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Date: 15 January 2020 Total Pages: 3+Appendices

To:	Copy:	Name	Organisation	Address
√		Mark Pelan	Gleeson Quarries Ltd.	Mark.Pelan@gleesoncox.co.nz
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√		Kate Madsen	Paua Planning Ltd.	kate@pauaplanning.co.nz

Project No: 2325-12	**Ref:** Huntly Quarry Managed Fill Sites 2-4 – Geotechnical S92 Response	**Revision:** A

This letter is submitted in aid of a response to a request for additional information provided by the Waikato District Council under Section 92 of the Resource Management Act 1991. The section 92 request was provided by the council in the letter dated 18th December 2019. This letter is specifically in response to Point 1a under "Planning and General" and Point 4 titled "Geotechnical" as quoted below:

1. Planning and General

a) Please confirm the separation distance that will be maintained between the edge of Fill Area 3 and the northern most property boundary

4. Geotechnical

The Gaia Engineering Geotechnical Assessment Report has been peer reviewed by Baseline Geotechnical. The Baseline Geotechnical preliminary review was dated the 9 October 2019 and resulted in ongoing discussions between Baseline Geotechnical and the Gaia Engineers around the stability of the proposed fill sites. Baseline Geotechnical has also reviewed the revised Gaia Geotechnical Design report. As a result of that further review, there are three items that Baseline Geotechnical are of the opinion remain outstanding. These matters relate to Waikato Coal measures shear surfaces; fill site 2 geology; and seismic design analyses. Those matters are set out in more detail in the attached s92 Geotechnical request letter from Baseline Geotechnical. Please review that correspondence and provide a response to the 'additional information' aspects set out in that correspondence.

The letter from Baseline Geotechnical referenced above was appended to the Waikato District Council Document and is dated 11th December 2019.

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Please find our response to these queries addressed below and in the comment tracking/summary sheet included in Appendix A. Additional documents, drawings and calculation outputs are included in Appendix B and C.

1. Peer Review Comment Sheet

A register of comments received from the Waikato Regional Council's peer review, Baseline Geotechnical, has been maintained over the course of the peer review process.

The register summarises the multiple rounds of comments and response including additional response to the remaining outstanding comments. The current version of this sheet is dated 03 December 2019 and is provided in Appendix A.

2. Fill Site 3 to Property Boundary Setback

The conceptual fill layout is setback approximately 28m from the property boundary directly north of the site to the toe of the fill. Conceptual stability modelling has demonstrated that no credible stability risk to the neighbouring property exists within this setback zone.

It is believed that a setback of this size would also provide a suitable buffer to allow access for maintenance of fill batter slopes and any installed drainage. The exact setback distance from the northern property boundary will be confirmed during detailed design.

3. Revised Fill Site 2 Geology

As part of the ongoing detailed investigation and design works for Fill Site 2 at the Huntly Quarry, additional investigation near the toe of the proposed fill has since been carried out.

The 6 additional test pits have been completed to depths ranging from 2.0 to 6.2m deep, primarily concentrated near the toe of the proposed fill. Draft test pit logs and a revised site plan showing the location of the additional test pits is included in Appendix B and Appendix C.

The additional test pits encountered improved ground conditions over those initially used for concept stability calculations. The improved ground conditions comprise weathered greywacke soils of the Newcastle Group in place of the previously assumed Waikato Coal Measures. Weathering depth to weak highly weathered material was found do be within 1.5m of the surface near the invert of the gully such as in TP209 and TP211.

Revised slope stability calculations based on the weathered greywacke toe founding material as opposed to the original Waikato Coal Measures toe founding material are provided in Appendix D.

4. Slope Stability & Seismic Displacement Calculations

Additional/revised slope stability calculations based on the outstanding comments listed in the letter provided by Baseline Geotechnical have been completed and are included in Appendix D.

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Seismic Displacement analysis based on the revised limit equilibrium analysis has increased the predicted displacements in the order of 80mm with a 15% probability of exceedance. We consider the risk of such displacements on a fill slope that is able to be maintained to be sufficiently low. A copy of the calculation is also provided in Appendix D.

5. Limitations

The responses and additional calculations provided in this letter will need to be confirmed during detailed design for each fill site.

Yours sincerely
Gaia Engineers Ltd

Prepared By:	Reviewed & Approved By:
	
Matthew Kernot Senior Engineering Geologist	**Dr Ka-Ching Cheung** Director

Appendices
Appendix A – Revised Comment Tracking Sheet
Appendix B – Test Pit Location Plan and Geological Cross Section
Appendix C – Draft Additional Test Pit Logs
Appendix D – Revised Limit Equilibrium Slope Stability Analyses & Seismic Displacement Calculation

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Appendix A
Revised Comment Tracking Sheet

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HUNTLY QUARRY – FILL DISPOSAL SITES
SUMMARY REGISTER OF GEOTECHNICAL COMMENTS FROM PEER REVIEWER

Project:	**Huntly Quarry – Fill Disposal Sites**
Subject:	**Resource Consent Report**

DOCUMENT REVISION:	**03**	**Name of Reviewer(s):**	Cameron Lines
Document Issue Date:	**03rd December 2019**	**Organisation:**	Baseline Geotechnical
Purpose of Review:	**Peer Review of geotechnical report to advise Waikato Regional Council.**	**Available Documents:**	1) 2325-12-GQ-01 (Huntly Quarry Disposal Sites – Geotechnical Assessment)_Rev B. 2) 2325-12-GQ-01 (Huntly Quarry Disposal Sites – Geotechnical Assessment)_Rev C.

No.	Element	Peer Reviewer Comment Description	Gaia Response	Closed Out (Y/N) Comment	Further Reviewer Comment	Gaia Response	Closed Out (Y/N) Comment
1	Ground Model	Date (09/10/19) Provide reference to the key geotechnical risk presented by each lithological unit. Specific reference to: a) Potential presence and orientation of low strength, bedding parallel shears within Waikato Coal Measures b) Fast groundwater seepages within historic mining fill c) Trial Pits failing to intersect contact between mining fill and underlying material d) Depth of the Newcastle Group Greywacke and relationship to the development	Date (15/10/19): a) During our previous test-pit investigation only limited evidence of bedding planes were observed due to the depth reached with test-pits. Where bedding was observed it was most visible in the moderately weathered material half way up the gullies. In the base of the gullies relatively unweathered Waikato Coal Measure mudstone was encountered where a more chaotic fabric was exhibited. As such, absolute bedding direction was difficult to ascertain. We consider bedding plane weaknesses to be of low risk to the development due to the nature of the fill being constructed from the fill toe (where the ground is relatively flat) and back up the gully, effectively buttressing the Waikato Coal Measure slopes. No major cuts exposing bedding aligned weakness planes are proposed as part of the development. Sensitivity of the foundation material at the fill toe can be tested based on different configurations of potentially present bedding fabric. If bedding direction cannot be determined reliably during detailed investigations, generalised anisotropic strength models		Date (3/11/19): a) For Overburden Disposal Areas (OBDA) paced on a foundation of Waikato Coal Measures (WCM). Bedding orientation and strength is a key geotechnical risk. The chaotic fabric described may be as a result of faulting, suggesting low strength, pre-sheared surfaces on bedding are a strong possibility. Currently Gaia have not demonstrated a good understanding of the actual WCM bedding orientation or condition and have not analysed worst case combinations of orientation/strength. Given this, we don't understand how Gaia can classify the risk as low, when every major slope failure in adjacent coal mine cuts or fills have occurred on these very structures. It has been our experience that pre-sheared, gently inclined bedding surfaces within WCM can result in failure even at the toe of gently inclined slopes. There are any number of investigation techniques available to confirm bedding orientation and condition. Gaia are not limited to test pits if other techniques would provide better data. b) The deep drains proposed are a good idea. Thought will need to be given to the effect on groundwater in the fill, which will define the groundwater conditions for analysis. c) We are comfortable with the approach, but the stability of this Fill site for a combination of worst-	Date (07/11/19): Please refer to Rev. C of the report which now includes Section 4.3 which discusses geological risk and mitigation strategies including Waikato Coal Measures bedding. a) It is accepted that the general bedding direction is difficult to ascertain at this time. As such we have undertaken preliminary stability analysis assuming worst case bedding direction with a credibly low strength (shallow dipping out of the slope). The analysis is discussed in Section 7.0 of the Rev. C report The analysis shows that the overall stability of the fill is still largely governed by the design and construction of the fill itself. During detailed design, if failures along low angle bedding shears near the toe of the fill are found to be a risk to the fill then these can be mitigated with specifically designed toe-keys. It is anticipated that detailed investigation and design will confirm whether or not these concerns are present near the toe of the fill and consequently will govern the design of the toe-keys as necessary. b) Conservative groundwater parameters were adopted in the concept stability analysis likewise; residual pore water pressures were modelled the fill. c) Noted, thank you.	Comment Closed Out

No.	Element	Peer Reviewer Comment Description	Gaia Response	Closed Out (Y/N) Comment	Further Reviewer Comment	Gaia Response	Closed Out (Y/N) Comment
			can be applied to simulate a range of potential bedding parallel weaknesses. b) Subsequent to the release of the report the client has proposed the installation of deep counterfort drains at Fill Site 3 to relieve the groundwater from the historic mining fill. This will form part of the detailed investigation and design. Response of the groundwater perched within the historic fill can be monitored during and after construction of the drains. c) As for part (b) the client intends to construct the deep drains with a long-reach excavator. We intend to use this excavator to assess the thickness and basal interface qualities of the historic fill. We consider this work to be part of the site investigation for detailed design of Fill Site 3. If the long-reach excavator is unable to identify the fill and in-situ ground interface, deep geotechnical drilling will be undertaken. d) Except for Fill Site 5 (excluded from peer review) the other three sites are underlain by Waikato Coal Measures. The thickness of this unit (whilst not certain) is considered to be great enough that the influence of the basement greywacke is considered to be inconsequential to the proposed fill development. If greywacke is encountered during detailed design investigations then this position will be revised and the impact analysed accordingly.		case conditions will still need to be demonstrated at consenting stage (refer 2 below). d) We are comfortable with the approach. This risk is not as great as the WCM bedding shear risk described above.	d) Noted, thank you.	Comment Closed Out
					Additional Reviewer Comment Date (26/11/19)	Date (02/1219)	
					Foundation of Fill Site 2: You noted that recent more detailed investigation information at the toe of this fill area indicates greywacke soils and	As part of the on-going detailed design of Fill Site 2, additional test pits were carried out near the toe of the fill. These pits have confirmed the presence of	

No.	Element	Peer Reviewer Comment Description	Gaia Response	Closed Out (Y/N) Comment	Further Reviewer Comment	Gaia Response	Closed Out (Y/N) Comment
					weathered rock. This is expected to result in improved stability performance and reduced geotechnical risk. Please provide a summary of the conditions encountered, and revise ground conditions appropriately in your stability modelling.	weathered Newcastle Group greywacke. The pits reached between 1.6 and 6.2m depth and encountered residually to highly weathered material in the invert of the gully. Preliminary stability modelling for Fill Site 2 has been undertaken based on a residually to highly weathered greywacke toe.	
2	Stability Analyses	Date (09/10/19) Expected stability of the proposed fill has not been demonstrated by analysis.	Date (15/10/19) If it is deemed necessary for a Resource Consent application, we propose running preliminary 2D stability analyses of the existing ground and the currently proposed fill profiles at each fill site as a proof of the concept. Preliminary stability calculations will be based on currently known conditions and will require a number of assumptions to be made. Detailed stability calculations and design will still be required as part of the detailed design of each fill after Resource Consent is granted. Please note that based on past experience with similar projects (such as a similar sized fill site at the Drury Quarry) and engineering judgement, it is our opinion that the assessed site is suitable for the proposed development. Detailed design for the construction of the fills will be undertaken as part of the Resource Consent Conditions.		Date (03/11/19): Given that the ground and groundwater conditions are not presently well enough understood at the fill sites to address the key geotechnical risks. We still don't understand the basis on which Gaia consider the sites suitable. However, there is a potential alternative to further time consuming and costly ground investigation. If Gaia can demonstrate that the fills can achieve an acceptable Factor of Safety in preliminary 2D limit equilibrium analyses, for a series of worst-case ground conditions, then this would adequately demonstrate the suitability of the sites (i.e. actual stability can only be better than that analysed). The analyses should allow for gently inclined (out of slope) bedding orientations, residual strengths on bedding (or mine fill/WCM contact) and a reasonable assumption around long term groundwater in line with anticipated underfill drainage works.	Date (07/11/19): Concept stability analysis presented in Revision C of the report have shown that the stability of the site is largely controlled by the fill stability itself. It is noted that we have incorporated a low strength, low angle bedding orientation anisotropy in the analysis. We are satisfied that residual risks posed by unknowns related to the underlying geology can be sufficiently mitigated through design of toe-keys, structural bunds and internal drainage blankets during detailed design.	Comment Closed Out
					Additional Reviewer Comment Date (26/11/19)	Date (02/1219)	
					a) Bedding shears in Waikato Coal Measures (WCM) have been analysed using an anisotropic function. Lower bound strengths have been set at c'=0, phi,=28° for a dip magnitude of 4°to 20° degrees. The basis for this was back analysing existing topography to a Factor of Safety (FoS) of 1.2. Those numbers for strength on bedding shear values are higher than normally considered in the North Waikato Basin. Typical failure back	a) We have completed additional sensitivity checks on our existing preliminary slope stability models and have found that the worst credible strength parameter for the WCM anisotropic function to be c'=0 and phi=18~19°. We have re-run the calculations based on this worst-case strength parameter. Our previous conclusions that the proposed slopes are not especially sensitive to the possible presence of bedding related shears remains valid.	

No.	Element	Peer Reviewer Comment Description	Gaia Response	Closed Out (Y/N) Comment	Further Reviewer Comment	Gaia Response	Closed Out (Y/N) Comment
					analysis, ring shear test results and design parameters for nearby mine slopes would normally be around c'=0, phi,=10°-15° for bedding shears. On this basis, can you please revise your back analysis based on a FoS=1.0 and then use the strengths derived from that change as the basis for your anisotropic parameters. b) Additionally, can you please demonstrate stability along the coal measures foundation by incorporating user defined slip planes sub-parallel to existing ground surface. A circular surface may not pick up planar foundation instability well. c) Currently your seismic models do not incorporate your anisotropic strengths in the WCM foundation. This will have a significant bearing on stability results. Please demonstrate this in your modelling cases. d) Some seismic analyses indicate a failure condition under the adopted Seismic Load (FoS <1.0). You indicated that this could be addressed by way of a displacement analysis. I am comfortable with that approach. Can you please provide the results of the displacement analysis when the items above have been addressed in the stability modelling.	b) All analyses have been run using non-circular failure searches. The divisions per slice was set to 50 to help allow the calculated surface to follow the most critical path. We have also included a manual non-circular surface analysis following the anisotropic layer as requested for Fill Sites 3 and 4. c) Additional analyses have been run under a higher seismic loading of 0.24g which was established based on NZTA Bridge Manual 3rd edition, Amendment 3 during detailed design of Fill Site 5. Anisotropic bedding material has been included as requested. d) Critical seismic PGA where FoS≈0.6 has subsequently been calculated and preliminary displacement analyses undertaken using an effective earthquake magnitude of 5.8. For a 15% probability of exceedance displacements were calculated to be between 70mm and 80mm across the four sites. Displacement calc. summary sheets for each fill are attached. We believe that displacements of this magnitude can be tolerated by such earth fill structures which have the ability to be maintained by the owner using benches.	
3	Groundwater	Date (09/10/19) Influence of underlying groundwater conditions in the foundation soils on the stability performance of the fills.	Date (15/10/19) Surficial groundwater regimes are currently heavily influenced by the presence of farm dams, ponds, infilled gullies etc. As such, we have recommended that these dams and ponds be released and drainage measures installed. Subsequent groundwater conditions will be reassessed. It is anticipated that this would happen post Resource Consent and during detailed design and construction stages		Date (03/11/19): We are comfortable with what is proposed. A reasonable assumption around foundation groundwater pressures in line with proposed drainage works will need to be made in analyses discussed in 2. Above.	Date (07/11/19): Noted. See point 2.	Comment Closed Out
9	Fill Extents	Date (09/10/19) Extent of fill footprint not finalised at this pre-application stage will need to	Date (15/10/19) It is our understanding that the concept fill footprints provided by our client are representative of the required fill. From		Date (03/11/19): We understand that during construction deviations in places may need to be made. The proposed	Date (07/11/19): Please see revised drawing included in Appendix A of the Rev. C report.	Comment Closed Out

No.	Element	Peer Reviewer Comment Description	Gaia Response	Closed Out (Y/N) Comment	Further Reviewer Comment	Gaia Response	Closed Out (Y/N) Comment
		be confirmed prior to consent application	discussion with our client we understood that it is desirable to maintain a scope to deviate slightly from the concept footprints where required during the detailed design stage. These deviations are largely for operational reasons and are unlikely to be significant from a geotechnical perspective. We propose that a "Footprint Limit" or similar be added to the concept drawings to aid with visualisation of this.		footprint limit would assist our understanding of the anticipated extent of the deviations that may occur.	The fill footprints are all confined to the gully they reside in. Comment has been added to Section 8.4 of the Rev C report to discuss this.	
11	Whole-of-life considerations	Date (09/10/19) Consideration for in-ground pore water pressure monitoring such as vibrating wire piezometers to be installed within the fill.	Date (15/10/19): In our experience with similar fills a sufficient approach has been to monitor settlement and displacement of the fills with sufficient placement of designed drainage blankets to speed up fill consolidation as each bench is completed. We propose installation of standpipe piezometers or similar as a mitigation strategy should unsatisfactory settlement/displacement be observed within the fills. Settlement and displacement vs time thresholds will be developed for each fill during detailed design.		Date (03/11/19): While monitoring of pore pressure build up in the fill would assist in managing global instability risk, the proposed drainage blankets are largely expected to adequately control this. Having given this further consideration, we are comfortable with the monitoring proposed by Gaia.	Date (07/11/19): Noted, thank you.	Comment Closed Out
12	Factual Data	Date (09/10/19) Show location of historic boreholes on site plans if significant to the project	Date (15/10/19): Historic boreholes and associated logs will be shown on the drawing and included in the appendices. Please note that these boreholes were not oriented so primarily provide stratigraphic depth information only.		Date (03/11/19): Thank you for resolving this. These will assist our further understanding of the site.	Date (07/11/19): Please see revised drawing 2325-12-01 Rev B included in Rev. C of the report. Borehole Logs are included in Appendix B of the Rev. C report	Comment Closed Out
13	Factual Data	Date (09/10/19) Discrepancy between trial pit names between logs and drawing for Fill Site 3	Date (15/10/19): Thank you for pointing this out. Site plans will be amended to match the provided logs.		Date (03/11/19): Thank you for resolving this.	Date (07/11/19): Please see revised drawing 2325-12-01 Rev B included in Rev. C of the report.	Comment Closed Out

Appendix B

Test Pit Location Plan & Geological Cross Section

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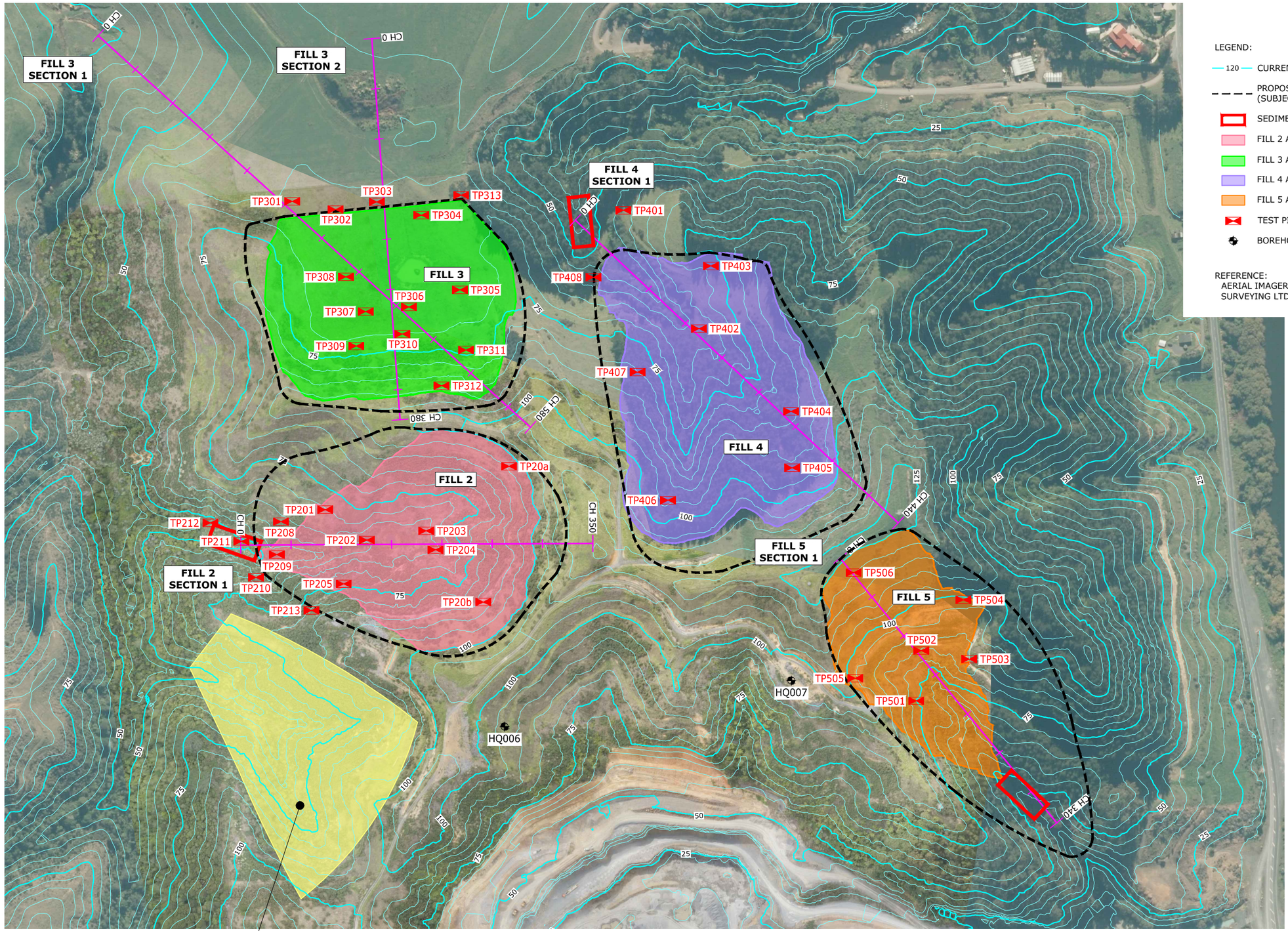

ASSOCIATION OF CONSULTING ENGINEERS NEW ZEALAND
A.C.E.N.Z.

LEGEND:

- 120 CURRENT CONTOURS (5m INTERVAL)
- PROPOSED FILL FOOTPRINT CONCEPT LIMIT (SUBJECT TO DETAILED DESIGN)
- SEDIMENT POND AREA (INDICATIVE ONLY)
- FILL 2 AREA
- FILL 3 AREA
- FILL 4 AREA
- FILL 5 AREA
- TEST PIT (TP)
- BOREHOLE (HQ)

REFERENCE:
AERIAL IMAGERY + CONTOURS FROM PILBROW SURVEYING LTD. APRIL 2019

FILL SITE 1 - NO LONGER CONSIDERED

SITE LAYOUT WITH CURRENT CONTOURS

SCALE 1:4000 (A3)

ORIGINAL IN COLOUR

INFORMATION

Rev.	Date	Revision Details
C	14/01/20	REVISED FOR INFORMATION
B	01/11/19	REVISED FOR INFORMATION
A	02/09/19	DRAFT FOR COMMENT

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Client: Gleeson Quarries

Client:

Project Director: K. C. CHEUNG	Signature:	Date:
Designed: M. KERNOT		
Design Review: K. C. CHEUNG		
Drawn: S. CHEN		
Drafting Check: M. KERNOT		

Project: HUNTLY QUARRY DISPOSAL SITES

Drawing Title: SITE LAYOUT WITH CURRENT CONTOURS

Project No. 2325/12

Scale: AS SHOWN ORIGINAL SHEET SIZE: A3

Drawing No. 2325-12-01 Rev. C

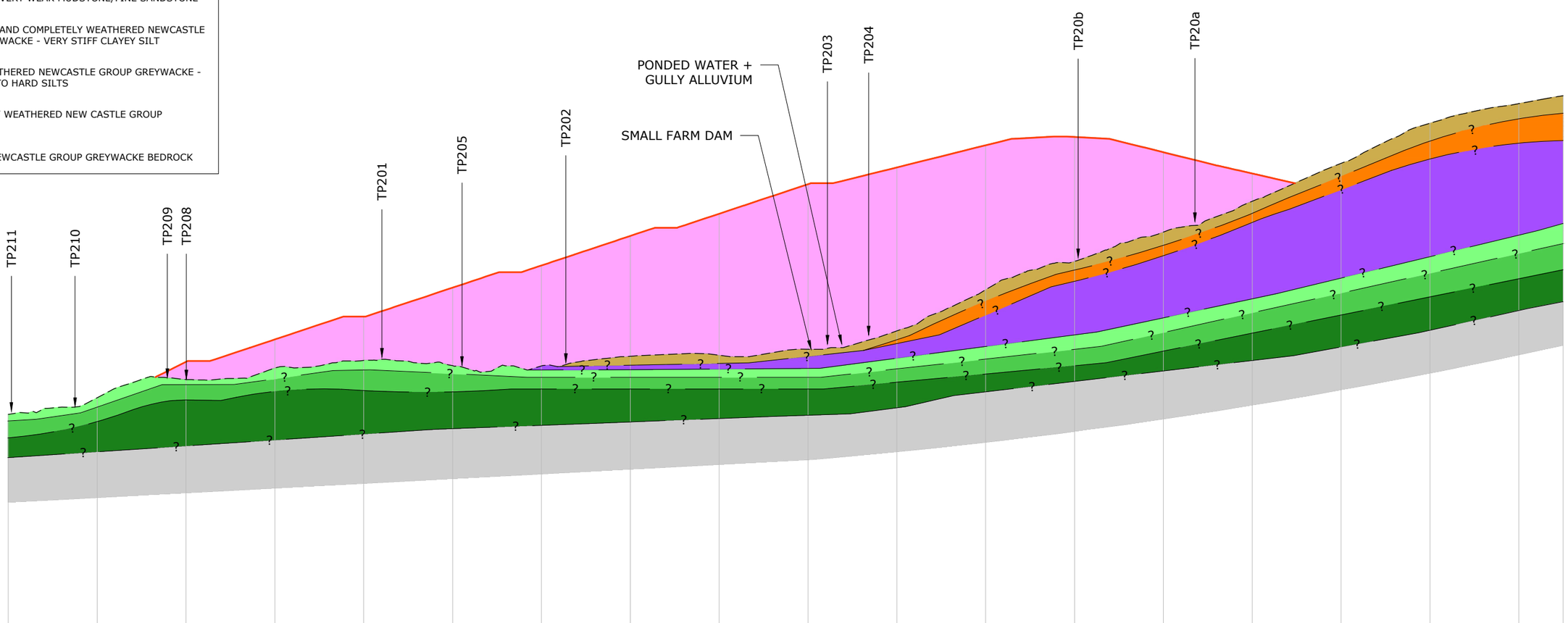
PLOT DATE:2019-01-14

FILE LOCATION :\12\2325_Huntly Quarry_Disposal Sites\50_Drawings\12\2325-12-01_15.dwg

ASSOCIATION OF CONSULTING ENGINEERS NEW ZEALAND
A.C.E.N.Z.

LEGEND:

- PROPOSED FILL
- RESIDUALLY WEATHERED WAIKATO COAL MEASURES - STIFF TO VERY STIFF CLAY/SILT
- COMPLETELY WEATHERED WAIKATO COAL MEASURES - VERY STIFF TO HARD SILT
- MODERATELY TO SLIGHTLY WEATHERED WAIKATO COAL MEASURES - VERY WEAK MUDSTONE/FINE SANDSTONE
- RESIDUALLY AND COMPLETELY WEATHERED NEWCASTLE GROUP GREYWACKE - VERY STIFF CLAYEY SILT
- HIGHLY WEATHERED NEWCASTLE GROUP GREYWACKE - VERY STIFF TO HARD SILTS
- MODERATELY WEATHERED NEW CASTLE GROUP GREYWACKE
- INFERRED NEWCASTLE GROUP GREYWACKE BEDROCK



DATUM: 0.00m

CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	350
PROPOSED LEVELS			59.82	64.87	70.00	76.51	81.50	88.15	93.14	99.80	103.57	108.55	110.41	106.99	102.21				
CURRENT LEVELS	48.00	51.74	55.83	58.43	60.15	58.98	58.90	61.08	61.32	62.66	66.80	76.05	82.42	89.00	95.97	104.50	113.51	117.92	119.71
CUT/FILL DEPTHS			3.99	6.44	9.85	17.53	22.60	27.07	31.83	37.14	36.77	32.51	27.99	17.98	6.24				

PROPOSED FILL 2 SECTION 1

SCALE 1:1000 (A3)

ORIGINAL IN COLOUR

DRAFT

Rev.	Date	Revision Details
B	14/01/20	REVISED FOR INFORMATION
A	02/09/19	DRAFT FOR COMMENT

GAIA ENGINEERS

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Client: Gleeson Quarries

Client:

Project Director: K. C. CHEUNG	Signature:	Date:
Designed: M. KERNOT		
Design Review: K. C. CHEUNG		
Drawn: S. CHEN		
Drafting Check: M. KERNOT		

Project: HUNTLY QUARRY DISPOSAL SITES

Drawing Title: PROPOSED FILL 2 SECTION 1

Project No. 2325/12

Scale: AS SHOWN ORIGINAL SHEET SIZE: A3

Drawing No. 2325-12-05 Rev. B

PLOT DATE: 2020-01-14

FILE LOCATION: J:\2325_Huntly Quarry_Disposal Sites\SD_Drawings\12\2325-12-01_15.dwg

Appendix C
Test Pit Logs

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TEST PIT LOG

TEST PIT ID. TP208

1:30 Sheet 1 of 1

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433553.7m	GROUND R.L (m):	63.20m	PIT FINISHED:	07/11/2019
	N.721344.3m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm) 2 4 6 8 10 12	Sample ID	Sample Type	R.L (m)
0.00-0.30 m TOPSOIL										63.0
0.30-1.00 m Clayey SILT; orange-brown mottles. Stiff, moist, moderate plasticity, fissured texture.					140	30				
1.00-3.50 m Clayey SILT with some completely weathered medium gravels; yellow and orange-brown with light grey inclusions. Gravels are extremely weak and friable	1		Colluvium		109	37				62.0
	2									61.0
	3									60.0
3.50-5.70 m SILT; yellow-brown and light grey mottles. Hard, low plasticity, moist [inferred completely weathered greywacke, limonite and MnO staining on relict fractures]	4		Newcastle Group Greywacke							59.0
	5									58.0
End of Pit @ 5.7 m	6									

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

TEST PIT LOG

TEST PIT ID. TP209

1:30 Sheet 1 of 1

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433549.6m	GROUND R.L (m):	51.30m	PIT FINISHED:	07/11/2019
	N.721311.6m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm) 2 4 6 8 10 12	Sample ID	Sample Type	R.L (m)
0.00-0.30 m TOPSOIL										
0.30-0.80 m Clayey SILT; yellow-brown. Stiff, moist, moderate plasticity, slightly fissured texture.			Colluvium							51.0
0.80-1.50 m Clayey SILT with some sand; yellow-brown and light grey mottles. Hard, low plasticity, moist [inferred completely weathered greywacke, limonite and MnO staining on relict fractures]	1		Newcastle Group Material							50.0
1.50-2.00 m Highly weatherd, grey, brown and orange, SANDSTONE; Very weak, very closely spaced joints with limonite and MnO staining, rare moderately weathered core stones										
End of Pit @ 2.0 m	2									49.0
	3									48.0
	4									47.0
	5									46.0
	6									

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

GAIA ENGINEERS	Test Pit Photographs	TP209	
		PROJECT: Huntly Quarry Disposal Sites	JOB No: 2325

TEST PIT LOG

TEST PIT ID. TP210

1:30 Sheet 1 of 1

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433528.9m	GROUND R.L (m):	61.70m	PIT FINISHED:	07/11/2019
	N.721288.9m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm) 2 4 6 8 10 12	Sample ID	Sample Type	R.L (m)
0.00-0.30 m TOPSOIL			Colluvium							
0.30-0.60 m Clayey SILT; orange-brown; Stiff, low plasticity, moist, fissured										
0.60-4.70 m Sandy SILT; light grey and orange. Hard, non plastic, moist [inferred completely weathered greywacke, very closely jointed, with limonite and MnO staining].	1		Newcastle Group Material							61.0
From 2.4 - 2.8m: pink streaks	2									60.0
	3									59.0
	4									58.0
4.70-5.70 m Completely weathered, grey, brown and orange, SANDSTONE; Very weak, very closely spaced joints with limonite and MnO staining, some highly weathered core stones	5									57.0
End of Pit @ 5.7 m	6									56.0

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

GAIA ENGINEERS	Test Pit Photographs	TP210	
		PROJECT: Huntly Quarry Disposal Sites	JOB No: 2325

TEST PIT LOG

TEST PIT ID. TP211

1:30 Sheet 1 of 1

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433514.4m	GROUND R.L (m):	48.20m	PIT FINISHED:	07/11/2019
	N.721324.7m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm)	Sample ID	Sample Type	R.L (m)
0.00-0.20 m TOPSOIL										
0.20-0.60 m Sandy SILT with some clay; light grey and yellow-brown. Hard, non plastic, moist [inferred completely weathered greywacke].										
0.60-1.60 m Highly weathered, grey, brown and orange, SANDSTONE; Very weak, very closely spaced, smooth, planar joints with limonite and MnO staining, rare moderately weathered core stones	1		Newcastle Group Material							48.0 47.0
End of Pit @ 1.6 m	2 3 4 5 6						2 4 6 8 10 12			46.0 45.0 44.0 43.0

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

TEST PIT LOG

TEST PIT ID. TP212

1:30 Sheet 1 of 1

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433483.7m	GROUND R.L (m):	47.70m	PIT FINISHED:	07/11/2019
	N.721343.1m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm)	Sample ID	Sample Type	R.L (m)
0.00-0.30 m TOPSOIL										
0.30-1.10 m Clayey SILT with trace sand; yellow-brown and orange-brown mottles. Very stiff, moist, moderate plasticity, fissured	1				113	45				47.0
1.10-3.20 m Sandy SILT; light grey and orange. Hard, non plastic, moist [inferred completely weathered greywacke].	2		Newcastle Group Material							46.0
From 3.0m - becoming very weak rock strength	3									45.0
End of Pit @ 3.2 m	4									44.0
	5									43.0
	6									42.0

Scala (blows/100mm): 2 4 6 8 10 12

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

GAIA ENGINEERS	Test Pit Photographs	TP212	
		PROJECT: Huntly Quarry Disposal Sites	JOB No: 2325

TEST PIT LOG

TEST PIT ID. TP213

1:30 Sheet 1 of 2

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433584.1m	GROUND R.L (m):	81.10m	PIT FINISHED:	07/11/2019
	N.721256.2m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm)	Sample ID	Sample Type	R.L (m)
0.00-0.50 m TOPSOIL & Track Fill										81.0
0.50-3.50 m Silty CLAY; yellow-brown. Stiff to very stiff, moist, moderate plasticity	1		Newcastle Group Material		177	27				80.0
	2				164	63				79.0
	3									78.0
3.50-5.40 m Clayey SILT; light grey and yellow-brown mottles with pink veining. Very stiff, moderate plasticity, moist [inferred completely weathered greywacke].	4									77.0
	5									76.0
5.40-6.20 m SILT with trace clay; light grey and fine orange veining. Hard, moist, low plasticity, limonite and MnO present on very closely spaced relict jointing [inferred completely weathered greywacke].	6									

Scala (blows/100mm): 2 4 6 8 10 12

Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC		

Logged in accordance with NZ Geotechnical Society (2005) guidelines

TEST PIT LOG

TEST PIT ID. TP213

1:30 Sheet 2 of 2

PROJECT:	Huntly Quarry Disposal Sites	CLIENT:	Gleeson Quarries Ltd.	JOB No:	2325
LOCATION:	Huntly Quarry	SURVEY CIRCUIT:	NZGD2000 Mt Eden Circuit	PIT STARTED:	07/11/2019
COORDINATES:	E.433584.1m	GROUND R.L (m):	81.10m	PIT FINISHED:	07/11/2019
	N.721256.2m	DATUM:	Auckland Vertical Datum 1946	WEATHER:	Fine

Soil/Rock Description	Depth(m)	Graphic Log	Geologic Unit	Ground water	Vane Shear Strength (kPa) Tp	Vane Shear Strength (kPa) Tr	Scala (blows/100mm) 2 4 6 8 10 12	Sample ID	Sample Type	R.L (m)
SILT with trace clay; light grey and fine orange veining. Hard, moist, low plasticity, limonite and MnO present on very closely spaced relict jointing [inferred completely weathered greywacke].	7									75.0
End of Pit @ 6.2 m	8									74.0
	9									73.0
	10									72.0
	11									71.0
	12									70.0

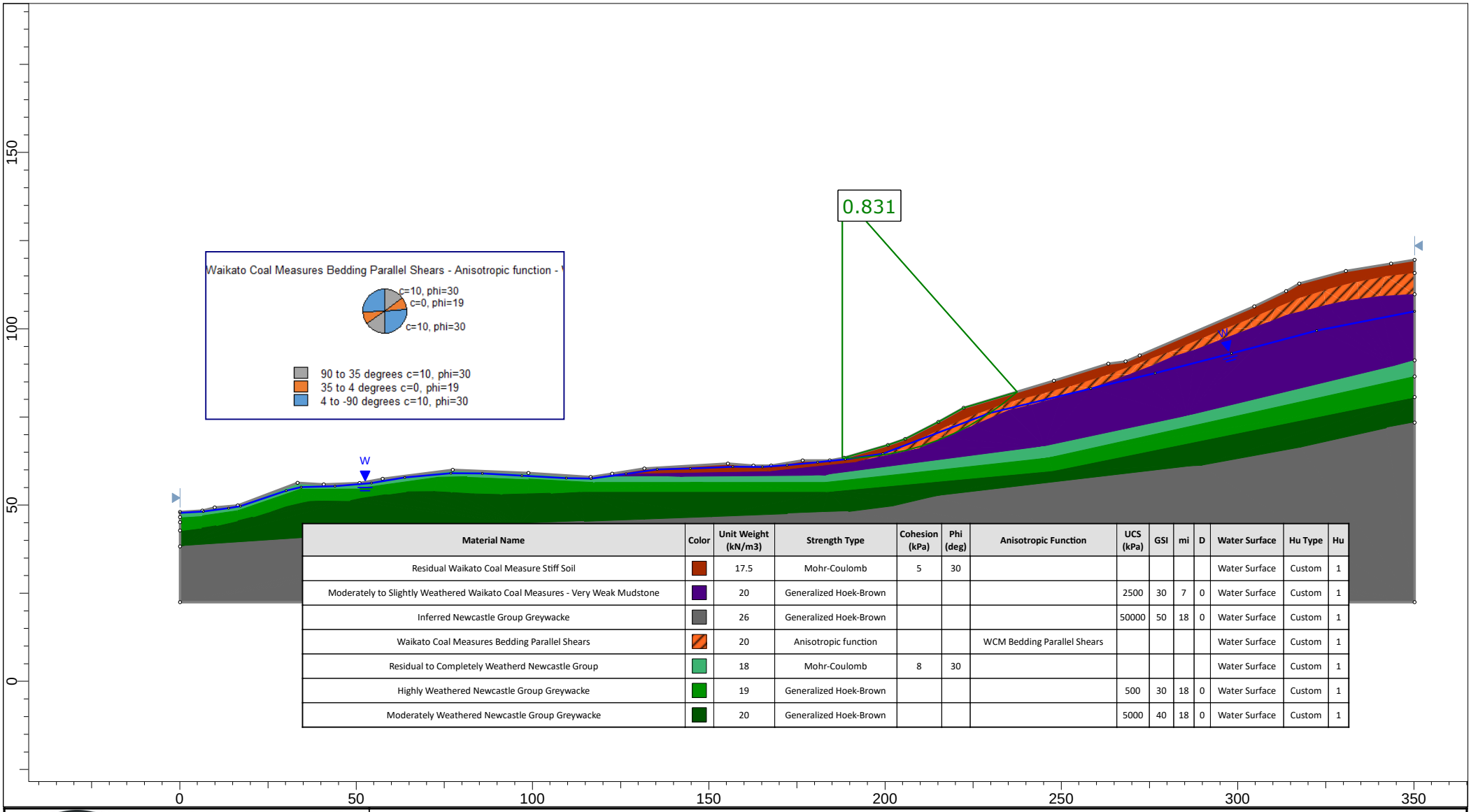
Contractor:	Gleeson Civil Ltd.	Remarks:	Groundwater notes:
Plant:	Hitatchi 30t Excavator	SV readings corrected to BS1377 - Dial No. 1872	Groundwater Not Encountered
Logged:	PS		
Checked:	KCC		
Approved:	KCC	Logged in accordance with NZ Geotechnical Society (2005) guidelines	

GAIA ENGINEERS	Test Pit Photographs	TP213	
		PROJECT: Huntly Quarry Disposal Sites	JOB No: 2325

Appendix D

Revised Limit Equilibrium Slope Stability Analyses & Seismic Displacement Calculation

5 Carmont Place, Mt Wellington, Auckland 1060, New Zealand Tel: 09 276 5673
PO Box 51 295 Pakuranga, Auckland 2140 www.gaia-engineers.co.nz



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1
Inferred Newcastle Group Greywacke		26	Generalized Hoek-Brown				50000	50	18	0	Water Surface	Custom	1
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1
Residual to Completely Weatherd Newcastle Group		18	Mohr-Coulomb	8	30						Water Surface	Custom	1
Highly Weathered Newcastle Group Greywacke		19	Generalized Hoek-Brown				500	30	18	0	Water Surface	Custom	1
Moderately Weathered Newcastle Group Greywacke		20	Generalized Hoek-Brown				5000	40	18	0	Water Surface	Custom	1

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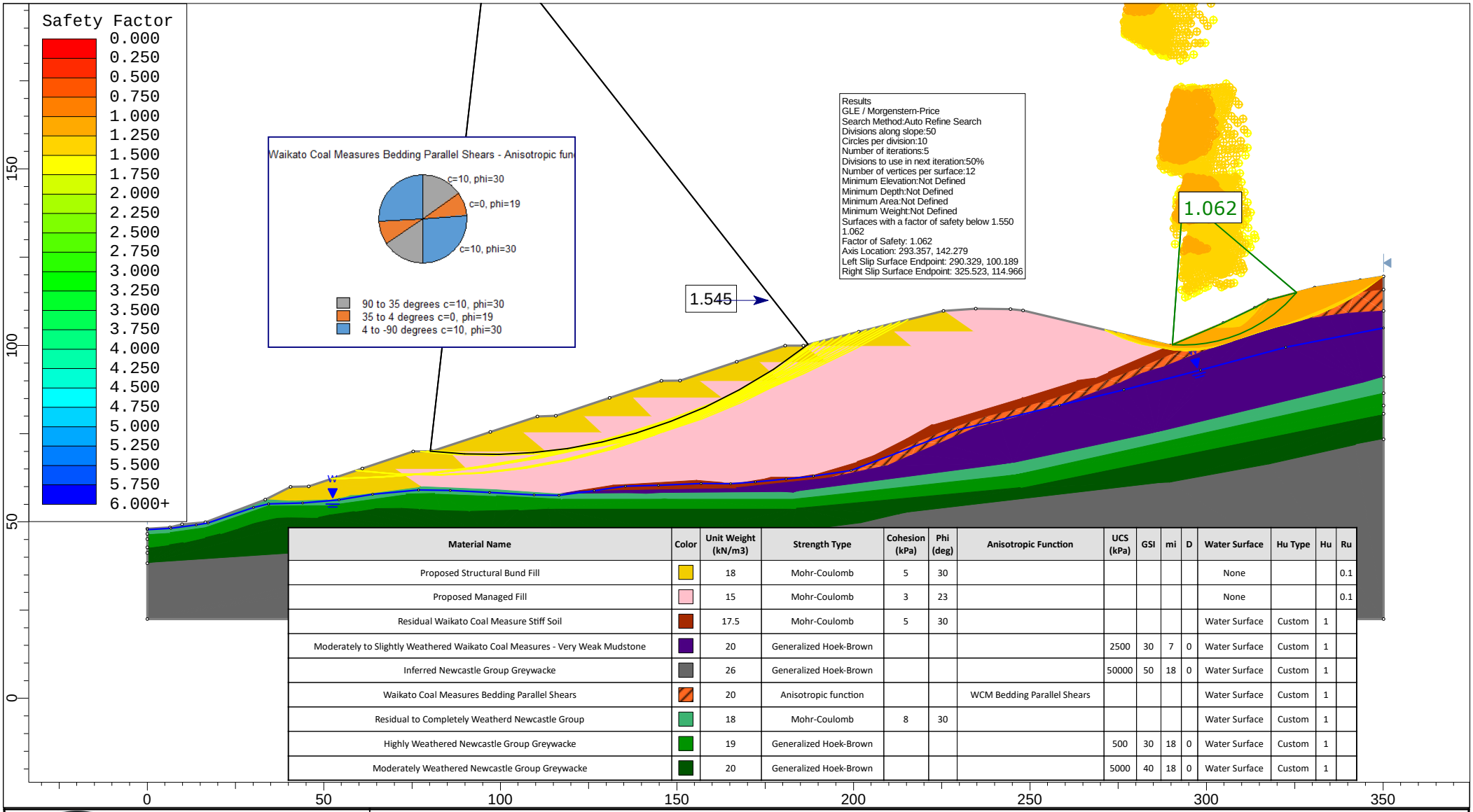
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 2 - Cross Section 1, Existing Ground - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers Ltd.
Date	Oct 2019		*File Name* Fill Site 2 - Concept Stability Calcs Rev B.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Inferred Newcastle Group Greywacke		26	Generalized Hoek-Brown				50000	50	18	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	
Residual to Completely Weatherd Newcastle Group		18	Mohr-Coulomb	8	30						Water Surface	Custom	1	
Highly Weathered Newcastle Group Greywacke		19	Generalized Hoek-Brown				500	30	18	0	Water Surface	Custom	1	
Moderately Weathered Newcastle Group Greywacke		20	Generalized Hoek-Brown				5000	40	18	0	Water Surface	Custom	1	

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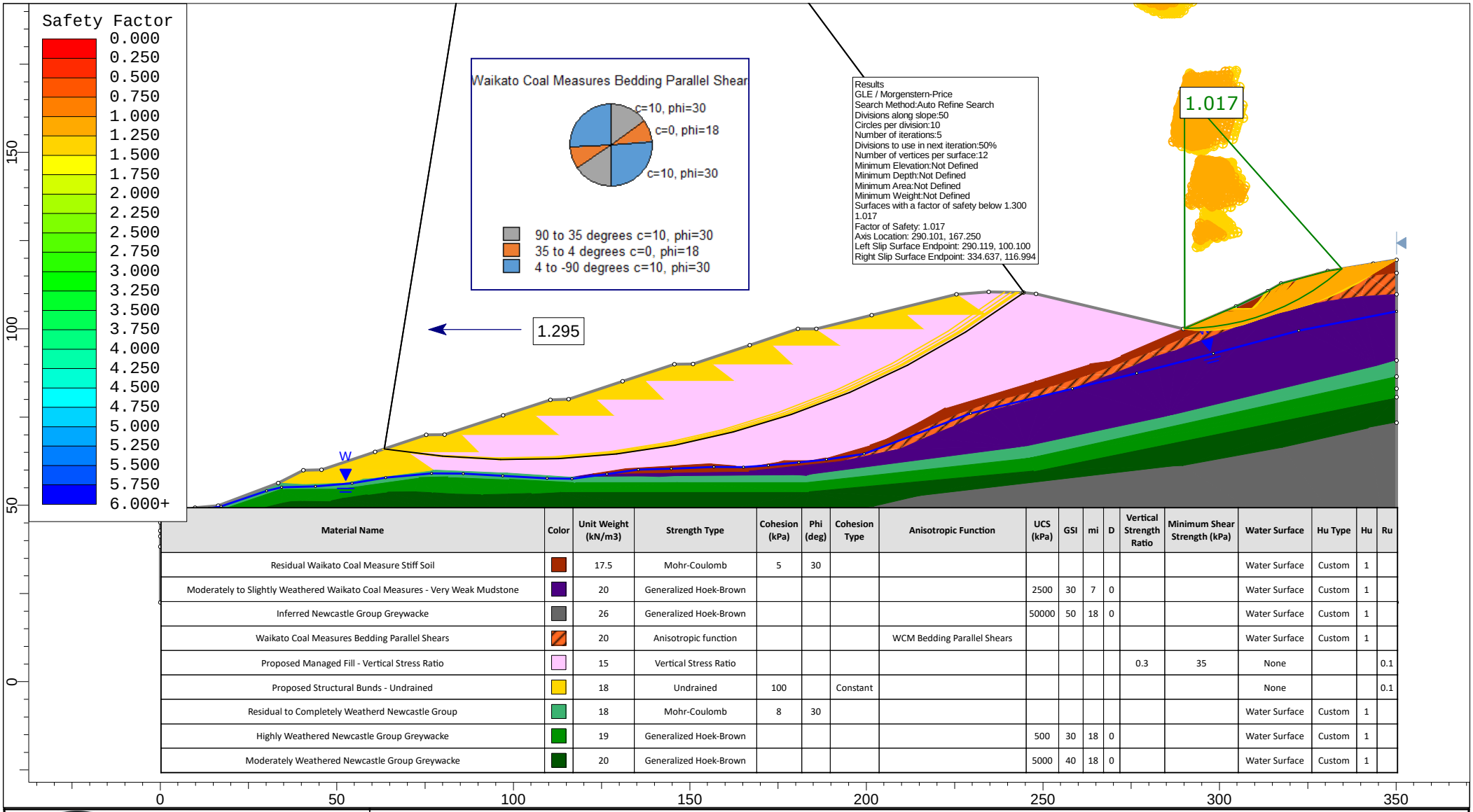
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 2 - Cross Section 1, Proposed Fill - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers Ltd.
Date	Oct 2019		*File Name* Fill Site 2 - Concept Stability Calcs Rev B.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Inferred Newcastle Group Greywacke		26	Generalized Hoek-Brown					50000	50	18	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Proposed Structural Bunds - Undrained		18	Undrained	100		Constant								None			0.1
Residual to Completely Weatherd Newcastle Group		18	Mohr-Coulomb	8	30									Water Surface	Custom	1	
Highly Weathered Newcastle Group Greywacke		19	Generalized Hoek-Brown					500	30	18	0			Water Surface	Custom	1	
Moderately Weathered Newcastle Group Greywacke		20	Generalized Hoek-Brown					5000	40	18	0			Water Surface	Custom	1	

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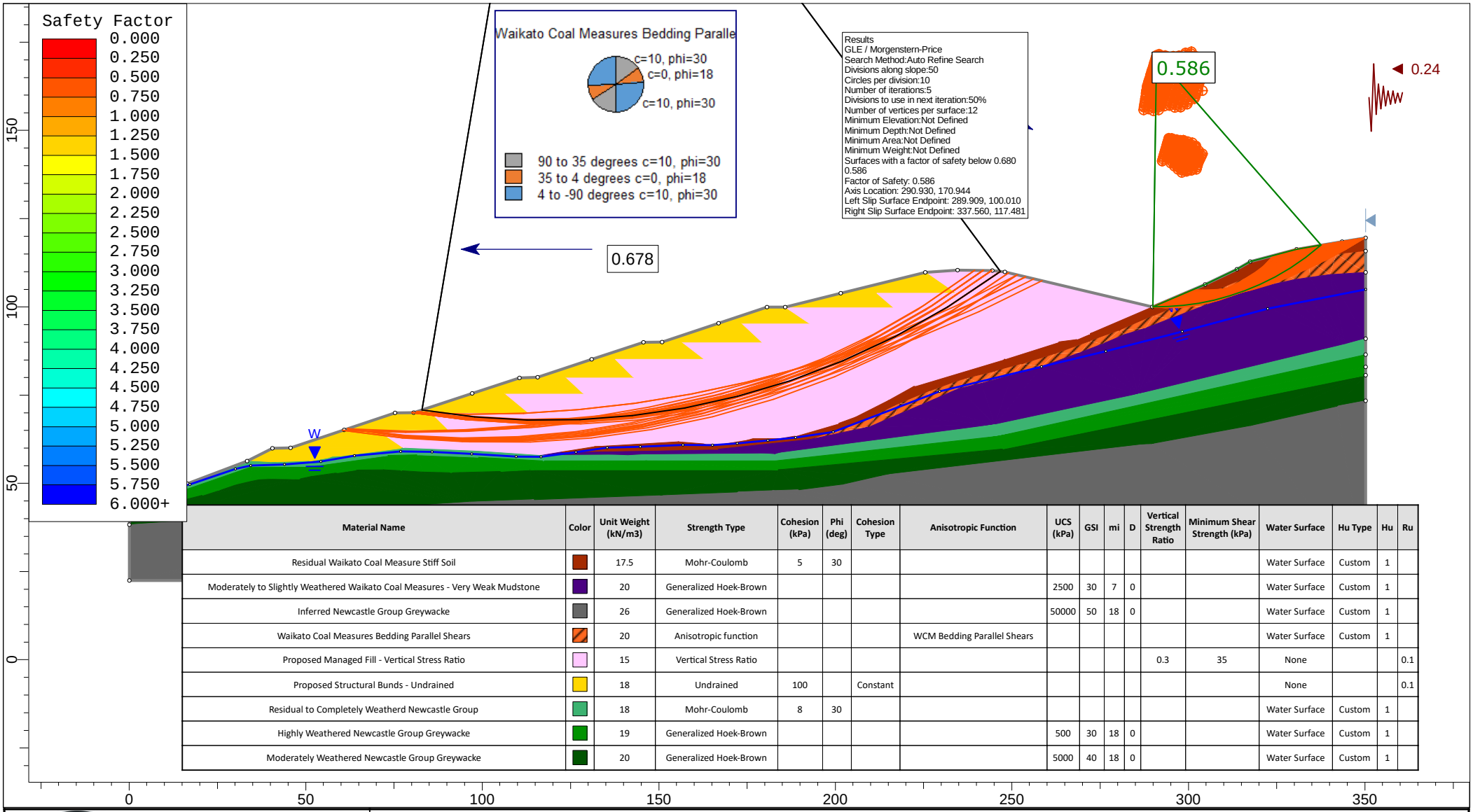
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 2 - Cross Section 1, Proposed Fill - Undrained Case		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers Ltd.
Date	Oct 2019		*File Name* Fill Site 2 - Concept Stability Calcs Rev B.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Inferred Newcastle Group Greywacke		26	Generalized Hoek-Brown					50000	50	18	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Proposed Structural Bunds - Undrained		18	Undrained	100		Constant								None			0.1
Residual to Completely Weatherd Newcastle Group		18	Mohr-Coulomb	8	30									Water Surface	Custom	1	
Highly Weathered Newcastle Group Greywacke		19	Generalized Hoek-Brown					500	30	18	0			Water Surface	Custom	1	
Moderately Weathered Newcastle Group Greywacke		20	Generalized Hoek-Brown					5000	40	18	0			Water Surface	Custom	1	

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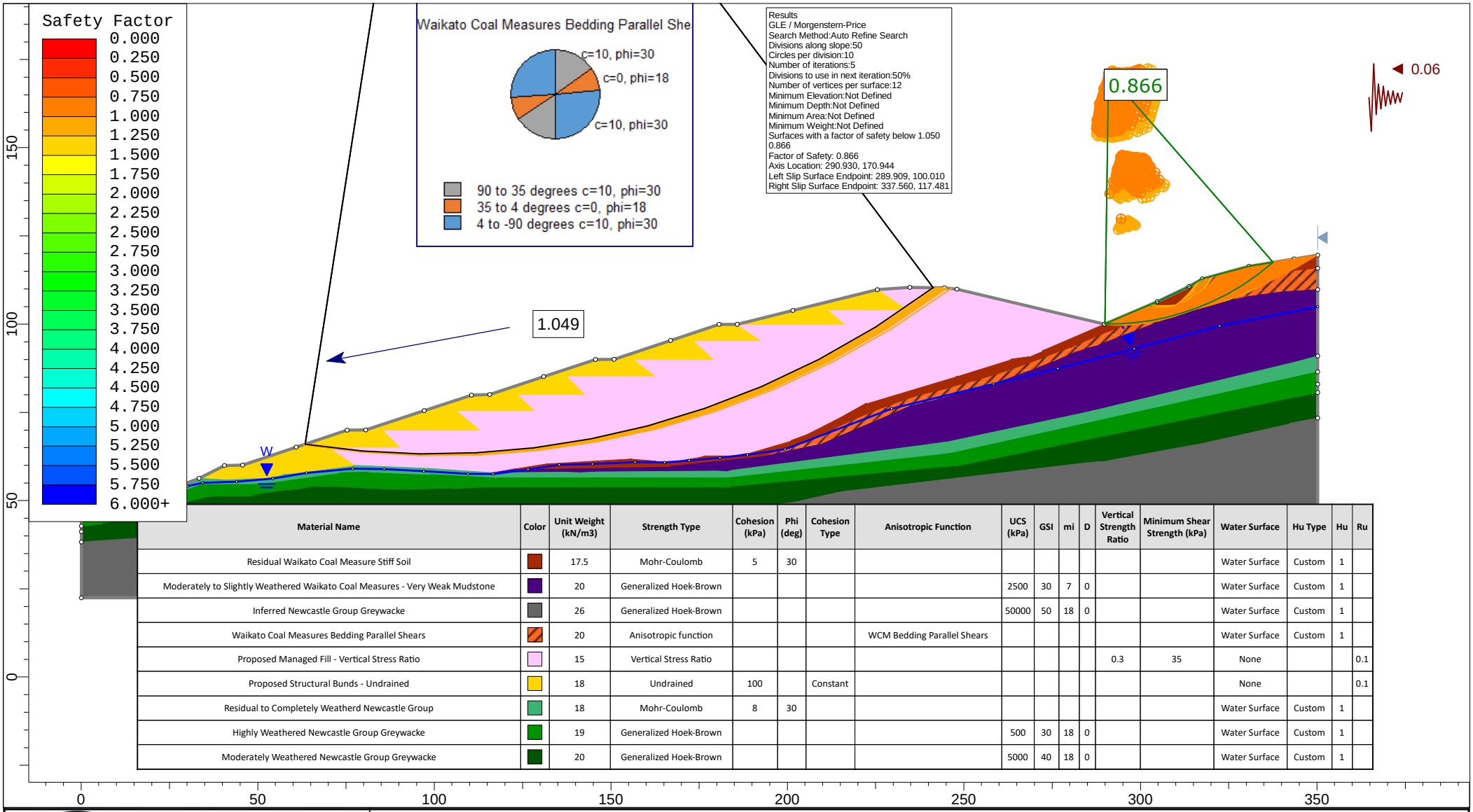
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 2 - Cross Section 1, Proposed Fill - Seismic Loading		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers Ltd.
Date	Oct 2019		*File Name* Fill Site 2 - Concept Stability Calcs Rev B.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Inferred Newcastle Group Greywacke		26	Generalized Hoek-Brown					50000	50	18	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Proposed Structural Bunds - Undrained		18	Undrained	100		Constant								None			0.1
Residual to Completely Weatherd Newcastle Group		18	Mohr-Coulomb	8	30									Water Surface	Custom	1	
Highly Weathered Newcastle Group Greywacke		19	Generalized Hoek-Brown					500	30	18	0			Water Surface	Custom	1	
Moderately Weathered Newcastle Group Greywacke		20	Generalized Hoek-Brown					5000	40	18	0			Water Surface	Custom	1	

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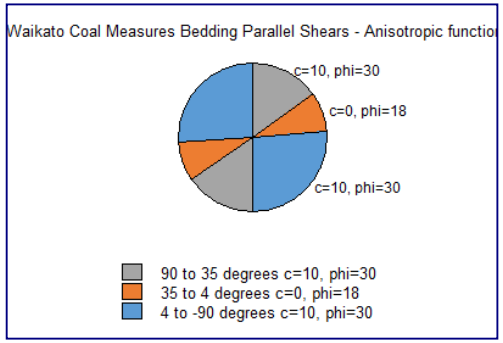
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 2 - Cross Section 1, Proposed Fill - Critical Seismic Loading		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers Ltd.
Date	Oct 2019		*File Name* Fill Site 2 - Concept Stability Calcs Rev B.slmd



Results
Bishop simplified
Search Method:Auto Refine Search
Divisions along slope:50
Circles per division:10
Number of iterations:5
Divisions to use in next iteration:50%
Number of vertices per surface:12
Minimum Elevation:Not Defined
Minimum Depth:Not Defined
Minimum Area:Not Defined
Minimum Weight:Not Defined
Every available surface
0.984
Factor of Safety: 0.984
Axis Location: 522.095, 170.631
Left Slip Surface Endpoint: 525.902, 86.859
Right Slip Surface Endpoint: 579.221, 109.240

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1

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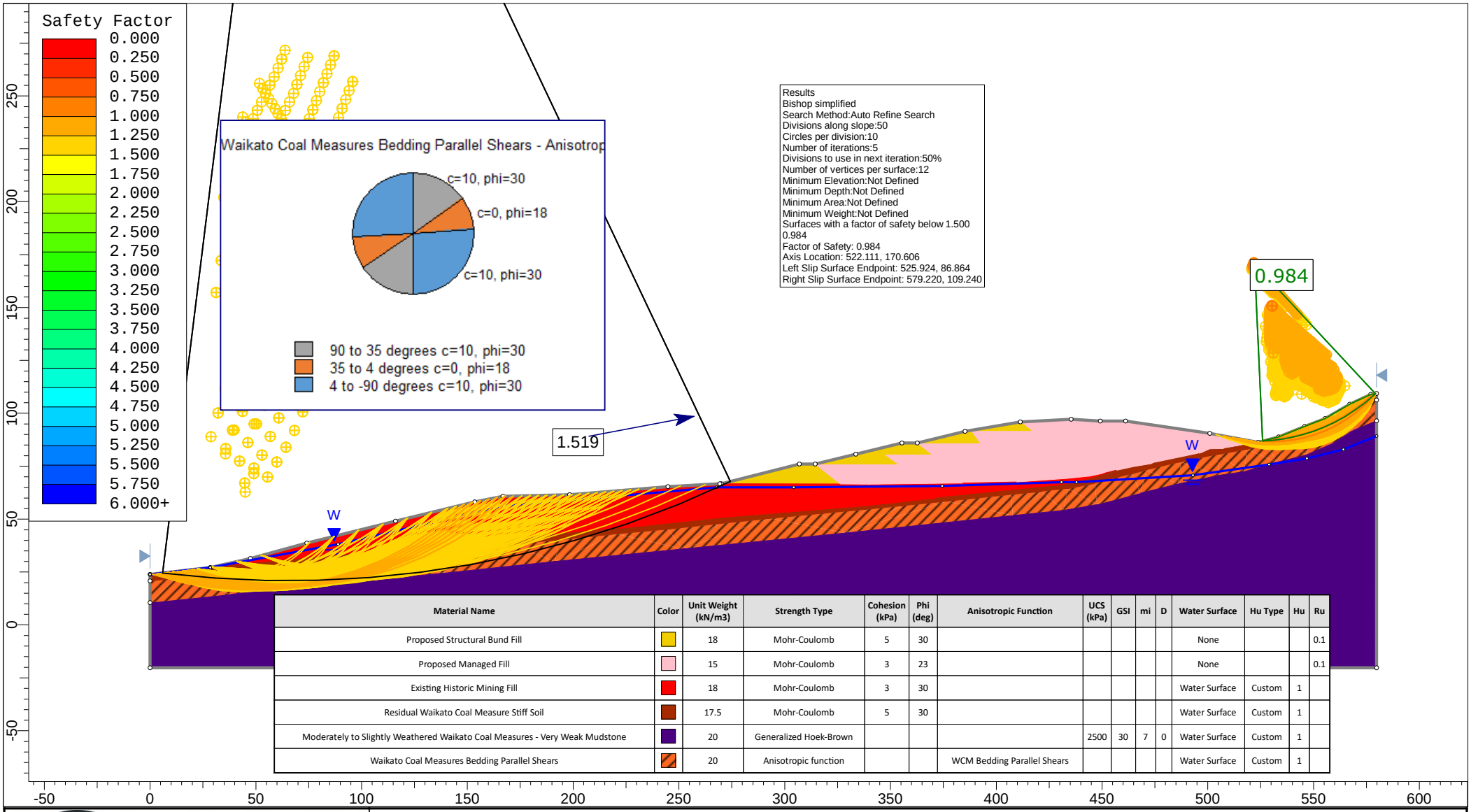
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Existing Slope - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019		*File Name* Fill Site 3 Cross Section 1.slmd

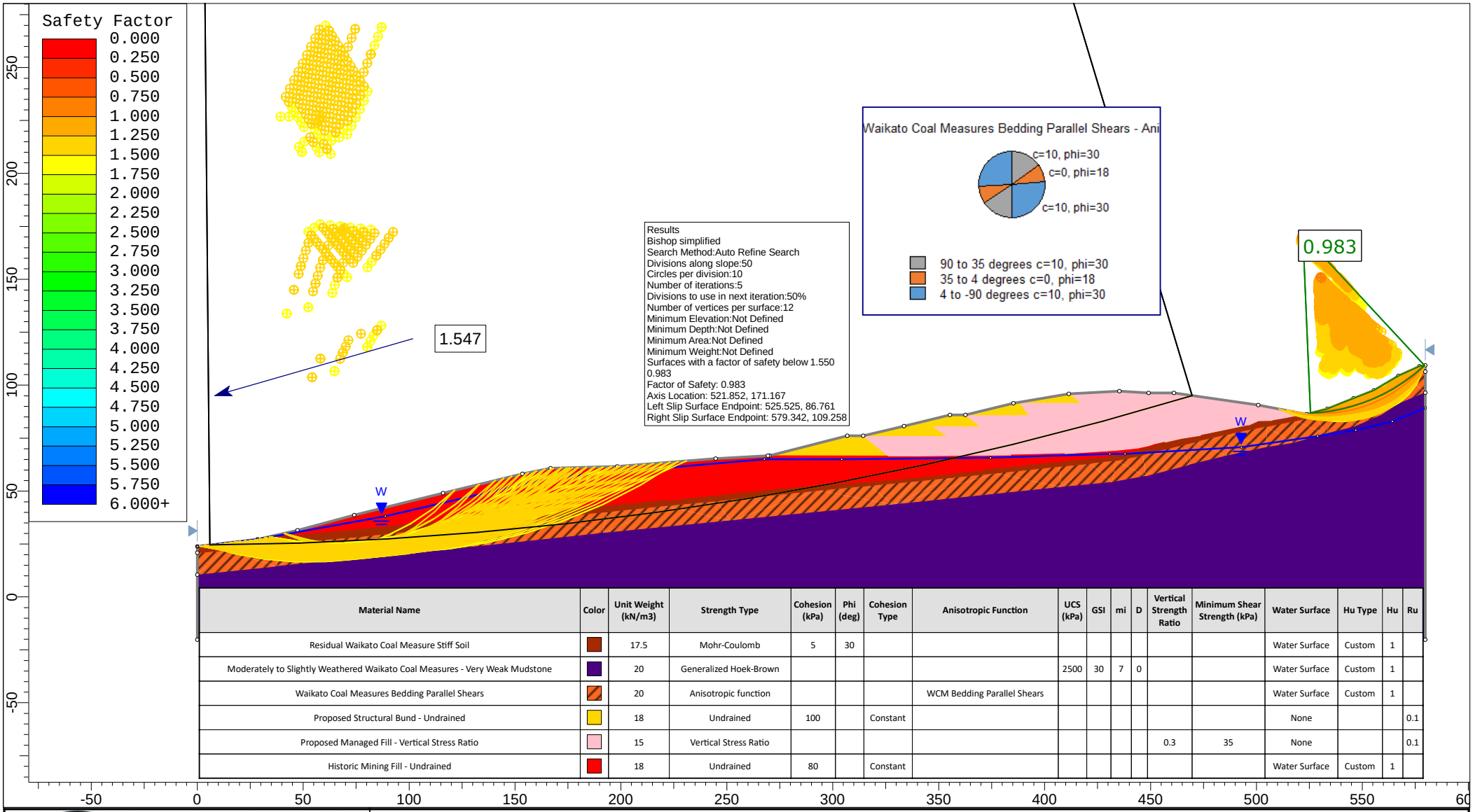


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	

GAIA ENGINEERS

SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Proposed Fill - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 1.slmd

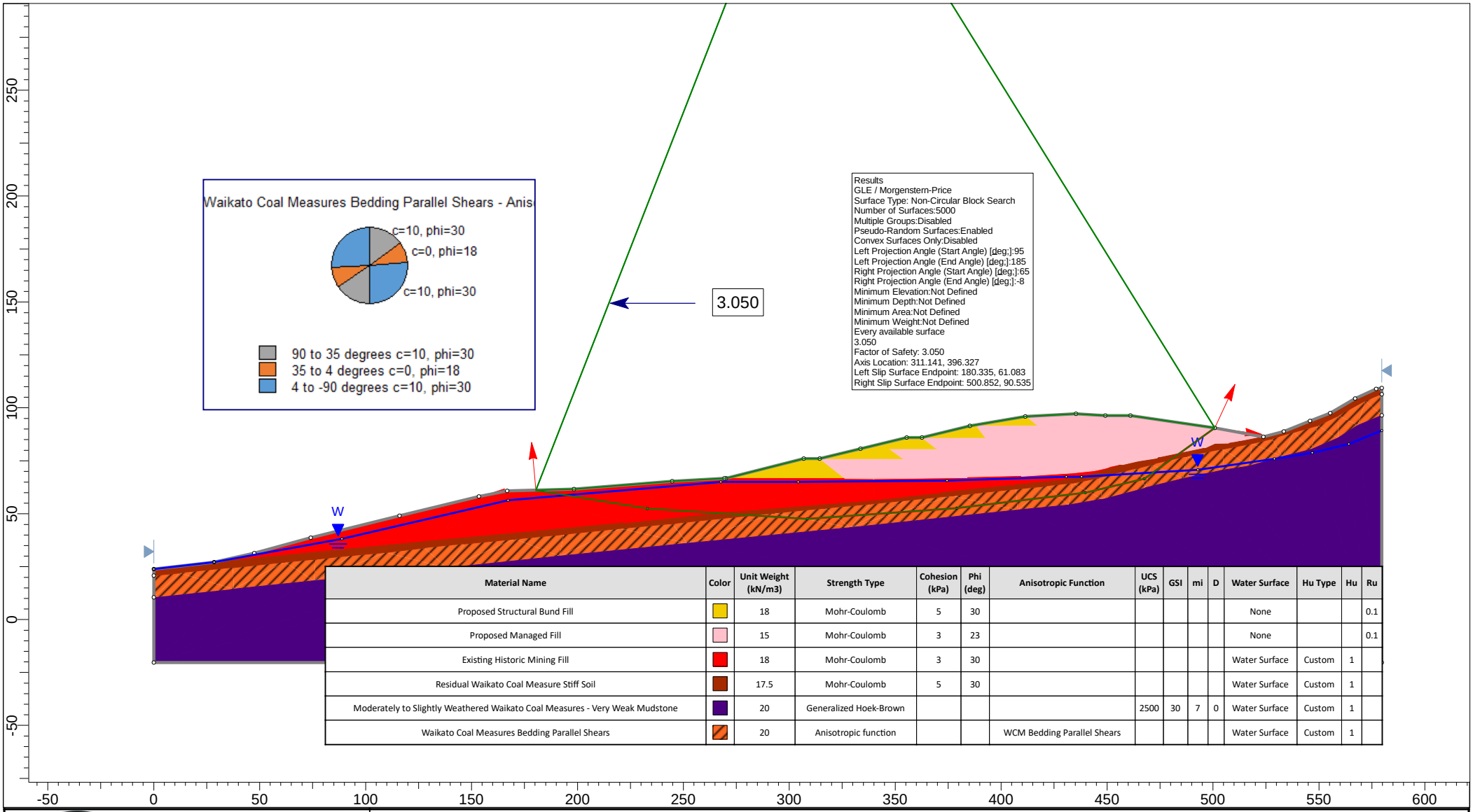


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

GAIA ENGINEERS

SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Proposed Fill - Undrained Case		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019		*File Name* Fill Site 3 Cross Section 1.slmd

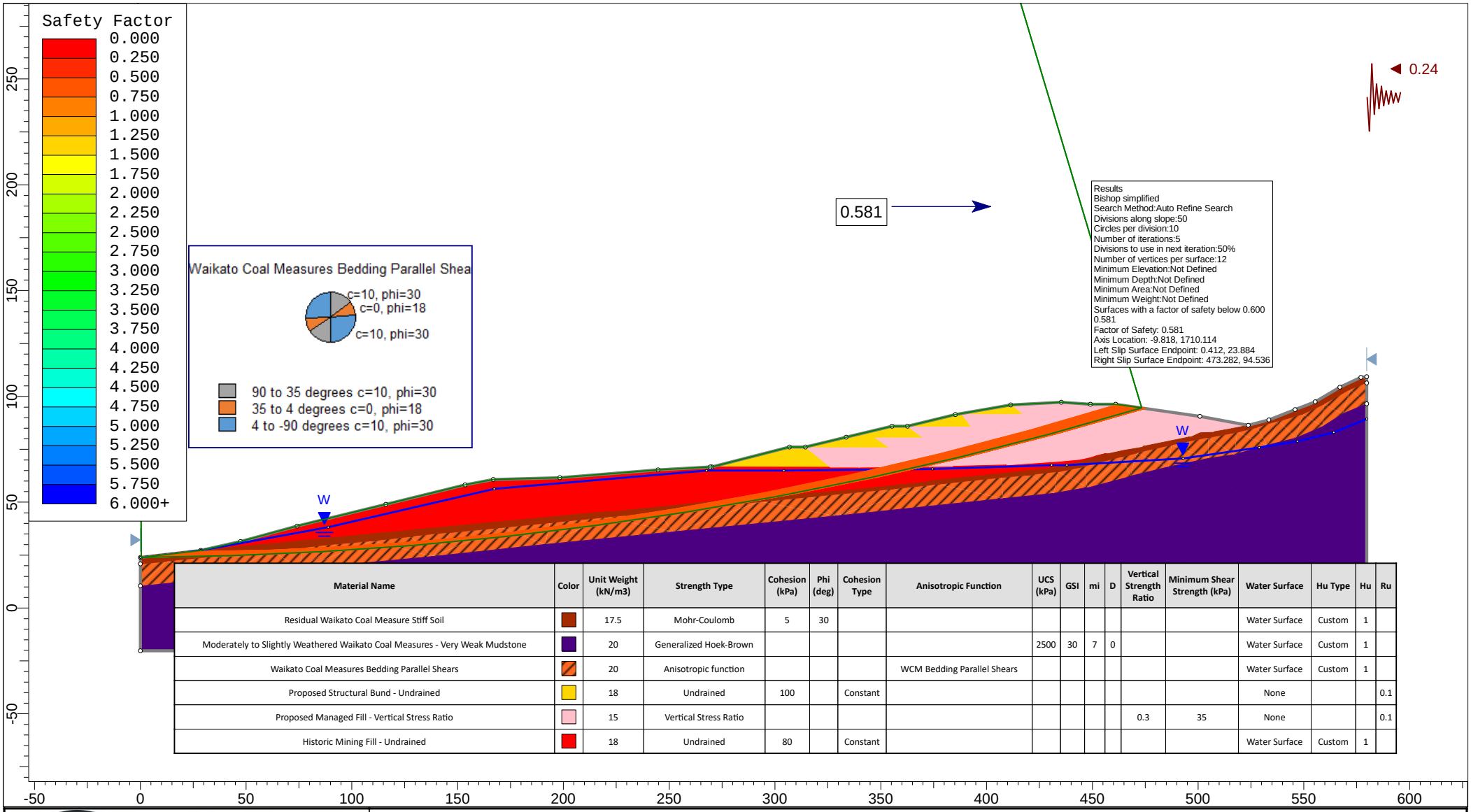


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	

GAIA ENGINEERS

SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Proposed Fill - Bedding Shears - Manual Slip Surface		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

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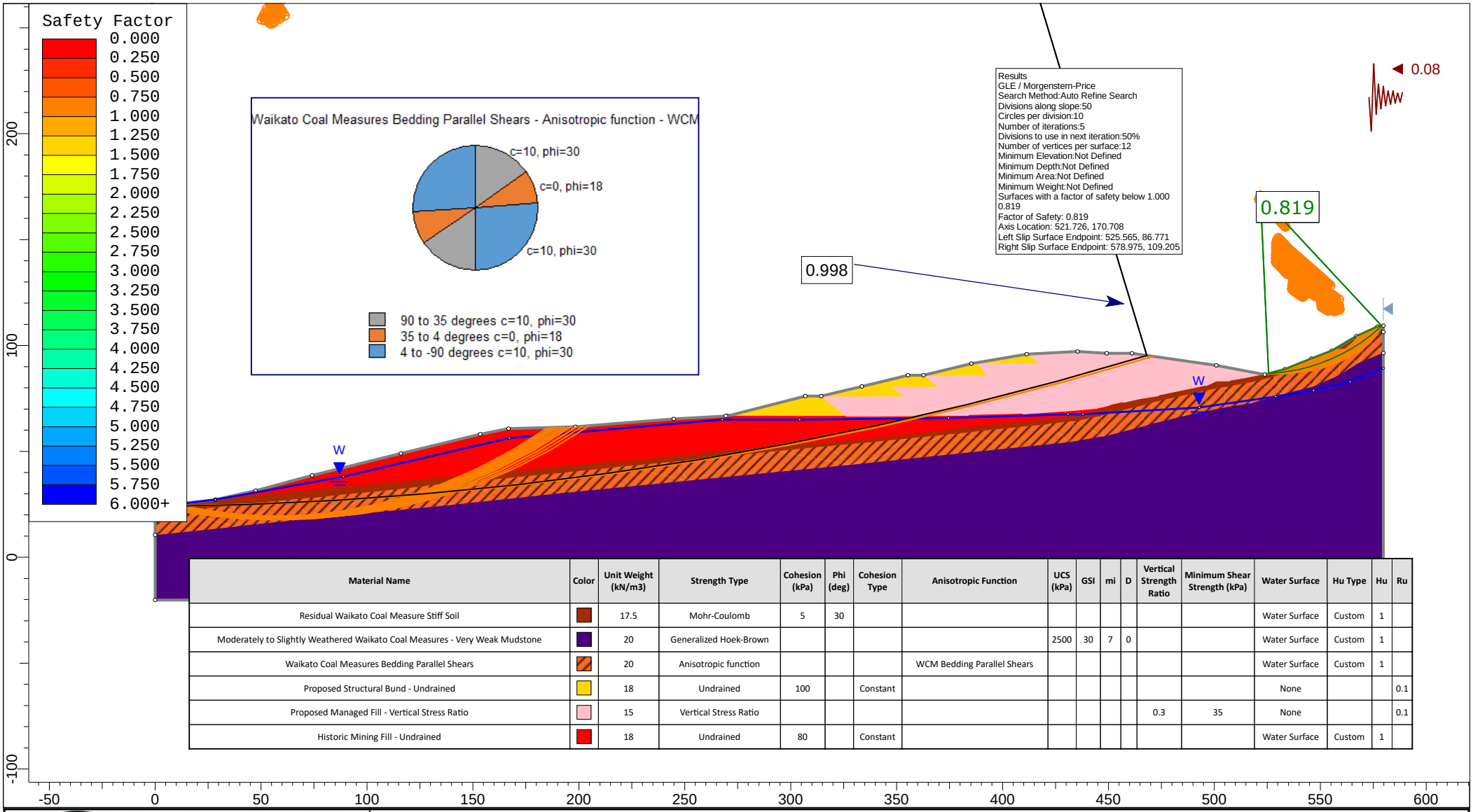
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Proposed Fill - Seismic Loading		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

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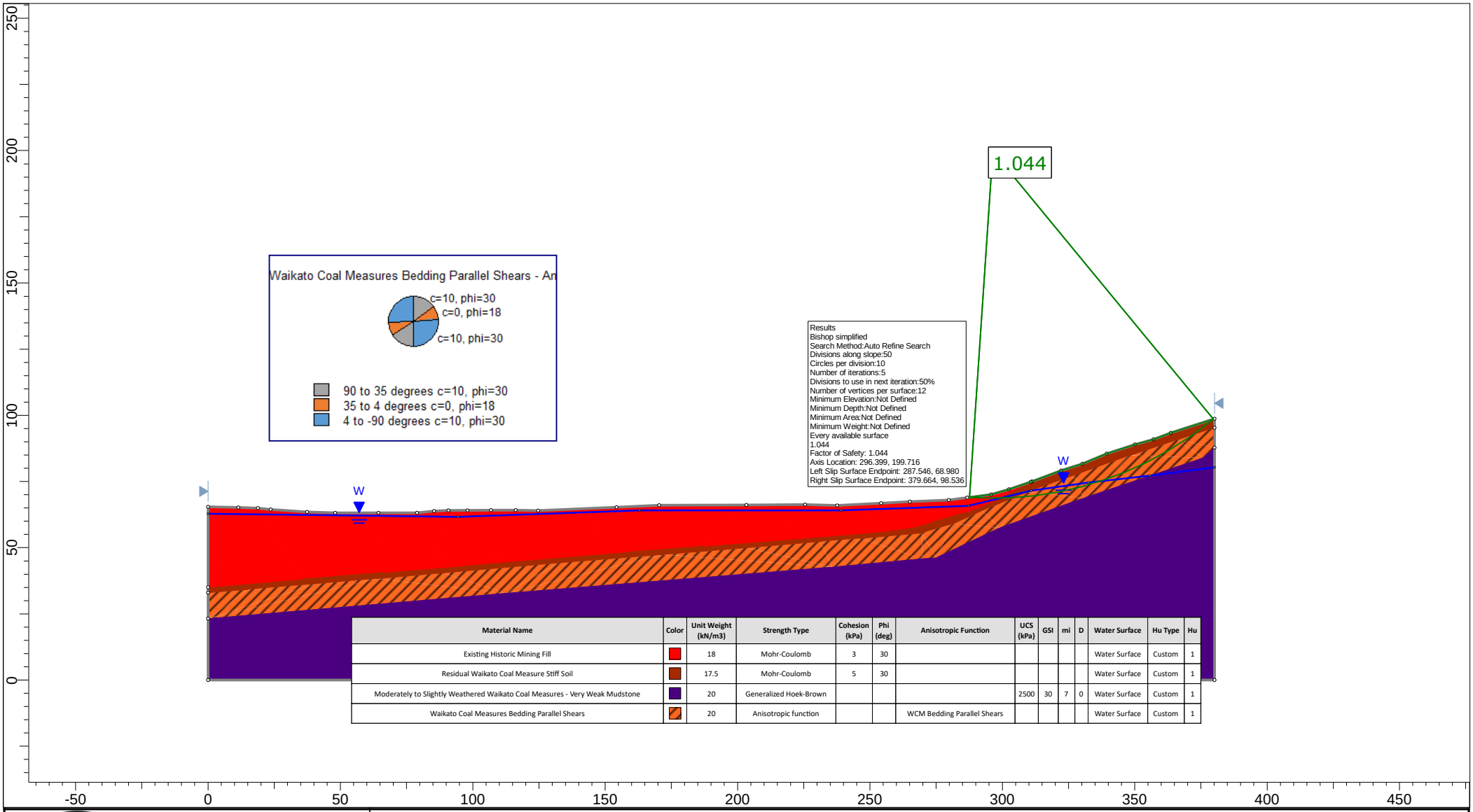
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3, Cross Section 1, Proposed Fill - Crtical Seismic Loading		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1

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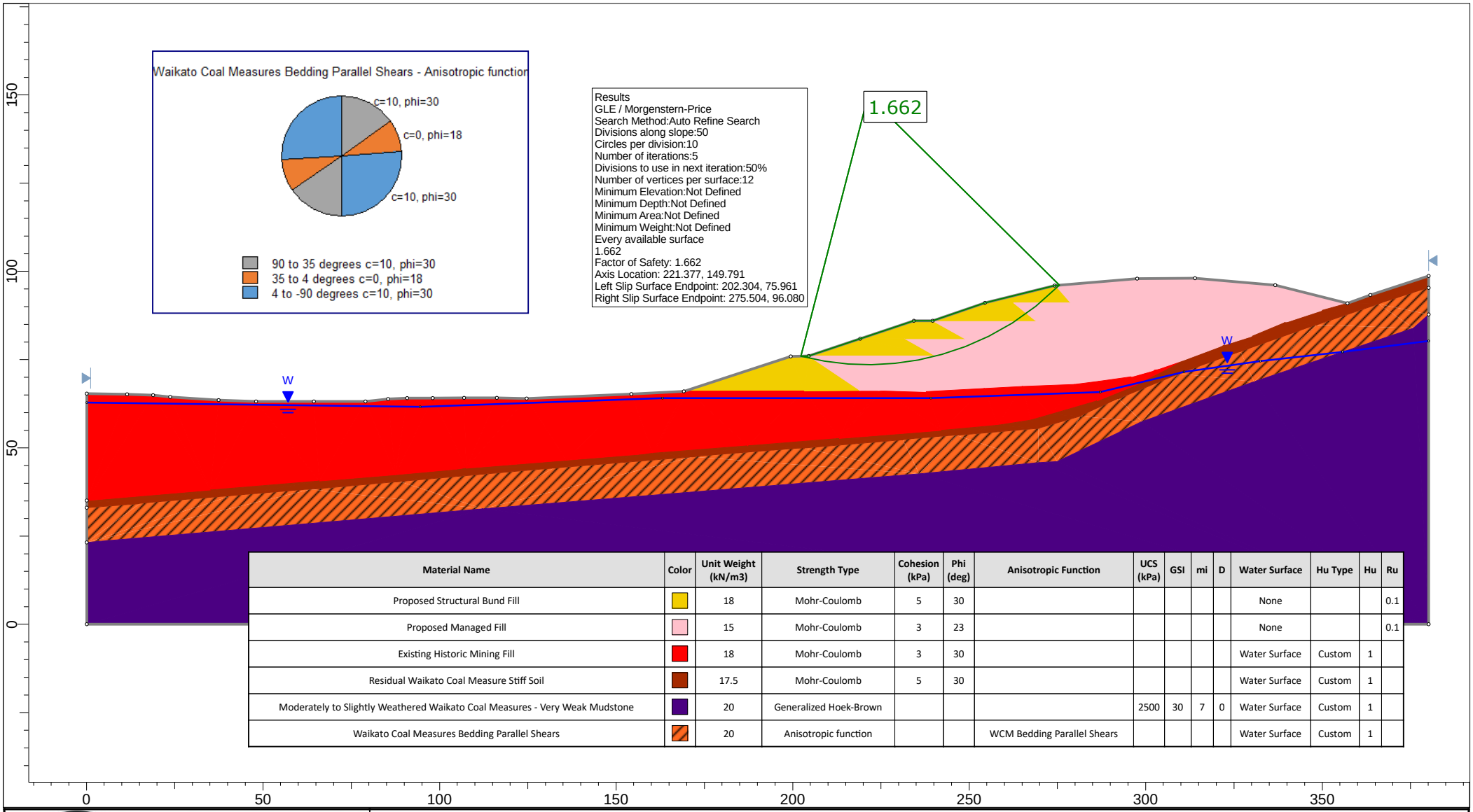
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Existing Slope - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:2000	*Company* Gaia Engineers
Date	Oct 2019		*File Name* Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	

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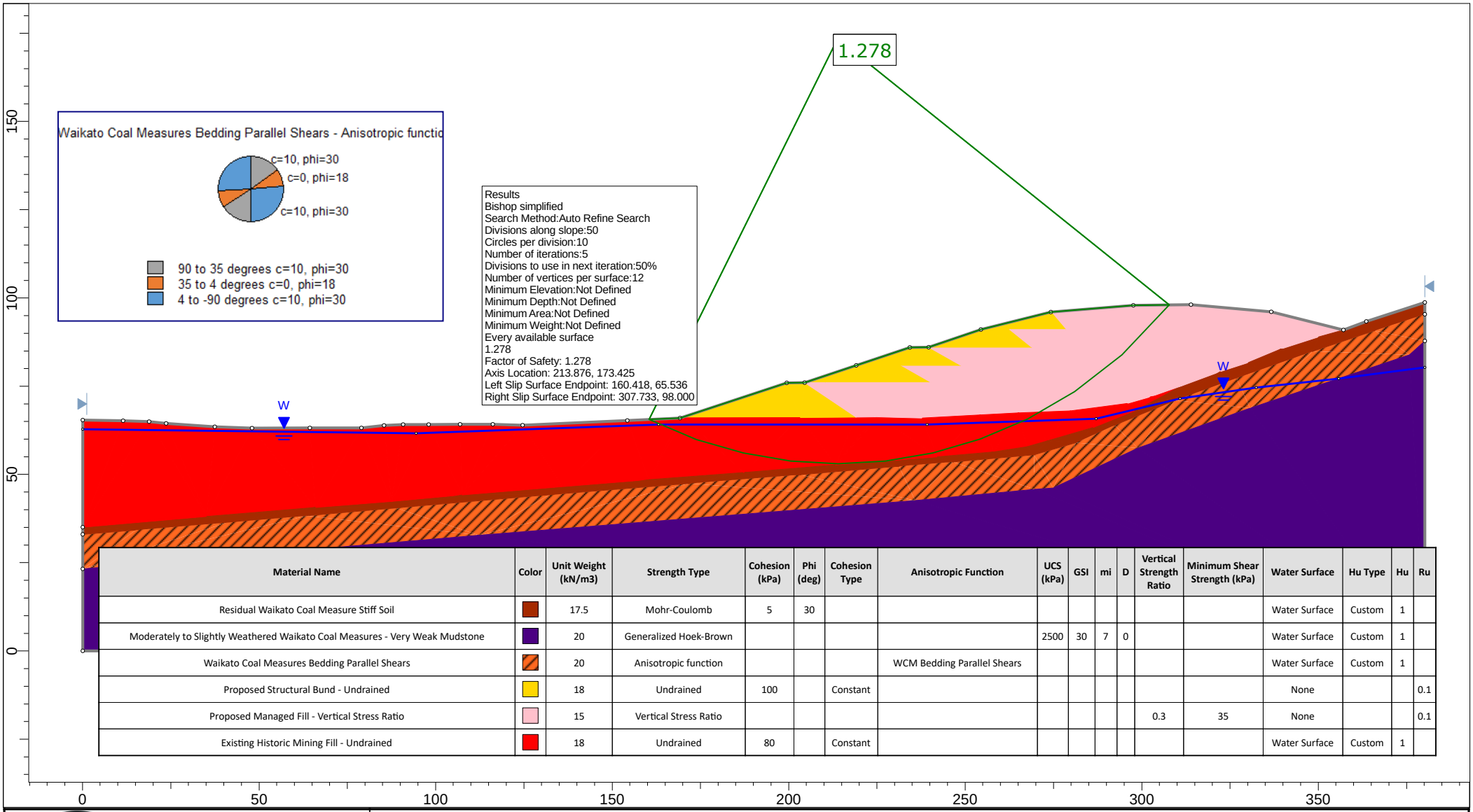
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Proposed Fill - Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

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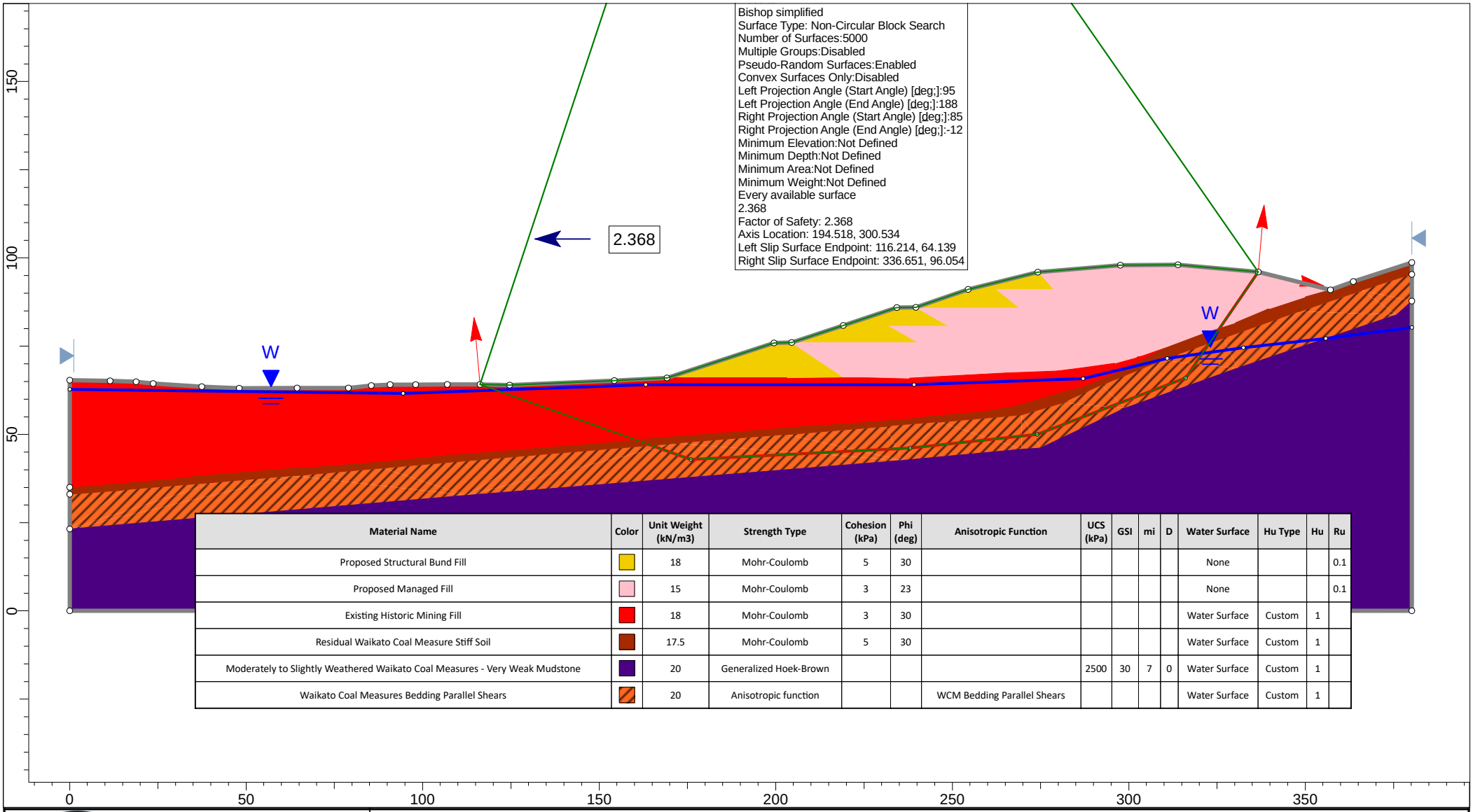
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Proposed Fill - Undrained Case		
Drawn By MK	*Scale* 1:1500	*Company*	Gaia Engineers
Date Oct 2019		*File Name*	Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Existing Historic Mining Fill		18	Mohr-Coulomb	3	30						Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	

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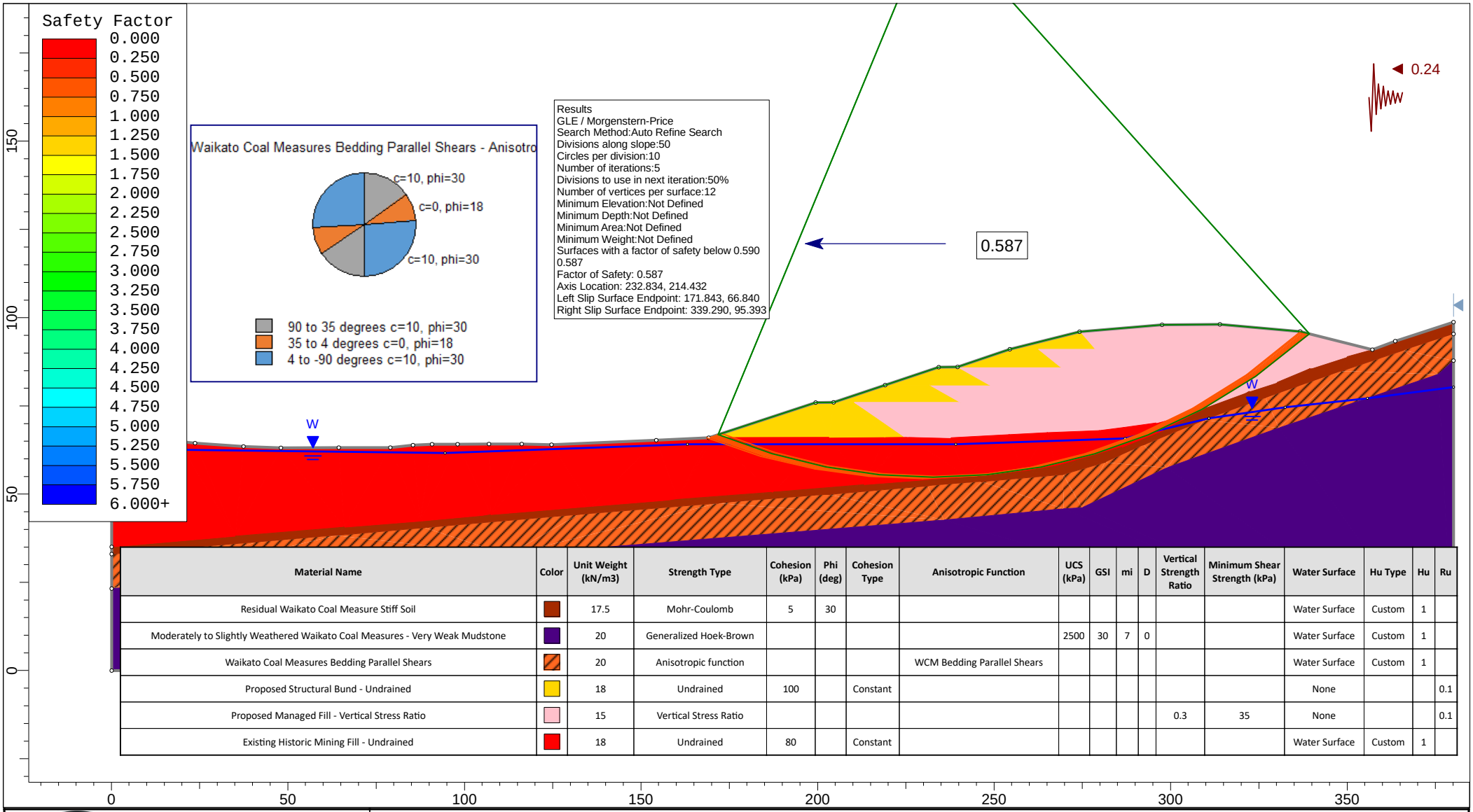
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Proposed Fill - Bedding Shears - Manual Slip Surface		
Drawn By	MK	*Scale*	1:1500
Company	Gaia Engineers		
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

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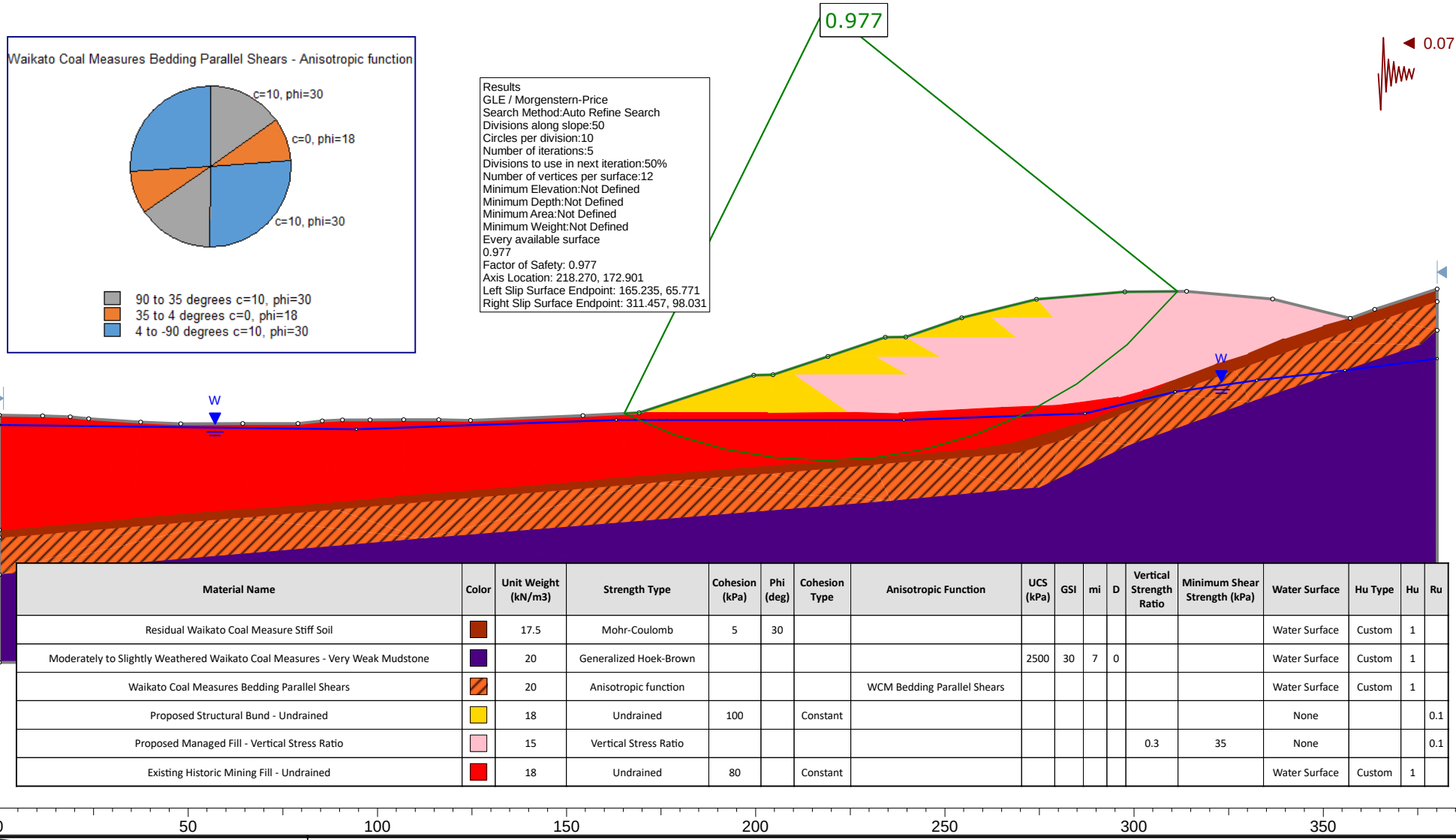
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Proposed Fill - Seismic Loading		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Historic Mining Fill - Undrained		18	Undrained	80		Constant								Water Surface	Custom	1	

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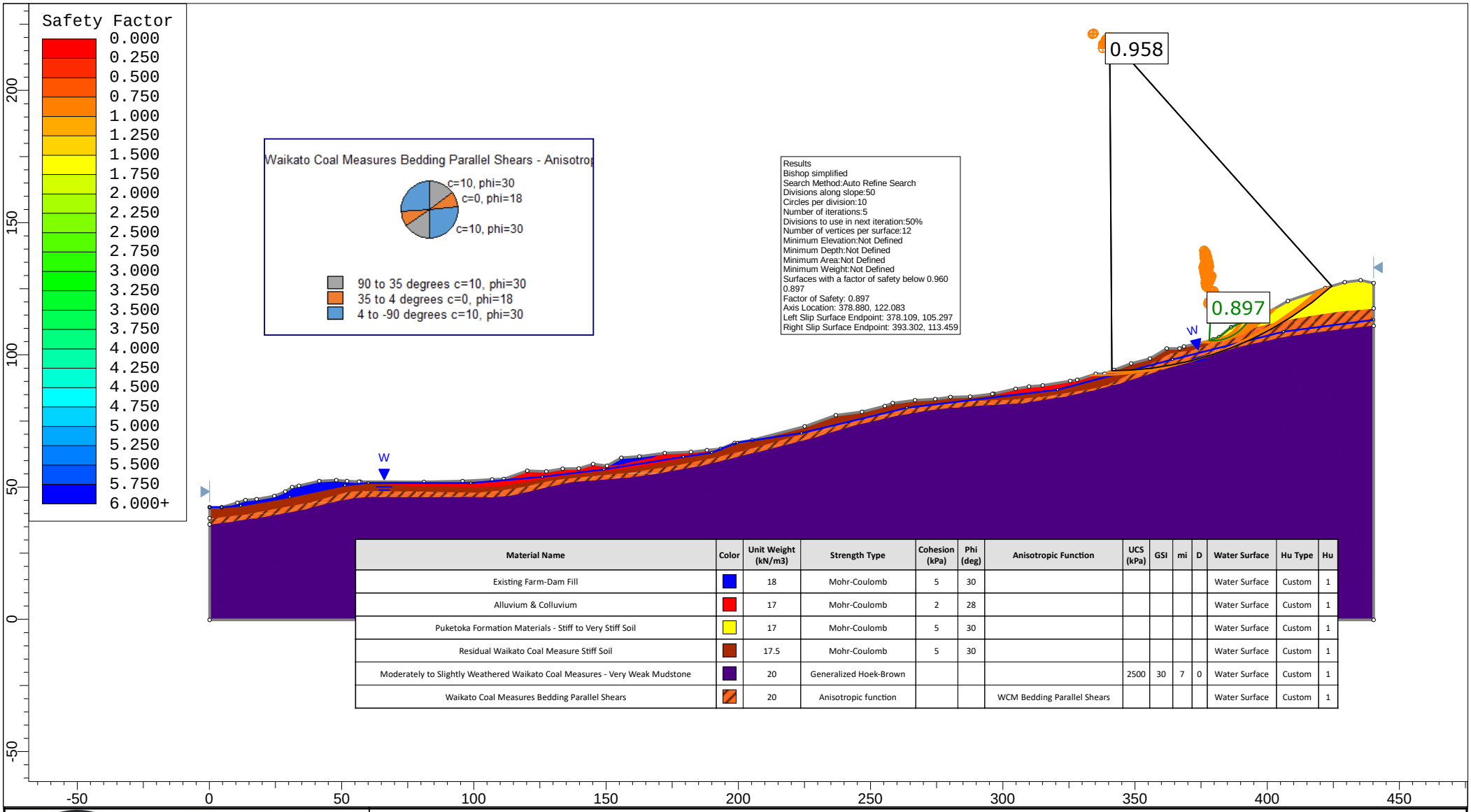
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 3 - Cross Section 2, Proposed Fill - Critical Seismic Case		
Drawn By	MK	*Scale* 1:1500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 3 Cross Section 2.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30						Water Surface	Custom	1
Alluvium & Colluvium		17	Mohr-Coulomb	2	28						Water Surface	Custom	1
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30						Water Surface	Custom	1
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1

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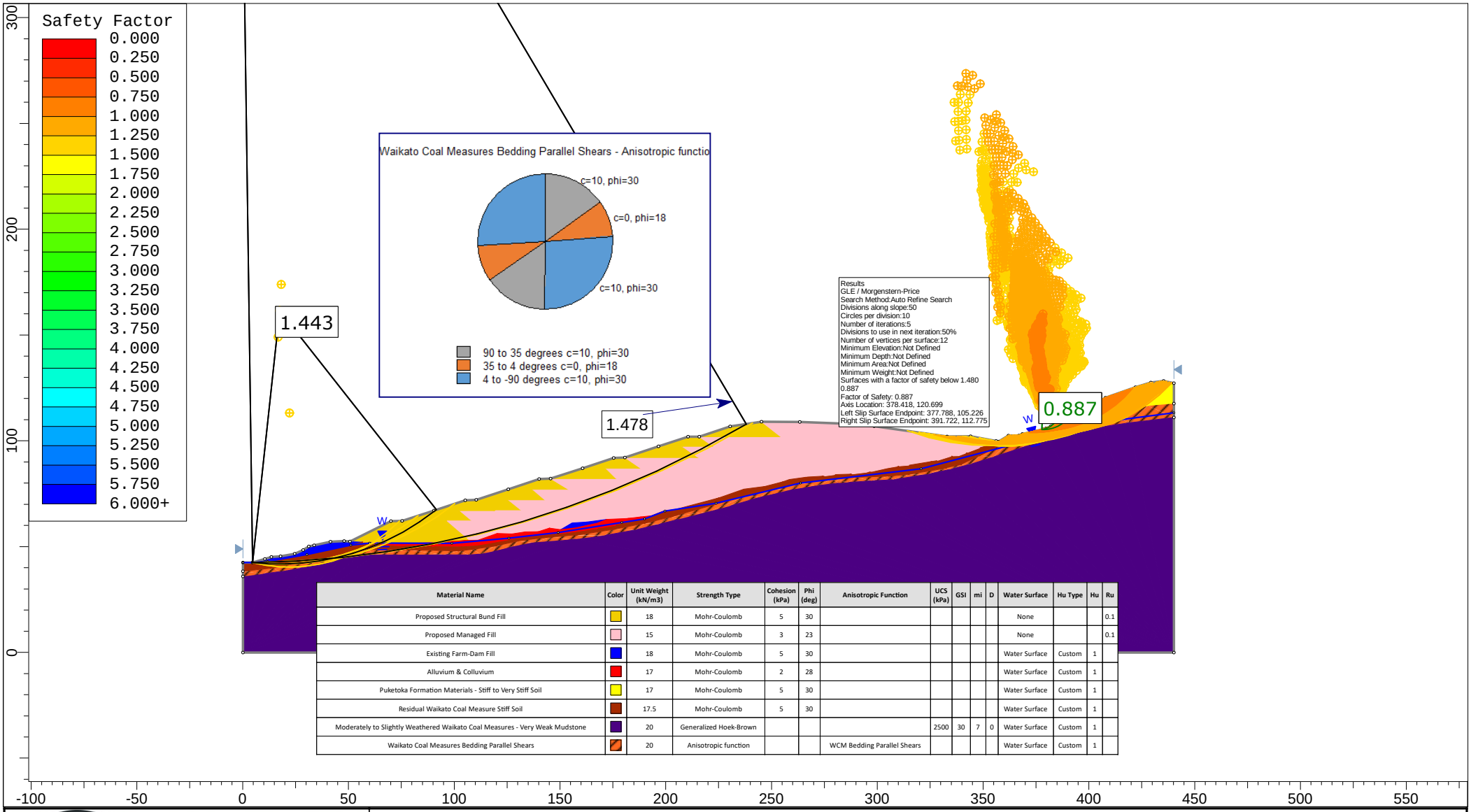
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Existing Slope - WCM Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:2000	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 4 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Anisotropic Function	UCS (kPa)	GSI	mi	D	Water Surface	Hu Type	Hu	Ru
Proposed Structural Bund Fill		18	Mohr-Coulomb	5	30						None			0.1
Proposed Managed Fill		15	Mohr-Coulomb	3	23						None			0.1
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Alluvium & Colluvium		17	Mohr-Coulomb	2	28						Water Surface	Custom	1	
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30						Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown				2500	30	7	0	Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function			WCM Bedding Parallel Shears					Water Surface	Custom	1	

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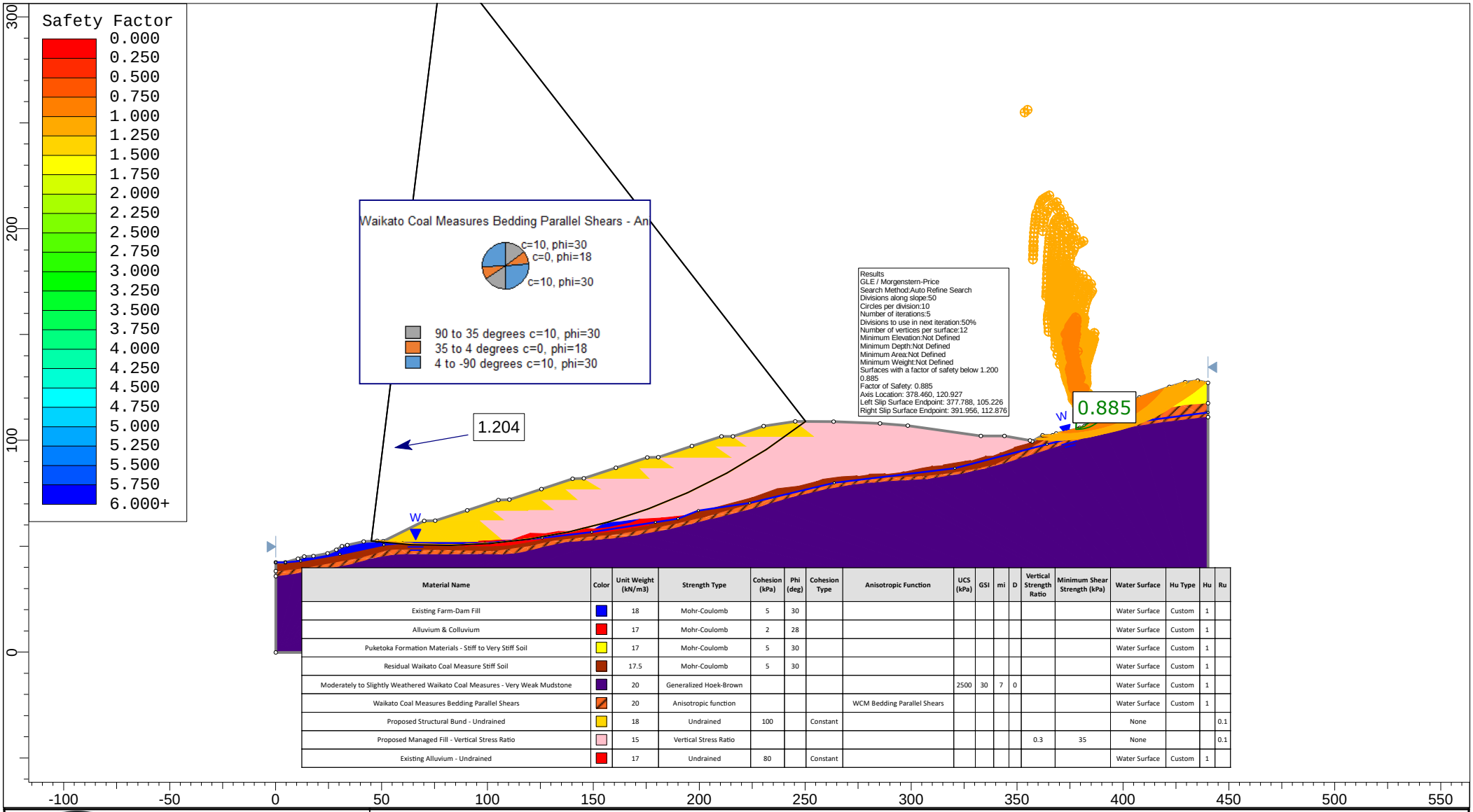
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Proposed Fill - WCM Bedding Parallel Shears		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 4 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Alluvium & Colluvium		17	Mohr-Coulomb	2	28									Water Surface	Custom	1	
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Alluvium - Undrained		17	Undrained	80		Constant								Water Surface	Custom	1	

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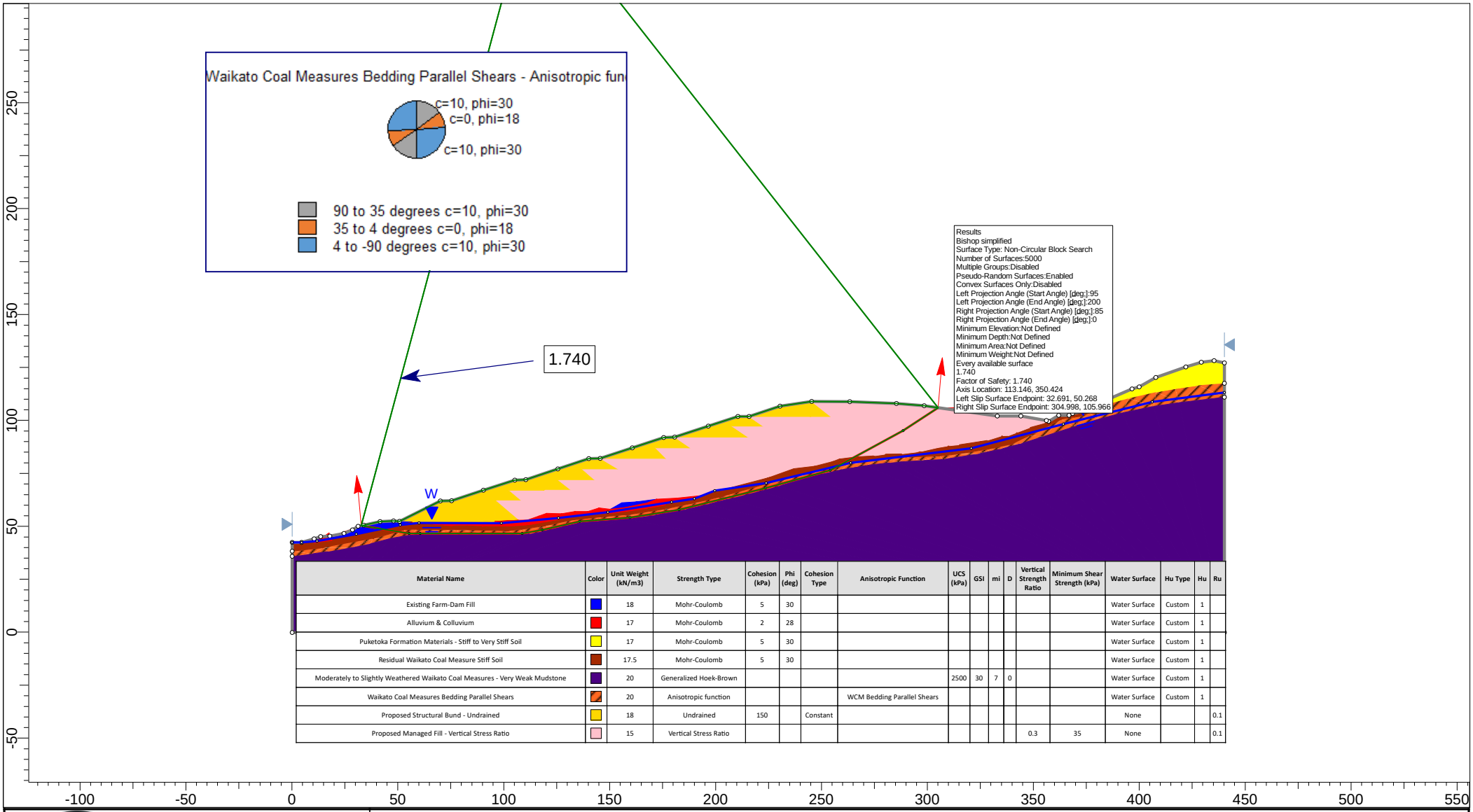
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Proposed Fill - Undrained Case		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019		*File Name* Fill Site 4 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Alluvium & Colluvium		17	Mohr-Coulomb	2	28									Water Surface	Custom	1	
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	150		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1

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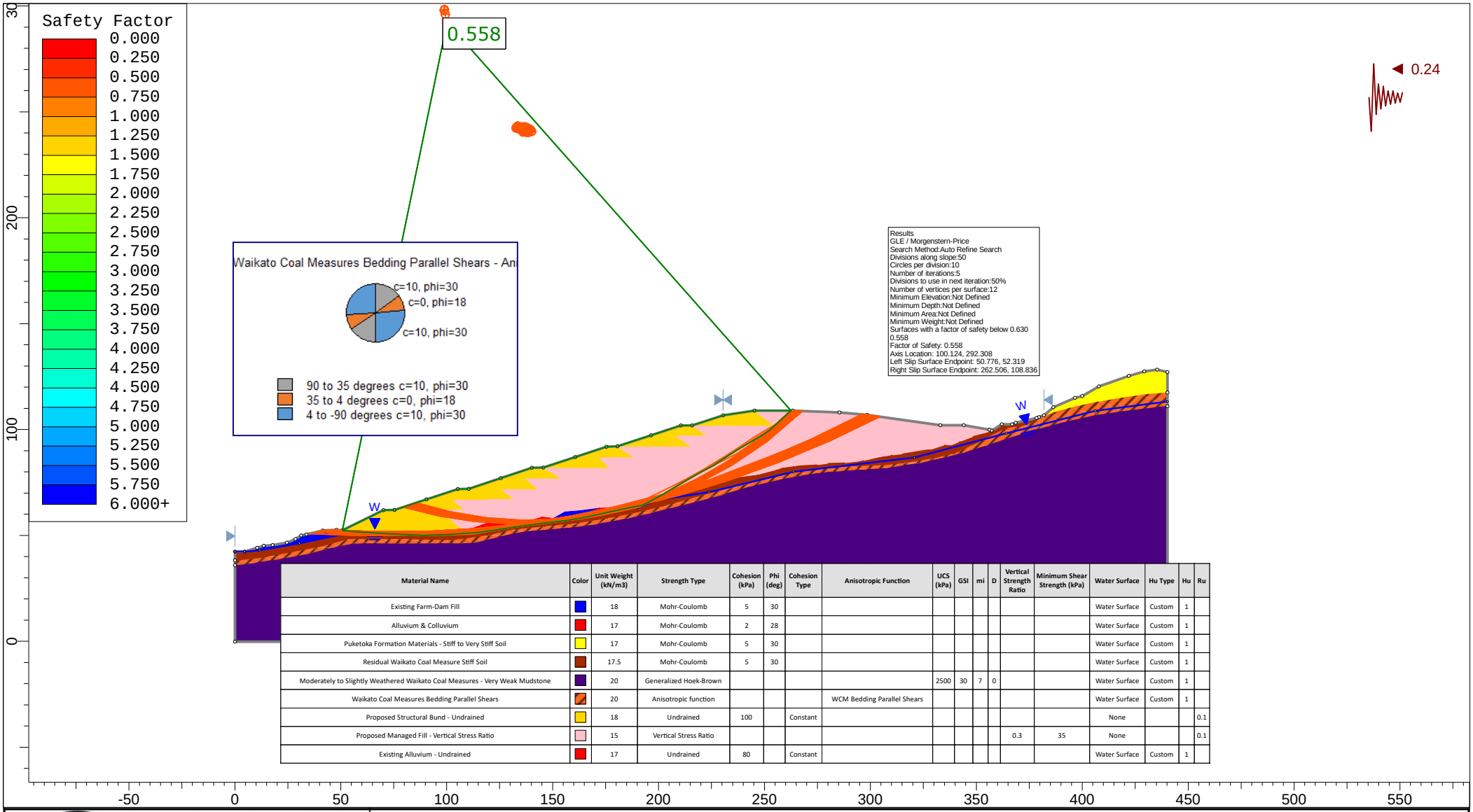
Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Proposed Fill - Bedding Shears - Manual Slip Surface		
Drawn By	MK	*Scale*	1:2500
Company	Gaia Engineers		
Date	Oct 2019	*File Name*	Fill Site 4 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Alluvium & Colluvium		17	Mohr-Coulomb	2	28									Water Surface	Custom	1	
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Alluvium - Undrained		17	Undrained	80		Constant								Water Surface	Custom	1	

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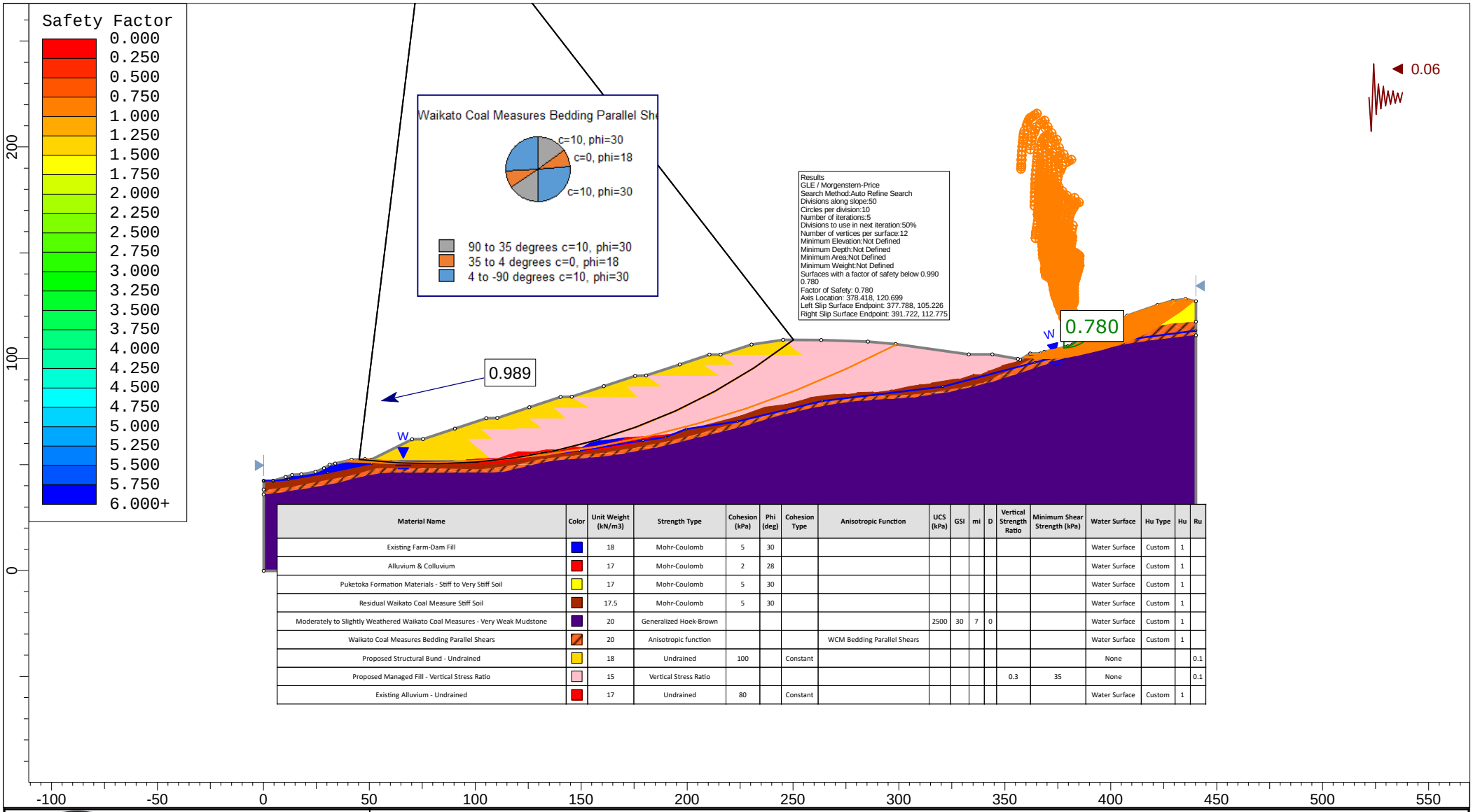
SLIDEINTERPRET 8.021

Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Proposed Fill - Seismic Loading		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019		*File Name* Fill Site 4 Cross Section 1.slmd



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	Anisotropic Function	UCS (kPa)	GSI	mi	D	Vertical Strength Ratio	Minimum Shear Strength (kPa)	Water Surface	Hu Type	Hu	Ru
Existing Farm-Dam Fill		18	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Alluvium & Colluvium		17	Mohr-Coulomb	2	28									Water Surface	Custom	1	
Puketoka Formation Materials - Stiff to Very Stiff Soil		17	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Residual Waikato Coal Measure Stiff Soil		17.5	Mohr-Coulomb	5	30									Water Surface	Custom	1	
Moderately to Slightly Weathered Waikato Coal Measures - Very Weak Mudstone		20	Generalized Hoek-Brown					2500	30	7	0			Water Surface	Custom	1	
Waikato Coal Measures Bedding Parallel Shears		20	Anisotropic function				WCM Bedding Parallel Shears							Water Surface	Custom	1	
Proposed Structural Bund - Undrained		18	Undrained	100		Constant								None			0.1
Proposed Managed Fill - Vertical Stress Ratio		15	Vertical Stress Ratio									0.3	35	None			0.1
Existing Alluvium - Undrained		17	Undrained	80		Constant								Water Surface	Custom	1	

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Project	Huntly Quarry - Fill Disposal Sites		
Analysis Description	Fill Site 4, Cross Section 1, Proposed Fill - Seismic Loading Critical		
Drawn By	MK	*Scale* 1:2500	*Company* Gaia Engineers
Date	Oct 2019	*File Name*	Fill Site 4 Cross Section 1.slmd

Sliding Block Displacement Analysis

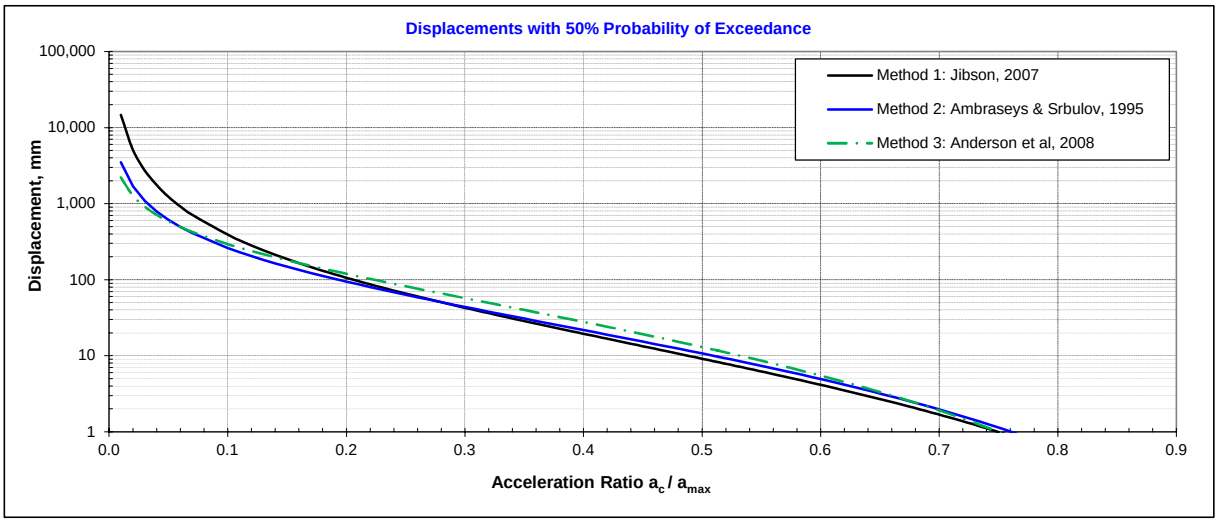
DCLS Event

Project: **Huntly Quarry - Fill Disposal Sites**
Section: **Fill Sites 2 -4 - Preliminary Displacement Calc**
Designer: **MK**

Print Date: **16-Jan-20**

Item	Symbol	Value	Units	Comment
Inputs				
Earthquake magnitude	M_w	**5.8**		For Huntly from Bridge Manual Table 6A.1
Hypocentral (slope) distance	D_e	**40**	km	
PGA coefficient	$C_{0,1000}$	**0.23**		For Huntly from Bridge Manual Table 6A.1
Site Subsoil Category	S	**C**		T_n < 0.6 sec
Importance Level	IL	**2**		From Bridge Manual Table 2.1
Return period factor	R_u	**1**		For annual probabilities of exceedance of 1 in 500 years from NZS 1170.5 Table 3.5
Critical acceleration	a_c	**0.06**	g	Estimate from limit equilibrium slope stability analysis
Probability of exceedance	p	**15**	%	Bridge Manual uses 50% (Clause 6.3.2)
Initial fundamental period	T_s	0.18	s	Used in Bray & Travasarou 2007
Calculated Parameters				
Site subsoil class factor	f	1.33		From Bridge Manual Section 6.2.1
Peak ground acceleration (PGA)	a_{max}	**0.24**	g	From Bridge Manual Section 6.2.1
Peak ground velocity	v_o	0.24	m/s	Used in RRU and Anderson et al. Taken as 1.0 x a_{max}
Degraded period	$1.5T_s$	0.27	s	Used in Bray & Travasarou 2007. Taken as 1.5 x T_s
Spectral acceleration at $1.5T_s$	$S_a(1.5T_s)$	0.42	g	Used in Bray & Travasarou 2007 with consideration of depth reduction factor r_d
Acceleration ratio: a_c / a_{max}	a_r	0.25		
Normal distribution factor	z_n	1.036		Z_n = NORMINV((1-p/100),0,1) - Excel Function
Calculated Displacements				
Method 1: Jibson, 2007	d_j	**66**	mm	Uses M_w - moment magnitude
Ambraseys & Menu, 1988	d_{am}	356	mm	Based on M_s between 6.6 to 7.2 (M_s > M_w)
Method 2: Ambraseys & Srbulov, 1995	d_{as}	**63**	mm	Uses M_s - surface wave magnitude
RRU Bulletin 84 (Wood & Elms)	d_{rru}	165	mm	
Method 3: Anderson et al, 2008	d_{an}	**82**	mm	
Bray & Travasarou, 2007	d_{br}	298	mm	

Upper Bound Displacement	d	**83**	mm	Upper bound value from 3 methods - Based on Bridge Manual Section 6.1.2 & 6.3.4
	$d_{200\%}$	**166**	mm	200% of displacement from one ULS event, Not relevant for MCE event
				Based on Bridge Manual Section 6.3.4



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