

Camelot Cave

Geotechnical effects assessment

Proposed Southwestern Pit
Oparure Quarry
Te Kuiti



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1 Introduction

Graymont [NZ] Limited [Graymont] is proposing a major development to expand its operations at Oparure limestone quarry, located northwest of Te Kuiti in the Waitomo District. The expansion is referred to as the Southwestern Pit, which will be developed and operated as an integral part of the Oparure Quarry.

The project has been in development for several years and a consent application was lodged with Waikato Regional Council [WRC] on 19 October 2022. Subsequently, requests for information were issued by WRC and responses provided by the applicant through 2023 to 2025.

We understand that Graymont have now chosen to lodge their application for consent to the EPA under the Fast Track Approvals Act [2024].

A key component of the project is managing the risk of damage to the Camelot Cave system which is known to exist within the land proposed for quarrying.

This report provides a geotechnical review and analytical assessment of the proposed South-Western Pit extent and its interaction with the Camelot Cave system. It draws on a combination of extensive existing information provided by others in support of the previous consent application and site observations made during site visits to the existing Oparure Pit and adjacent land area that would host the South-Western pit. It considers the risk to the Camelot Cave system and the suitability of associated mitigation measures that are proposed. We understand that the report will be provided as a supporting document for the substantive application under the FTAA.

The original scope of works which involved our geotechnical review was set out in our offer of service dated 23 February 2026. Analytical assessment and site mapping of the existing pit was set out in a second offer of service dated 15 April 2026.

2 Development proposal

The South-Western Pit has been designed to accommodate limestone extraction that could extend up to 53 years, based on current demand. The pit is expected to be up to 60 m deep, 1,000 m long and 850 m wide. The lowest elevation for proposed extraction is approximately RL 161 m.

The stage plans for the development [refer Appendix A] illustrate that the initial development will comprise the construction of a haul road from the existing operational area of the Oparure Quarry and progressive overburden stripping and excavation of limestone in the eastern part of the South-Western Pit.

Development will then broadly work its way to the south, developing down the eastern half of the South-Western Pit, before quarrying moves back to the north along the western margin [i.e. excavation broadly occurs in a clockwise direction].

Initially overburden will be placed into the current Oparure Pit, before being placed into exhausted parts of the Southwestern Pit after year 13.

We understand that Graymont have proposed a buffer zone around the likely subsurface extent of the Camelot Cave system. The purpose of this zone would be to provide an appropriate initial setback

from the cave system in early-stage excavation to account for uncertainty in cave position and to allow a more detailed investigation to confirm its extent and refine the pit design as required to ensure that the cave is not encountered in excavation.

A key part of our geotechnical review is consideration of a proposed buffer zone to ensure it is sufficiently sized to manage the risks to Camelot Cave given some of the uncertainties in the cave's position.

3 Site description

The proposed area of excavation of the South-Western Pit commences approximately 500 m to the west of the current Oparure Pit avoiding an area of historic overburden disposal located immediately adjacent to the west walls of the Oparure Pit.

The footprint of the South-Western Pit covers an area that is largely pastureland, with some areas of low vegetation, scrub and the occasional mature tree. The elevation of the site ranges from approximately RL 270 m in the northern part of the site to approximately RL 190 m at the southernmost extent of the proposal.

The geomorphology of the site is consistent with what could be expected of limestone karst terrain, i.e. a series of blind gullies, interrupted by active or collapsed dolines [tomos].

Flaggy limestone rock is exposed in many surface outcrops within the proposed footprint of the South-Western Pit. The rock outcrops display sub-horizontal bedding with bed thicknesses typically measuring between 50 mm and 250 mm.

4 Summary of existing information

The Camelot Cave system is described in several of the reports that have been prepared to support the original consent application and the subsequent referral process and substantive application under the FTAA.

Key documents include:

- PDP [2022] Graymont Southwestern Pit – Geology and Soils Report. Prepared by Pattle Delamore Partners Limited. Ref: C03870503R001, dated October 2022. Prepared for: Graymont [NZ] Limited.
- Boffa Miskell [2022] Subterranean Habitat: Troglobite fauna impact assessment Southwestern Pit Prepared for Graymont New Zealand Limited. 10 October 2022.
- PDP [2024a] Water Assessment – Proposed Western Pit. Prepared by Pattle Delamore Partners Limited. Ref: C03870503, dated October 2024. Prepared for: Graymont [NZ] Limited.
- Graymont [NZ] Limited. Resource consent application to develop, operate and progressively rehabilitate the Western Pit Summary Document [undated].
- BBO Memo [2024] Opārure Western Pit Amended Application – Southern Catchment Pit, dated 19 December 2024.

- PDP [2024b] Memorandum - Graymont Southern Catchment Pit – Water Quantity/Quality Assessment dated 5 December 2024.

5 Assessment of background information

5.1 Geology and geomorphology

PDP [2022] provided a summary of the expected geology and geomorphic conditions. That document describes the key geological unit for the quarry as the Otorohanga Limestone, a bioclastic limestone that exhibits flaggy bedding and is strongly jointed. PDP [2024a] describe the limestone as being interbedded with land derived sediments that are mechanically weaker, but more resistant to chemical dissolution.

PDP describe the general bedding orientation in the Otorohanga Limestone as gently dipping towards the east and northeast with local steepening near faulting. They also note that in the Oparure Pit the bedding was measured and had an orientation of 3-5° [dip] towards the east [dip direction, Figure 5-1].

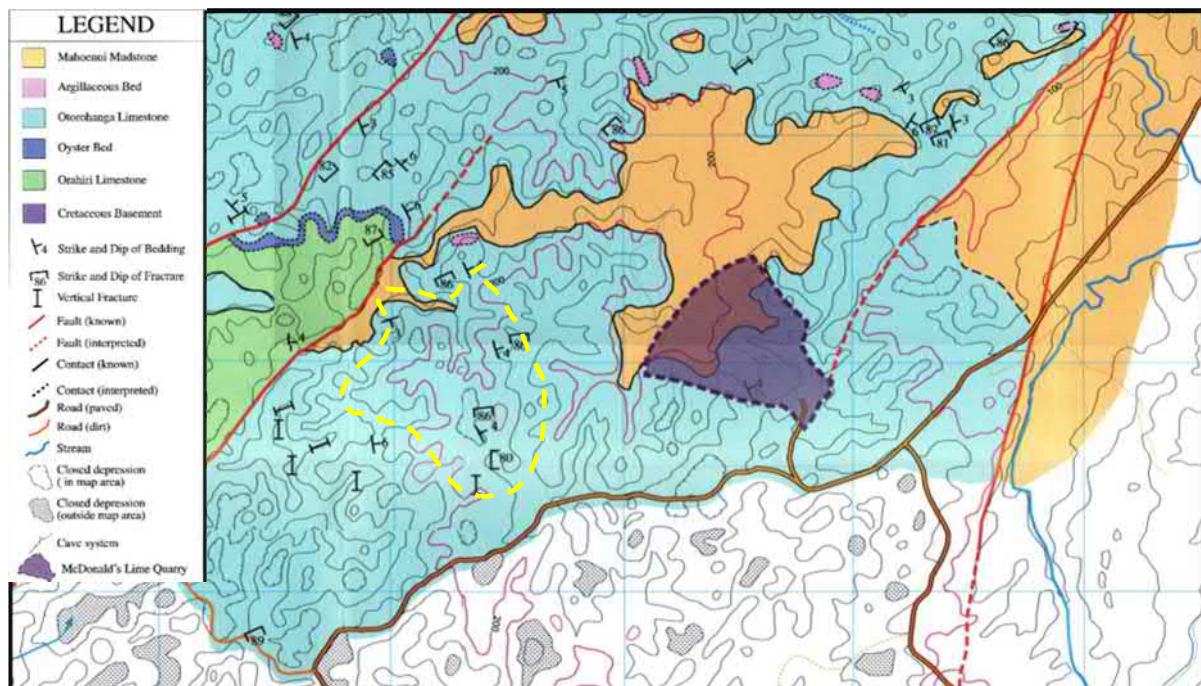


Figure 5-1: Geological Map of proposed South-Western Pit Footprint [yellow]. Excerpt from Frostad [2004]¹

Regional scale faulting is described in PDP [2022] as being dominated by the Waipapa Fault located 2 km to the east of the Oparure Pit, and the Hikurangi Fault located several kilometres to the west. These regional scale faults broadly strike north south or NNE-SSW.

Smaller scale faults in the Oparure Pit are described by PDP [2022] as having a similar orientation to the regional scale faults and are typically downthrown to the west.

¹ Frostad C.J., 2004. The structural controls on karst development, Opāpure Block, North Island, New Zealand. University of Calgary 2004.

The dominant joint set is defined by PDP [2022] as sub-vertical defects striking to the northeast or east.



Figure 5-2: Geomorphology of the Southwestern Pit Area [footprint in yellow]. Blue arrows delineate trends in doline and blind gully development.

5.2 Cave development processes

The Waikato Regional Plan defines “cave” as a natural cavity, fissure or canyon in a rock large enough to be entered by a human and which acts as a conduit for water flow, seepage water, or ground water between input points such as stream sinks, and output points such as springs or seeps.

A series of cave systems have been identified in the area surrounding the current Oparure Pit and within the footprint of the proposed South-Western Pit.

Cave development is expected to be related to chemical dissolution of the limestone by slightly acidic surface water. PDP [2024a] set out a general model for cave development which is summarised as follows:

- Flow occurs through the persistent, primary east to northeast striking joint network, noting that many of the observed cave systems described in PDP [2022], PDP [2024] and Boffa Miskell [2022] have a significant northeast trend to them.
- Occasional short changes in direction provided by smaller scale southeast to northwest trending joints. While not specifically described by PDP and Boffa Miskell it has been our observation that larger changes in direction may be provided by regional fault parallel north-south striking defects.
- Basal subterranean flow down the dip of the limestone bedding [approximately 3-5° to the east].

5.3 Camelot Cave

An entrance to the Camelot Cave system has been identified immediately to the east of the proposed footprint of the proposed South-Western Pit as illustrated on Figure 002, Appendix B.

The cave has previously been mapped by the Speleological Society in 1985 as illustrated in Figure 5-3. Access was achieved by way of a 70 m deep open shaft.

In addition to known cave systems described in PDP [2022], Boffa Miskell [2022] employed cavers to undertake a grid search of the South-Western Pit footprint which identified around 100 possible caves, 60 of which were explored and at least 20 were found to be accessible to humans.

Boffa Miskell [2022] found that no cave was long or well developed. The majority being tight crawl spaces with narrow vertical cracks and floors covered in sediment. None of the caves had a live stream, with the exception of Camelot Cave.

All cave surveys were discontinued due to a low oxygen environment discovered in early expeditions into the Camelot Cave, which has limited the gathering of additional data on this cave system.

A large stream entrance to the cave system [“stream sink”] has been identified approximately 2.5 km to the southwest of the 70 m deep shaft entrance near to the proposed Southwestern Pit. The stream sink has been surveyed and has a stream bed elevation of 249 m RL. The difference in elevation between this stream sink and the 70 m deep shaft near the Southwestern Pit indicates a 2.5° stream bed slope between the two. This is consistent with an overall 3-5° bedding dip towards the east in the Otorohanga Limestone.

6.2 Defects

A total of 37 defects were mapped across six slope batters. The location of the mapped defects is outlined in Figure 6-1 and Figure 6-2 presents all mapped structural defects on a stereonet plot in dip/dip direction format.



Figure 6-1: Observed structural defects [orange discs, labelled with defect orientation] within Oparure pit. Figure facing northeast.

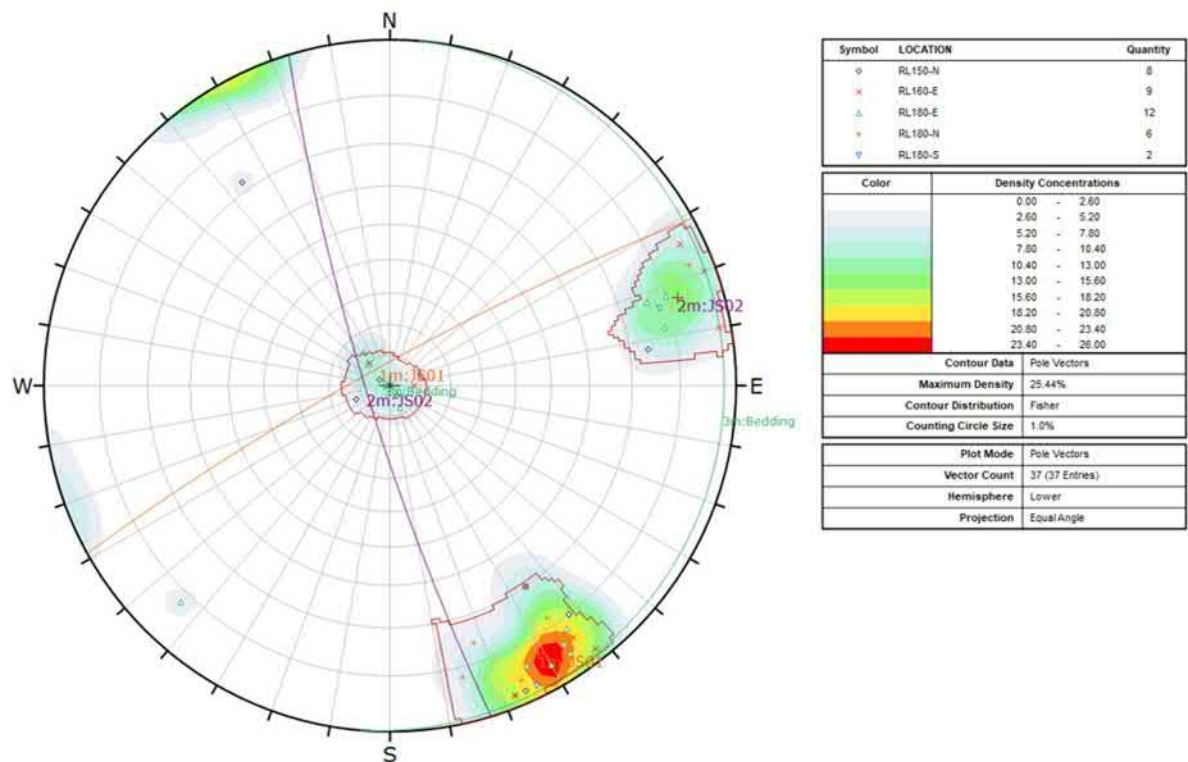


Figure 6-2: Stereonet plot of all measured structural defects.

Defects were manually grouped into two major joint sets [denoted JS01 & JS02] and one bedding group, based on pole density concentrations from site observations. Surfaces observed along the two major joint sets within the quarry are typically undulating-smooth and clean. Bedding is typically undulating to planar and smooth to rough, with narrow to very narrow silt infill in some of the bedding observed. Table 6-1 presents a summary of the defect sets observed.

Table 6-1 Summary of structural defects observed [29 April 2026].

Joint Set	Dip [°]	Dip Direction [°]	Spacing [m]	Persistence [m]	Roughness
JS01	83 [70-88]	331 [322-346]	2.2 [0.5-5.1]	20 +	Undulating, Smooth/Rough
JS02	82 [74-88]	253 [244-262]	1.7 [1.0-5.9]	15-20	Undulating, Smooth/Rough
Bedding	2 [4-12]	095 [068-336]	0.13 [0.12-0.15]	-	Planar/Undulating, Smooth/Rough

6.3 Groundwater

At the time of the site visit, the pit was generally dry. A single localized seepage was observed 5 m above the quarry floor, along the east wall [RL 155 m] [Appendix B – Figure 003].

7 Conceptual ground model

Our observations in the Oparure Pit, and in rock outcrop in the proposed South-Western Pit footprint to the West, is that there are two main structural joint orientations. These are a primary set of sub-vertical joints that strike between 030-050° [i.e. the northeast to east trending structures described by PDP] and a secondary set of sub-vertical joints that strike 170-200° [i.e. consistent with the major faulting orientation described by PDP].

We have observed a significant aperture in the more persistent joints in the network, particularly those that trend northeast to east. These defects display an aperture in the order of hundreds of millimetres and are often infilled with limestone debris, overlying topsoil and vegetation.

In terms of surface geomorphology in the South-Western Pit footprint, the orientation of blind gullies and collapsed dolines/tomos that are evident in the topography are consistent with the two main structural trends. This trend indicates that subsurface dissolution of limestone and development of underground voids is controlled by the fracture network within the limestone.

The orientation of the primary northeast trending joint system has been illustrated in Figure 7-1, from the upgradient stream sink. This suggests that a number of course corrections to the south are required for the stream sink to connect to the Camelot Cave at the 70 m shaft location. We have reviewed the aerial imagery for the site and have identified terrain with strongly developed north south jointing as illustrated in Figure 7-2. These zones are broadly consistent with mapped defect information from Frostad [2004, refer Figure 5-1], which indicate clusters of north south trending defects in similar locations.



Figure 7-1: Primary North-East structural [thick white line] trend from Stream Sink towards the proposed Southwestern Pit



Figure 7-2: Primary North-East structural trend with possible course corrections based on observed rock structural trends observed in rock outcrop [Thick white line represents indicative cave alignment, thin white lines are observed jointing and thick yellow lines inferred major changes in direction].

Given the analysis to date, we consider it most likely that the larger part of the north to south course corrections between the stream sink and the 70 m shaft are likely to occur beyond (to the west of) the proposed pit footprint. The level of uncertainty around this is least at the east of the pit, closest to the 70 m shaft and greatest at the western side of the pit. While we interpret a projected trend for the upstream extension of the Camelot Cave from the 70 m shaft, it is recognised that some form of additional cave mapping will be required to verify cave geometry when it is safe to do so.

Dye tracing [PDP 2024a] has identified that flowing water in Camelot Cave at the 70 m shaft location reports to Pōtea Spring and Pumphouse Spring, another 2.8 km to the northeast [refer Figure 001, Appendix B]. The distance and elevation of the outlet is also consistent with an overall 3-5° bedding dip towards the east in the Otorohanga Limestone.

Overall, we anticipate a north-east trend to the Camelot Cave system, with occasional course corrections to the southeast and south [i.e. down bedding].

7.1 Camelot Cave and proposed South-Western Pit geometry

We have reviewed the proposed pit development plans [refer Appendix A], which illustrate the indicative development of the pit over the proposed 53 year design life.

Preliminary cross sections have been developed that demonstrate the relationship between the proposed pit excavation and Camelot Cave at 8 years, 13 years and 53 years [refer Figures 005 and 006, Appendix B].

We have conservatively assumed a cave floor RL of 150 m based on a 70 m deep shaft entering from approximately RL 220 m at the cave entrance immediately to the east of the proposed South-Western Pit.

Comparison of the anticipated cave position with the 8-year pit illustrates a 220 to 330 m horizontal offset as well as a vertical offset of 20-40 m.

Eventually, the final pit design will extend over the Camelot Cave system, with a vertical offset between the cave roof and the pit floor currently shown at approximately 8-10 m.

We have produced a type-section of the expected geological model in the South-Western Pit through the proposed long term quarry design [presented in Appendix A – Figure 003].

There is a recognised level of uncertainty in the detailed position of the Camelot Cave system. A portion of the cave has been mapped [as illustrated in Figure 5-3] but the geometry of the part of the cave to the west that will eventually lie beneath the floor of the proposed Southwestern Pit has not been verified.

7.2 Geotechnical risk & potential for environmental effects

Key geotechnical risks to Camelot Cave that may result in environmental effects as a result of the development of the proposed South-Western Pit include:

- Pit excavation encountering the cave system.
- Damage to the cave system due to the mining method.

These are each discussed in the following sections.

7.2.1 Risk of excavation encountering Camelot Cave

We have considered the staged excavation sequence proposed by Graymont along with a proposed buffer zone 200 m wide [100 m in plan on either side of the centre line of the Camelot Cave], which is illustrated in Figure 001 & 002, Appendix B. The purpose of the buffer zone is to allow for early stage mining to be undertaken remote from the cave system, while gathering more data about its exact extents. This is further illustrated in the two cross sections provided in Appendix B [Figures 005 & 006]. This buffer zone has been applied to an inferred Camelot Cave position based on extending the mapped sections of cave to the west along strike of the major NE trending defect set which is known to accommodate a large part of the cave system.

The cross sections illustrate the year 8, year 13 and year 53 [final] proposed pit development stages in relation to the projected location of Camelot Cave.

The cross sections demonstrate that the actual distance, considering both horizontal and vertical offsets is as follows:

- Year 8: 220-330 m
- Year 13: 70-190 m
- Year 53: 8-16 m

At year 8 the offset between the cave and the pit is significant and the vertical elevation difference between the base of pit and crown of cave is between 20-40 m. Even considering the uncertainty in position of the cave system, the likelihood of accidental excavation into the cave during early pit development stages is considered to be very low.

We note that while the main cave system with the flowing stream is unlikely to be encountered in excavation, other inaccessible voids formed in north south trending defects that may have a direct connection to Camelot Cave could be discovered in these early excavation stages.

The distance between the pit floor and the crown of the cave is expected to be in the range 8-16 m for the final pit, but this is dependent on the verified position and extent of the cave system. There is a significantly higher risk of encountering the cave system (or associated collapsed tomos) in this final pit.

We consider the proposed buffer zone illustrated in Figure 2 (Appendix A) is appropriate with respect to the uncertainty in position of the cave system. A more detailed assessment of the risk of damage to the cave due to mining method is described below.

7.2.2 Risk of damage to Camelot Cave due to the mining method

In addition to the risk of excavation encountering the cave system sometime after year 13, there is always a potential for the mining method to result in damage to an adjacent cave system.

Extraction for the South-Western Pit is expected to be a continuation of the method adopted at the current Oparure Pit, which is traditional drill and blast to fragment followed by truck and shovel operations to extract the resource for processing.

Magnitude of blast vibrations is likely to be the key risk item which could result in cave damage, when compared to loading or vibration cases associated with operation of mobile plant.

When considering the proposed 200 m buffer zone and the actual distances from excavation to the cave provided in the year 8 to year 13 quarry design stages, we anticipate that blasting vibrations are unlikely to be sufficiently large to result in damage to the cave system. This is because the cave is likely to have experienced a number of large magnitude earthquakes over its life, which (for the purposes of this assessment) is conservatively considered to be in the tens to hundreds of thousands of years old.

As the pit excavation approaches Camelot Cave in later quarry stages progressively less blast vibration attenuation can be expected to occur and the magnitude of vibrations felt in the cave crown can be expected to become progressively more significant, with an increasing potential for damage to the cave.

BGL have completed a preliminary geotechnical assessment which considers the Camelot Cave system and effects of blasting vibration as staged excavation approaches the cave system.

8 Camelot cave system stability assessment

8.1 Methodology

Our cave wall and roof stability assessment has been undertaken using RS2 software version 11.026, a finite element modelling (FEM) software package that analyses stress, deformation, and stability in soil and rock. A type section along Section C-C' was used to assess the deformation within the walls and roof of the Camelot cave system based on the proposed South-Western pit design.

8.2 Material parameters and groundwater for design

Material parameter selection has been undertaken based on our observations of materials in the field, parameters from previous assessments and publications, and our experience with similar materials. We have conservatively applied material parameters for intact rock based on a Generalized Hoek Brown criterion but adopting a GSI consistent with massive rock. We then modelled the three key defect sets individually based on observed defect conditions. Material parameters estimated for the Otorohanga Limestone rock mass and joint material parameters are outlined in Table 8-1 - Table 8-3 and Appendix C.

Table 8-1 Materials parameters for RS2 stability analyses.

Material	Strength Function	Bulk Density [kN/m³]	Poisson's Ratio	Intact Youngs Modulus [GPa]	Rock Deformation Modulus [GPa]	Cohesion [kPa]	Friction Angle [°]	UCS [MPa]	GSI	mi	D
Otorohanga Limestone	Generalized Hoek-Brown	24	0.23	1.7	0.55	n/a		20	99	10	0
Otorohanga Limestone (Blast-Damage)								20	89	10	1.0

Table 8-2 Barton-Bandis joints and defects parameters for RS2 stability analyses.

Joint ID	Slip Criterion	JCS [kPa]	JRC	Residual Friction Angle [°]	Normal Stiffness [GPa/m]	Shear Stiffness [GPa/m]
Joint 1 [Joint Set 1]	Barton-Bandis	20,000	8	28	3.5	0.99
Joint 2 [Joint Set 3]	Barton-Bandis	20,000	8	28	4.7	1.3

Table 8-3 Mohr-Coulomb bedding parameters for RS2 stability analyses.

Joint ID	Slip Criterion	Peak Cohesion [kPa]	Peak Friction Angle [°]	Normal Stiffness [GPa/m]	Shear Stiffness [GPa/m]
Bedding	Mohr-Coulomb	4	30	6.0	2.0

Groundwater within the Otorohanga Limestone is expected to be running along the cave system. On this basis, we have conservatively assumed this RL 150 m in our modelling.

8.3 Southwestern Pit excavation-induced deformation

We have adopted the proposed site geometry, presented in Section C-C', sourced from Graymont. This section is cut perpendicular to the assumed orientation of the Camelot cave system. The location of Section C-C' is outlined in Appendix B, Figure 002.

We have assumed the geometry of the cave system is structurally controlled by the defects observed, where the cave roof and floor are bedding-controlled and sidewalls influenced by the major joint sets observed.

We have adopted a similar slope geometry to the final 53-year design when considering a range of interim cutbacks leading to proposed 53-year design. This includes an 18 m high overall slope with a slope angle of 34°. The proposed batter slopes are approximately 6 m in height separated by approximately 7.5 m benches and a 10.5 m wide haul road.

We have completed stability analyses for the proposed 53-year design surface for cross section C-C' illustrated in Appendix B – Figure 007 and have applied the material parameters outlined in Table 8-1 and Table 8-2. Deformation at the pit floor and at the cave are summarised in Table 8-4.

Table 8-4 Summary of pit floor and cave system displacement from 53-year Southwestern design levels.

Scenario	Calculated max Displacement observed along the pit floor [mm]	Calculated max Displacement observed within Camelot Cave [mm]
53-year Pit level	26.4	20.8

8.4 Blast-induced seismicity

BGL have received site specific blast monitoring data from Red Bull Powder (the blasting contractor) from recent blasting operation in the Oparure Pit. Near field vibration monitoring was undertaken for Blasts GM0104 and GM0105, using various charge weights and observed scaled distance. Table 8-5 presents a summary of blasting data provided to BGL. Monitoring of blasting vibrations generally provides a Peak Particle Velocity and frequency as an output. The RS2 modelling software requires vibrations to be considered as an acceleration [PGA]. Equivalent seismic loads were estimated based on literature and field data³ as set out below.

Table 8-5 Near field vibration monitoring data [Sourced from Red Bull Powder].

Shot Name	PPV [mm/s]	ACCL [g]	Distance to Shot [m]	MIC
GM0104-7467	47.2	2.51 @ 102 Hz	50.6	160
GM0104-7554	1.21	0.0334 @ 64 Hz	160.9	160
GM0-105-7467	5.57	0.235 @ 128 Hz	107	40
GM0105-7554 [End]	3.74	0.116 @ 64 Hz	83.3	40

³ Hustrulid, W. [1999]. Blasting Principles for Open Pit Mining – Volume 1 General Design Concepts.

GM0105-7554 (Start)	1.24	0.04 @ 40 Hz	450	40
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The blast monitoring data presents the weight of the explosives used and relationship between scaled distance [Ds] with Peak Particle Velocity [PPV], where:

$$PPV = 539.18 * Ds^{-1.932}$$

An equivalent seismic load was then derived based on the offset distance between the South-Western Pit wall and the assumed Camelot Cave system, where we have adopted a conservative higher bound frequency of 100 Hz:

$$PPA (PGA, g) = \frac{2\pi f * PPV}{10}$$

We have adopted various peak particle accelerations as seismic load scenarios to observe the structural performance of Camelot Cave. PPA loads used in our analytical assessment are outlined in Table 8-6.

Table 8-6 Estimated Blast-induced Peak Particle Acceleration [g] based on recent Oparure Pit near field monitoring data.

Charge Weight [kg]	Offset Distance [m]	Projected Peak Particle Acceleration (PPA, g)
120	45	2.21
	40	2.78
76	40	1.79
	35	2.31
	30	3.11
40	35	1.24
	30	1.67
	25	2.38
	20	3.66

We have carried out stability analyses within a localized section of Section C-C', outlined in Appendix B – Figure 007, and have applied the material parameters outlined in Table 8-1 – Table 8-3, under various peak particle accelerations (PPA) outlined in Table 8-6. Results are shown in Appendix D and are summarised in Table 8-7.

Table 8-7 Summary of analysis results for blast excavation offsets.

Scenario- Explosive weight, setback distance [kg, m]	Peak Particle Acceleration [PPA] [g]	Maximum displacement observed under horizontal loading [mm]		Maximum displacement observed under vertical loading [mm]		Maximum displacement observed under oblique loading [mm]	
		Roof	Sidewalls	Roof	Sidewalls	Roof	Sidewalls
40 kg, 30 m	1.67	5.3	6.3	12.2	11.0	8.9	8.6
40 kg, 25 m	2.40	8.1	9.8	17.6	15.9	12.8	12.4
120 kg, 40 m	2.78	9.5	11.8	20.4*	18.4*	14.9	14.4
76kg, 30 m	3.11	10.9	13.7	22.7*	20.6*	16.6	16.1
40 kg, 20 m	3.66	13.2	17.4	26.7*	24.2*	19.6	19.0

* non convergence – inferred acceleration to failure

8.5 Discussion

Our analyses demonstrate the magnitude of projected displacement within Camelot Cave as a response to excavation of the South-Western Pit and under various blasting vibration loadings.

Based on the stability/deformation analyses, the calculated maximum displacement post-excavation is approximately 26.4 mm and 20.8 mm along the pit floor and cave system, respectively. However, this does not appear to be the limiting case when considered in the context of the blast vibration analyses.

Under our blasting-induced PPA scenarios, a PPA of 2.4 g [equivalent to a blasting scenario of 40 kg explosive weight with an offset distance of 25 m] induces a maximum displacement within the cave walls of 12-18 mm. While short duration, noticeable vibrations in the cave walls can be expected, the effect on cave stability is expected to be limited to drop outs of small scale, in localised areas of already marginally stable, closely jointed limestone. The overall integrity of the cave walls and roof is not expected to be compromised.

Under PPA loads of 2.78 g or higher, non-convergence in our plastic analysis was observed. Instances where non-convergence was observed suggest that the model is not in equilibrium, which is attributed to failure in portions of the model. We note that non-convergence observed in horizontal loading and oblique loading scenarios are often associated with separation of bedding at the ground surface and localized joint failure, respectively as opposed to failure around the cave itself

Under vertical loading scenarios, PPA values of 2.78 g – 3.66 g returned non-convergence results consistent with delamination of bedding and localised slip of the near vertical joints. These scenarios identify a high risk of at least partial collapse of the cave roof.

9 Recommendations, Effects and Risk Mitigation

9.1 Excavation offset limit

Our preliminary analysis has considered the cave performance under various equivalent seismic loads from blasting. Based on our assessment, we have assessed a critical seismic load threshold of 2.4 g which returns displacements at the cave of 12-18 mm.

We therefore recommend reducing charge weights as excavation approaches the cave system as set out in Table 9-1.

Table 9-1 Proposed weight explosive offset limit.

Weight Explosives [kg]	Offset Limit [m]	Equivalent PGA [g]
40 kg	25 – 35 m	2.38 g
76 kg	35 – 45 m	2.31 g
120 kg	45 m +	2.21 g

To better manage the offset limit, continual near field monitoring may further assess the PPA from various weight explosives to better assess the offset limit.

9.2 Assessment of effects

It is our opinion that the effect of blasting vibrations at the limiting threshold of 2.4 g could be considered less than minor. While we recognise there are no published criteria to compare against, we considered this level of effect as being consistent with what might be considered a less than minor effect in a ground settlement effects assessment. This threshold in a settlement effects context [for potential damage to dwellings or infrastructure] is often considered to be in the range 10-20 mm.

This level of displacement is localised at the cave edges and is expected to largely be taken up by block juggling and slip along joint surfaces. The level of displacement calculated is expected to be protective of the overall cave integrity.

9.3 Risk mitigation measures and conditions of consent

The risk of physical effects on Camelot Cave is expected to be negligible in the early stages of excavation outside the defined buffer zone but progressively increases over the life of the quarry as the excavation progresses to the south.

It is our opinion that the proposed **Camelot Cave Buffer Zone** of 200 m will provide adequate physical protection to Camelot Cave during the early excavation stages and provide sufficient time to verify the cave extents, geometry and roof conditions. We are confident that continued advances in surveying and remote sensing technology over the life of the quarry will further enhance the ability to accurately map and verify cave geometry. Once the physical position of Camelot Cave has been confirmed, we consider that a staged approach to excavation could be adopted, provided that the effective seismic loading does not exceed 2.4 g.

Once the position of the cave has been confirmed, a **Blast Vibration Restriction Zone** (BVRZ) between 100 m and 25 m of the nearest cave wall, floor or roof, should be put in place. Blasting activities within this zone would need to demonstrate [by blast design and blast monitoring] that a PPA less than or equal to 2.4g will be experienced at the cave. We consider that implementation of a BVRZ would appropriately manage the risk of the cave experiencing blast vibration effects above the defined threshold; the initial data we have been provided by Red Bull indicates that this outcome is achievable.

It may be possible to eventually undertake blasting activities closer than 25 m, by adopting reduced charge weights and delays, and refining our finite element models to assess the specific geometry of the pit in relation to the cave. However, there is currently no specific data and analyses that would support this approach. Until that information is available, we recommend a **No Blast Zone** be implemented within 25 m of the nearest cave wall, floor or roof.

We consider that these recommendations could be readily incorporated into conditions of consent. Additionally, proposed controls on the Maximum Instantaneous Charge (MIC) and delays to limit PPA to below the threshold for protection of the cave system and provision for vibration monitoring at the

cave could be incorporated into a blasting and vibration management plan to address any remaining residual uncertainty.

10 Summary and Conclusions

We have completed our assessment of the potential interaction between the proposed South-Western Pit extension at Graymont's Oparure Quarry and the Camelot Cave system which traverses the proposed pit footprint.

Based on the available information there still is uncertainty around the actual extent and geometry of Camelot Cave. In the early stages of quarrying, however, there is a negligible risk to Camelot Cave. In the future, there is likely to be limited cover between the final pit floor [53 year] and the crown of the cave system as it is currently understood.

Graymont propose a 200 m wide buffer zone [**Camelot Cave Buffer Zone**] around the projected extension of Camelot Cave beneath the South-Western Pit. This buffer zone would exclude excavation and/or overburden placement in the early stages of pit development and allow for further investigation of the cave location and refinement of the design.

We have considered the proposed buffer zone and the potential for damage to the cave system from quarrying activities occurring outside the buffer zone. It is our opinion that the likelihood of damage either due to excavation encountering the cave itself or due to blasting is very low and therefore the risk of damage to the cave is also considered to be low with the Camelot Cave Buffer Zone in place. It is our opinion that this buffer zone is appropriate.

Once the physical location of the cave has been confirmed, our analytical work demonstrates that damage to the cave is not anticipated below a threshold Peak Particle Acceleration of 2.4 g.

We consider that a **Blast Vibration Restriction Zone** between 100 m and 25 m from the nearest cave edge [as set out in Section 9.3] along with a Blast Vibration Management Plan would appropriately manage the risk of damage to the cave.

We recommend a **No Blast Zone** within 25 m of the cave edge based on the current blast vibration data available.

Overall, based on the analytical work undertaken to date, we consider that the potential for effects on Camelot Cave can be considered less than minor, providing the recommendations set out above are adopted along with appropriate consent conditions.

11 Applicability

This report has been prepared for the exclusive use of our client Graymont [NZ] Limited with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We trust that this report meets your present requirements. If you have any queries or wish to discuss any aspect, please contact the undersigned.

For and on behalf of Baseline Geotechnical Limited:

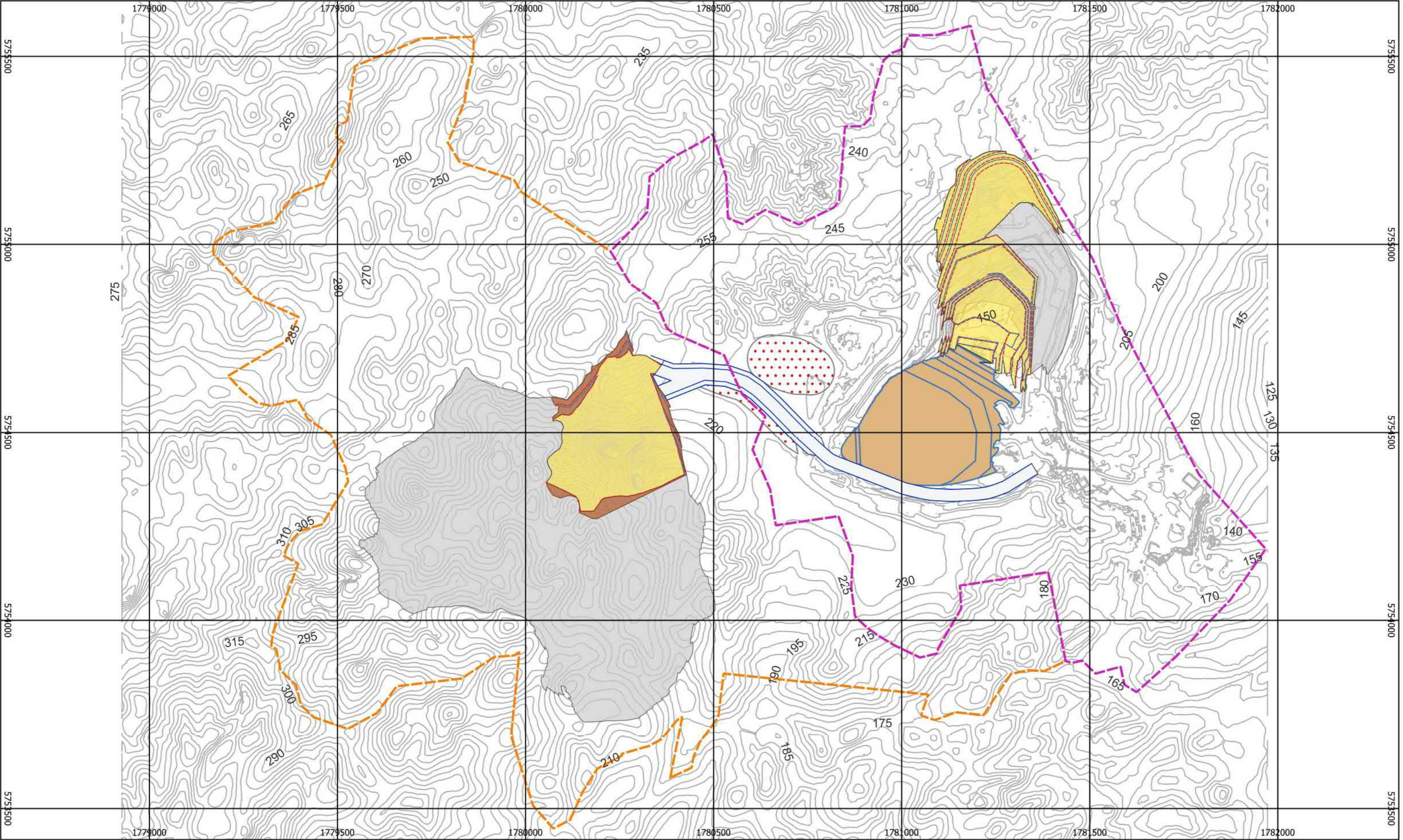

.....

Charles Li
Engineering Geologist


.....

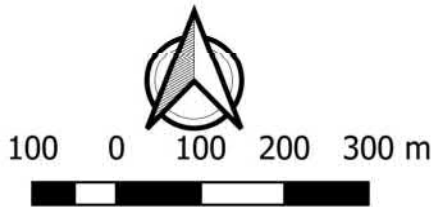
Cameron Lines
Principal Engineering Geologist

Appendix A – Staged Development Plans



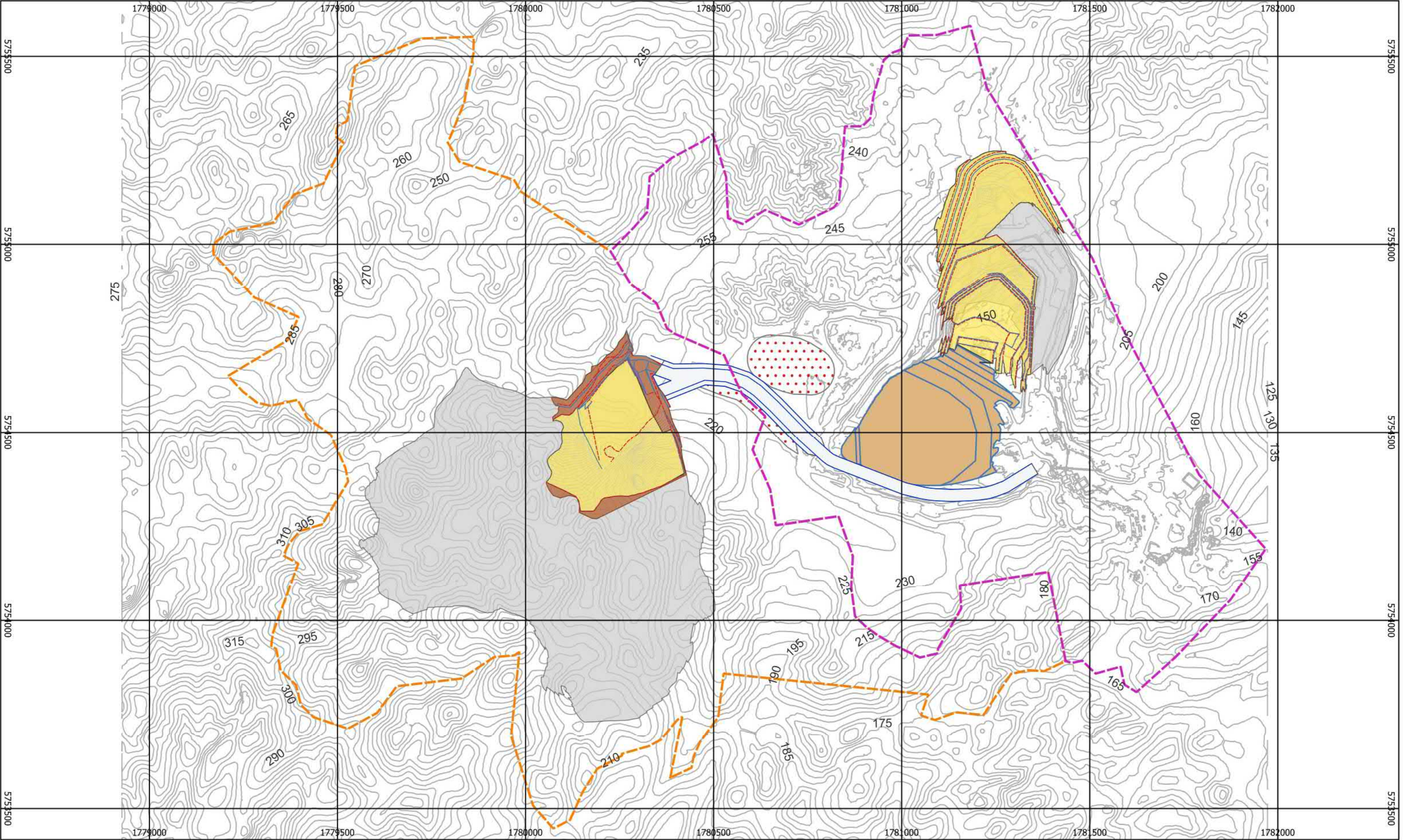
LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
- - - Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
— Permit Boundary MP 60802	Pit Area	Crest
— Permit Boundary MP 41694	Haul Road	Toe



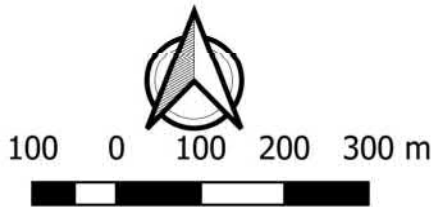
PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR00

NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
SCALE: 1:9000
DRAWN BY: KL CHAN



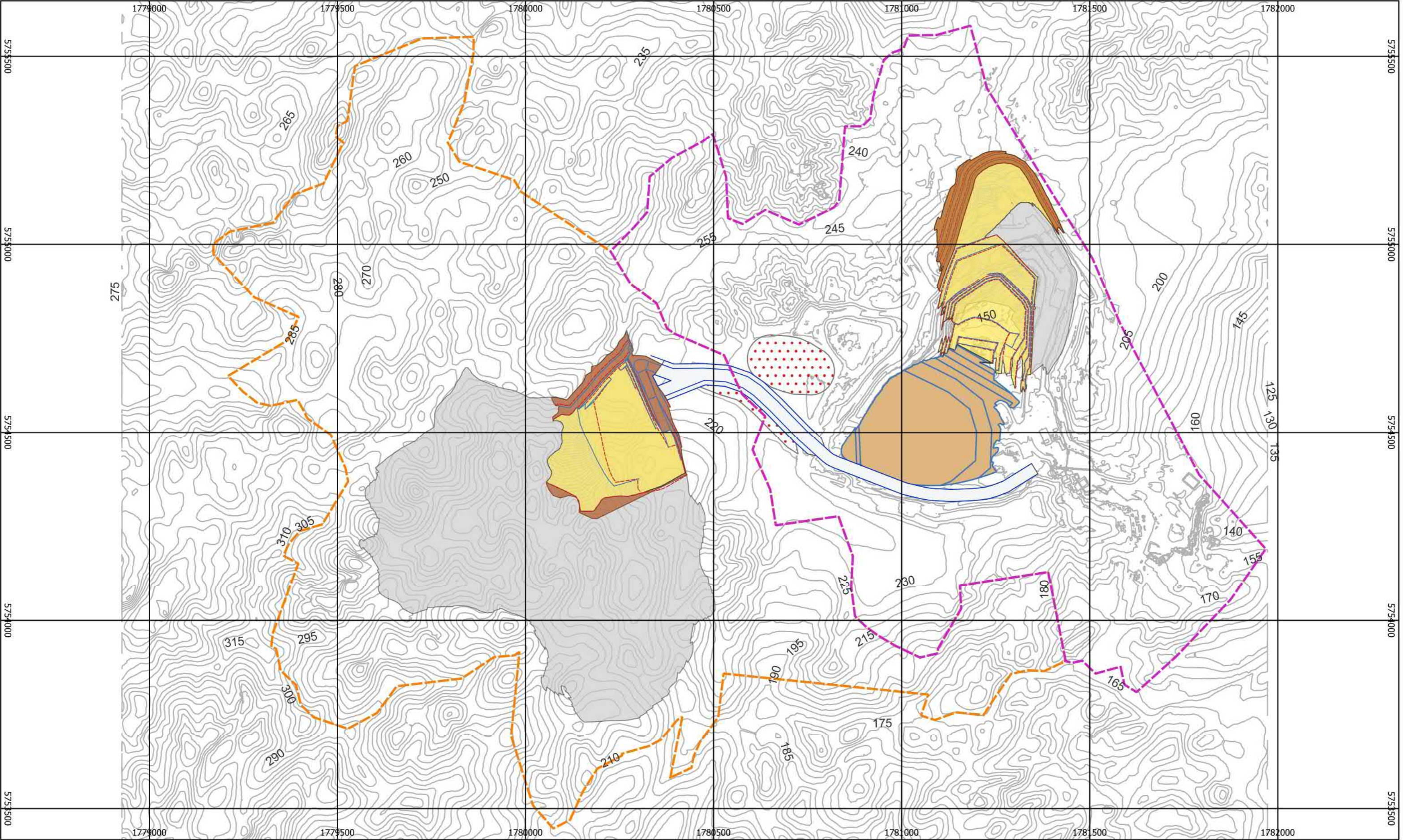
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— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
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Permit Boundary MP 41694	Haul Road	Toe



PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR01

NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
SCALE: 1:9000
DRAWN BY: KL CHAN



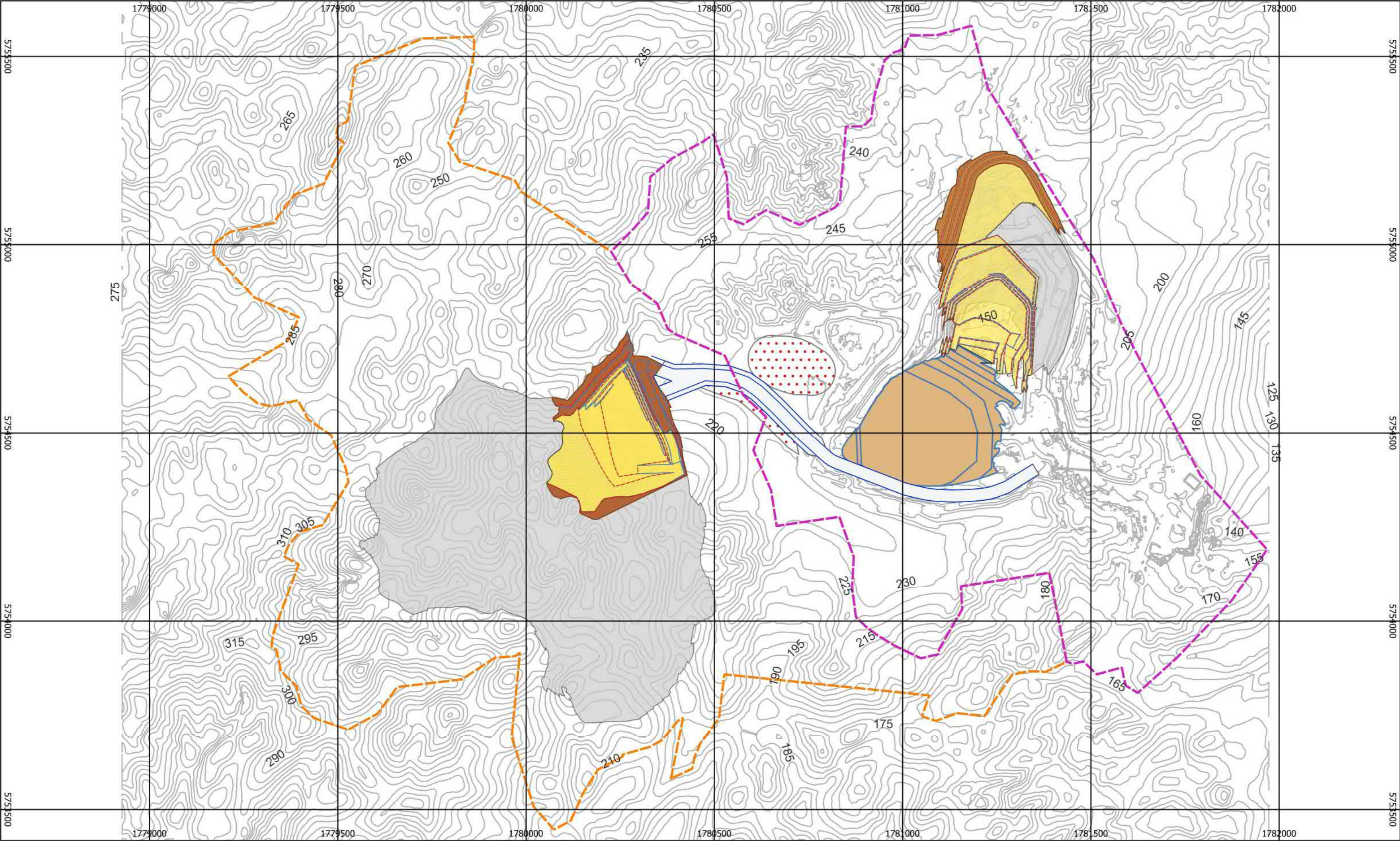
LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
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— Permit Boundary MP 41694	Haul Road	Toe

PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR02

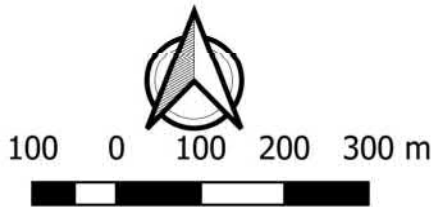
NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
SCALE: 1:9000
DRAWN BY: KL CHAN





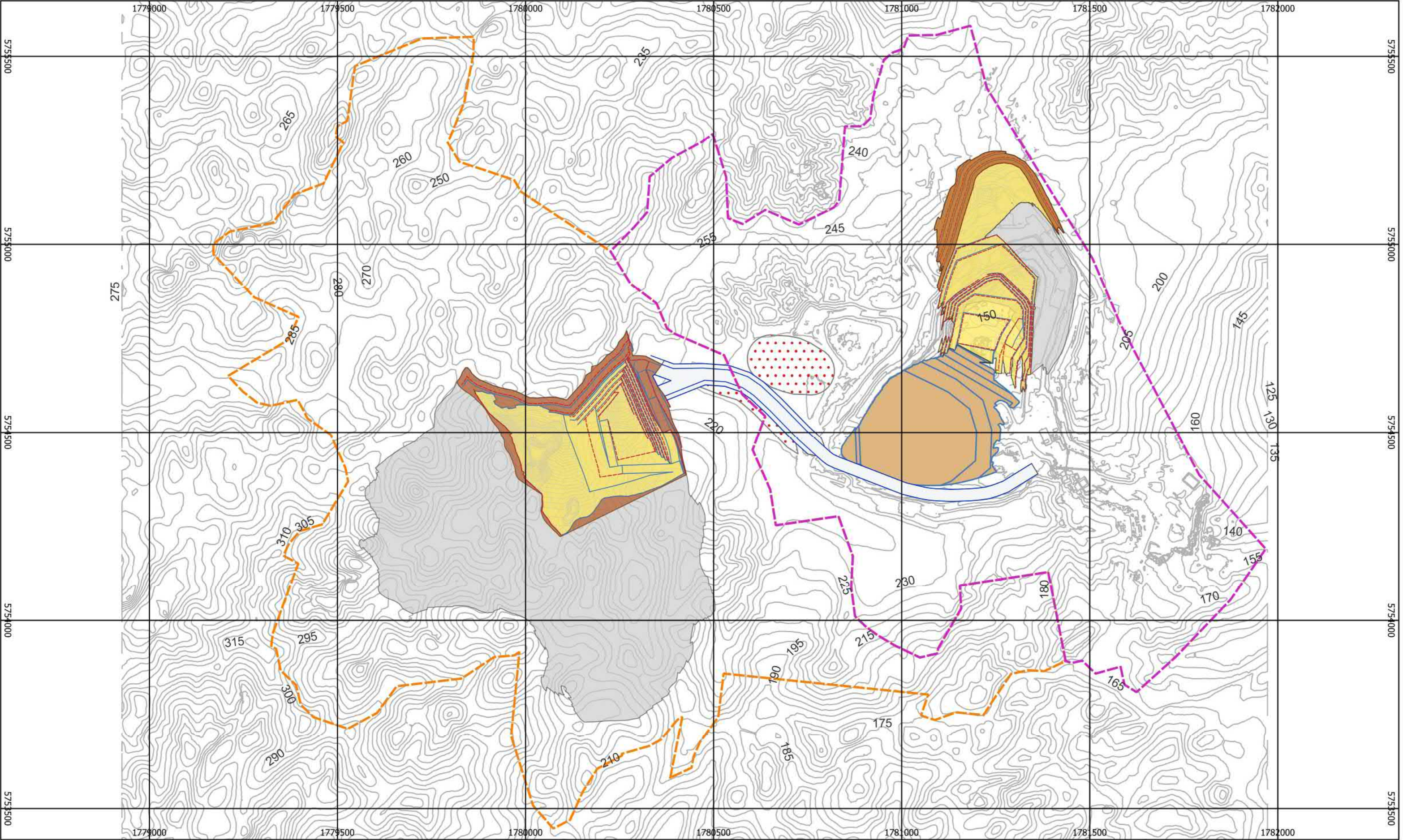
LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
- - - Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
— Permit Boundary MP 60802	Pit Area	Crest
— Permit Boundary MP 41694	Haul Road	Toe



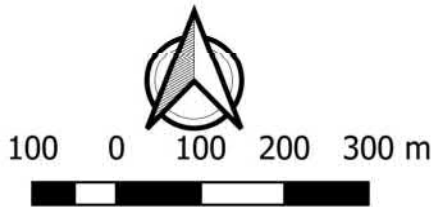
PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR03

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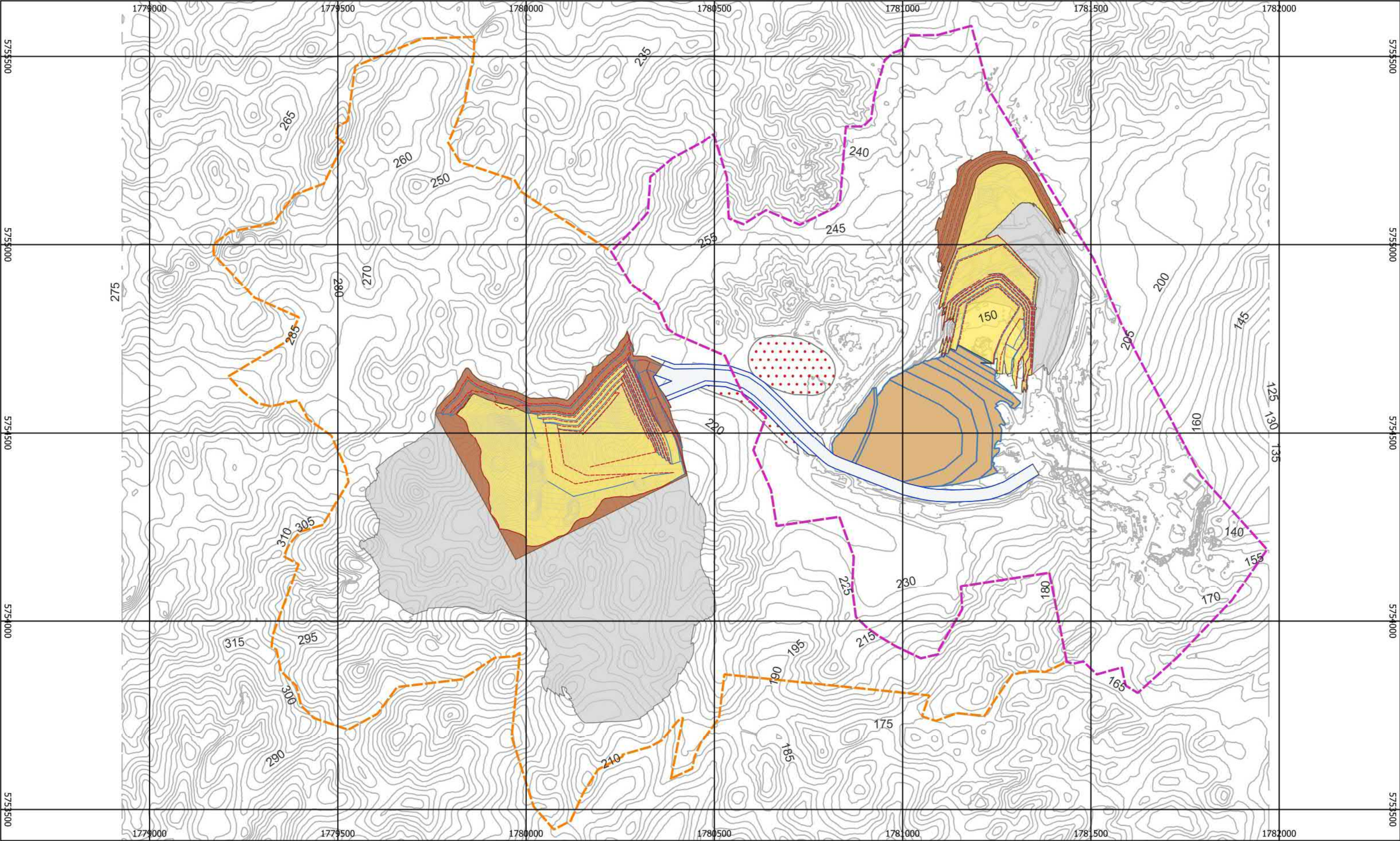


LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
— Permit Boundary MP 60802	Pit Area	Crest
— Permit Boundary MP 41694	Haul Road	Toe

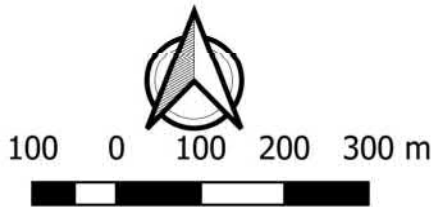


PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR05
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DRAWN BY: KL CHAN

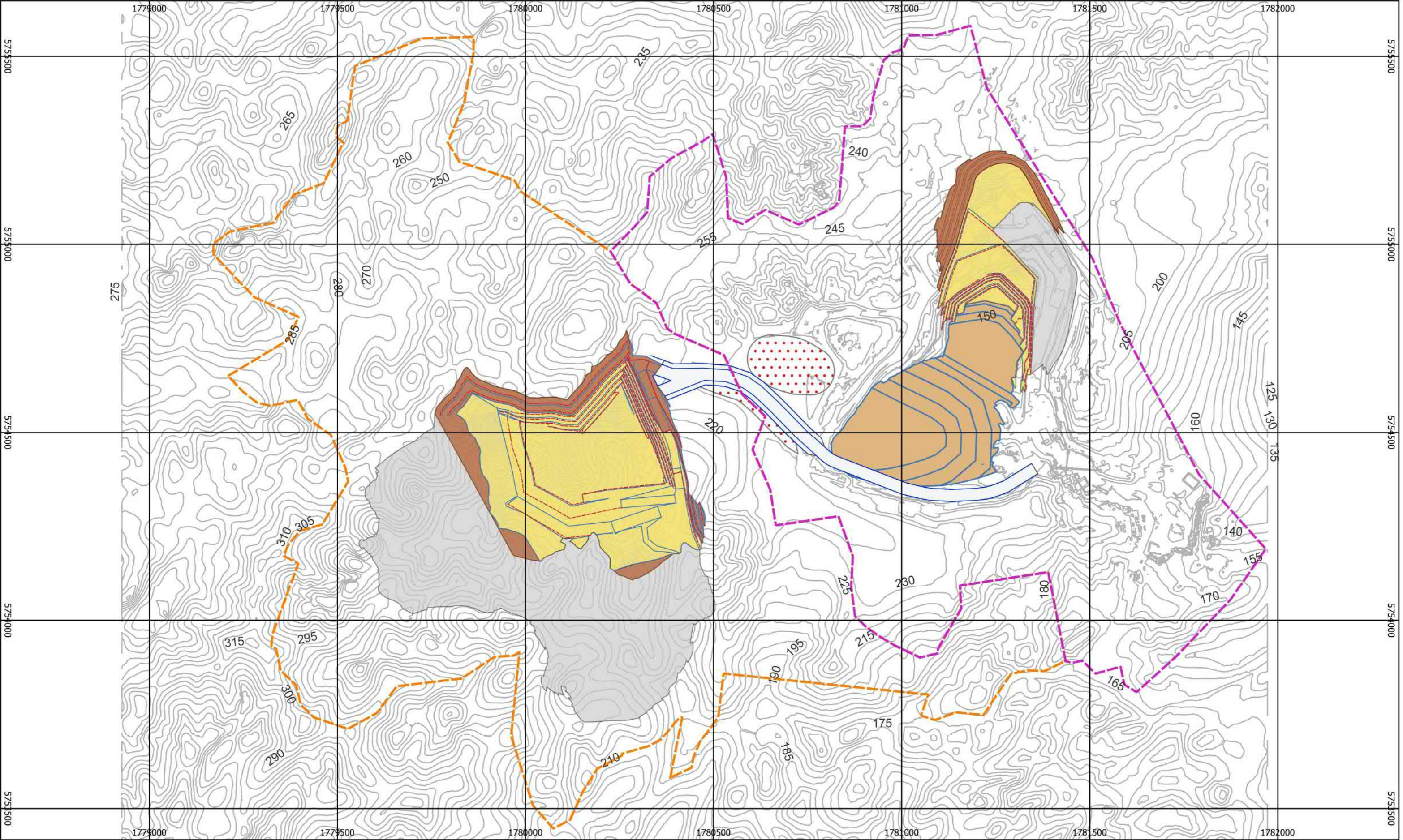


LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
Permit Boundary MP 60802	Pit Area	Crest
Permit Boundary MP 41694	Haul Road	Toe

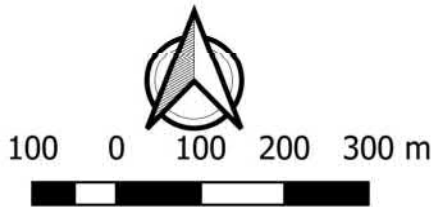


PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
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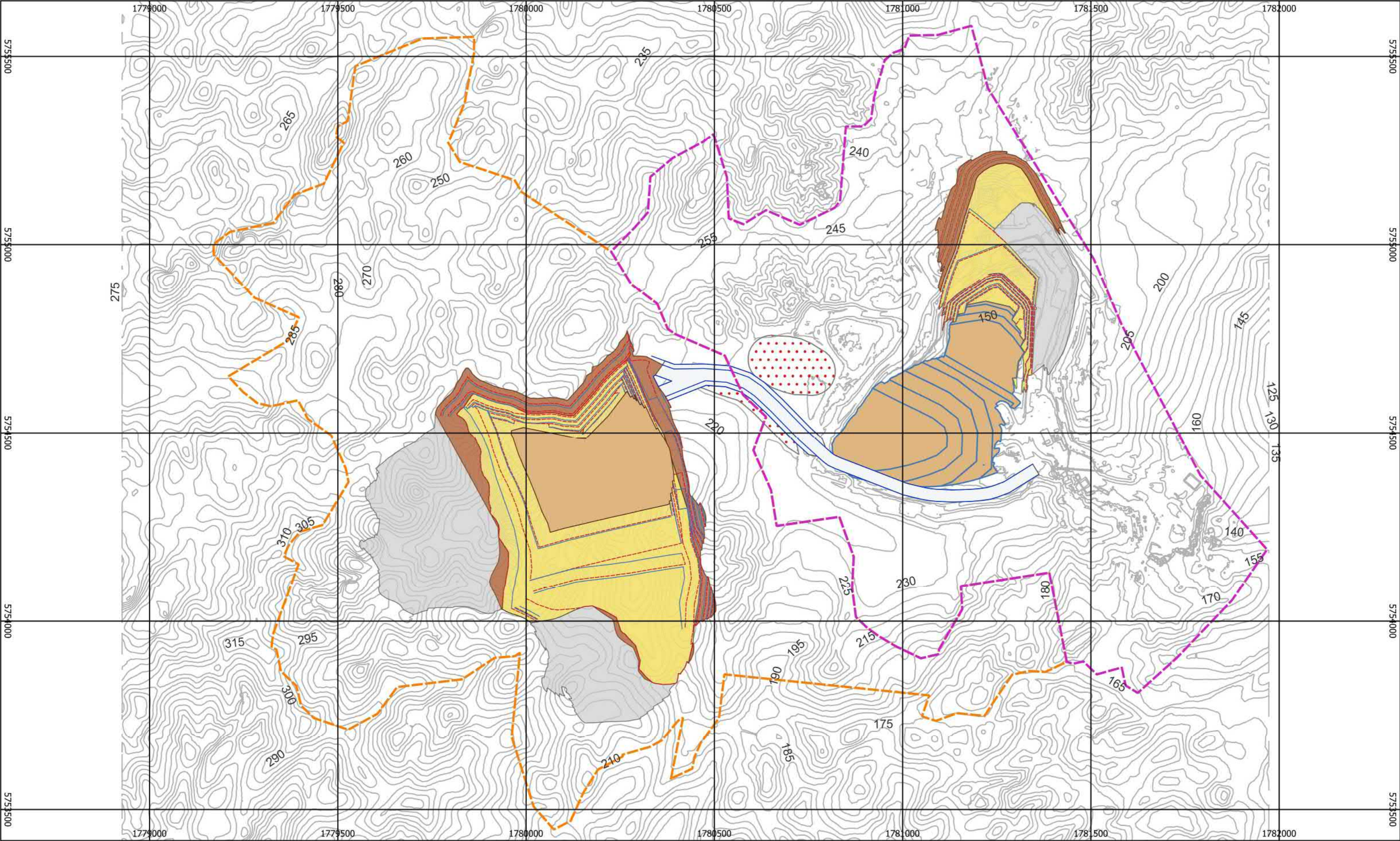


LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
Permit Boundary MP 60802	Pit Area	Crest
Permit Boundary MP 41694	Haul Road	Toe

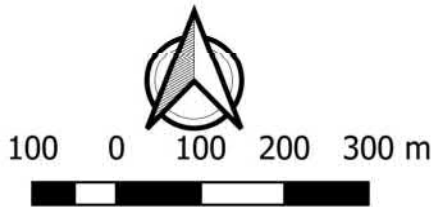


PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR13
NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
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DRAWN BY: KL CHAN

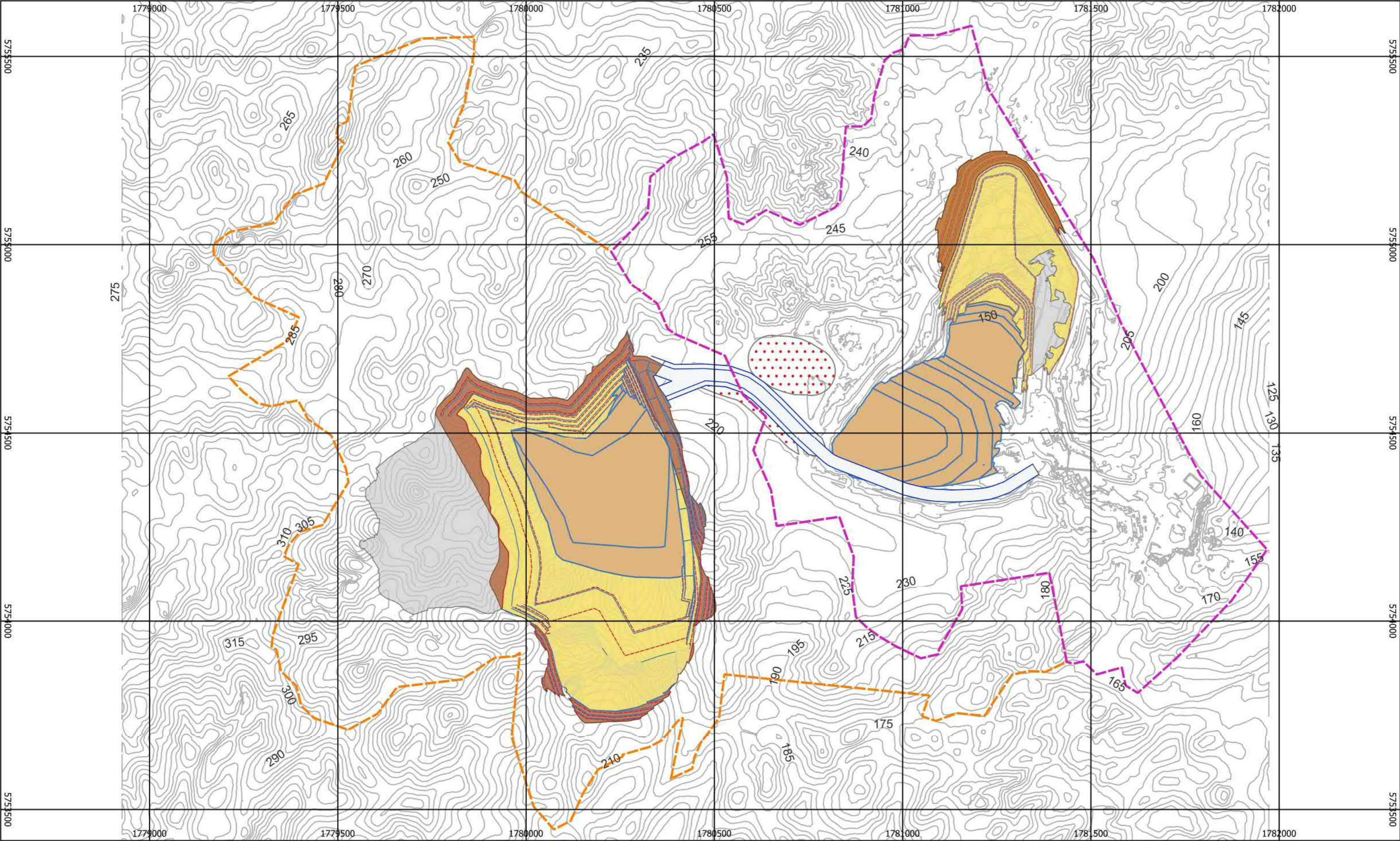


LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
— Permit Boundary MP 60802	Pit Area	Crest
— Permit Boundary MP 41694	Haul Road	Toe

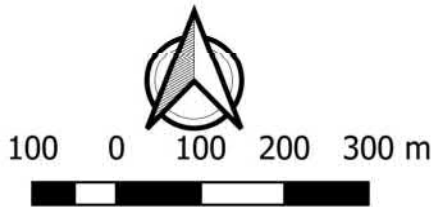


PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR23
NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
SCALE: 1:9000
DRAWN BY: KL CHAN

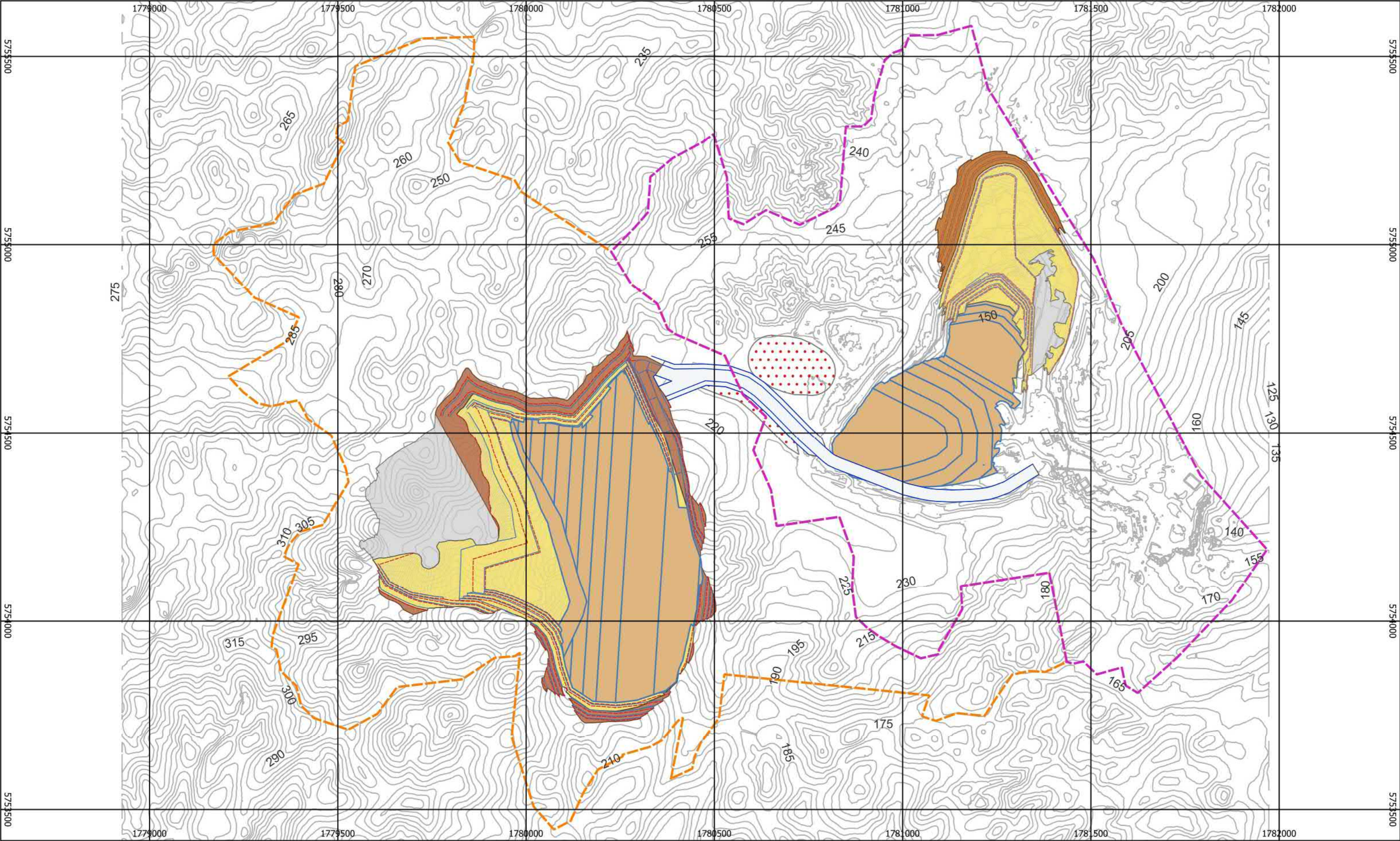


LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
Permit Boundary MP 60802	Pit Area	Crest
Permit Boundary MP 41694	Haul Road	Toe

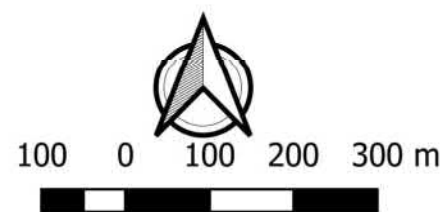


PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR33
NZGD 2000 NEW ZEALAND TRANSVERSE MERCATOR
SCALE: 1:9000
DRAWN BY: KL CHAN



LEGEND

— Contours Major 5m	Active Overburden Stripping	Soil Stockpile
— Contours Minor 1m	Active Quarry Bench	Overburden Backfill Area
Permit Boundary MP 60802	Pit Area	Crest
Permit Boundary MP 41694	Haul Road	Toe



PROJECT: OPARURE SOUTH WEST PIT STAGE PLANS
TITLE: END OF YEAR43
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SCALE: 1:9000
DRAWN BY: KL CHAN

Appendix B – Figures



Legend

Camelot Cave

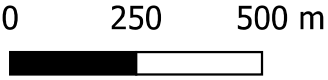
Assumed extension of Camelot Cave

Year 53 pit design outline

Camelot Cave buffer zone

Key Features

River line (LINZ)



1. Pit shell designs provided to BGL by Graymont [NZ] Limited on 30/03/2026.
2.Aerial imagery provided to BGL by Graymont [NZ] Limited on 19/03/2026, titled "Orthoimage_ALL_OSM". Surrounding aerial imagery sourced from LINZ, titled "Waikato 0.3m Rural Aerial Photos [2023-2024]"
3. Camelot Cave location sourced from Crossley P.C., 2014 New Zealand Cave Atlas North Island, Speleological Society Inc, Digital Library.

Drawn	ASW	16/06/2026
Checked	CJL	16/06/2026
Project No. BGL000266		
Scale: 1:15000 Original Size: A3		



BASLINE

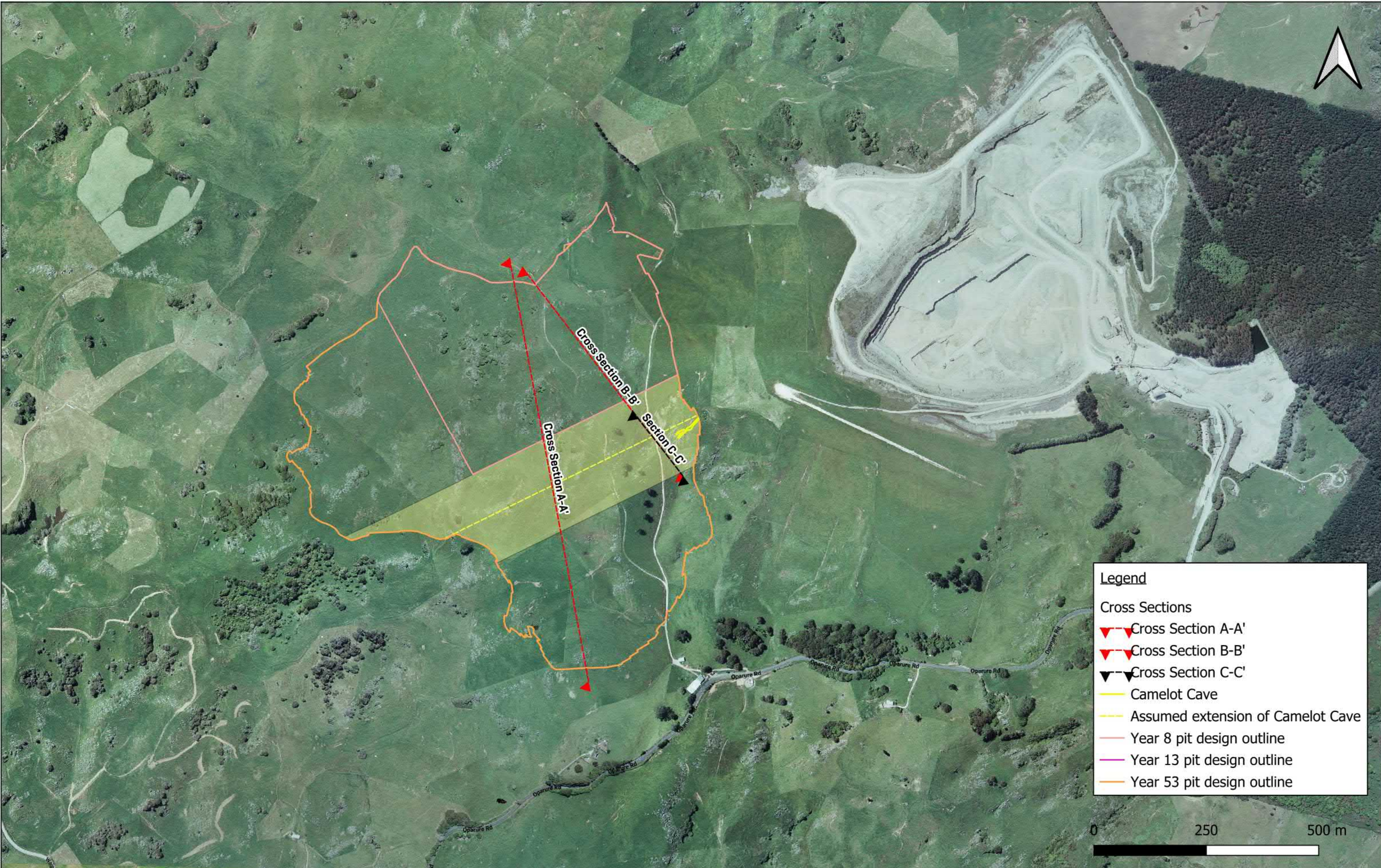
GEOTECHNICAL

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GRAYMONT

Proposed Southwestern Pit and Surrounds
Proposed Southwestern Pit - Oparure Quarry
Graymont (NZ) Ltd





1. Aerial imagery provided to BGL by Graymont [NZ] Limited on 30/04/2026

2. Contour information was provided to BGL by Graymont [NZ] Limited on 30/04/2026. Elevation information is referenced in NZGD2000 Ellipsoidal height.

Drawn	CLi	04/06/2026
Checked	CJL	04/06/2026
Project No. BGL000266		
Scale: 1:1500 Original Size: A3		



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GRAYMONT

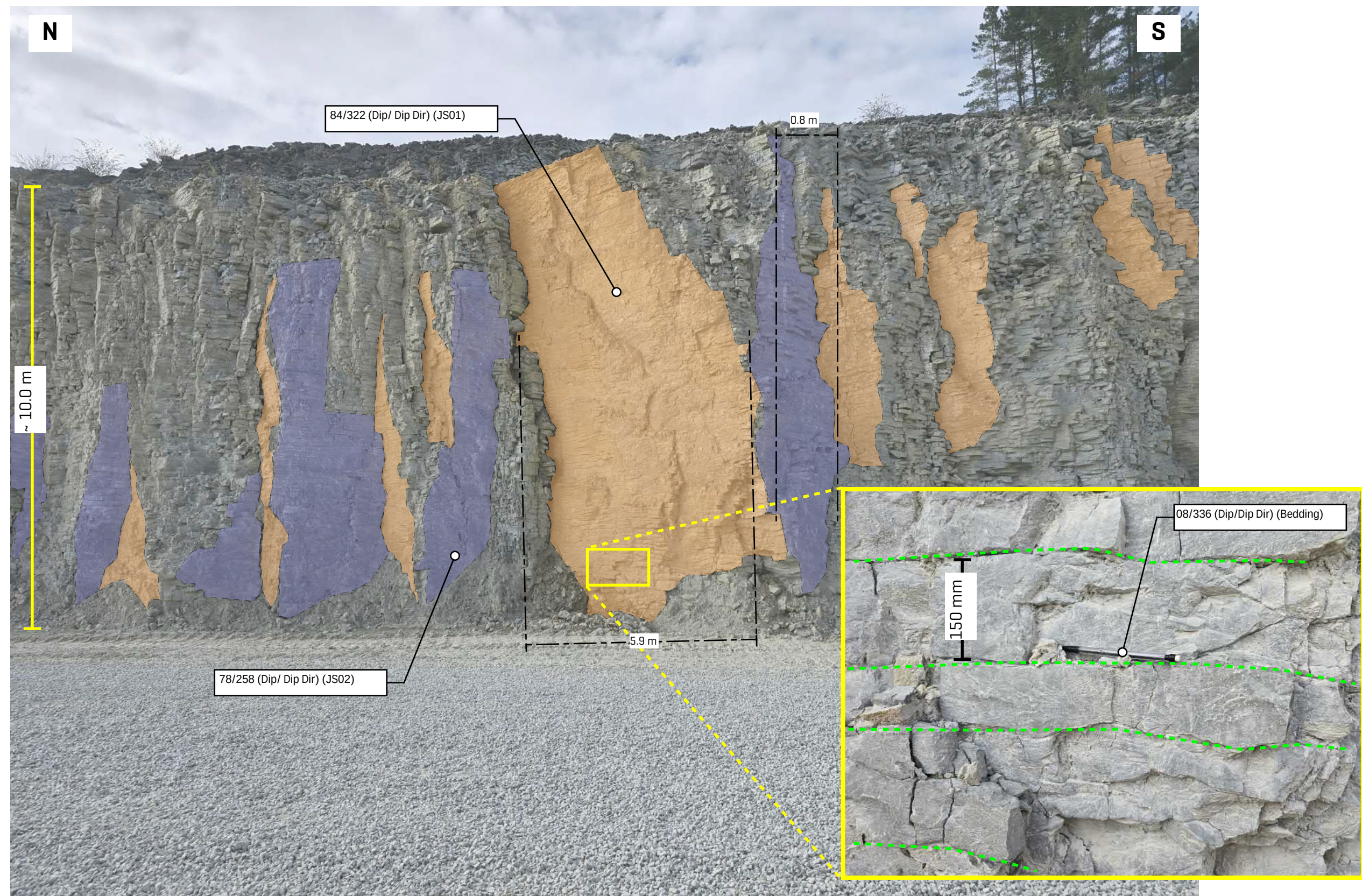
Site plan

BGL Site visit (29 April 2026) - Oparure Quarry

Graymont [NZ] Ltd

Figure Number: Appendix B - Figure 003

Rev 1.0



1. Site photo was captured on 29 April 2026 along RL 180 m.
2. Elevation data was provided by Graymont NZ Limited, projected in NZGD2000 Ellipsoidal Height.
3. Structural measurements were taken by BGL personnel.



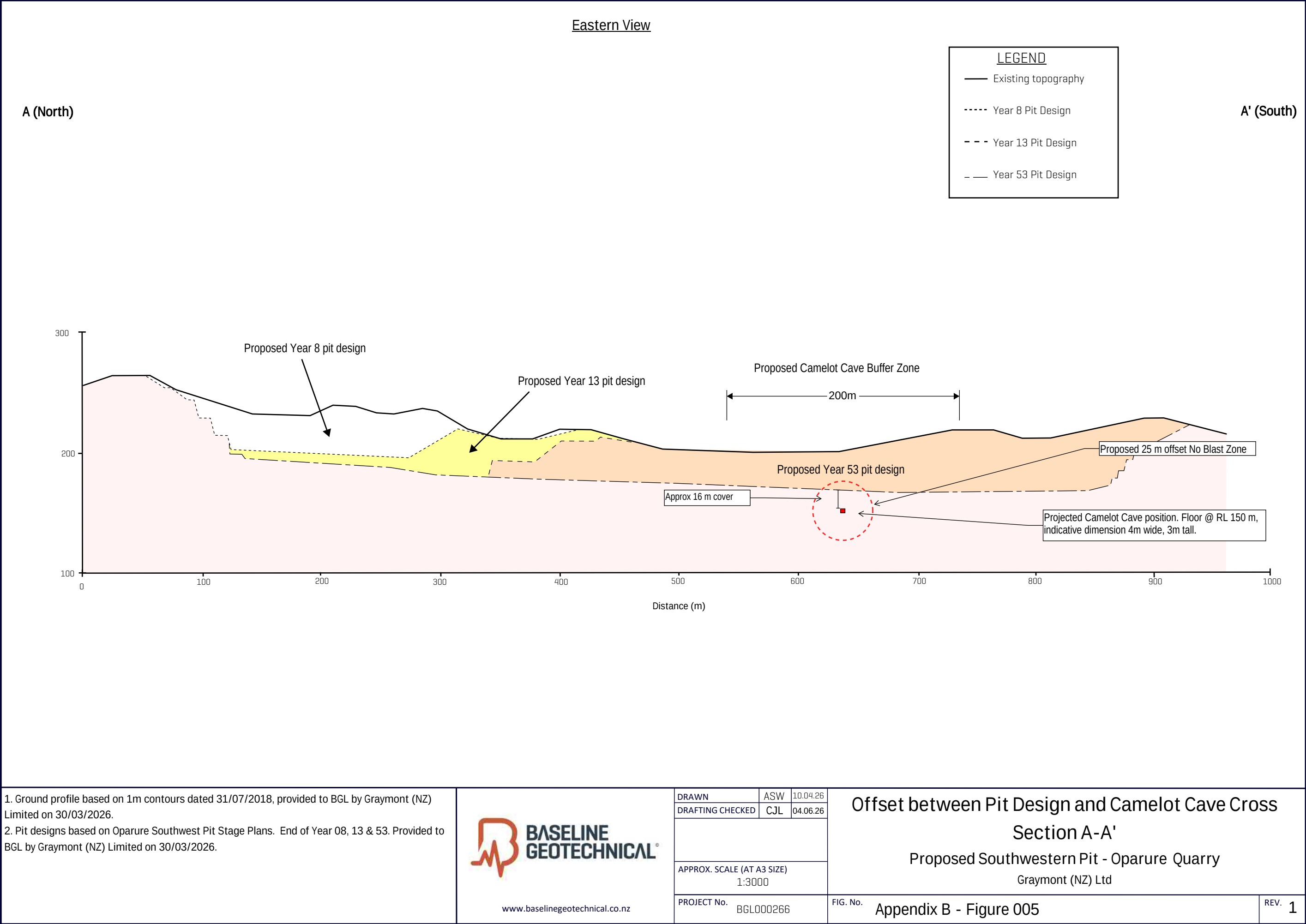
www.baselinegeotechnical.co.nz

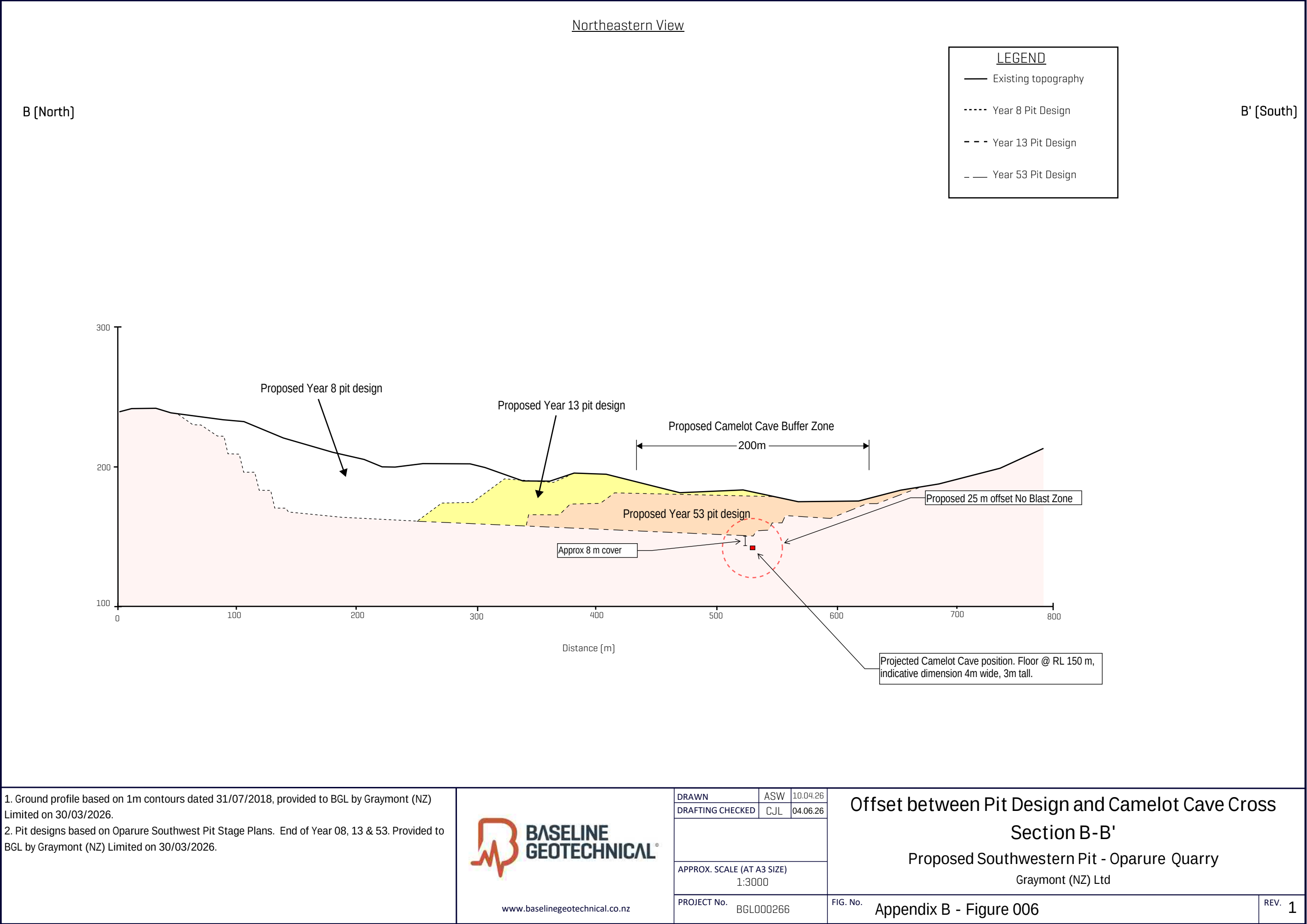
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DRAFTING CHECKED	CJL	04.06.26
APPROX. SCALE (AT A3 SIZE) NTS		
PROJECT No.	BGL000266	

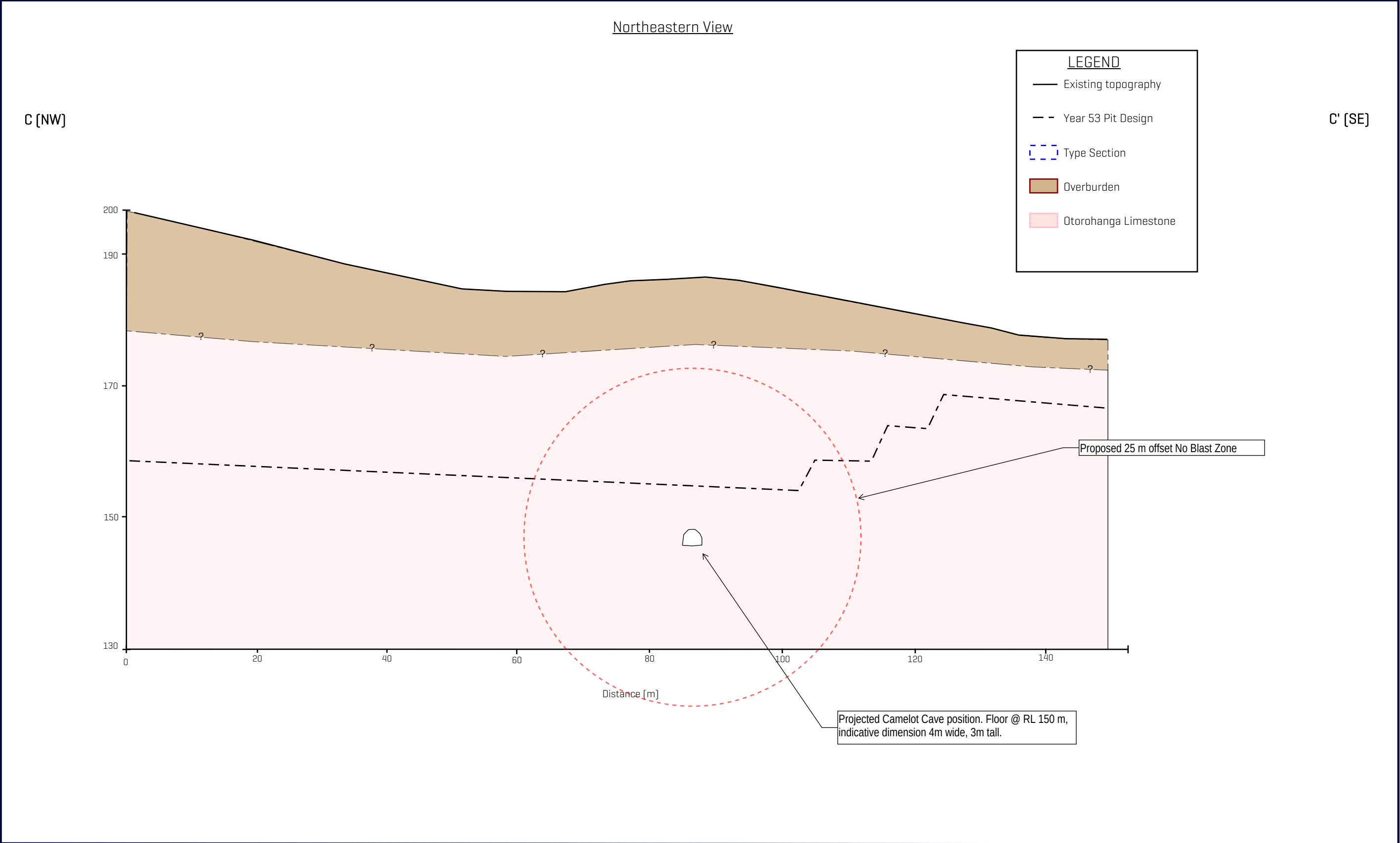
Basis for ground conditions at the proposed
Southwestern Pit
Oparure Quarry - RL 180 m, E (Zone E)
Graymont (NZ) Limited

FIG. No. Appendix B - Figure 004

REV 1







1. Ground profile based on 1m contours dated 31/07/2018, provided to BGL by Graymont [NZ] Limited on 30/03/2026. 2. Pit designs based on Oparure Southwest Pit Stage Plans. End of Year 08, 13 & 53. Provided to BGL by Graymont [NZ] Limited on 30/03/2026. 3. Depth of overburden soil was inferred based on existing historical boreholes, supplied from Graymont NZ Limited.	 www.baselinegeotechnical.co.nz	DRAWN CLi 10.05.26	Conceptual Ground Model Cross Section C-C' Proposed Southwestern Pit - Oparure Quarry Graymont (NZ) Ltd			FIG. No. Appendix B - Figure 007	REV. 0					
		DRAFTING CHECKED CJL 04.06.26										
		APPROX. SCALE (AT A3 SIZE) 1:550										
		PROJECT No. BGL000266										

Appendix C - Material Parameters

Analysis of Rock Strength using RocLab - Otorohanga Limestone (D=0)

Hoek-Brown Classification

intact uniaxial comp. strength (σ_{ci}) = 20 MPa
 GSI = 99 m_i = 10 Disturbance factor (D) = 0
 intact modulus (E_i) = 18000 MPa
 modulus ratio (MR) = 900

Hoek-Brown Criterion

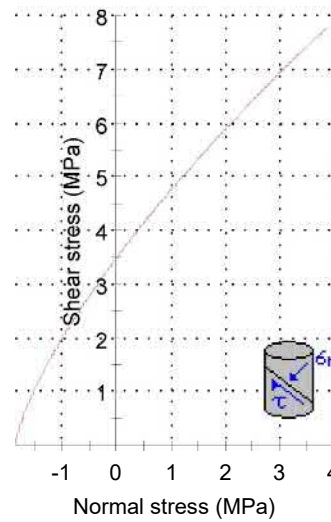
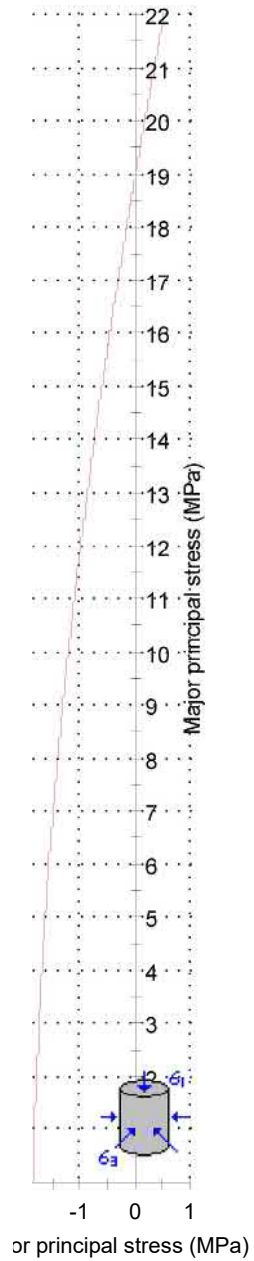
m_b = 9.649 s = 0.8948 a = 0.500

Mohr-Coulomb Fit

cohesion = 3.330 MPa friction angle = 51.46 deg

Rock Mass Parameters

tensile strength = -1.855 MPa
 uniaxial compressive strength = 18.919 MPa
 global strength = 17.572 MPa
 deformation modulus = 17855.17 MPa



Analysis of Rock Strength using RocLab - Otorohanga Limestone (D=1)

Hoek-Brown Classification

intact uniaxial comp. strength (σ_{ci}) = 20 MPa
 GSI = 89 m_i = 10 Disturbance factor (D) = 1
 intact modulus (E_i) = 18000 MPa
 modulus ratio (MR) = 900

Hoek-Brown Criterion

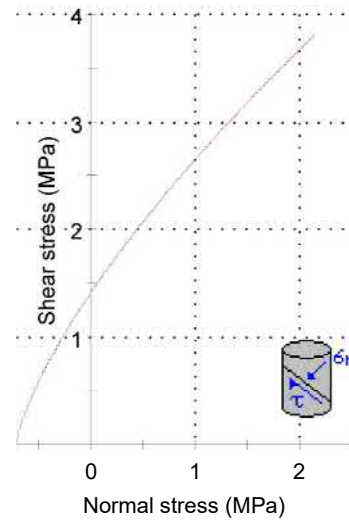
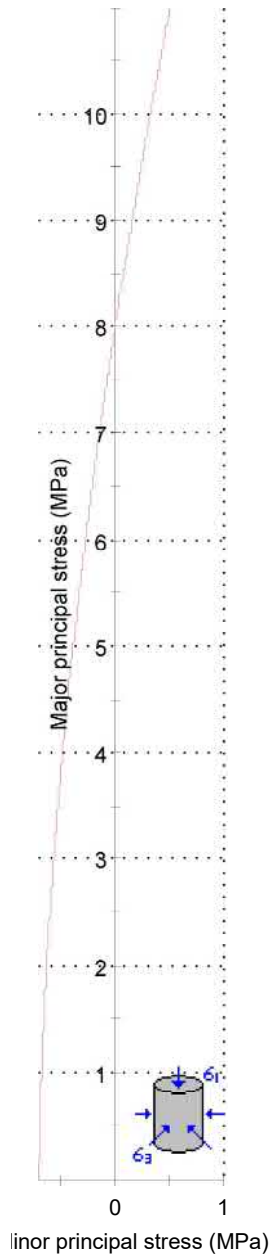
m_b = 4.558 s = 0.1599 a = 0.500

Mohr-Coulomb Fit

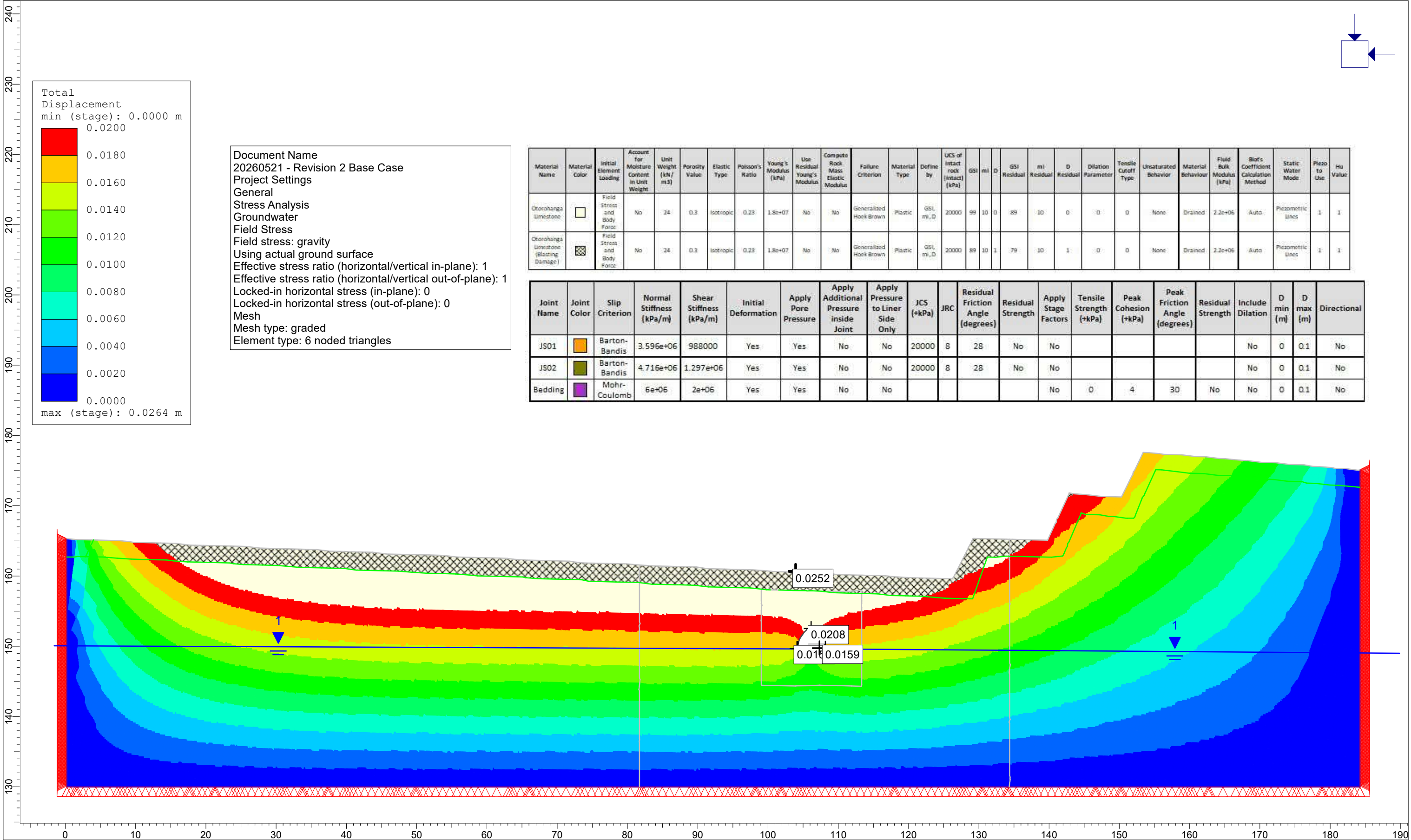
cohesion = 1.360 MPa friction angle = 50.95 deg

Rock Mass Parameters

tensile strength = -0.702 MPa
 uniaxial compressive strength = 7.994 MPa
 global strength = 8.320 MPa
 deformation modulus = 7390.88 MPa



Appendix D - RS2 Results



Total Displacement
min (stage): 0.0000 m
0.0200
0.0180
0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
max (stage): 0.0264 m

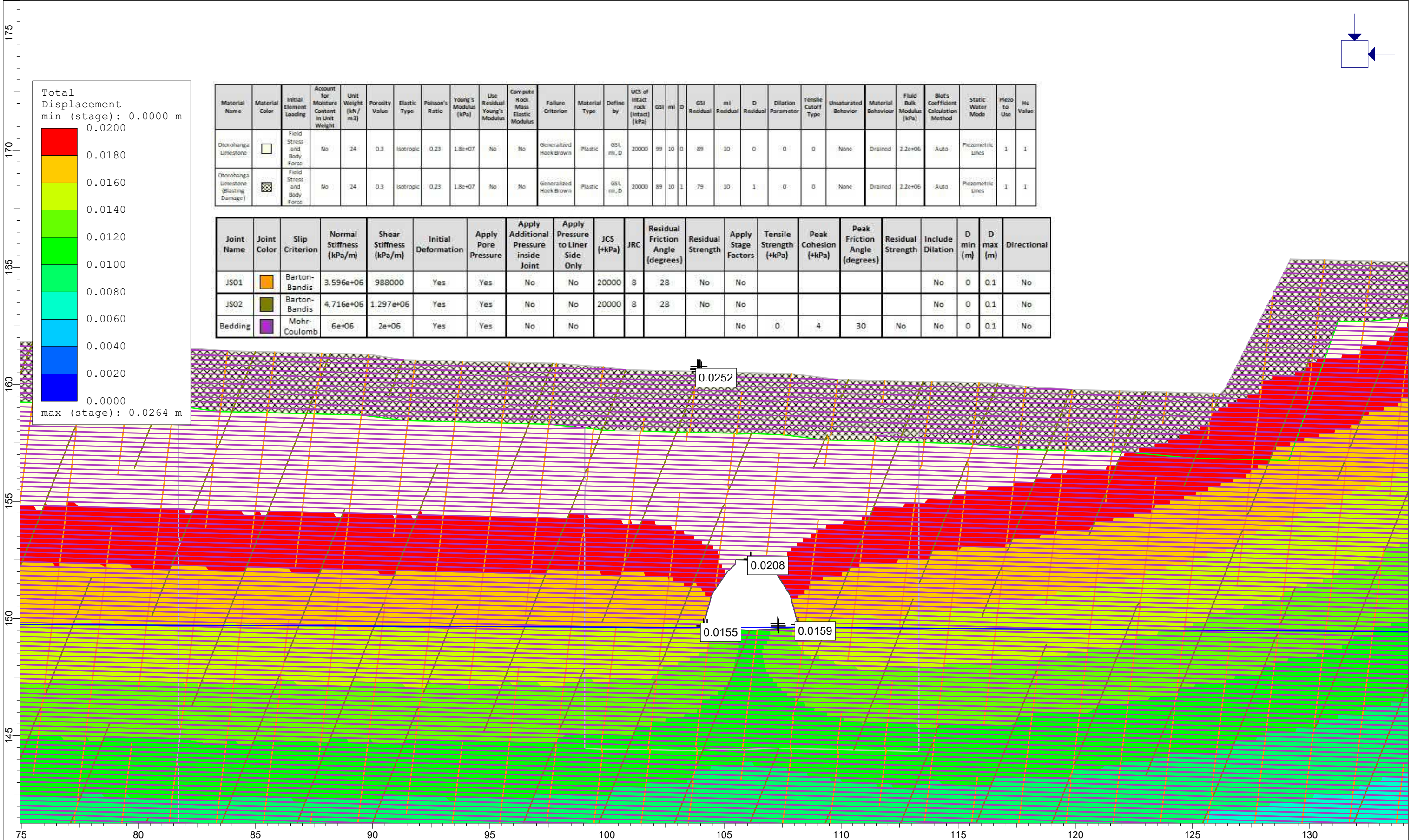
Document Name
20260521 - Revision 2 Base Case
Project Settings
General
Stress Analysis
Groundwater
Field Stress
Field stress: gravity
Using actual ground surface
Effective stress ratio (horizontal/vertical in-plane): 1
Effective stress ratio (horizontal/vertical out-of-plane): 1
Locked-in horizontal stress (in-plane): 0
Locked-in horizontal stress (out-of-plane): 0
Mesh
Mesh type: graded
Element type: 6 noded triangles

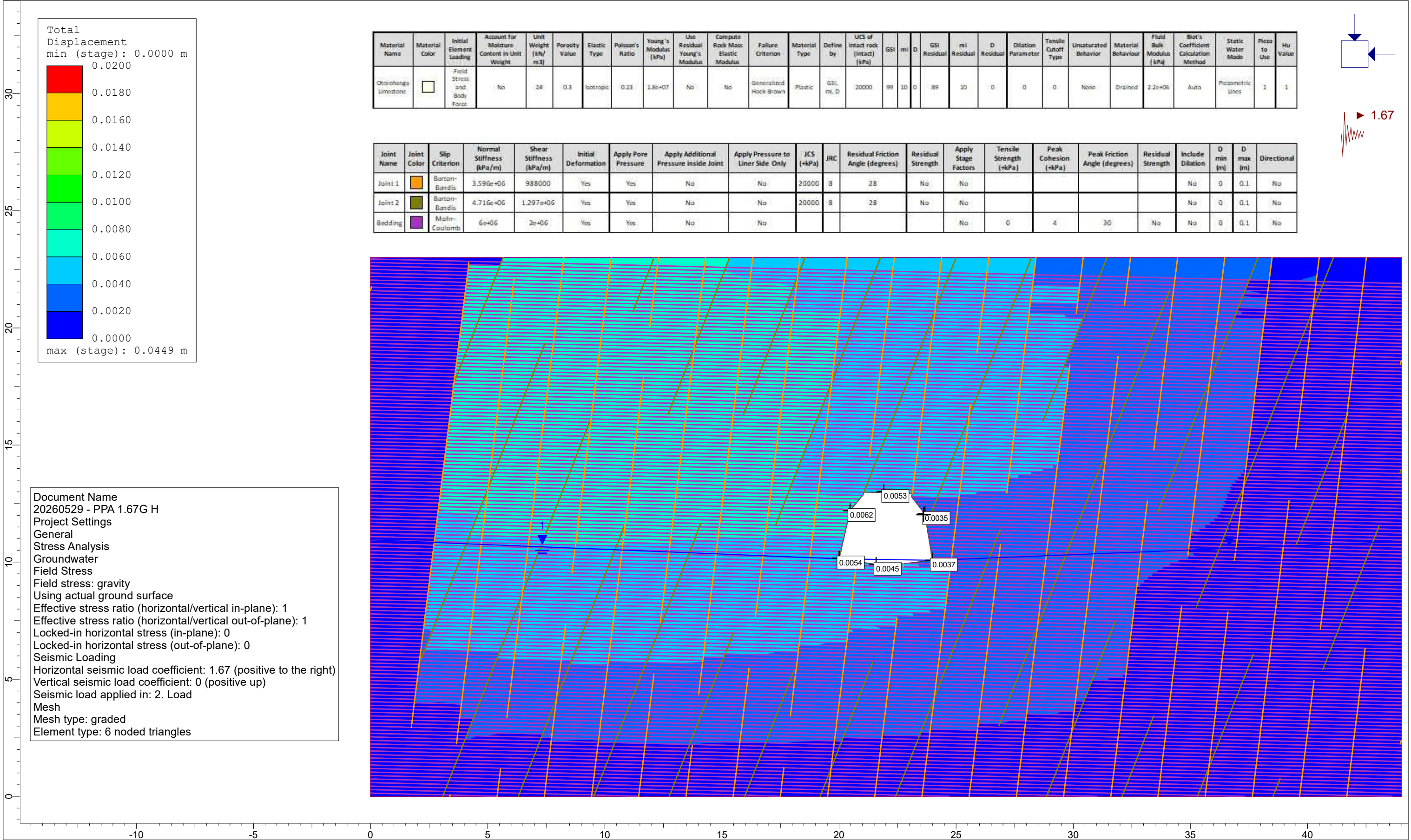
Material Name	Material Color	Initial Element Loading	Account for Moisture Content in Unit Weight	Unit Weight (kN/m3)	Porosity Value	Elastic Type	Poisson's Ratio	Young's Modulus (kPa)	Use Residual Young's Modulus	Compute Rock Mass Elastic Modulus	Failure Criterion	Material Type	Define by	UCS of Intact rock (kPa)	GSI m	D	GSI Residual	m	D	Dilation Parameter	Tensile Cutoff Type	Unsaturated Behavior	Material Behaviour	Fluid Bulk Modulus (kPa)	Blot's Coefficient Calculation Method	Static Water Mode	Piezometric Lines	Piezo to Use	Hu Value
Otorohanga Limestone		Field Stress and Body Force	No	24	0.3	Isotropic	0.23	1.8e+07	No	No	Generalized Hoek Brown	Plastic	GSL m, D	20000	99	10	0	89	10	0	0	0	None	Drained	2.2e+06	Auto	Piezometric Lines	1	1
Otorohanga Limestone (Blasting Damage)		Field Stress and Body Force	No	24	0.3	Isotropic	0.23	1.8e+07	No	No	Generalized Hoek Brown	Plastic	GSL m, D	20000	89	10	1	79	10	1	0	0	None	Drained	2.2e+06	Auto	Piezometric Lines	1	1

Joint Name	Joint Color	Slip Criterion	Normal Stiffness (kPa/m)	Shear Stiffness (kPa/m)	Initial Deformation	Apply Pore Pressure	Apply Additional Pressure inside Joint	Apply Pressure to Liner Side Only	JCS (+kPa)	JRC	Residual Friction Angle (degrees)	Residual Strength	Apply Stage Factors	Tensile Strength (+kPa)	Peak Cohesion (+kPa)	Peak Friction Angle (degrees)	Residual Strength	Include Dilation	D min (m)	D max (m)	Directional
JS01		Barton-Bandis	3.596e+06	988000	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
JS02		Barton-Bandis	4.716e+06	1.297e+06	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Bedding		Mohr-Coulomb	6e+06	2e+06	Yes	Yes	No	No					No	0	4	30	No	No	0	0.1	No

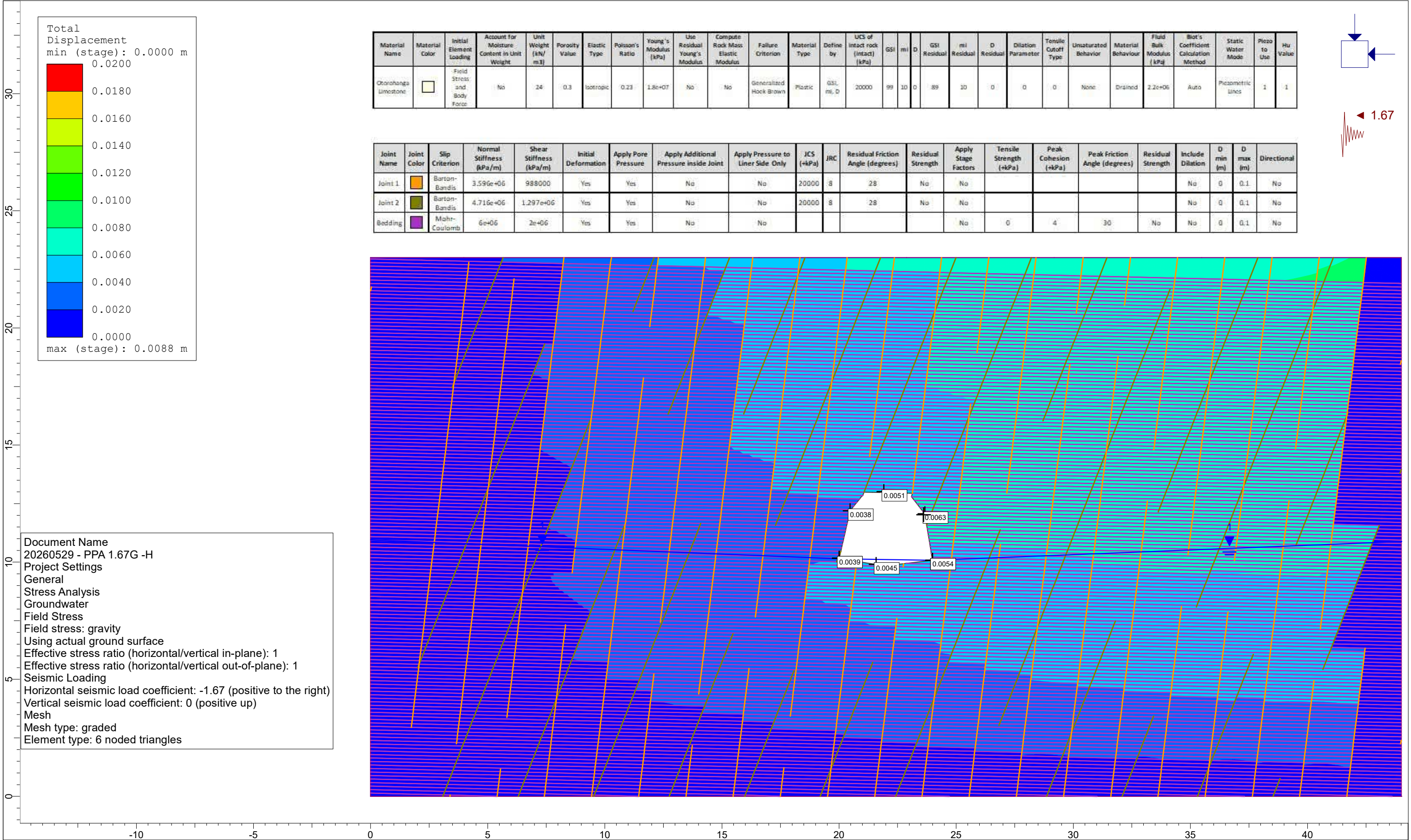


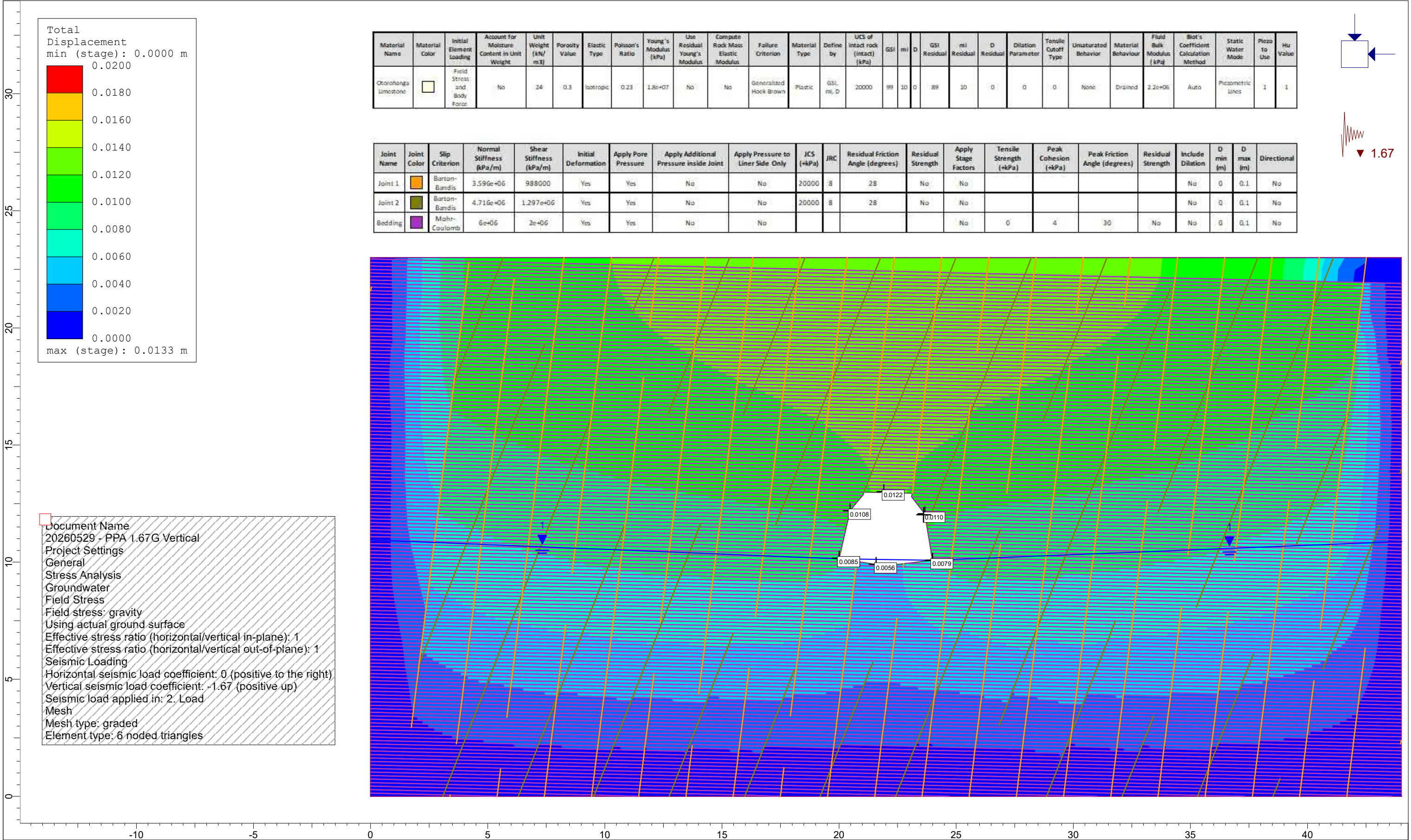
Project	Southwestern Pit, Oparure Quarry				
Analysis Description	Camelot Cave System Stability, Pakeho Pit Excavation [53-year Design]				
Drawn By	CLi	Scale	1:500	Company	Baseline Geotechnical Limited
Date	4/06/2026	File Name	20260521 - Revision 2 Base Case.fez		

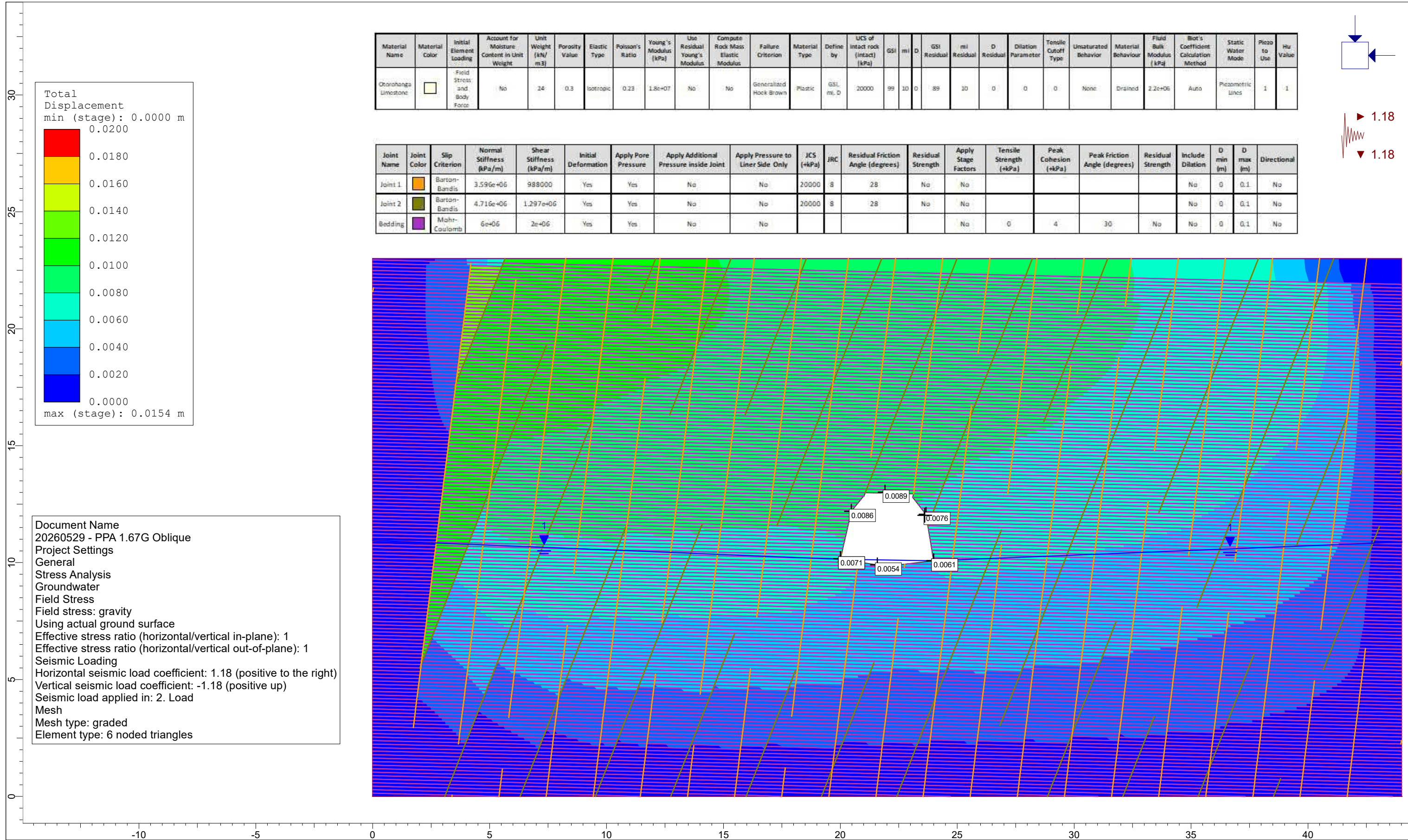


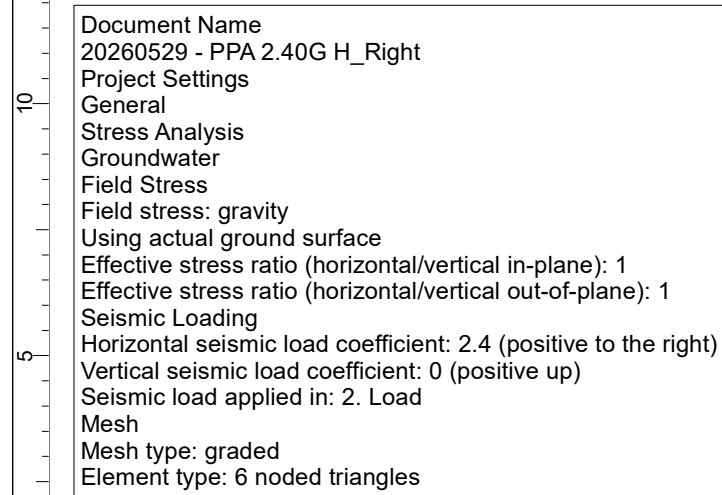


		ProjectSouthwestern Pit, Oparure Quarry	
Analysis Description		Peak Particle Acceleration [PPA] - 1.67 g [Horizontal] Scenario	
Drawn By	CLi	Scale	1:150
Date	4/06/2026	Company	Baseline Geotechnical Limited
		File Name	20260529 - PPA 1.67g H_R.fez

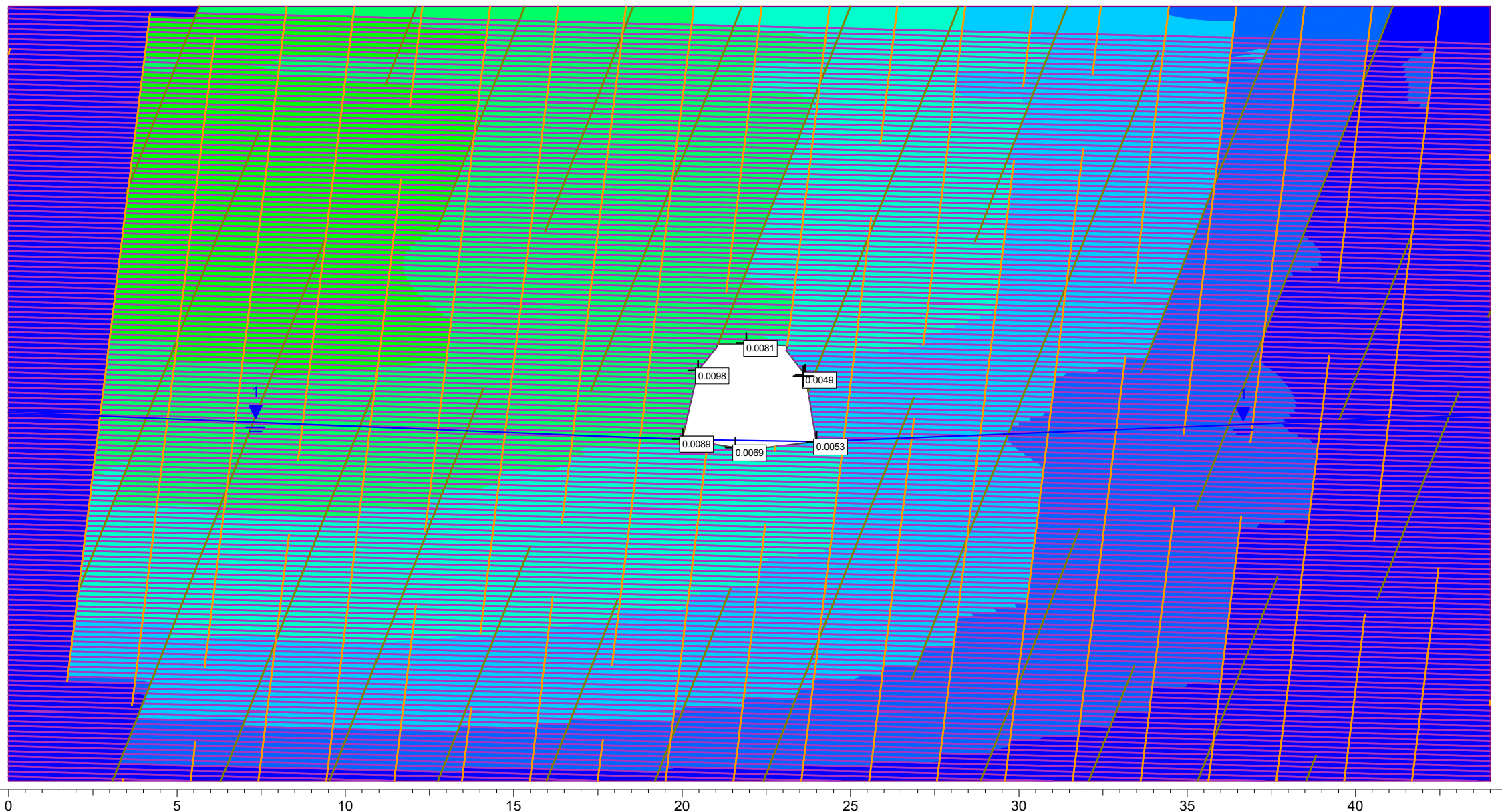


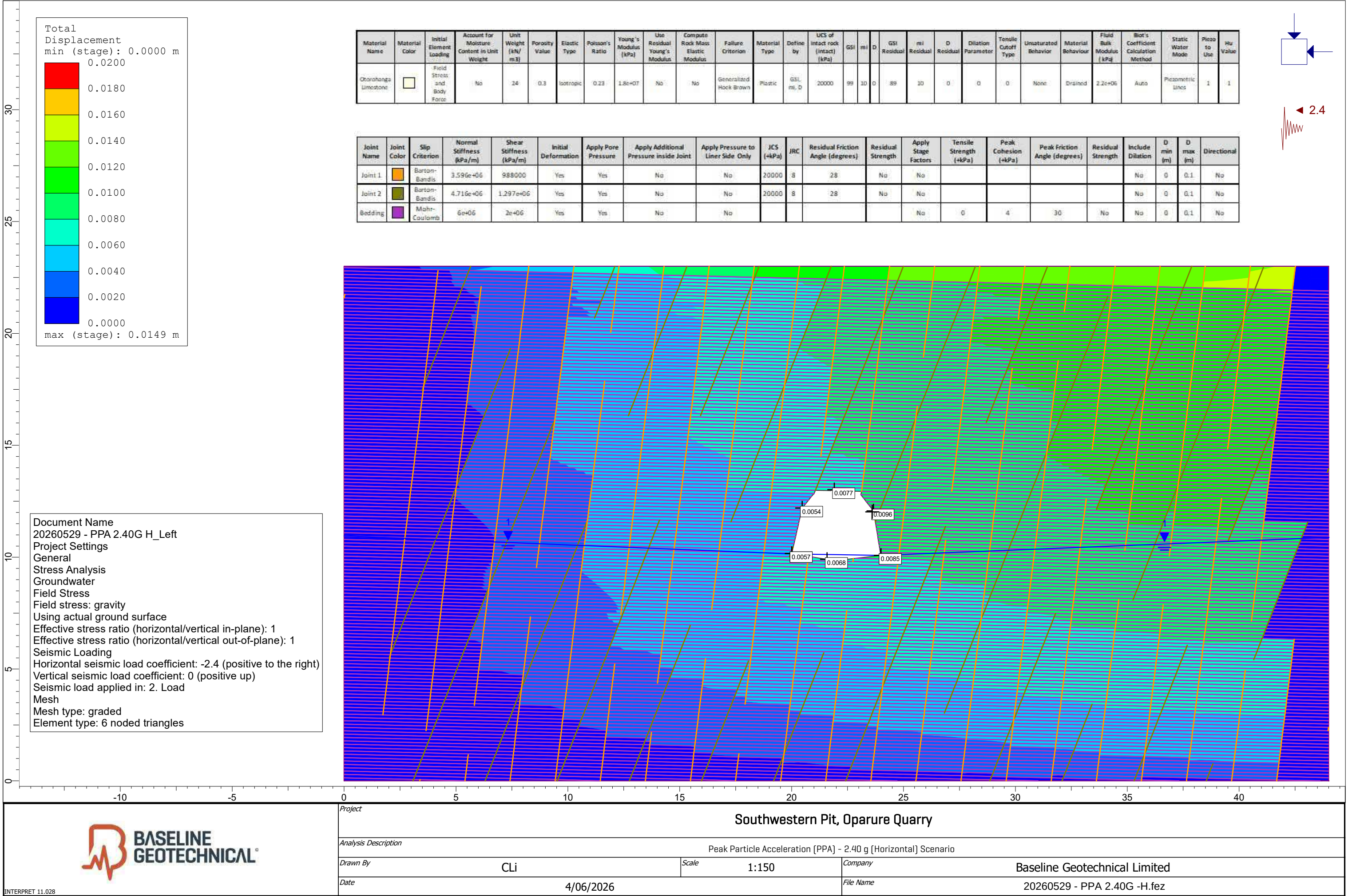


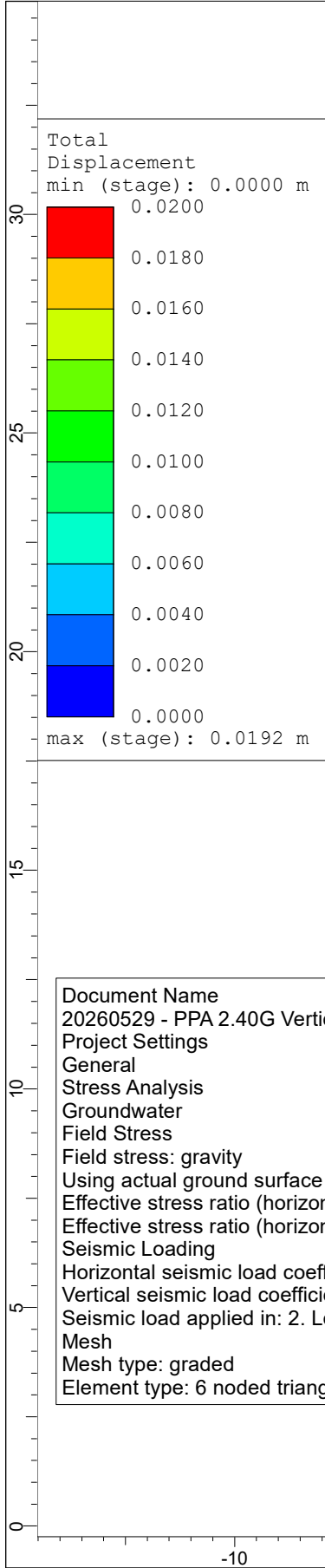




Joint Name	Joint Color	Slip Criterion	Normal Stiffness (kPa/m)	Shear Stiffness (kPa/m)	Initial Deformation	Apply Pore Pressure	Apply Additional Pressure inside Joint	Apply Pressure to Liner Side Only	JCS (kPa)	JRC	Residual Friction Angle (degrees)	Residual Strength	Apply Stage Factors	Tensile Strength (kPa)	Peak Cohesion (kPa)	Peak Friction Angle (degrees)	Residual Strength	Include Dilation	D min (m)	D max (m)	Directional
Joint 1		Baron-Bandis	3.596e+06	988000	Yes	Yes	No	No	20000	8	28	No	No				No	No	0	0.1	No
Joint 2		Baron-Bandis	4.716e+06	1.297e+06	Yes	Yes	No	No	20000	8	28	No	No				No	No	0	0.1	No
Bedding		Mahr-Coulomb	6e+06	2e+06	Yes	Yes	No	No					No	0	4	30	No	No	0	0.1	No

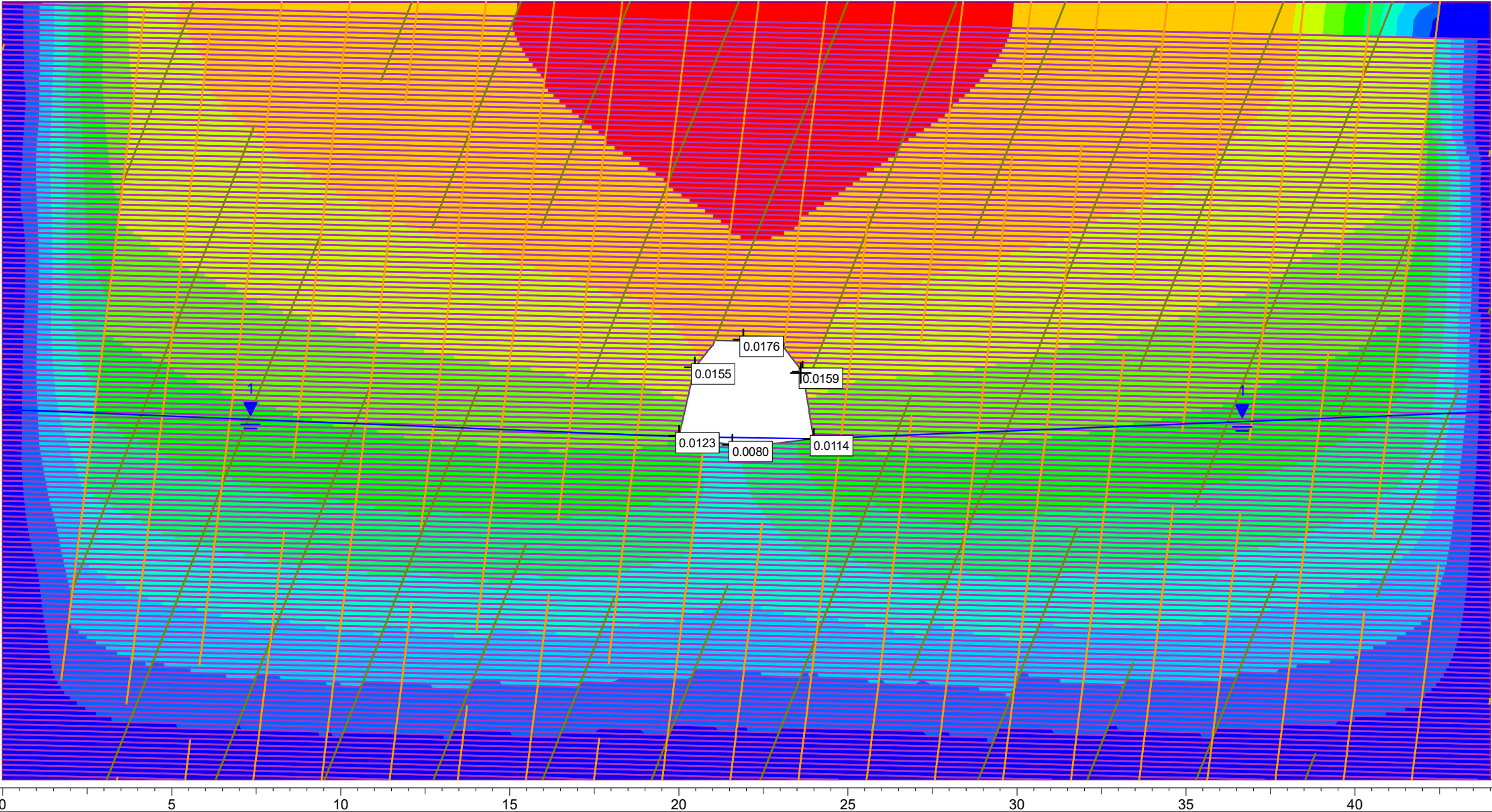




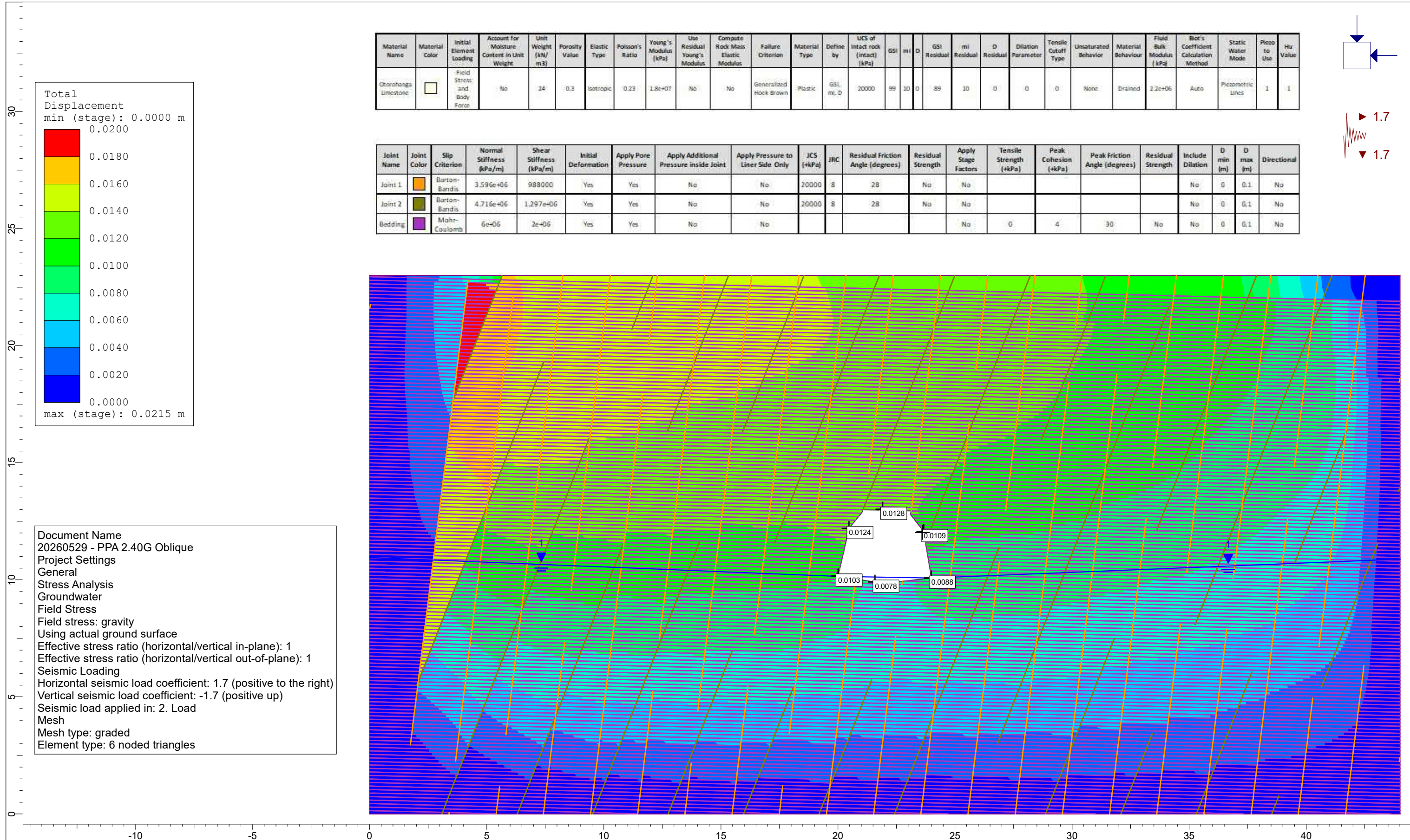


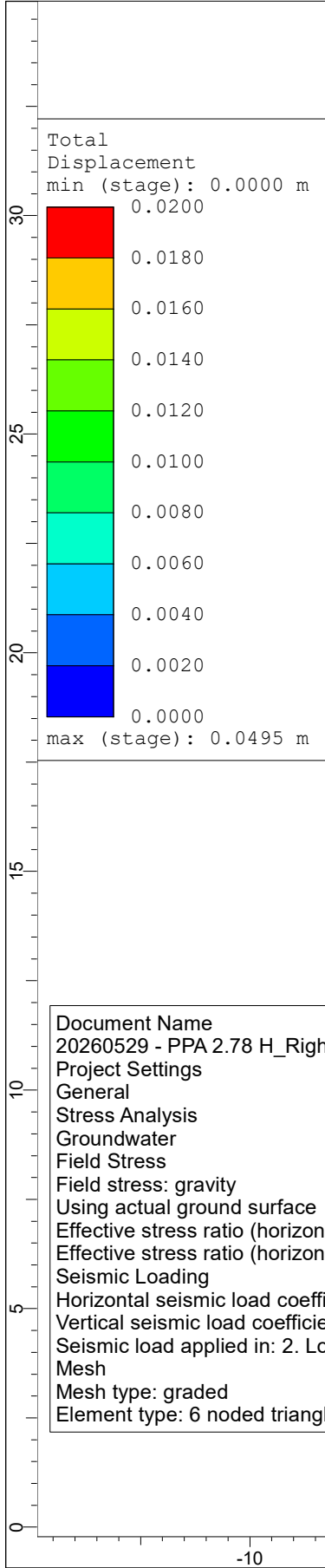
Material Name	Material Color	Initial Element Loading	Account for Moisture Content in Unit Weight	Unit Weight (kN/m3)	Porosity Value	Elastic Type	Poisson's Ratio	Young's Modulus (kPa)	Use Residual Young's Modulus	Compute Rock Mass Elastic Modulus	Failure Criterion	Material Type	Define by	UCS of intact rock (Intact) (kPa)	GSI	m	D	GSI Residual	m Residual	D Residual	Dilation Parameter	Tensile Cutoff Type	Unsaturated Behavior	Material Behaviour	Fluid Bulk Modulus (kPa)	Biot's Coefficient Calculation Method	Static Water Mode	Piezo to Use	Hu Value
Olorohanga Limestone		Field Stress and Body Force	No	24	0.3	Isotropic	0.23	1.8e+07	No	No	Generalized Hock Brown	Plastic	GSI, m, D	20000	99	10	0	89	10	0	0	0	None	Drained	2.2e+06	Auto	Piezometric Lines	1	1

Joint Name	Joint Color	Slip Criterion	Normal Stiffness (kPa/m)	Shear Stiffness (kPa/m)	Initial Deformation	Apply Pore Pressure	Apply Additional Pressure inside Joint	Apply Pressure to Liner Side Only	JCS (+kPa)	JRC	Residual Friction Angle (degrees)	Residual Strength	Apply Stage Factors	Tensile Strength (+kPa)	Peak Cohesion (+kPa)	Peak Friction Angle (degrees)	Residual Strength	Include Dilation	D min (m)	D max (m)	Directional
Joint 1		Barton-Bandis	3.596e+06	988000	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Joint 2		Barton-Bandis	4.716e+06	1.297e+06	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Bedding		Mohr-Coulomb	6e+06	2e+06	Yes	Yes	No	No					No	0	4	30	No	No	0	0.1	No



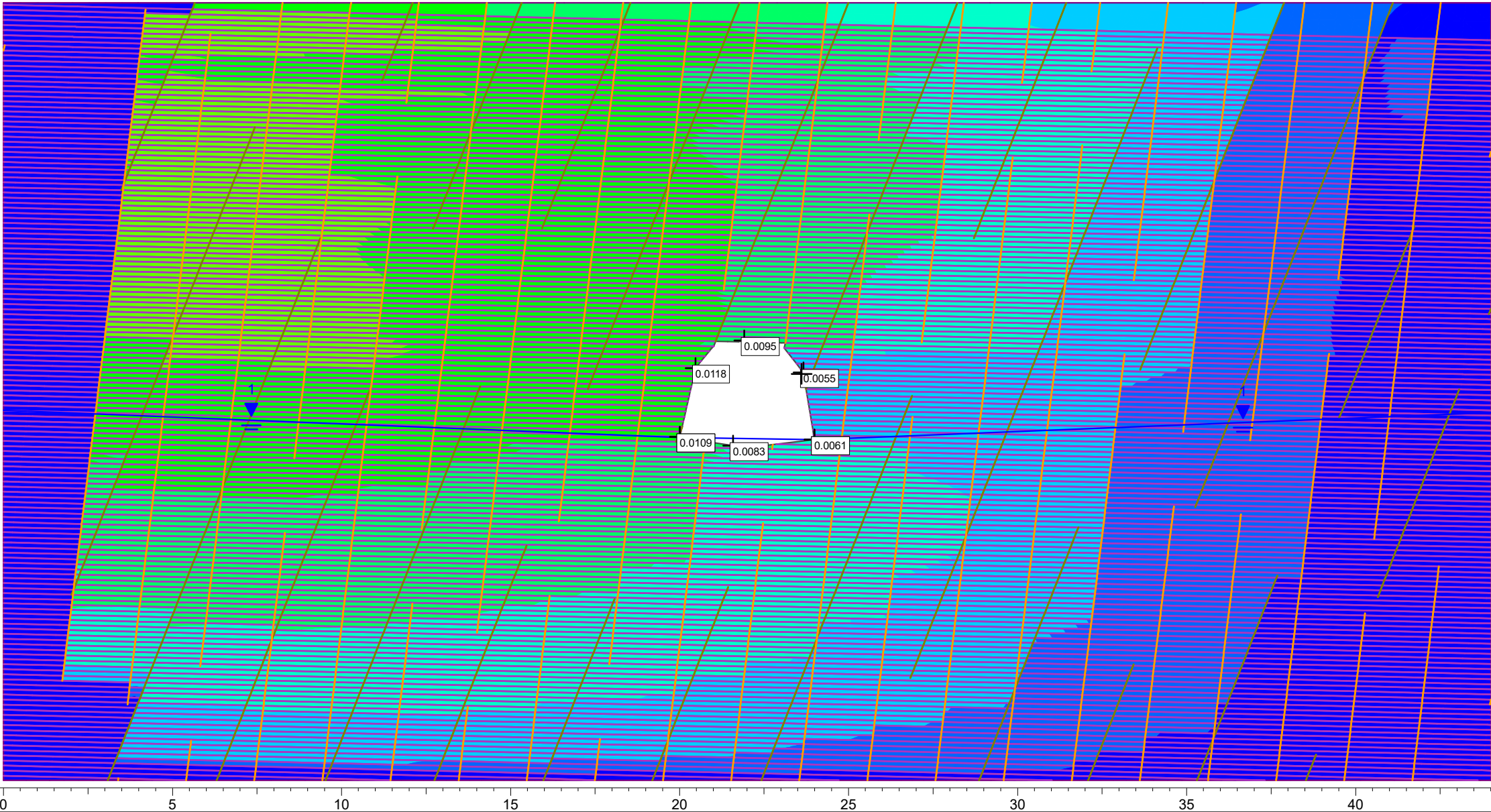
Document Name
20260529 - PPA 2.40G Vertical
Project Settings
General
Stress Analysis
Groundwater
Field Stress
Field stress: gravity
Using actual ground surface
Effective stress ratio (horizontal/vertical in-plane): 1
Effective stress ratio (horizontal/vertical out-of-plane): 1
Seismic Loading
Horizontal seismic load coefficient: 0 (positive to the right)
Vertical seismic load coefficient: -2.4 (positive up)
Seismic load applied in: 2. Load
Mesh
Mesh type: graded
Element type: 6 noded triangles





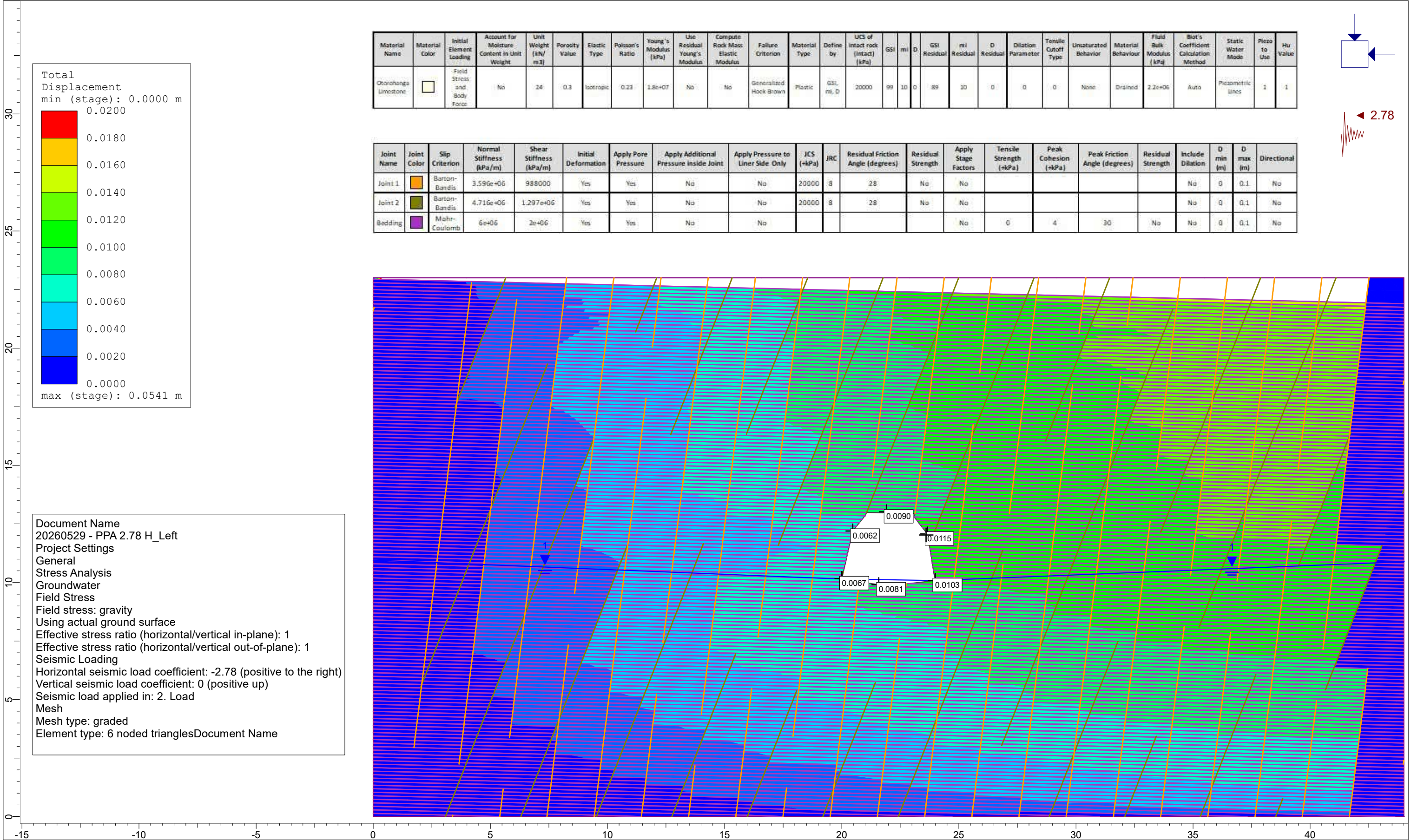
Material Name	Material Color	Initial Element Loading	Account for Moisture Content in Unit Weight	Unit Weight (kN/m3)	Porosity Value	Elastic Type	Poisson's Ratio	Young's Modulus (kPa)	Use Residual Young's Modulus	Compute Rock Mass Elastic Modulus	Failure Criterion	Material Type	Define by	UCS of intact rock (intact) (kPa)	GSI	m	D	GSI Residual	m Residual	D Residual	Dilation Parameter	Tensile Cutoff Type	Unsaturated Behavior	Material Behaviour	Fluid Bulk Modulus (kPa)	Biot's Coefficient Calculation Method	Static Water Mode	Piezo to Use	Hu Value
Olorongo Limestone		Field Stress and Body Force	No	24	0.3	Isotropic	0.23	1.8e+07	No	No	Generalized Hock Brown	Plastic	GSI, m, D	20000	99	10	0	89	10	0	0	0	None	Drained	2.2e+06	Auto	Piezometric Lines	1	1

Joint Name	Joint Color	Slip Criterion	Normal Stiffness (kPa/m)	Shear Stiffness (kPa/m)	Initial Deformation	Apply Pore Pressure	Apply Additional Pressure inside Joint	Apply Pressure to Liner Side Only	JCS (+kPa)	JRC	Residual Friction Angle (degrees)	Residual Strength	Apply Stage Factors	Tensile Strength (+kPa)	Peak Cohesion (+kPa)	Peak Friction Angle (degrees)	Residual Strength	Include Dilation	D min (m)	D max (m)	Directional
Joint 1		Barton-Bandis	3.596e+06	988000	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Joint 2		Barton-Bandis	4.716e+06	1.297e+06	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Bedding		Mohr-Coulomb	6e+06	2e+06	Yes	Yes	No	No					No	0	4	30	No	No	0	0.1	No



Document Name
20260529 - PPA 2.78 H_Right
Project Settings
General
Stress Analysis
Groundwater
Field Stress
Field stress: gravity
Using actual ground surface
Effective stress ratio (horizontal/vertical in-plane): 1
Effective stress ratio (horizontal/vertical out-of-plane): 1
Seismic Loading
Horizontal seismic load coefficient: 2.78 (positive to the right)
Vertical seismic load coefficient: 0 (positive up)
Seismic load applied in: 2. Load
Mesh
Mesh type: graded
Element type: 6 noded triangles

		Southwestern Pit, Oparure Quarry	
Project		Analysis Description	
Analysis Description		Peak Particle Acceleration [PPA] - 2.78 g (Horizontal) Scenario	
Drawn By		Scale	Company
CLi		1:150	Baseline Geotechnical Limited
Date		File Name	
4/06/2026		20260529 - PPA 2.78 H_Right.fez	



Material Name	Material Color	Initial Element Loading	Account for Moisture Content in Unit Weight	Unit Weight (kN/m3)	Porosity Value	Elastic Type	Poisson's Ratio	Young's Modulus (kPa)	Use Residual Young's Modulus	Compute Rock Mass Elastic Modulus	Failure Criterion	Material Type	Define by	UCS of Intact rock (Intact) (kPa)	GSI	m	D	GSI Residual	m Residual	D Residual	Dilation Parameter	Tensile Cutoff Type	Unsaturated Behavior	Material Behaviour	Fluid Bulk Modulus (kPa)	Biot's Coefficient Calculation Method	Static Water Mode	Piezo to Use	Hu Value
Olorunga Limestone		Field Stress and Body Force	No	24	0.3	Isotropic	0.23	1.8e+07	No	No	Generalized Hock Brown	Plastic	GSI, m, D	20000	99	10	0	89	10	0	0	0	None	Drained	2.2e+06	Auto	Piezometric Lines	1	1

Joint Name	Joint Color	Slip Criterion	Normal Stiffness (kPa/m)	Shear Stiffness (kPa/m)	Initial Deformation	Apply Pore Pressure	Apply Additional Pressure inside Joint	Apply Pressure to Liner Side Only	JCS (+kPa)	JRC	Residual Friction Angle (degrees)	Residual Strength	Apply Stage Factors	Tensile Strength (+kPa)	Peak Cohesion (+kPa)	Peak Friction Angle (degrees)	Residual Strength	Include Dilation	D min (m)	D max (m)	Directional
Joint 1		Barton-Bandis	3.596e+06	988000	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Joint 2		Barton-Bandis	4.716e+06	1.297e+06	Yes	Yes	No	No	20000	8	28	No	No					No	0	0.1	No
Bedding		Mohr-Coulomb	6e+06	2e+06	Yes	Yes	No	No					No	0	4	30	No	No	0	0.1	No

Document Name
20260529 - PPA 2.78 H_Left
Project Settings
General
Stress Analysis
Groundwater
Field Stress
Field stress: gravity
Using actual ground surface
Effective stress ratio (horizontal/vertical in-plane): 1
Effective stress ratio (horizontal/vertical out-of-plane): 1
Seismic Loading
Horizontal seismic load coefficient: -2.78 (positive to the right)
Vertical seismic load coefficient: 0 (positive up)
Seismic load applied in: 2. Load
Mesh
Mesh type: graded
Element type: 6 noded triangles

