Before the Hearing Commissioners
appointed by the Grey District Council and
West Coast Regional Council

Under	the Resource Management Act 1991
In the matter of	Resource consent applications by TiGa Minerals and Metals Ltd to establish and operate a mineral sands mine on State Highway 6, Barrytown (RC-2023-0046; LUN3154/23)

Statement of evidence of Cameron Andrew Wylie

19 January 2024

Applicant's solicitors:
Alex Booker/Alex Hansby
Anderson Lloyd
Level 3, 70 Gloucester Street, Christchurch 8013
PO Box 13831, Christchurch 8140
p + 64 27 656 2647
alex.booker@al.nz

anderson lloyd.

Qualifications and experience

1 My full name is Cameron Andrew Wylie.

2 I am a Geotechnical Engineer Member Engineering NZ; Chartered Professional Engineer (CPEng), Member Australasian Institute of Mining and Metallurgy (AusIMM) and Chartered Professional (CP) Mining Geotechnics; Chartered Member NZ Institute of Directors and with Master of Science (MSc) in Geology, BSc (Geology)

3 I am currently employed as Principle Geotechnical Engineer and Managing Director of Resource Development Consultants Ltd and have held that position since 2007.

4 My previous work experience includes 35 years' experience continuous experience in civil and mining work including large scale excavations and tailings dam storage facilities in NZ and overseas. In NZ on the West Coast, I am currently engaged with NZ Coal and Carbon at the Rajah and Echo Mines and have undertaken review services for the West Coast Regional Council, Greymouth District Council and Buller District Council in relation to previous proposals at Escarpment Mine.

5 My role in relation to TiGa Minerals and Metals Limited's (TiGa) application to establish and operate a mineral sands mine at SH6 Barrytown (Application and Application Site) has been to provide advice in relation to geotechnical stability of the proposed mine excavation, tailings storage and workability of the in-pit tailings.

6 My assessment is based upon the proposal description attached to the evidence of Ms Katherine McKenzie as Appendix 1.

7 In preparing this statement of evidence I have considered the following documents:

(a) technical reports concerning geotechnical conditions prepared by Subterra (2022) and description of site geology by RSC Mining and Mineral Exploration;

(b) submissions relevant to my area of expertise:

(i) the statement of evidence on hydrology by Jens Rekker for TiGa MM;

(ii) the statement of evidence on mining planning and rehabilitation by Stephen Miller for TiGa MM;

(iii) the statement of evidence on coastal processes by Gary Teear for TiGa MM.

8 I became involved on the project in late 2022. I have not visited the site in my capacity on the project but have visited the region many times generally.

Code of Conduct for Expert Witnesses

9 While this is not a hearing before the Environment Court, I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2023 and that I have complied with it when preparing my evidence. Other than when I state I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope of evidence

10 I have prepared evidence in relation to:

(a) the existing geotechnical environment of the Application Site;

(b) the key findings of my assessment of effects;

(c) matters raised by submitters to the Application;

(d) matters raised in the West Coast Regional Council's (**WCRC**) and Grey District Council's (**GDC**) staff reports (reports issued under s42A of the RMA); and

(e) proposed conditions of consent.

The existing environment

11 As it relates to geotechnical aspects of the proposed project:

(a) The proposed project is to extract Heavy Mineral sands contained within the Holocene Beach Placer deposit at Barrytown.

(b) The project geology, mining, processing and tailing storage are not complicated from a geotechnical perspective. Including as it relates to tailings storage, being without the use of chemical additives in the processing stream.

(c) The site is within existing, modified farmland, sloping from SH6 west towards the coast, with elevation difference of ~15m across the project footprint.

(d) Key relevant features which border the property include:

(i) Canoe Creek Lagoon to the west;

(ii) Rusty Pond to the north;

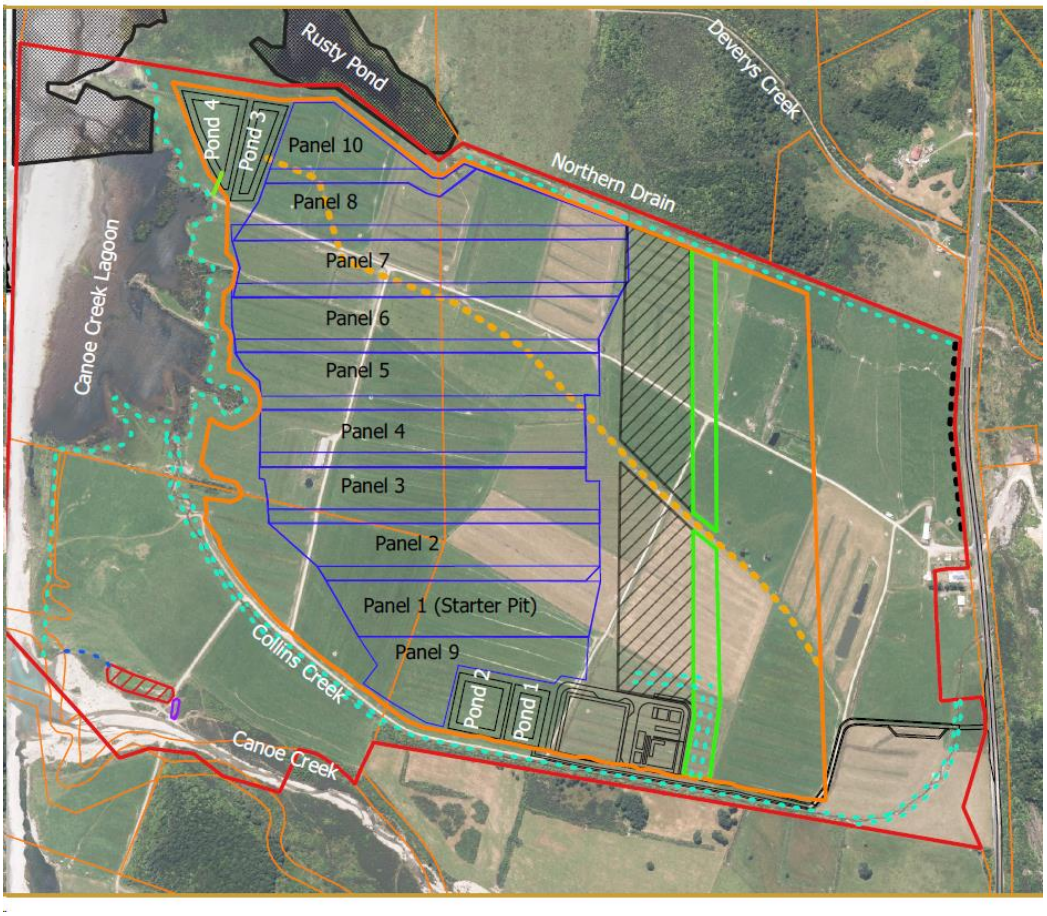
(iii) The Norther Drain on the northern boundary; and

(iv) Collins Creek to the south.

(v) Canoe Creek lies outside the mining block.

(e) Setbacks of 20m apply to the Canoe Creek Lagoon, Rusty Pond and property boundaries (Figure 1).

Figure 1 Site Features



12 For the consideration of geotechnical stability; geotechnical investigation Subterra (2022), historical and recent geological work by RSC and hydrology investigations as reported in evidence by Mr Rekker confirm the general sequence:

(a) Topsoil 0.2m – 0.6m thick, overlies Overburden.

(b) Overburden overlies mineralisation and comprises Clayey, silty Gravel derived broadly from colluvial outwash. Recent drilling from

hydrogeological study confirms the thickness of clay deepens towards the bounding creeks and wetlands.

(c) Mineralisation occurs as marine placer deposits of heavy minerals, concentrated by longshore drift and pushed up by wave action;

(i) Lensoidal shaped mineral concentrations follow the dip of the beach towards the sea at ~5° to 10°;

(ii) Deposits are generally very well sorted fine sand, with occasional clay and gravel intercalations;

(iii) Mineralisation overlies Basement.

(d) Basement comprises barren Gravel with an abrupt contact;

(e) Groundwater is at 0.5m to 4m below existing ground level as reported by Mr Rekker and 1.45m as measured by Subterra (2022) following drilling.

13 The mine plan is to extract in Panels numbered 1 to 10 (Figure 1).

14 Mining will be by open pit to ~9m below current ground level, and will be undertaken with excavators, mine trucks and dozers.

15 It is anticipated that mining will be complete within 5-7 years, with each Panel taking 4 to 6 months to complete.

16 The mining and rehabilitation plans are provided in statement of evidence by Mr Miller.

17 Each panel (Figure 2) will:

(a) Advance west to east;

(b) Be 100m wide including the 20m wide running road; with

(c) 80m wide at the excavation face.

18 The mining sequence in general (Figure 2) is to:

(a) Strip the topsoil;

(b) Strip the barren overburden;

(c) Mine the mineralised sands by excavator to a hopper;

(d) Pump the ore as a slurry to the processing plant; and

(e) Backfill the mining void with tailings and overburden concurrent with the advance of the mining face.

19 Backfilling is:

(a) Continuous; with

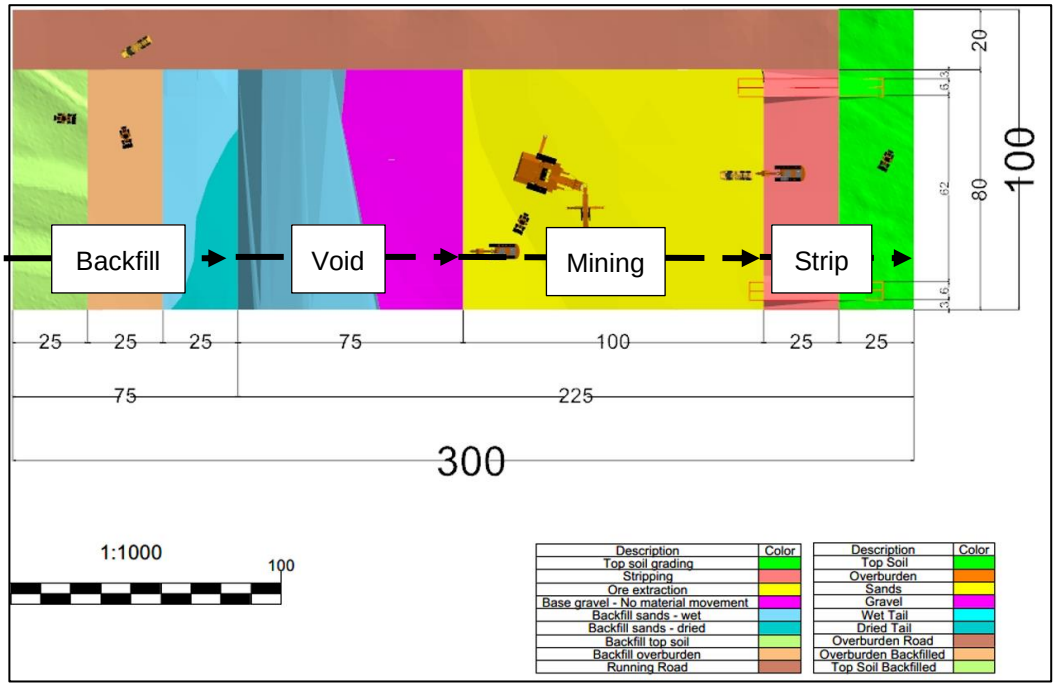
(b) Tailings placed using hydraulic methods; followed by

(c) Overburden placed by earthworks machine and topsoil; and finished with

(d) Topsoil grading to the closure condition (farm use).

20 Tailings return is by slurry, thickened at the point of disposal into the mine void to reduce water handling at that end of the operation.

Figure 2. Active Mine Void Dimension and Mining Sequence



21 Topsoil and overburden will be stockpiled in the start-up phase, and then placed directly onto tailings once the production sequence is established.

22 The tailings comprise fine sand and are expected to drain naturally, allowing overburden to be placed directly on to tails.

23 The final surface will be contoured and grassed as the mine progresses.

24 For stability, backfilling the pit with tailings and overburden will effectively buttress the excavation:

(a) Consequently the starting cut will only be exposed nominally < 1 month before it is backfilled.

(b) This is based on the 4-6 months estimated to complete the whole Panel with the mining face advancing 35m / day and tailings backfill following behind.

(c) This time of exposure occurs as stripping topsoil and overburden, and the advance of the mining face, proceeds ahead of the tailings backfill.

25 The backfilled, rehabilitated pit will be consolidated due to hydraulic and machine placement of materials, and achieve strength not significantly less than the original ground.

26 The rehabilitated surface will be grassed at least equivalent to the current condition.

27 In terms of geotechnical effect, the starter cuts for Panels 5 to 10 adjacent to Canoe Creek Lagoon, Rusty Pond and the Northern Boundary present the critical geotechnical condition.

28 Stability analyses has been undertaken using generally accepted limit equilibrium methods which produce a Factor of Safety (FoS) against failure, and Finite Element Methods (FEM) which produce an estimate of the deformation caused by excavation, in the ground behind the cut.

(a) For this project with the very short duration of exposure and ability to buttress the slope, it is appropriate to consider both the limit equilibrium (Factor of Safety) and magnitude of deformation to assess the suitability of the proposed excavation.

(b) The limit equilibrium Factor of Safety (FoS) balances forces resisting failure against forces driving failure; a FoS=1 is a slope in balance. Typical acceptable FoS in NZ may range from < 1 under earthquake (short term, extreme conditions) to 1.5 for residential development.

(c) Finite element methods provide an indication of how the slope may deform due to excavation.

(i) Many slopes that are out of balance (i.e. FoS < 1) can be seen to “creep” or “slump” suffering relatively minor displacement which may be acceptable.

(ii) Earthquake analyses are also allowed to dip to FoS<1.0 considering the event is transient of very short duration, and where displacement as indicated by FEM is generally considered within acceptable limits.

(d) For this excavation, because of the short time of exposure and because the slope will be buttressed by tailings and overburden, some deformation can be tolerated.

29 Earthquake loads comprising peak ground acceleration (pga) have been assessed in accordance with AS/NZS 1170:2016 Structural Design Actions and MBIE Earthquake Geotechnical Engineering Practice (Module 1; Nov 2021) considering:

(a) Time of exposure. AS/NZS 1170:2016 allows loads to be scaled according to the time of exposure. This recognises the reduced likelihood of any one (earthquake) event for a shorter design life.

(b) In this case we have used a design working life < 6 months to estimate seismic loads for geotechnical assessment of stability. This matches the actual operating condition where the mining void is backfilled with advance.

(c) The selected earthquake source location is Greymouth, with Importance Level 2 applied.

(d) Seismic loads for the Serviceability Limit State (SLS1) (1/25 year event) = 0.13g, and for the Ultimate Limit State (ULS) (1/100 year event) = 0.27g.

(e) Deformation has also been checked considering a large event based the 50 year design, 1/500 year event with pga =0.53g.

30 The groundwater level used for assessment is 1m below current ground.

31 Acceptable factors of safety (FoS) are indicated for the static case (FoS = 1.2).

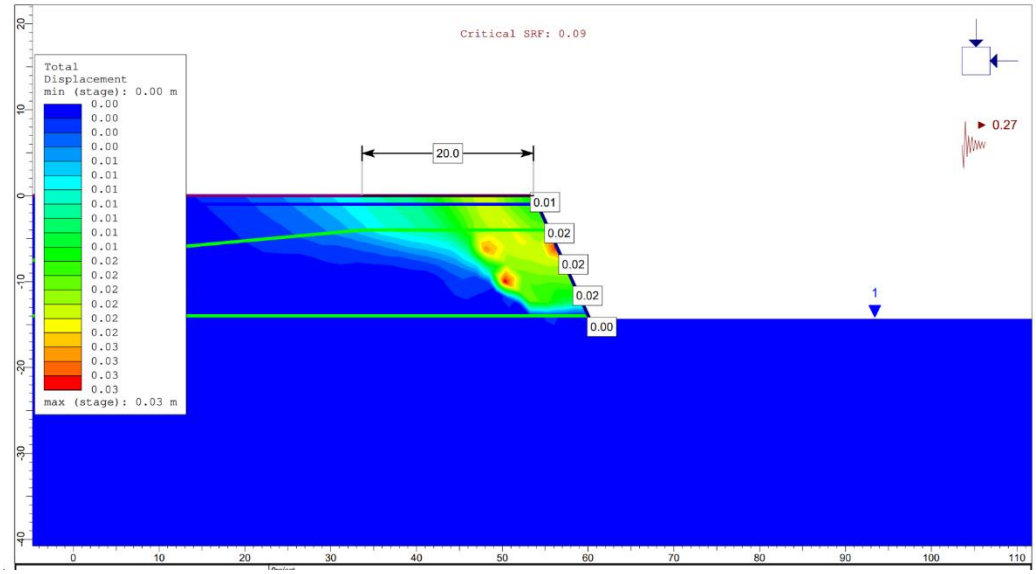
32 For the seismic cases FoS < 1 so that FEM derived ground displacement needs to be considered to confirm the suitability of the proposed excavation.

(a) Seismic case SLS1 (0.13g) FoS = 0.9 with indicative displacement < 0.05m at the excavation and 0.01m at a distance ~12m behind the crest of the cut face.

(b) Seismic case ULS (0.27g) FoS = 0.7 with indicative displacement < 0.05m at the excavation face and 0.01m at a distance ~20m behind the crest of the cut face as shown in Figure 3.

(c) Check seismic case for pga=0.53 also indicates the magnitude of displacement < 0.04m all within the 20m setback.

Figure 3 Indicative Displacement due to ULS event



33 Displacement of this magnitude is expected to be practically not visible to the eye, with:

(a) Very Low likelihood to breach the waterbodies outside of the 20m setback.

34 When buttressed with tailings (i.e. not including overburden) the FoS improves to 1.4 and 1.1 respectively, with no deformation in the wall expected.

Assessment of effects

35 Our scope has been to assess geotechnical aspects of:

(a) Mining Operations including stability of excavation and tailings operations; and

(b) Tailings storage assessment and risk assessment.

36 For the assessment of effects:

(a) There are no known geohazards identified in any of the public databases, and none have been subsequently identified on site. In particular:

(b) The property is clear of recent faults; and

(c) Liquefaction potential based on testing by others (Subterra 2022) is considered unlikely due to the presence of thick clay layers in the near surface.

37 I have carried out a geotechnical assessment of the proposed mining plan including stability of the wall, and consider any potential effects are minor and confined within the 20m setback from waterbodies and property boundaries.

(a) The open pit is expected to be stable for the proposed configuration with no substantial ground displacement due to instability in the pit face or behind the pit crest.

(b) Canoe Creek Lagoon, Rusty Pond, Collins Creek, Northern Drain and property boundaries are at low risk of adverse effect due to instability as a result of mining operation.

(c) The closure "engineered landform" as described by Mr Millar in his evidence setting out the rehabilitation plan, is resilient from a geotechnical perspective considering the effect of earthquake.

.Matters raised by submitters

38 Matters raised by submitters include:

(a) The effect of the M8 Earthquake generated by the Alpine Fault; and

(b) The effect of the proposed mine on the exposure of the coast to extreme inundation.

39 Both events are "extreme" and are in my opinion best considered through Risk assessment. In this case we believe the NZ Society of Large Dam (NZSOLD) Safety Guidelines 2023 present the best framework.

40 The scenario is that a M8 earthquake causes failure of the pit wall which leads to deformation sufficient to impact the nearby Canoe Creek Lagoon and Rusty Pond.

41 The issue is to assess the level of risk posed by the event considering Likelihood x Consequence ranked against the standard Risk matrix in Figure 4.

Figure 4 Standard Risk Matrix

Likelihood		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

42 The M8 Earthquake is described as the Maximum Credible Earthquake (MCE) (ref https://af8.org.nz/response-planning). NZSOLD (2023) uses the term Safety Evaluation Earthquake as broadly the MCE equivalent suggest the MCE could range between:

(a) 1 in 500 Annual Exceedance Probability (AEP) for Low Impact dam to 1 in 10,000 AEP for a High Impact dam. Earthquakes of very low probability are much larger than “everyday” events so that the higher consequence of failure, the more rigorous the design has to be to resist greater design loads.

(b) In any case, these events equating to 0.001% and 0.001% probability of the event occurring within a given year.

(c) Against commonly accepted definitions (reference Queensland Emergency Risk Management Framework (QERMF) Risk Assessment Process Handbook 2023), the likelihood of occurrence on annual probability basis is Rare to Extremely Rare (Figure 5).

(d) Further reduced because for each Panel, the time of exposure is < 6 months (being the time to complete the full panel) and likely ~ 1 month as previously described.

Figure 5 Likelihood of Occurrence Matrix (QERMF, 2023)

Likelihood	Annual exceedence probability (AEP)	Average recurrence interval (ARI) (indicative)
Almost certain	63% per year or more	Less than 1 year
Likely	10% to <63% per year	1 to <10 years
Unlikely	1% to <10% per year	10 to <100 years
Rare	0.1% to <1% per year	100 to <1000 years
Very rare	0.01% to <0.1% per year	1000 to <10,000 years
Extremely rare	Less than 0.01% per year	10,000 years or more

43 For risk assessment, the Canoe Creek Lagoon and Rusty Pond are the features with significant consequence of damage due to this event.

(a) In considering the exposure to the M8 hazard: The critical conditions is the starter boundary cuts in Panels 6-10.

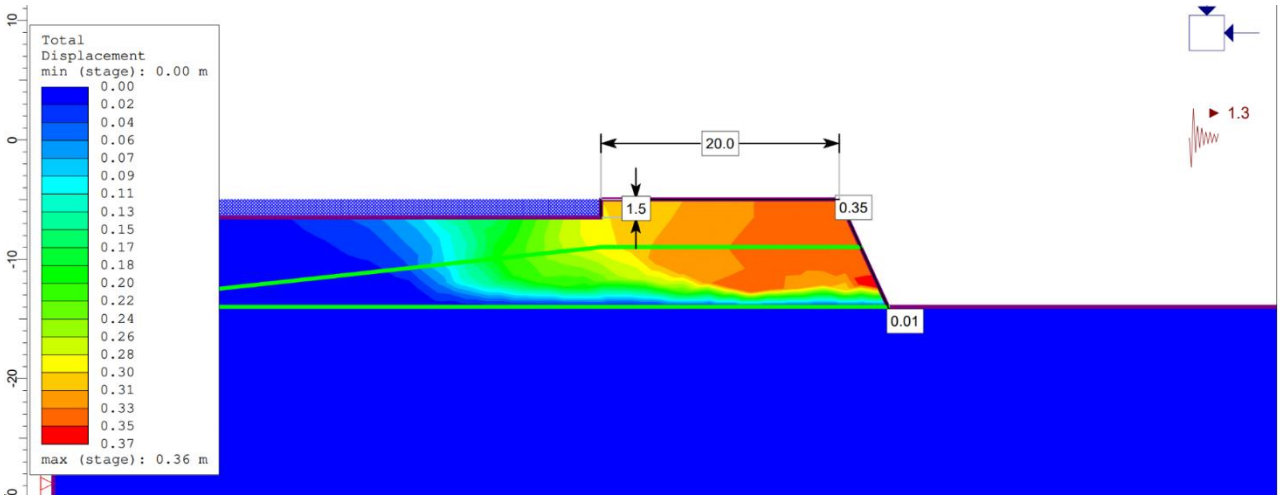
(b) From a geotechnical perspective, the backfilled, closed condition is not significantly different to the existing (pre-mining) state.

44 An indicative assessment of deformation due to a very large event assuming pga=1.3 is in Figure 6.

(a) There is no definitive ground acceleration defined for a M8 event so we have used this very large value as a reasonable indication.

(b) For reference, Christchurch (2011) earthquake recorded pga's up to ~ 1.37-1.51 are the highest levels recorded in NZ and some of the highest in the world.

Figure 6 M8 Indicative Deformation



45 The consequence of the M8 event would be to induce instability likely to occur as slumping into the mine void, with no significant toe run-out. In effect the wall would "sit down" into the pit.

(a) The indicative displacement at the 20m boundary is to reduce the ground level ~0.25m.

(b) The effect would be to cause the lagoon (and pond) to spillover into the mine void, lowering water levels within both.

(c) Sediment entrainment out of the lagoon (and pond) would not be expected as the gradient of the induced discharge channel is too low.

(d) For the closed condition, there is no difference in risk due to the M8 event against the pre-mining condition.

46 To reinstate this level of damage would be to backfill the pit and re-establish the enclosing ground level.

(a) Reinstatement materials would comprise overburden of similar composition of the original materials, placed by earth moving equipment already on site.

47 Against NZSOLD (2023) guidelines (Figure 7), the consequence of damage induced on the adjacent wetlands as a result of the M8 event is assessed as Moderate to Minimal.

Figure 7 Consequence Guidelines (NZSOLD 2023)

Damage Level	Specified categories				
	Community	Cultural	Critical or major infrastructure		Natural environment
			Damage	Time to restore to operation 1	
Catastrophic	One or more of the following apply: • 50 or more household units rendered uninhabitable. • 20 or more commercial or industrial facilities rendered inoperable. • 2 or more community facilities rendered inoperable or uninhabitable.	Irreparable loss to 2 or more historical or cultural sites.	Two or more critical or major infrastructure facilities rendered inoperable.	One year or more.	Extensive and widespread damage, with permanent, irreparable effects on the natural environment.
Major	One or more of the following apply: • 4 or more but less than 50 household units rendered uninhabitable. • 5 or more but less than 20 commercial or industrial facilities rendered inoperable. • 1 community facility rendered inoperable or uninhabitable.	One or both of the following apply: • irreparable loss to 1 historical or cultural site. • loss to 1 or more historical or cultural sites where it is possible, but impracticable, to fully restore the site.	One critical or major infrastructure facility is rendered inoperable.	Three months or more but less than 1 year.	Extensive and widespread damage where it is possible, but impracticable, to fully restore or repair the damage.
Moderate	One or more of the following apply: • 1 or more but less than 4 household units rendered uninhabitable. • 1 or more but less than 5 commercial or industrial facilities rendered inoperable. • loss of some functionality of one or more community facilities.	Significant loss to 1 or more historical or cultural sites where it is practicable to restore the site.	One or more critical or major infrastructure facilities are affected by the loss of some functionality.	Less than 3 months.	Significant damage that is practicable to restore or repair.
Minimal	Minor damage that does not materially affect the functionality of any household unit, commercial or industrial facility, or community facility (or no damage).	Loss to 1 or more historical or cultural sites that will require minor restoration only (or no loss to any historical or cultural site).	Minor damage to 1 or more critical or major infrastructure facilities (or no damage).	One week or less.	Only minor rehabilitation or restoration may be required or recovery is possible without intervention (or no damage).
Notes: 1. The estimated time required to repair the damage sufficiently to return the critical or major infrastructure to the normal operation that the infrastructure had immediately before the failure of the dam					

48 Our view is that risk assessment confirms damage due to the adjacent water bodies as a result of an M8 earthquake is Low, considering:

(a) Rare likelihood of occurrence;

(b) Moderate consequence of occurrence.

In that case we suggest that no mitigation is required.

49 For an extreme storm event, reference should be made to Mr Tears evidence concerning Coastal Processes as the relevant expert.

50 Notwithstanding that, as a comment, from the geotechnical perspective, following closure, the land will return to the pre-mining condition, with no significant difference in susceptibility to coastal or erosion events.

51 During Operations, from a Risk perspective, the likelihood of occurrence at the time of exposure of the boundary cut is also Rare with a Low risk of damage.

(a) Reinstatement would also be an extension of the mine operations as suggested above.

(b) In that case we also suggest with no mitigation required.

Matters raised by WCRC and GDC staff reports

52 Matters raised by the Officers report concern:

(a) the effect of groundwater injection on the stability of the pit wall; and

(b) Potential for uncontrolled wall collapse due to unforeseen ground.

53 The stability model has been developed considering the natural groundwater levels and remedial measures such as infiltration that may be required to sustain the ecology of the site.

(a) Groundwater has been modelled at 1m below surface with stability tested against seismic loads applicable to the operational phase of the mine when injection/infiltration may be active.

(b) In all cases the stability of the wall is considered acceptable with displacement < 0.01m at the 20m setback boundary for the ULS condition.

(c) This level of deformation is unlikely to be visible to the naked eye with no obvious effect on the Canoe Creek Lagoon, Rusty Pond or Northern Drain.

(d) In our view, no specific Water Management Plan or Mitigation is required.

54 When considering the effect of groundwater injection on wall stability the following is relevant:

(a) Pit wall stability is related to groundwater (pore) pressure.

(b) Higher groundwater pressures result in instability all things being equal.

(c) Groundwater pressures are related to groundwater levels which at this site, are not confined.

(d) Elevated groundwater pressures are naturally found in artesian systems. Artesian aquifers are confined by continuous layers with low permeability that form hydraulic barriers (aquicludes) which allow pressure to develop within the system.

(e) While there are springs reported in general vicinity, above ground artesian pressures, were not reported from recent testing outside a 5 m radius of the trial injection bore while it was in operation at 6.4 litres per second (refer Mr Rekker's evidence).

55 Groundwater injection if required will be by shallow (allow < 5m deep) infiltration trenches or injection wells under gravity.

56 As a consequence, no significant change in formation pore pressures are expected.

(a) The likely effect of injection will be to maintain the current groundwater level, being possibly with some minor increase in levels close to the trench or well.

57 Stability analyses presented to date is already based on:

(a) Groundwater level at 1m below ground.

(b) This is a "high" level already and unlikely to significantly change due to gravity infiltration.

58 We expect no negative influence on the stability of the excavation due to groundwater recharge. Ground deformation associated with mining operations including potential injection/infiltration will have no discernible effect on Canoe Creek Lagoon, Rusty Pond, Northern Drain and land beyond the property boundary.

59 As it relates to uncontrolled pit wall collapse.

(a) Modelling suggests this is Unlikely based on currently known ground conditions.

(b) The mining method with a very short time of exposure followed by backfill with tailings and overburden, facilitates a very fast response to any adverse condition should it occur.

(c) The means to rectify any adverse deformations are immediately at hand.

(d) Mining Panels 1 to 5 are clear of the Coastal Lagoon, Rusty Pond, Northern Drain and Collins Creek and are well placed to test the stability case with Very Low potential for any adverse effects on water bodies and adjacent land.

(e) Monitoring ground response to the panels and additional investigation to confirm conditions ahead of mining in Panels 6 – 10 is recommended as a normal part of mine processes (See Proposed Consent Conditions).

(f) We consider the likelihood of uncontrolled pit wall collapse to be very unlikely with no mitigation required.

Proposed consent conditions

60 I consider there should be:

(a) An annual geotechnical review;

(b) Monitoring of pit wall performance with a focus on Panel 1 to 5 to confirm the geometry, setback and results of stability analyses. Monitoring is likely to include in-ground inclinometers to measure slope deformation and piezometers to measure groundwater response; and

(c) Ground Investigation to confirm geotechnical conditions for Panel 6 to 10.

61 This has been included in the Proposed Conditions of Consent (Condition 5.2).

Conclusion

62 I have carried out a geotechnical assessment of the proposed mining plan including stability of the wall, and consider any potential effects are confined within the 20m setback from waterbodies and property boundaries

63 The critical geotechnical condition is at the boundary cut before the pit is backfilled. Stability modelling based on current understanding of the ground model confirms the suitability of the excavation with any potential damage due to instability being contained within the 20m setback.

64 Backfilling the mining void with tailings and overburden to finish the site to grazing will effectively return the site to the pre-mining condition from a geotechnical point of view.

65 The risk of extreme earthquake (a M8 event) and coastal inundation are both considered Low with moderate consequential damage with no specific mitigation required.

66 Groundwater injection if required is not expected to adversely influence wall stability. Field testing has shown that elevated groundwater pressures that could impact stability cannot be sustained on the site. The current stability modelling already assumes groundwater levels at 1m below surface which is unlikely to be significantly raised by gravity infiltration.

67 The risk of uncontrolled pit wall collapse is Very Low with remedial measures immediately available to rectify any situation should it occur, and ground monitoring and additional ground investigation recommended to confirm the geotechnical model.

Cameron Andrew Wylie

Dated this 19th day of January 2024