29 April 2015

Mr Darcy Maddern
Holcim New Zealand Limited
PO Box 13341
Johnsonville
Wellington 6440
Via email.

Dear Darcy

RE: Addendum Slope Stability Report for the North Wall and Area H, KiwiPoint Quarry, Wellington

Our Reference: 10319.000.001-03

1 Introduction

In February 2015, ENGEO Limited (ENGEO) (formally Geoscience Consulting NZ Limited) issued a Slope Stability Review report for the proposed KiwiPoint quarry development to Holcim New Zealand Limited. In a meeting attended by ENGEO at the KiwiPoint office on 26 March 2015, it was requested that further slope stability modelling be undertaken to support the consenting process for the development.

2 Slope Stability Modelling

The February 2015 report assessed slope stability for the North Wall using three proposed scenarios:

- **Scenario 1:** The existing North Wall with batter slopes at approximately 80°;
- **Scenario 2:** The maximum resource extraction possible within the current quarry limits whilst improving current levels of stability with upper batter slopes at 55° as indicated by Ormiston and Associates drawing number 3655-2 dated 12 March 2014; and
- **Scenario 3:** Maximum resource extraction possible if the cell phone tower can be relocated and the wall can be extended to within 20 m from the quarry boundary (required setback).

The results of the initial slope stability assessments are detailed in our February 2015 report and that report should be read in conjunction with this addendum report. For the current assessment, the following additional slope stability modelling has been undertaken:

- An assessment of the three development scenarios for the north wall using the existing slope stability parameters, with the addition of the approximate location of the existing houses at the top of the slope. The modelling has been undertaken to assess the effect of global slope failure on the houses using static conditions, SLS and ULS earthquake events and varying groundwater levels;

- An assessment of the slope stability of the proposed development in Area H (using the proposed 45° cut angle) including the approximate locations of existing houses at the top of the slope. As above, the modelling has been undertaken to assess the effect of global slope failure on the houses using static conditions, SLS and ULS earthquake events and varying groundwater levels;
- An assessment of slope stability using the three scenarios for the North Wall as well as Area H, using the actual earthquake data from the largest earthquake affecting Christchurch CBD during the Christchurch Earthquake Sequence in 2010-2011. This modelling has been undertaken to allow comparison between the effects of a known recently experienced New Zealand earthquake and the effects of a similar code defined (SLS and ULS) earthquake in the Wellington Region. The peak ground acceleration experienced in the Christchurch CBD of up to 0.46g equates approximately to a 1 in 800 year earthquake in the Wellington Region, in comparison to a code defined ULS earthquake (1 in 500 year event) of 0.35g.

In the slope stability analysis, the degree of stability of a slope is expressed as the 'factor of safety' (FOS) which is the ratio of the forces resisting failure to the driving forces causing instability. Theoretical failure of a slope is possible when the FOS is less than 1.0, while increasing values above 1.0 indicate improving stability. Depending on the levels of certainty around the various input parameters in the ground model, a minimum FOS of 1.5 and 1.2 are commonly adopted for slopes under long term static / seismic conditions respectively.

In each case, failure surfaces and the associated FOS likely to affect the houses at the crest of the slopes have been modelled and reported. The modelling results are discussed in detail in the following sections.

In this assessment, a "traffic light" system has been utilised in the results tables, as follows:

- A red light signifies that slope failure is likely to occur (FOS <1);
- An amber light signifies that slope failure is possible (FOS >1 but FOS <1.5 in static conditions and <1.2 in seismic conditions); and
- A green light signifies that slope failure is unlikely to occur (FOS >1.5 in static conditions and >1.2 in seismic conditions).

3 Slope Stability Modelling Results

3.1 North Wall – Equivalent Christchurch Earthquake

Earthquake data from the Christchurch CBD on 22 February 2011 has been used in this assessment. The peak ground acceleration recorded in the CBD during this earthquake was 0.46g. Table 1 indicates the results of such an earthquake event on the North Wall.

Table 1. Results of modelling Christchurch CBD event

Scenario	Factor of Safety	
	Failure through Highly to Moderately Weathered Rock	Failure through Slightly Weathered Rock
1	0.72	1.43
2	0.72	1.64
3	0.81	2.11

Note: A dry slope was modelled in this case as the probability of a 1 in 800 year earthquake occurring at the same time as high groundwater levels is low.

The results indicate that in an earthquake similar to that experienced in the Christchurch CBD on 22 February 2011, failure of the upper part of the slope comprising highly to moderately weathered rock is likely (i.e. FOS is below 1). Global slope failure through the slightly weathered Greywacke is unlikely.

3.2 North Wall – Failures Affecting Houses at Crest

The existing slope stability models for each scenario have been used with the addition of the approximate location of the existing houses at the crest of the slope. The FOS of failure surfaces likely to affect houses at the crest are shown in Table 2.

Table 2 Results of modelling slope failures affecting the existing houses at the crest of the slope

Scenario	Factor of Safety						
	High Groundwater			No Groundwater			
	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)	Static	1 in 50 year Earthquake (0.13g)	1 in 500 year Earthquake (0.35g)	Christchurch CBD (0.46g)
1	5.27	3.61	N/A	6.32	4.98	3.62	3.68
2	5.18	3.12	N/A	5.81	5.13	3.26	3.25
3	3.43	2.60	N/A	4.63	3.21	2.40	2.11

N/A = A 1 in 500 year earthquake event with high groundwater level has not been modelled due to the low probability of these two events occurring simultaneously.

The results indicate that in all scenarios the houses at the crest of the slope are unlikely to be affected by the earthquake events modelled (i.e. FOS more than 1).

Note that the FOS generally reduces between Scenario 1, 2 and 3 as the crest of the slope is modelled to be closer to the houses. For example, the crest of the existing steep slope (Scenario 1) is further away from the houses than in Scenario 3 where the slope has been battered back to a shallower angle.

3.3 Area H

Table 3 provides the results of the slope stability modelling at Area H. The approximate location of the existing houses has been added to the model.

Table 3. Area H Slope Modelling Results.

Groundwater	Scenario	Factor of Safety			
		Failure through Highly to Moderately Weathered Rock (lowest FOS)	Failure through Highly to Moderately Weathered Rock affecting houses	Failure through Slightly Weathered Rock (lowest FOS)	Failure through Slightly Weathered Rock affecting houses
High	Static	1.20	1.75	2.03	2.22
	1 in 50 year Earthquake (0.13g)	0.98	1.26	1.67	1.73
	1 in 500 year Earthquake (0.35g)	N/A	N/A	N/A	N/A
No	Static	1.32	2.09	2.45	2.78
	1 in 50 year Earthquake (0.13g)	1.09	1.49	1.77	2.76
	1 in 500 year Earthquake (0.35g)	0.81	0.99	1.46	1.90
	Christchurch CBD (0.46g)	0.70	0.85	1.40	1.85

N/A = A 1 in 500 year earthquake event with high groundwater level has not been modelled due to the low probability of these two events occurring simultaneously.

The results indicate that:

- **<u>In the Static case:</u>** Both results for failure in static conditions in highly to moderately weathered rock are above a FOS of 1 but below the ideal result of 1.5 (being 1.20 and 1.32). However, if these failures were to occur, the houses at the crest of the slope are unlikely to be affected (FOS 1.75 and 2.09). Failures through slightly weathered rock are unlikely to occur in static conditions.

- **<u>In a 1 in 50 year (SLS) earthquake:</u>** In all cases the FOS is very close to or greater than 1, and therefore the global stability of the slope is expected to be largely maintained during an earthquake of this magnitude (0.13g). Note that this model does not allow for small scale rock failures from the rock face, which are expected in this size of event.

- **<u>In a 1 in 500 year (ULS) earthquake:</u>** In a 1 in 500 year earthquake, the two models representing failure in highly to moderately weathered rock have returned a FOS < 1 and therefore failure is possible, although the FOS for slope failure affecting the houses above is close to 1. If failure of the slope in a 1 in 500 year earthquake is not acceptable, further seismic analysis can be undertaken to assess the likely amount of displacement to be expected in such an event. Failure in slightly weathered rock is unlikely.

- **<u>In an earthquake similar to the February 2011 event:</u>** the two models representing failure in highly to moderately weathered rock have a FOS considerably less than 1 and therefore slope failure is likely to affect the houses at the crest of the slope. Failure in slightly weathered rock is unlikely.

Outputs from the slope modelling software are appended to this report.

4 Limitations

i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Holcim New Zealand Limited, their professional advisers and the relevant Territorial Authorities in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.

ii. The recommendations in this report are based on the ground conditions indicated from published sources, site inspections and subsurface investigations based on accepted normal methods of site investigations. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it must be appreciated that actual conditions could vary from the assumed model.

iii. This Limitation should be read in conjunction with the IPENZ/ACENZ Standard Terms of Engagement.

iv. This report is not to be reproduced either wholly or in part without our prior written permission.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned on 04 472 0820 if you require any further information.

Report prepared by

Karen Jones

Senior Engineering Geologist

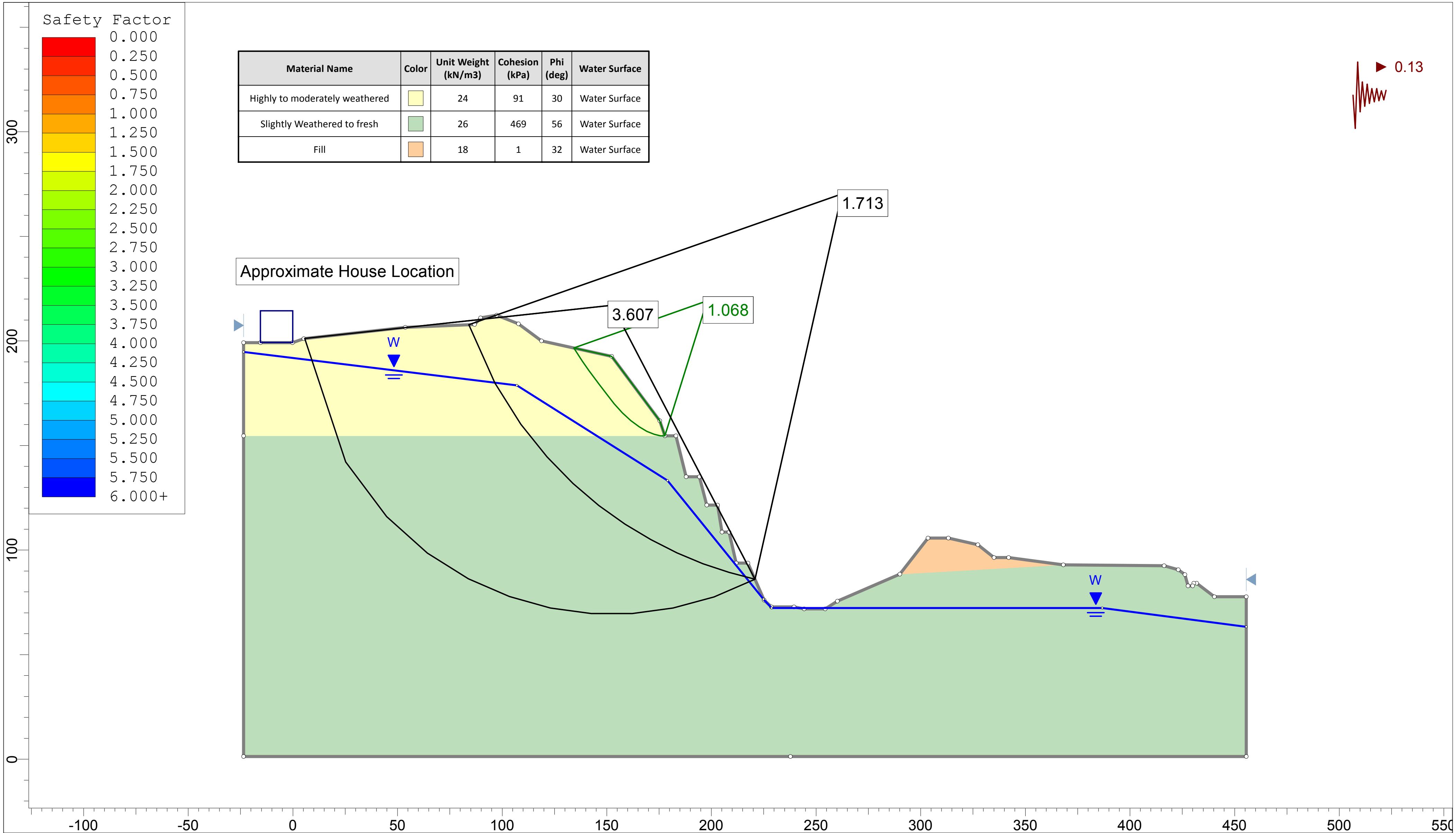
Reviewed by

Guy Cassidy, MIPENZ, PEngGeol

Principal Engineering Geologist

Enc. Slope Stability Models

North Wall – Scenario 1



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	91	30	Water Surface
Slightly Weathered to fresh		26	469	56	Water Surface
Fill		18	1	32	Water Surface

GEOSCIENCE A proud partner of ENGEO	Client	Holcim New Zealand Limited	Project	KiwiPoint Quarry
	Drawn By SC	Approved By GC	Analysis	North Wall, Scenario 1, SLS, high groundwater
	Date 24/04/2015	Revision		
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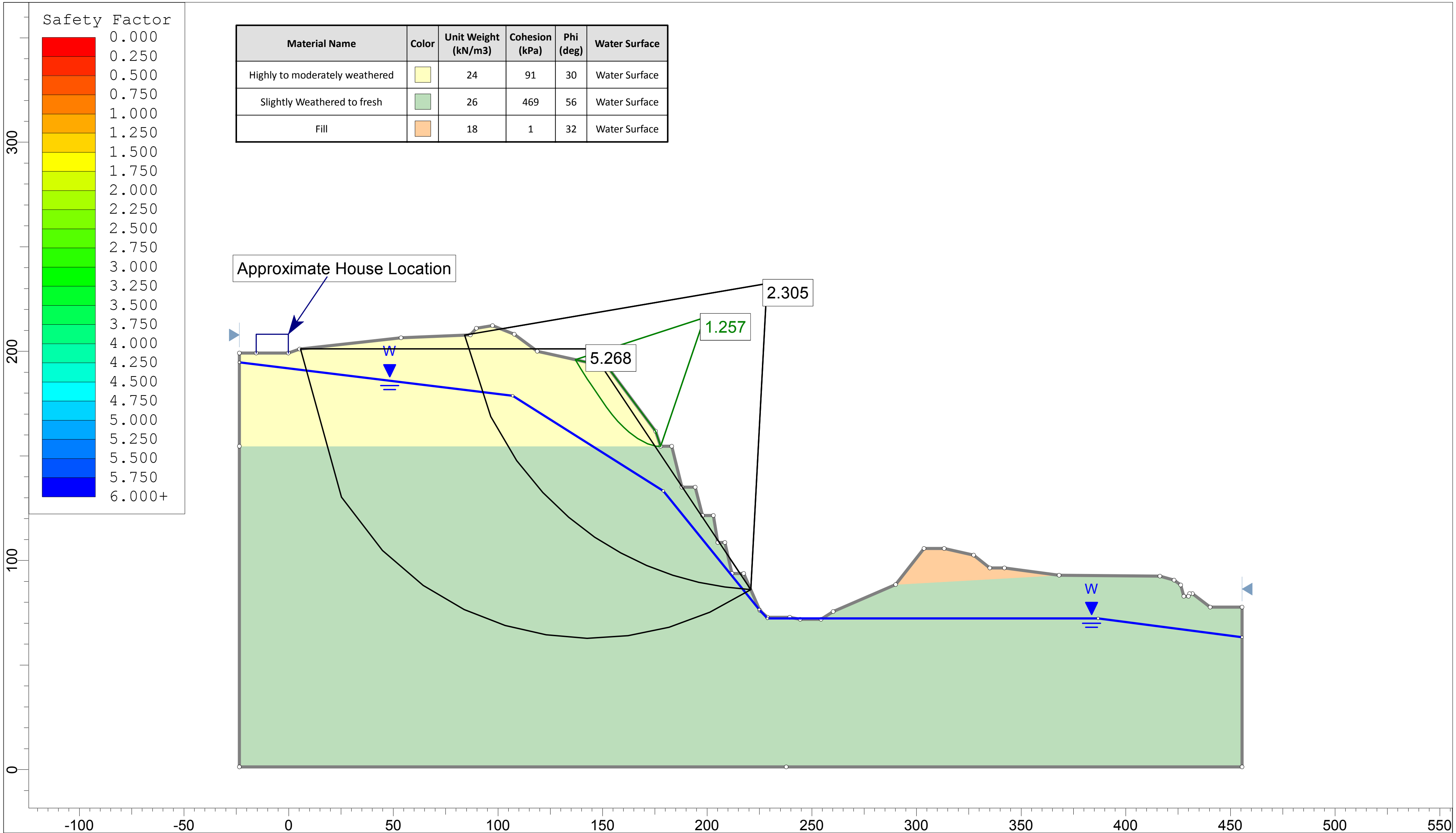

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Drawn By SC	Approved By GC	Analysis	North Wall Scenario 1, static, high groundwater
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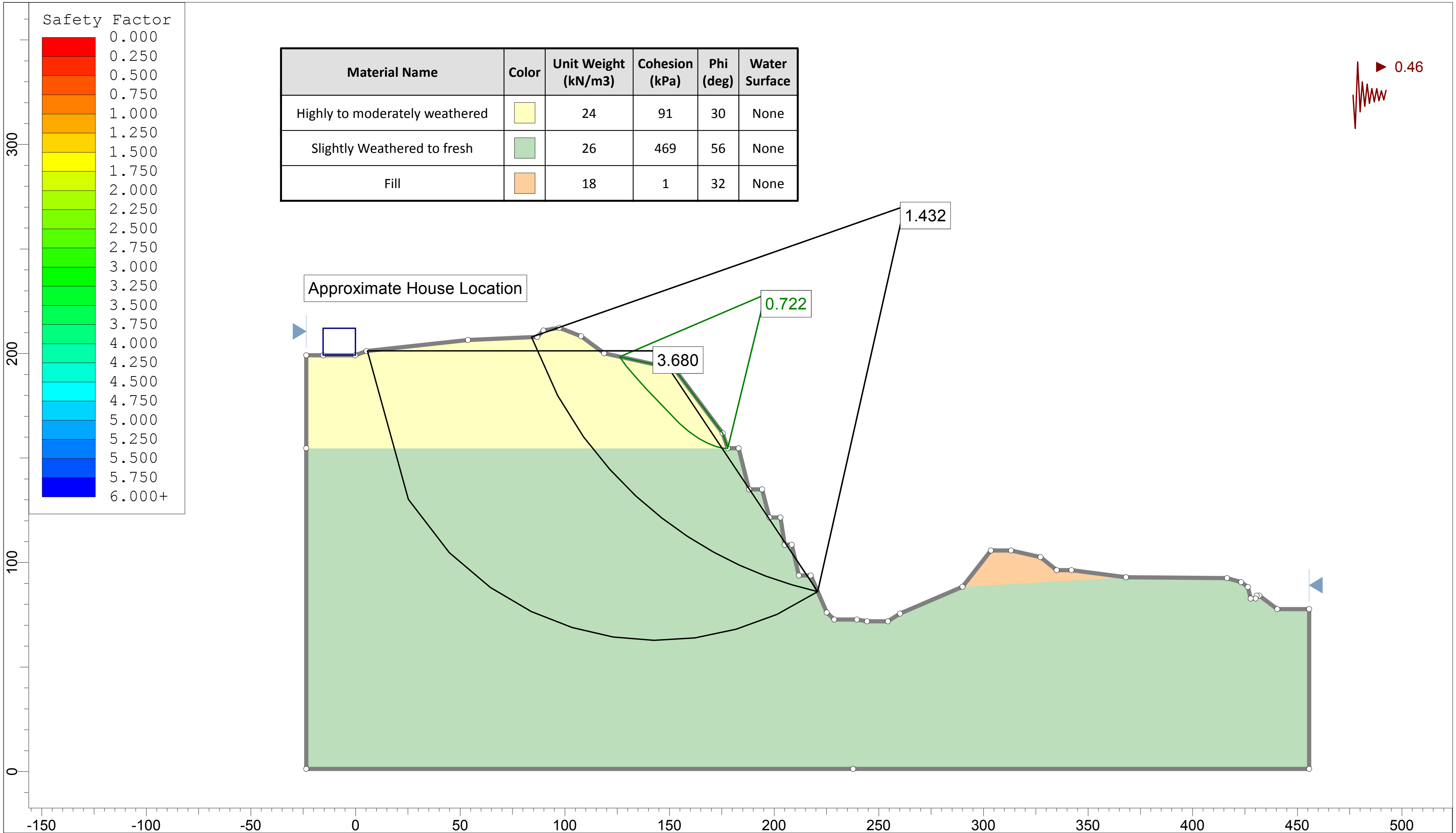

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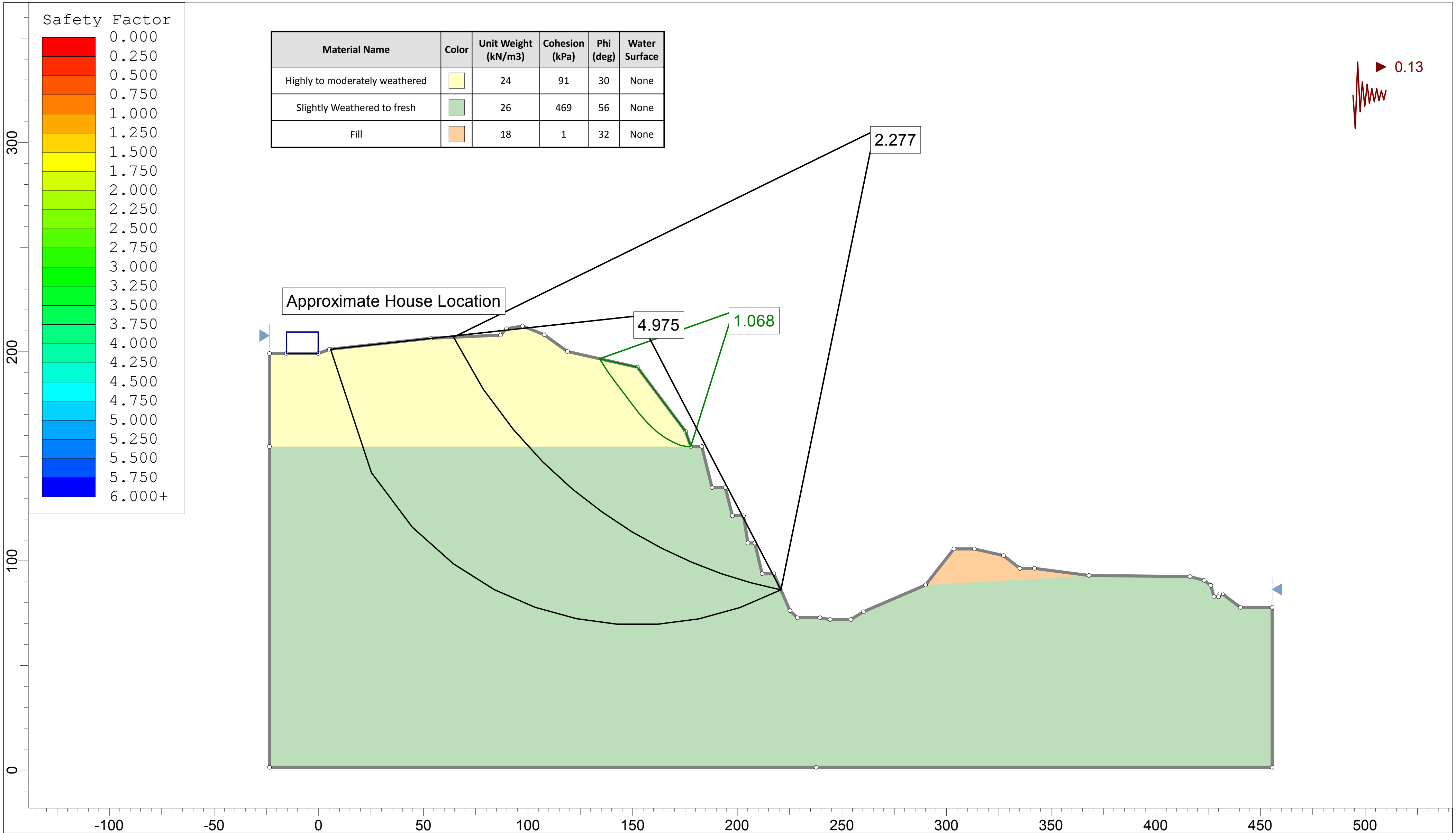

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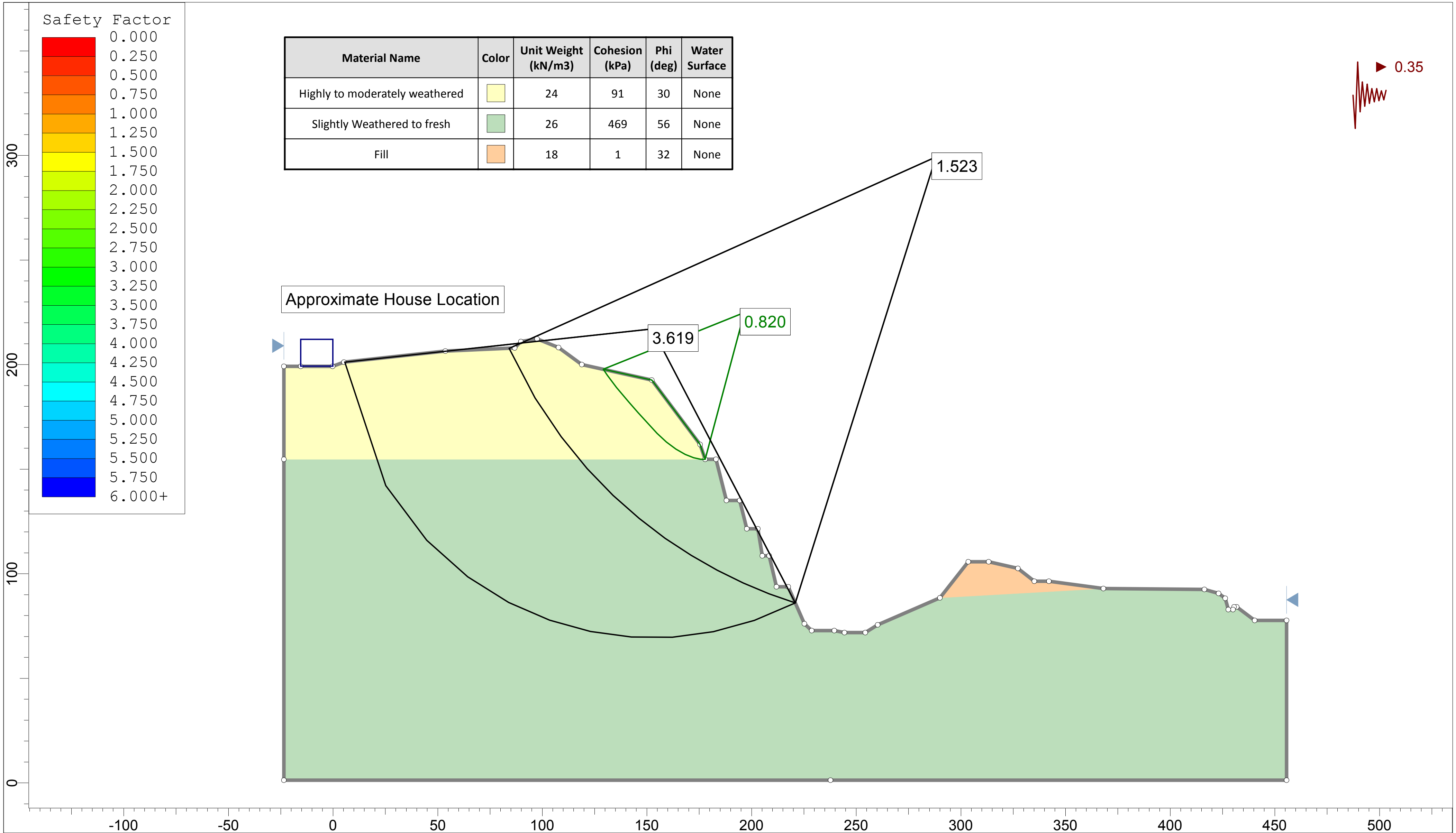

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Drawn By SC	*Approved By* GC	*Analysis*	North Wall Scenario 1, ULS, no groundwater
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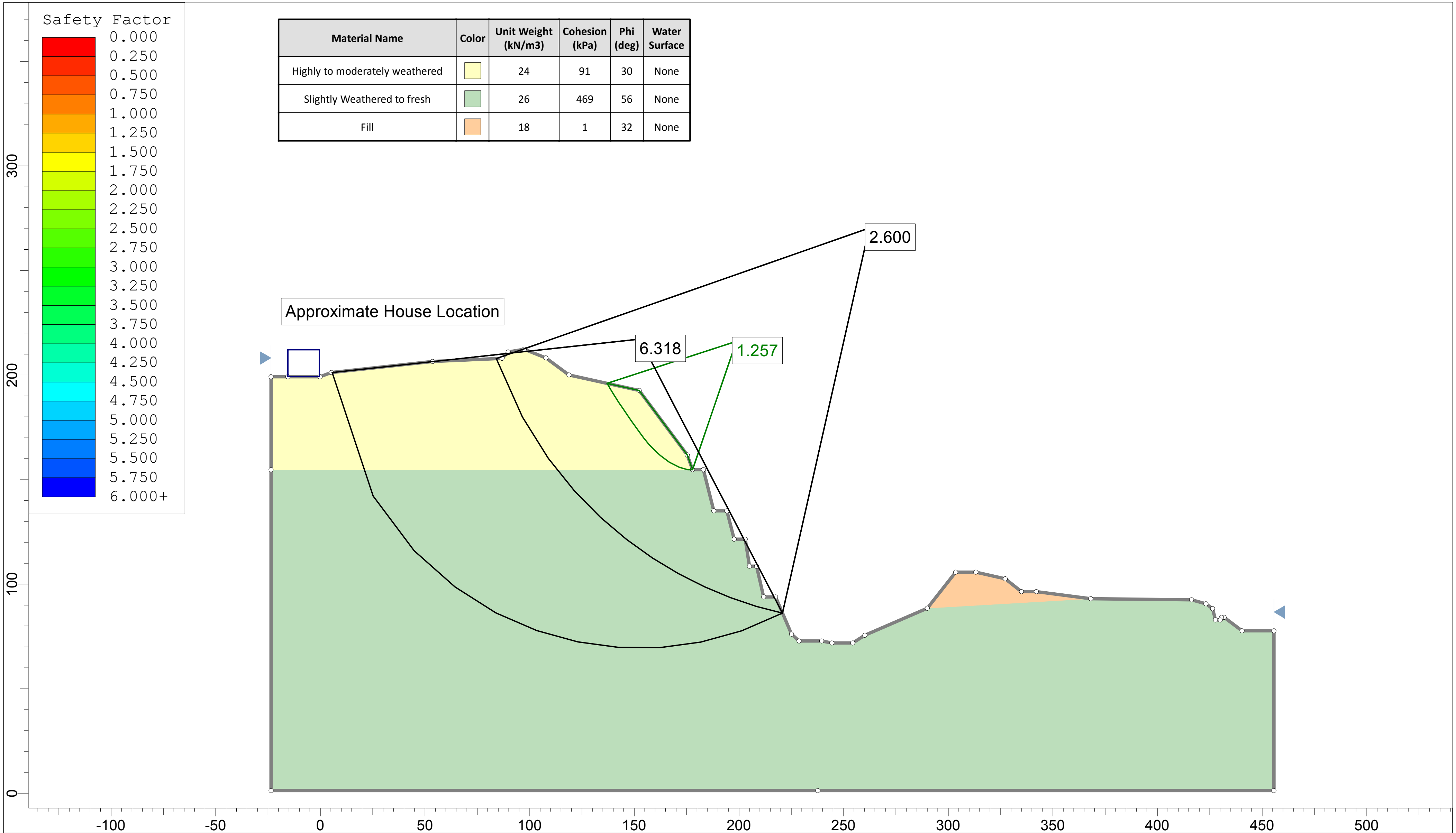

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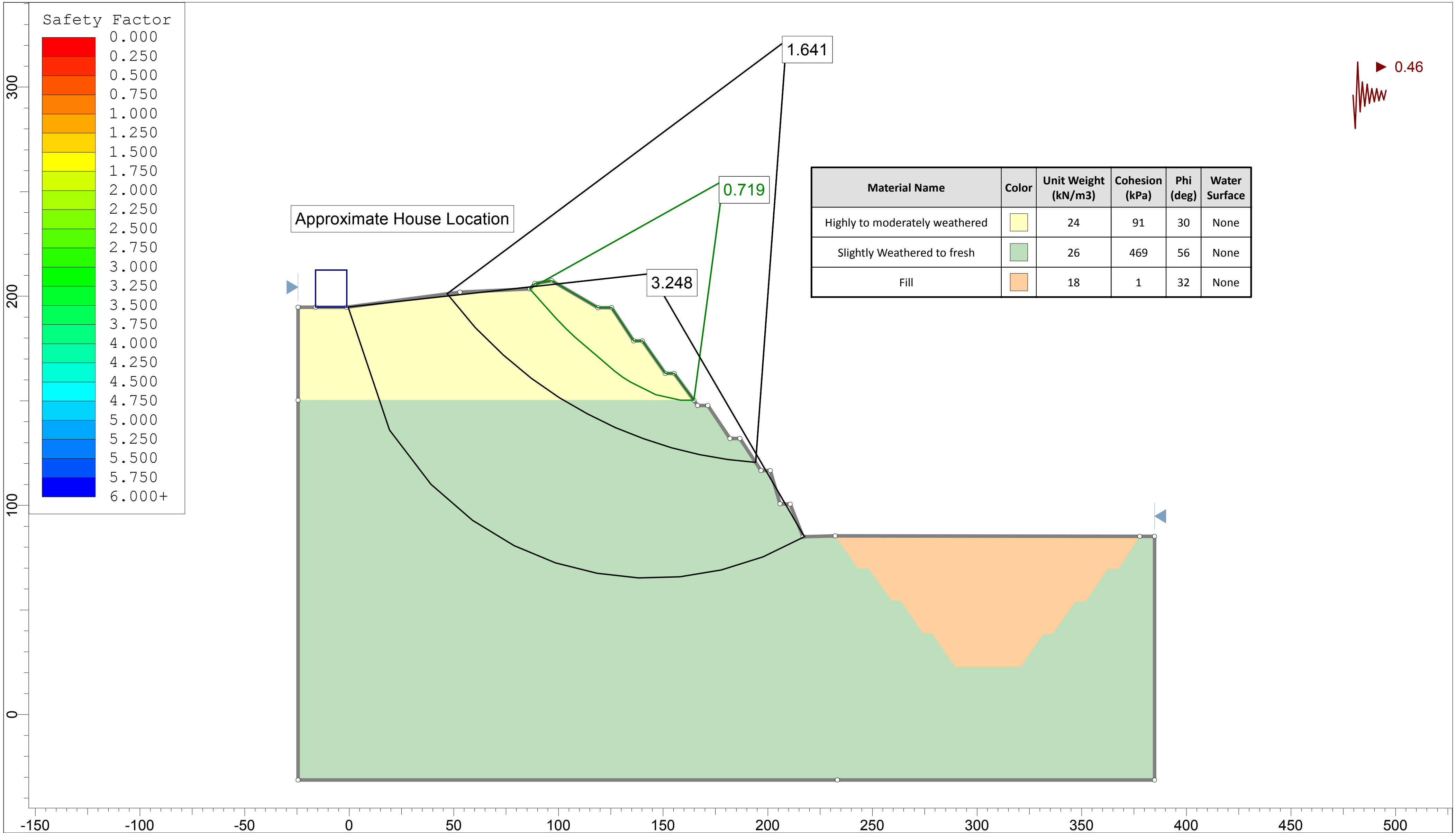
North Wall – Scenario 2



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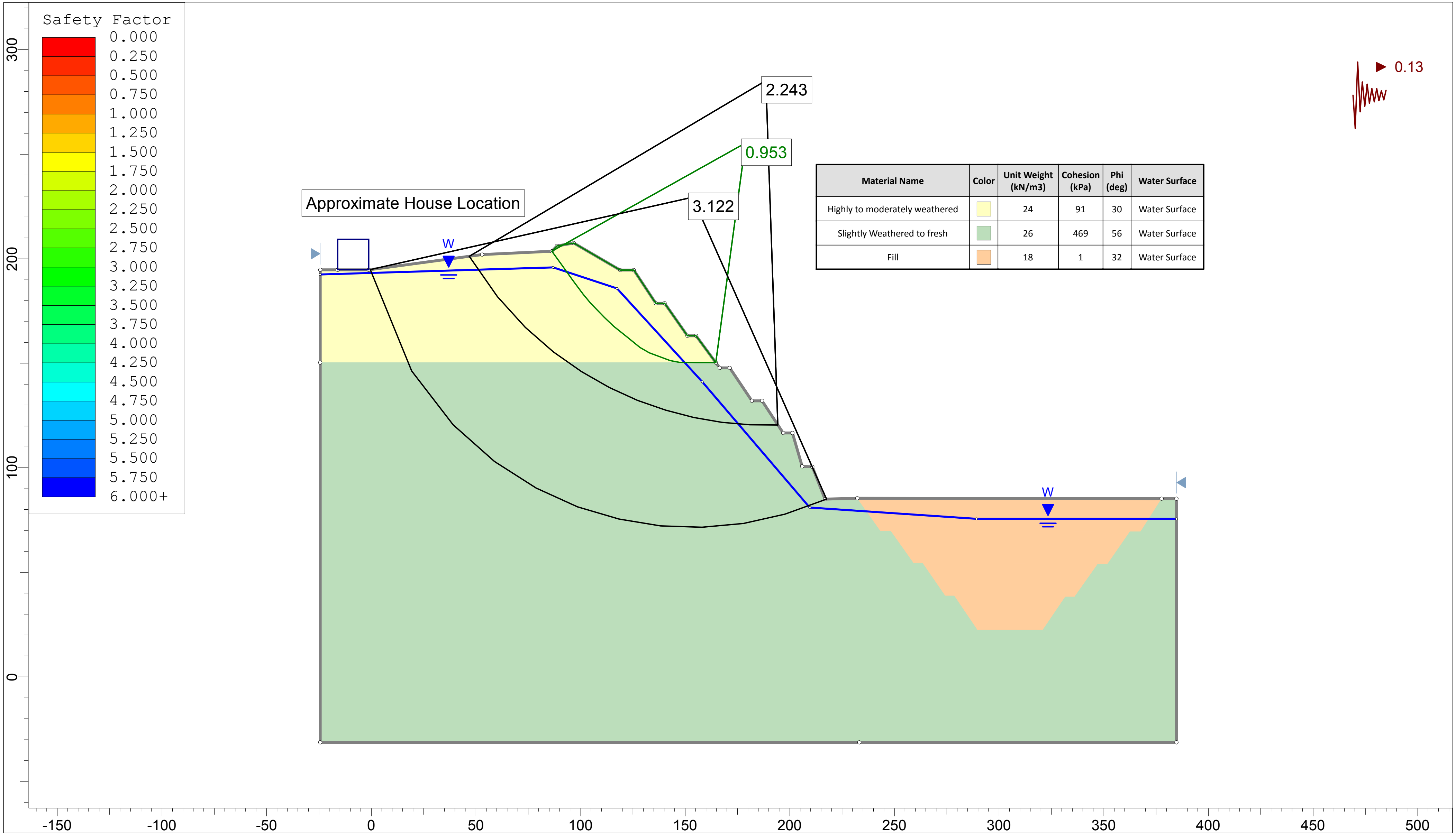

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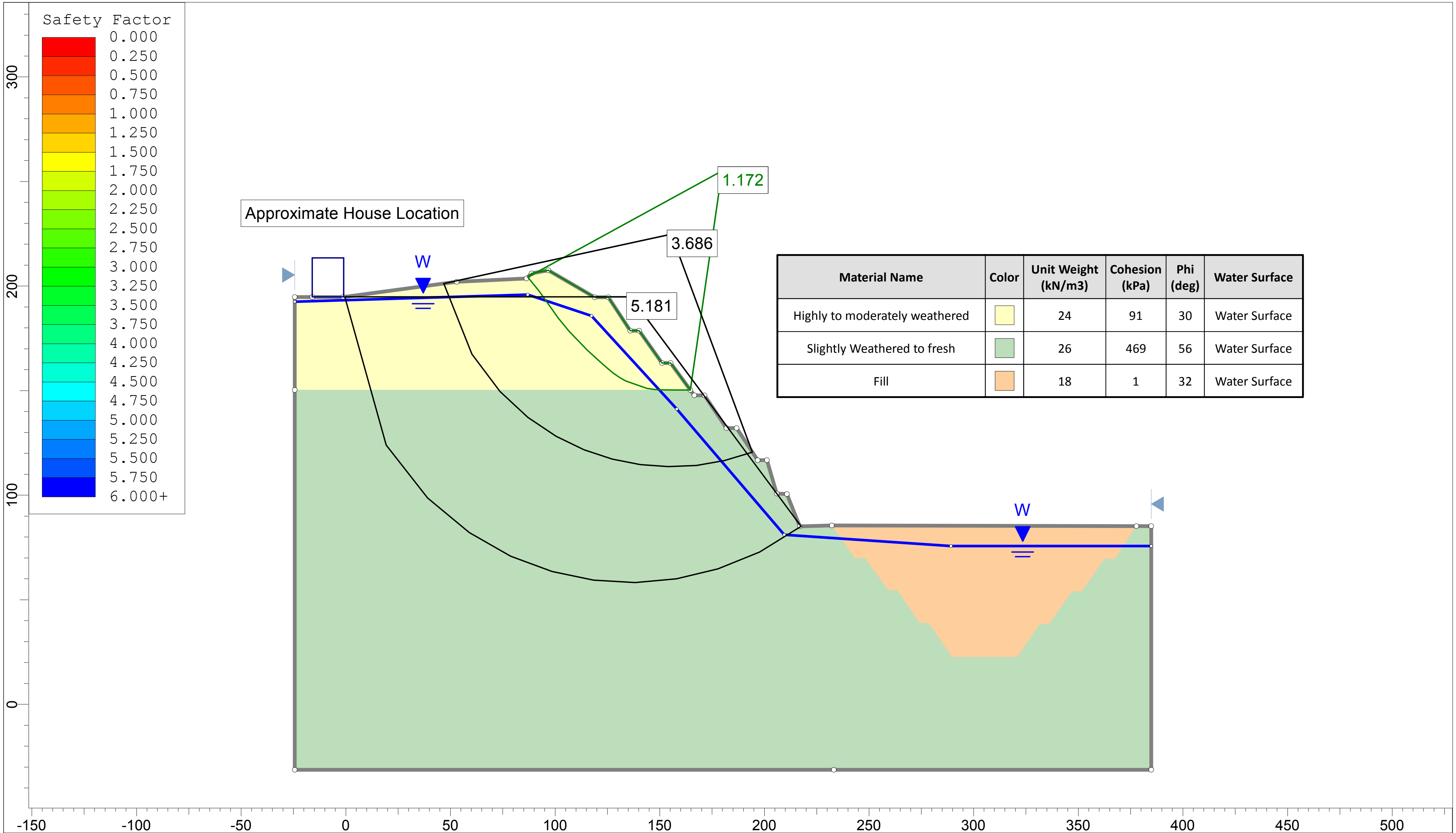

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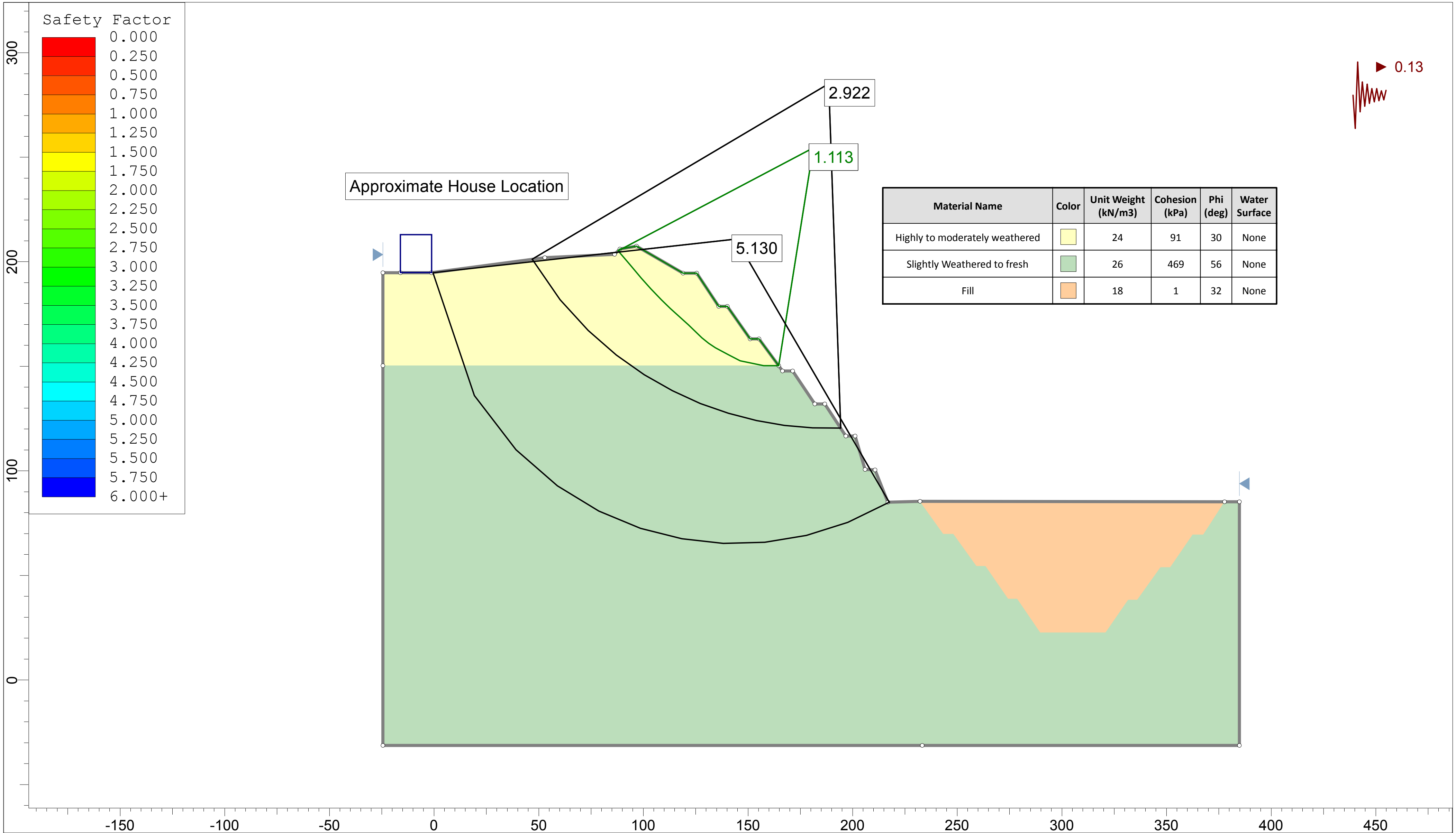

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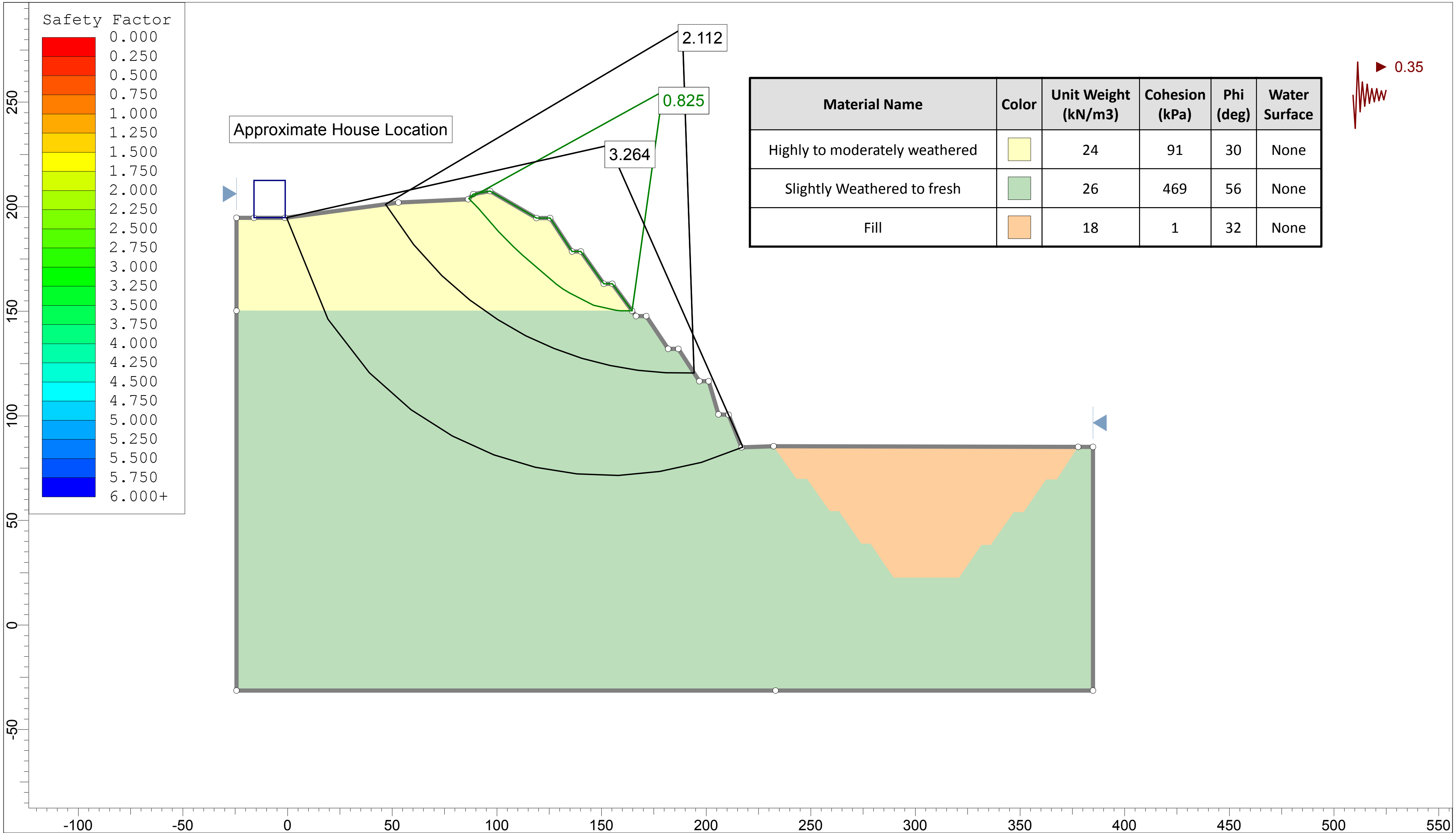

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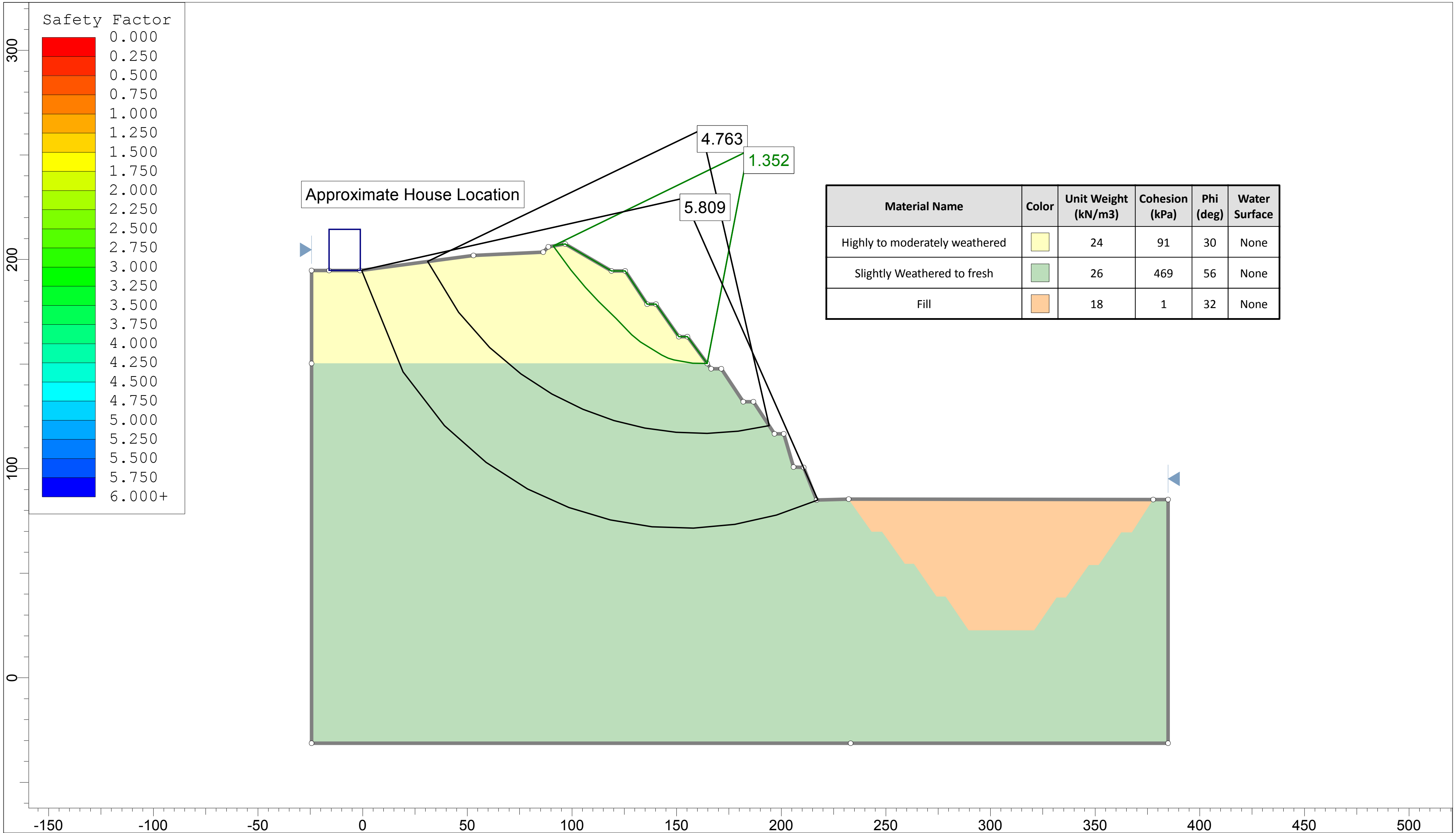

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Date	24/04/2015	*Revision*			
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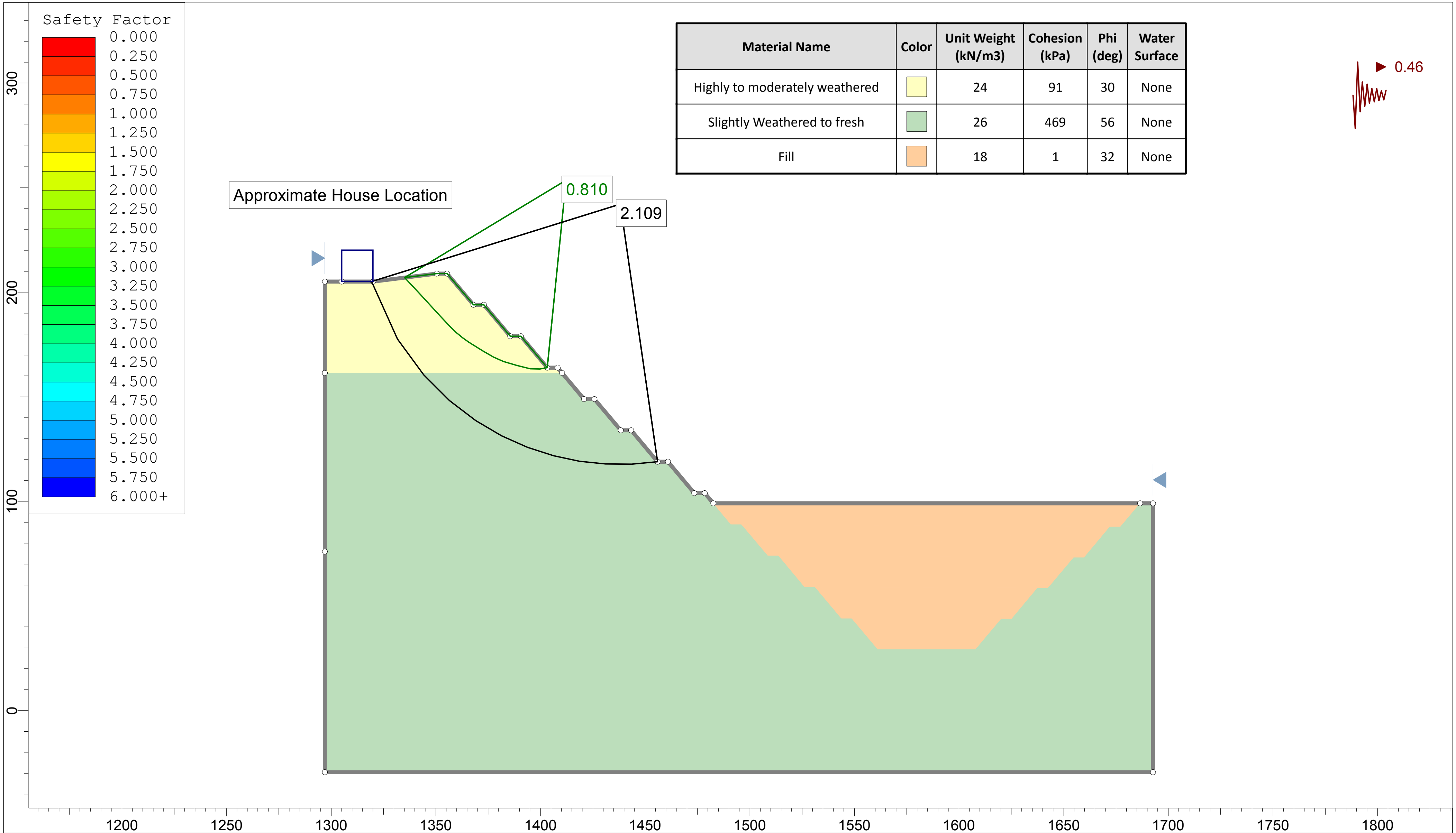
North Wall – Scenario 3



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Drawn By	SC	Approved By	GC	Analysis	North Wall Scenario 3, Chch, no groundwater
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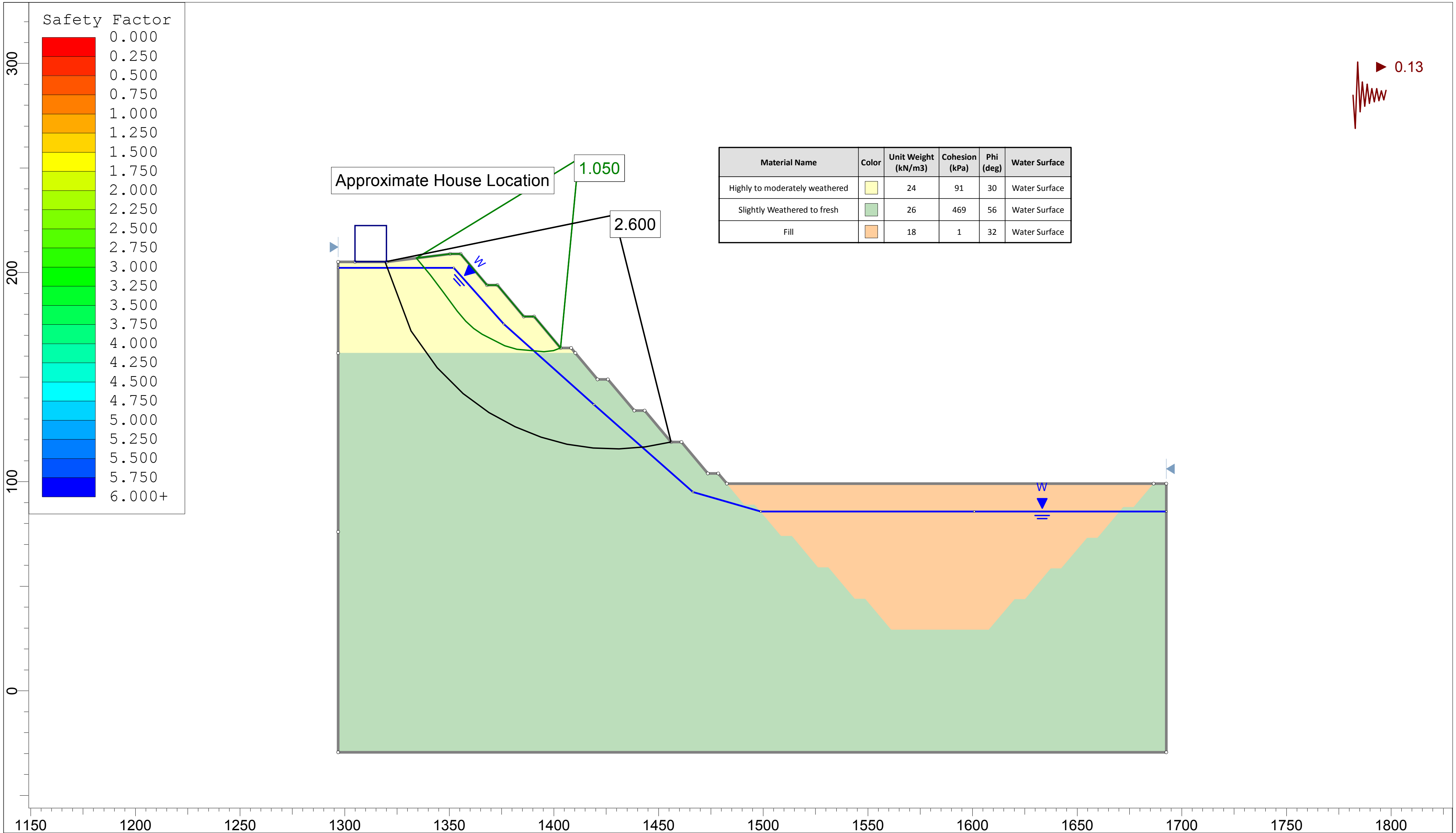

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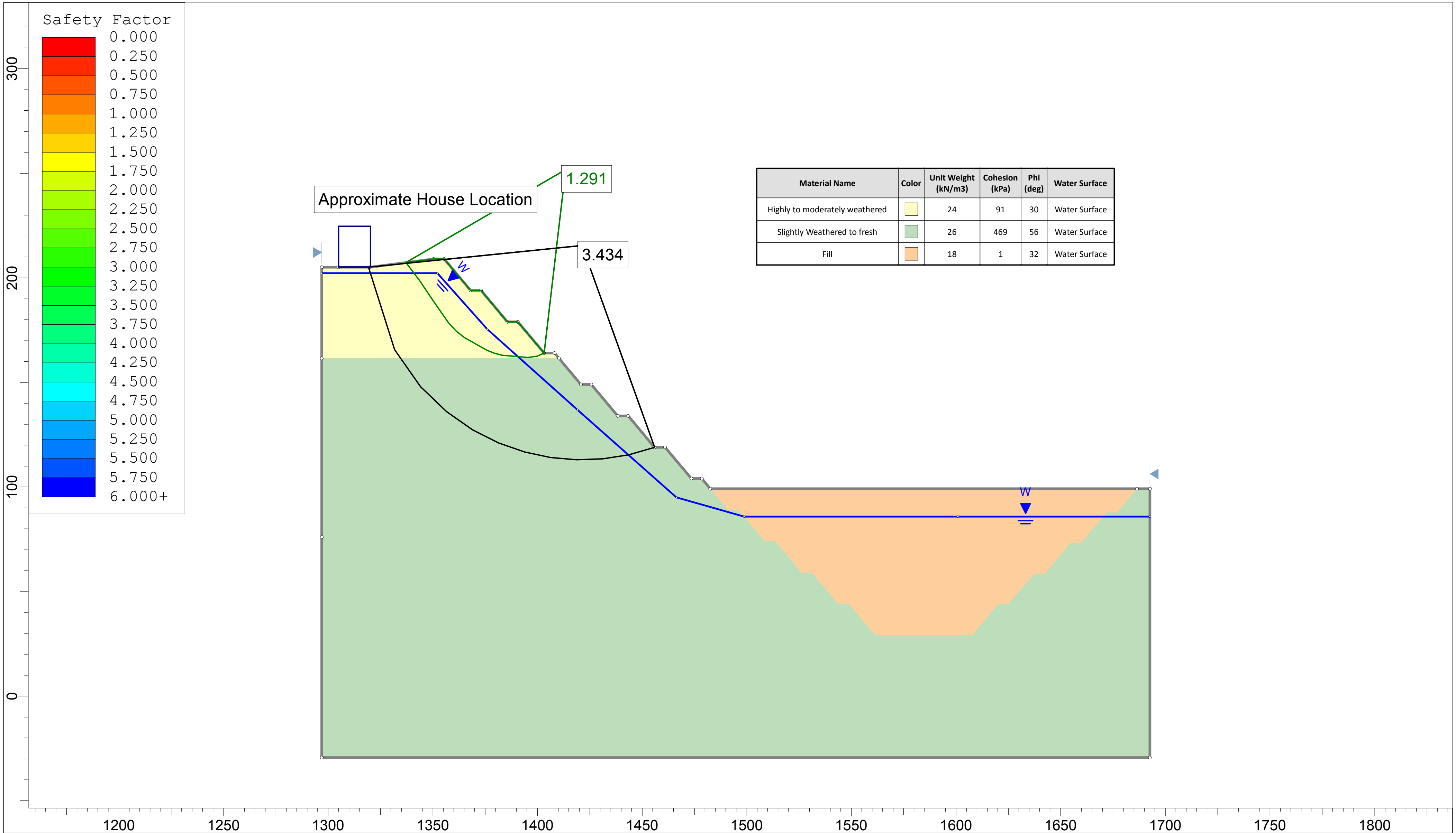

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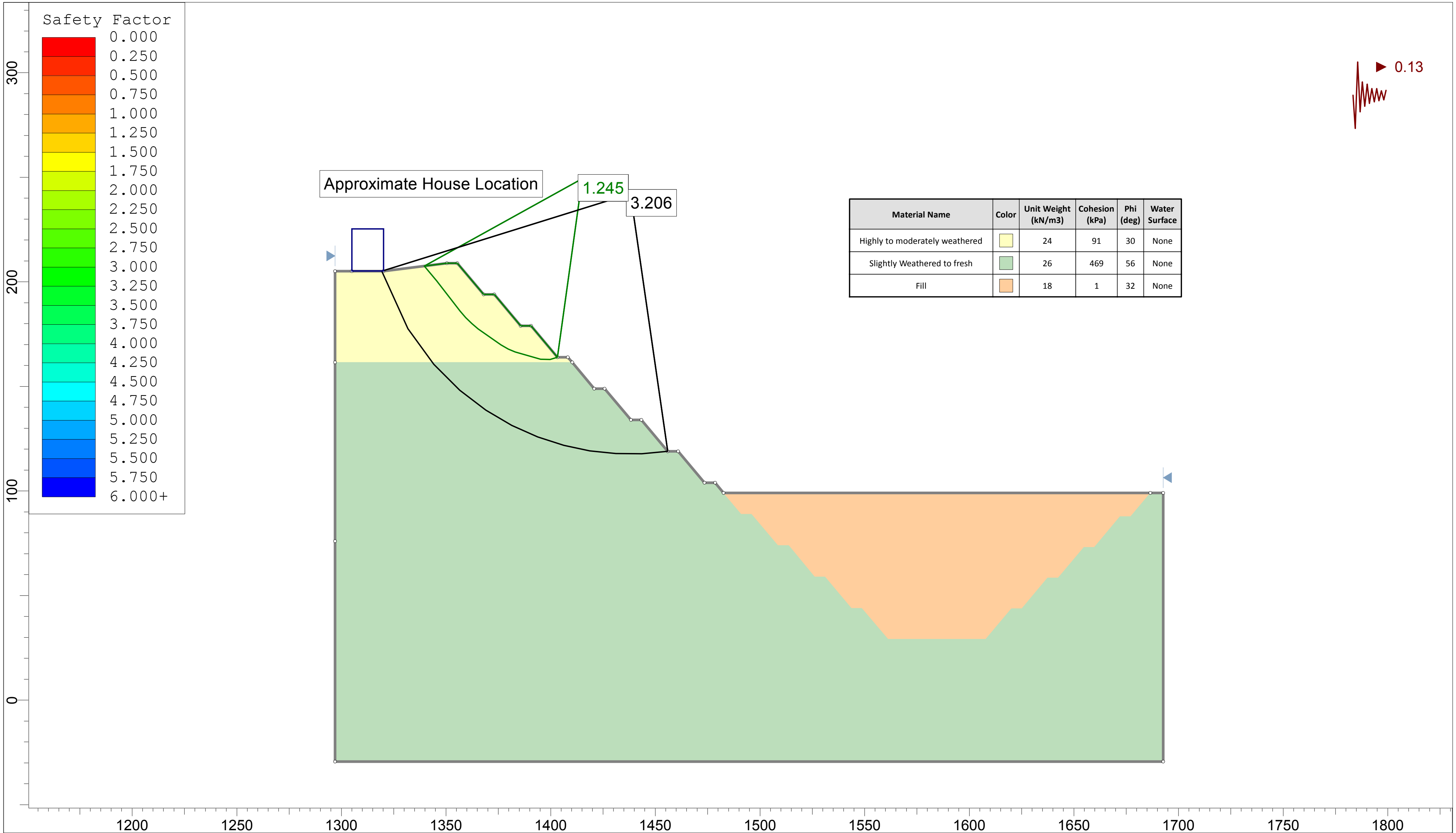

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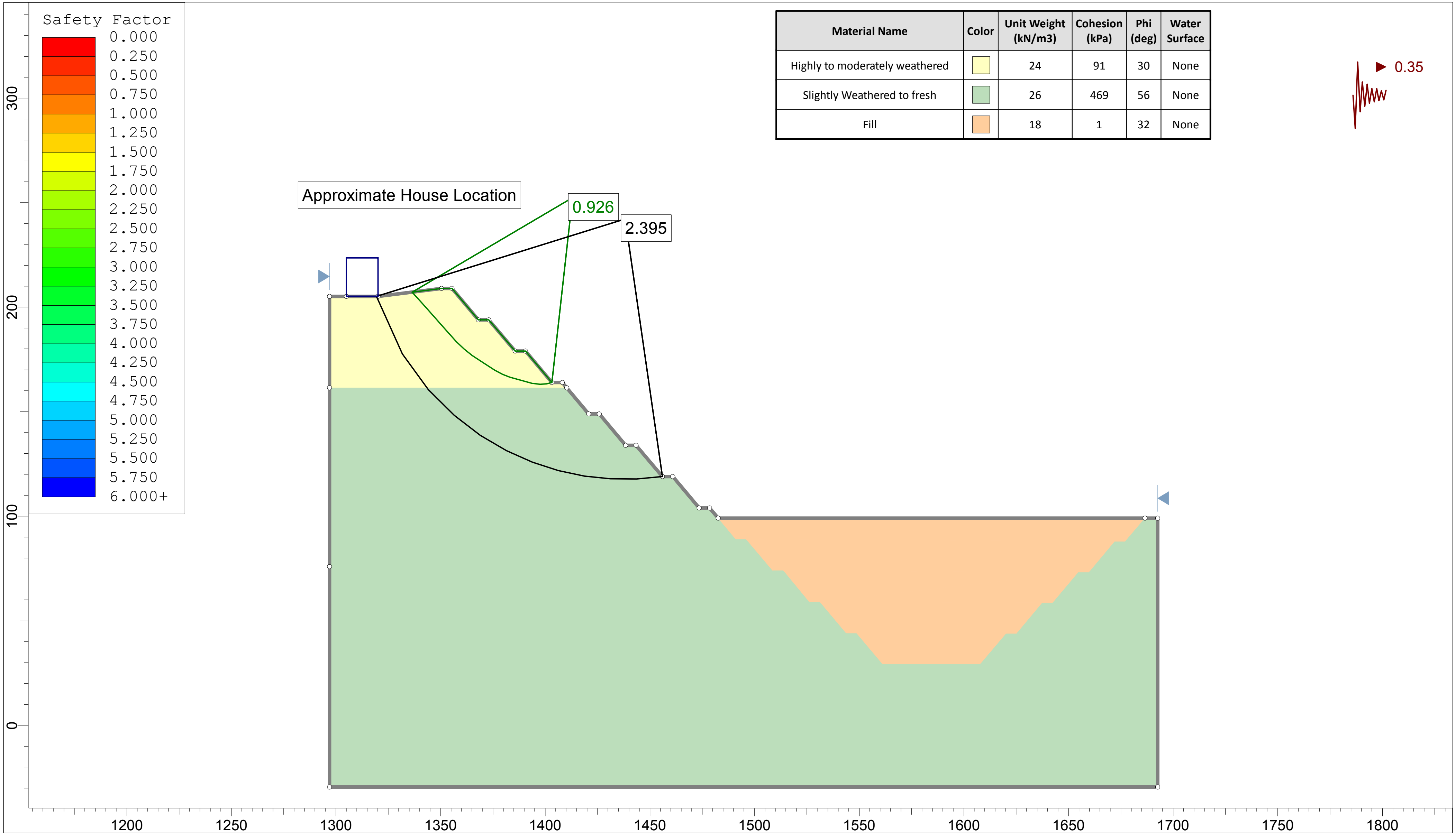

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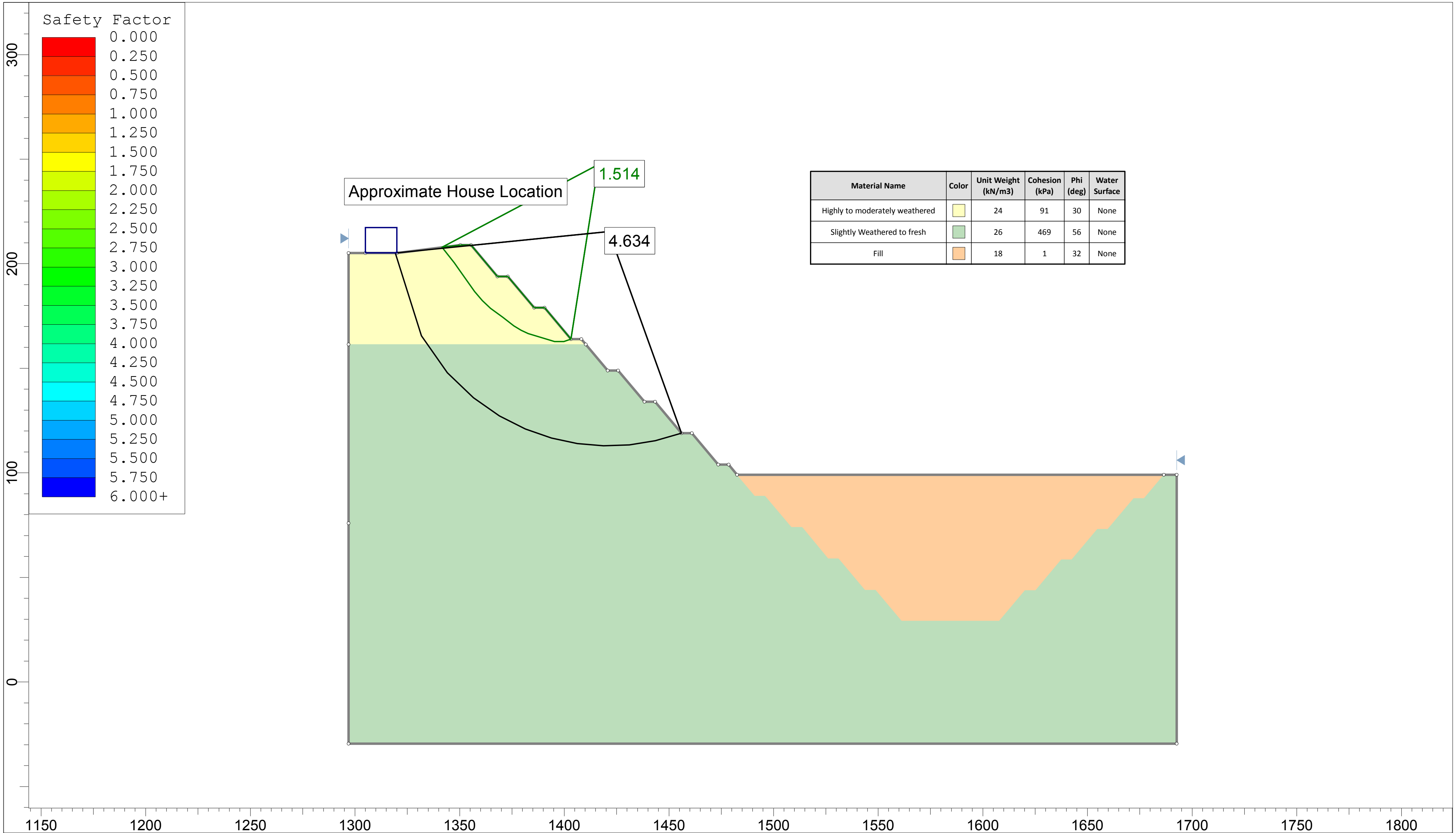

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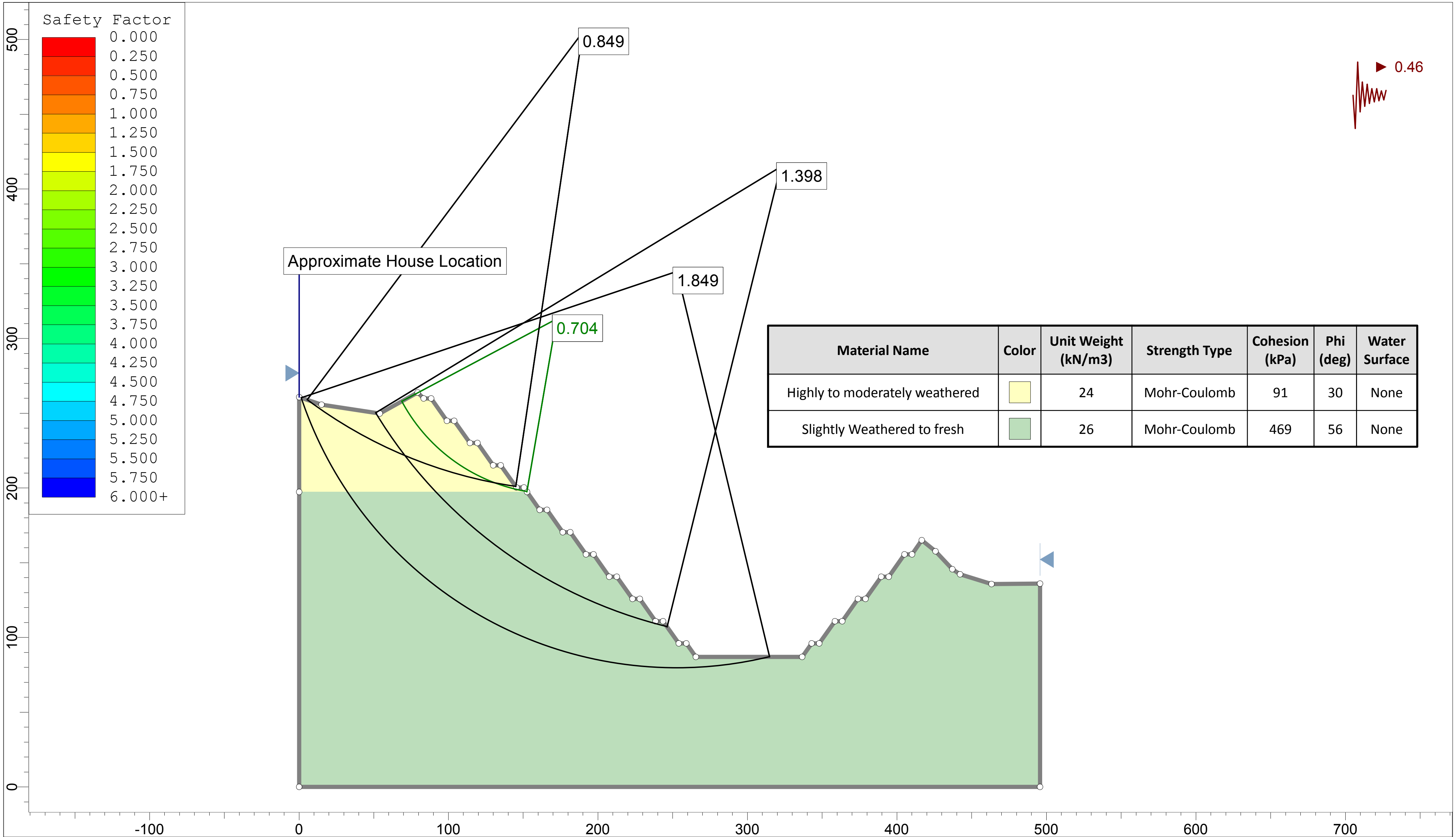
SLIDEINTERPRET 6.027 Geoscience Consulting (NZ) Ltd	Scale 1:2500	Page Size A4	Reference	10315.000.000

Area H

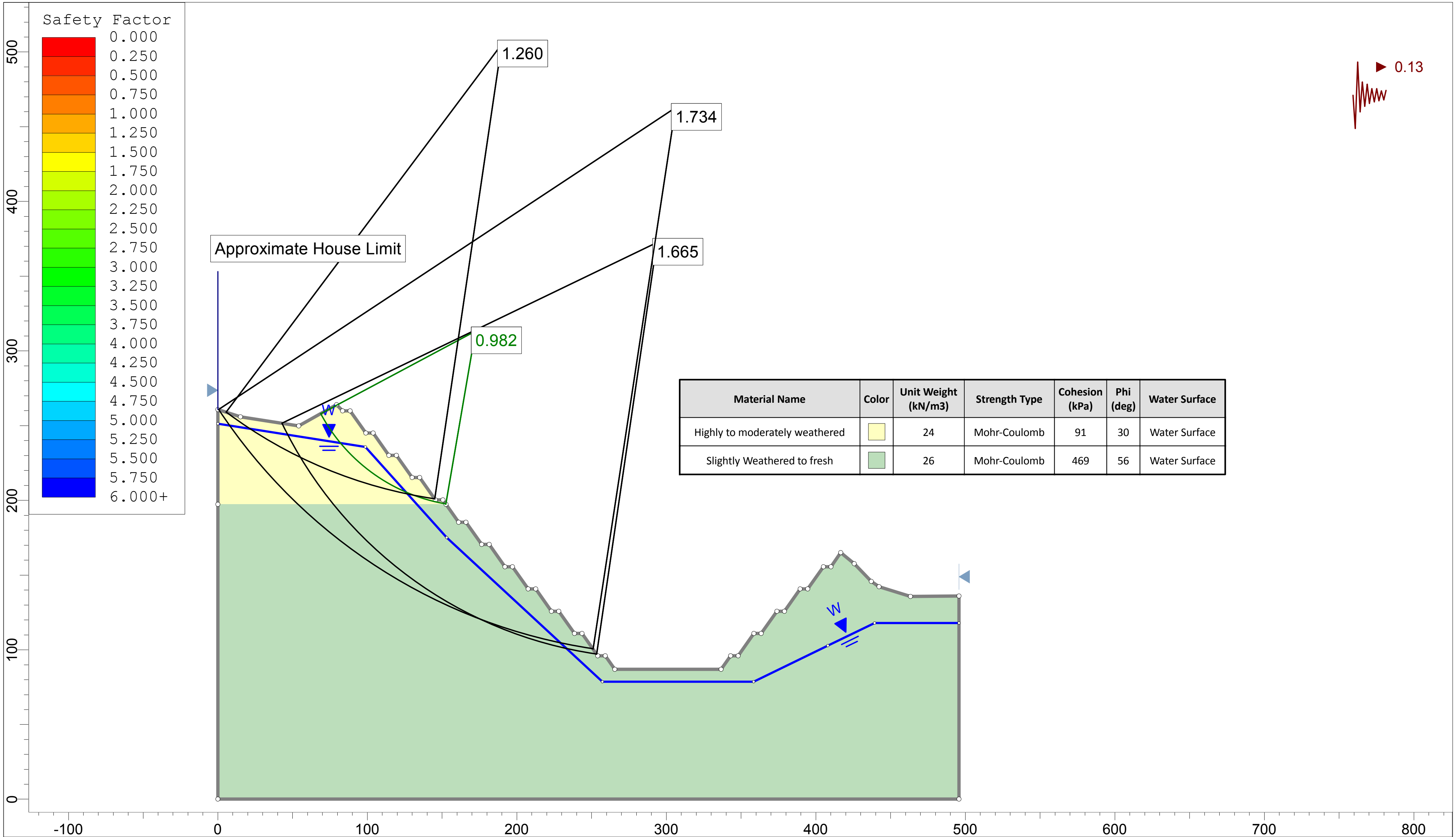


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None

ENGEO Expect Excellence

SLIDEINTERPRET 6.027 ENGEO Ltd

Client	Holcim New Zealand Limited	*Project*	KiwiPoint Quarry
Drawn By SC	*Approved By* GC	*Analysis*	Area H, Christchurch event
Date 28/04/2015	*Revision*		
Scale 1:3500	*Page Size* A3	*Reference*	10315.000.000

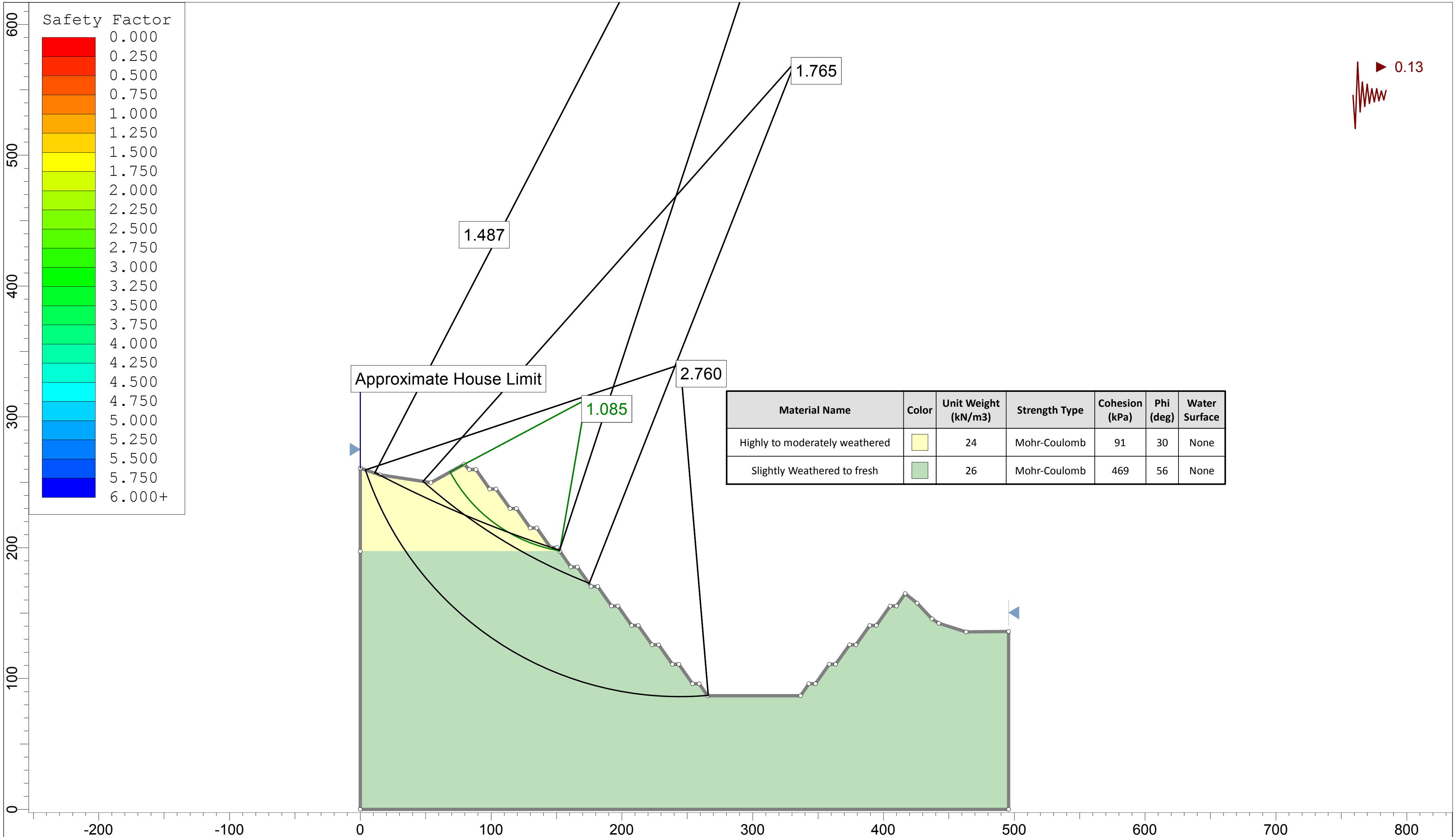


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	Mohr-Coulomb	91	30	Water Surface
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	Water Surface

ENGEO
Expect Excellence

SLIDEINTERPRET 6.027 ENGEO Ltd

Client	Holcim New Zealand Limited		
Drawn By SC	*Approved By* GC	*Project*	KiwiPoint Quarry
Date 28/04/2015	*Revision*	*Analysis*	Area H, SLS, high groundwater
Scale 1:3500	*Page Size* A3	*Reference*	10315.000.000

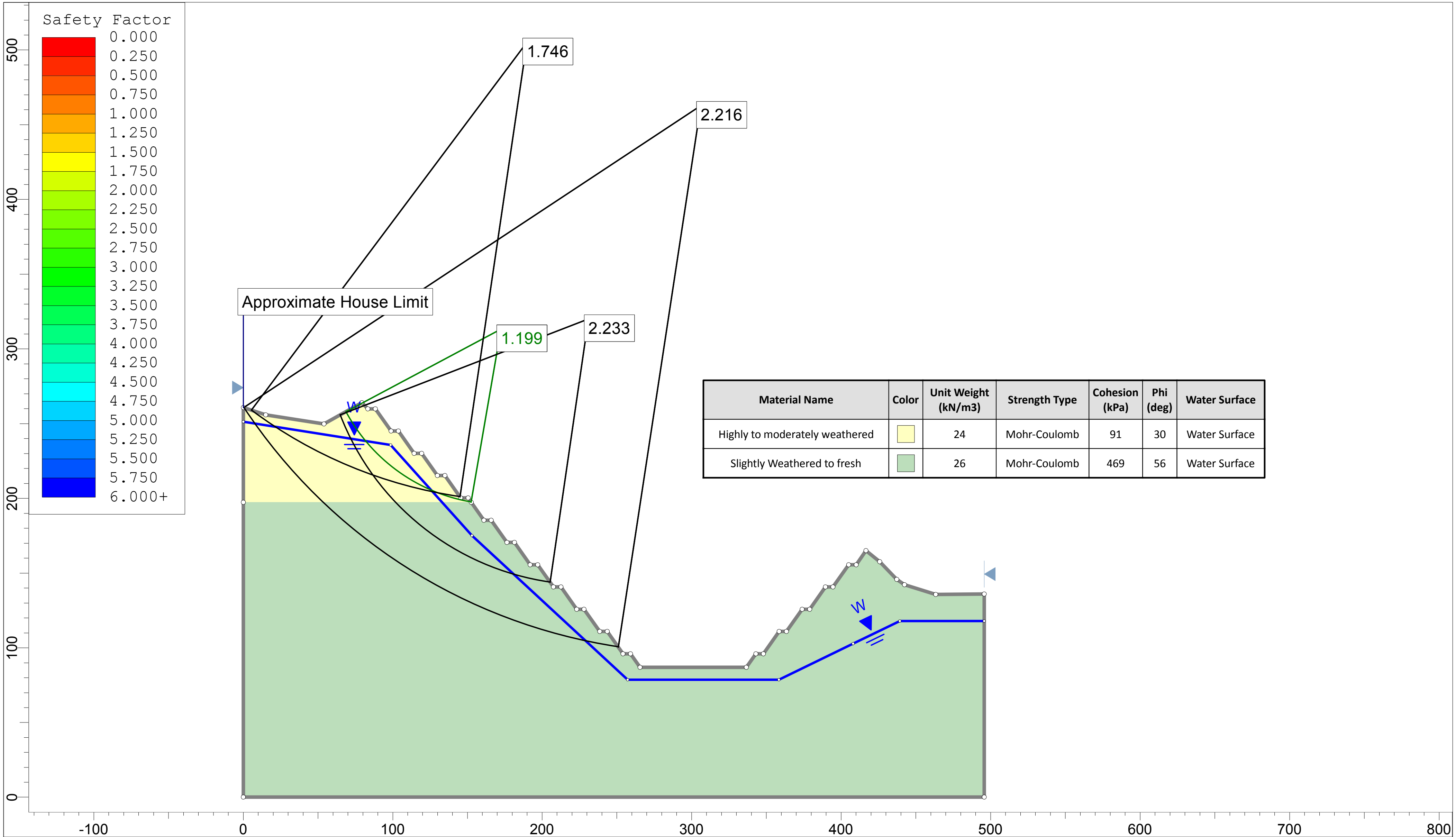


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None

ENGEO Expect Excellence

SLIDEINTERPRET 6.027 ENGEO Ltd

Client Holcim New Zealand Limited		*Project* KiwiPoint Quarry	
Drawn By SC	*Approved By* GC	*Analysis* Area H, SLS, no groundwater	
Date 28/04/2015	*Revision*		
Scale 1:4000	*Page Size* A3	*Reference* 10315.000.000	



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	Mohr-Coulomb	91	30	Water Surface
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	Water Surface

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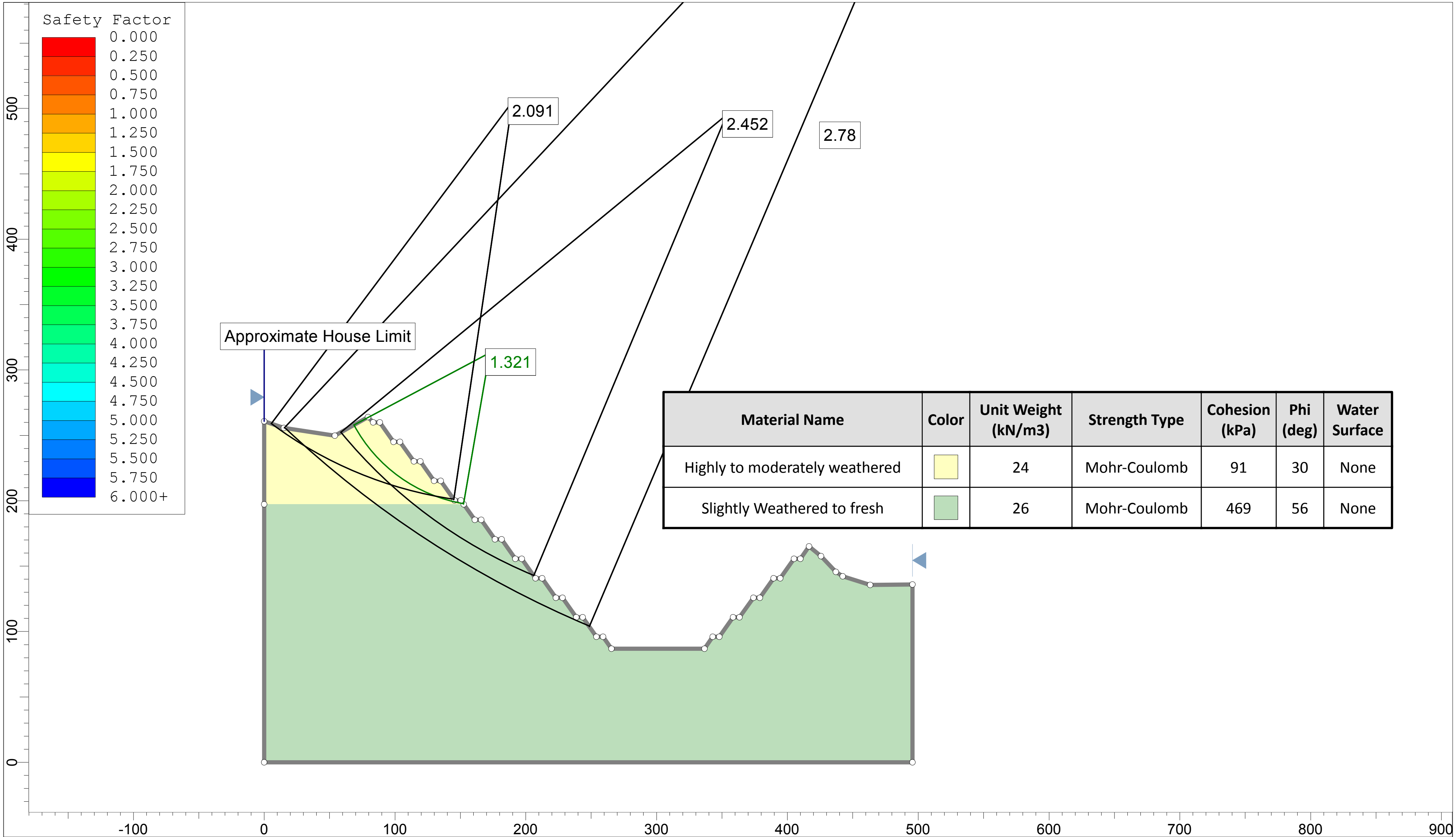
Client Holcim New Zealand Limited		*Project* KiwiPoint Quarry	
Drawn By SC	*Approved By* GC	*Analysis* Area H, static, high groundwater	
Date 28/04/2015	*Revision*		
Scale 1:3500	*Page Size* A3	*Reference* 10315.000.000	



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None

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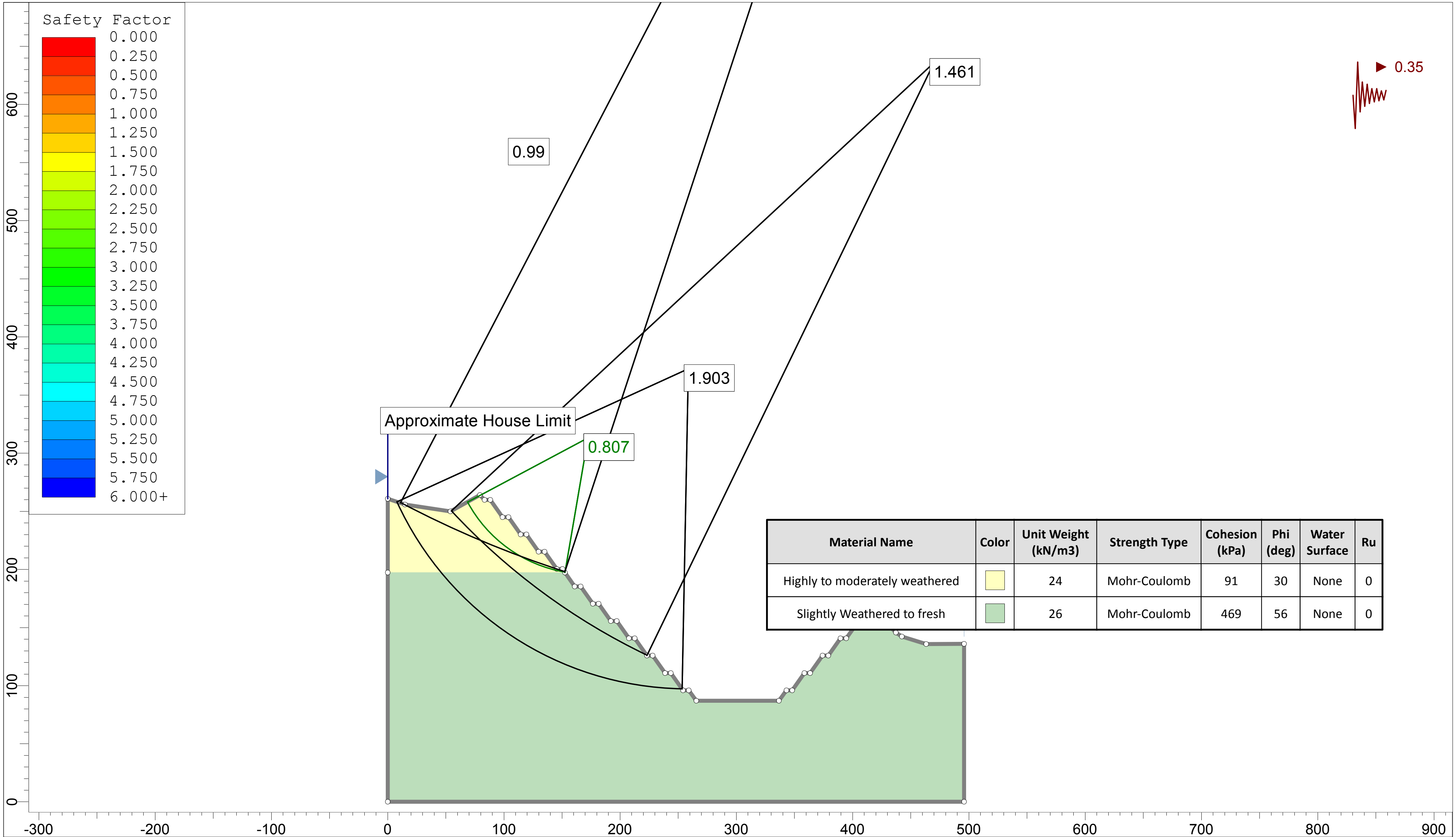
SLIDEINTERPRET 6.027 ENGEO Ltd

Client	Holcim New Zealand Limited	Project	KiwiPoint Quarry
Drawn By: SC	Approved By: GC	Analysis	Area H, static, no groundwater
Date: 28/04/2015	Revision:		
Scale: 1:4000	Page Size: A3	Reference	10315.000.000



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Highly to moderately weathered		24	Mohr-Coulomb	91	30	None	0
Slightly Weathered to fresh		26	Mohr-Coulomb	469	56	None	0

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SLIDEINTERPRET 6.027

ENGEO Ltd

Client	Holcim New Zealand Limited			*Project*	KiwiPoint Quarry
Drawn By	SC	*Approved By*	GC	*Analysis*	Area H, ULS, no groundwater
Date	28/04/2015	*Revision*			
Scale	1:4500	*Page Size*	A3	*Reference*	10315.000.000