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Report

Omaroro Lower Playing Field - Geotechnical Interpretive Report

Prepared for Wellington Water Limited

Prepared by Beca Limited

1 December 2017

Document Acceptance

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1 Introduction

Beca Ltd (Beca) has been commissioned by Wellington Water Ltd. (WWL) to undertake the preliminary design of earthworks and potential retaining wall options for the lower playing field associated with the Omaroro/ Prince of Wales/Omāroro Reservoir construction. As part of this commission we have undertaken geotechnical investigations and analyses to inform the design and associated costings.

The report presents the following:

- Ground conditions and parameters
- Design criteria for the proposed permanent field raising, temporary stockpiling and retaining walls
- Design analyses associated with the proposed permanent field raising, temporary stockpiling and retaining walls
- Conclusions and recommendations

This report should be read in conjunction with the Geotechnical Factual Report (Beca, Oct 2017).

2 Proposed Development

As part of the construction of the Prince of Wales/Omāroro Reservoir it is proposed to permanently raise the levels of the upper and lower playing fields. Additionally, it is proposed, to use both fields for temporary stockpiling of material (soil and rock). Beca 2012 includes analyses for geotechnical requirements for the upper field.

The lower playing field is proposed to be permanently raised by between 1m – 1.8m. Additionally, it is proposed to temporarily stockpile material from the reservoir construction to a height of up to 5.5m, with slope batters formed at 1V: 1.5H.

Given the geometry of the playing fields, a number of retaining structures are required to accommodate the proposed permanent raising and temporary stockpiling for the lower playing field.

3 Site Description

The lower playing field is located at the end of Salisbury Terrace, Mount Cook, Wellington. The field is bounded by Salisbury Terrace to the East and the surrounding town belt to the north and West. Residential housing is situated the other side of Salisbury Terrace with the proposed reservoir and upper playing field to north-west.

The lower playing field is a flat platform used for recreational sporting activities. There is an existing timber pole retaining wall located on the western end of Salisbury Terrace.

4 Published Geology

The published geology (Begg & Johnston, 2000; Begg & Mazengarb, 1996) shows the site to be underlain by alternating sandstones (greywacke) and mudstones of the Rakaia Terrane.

Higher detailed maps (Semmens et al., 2010) show that on the lower playing field the Rakaia Terrane greywacke is overlain by reclamation fill of variable thickness.

A currently inactive splinter fault connecting the Lambton and Terrace Faults is known to pass through the lower playing field, exiting near the clubhouse at the northern end (Semmens et al., 2010; Begg & Mazengarb, 1996).

5 Site Investigations

Site investigations were undertaken between 5 October and 11 October 2017. The investigations comprised three machine boreholes. The boreholes were initially vacuum extracted to 1.5m depth, and drilling was undertaken using the triple-tube method.

A summary of machine boreholes undertaken is given Table 1, and the locations of the boreholes are shown on the site plan in Appendix A.

Table 1 - Summary of Boreholes Drilled

BH No.	Location	Easting	Northing	RL ground (m)	Total Depth (m)
BH01	Northeastern corner of lower field; opposite 12 Salisbury Tce.	1748389	5425760	59	10.79
BH02	Eastern edge of lower field; opposite 11 Salisbury Tce.	1748398	5425738	59	10.37
BH03	Eastern edge of lower field; opposite 8 Salisbury Ave.	1748394	5425680	59	7.75

6 Ground Conditions

6.1 Ground Profile

The materials encountered within the machine boreholes and Standard Penetration Tests (SPT's) were generally consistent with the published geology. A summary of the generalised soil profile across the site is presented in Table 2 below. A typical geotechnical section extending through the site is presented in Appendix B.

Table 2 – Summary Ground Profile

Geological Unit	Description	Depth to top of layer (m bgl)	Approximate Thickness (m)	SPT 'N' Value Range [1] (Average)	Shear Vane Strength Range [2] (Average)
Fill	Firm, high plasticity minor gravel and clay SILT	0	1.0 – 9.0	2 – 12 (5)	22
Completely to highly weathered greywacke	Soft to very dense, high plasticity clay and gravelly SILT	1.0 – 9.0	2.0 - 6.0	29 – 50+ (37)	60 – 70 (65)
Moderately to slightly weathered greywacke	Moderately to highly weathered greywacke	3.00+	N/A	50+	Unable to Penetrate (UTP)

Notes:
1. The SPT N values are uncorrected (in blows/300mm).
2. The Shear Vane Strength is the peak corrected value obtained using a hand-held shear vane (in kPa).

Based on the ground investigations the generalised ground profile of the lower playing field is fill overlying weathered greywacke rock. The thickness of fill was found to increase from about 0.30m in the south of the field, to about 9.0m at the northern end of the field.

The field was created using cut and fill. It is understood that this included re-directing the stream along the western edge of the field. Based on the depth to *in-situ* soil and rock in the three boreholes, the natural slope angles of the surrounding hills, and field observations of rock outcrops surrounding the site, we have created a paleo-topographic map of the lower playing field (Figure 1). Based on our interpretation, the stream likely flowed through a gully where the field is now.

Figure 1 – Interpreted paleo-topography of the lower playing field

Based on the geotechnical investigations and surface topography we have interpreted the historical (paleo-topography) surface.

6.2 Groundwater

Groundwater was encountered at approximately 7.10 m, 4.80 m, and 1.75 m below ground level (bgl) in BH01, BH02 and BH03 respectively. At the time of the measurements water levels in BH01 and BH02, were cased to a depth of 3m. No casing was installed when the water level in BH03 was measured. None of the boreholes had been developed to remove drilling muds or other fluids added during the drilling process, and hence the water levels are indicative only and do not allow for the interpretation of water levels or vertical gradients between individual units. Table 3 summarises the water level measurements.

Table 3 - Groundwater Measurements

Borehole/ Piezometer ID	Date of measurement	Water level (m, bgl)	Water level (m, RL)
BH01	10/10/2017	7.10	51.90
BH02	10/10/2017	4.80	54.20
BH03	09/10/2017	1.75	57.25

A water level of 1.5m bgl was adopted for our analyses.

7 Design Parameters

The following design parameters were derived from published correlations, geotechnical investigation data and previous experience with similar materials encountered within the Wellington region. The recommended design parameters are summarised in Table 4 below.

Table 4 – Design Parameters

Geological Unit	Unit Weight, γ (KN/m³)	Friction Angle, Ø (Degrees)	Cohesion, C' (kPa)	Undrained Shear Strength, S_u (kPa)
Unengineered Fill	18	28	2	22
Completely weathered to highly weathered greywacke	22	45	50	60
Moderately to slightly weathered greywacke	22	45	100 - 300	-

8 Seismic Design Criteria

8.1 Site Subsoil Class

Based on the findings from geotechnical investigations a subsoil class 'Class C – Shallow Soils' should be used based on the NZS1170.5:2004.

8.2 Peak Ground Acceleration

Peak ground accelerations (PGAs) for the buildings are derived in accordance with NZS 1170.5:2004, as follows.

C(T) = Ch(T) Z R N(T,D)

where,

Ch(T), the spectral shape factor = 1.33,

Z, the hazard factor = 0.4,

Ru, the return period factor (see Table 5 below),

N(T,D), the near-fault factor = 1.0.

The appropriate design PGA values for ultimate limit state (ULS) and serviceability limit state (SLS) are presented in Table 5 below.

Table 5 – Summary of Design PGAs for Buildings A1 and A2

Structure	Load Case	Design Life (DL) Importance Level (IL)	Annual Probability of Exceedance [1]	Return Period Factor (Ru or Rs)	PGA (g)
Retaining Wall	SLS1	DL = 50 years IL=1	1/25	0.25	0.13
	ULS		1/500	1.0	0.53

Notes:
1. The annual probability of exceedance is derived from Table 3.3 of AS/NZS 1170.0:2002.

8.3 Slope Stability Requirements

The design sets out to achieve the factors of safety against slope failure in Table 6 below.

Table 6 - Minimum factors of safety for slope stability

Design Case	Minimum Factor of Safety (FoS)
Short term static	1.3
Long term static	1.5
Seismic SLS	1.0
Seismic ULS	1.0 or acceptable displacement

9 Geotechnical Considerations

The main geotechnical considerations for this site are the potential for slope instability, construction issues around earthworks, and liquefaction. These are discussed below.

9.1 Liquefaction

Liquefaction is a phenomenon where saturated low plasticity soils temporarily lose strength due to high pore pressure development during earthquake shaking. It predominantly occurs in loose silts and sands below the groundwater table.

As seen under current information liquefaction in the area is believed to be low. Although sand and silt layers are present these tend to be minimal in extent or above the water table.

9.2 Slope Stability

Re-profiling and placement of new fill may cause slope stability issues. The existing slope profile, proposed permanent field raising and temporary stockpiling have been checked under static and seismic loading. These analyses have been undertaken using the software Slope/W 2016 from GeoSlope International Ltd using the Morgenstern and Price method (Morgenstern and Price, 1965).

Analysis has been carried out on a section of the field with includes the timber pole retaining wall at the base of the existing slope. The resulting factors of safety are presented in Table 7 below, and in Appendix C.

The following design assumptions were made:

- The construction of the existing timber pole retaining wall is 250mm SED pole at 1.0m c/c
- The embedment depth of the timber poles is as least the same height as the retained portion
- The fill behind the wall varies in height between approx. 5.5m and 9m bgl.
- The long term water level is 1.5m bgl
- The short term water level is at the ground level
- The stability of the existing slope and retaining wall has a factor of safety of at least 1.5 under static conditions
- The location of the proposed swale is as per the location in the feasibility study (Beca, 2017).

9.2.1 Back Analysis (Existing Slope Stability)

The analysis results for the existing slope are presented in Table 7 below. Under static conditions the factors of safety are within the acceptable limits. Under the seismic ULS event a factor of safety less than 1.0 achieved. The magnitude of this movement has been assessed to be less than 100mm using the recommendations of Jibson (Jibson, 2007).

Table 7 - Slope stability factors of safety

Analysis Case	Analysis Condition	Calculated Factor of safety (FOS)
Existing slope profile (Back analyses)	Static – Long term	1.52
	Static – Short term	1.35
	Seismic - SLS	1.14
	Seismic - ULS	0.56
Permanent field raising	Static – Long term	1.34
	Static – Short term	1.13
	Seismic – SLS	1.06
	Seismic - ULS	0.57

The analysis suggests that permanently raising the lower playing field will result in instability of the existing slope. Options to support the existing slope and accommodate the permanent field raising are discussed in Section 10.

9.2.2 Temporary Stockpiling

A sensitivity analysis was carried out to determine the recommended location for the temporary stockpiling of material. A range of offsets were analysed from the crest of the proposed new retaining wall to the toe of the stock piled material. The offset started at 2m from the crest of the proposed new wall and increased in 1m increments until the acceptable factor of safety was achieved.

For the critical section with the highest risk of slope instability it is recommended that the temporary stock piled material is stored greater than 10m from the crest of the proposed new retaining wall.

10 Retaining Options

Based the stability analysis carried out, additional support will be required to achieve acceptable factors of safety for slope stability for the proposed development. This additional support is required towards the northern end of the lower playing field where the existing timber pole wall is located. Analysis has looked at three potential solutions:

1. **Install anchors into the existing timber pole wall** – Analysis suggests that installing anchors into the existing timber pole wall will achieve the required factor of safety for global stability. The design assumes the following:

    - RB32 anchors, approximately 8m long with 6m bond length and 150mm diameter hole
    - The anchors are installed at least 0.5m within the highly weathered greywacke.

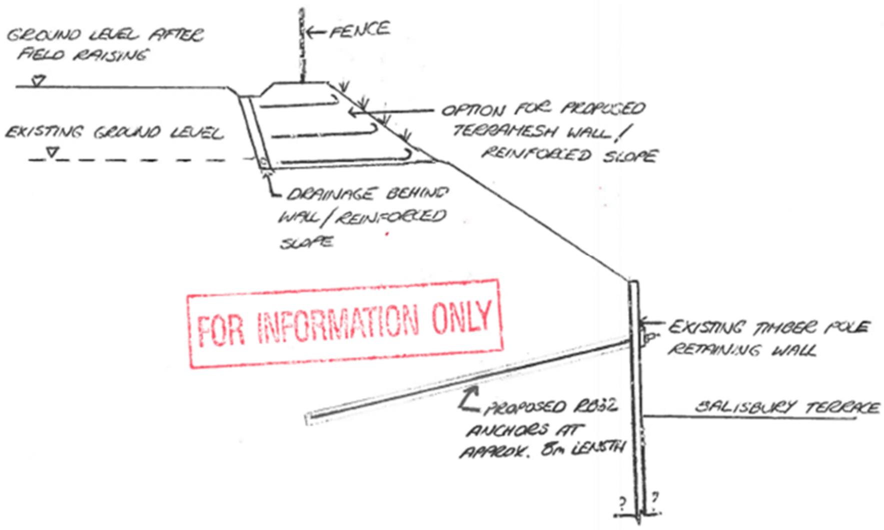


Figure 2 - Sketch of proposed anchor solution

Replace existing timber pole wall with new, larger wall – Another option to achieve the required factor of safety for global stability includes replacing the existing timber pole wall with a new retaining structure. An example of this options is captured in figure x below.

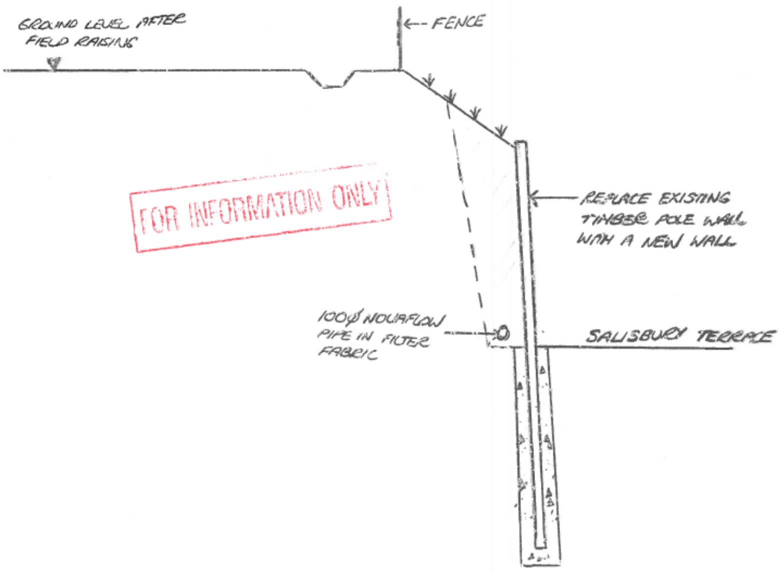


Figure 3 - Sketch of proposed new retaining wall solution

11 Conclusions and Recommendations

- The soil profile is relatively consistent throughout the site, however the fill overlying the highly weathered Greywacke varies in thickness, and is up to 9m thick.

- Groundwater across the site is expected to vary between approximately 1.5m to 7m bgl. The level of groundwater could be shallower during high rainfall events. A water level of 1.5m bgl was adopted for the analyses.
- Subsoil site class is Class C.
- The risk of liquefaction is expected to be low.
- Based on the analysed cross section, the proposed permanent field raising option will make the slope unstablt. As a result, a method of slope reinforcement is recommended.
- The recommended option is to retrofit the existing timber pole wall with RB32 anchors at approx. 8m long. It is recommended that the anchors are embedment into the highly weathered Greywacke.
- In the area where is existing timber pole retaining wall is located, it is recommended that the 5.5m high temporary stockpile material is offset from the toe of the proposed wall by 10m.

12 Applicability

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

13 References

Beca (2012): Hospital Prince of Wales Reservoir Geotechnical Report - Addendum

Beca (2017): Prince of Wales/Omaroro Reservoir – Raising of Playing Fields Feasibility Study

Beca (2017): Prince of Wales/Omaroro Reservoir – Geotechnical Factual Report

Jibson R.W. (2007): Regression models for estimating co-seismic landslide displacement, *Engineering Geology,* Elsevier Science Ltd, v91, pp209-218.

Pender, M. J. (1980): Friction and cohesion parameters for highly and completely weathered Wellington greywacke.

Morgenstern, N.R., and Price, V.E. (1965): The analysis of the stability of general slip surfaces. *Géotechnique*,
v15 n1 pp79–93.

Appendix A

Site Plan

Site Investigation Location Plan

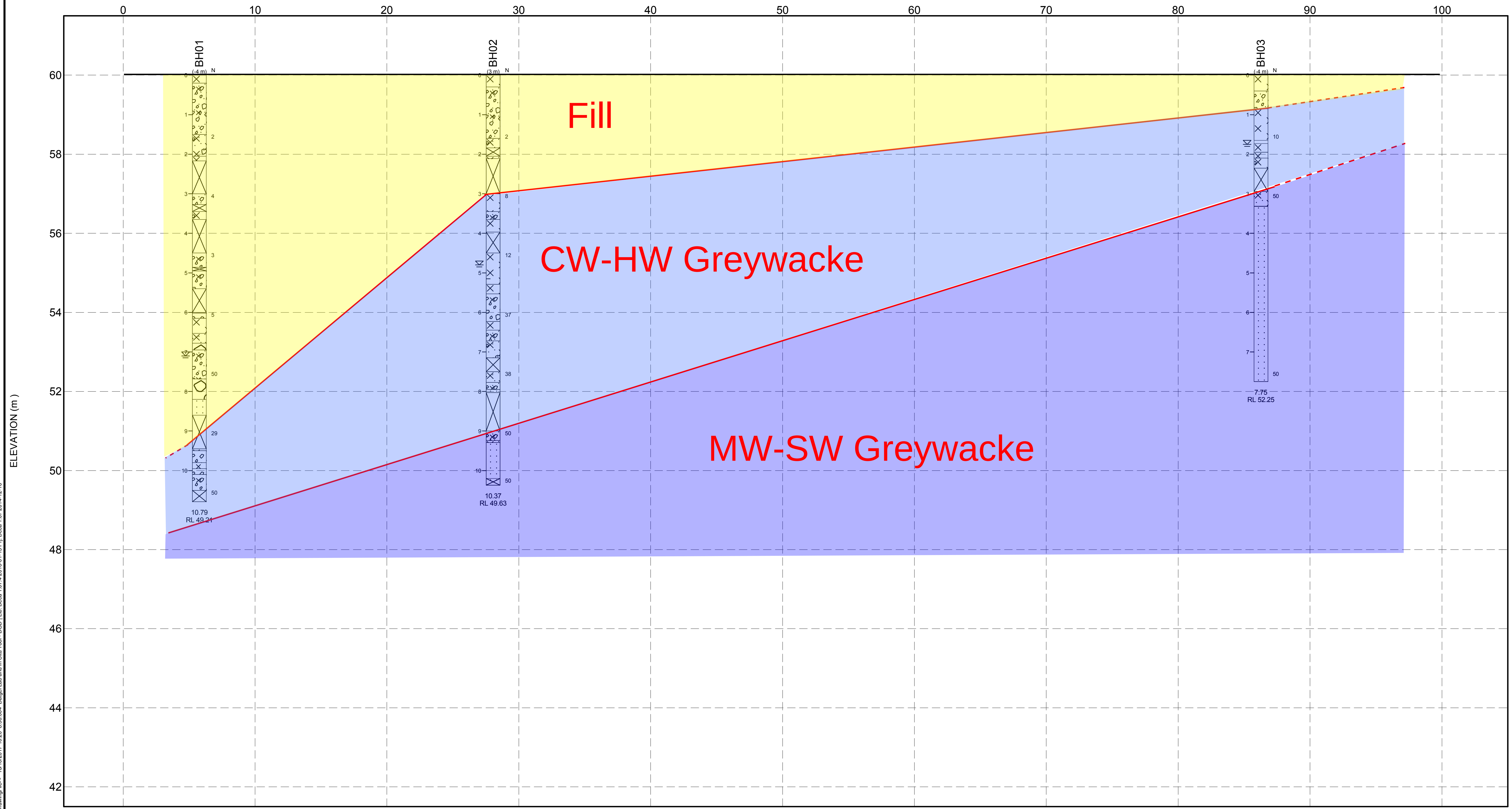
Appendix A

Beca

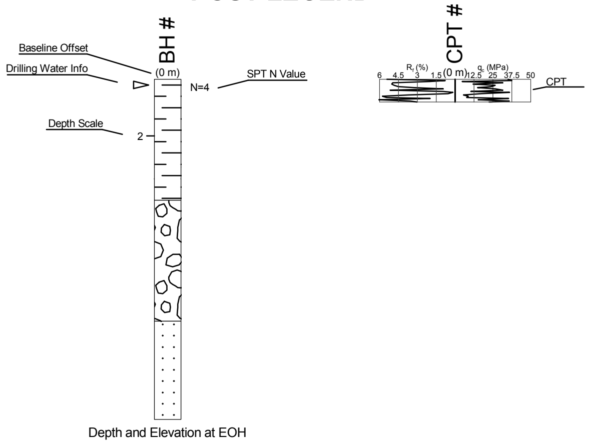
6513361

Appendix B

Typical Cross-section



POST LEGEND



MATERIAL GRAPHIC

SILT · No Core · Silty GRAVEL · Sandy SILT · Clayey SILT

Silty sandy GRAVEL · Sandy GRAVEL · COBBLES · SILTSTONE

Sandy gravelly SILT · Gravelly SILT · GRAVEL · SANDSTONE

H 1:300 (0 2 4 6 8 10m)

V 1:100 (0 1 2 3 4 5m)

Coord.System: NZTM Height Datum:

Beca

TITLE	DRAWN	DATE
Wellington Water Prince of Wales Park, Salisbury Terrace, Wellington Prince of Wales/Omaroro Reservoir Geological Cross Section	CK	16/10/2017
	CHECKED	DATE 16/10/2017
	SCALE H 1:300 V 1:100	A3
	PROJECT No 6513361	FIGURE No

Appendix C

Slope/W Outputs

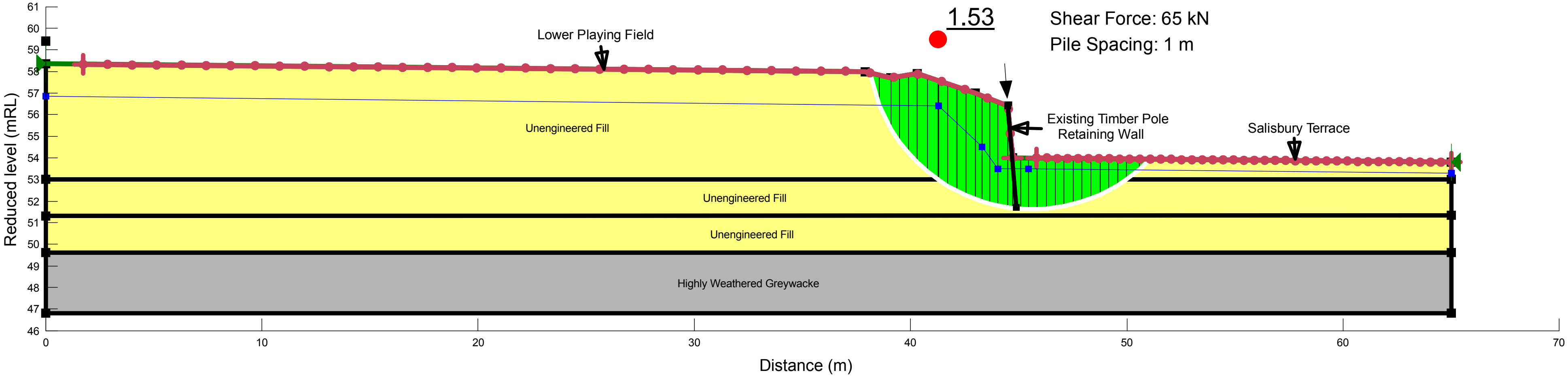
Horz Seismic Coef.:

Method: Morgenstern-Price

Name: Unengineered Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1

Horz Seismic Coef.:



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Existing Soil Profile.gsz Existing slope profile - Static (Long-term)	6513361 Scale: 1:200	Date: 22/11/2017 Figure 1

Version: 8.16.1.13452

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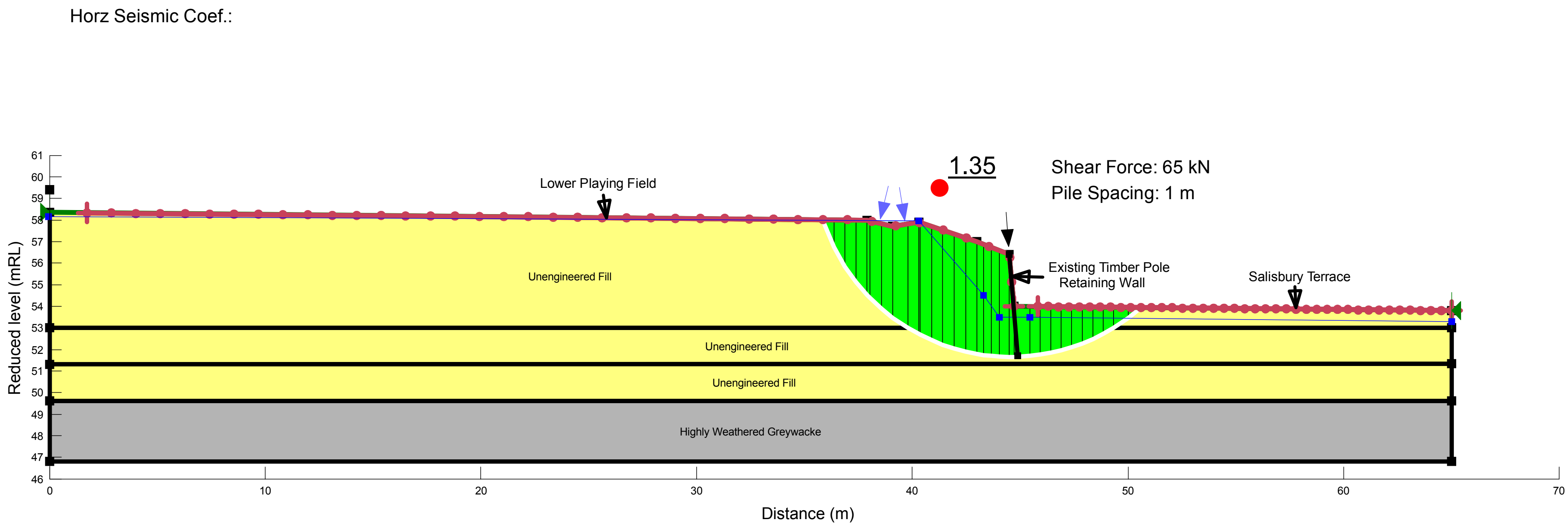
DO NOT SCALE

Horz Seismic Coef.:

Method: Morgenstern-Price

Name: Unengineered Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Existing Soil Profile.gsz Existing slope profile - Static (Short-term)	6513361 Scale: 1:200	Date: 22/11/2017 Figure 1

Version: 8.16.1.13452

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22/11/2017,3:03:09 p.m.

DO NOT SCALE

Horz Seismic Coef.: 0.13

Method: Morgenstern-Price

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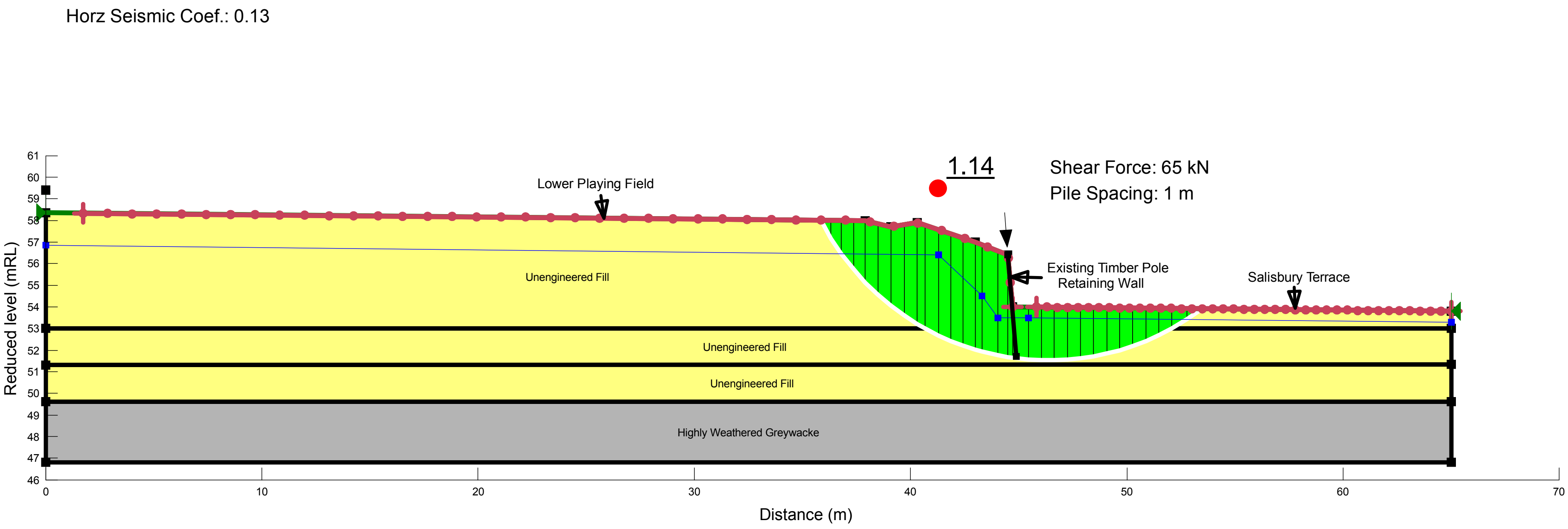
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Existing Soil Profile.gsz Existing slope profile - Seismic SLS	6513361	Date: 22/11/2017
			Scale: 1:200	Figure 3

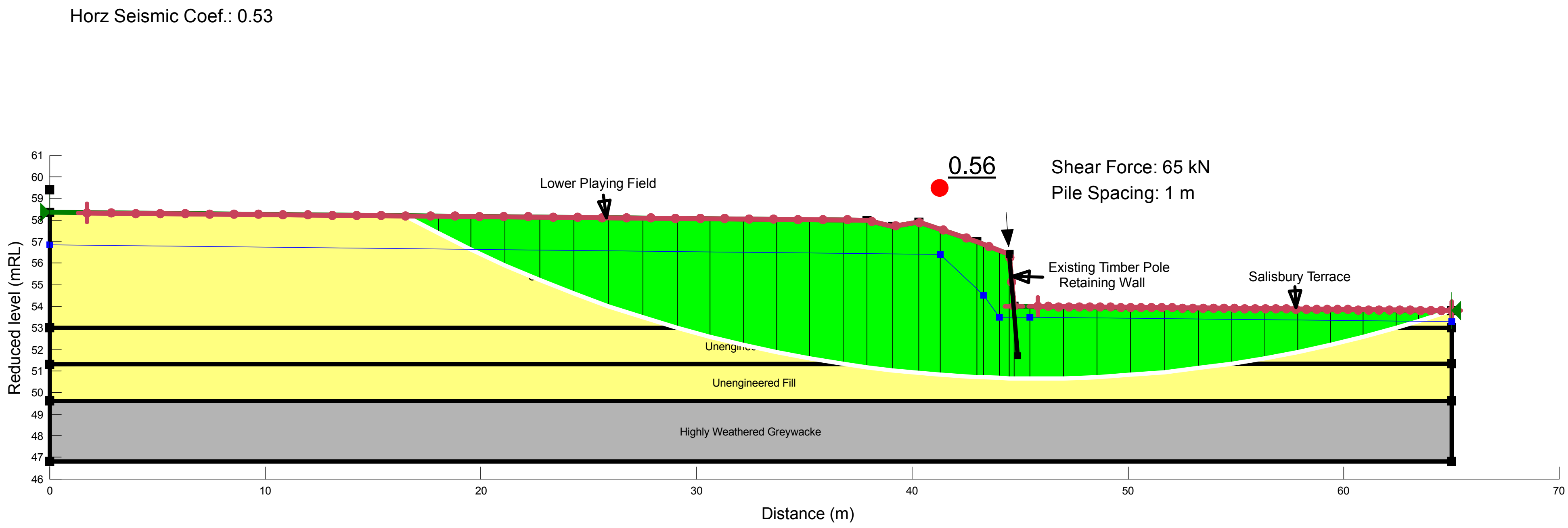
Version: 8.16.1.13452

Horz Seismic Coef.: 0.53

Method: Morgenstern-Price

Name: Unengineered Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Existing Soil Profile.gsz Existing slope profile - Seismic ULS	6513361	Date: 22/11/2017
			Scale: 1:200	Figure 4

Version: 8.16.1.13452

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DO NOT SCALE

Horz Seismic Coef.: 0.2

Method: Morgenstern-Price

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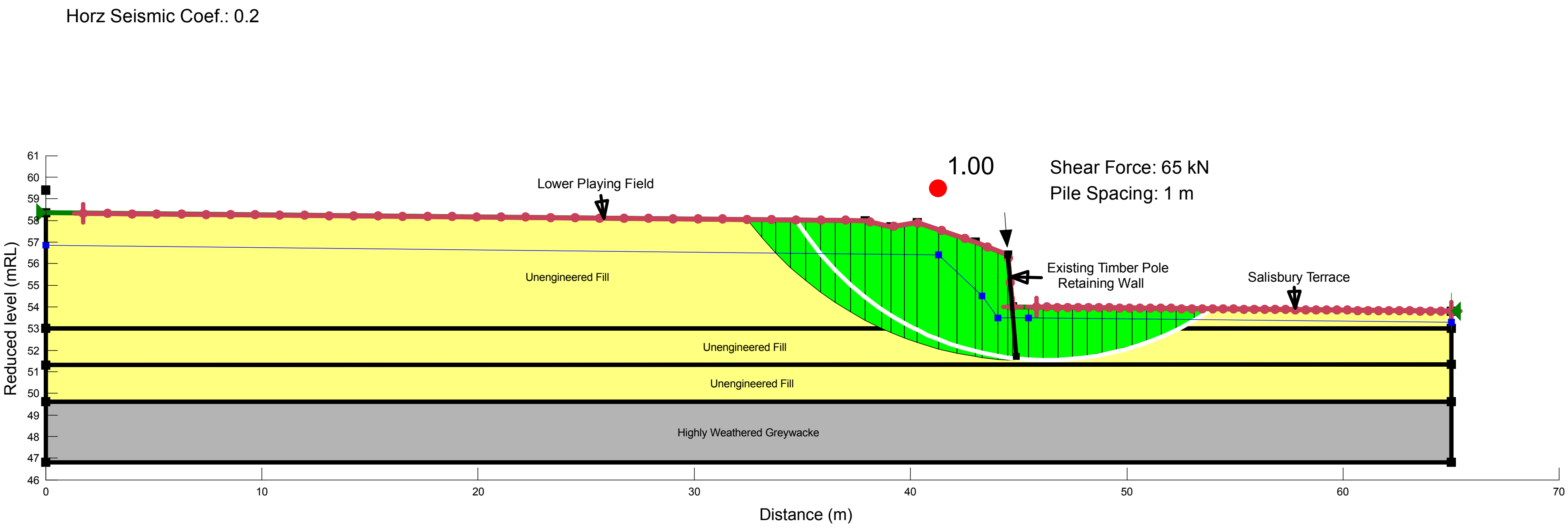
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Existing Soil Profile.gsz Existing slope profile - Seismic (Yield)	6513361	Date: 22/11/2017
			Scale: 1:200	Figure 5

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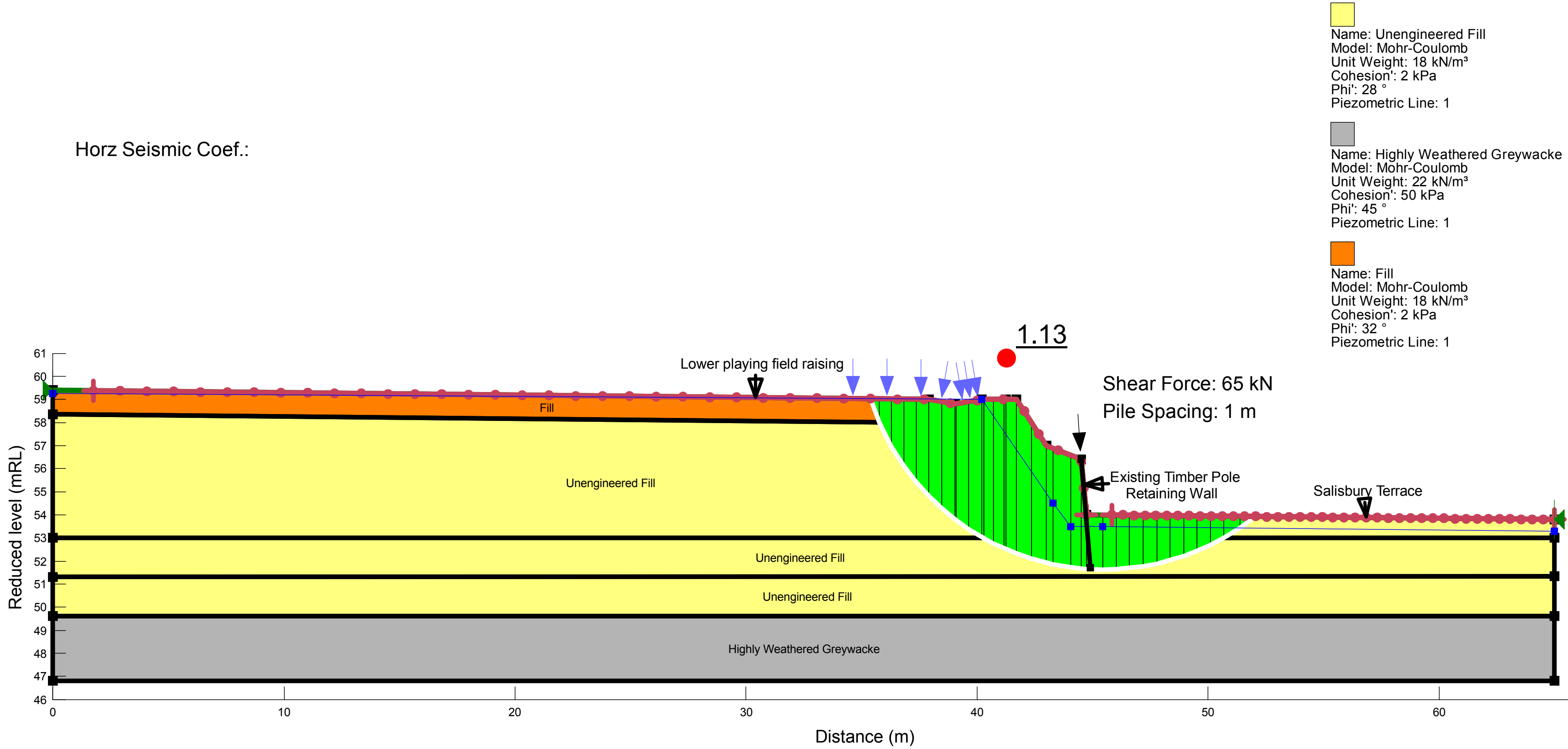
Horz Seismic Coef.:

Method: Morgenstern-Price



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Permanent field raising.gsz Field raising - Static (Short-term)	3208168	Date: 22/11/2017
			Scale: 1:200	Figure 6

Version: 8.16.1.13452

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DO NOT SCALE

Horz Seismic Coef.:

Method: Morgenstern-Price

Horz Seismic Coef.:

Name: Unengineered Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 28 °
Piezometric Line: 1

Name: Highly Weathered Greywacke
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 50 kPa
Phi': 45 °
Piezometric Line: 1

Name: Fill
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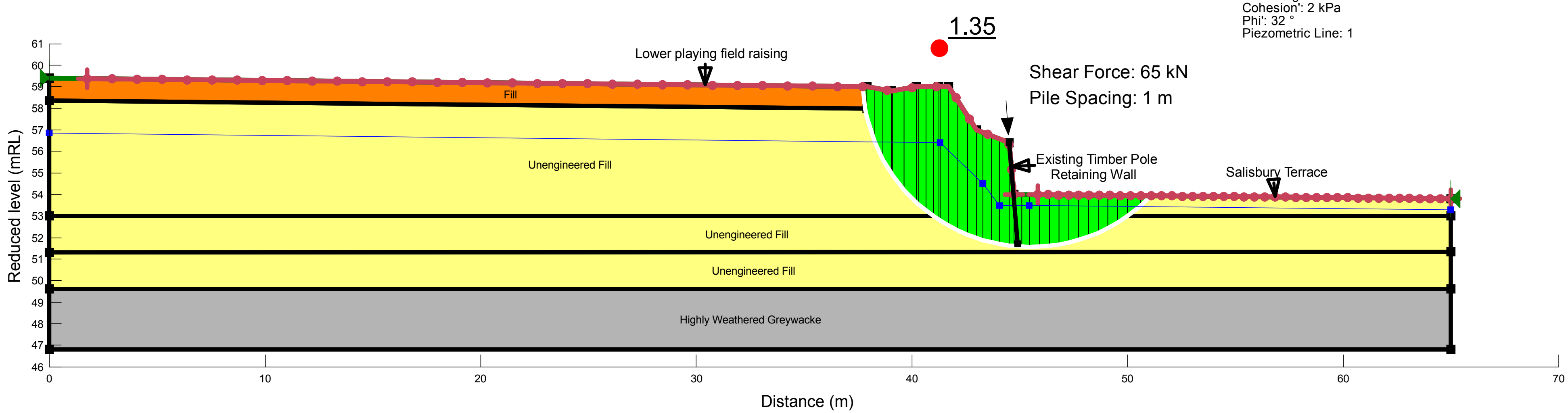
Piezometric Line: 1



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Permanent field raising.gsz Field raising - Static (Long-term)	3208168	Date: 22/11/2017
			Scale: 1:200	Figure 7

Version: 8.16.1.13452

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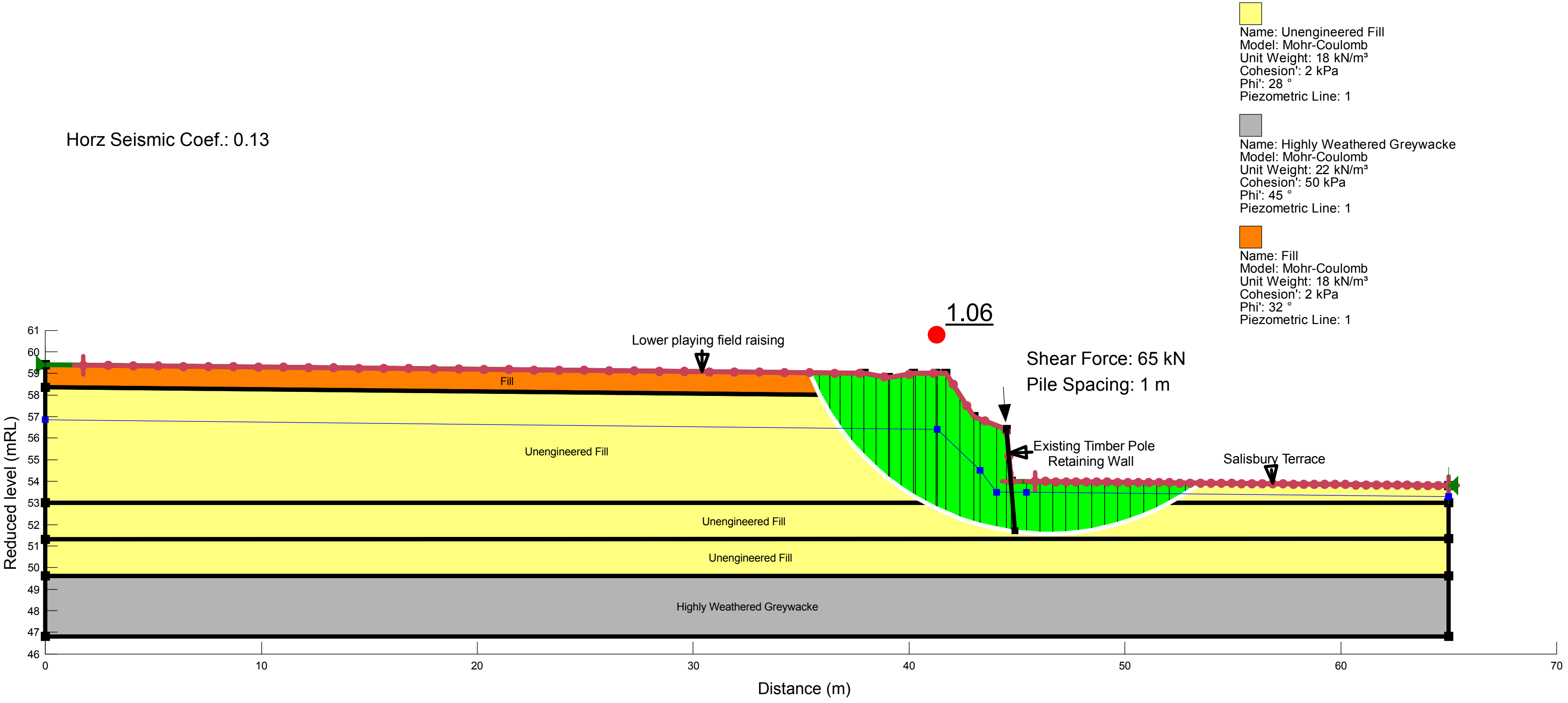
Horz Seismic Coef.: 0.13

Method: Morgenstern-Price



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Permanent field raising.gsz Field raising - Seismic SLS	3208168	Date: 22/11/2017
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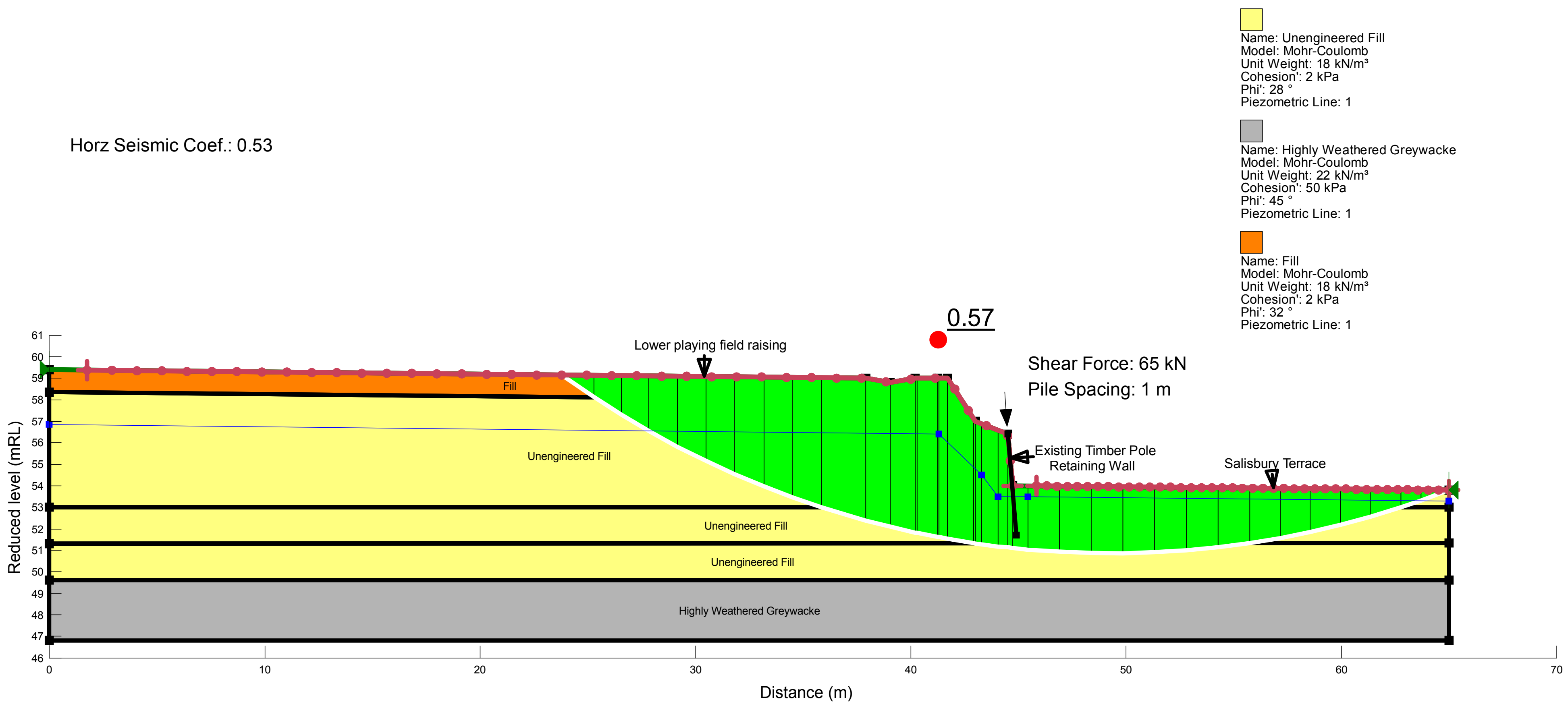

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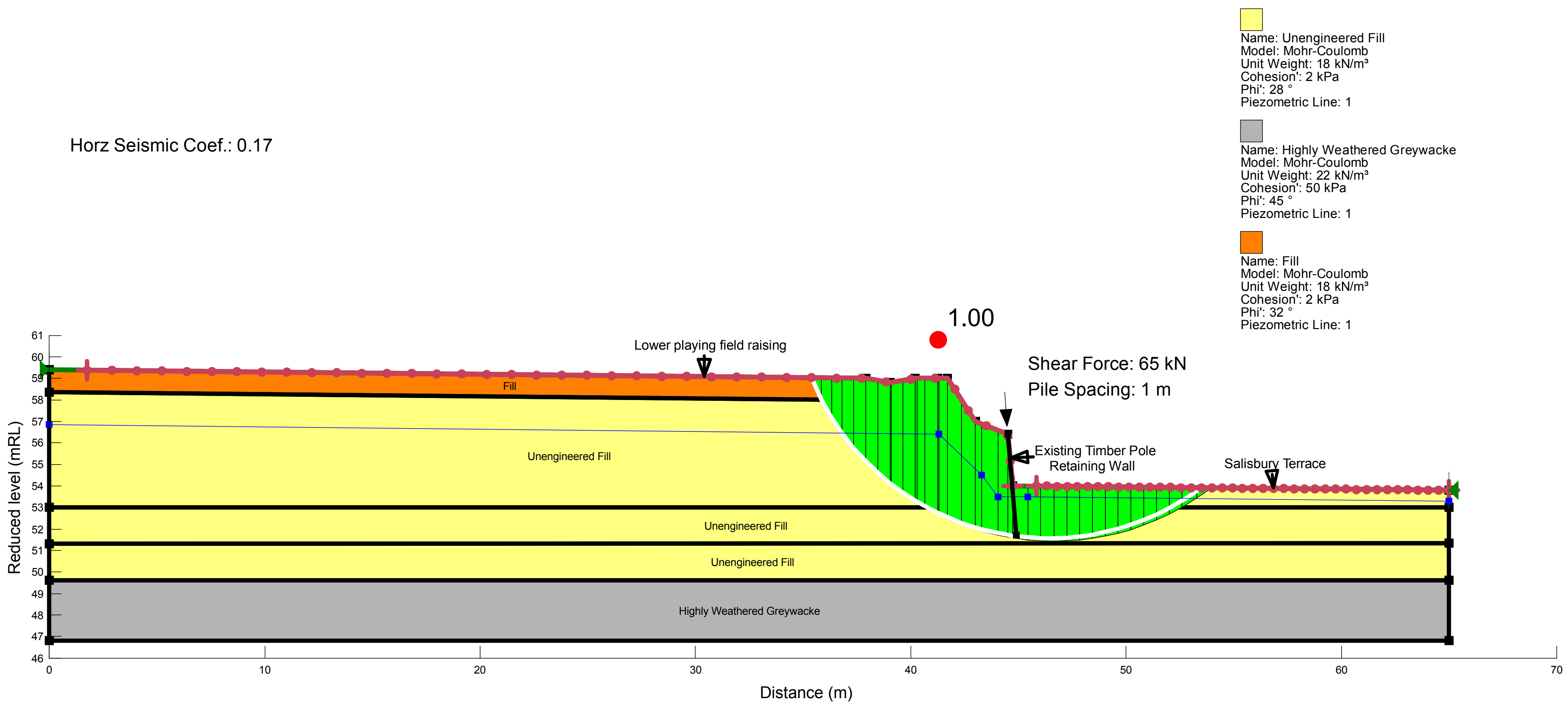
Method: Morgenstern-Price



Beca	Omaroro - Lower playing field	Omaroro - Lower playing field - Permanent field raising.gsz Field raising - Seismic (Yield)	3208168	Date: 22/11/2017
			Scale: 1:200	Figure 10

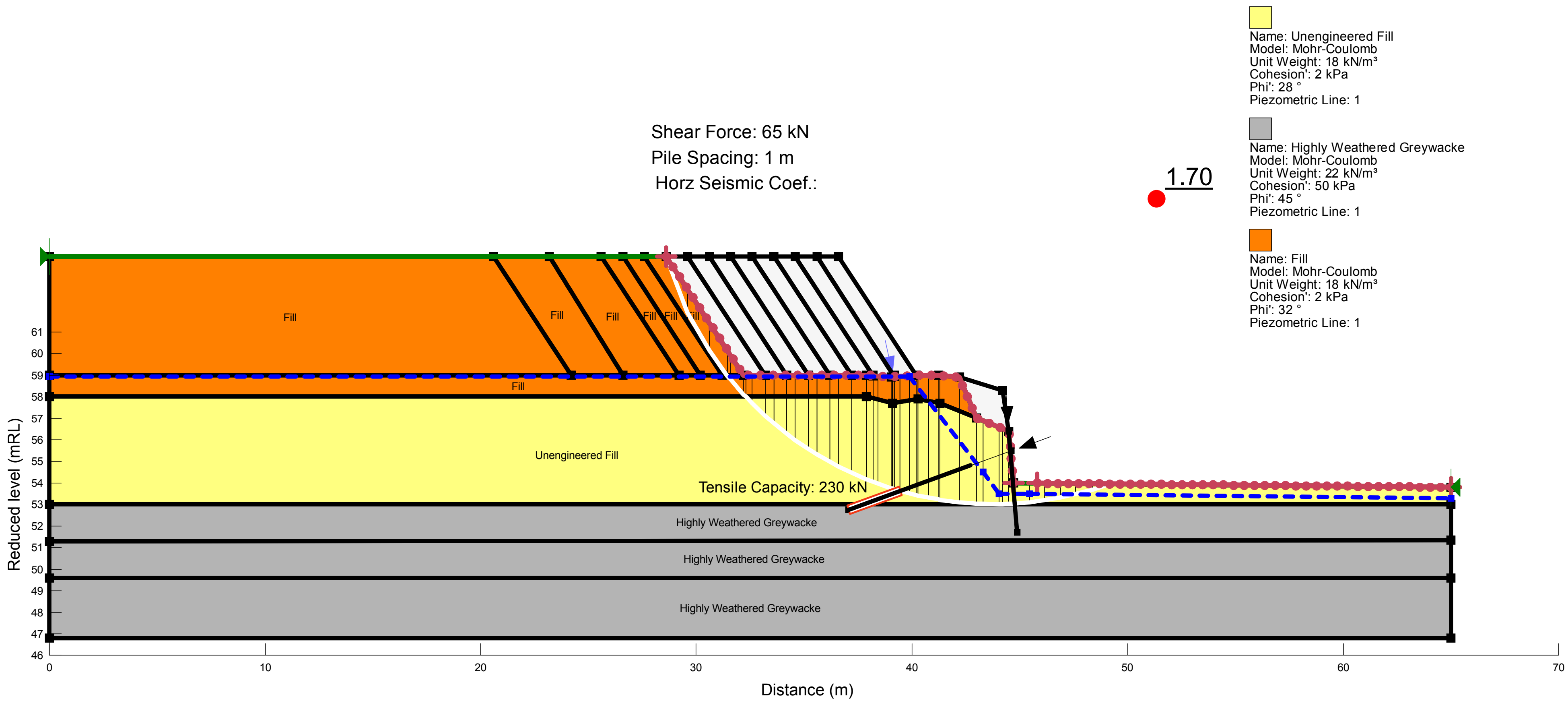
Version: 8.16.1.13452

\\Beca.net\projects\651\6513361\TGE\Slope Stability\,Omaroro - Lower playing field - Permanent field raising.gsz, Katie Muldrew, 22/11/2017,4:14:32 p.m.

DO NOT SCALE

Horz Seismic Coef.:

Method: Morgenstern-Price



Beca	Omaroro Lower Playing Field	Omaroro - Lower field - stockpiling (reduced fill).gsz Stockpiling - Static (10m back) ((WT) (anchor)	6513361	Date: 27/11/2017
			Scale: 1:200	Figure 11

Version: 8.16.1.13452

\\Beca.net\projects\651\6513361\TGE\Slope Stability\,Omaroro - Lower field - stockpiling (reduced fill).gsz, Katie Muldrew,
27/11/2017,1:04:58 p.m.

DO NOT SCALE