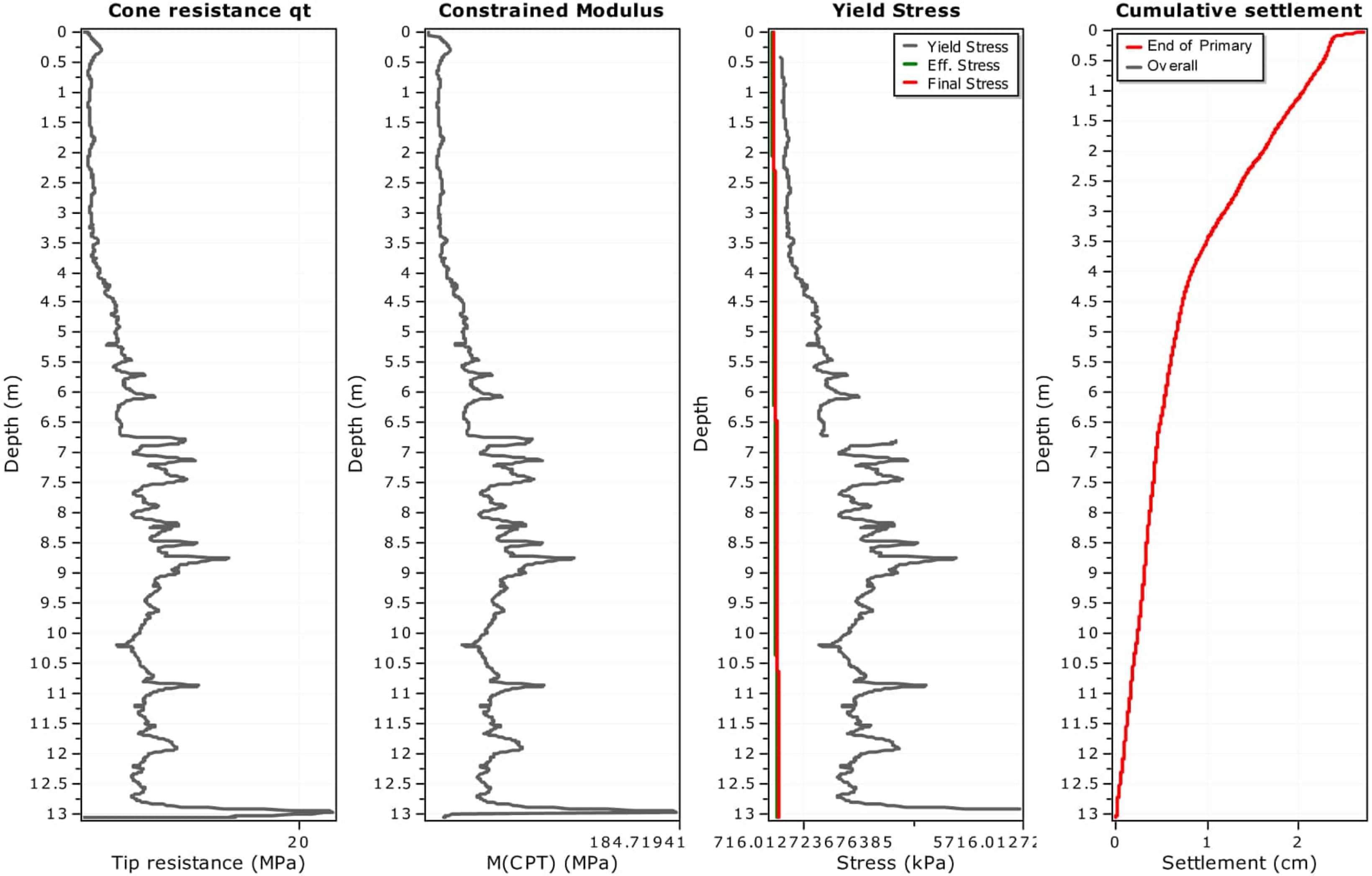
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 36.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: No

Time period for primary consolidation: N/A

Time period for second. settlements: N/A

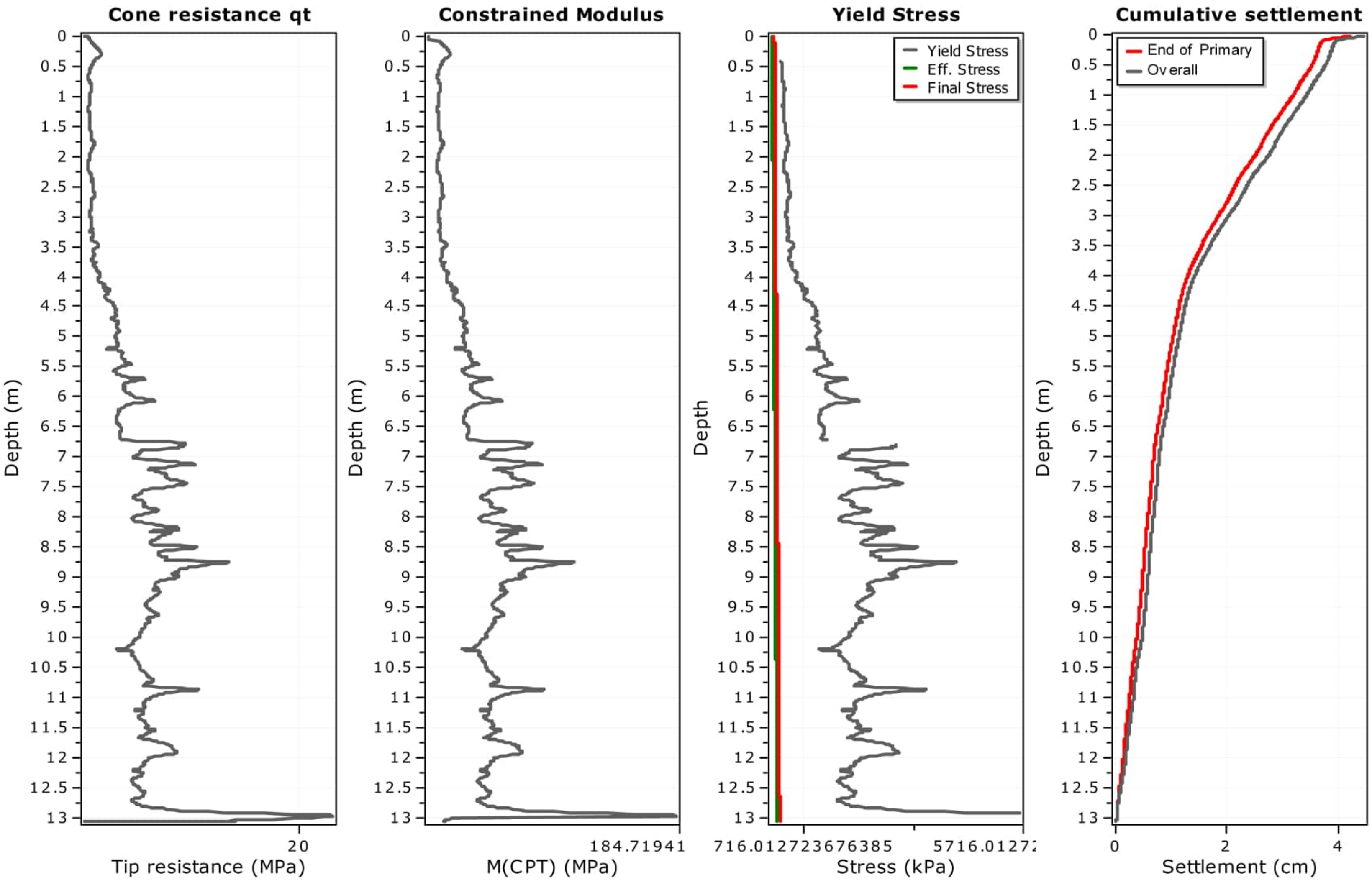
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 56.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

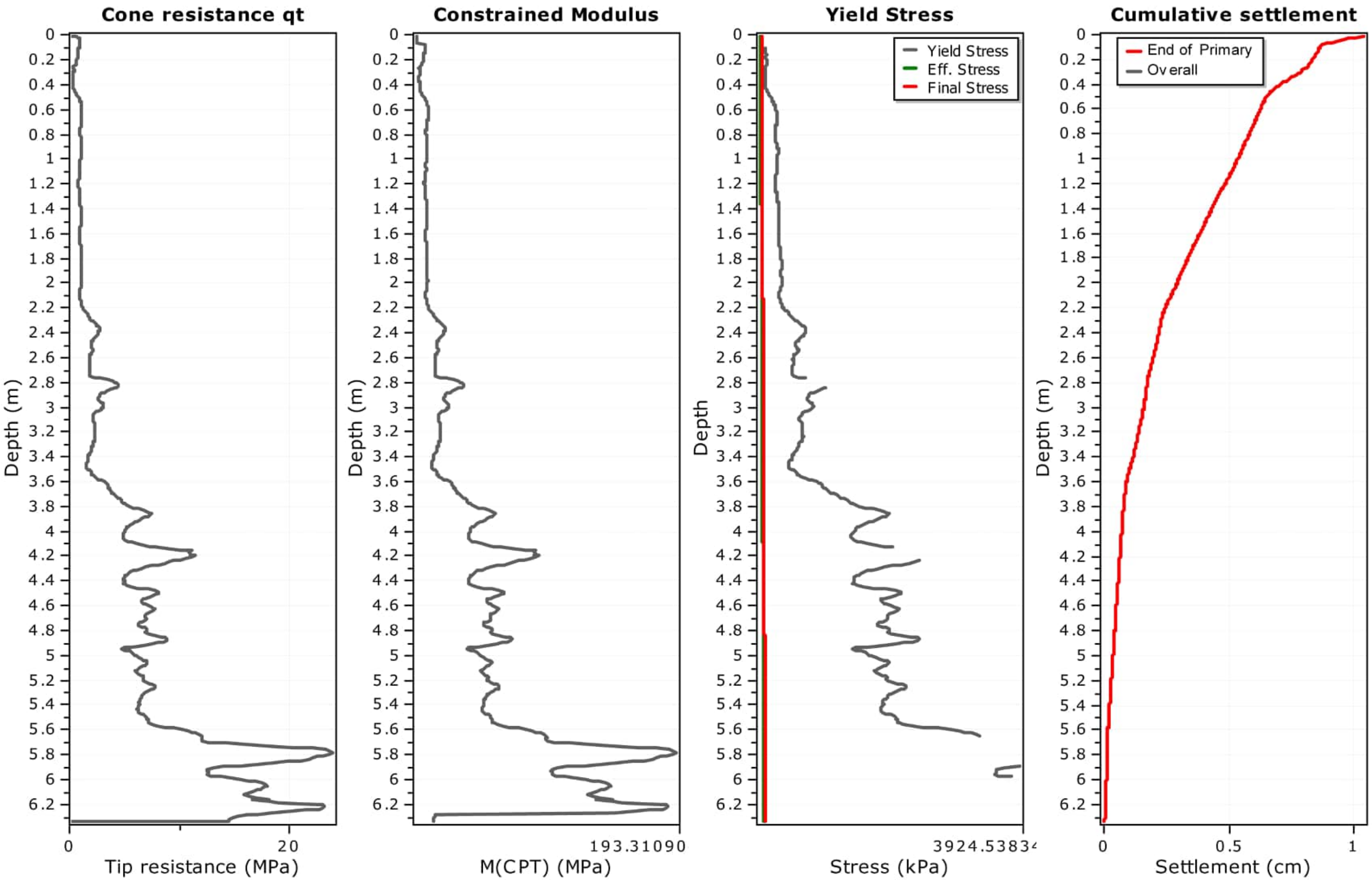
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 18.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

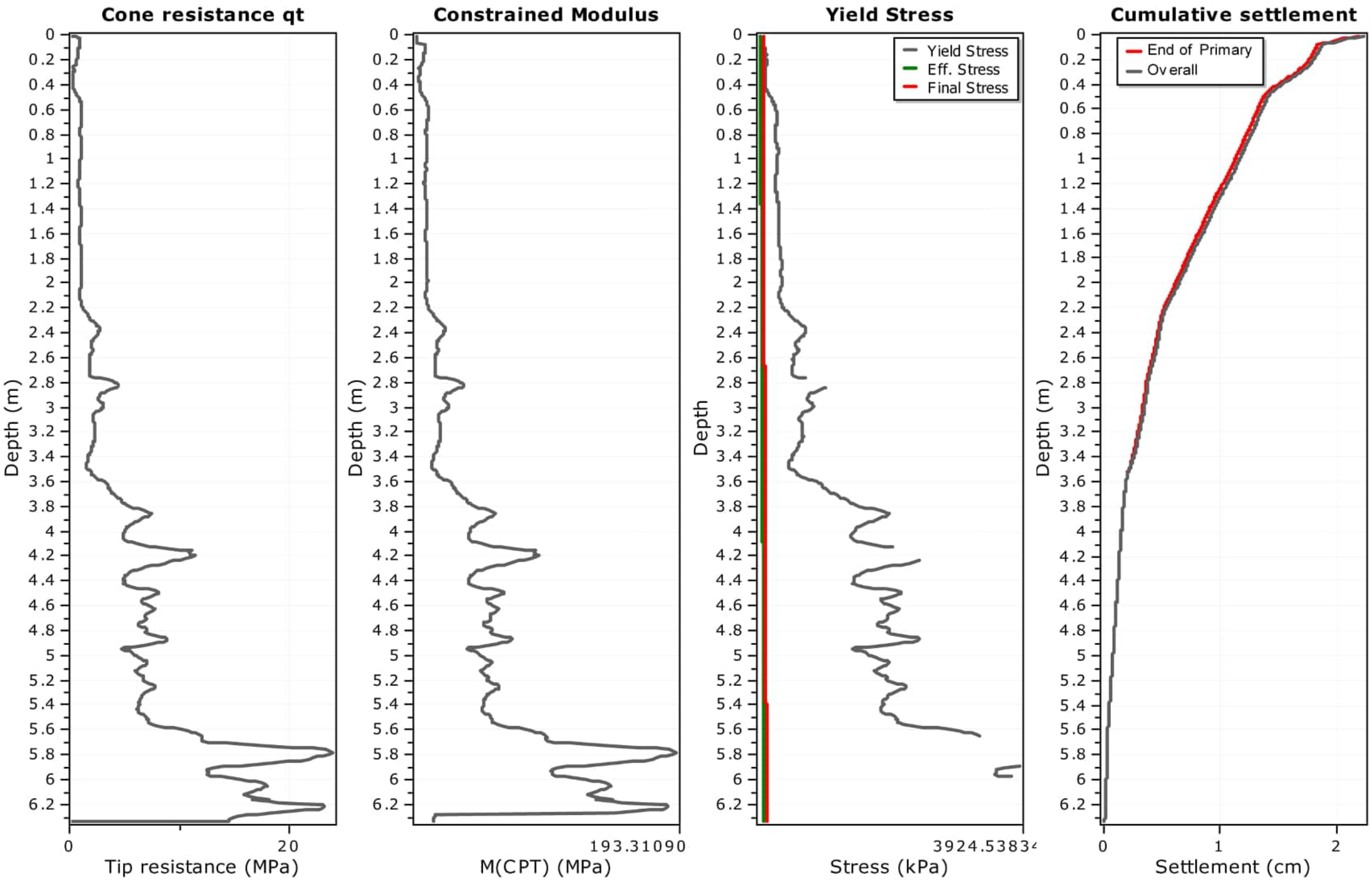
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 38.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

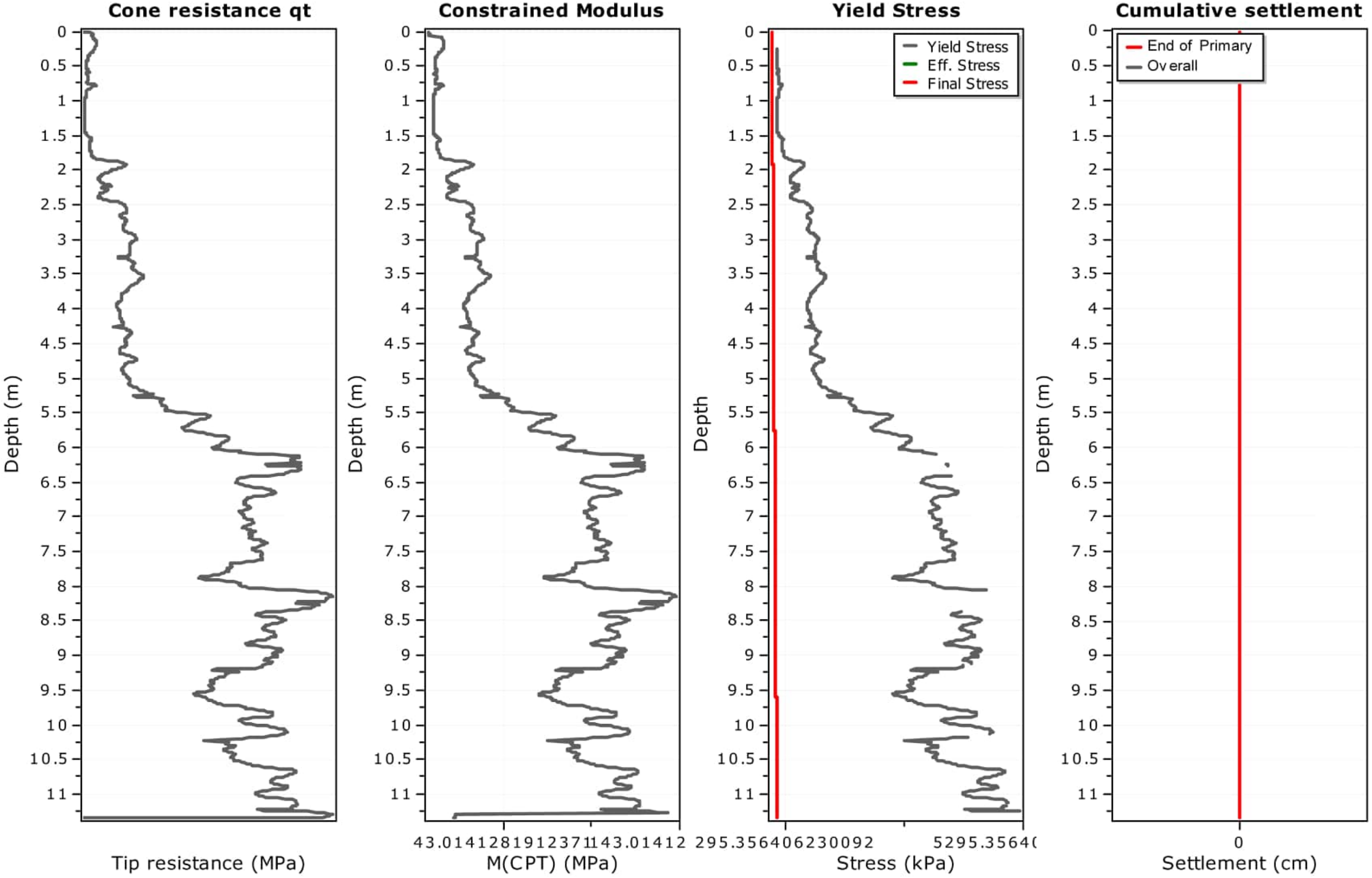
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

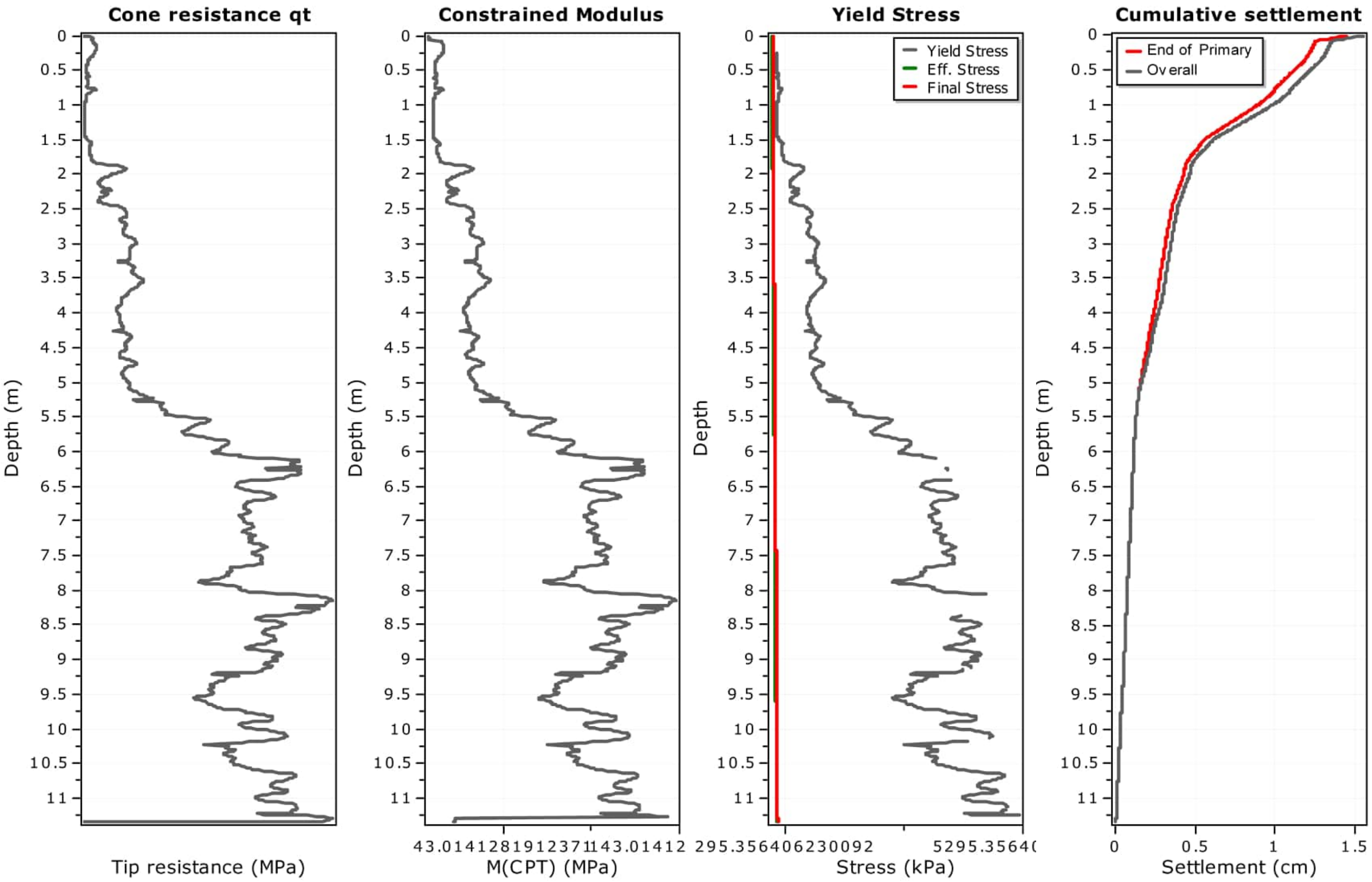
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 20.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT07

Total depth: 11.40 m, Date: 20/11/2024

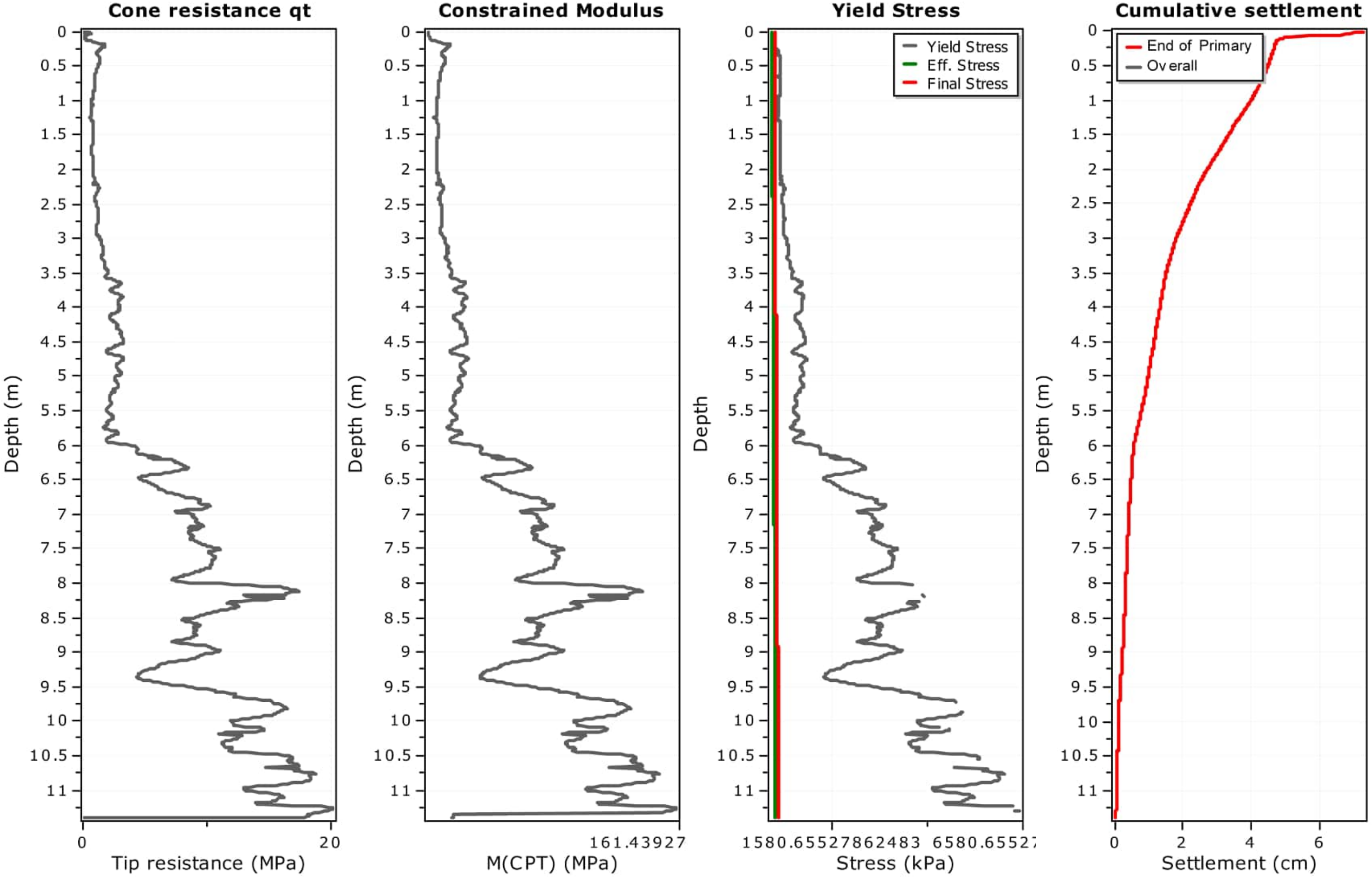
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 72.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT07

Total depth: 11.40 m, Date: 20/11/2024

Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

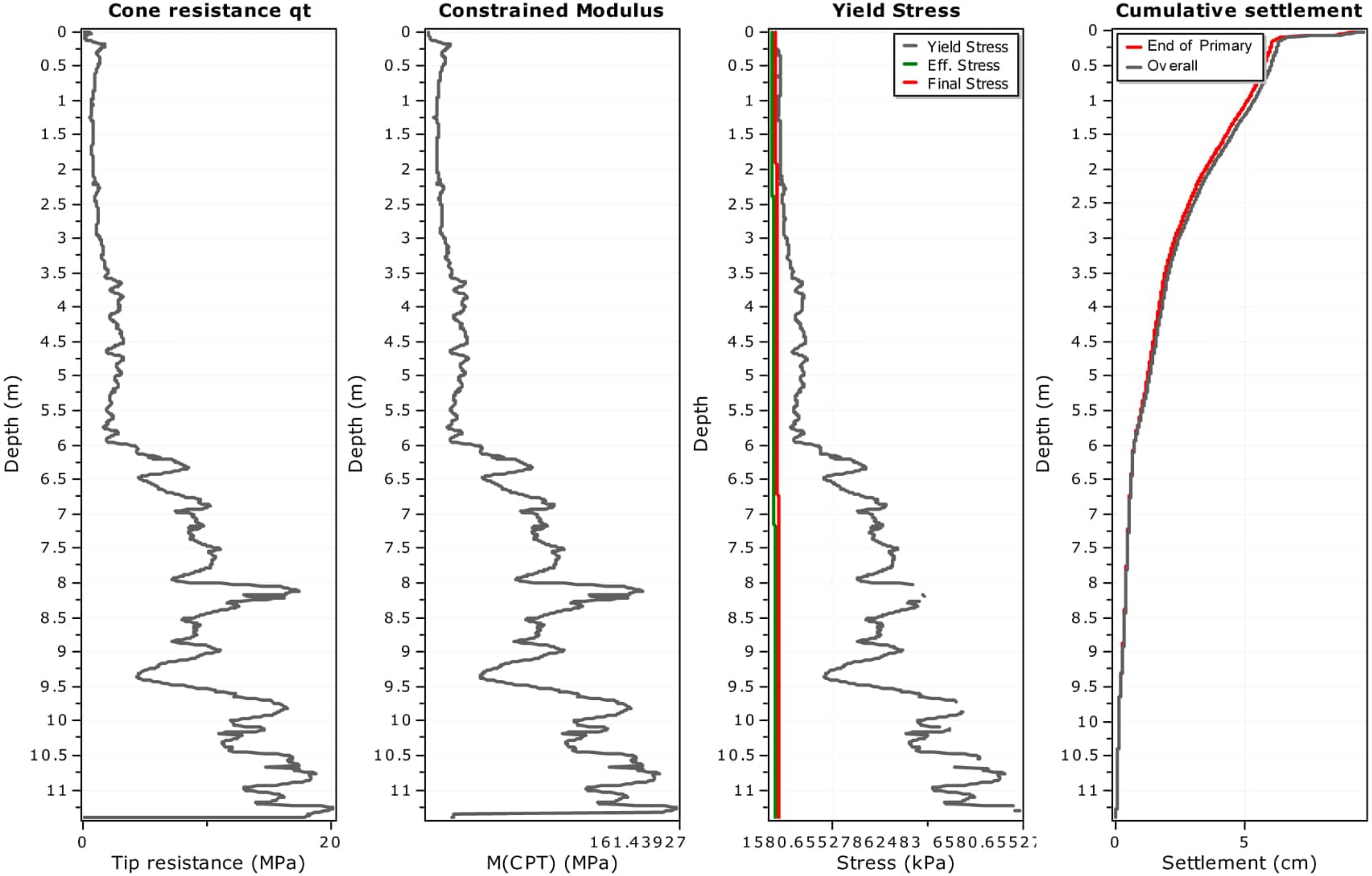
Cone Type:

Cone Operator:

Project:

Location:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 92.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT08

Total depth: 18.54 m, Date: 20/11/2024

Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

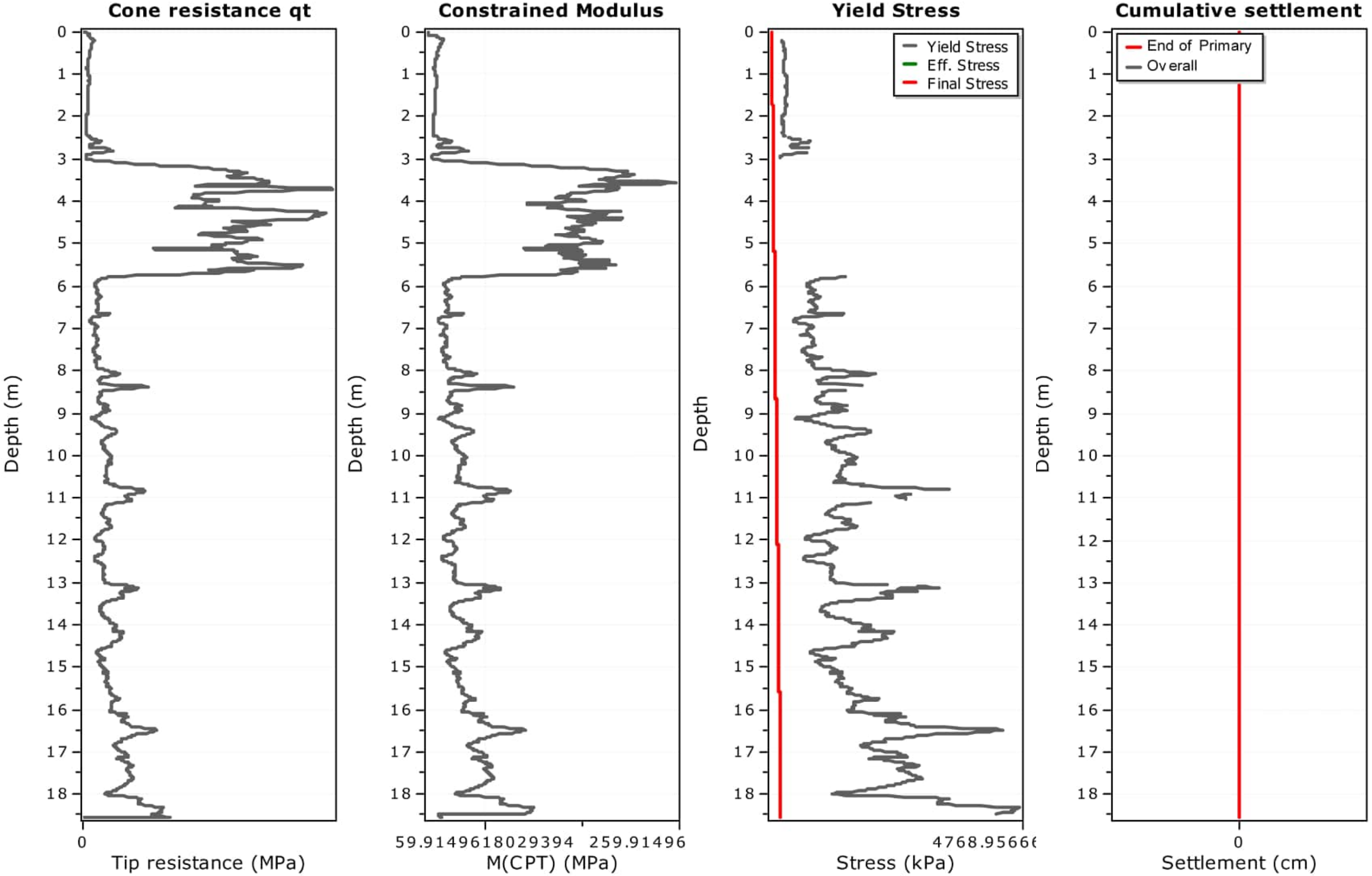
Cone Type:

Cone Operator:

Project:

Location:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

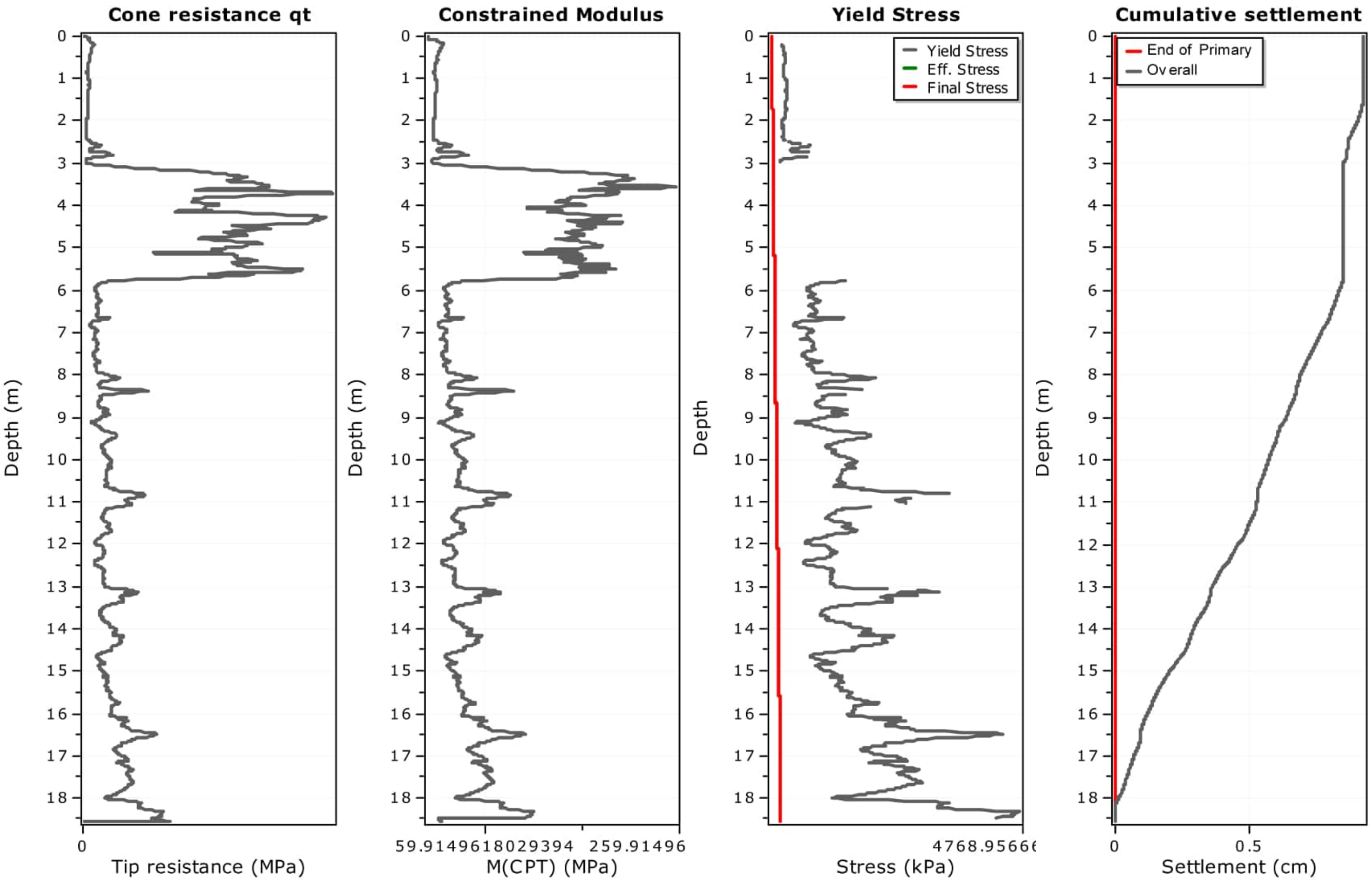
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 0.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

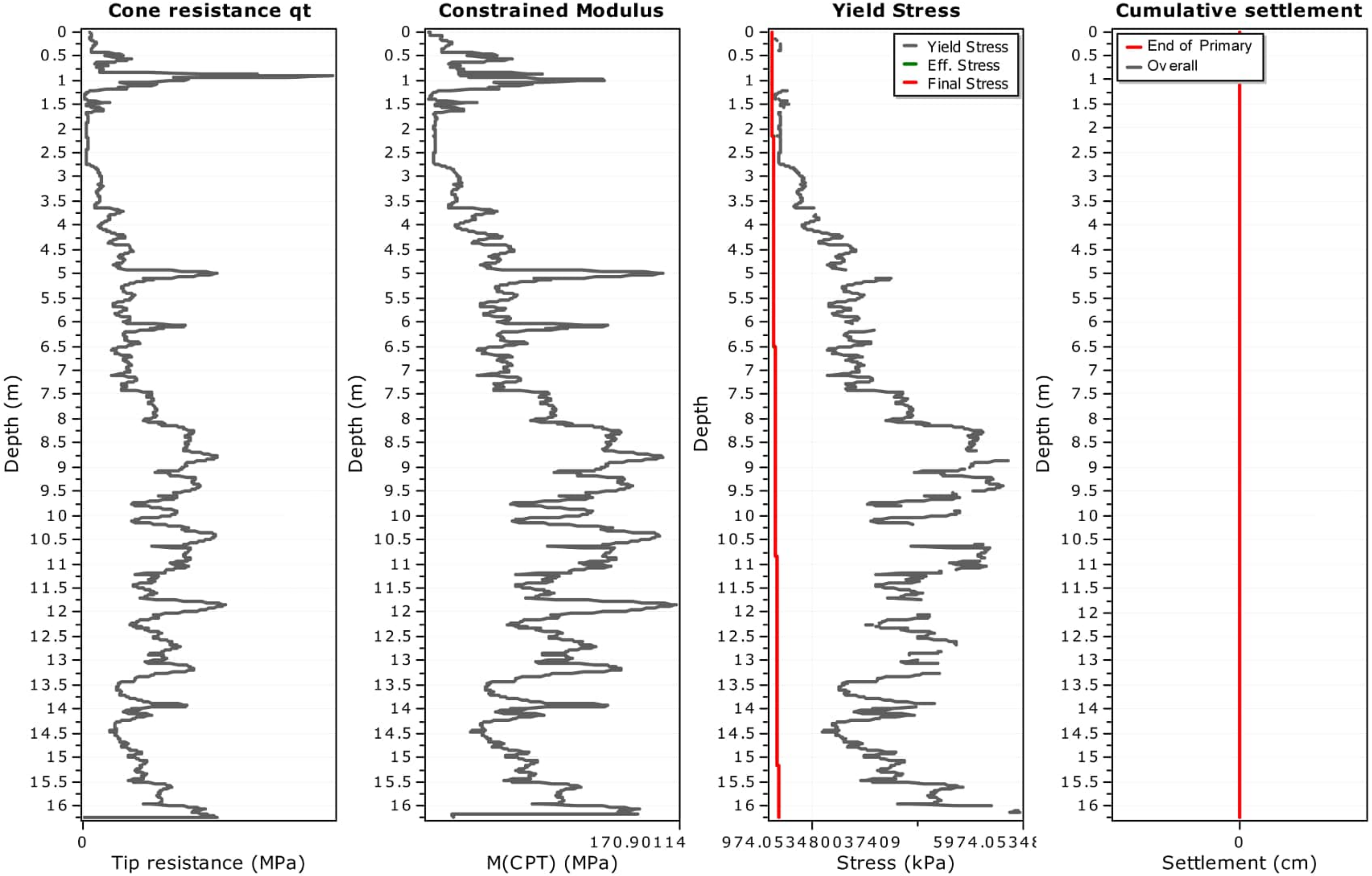
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

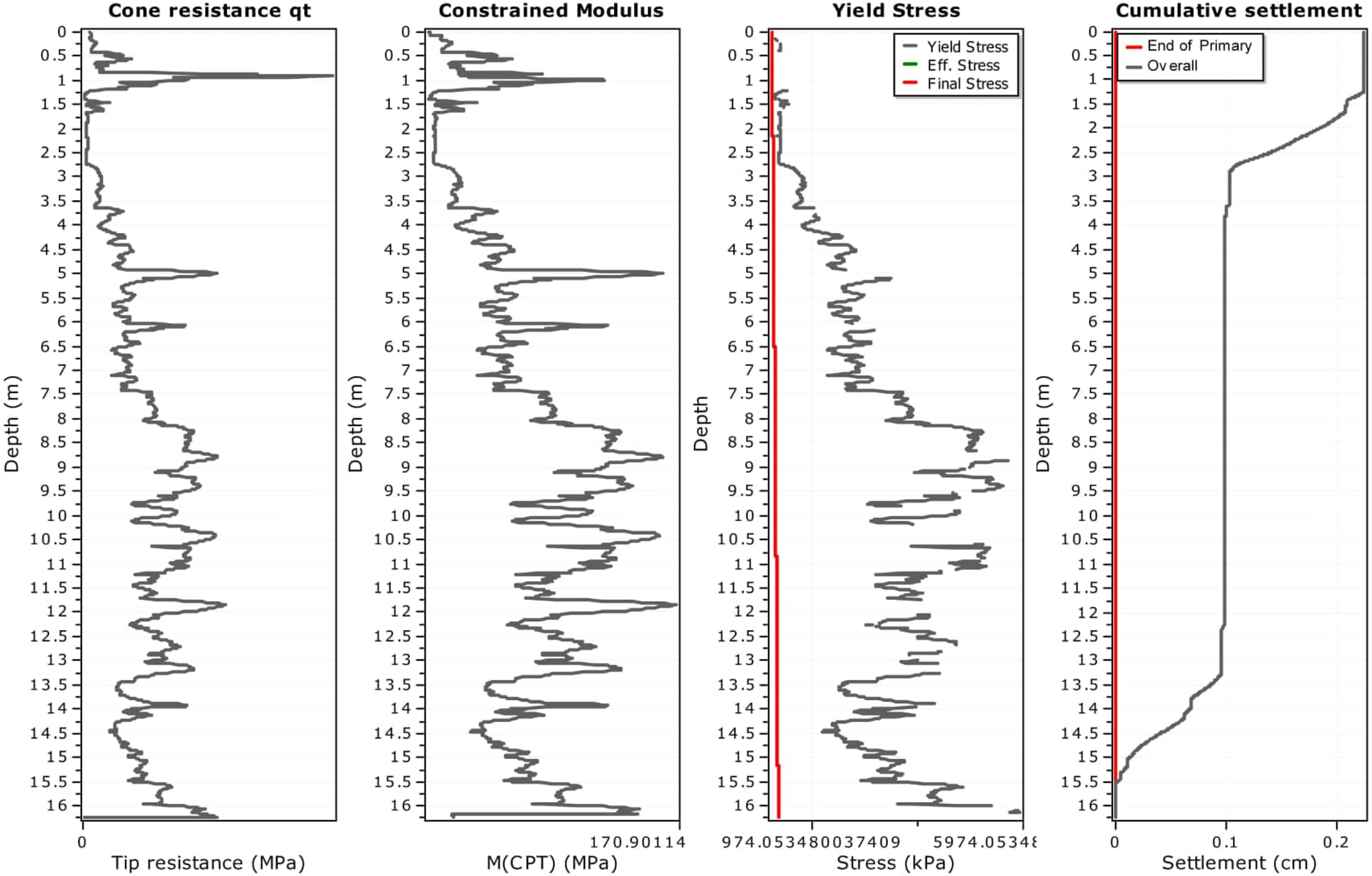
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

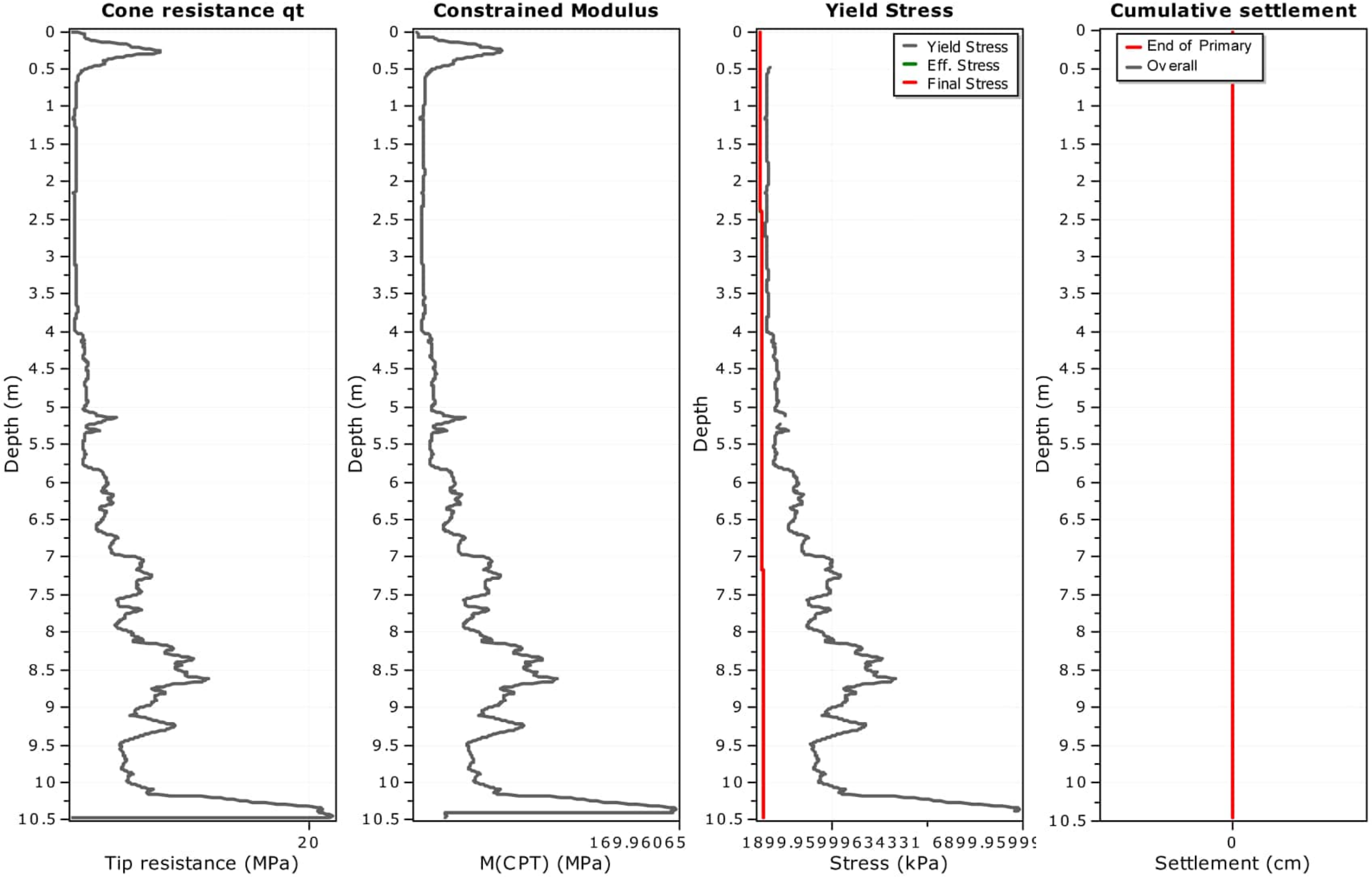
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT10

Total depth: 10.47 m, Date: 20/11/2024

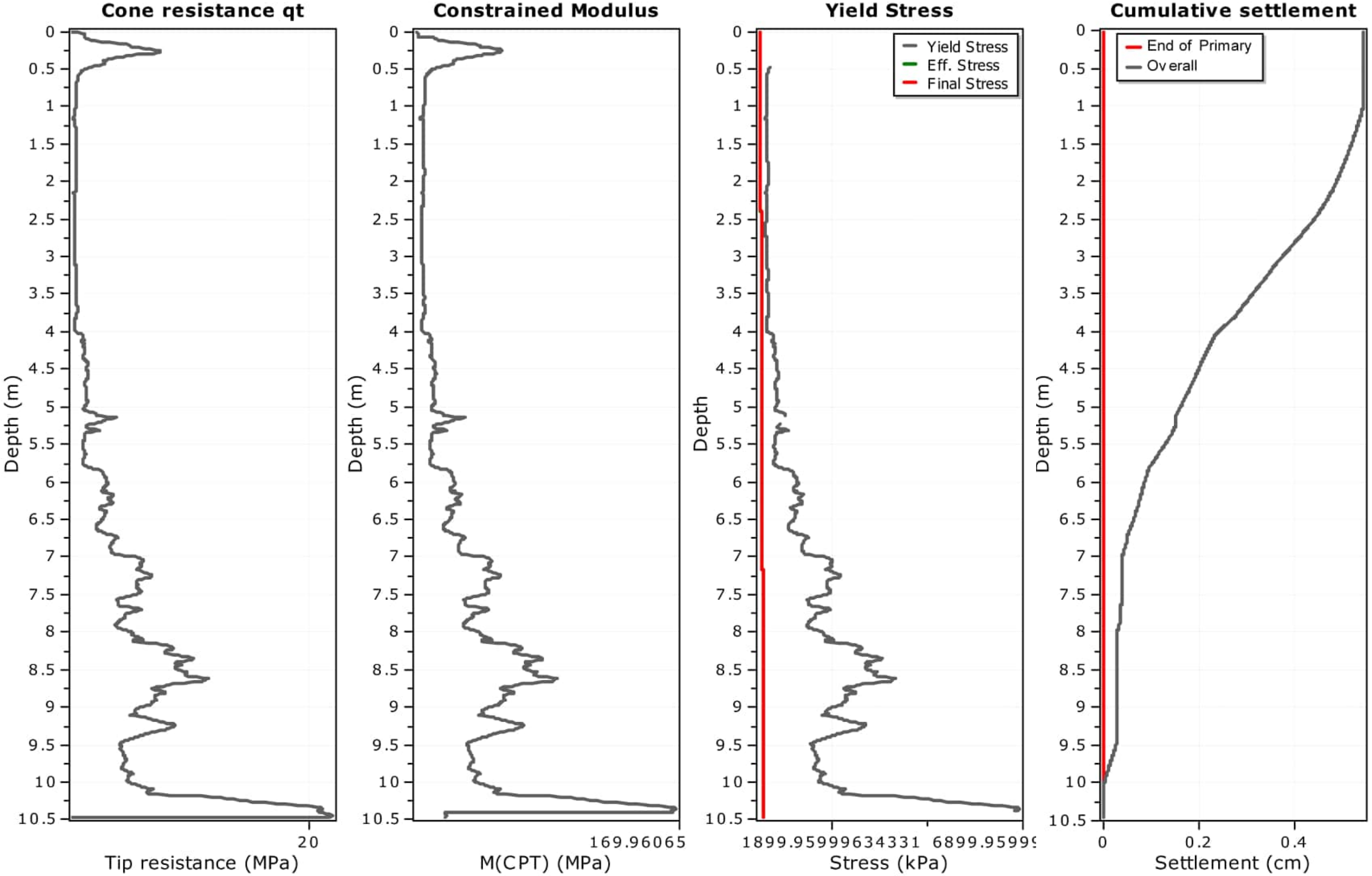
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Project: Cone Type:

Location: Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 0.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT11

Total depth: 11.83 m, Date: 20/11/2024

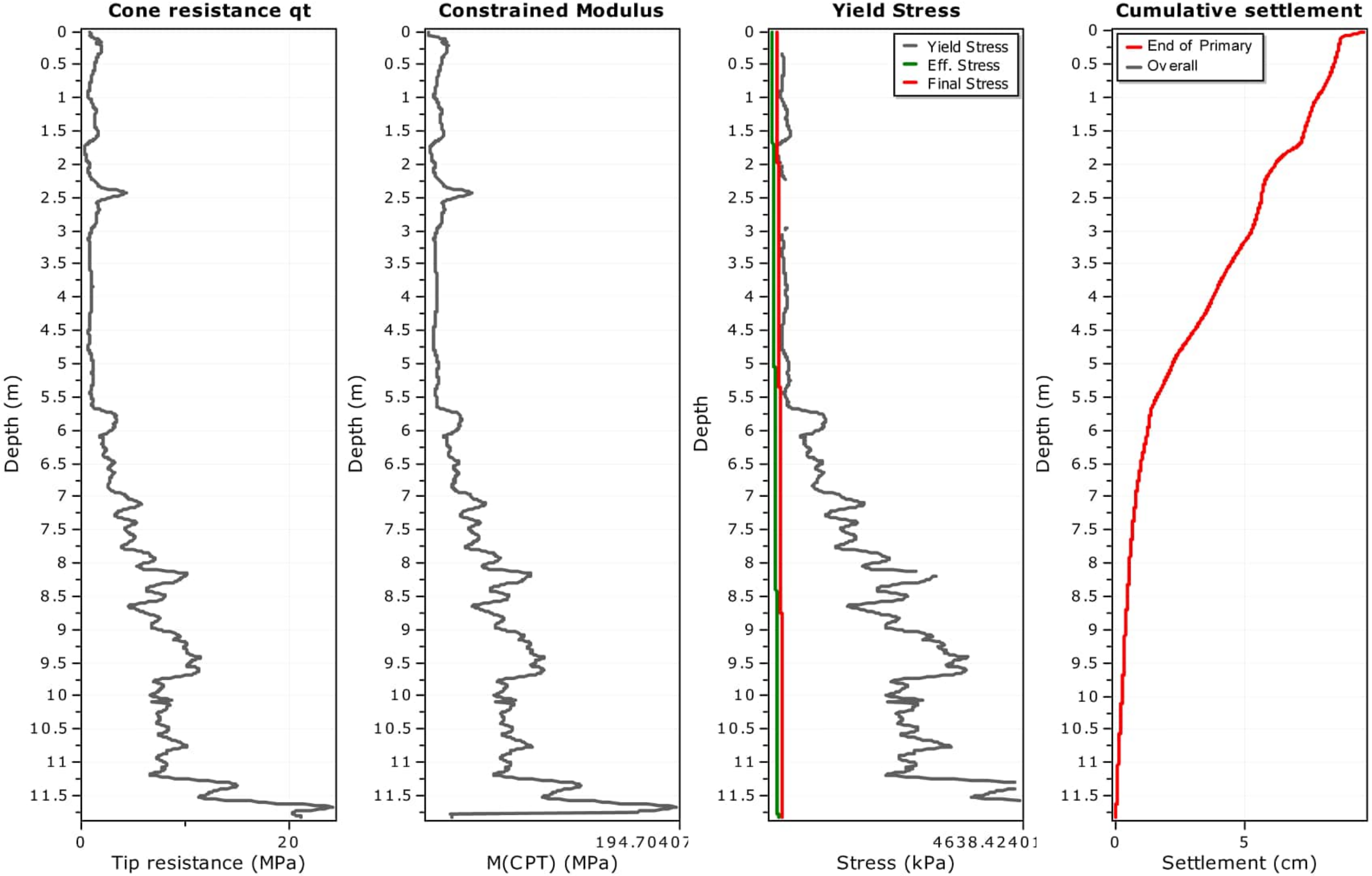
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 90.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT11

Total depth: 11.83 m, Date: 20/11/2024

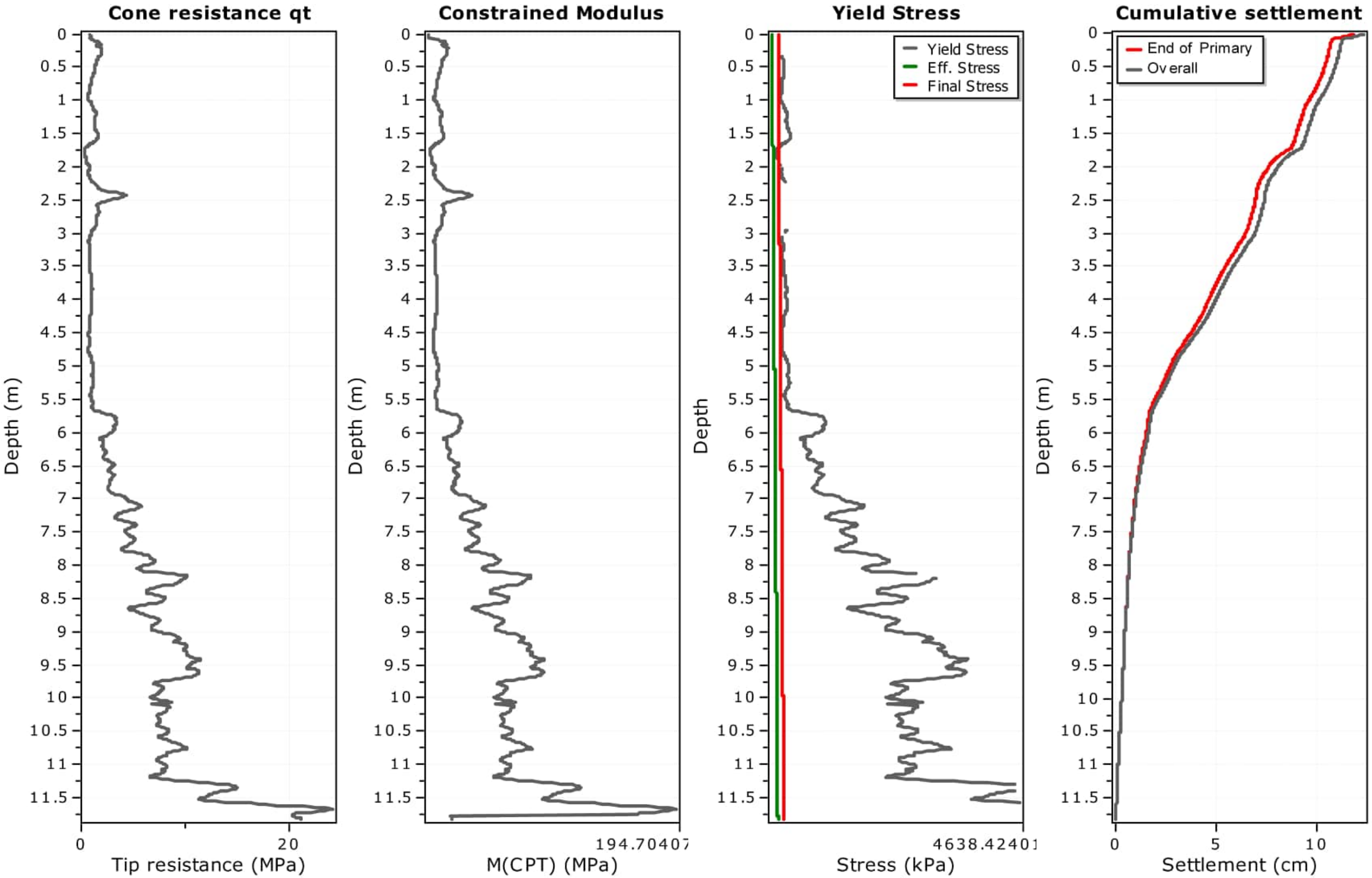
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 110.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

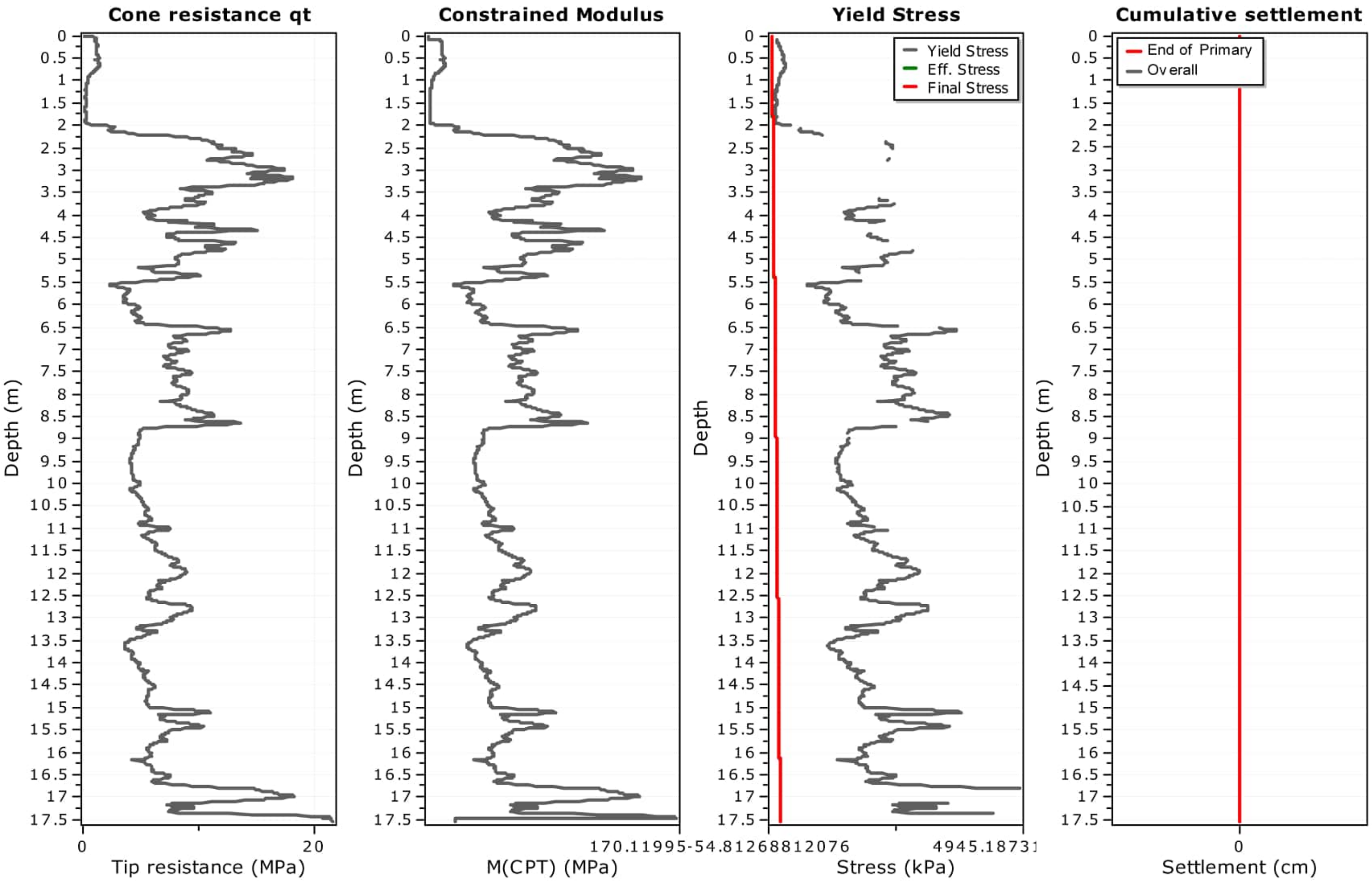
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT12

Total depth: 17.55 m, Date: 20/11/2024

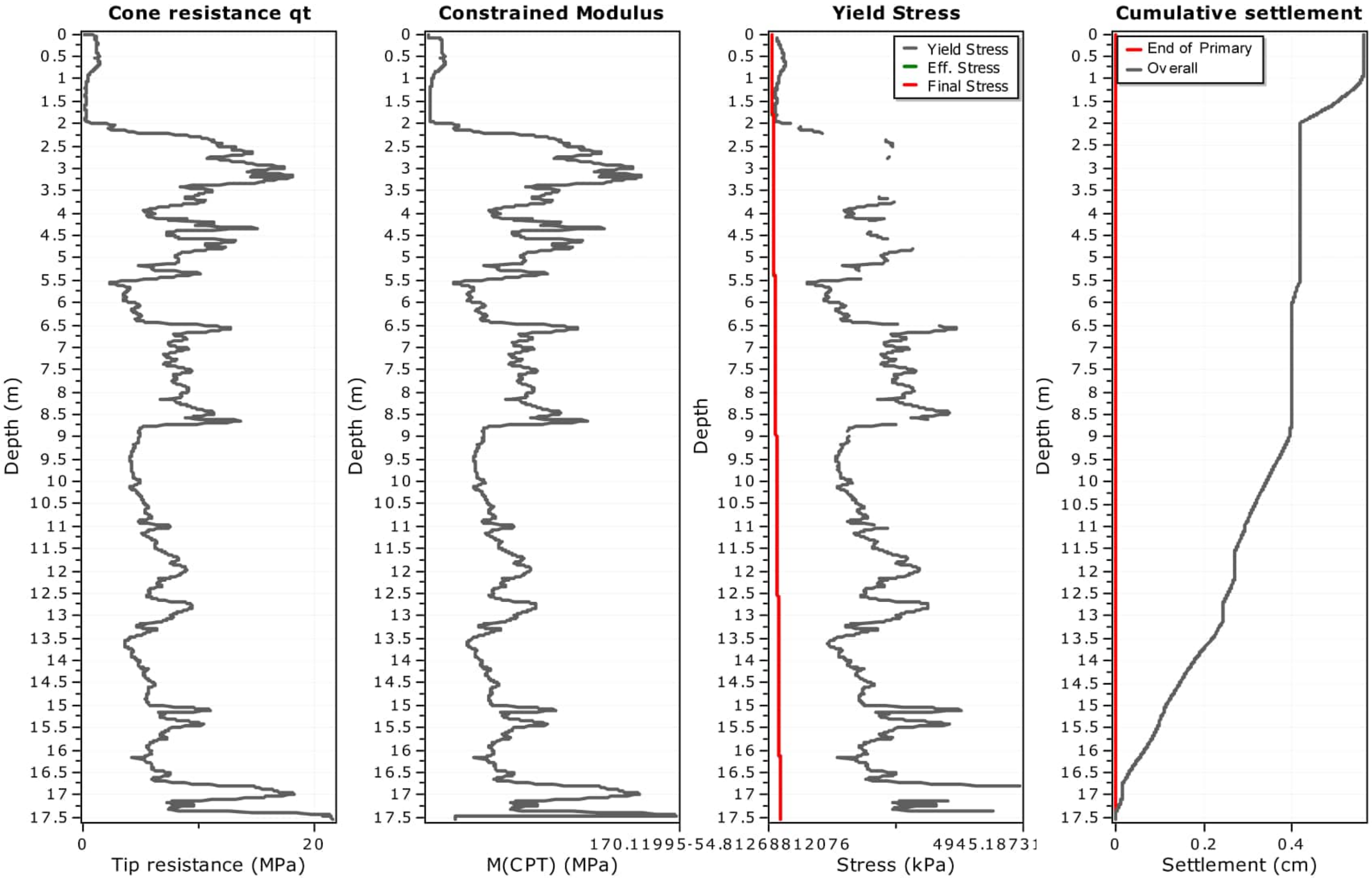
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 0.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

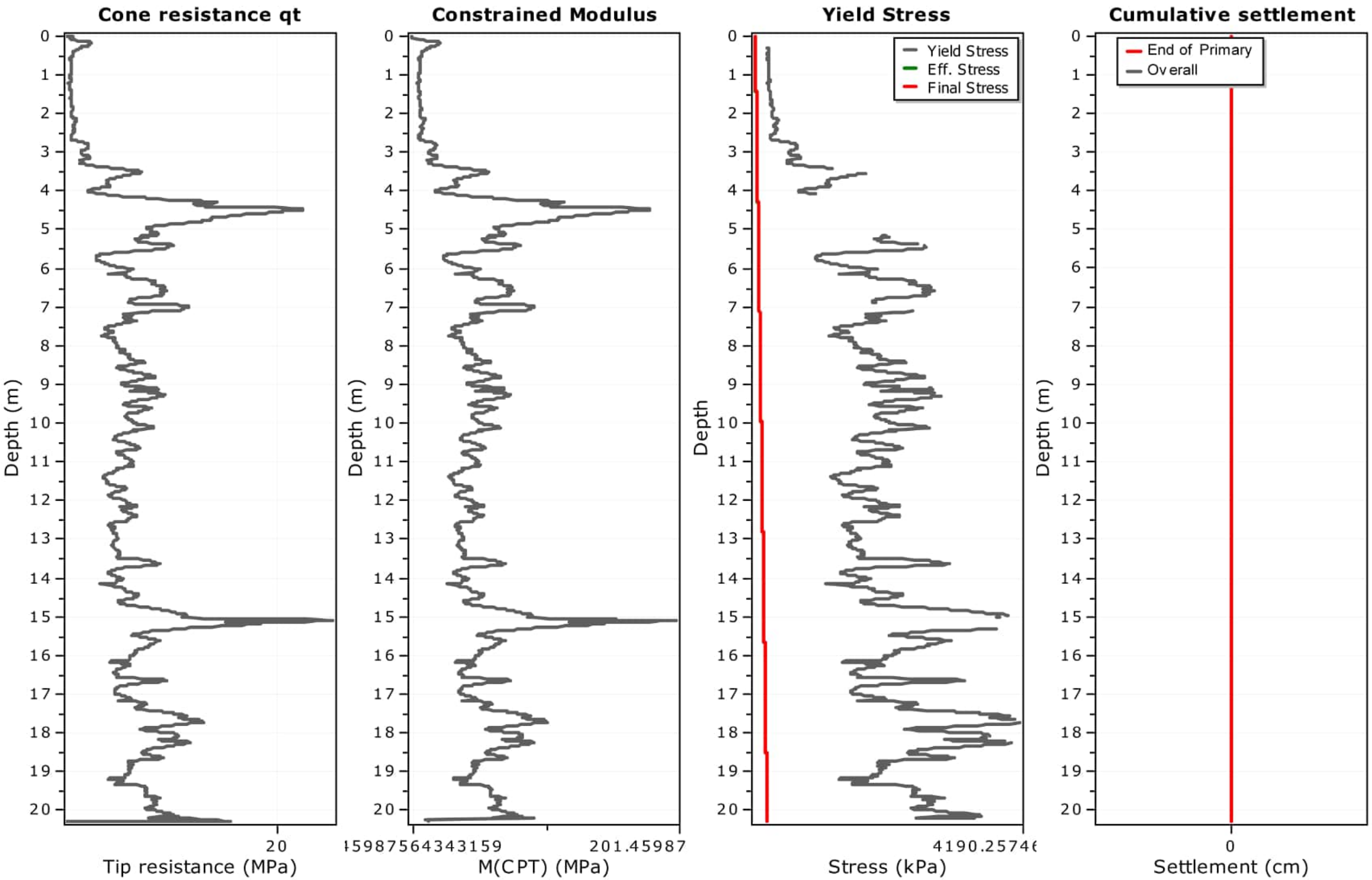
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

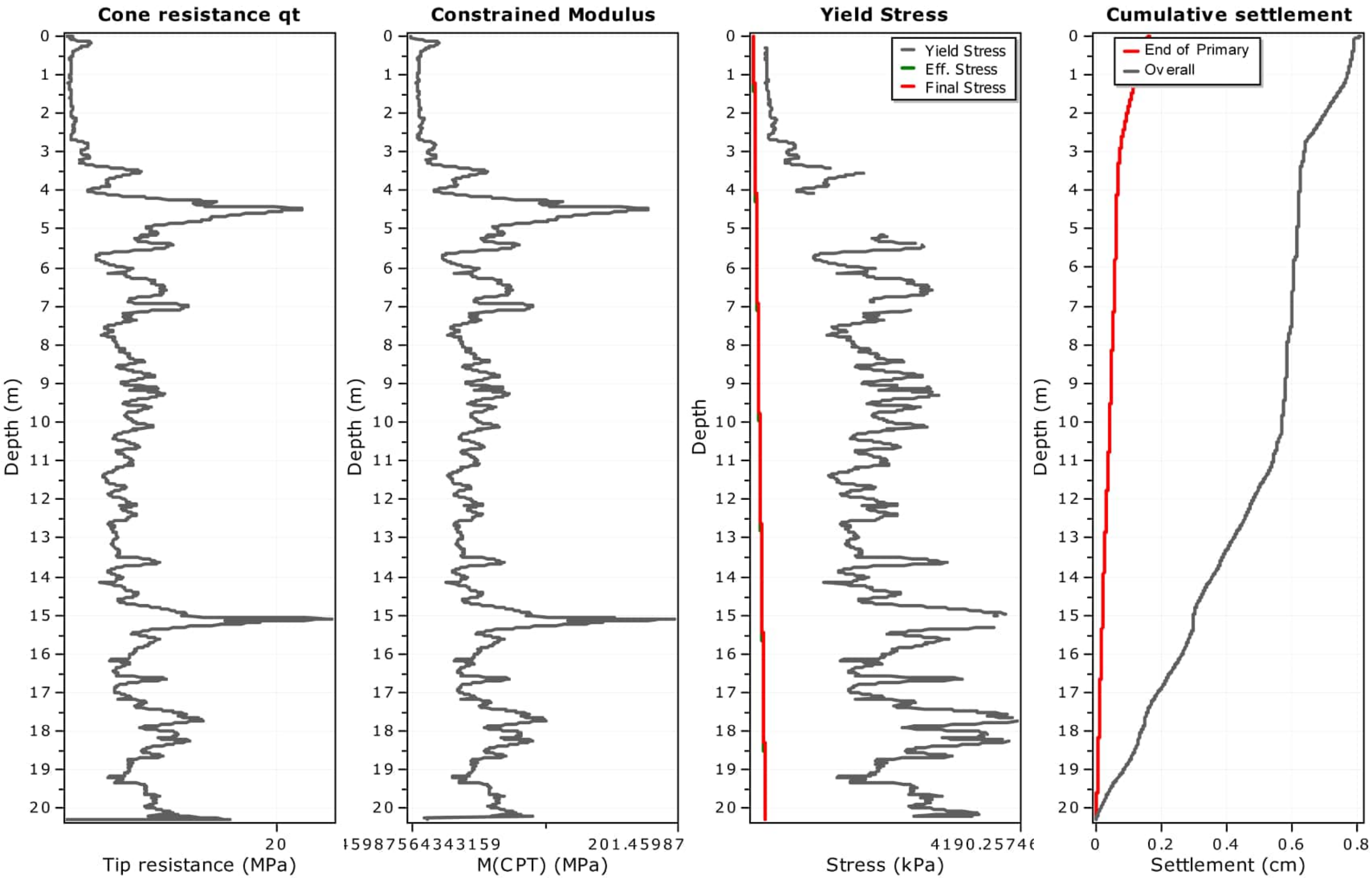
https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT13

Total depth: 20.29 m, Date: 20/11/2024
Surface Elevation: 0.00 m, Est. GWL: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 2.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

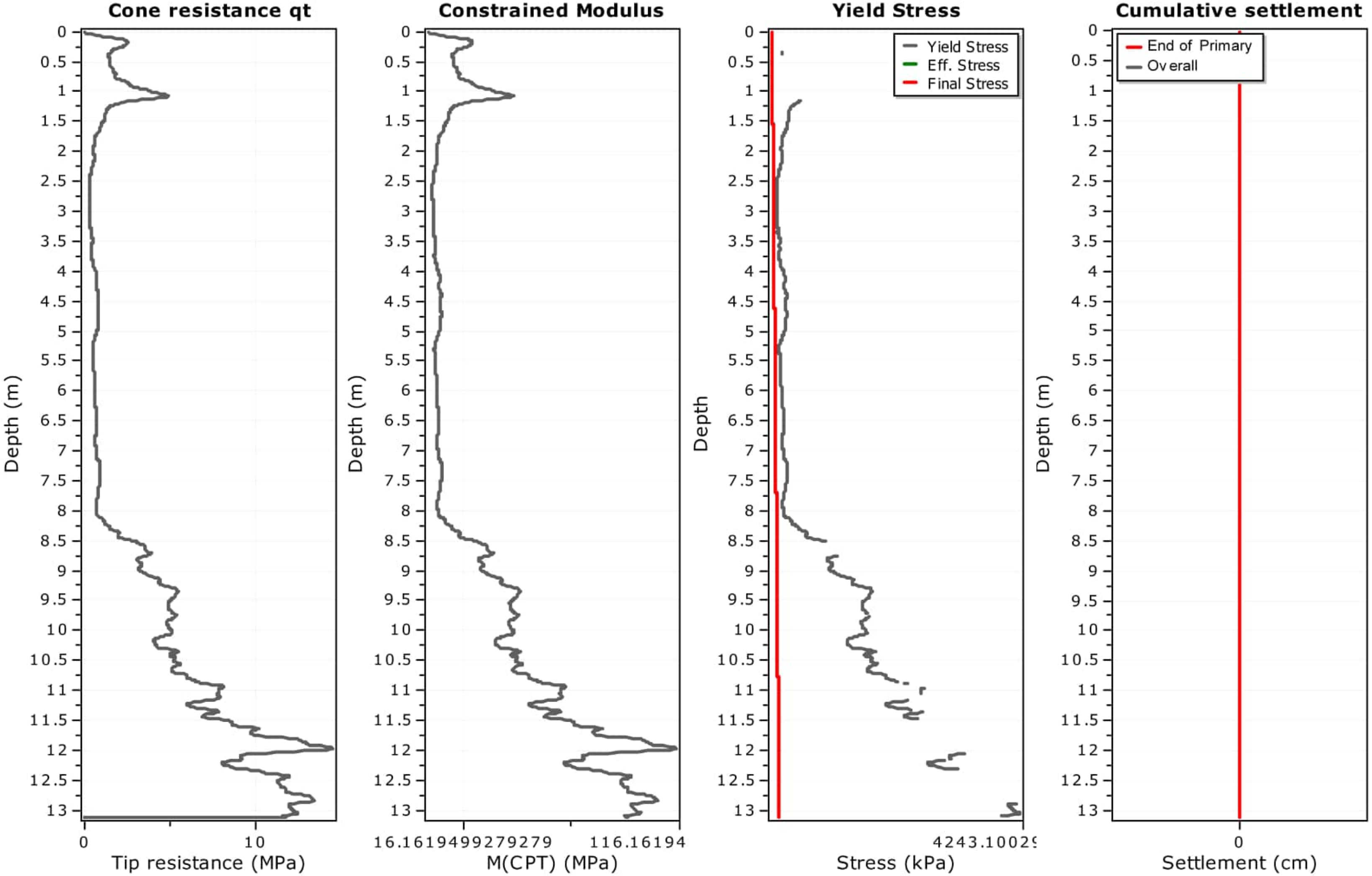
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 0.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: No
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2021-0014_CPT13

Total depth: 13.12 m, Date: 27/11/2024

Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

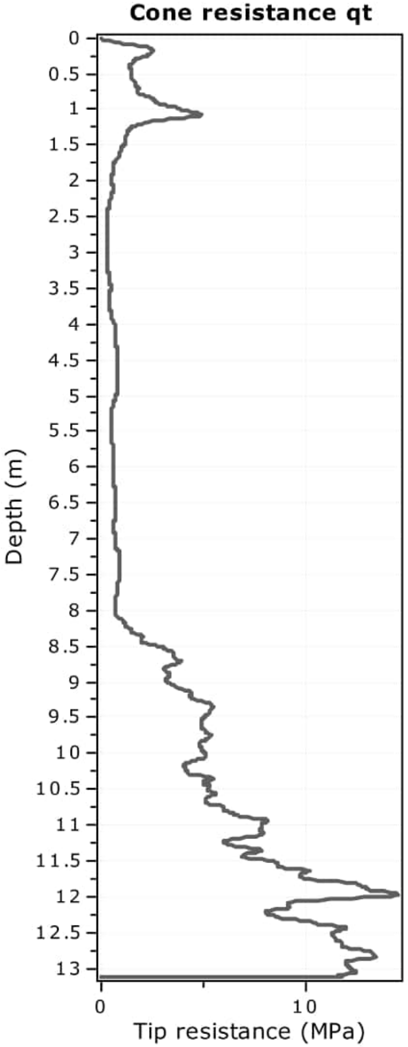
Project:

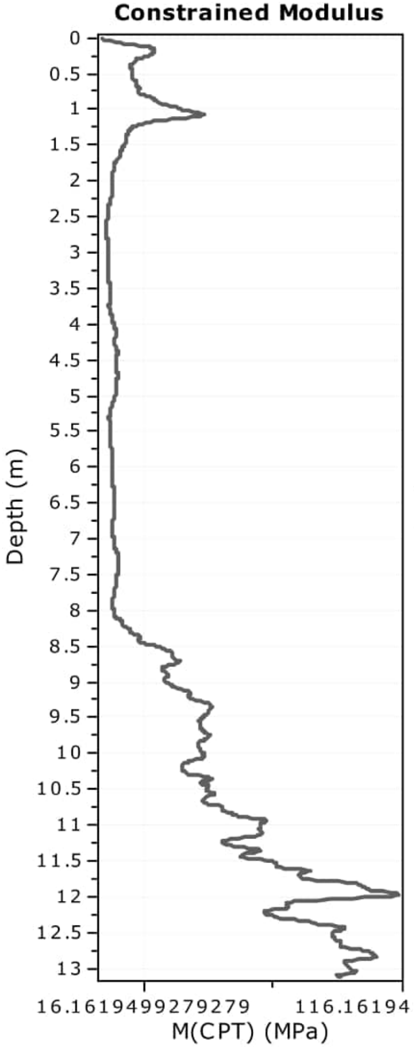
Location:

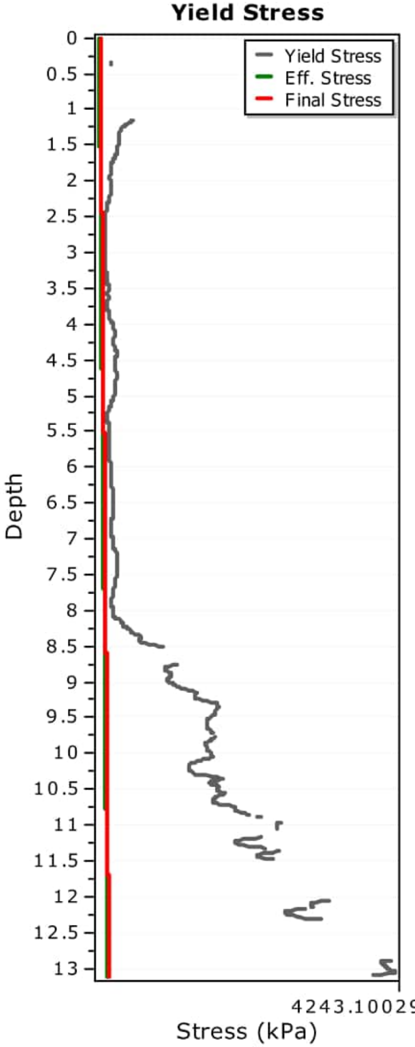
Cone Type:

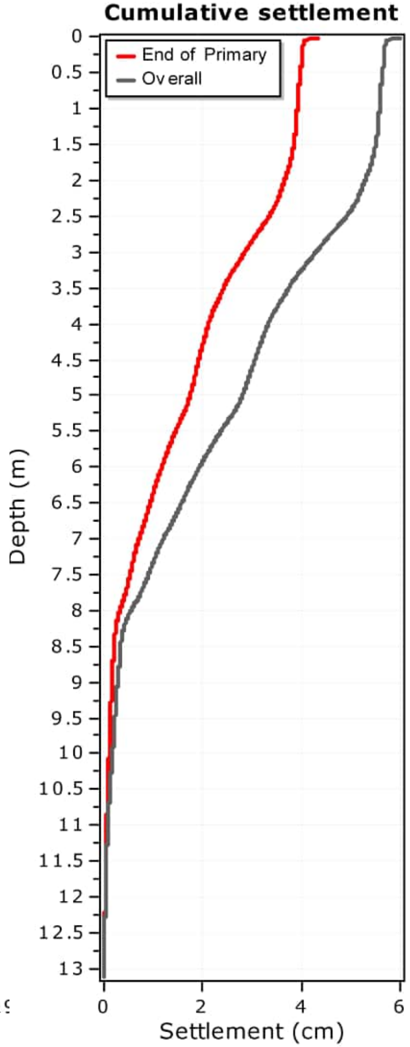
Cone Operator:

Settlements calculation according to theory of elasticity*









Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 20.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: No

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

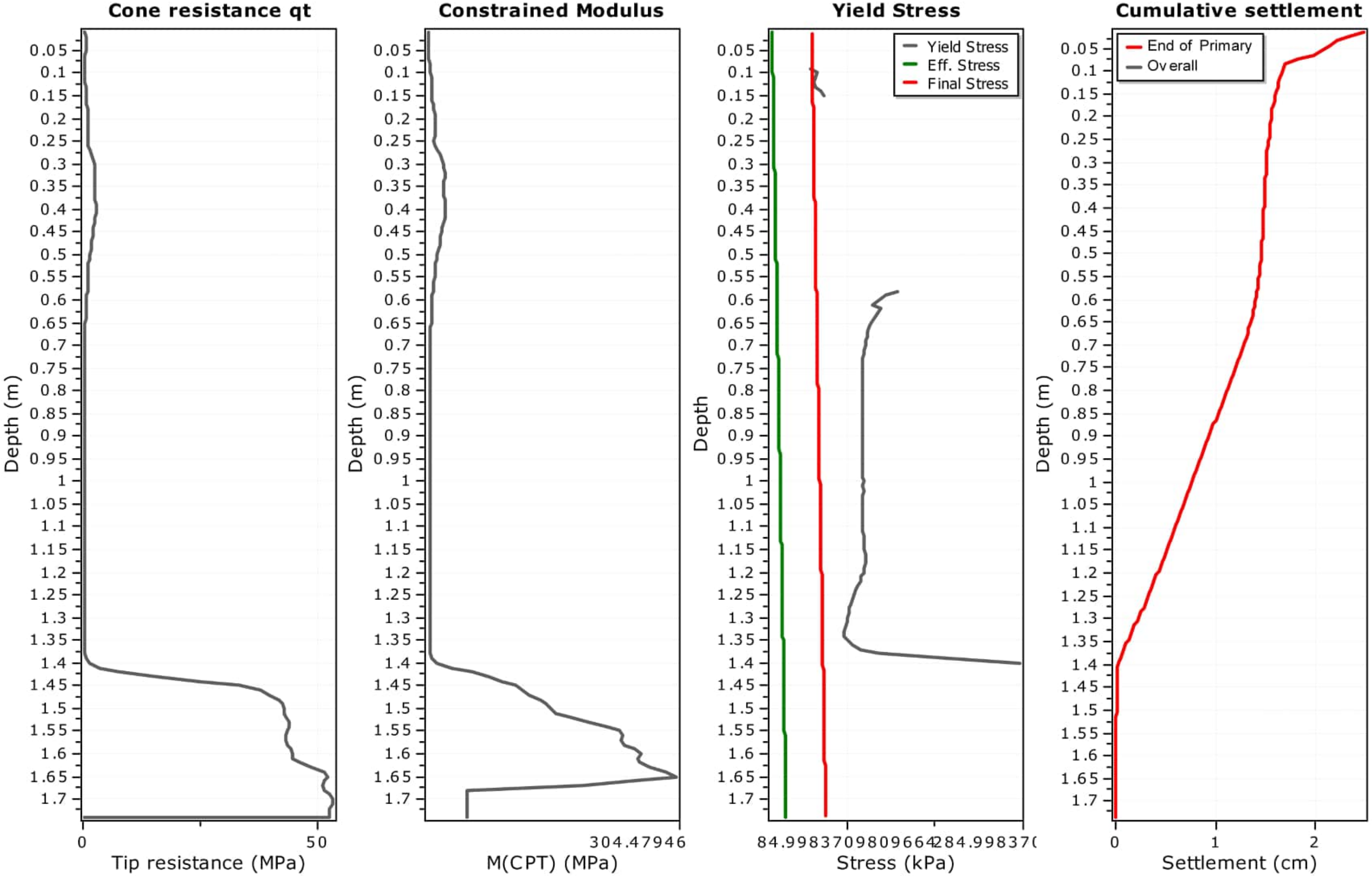
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 45.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: Yes
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT14

Total depth: 1.74 m, Date: 11/12/2024

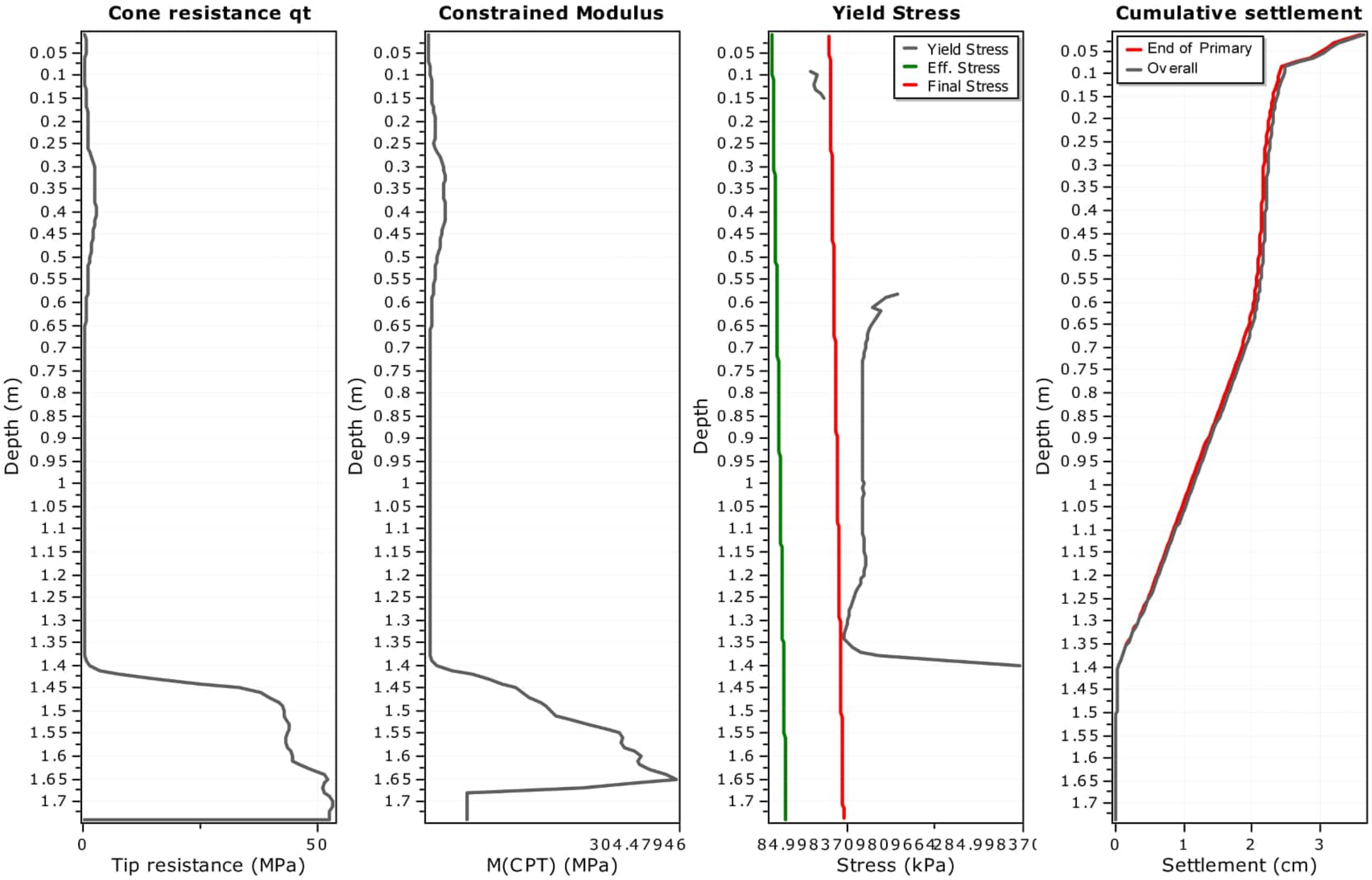
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 65.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: Yes

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

Project:

Location:

CPT: AKL2024-0257_CPT15

Total depth: 11.25 m, Date: 9/12/2024

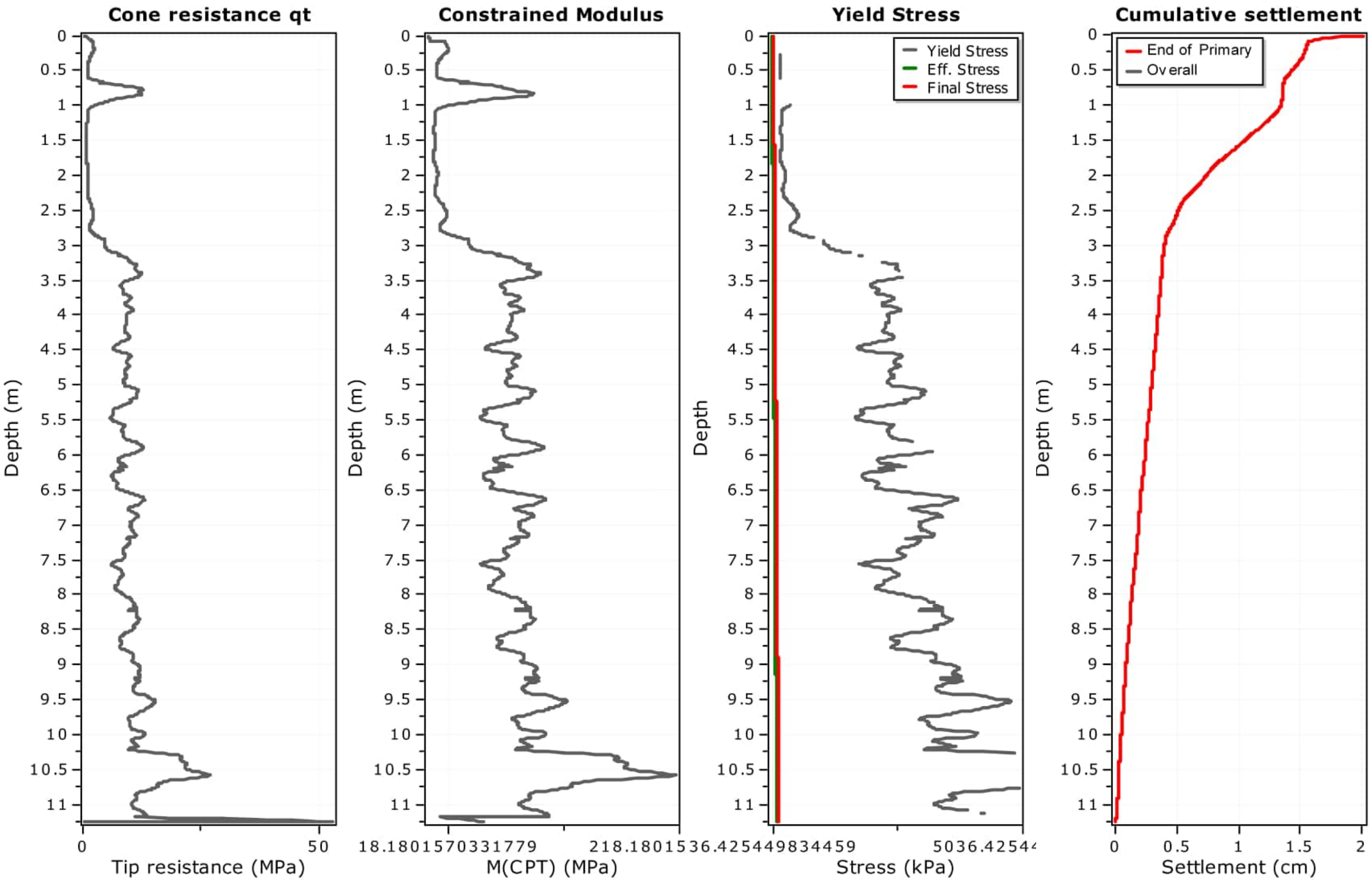
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Cone Type:

Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 36.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: Yes

Calculate secondary settlements: No

Time period for primary consolidation: N/A

Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

GEOLOGISMIKI Geotechnical Software

CMW Geosciences

https://www.cmwgeosciences.com/

CPT: AKL2024-0257_CPT15

Total depth: 11.25 m, Date: 11/12/2024

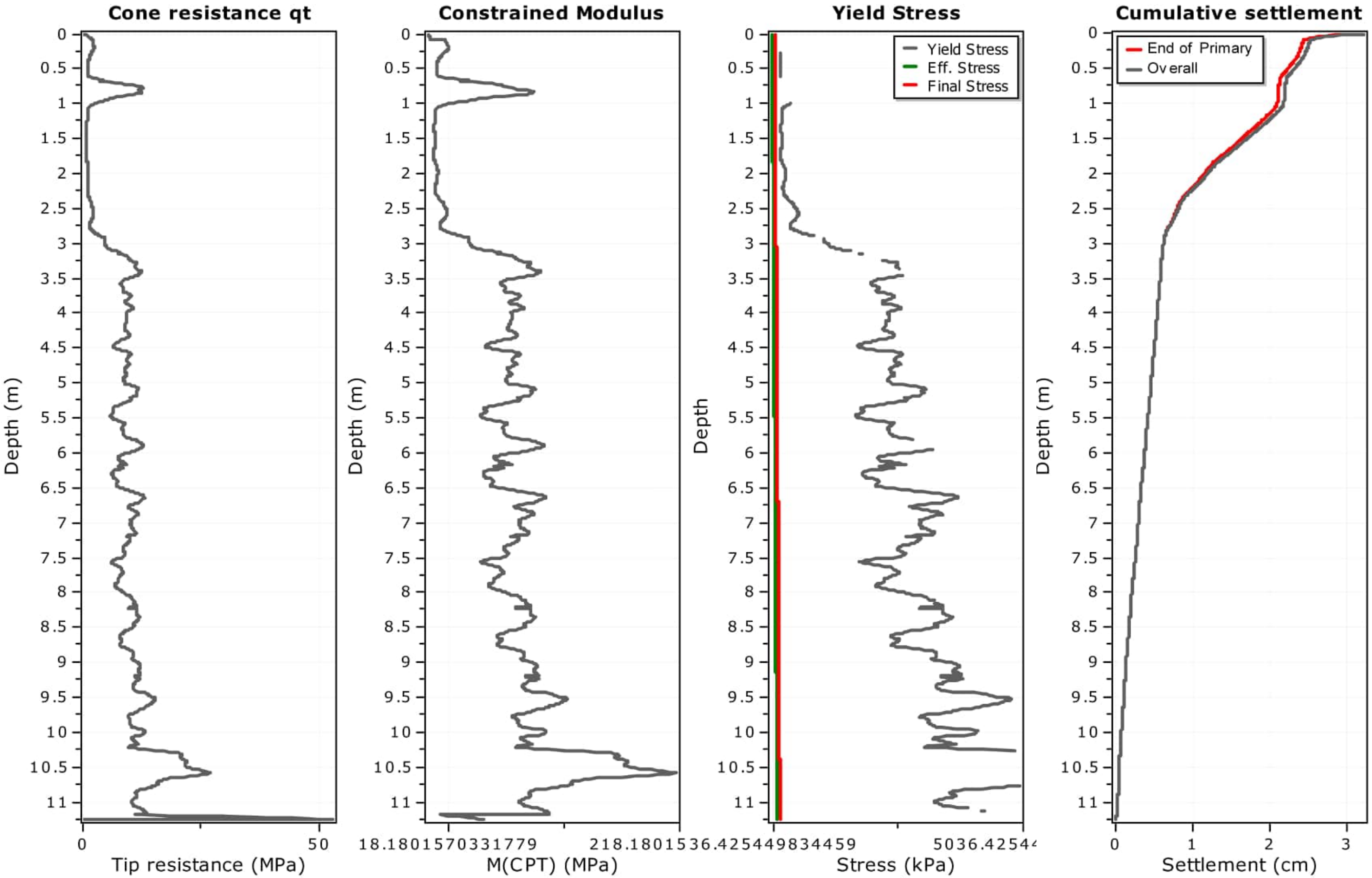
Surface Elevation: 0.00 m, Est. GWL: 0.00 m

Coords: X:0.00, Y:0.00

Project: Cone Type:

Location: Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular

Footing width: 100.00 (m)

L/B: 1.0

Footing pressure: 56.00 (kPa)

Embedment depth: 0.00 (m)

Footing is rigid: No

Remove excavation load: No

Apply 20% rule: Yes

Calculate secondary settlements: Yes

Time period for primary consolidation: 6 months

Time period for second. settlements: 594 months

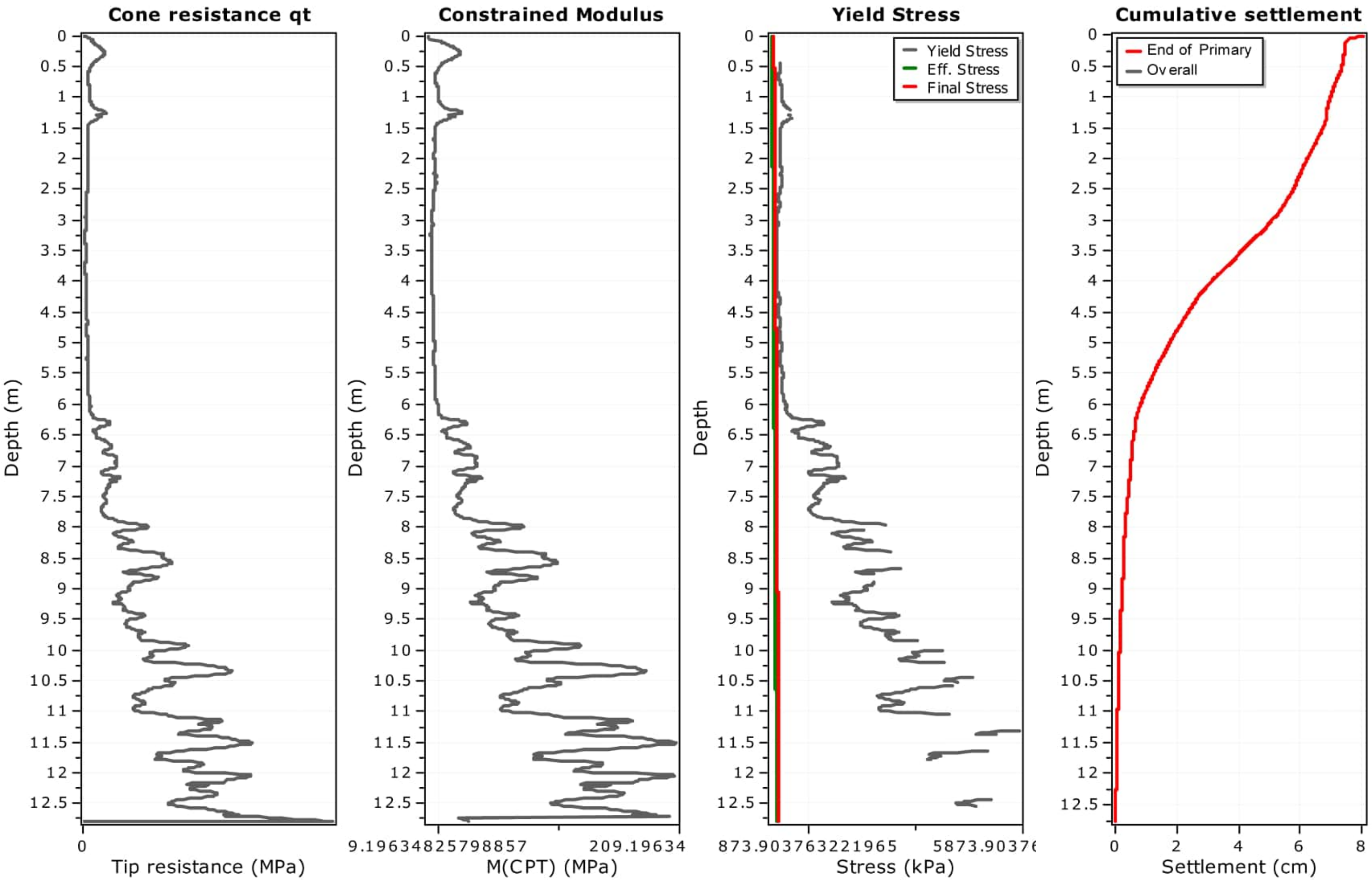
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 54.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: Yes
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

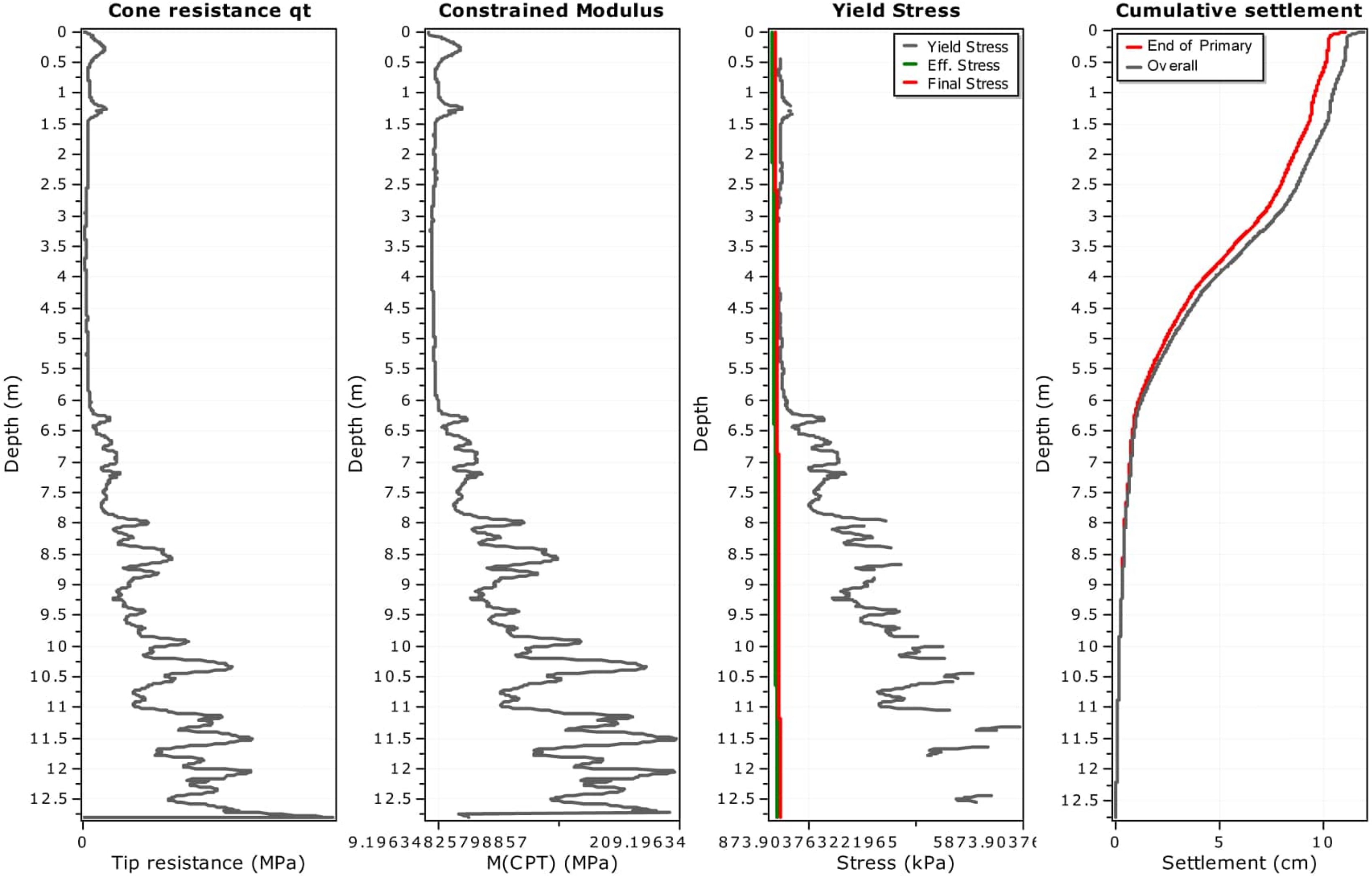
* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 74.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: Yes
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CMW Geosciences

https://www.cmwgeosciences.com/

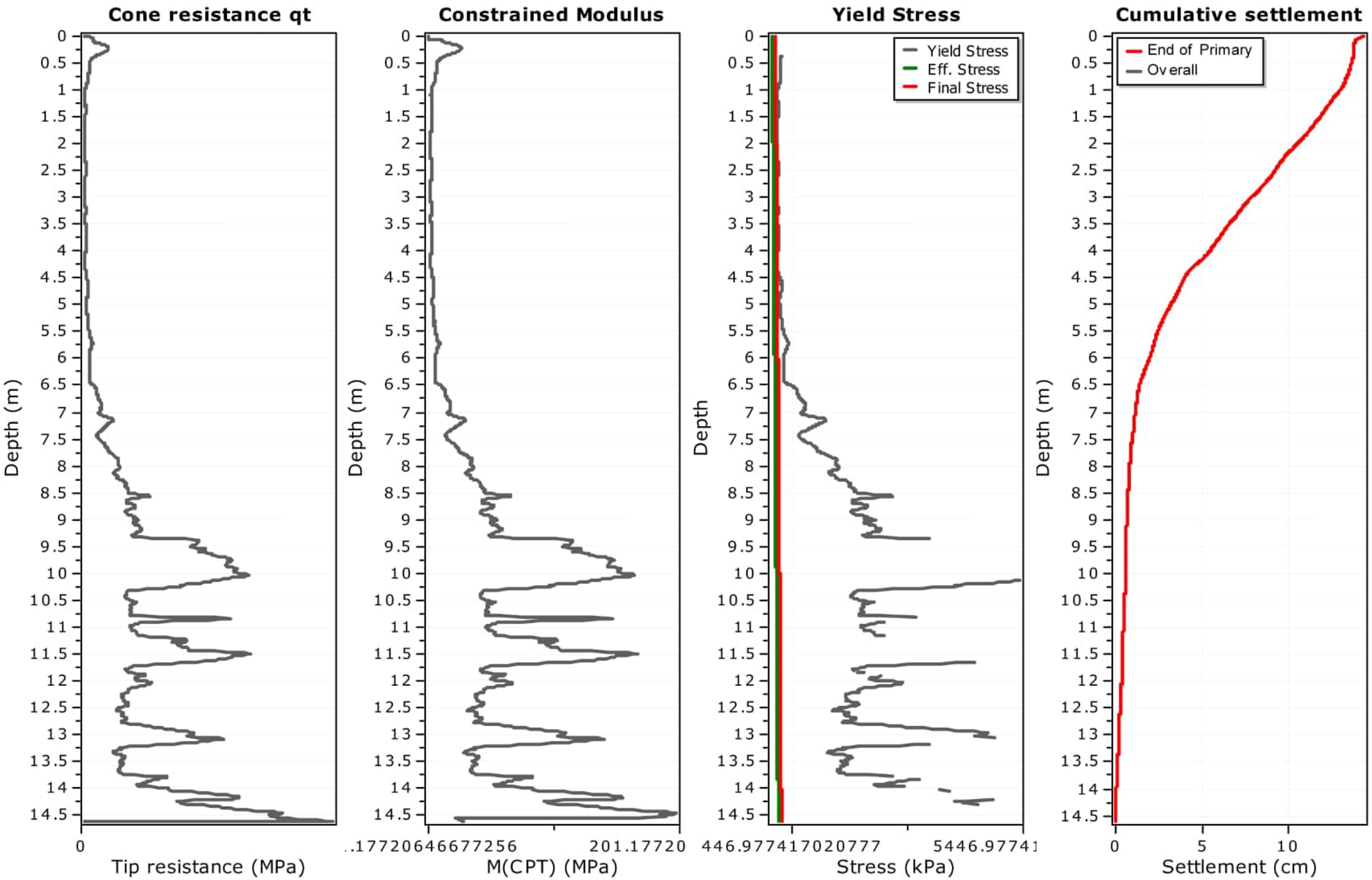
CPT: AKL2024-0257_CPT17

Total depth: 14.61 m, Date: 9/12/2024
Surface Elevation: 0.00 m, Est. GWL: 0.00 m
Coords: X:0.00, Y:0.00

Project:
Location:

Cone Type:
Cone Operator:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 72.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: Yes
Calculate secondary settlements: No
Time period for primary consolidation: N/A
Time period for second. settlements: N/A

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

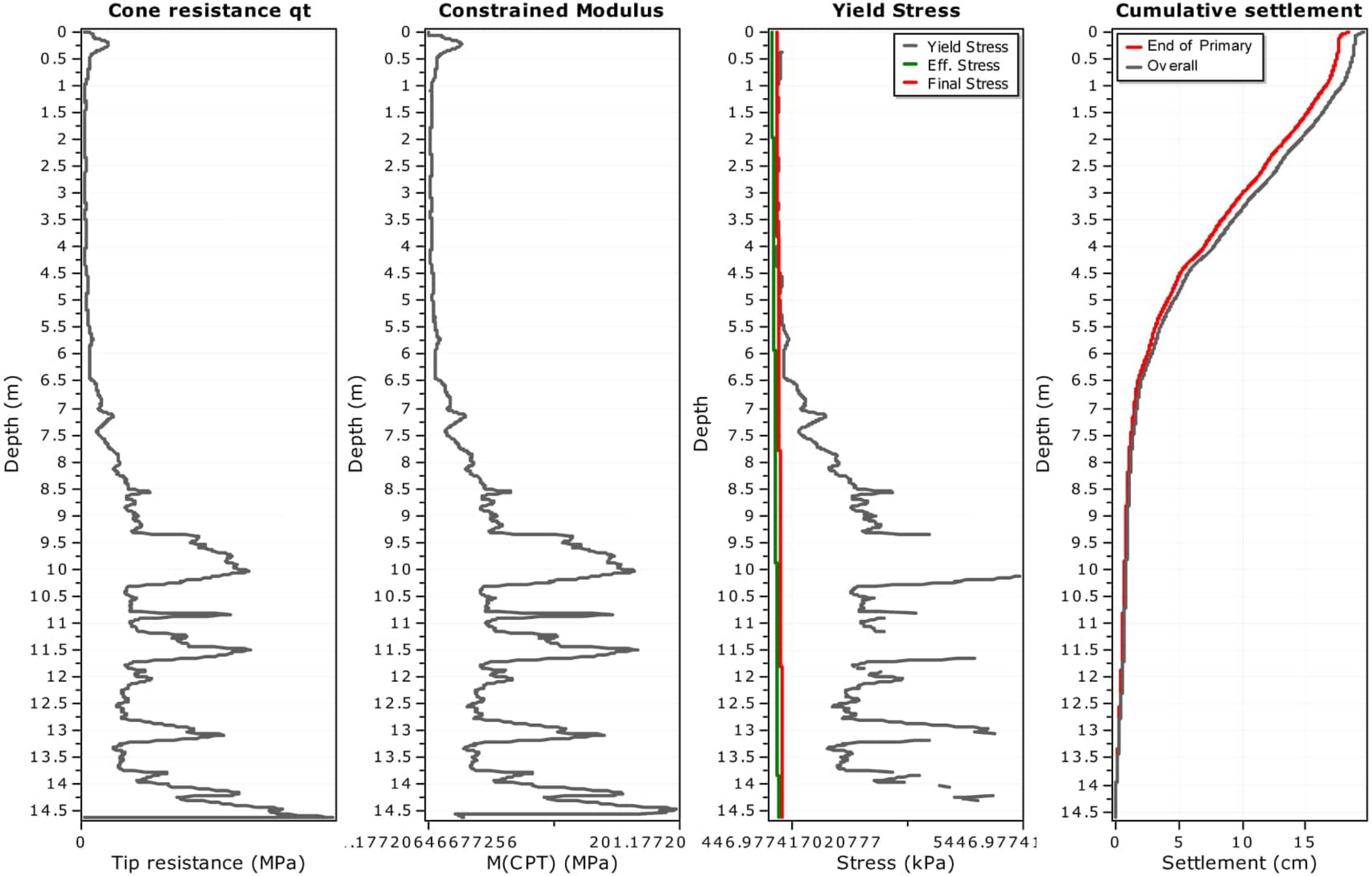
* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

CPT: AKL2024-0257_CPT17
Total depth: 14.61 m, Date: 11/12/2024
Surface Elevation: 0.00 m, Est. GWL: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

Settlements calculation according to theory of elasticity*



Calculation properties

Footing type: Rectangular
Footing width: 100.00 (m)
L/B: 1.0
Footing pressure: 92.00 (kPa)
Embedment depth: 0.00 (m)
Footing is rigid: No
Remove excavation load: No
Apply 20% rule: Yes
Calculate secondary settlements: Yes
Time period for primary consolidation: 6 months
Time period for second. settlements: 594 months

* Primary settlement calculation is performed according to the following formula:

$$S = \sum \frac{\Delta\sigma_v}{M_{CPT}} \Delta z$$

* Secondary (creep) settlement calculation is performed according to the following formula:

where t_p is the duration of primary consolidation

Appendix I: Geotechnical Works Specification

CMW Geosciences
Great People | Practical Solutions

27 March 2025

Proposed Residential Subdivision

Milldale Stages 10 to 13, Wainui East

EARTHWORKS SPECIFICATION

Fulton Hogan Land Development Limited

Job No. AKL2024-0257AE | Version 0

Auckland
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Rosedale 0632
New Zealand
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www.cmwgeosciences.com

Version control

Table 1: [Insert Table Caption]

Document version information	
Job number	AKL2024-0257AE
Prepared by	Melissa Campbell, Senior Engineering Geologist
Reviewed by	Chris Ritchie, Principal Engineering Geologist CMEngNZ, PEngGeol
Authorised by	Richard Knowles, Principal Geotechnical Engineer CMEngNZ, CPEng

Review and update history

Table 2: [Insert Table Caption]

Version	Date	Comments
A	26 March 2025	Initial draft for internal review
0	27 March 2025	Final draft for client review

CONTENTS

1.0 INTRODUCTION

CMW Geosciences (CMW) was engaged by Fulton Hogan Land Development Limited (FHLDL) to prepare an Earthworks Specification for a site located between Cemetery and Lysnar Roads, Wainui East, referred to as Milldale Stages 10 to 13, which is being considered for the construction of a residential subdivision.

This report has been prepared in support of the application by FHLDL for a Resource Consent to the Environmental Protection Authority (EPA) under the Fast-Track Approvals Act 2024 (FTAA).

This specification covers the geotechnical remediation works and associated earthworks outlined in the CMW Investigation Report (GIR), referenced AKL2024-0257AB Rev.3. It supplements the information provided on the design drawings and GIR. It provides detail on the required specification for:

- Site clearance and preparation including topsoil stripping and stockpiling.
- Geotechnical stabilisation works such as shear keys, geogrid reinforced earth slopes (with 30-degree face angle or less) and stability undercuts.
- Subsoil drainage installation.
- Cut to fill earthworks operations.
- Fill materials and testing requirements.
- Earthworks finishing and respread of topsoil; and,
- As-built records.

Excluded from the scope are geotextile reinforced slopes with a face and steeper than 30 degrees or retaining structures covered by a Building Consent. Such works will be carried out in accordance with an independent structure specific specification.

Unless varied onsite by the Geotechnical Engineer, the following specification requirements must be met in order for CMW to provide a Geotechnical Completion Report (GCR) for the works.

2.0 RELEVANT DOCUMENTS

2.1 Standards, Guidelines and Consents

The works shall comply with the relevant sections of the following standards, guidelines, and consents:

- Health and Safety at Work Act 2015 and Regulations 2016.
- All Project Resource Consent Conditions and Engineering Works Approvals.
- Auckland Council Code of Practice for Land Development and Subdivision Chapter 2 (v2, May 2023)
- Auckland Council Erosion and Sediment Control Guide, GD05 (August 2023).
- NZS 4431:2022 Engineered Fill Construction for Lightweight Structures.
- NZS 4402: 1986 Methods of Testing Soils for Civil Engineering Purposes; and,
- NZS 4404: 2010 Code of Practice for Urban Land Subdivision.
- WorkSafe NZ – Excavation Safety Good Practice Guidelines, July 2016.

2.2 Geotechnical Investigation Report

Details of the geotechnical investigation, soil and rock conditions encountered, and the design of the geotechnical remedial works are contained in the CMW report AKL2024-0257AB Rev.3. The contractor should be aware of the contents and comply with the recommendations contained in that report and any further specific design reports.

2.3 Construction Drawings

The works shall comply with the Construction Issue project drawings and details.

2.4 Conflicting Information

Where there is any conflict or discrepancy in the requirements of this specification and the documents listed above the matter shall be referred to the Geotechnical Engineer (CMW) for clarification.

3.0 GEOTECHNICAL OBSERVATIONS

The following items form hold points in the construction works that require observation, testing and approval by the Geotechnical Engineer (CMW):

- Foundations for filling once topsoil and unsuitable materials have been stripped prior to fill placement.
- Shear key excavations and undercuts to confirm depth and extents prior to backfilling.
- Subsoil drain excavations prior to placement of aggregate;
- Any imported soil fill materials prior to placement on site.
- Drainage aggregate quality prior to placement.
- Geotextile layers once in place and prior to backfilling.
- Filling placed at regular intervals to comply with the fill test frequency requirements below.
- Compaction of backfilling in critical service trenches.
- Flushing of the subsoil drainage system at the completion of earthworks.
- Any unforeseen ground conditions that may impact on the construction works or future land use; and,
- Installation of any settlement monitoring plates or points, application of pre-load and approval prior to its removal.

It is the contractor’s responsibility to ensure that the Geotechnical Engineer is given reasonable notice and opportunity to observe the above works and that the works do not proceed until approval has been gained from the Geotechnical Engineer.

24 hours is considered reasonable notice.

4.0 CONSTRUCTION SPECIFICATION

4.1 Site Preparation

The Contractor shall remove all vegetation from the site of the earthworks except for trees indicated for preservation by either markings on site or notes on the drawings.

Clearing shall mean the felling of all trees, except those indicated, removal of all growth other than grass and weeds, extraction of tree stumps, demolition of fences and other minor items remaining in the way of site stripping, and the complete disposal of all items. Stumping shall mean the removal of all roots greater than 25mm in diameter.

Cleared areas shall be stripped to remove all turf and organic topsoil to depths designated by the Engineer ahead of or during the stripping operations. Stripping shall also cover picking up any old topsoil stockpiles and any buried topsoil detected during the course of the works. The depth shall be sufficient to remove all materials considered unsuitable as fill or unsuitable to remain beneath fill but will not necessarily extend to the full limit of organic penetration.

4.2 Erosion and Sediment Control

The works shall be carried out in accordance with the project Erosion and Sediment Control Management Plan and associated drawings.

The contractor shall ensure good control of surface water runoff at all times by shaping of the surface in cut and fill areas to prevent ponding during rainfall events.

The location of temporary Sediment Retention Ponds (SRP) on sloping ground shall be decided upon with input from the Geotechnical Engineer. Where comment of SRP stability is sought by Council then all fill materials used to form batters, must be placed as engineered fill and tested accordingly unless advised otherwise by the Geotechnical Engineer.

When decommissioning temporary sediment ponds, all water softened material in the bases and sides of the ponds shall be removed and undercut to the satisfaction of the Geotechnical Engineer. Backfilling of temporary ponds shall be to the compaction standard for general filling unless otherwise specified.

4.3 Stockpiles

Topsoil stockpiles can add significant driving force for slope instability when placed at or near the crest of a slope. The location of all temporary stockpiles must be approved by the Geotechnical Engineer prior to placement. Where stockpiles cannot be avoided above sloping ground, they should be placed over a wide area with the height restricted under the direction of the Geotechnical Engineer.

4.4 Fill Foundations and Benching Slopes

The foundation on which filling is to be placed must be observed by the Geotechnical Engineer following clearing and prior to the placement of any filling to confirm the strength of the underlying soils is sufficient.

Where it is found, after clearing and stripping operations as specified, that the foundation on which filling is to be placed is unstable, or in cuttings if it is found after the excavation has been cut down to the levels shown in the drawings that unstable ground is encountered, then the Engineer may direct that the soft, yielding, or unstable materials causing such instability shall be removed to such depth as directed.

Benching of slopes prior to the placement and compaction of filling should be carried out in accordance with the normal requirements of NZS 4431 and related documents as mentioned above, especially on the steeper areas of the site, to ensure that the filling placed is keyed into the underlying natural ground. This would involve the cutting of benches approximately the width of a bulldozer, with a slight reverse gradient back into the slope. The optimum depth of each bench is best confirmed by careful Engineering inspections during construction.

4.5 Shear Key, Fill Drainage Key and Buttress Fill Excavations

All shear keys, fill drainage keys and buttress fills required to improve long term stability conditions are to be constructed in accordance with the design drawings and standard details. The key/buttress base width, lateral extent and benching requirements need to be confirmed on site by the Geotechnical Engineer during construction. In most cases this requires detailed logging of the excavation faces by a geo-professional and may require trial pits to be dug in the base of the excavation. The contractor should make allowance for the time and plant required for these inspections in their work programme.

4.6 Fill Materials and Conditioning

4.6.1 Material Types

Table 3: Material Types

Material Type	Description	Comments
T	Topsoil	Natural material at surface
F	Fine-grained	≥35% material passing the 75μm sieve. 100% passing 19mm sieve.
I	Intermediate-grained	15% to 35% passing the 75μm sieve. 100% passing 75mm sieve.
C	Coarse Grained or aggregate	15% material passing the 75μm sieve. 100% passing 150mm sieve.
R	Rock	Material described as rock as per NZGS Field Description of Soil and Rock
M	Manufactured	Any manufactured material created or modified for the purpose of earthworks (such as crushed concrete, recycled asphalt, etc)

The soils at this site are predominantly classified as material type F.

4.6.2 Blending of Unsuitables

The blending of 'unsuitables' into structural fills may be undertaken only at the discretion of the Geotechnical Engineer following a request by the contractor and with sufficient time for appropriate consideration. Approval for any such blending must be sought from and provided by the Geotechnical Engineer in writing prior to the commencement of any blending.

In consideration of any such requests, the Geotechnical Engineer will need to be able to assess, inter alia, the composition of the materials requested to be blended, the location on the site for the proposed fills, the fill depths and the elevation of the blended materials within the fills and any environmental constraints.

As a minimum, it is expected that any blended fills will be directed to comply with the following conditions:

All significant, solid inorganics (such as roots and stumps) to be removed prior to blending; and,

All inclusions of suitable man-made materials (e.g. concrete) and any excavated rock must comply with the normal compaction requirements specified herein in terms of size and ability for appropriate compaction to be achieved in close vicinity to the inclusions. Aqueduct

All blended materials must be appropriately mixed/ blended normal fill materials to the specified ratio. Un-mixed interlayering of normal engineered filling with unsuitables will not be accepted.

As a preliminary indication, it is expected that the ratio of unsuitables to suitable fill will not exceed 1 in 10 by volume.

It is expected that the Geotechnical Engineer will also need to apply limits to the location/ depth of blended fills within any specified fill area.

4.6.3 Hardfill

Hardfill used as structural filling shall be a graded, unweathered, durable, crushed rock product approved by the Geotechnical Engineer, with a grading suitable for compaction.

4.6.4 Material Conditioning

The cut materials on site may require some drying prior to compaction to achieve the required specification. This may be done by harrowing (such as with discs) and air drying when conditions permit or by the addition of hydrated lime. Block cutting to blend drier, deeper deposits with wetter, shallower deposits is typically a successful strategy in the geology on this site.

The addition of lime and/or cement to engineered filling in concentrations greater than 3% requires the approval of the Geotechnical Engineer.

All additives such as lime or cement proposed for use in backfill materials for Reinforced Earth Slopes or other materials in contact with geosynthetics must be approved and monitored by the Geotechnical Engineer.

4.7 Fill Placement, Compaction and Testing Requirements

4.7.1 Soil Fill

Soil placed in fills shall be conditioned and compacted until the following conditions are satisfied.

It should be noted that the surface of the fill area prior to placement of subsequent fill lifts should be in a state so as not to create a break in the consistency of the fill material between lifts. For example, if surfaces are left to dry out, or rolled to seal them from rainfall infiltration then the surface must be broken up and scarified with rippers or by other means to ensure a good bond between fill lifts.

The maximum lift of filling placed before compaction is dependent on the size and nature of the compaction equipment. Typically, 250mm to 300mm loose depth is considered the maximum for a Cat 815/820 type compactor. In any event the contractor must ensure that the fill is placed and compacted to achieve even and adequate compaction throughout each layer/lift.

The test criteria and frequency are set out below.

Table 4: Soil Fill Testing Requirements

Material Type	Test and Methods	Acceptance Requirements	Min. Frequency
F (Fine Grained)	Particle size distribution (NZS4407 test 3.8 or NZS4402.2.8.1)	Refer to Table 1	1 per source and 1 per change in material
	Dry density / water content relationship (NZS4402.4.1.1, NZS4402.4.1.2)	OMC and MDD determined	
	Water content (NZS4402.2.1)	Between OMC -2% and OMC +4%	
	Solid density (NZS4402.2.7.1 or 2.7.2)	Solid density determined	
	Field water content and density (NDM) (NZS4402.2.1 and NZS4407 test 4	Maximum 10% air voids over 10 tests. Maximum single value 12%	2 per 1,000m^3 (minimum 2 per lift)
	Shear strength (NZGS guideline for hand held shear vane)	Minimum average 140kPa over 10 tests. Minimum single value 110kPa	Minimum 1 set of tests per 500m^3 (minimum 2 per lift)
I (Intermediate Grained)	Particle size distribution (NZS4407 test 3.8 or NZS4402.2.8.1)	Refer to Table 1	1 per source and 1 per change in material
	Dry density / water content relationship (NZS4402.4.1.1, NZS4402.4.1.2)	OMC and MDD determined	
	Water content (NZS4402.2.1)	Between OMC -2% and OMC +4%	
	Solid density (NZS4402.2.7.1 or 2.7.2)	Solid density determined	
	Field water content and density (NDM) (NZS4402.2.1 and NZS4407 test 4	Maximum 10% air voids over 10 tests. Maximum single value 12%	2 per 1,000m^3 (minimum 2 per lift)
	Shear strength (NZGS guideline for hand held shear vane)	Minimum average 140kPa over 10 tests. Minimum single value 110kPa	Minimum 1 set of tests per 500m^3 (minimum 2 per lift)
C (Coarse Grained)	Particle size distribution (NZS4407 test 3.8 or NZS4402.2.8.1)	Refer to Table 1	1 per source and 1 per change in material
	Dry density / water content relationship (NZS4402.4.1.1, NZS4402.4.1.2)	OMC and MDD determined	
	Water content (NZS4402.2.1)	Between OMC -2% and OMC +4%	
	Solid density (NZS4402.2.7.1 or 2.7.2)	Solid density determined	
	Field water content and density (NDM) (NZS4402.2.1 AND NZS4407 test 4)	>90% MDD	1 per 1,000m^3 (min 2 per lift)
	Dynamic Cone Penetrometer	>5 blows per 100mm	2 per 1,000m^3 (min 2 per lift)

The test criteria and/or frequency may be relaxed at the discretion of the Geotechnical Engineer (CMW) for the project or in a discrete fill area subject to the consistency of the results achieved being acceptable over a specified period of time.

4.7.2 Site Won Rock Fill

A compaction specification is to be determined by the Geotechnical Engineer based on site trials.

4.7.3 Hardfill

The test criteria and frequency are set out below for hardfill.

Table 5: Hardfill Testing Requirements

Material Type	Test and Method	Acceptance Requirement	Min. Frequency
GAP 65	Particle size distribution (NZS4407 test 3.8 or NZS4402.2.8.1)	Refer GAP65 particle size criteria in NZS4431 (Table A2)	1 per source and 1 per change in material
	Dry density / water content relationship (NZS4402.4.1.1, NZS4402.4.1.2)	OMC and MDD determined	
	Solid density (NZS4402.2.7.1 or 2.7.2)	Solid density determined	
	Weathering quality index	AA, AB, AC, BA, BB or CA	
	Field water content and density (NDM) (NZS4402.2.1 AND NZS4407 test 4)	>95% MDD	1 per 1,000m^3 (min 2 per lift)
	Impact test – 4.5kg hammer (ASTM D 5874)	CIV > 25	1 per 50m^2 on each compacted layer (min 2 per lift)
GAP 40	Particle size distribution (NZS4407 test 3.8 or NZS4402.2.8.1)	Refer GAP40 particle size criteria in NZS4431	1 per source and 1 per change in material
	Dry density / water content relationship (NZS4402.4.1.1, NZS4402.4.1.2)	OMC and MDD determined	
	Solid density (NZS4402.2.7.1 or 2.7.2)	Solid density determined	
	Weathering quality index	AA, AB, AC, BA, BB or CA	
	Field water content and density (NDM) (NZS4402.2.1 AND NZS4407 test 4)	>95% MDD in general fills >98% MDD in road pavements	1 per 1,000m^3 (min 2 per lift)
	Impact test – 4.5kg hammer (ASTM D 5874)	CIV > 25	1 per 50m^2 on each compacted layer (min 2 per lift)

4.7.4 Compaction Testing Reporting Requirements

All test location coordinates to be recorded by handheld GPS with reference to the NZTM projection. If testing is undertaken by the contractor, test location coordinates, with date and test number reference are to be provided to the Geotechnical Engineer in electronic (excel) format on a weekly basis. Alternatively, the Geotechnical Engineer may approve the use of site plans to mark the location of tests in lieu of GPS location.

The volume of filling placed for each progress claim month (typically ending 20th of the month) including all filling placed (undercut and cut to fill) to be provided to the Geotechnical Engineer monthly by the contractor or Engineer to the Contract to allow assessment of test frequency adequacy.

Interim fill test summaries are to be provided to the Geotechnical Engineer for review on a regular basis.

4.8 Subsurface Drainage

4.8.1 General

Drainage for shear keys, fill drainage keys, buttress fills, underfill gully drains and counterfort drains shall be constructed in accordance with the design drawings and standard details.

4.8.2 Materials

4.8.2.1 Pipes

Drainage pipes used in subsoil drainage shall be 160mm diameter highway grade drain coil. Drain coil walls shall be perforated or solid as detailed in the design drawings or directed by the Geotechnical Engineer on site. Drain coils shall not have a geofabric filter sock unless requested by the Geotechnical Engineer on site.

4.8.2.2 Aggregate

Auckland Council now generally require that subsoil drainage has a 100-year design life and is essentially maintenance free, unless there is an entity such as body corporate or resident's association that maintenance responsibility can be transferred to. Maintenance by individual owners is not practical as the subsoil drainage systems usually cross over, and generally benefit, multiple lots.

This requires a high-quality drainage aggregate with the following properties:

- Self-filters against the soils present on site preventing loss of permeability over time; or, able to be practically wrapped in a suitable geofabric filter.
- High permeability, which translates to a low fines content; and
- Stable and not subject to crushing, weathering, internal erosion or piping, or significant loss of volume (settlement) over time.

Ideally the drainage aggregate should be a well graded self-filtering material such as a clean (free of significant cohesive fines) scoria SAP50 product or Transit F/2 specification filter media.

Alternatively, for shear key drainage, blanket drains, underfill drainage and all applications where full encapsulation with a geofabric filter cloth can be relatively simply and safely achieved, an open graded product, preferably 27/7 Scoria may be used. Care will need to be taken to ensure that the cloth fully encapsulates the aggregate. Observation of the cloth wrap should form an inspection hold point prior to backfilling over the drain. Drain coils in this instance do not require a filter sock.

For counterfort trench drains and applications where a full filter cloth wrap is not practical to construct, and the performance of the drain is not critical to maintaining slope stability then a SAP20 or SAP50 may be used without a filter cloth wrap. Drains which fall into this category must be defined and confirmed as such by the Geotechnical Engineer. Additionally, where such materials are used, regular visual inspections and approval of the aggregate quality and laboratory grading curves is required. This is to comprise visual inspection of each site stockpile prior to material being placed in the trench. One wet sieve grading curve from each site stockpile per week is required while material is being imported to site to monitor the fines content. Drain coils in this instance do not require a filter sock.

For counterfort trench drains and applications where a full filter cloth wrap is not practical to construct, and the performance of the drain is critical to maintaining slope stability then a TNZ/F2 or (approved) modified F2 aggregate must be used. In conjunction with this an approved high specification drainage pipe with filter cloth surround such as the Megaflo products may be specified.

Light compaction (i.e. tamping with back of excavator bucket) only is to be applied to drainage aggregates.

4.8.2.3 Filter Cloth

Any filter cloth surround specified on the drawings shall meet the requirements of Transit Specification TNZ/F7, Filtration Class 2 and Strength Class B unless otherwise specified on the drawings.

4.8.2.4 Trench Backfill in Service Trenches

It is important on all sloping land that service trenches running parallel to contours are avoided where possible as they can permit the ingress of surface water and/or lateral movement of trench sides that could lead to progressive land slippage, help develop tension cracks and possibly lead to slope and building instability.

Backfilling of all trenches should be to the general fill standard above unless specifically varied in writing by the Geotechnical Engineer and where possible the pipe bedding in all trenches on steep ground should contain a 50mm diameter perforated drain coil that is connected into each manhole on the line. This is to help prevent instability arising from the ingress of surface water and/or lateral movement of trench sides that could lead to progressive land slippage and is especially important where the lines are in close proximity to buildings.

The subdivision drain laying contractor must be made aware of these requirements and of the need to contact us when trench backfilling is to take place.

4.8.3 Depth and Extent

The location, extent and depth of the drainage shown on the design drawings may be varied on site by the Geotechnical Engineer in response to the ground conditions encountered.

4.8.4 Drainage Outlets and Inspection Points

Outlets for subsurface drainage shall be provided at regular intervals as shown on the drawings or as determined on site by the Geotechnical Engineer. Pipe outlets shall be specifically formed structures with adequate protection such as a headwall and/or rock rip rap. The position of all outlets shall be recorded on the as-built drawings.

Where possible it is good practice to include additional inspection and/or flushing points in the subsoil drainage system in the event that their performance needs to be confirmed in the future.

In any event, at least one temporary flush point is required for each subsoil drainage system to enable flushing of the system once the earthworks are substantially complete.

The flushing of the subsoil drainage system must be witnessed by the Geotechnical Engineer.

4.9 Finishing Works and Topsoil Spread

4.9.1 Overcut

All areas cut to below finished level should be reinstated with engineered filling to the satisfaction of the Geotechnical Engineer.

4.9.2 Topsoil Depth

Topsoil respread depth should be between 100mm and 300mm, or as directed by the Engineer to the contract. On ground steeper than 1V:3H the surface should be roughened under the supervision of the Geotechnical Engineer prior to topsoil placement.

4.9.3 Unsuitable Materials

At the conclusion of earthworks all surplus unsuitable materials should be removed from site or placed in designated permanent stockpiles. The size and location of such stockpiles must be approved by the Geotechnical Engineer and recorded on the as-built drawings.

4.9.4 Road Subgrades

Testing and formation of road subgrades will be carried out as part of the subdivision civil works package.

5.0 ASBUILT INFORMATION REQUIREMENTS

In order to provide a Geotechnical Completion Report (GCR) certain as-built information must be provided to CMW. It is the contractor’s responsibility to ensure that all of the following items are surveyed prior to placing filling. The survey of these items should therefore form a hold point in the construction sequence.

- The location and invert of all sub surface drainage; and,
- The depth of filling placed including all benching, undercuts, shear or fill drainage keys and temporary ponds which have been backfilled.

CMW require the following as-built information to be provided for the GCR:

- Cut and fill depth plan (including undercuts and shear keys).
- Final contour plan.
- Drainage locations and inverts (surface and subsurface).
- Drainage outlet locations (surface and subsurface).
- Details of any defined overland flow paths.
- Location and heights of any retaining walls and Mechanically Stabilised Earth (MSE) structures.
- Position and extent of any geogrid layers (in plan view).
- Material data for imported products used such as draincoils, aggregates and geofabrics as well as confirmation that products installed comply with the requirements of the project drawings and this specification; and,
- All Monitoring Data.

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