Before a Hearings Panel Appointed by the Selwyn District Council and Canterbury Regional Council

Under	the Resource Management Act 1991
And	
In the Matter of	applications under section 88 of the Act by Bathurst Coal Limited in relation to the closure and rehabilitation of the Canterbury Coal Mine in the Malvern Hills, Canterbury

Statement of Evidence of **Michael James Begbie (Geotechnical)** for Bathurst Coal Limited

Dated: 1 October 2021

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INTRODUCTION

1. My name is Michael James Begbie. I am a Principal Geotechnical Engineer for Bathurst Resources Limited (**BRL**).

2. I hold a Bachelor of Science and Master of Science with Honours (Structural Geology) from the University of Auckland, Master of Engineering Science in Geotechnical Engineering from the University of New South Wales and a Doctor of Philosophy from the University of Otago. I am a Chartered Professional member of the Australasian Institute of Mining and Metallurgy (AusIMM) under the discipline of Geotechnical.

3. I have over 20 years' professional experience with 15 years in geotechnical engineering and engineering geology in a variety of civil engineering, mining and exploration projects. I have specialised in structural and engineering geological mapping, site investigations, development of geotechnical models, soil and rock assessments, slope stability analysis and design, and natural hazard identification and assessment. I have extensive experience in providing geotechnical support to opencast mining/quarrying operations in a variety of geological environments throughout New Zealand. I have worked at BRL since 2017, prior to which I have 6 years' experience as a Senior Geotechnical Engineer with Solid Energy New Zealand and 5 years' experience with engineering consultancy Tonkin & Taylor Ltd.

4. My current role involves managing geotechnical risk and slope stability across BRL's North Island (Rotowaro and Maramarua Mines) and South Island (Canterbury Coal Mine (**CCM**)) and Takitimu Mines) domestic operational sites. These sites have inherent geotechnical complexities due to geologically young rocks being relatively weak in terms of material strength and mining into areas of historic underground workings. Work streams include pre-feasibility and feasibility studies, optimal pit slope design, dump design and construction, design of engineered final landforms, embankment design for stream diversions and dams, seismic assessment and design, stabilising options, stability monitoring and development and verification of geotechnical models. I have been involved in the CCM operation since 2017 undertaking regular geotechnical inspections of the site, providing slope design advice, geotechnical information for Principal

Hazard Management Plans (**PHMPs**) and peer review of the CCM Open Cut Geotechnical Review (2018).

5. I am an employee of BRL and am therefore providing this evidence in my capacity as a company representative. However, I note my qualifications and experience and the technical nature of my role as outlined above, which enable me to comment on geotechnical matters from a technical perspective.

SCOPE OF EVIDENCE

6. I prepared the "Final Engineered Landform Geotechnical Review" (**2021 Geotechnical Review**), which is attached as Appendix 8 to the Addendum AEE for Closure and Rehabilitation for the CCM.

7. I do not repeat the contents of the 2021 Geotechnical Review in full in my evidence. My evidence:

   (a) provides a brief description of the CCM site from a geotechnical perspective;

   (b) briefly outlines the proposed slope design for the final landform and explains the proposed management and monitoring measures to ensure slope stability;

   (c) confirms my assessment of the slope stability for the final landform;

   (d) responds to relevant submissions; and

   (e) responds to the relevant parts of the Council officers' Section 42A Report.

EXECUTIVE SUMMARY

8. As part of the closure and rehabilitation of CCM Bathurst Coal Limited (**BCL**) have designed a final Engineered Landform (**ELF**) that has slopes similar to the surrounding landform within similar catchments and I expect will provide a high level of stability over the long term. The ELF is to be built with a similar methodology to existing ELFs within the mine that have performed well and as planned. In summary, I expect that the proposed ELF will provide a stable

landform for the expected farming and forestry land uses. I consider there is a low risk of future instability given the design geometries and stability criteria proposed to be implemented. This has been demonstrated by the success of the existing ELFs on site.

SITE DESCRIPTION AND GEOLOGY

9. The opencast mining area of the CCM is excavated into a hill and ridge site flanked to the northwest and southeast by moderate to steep sided gullies. The natural slope angles vary across the site and neighbouring land and are generally between 15° and 30°. There are areas steeper than 35° to 40° correlating to the steep gully sides and exposed dip slopes of the sedimentary rock sequence. There is approximately 100m of relief between the valley floors and the ridge tops hosting the mine.

10. The geology of the CCM mining area is dominated by a layered sequence of sedimentary rocks that are Late Cretaceous to Paleocene (~100 – 60 Ma) in age. These sedimentary rocks unconformably overlie Jurassic to Triassic (~150 – 250 Ma) greywacke basement rocks and early Cretaceous (~145 – 113 Ma) volcanic rocks. The basal unit of the sedimentary sequence exposed at the mine is made up of cemented clasts of pre-existing rocks that form the Monro Conglomerate. This unit is overlain by interbedded mudstones, siltstones and sandstones including coal seams that form the main coal producing horizon, referred to as Broken River Coal Measures (**BRCM**). The BRCM grades into locally cemented fine grained sands known as the Conway Formation. Pleistocene age (~2.6 – 0.12 Ma) loess and gravel deposits unconformably overlie the lower rock units.

11. In terms of structure, bedding within the sedimentary sequence exposed at the mine has an overall moderate to steep (40° to 50°) dip to the southeast. The orientation of bedding is very consistent along strike. Bedding planes are the most persistent weakness identified in the sedimentary sequence. These low strength planes referred to as bedding shear surfaces occur within the BRCM and have been identified as critical features influencing slope stability. The orientation of bedding, and hence these low strength bedding parallel shears, relative to the pit walls have been the main control on the slope design angle and orientation at CCM. In most cases, when the

bedding surface dips unfavourably out of the slope, the wall has been designed parallel to bedding with restrictions on batter height to reduce the overall slope angle and minimise slab/buckle type failures associated with thinly bedded sedimentary sequences. This design has ensured adequate slope stability performance during the operational phase of the mine which I expect will continue through rehabilitation.

SLOPE DESIGN, MANAGEMENT AND STABILITY ASSESSMENT

12. The natural slopes surrounding the mine area comprise moderate to steep hills and localised steeper gully areas. As part of closure and rehabilitation, the final pit is to be partially backfilled and cut slopes re-profiled to provide a stable long-term landform. The highwalls will have additional support installed with buttress fills placed at the toe of the slopes. The buttress slopes will be constructed with overburden materials with foundations in competent in situ rock. The final topography will generally resemble the surrounding landform in terms of slope angles.

13. As noted at paragraph 11, the CCM cut slopes and engineered fill slopes have performed well during the mining operation with minimal stability issues. As set out in Tables 1 and 3 to the 2021 Geotechnical Review, the proposed closure slopes have a lower angle and have a higher factor of safety than the slopes present during the operational phase of the mine phase. Given that, I consider that the maximum slope angles of the final landform will not pose a geotechnical risk in terms of slope instability.

Slope Design Parameters

14. Based on the current understanding of the geological structure and material parameters of the various rock formations and overlying loess/gravels, slope design parameters have been developed for final slope angles in the in situ and engineered landform materials. These slope design parameters have been confirmed by geotechnical analysis[1]. The following sections set out the Geotechnical analysis undertaken, the slope design criteria adopted and the acceptability of the proposed landform from a stability perspective.

[1] CCM – Final Engineered Landform Geotechnical Review 2021 at Appendix A.

15. I refer to the CCM – Open Cut Geotechnical Review (BRL 2018) (**2018 Geotechnical Review**) for details of the geotechnical data that underpins the final landform stability assessment. By way of summary this review presents a geological and structural model of the CCM site, engineering geological properties of the different rock types and groundwater assumptions from field measurements. This information was combined into a geotechnical model and slope design parameters developed during the operational phase of the mine for the cut slopes and ELFs. The key outcomes from the 2018 Geotechnical Review were:

    (a) a geological model was developed to link the regional geology to the CCM site geology including a 3D stratigraphic geology model incorporating 22 separate coal seams constructed;

    (b) a structural model was developed describing the orientation and spatial distribution of rock mass discontinuities (e.g. bedding, bedding plane shears, faults etc) that are likely to influence stability of the slopes;

    (c) classification of the geomechanical engineering properties of the various rock and soil types and structural defects using a combination of laboratory testing, field observations and slope stability back analysis;

    (d) a site specific seismic hazard assessment was undertaken due to the number of major active faults recognised in the vicinity of the CCM. A probabilistic 100 year return period and horizontal peak ground acceleration of 0.23 g was determined appropriate for slope stability analysis at the site[2]; and

    (e) cut slope design parameters were developed for footwall cuts based on slope stability analysis and a detailed sensitivity analysis of water pressures and potential slope failure depths.

16. Based on the current understanding of the geological structure and material parameters of the various rock formations and overlying loess/gravels, slope

[2] Davis Ogilvie and Partners Ltd, 19th August 2016. Site specific seismic hazard assessment for Canterbury Coal Mine.

design parameters have been developed for final slope angles in the in situ and engineered landform materials. These slope design parameters have been confirmed by geotechnical analysis[3]. The following sections set out the geotechnical analysis undertaken, the slope design criteria adopted and the acceptability of the proposed landform from a stability perspective.

Slope Stability Assessment

17. The CCM cut slopes and engineered fill slopes have performed well during the mining operation with minimal stability issues. This favourable historic stability performance suggests the cut and fill slope angles and wall orientations constructed to form the pit have been appropriate for the material types and height of the slopes. As the final landform is being created the risk of geotechnical hazard is reduced and upon completion there is expected to be a very low geotechnical risk to the site and surrounding environment in terms of slope failures exposing overburden material.

18. Stability analyses to assess the long-term stability of the final landform were undertaken using limit equilibrium software. The analysis compares driving and resisting forces within a slope and determines a ratio (or Factor of Safety (**FoS**)) where values greater than 1 are increasingly more stable (failure is assumed to occur when the factor of safety is less than 1). The slope stability models assess the potential for instability including slumping through different failure mechanisms applicable to the final landform to determine those with the lowest level of stability.

Design Criteria

19. As set out in detail in the 2021 Geotechnical Review, the design criteria for the final landform slope stability are based on a design FoS of 1.3 for static 'design' groundwater conditions and 1.1 for 'elevated' groundwater conditions[4].

20. The 'design' scenario is for anticipated 'normal' groundwater conditions expected in the slopes within the design life whereas the 'elevated' scenario

[3] CCM – Final Engineered Landform Geotechnical Review 2021 at Appendix A.
[4] At Section 8.2, Page 14.

is for unfavourable groundwater conditions associated with heavy and/or prolonged rainfall events. The adopted design criteria assume the rehabilitated land will be returned to a mixture of forestry and farming use. These criteria are in general accordance with suggested limit equilibrium criteria accepted in other regions for similar low risk land use areas. For example, Auckland Council adopt a FoS of 1.2 for low risk areas such as parks and bush reserve land[5].

21. For seismic stability the design criteria requires either the FoS to be ≥ 1.0 or if FoS < 1.0 then permanent displacements must be less than 0.5m for a 250 year event design earthquake.

Slope Analysis

22. Overall, slope analysis results demonstrate satisfactory levels of stability for the final landform slopes under design groundwater conditions. The minimum calculated FoS was > 1.4[6]. This demonstrates that the slopes exceed the adopted design criteria.

23. In an elevated groundwater scenario, where there is potential for higher piezometric pressures the slopes are expected to remain stable and meet the stability design criteria.

24. The mine site is located in an area of high seismicity compared to other regions of New Zealand. I assessed the effects of a seismic load for the long-term stability of the proposed final landform. An earthquake event for the final landform was analysed using a pseudo-static approach, in which a horizontal load (0.31 g Peak Ground Acceleration (**PGA**)) was applied to the model to simulate the seismic loading. The assessment indicated displacement up to 0.1m could be expected for a 250-year event design earthquake. This level of displacement meets the adopted design criteria, and I consider the expected performance is therefore appropriate for the proposed end land use of farming and forestry[7].

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[5] Auckland Council – Code of Practice for Land Development and Subdivision – Section 2 Earthworks and Geotechnical Requirements. Version 1.6, 24 September 2013. Table 2.C.1 Factors of Safety.
[6] CCM – Final Engineered Landform Geotechnical Review 2021 at Table 4, Page 17
[7] CCM – Final Engineered Landform Geotechnical Review 2021 at Section 8.4.3, Page 16

25. In summary, the stability analyses demonstrate the final ELF is expected to provide a stable land form with a high level of stability. It has been designed to achieve this stability in the event of a seismic event.

Final Landform Settlement

26. As with any area where fill material is placed the CCM ELF's will also be subject to some settlement or consolidation over time[8]. A conservative 0.5% self settlement has been assumed for the truck rolled fill placement equating to an estimated settlement range between 50mm and 250mm. Most of the settlement is expected to take place during construction and shortly after completion (~<12 months). Any settlement post construction, albeit very small, will pose no hazard to the safe use of the land.

MONITORING REQUIREMENTS

27. The final landform will require temporary monitoring for a prescribed period as the landform is constructed and for a period post construction. While the proposed landform has been designed to appropriate standards to ensure long-term stability, monitoring is required to ensure that the slopes perform as designed. The landform should be inspected monthly during construction and then 3 monthly for a period of 12 months following completion. During construction, the landform will be surveyed with a drone on a monthly basis to similarly assess for signs of instability and conformance with slope design parameters. Any issues or deviations will be referred to the design engineer for risk assessment. The post construction monitoring period is of sufficient duration for inspection of ELF stability performance and any additional maintenance requirements. After this time, I consider that the ELF will have achieved a condition of long term stability equivalent to the surrounding unmodified landform.

RESPONSE TO SUBMISSIONS

28. As outlined in Craig Pilcher's and Claire Hunter's evidence for BCL, the closure proposal for the CCM is now substantially reduced from the expansion proposal that submitters originally commented on.

[8] CCM – Final Engineered Landform Geotechnical Review 2021 at Section 9, Page 18

29. The Royal Forest and Bird Society (**Forest and Bird**) raised a query in their submission regarding the probability of the Alpine Fault rupturing within the next 50 years and in the event of such a significant earthquake after mine closure could this expose the Potential Acid Forming (**PAF**) material buried in the ELF resulting in effects on downstream waterways. I have addressed this submission below.

30. The Alpine Fault is approximately 80 km NW of the CCM site and as discussed in the BRL Geotechnical Review[9] there are a number of active faults that are potential earthquake sources in close proximity to the mine (e.g., Porters Pass, Springfield, Hororata, Rockwood and Greendale Faults: GNS Active Faults Database). The response has been to include a relatively high PGA in the geotechnical analyses.

31. In an Alpine Fault event some of the energy may be redistributed onto other faults. While, the nature and extent of seismic loading onto other structures is difficult to measure and impossible to predict with any degree of certainty. Noting, that, the mine has previously experienced a large seismic event (M7.1 2010 Darfield) and reported minimal damage.

32. In large earthquake events ground movement such as land sliding typically occurs on marginally stable slopes. On the other hand, the final ELF has relatively low angle slopes and designed to an acceptable design FoS. As referred to at paragraph 24 above, I assessed the effects of a seismic load for the long-term stability of the proposed final landform. The assessment indicated displacement up to 0.1m could be expected for a 250-year event design earthquake, which meets the adopted acceptable seismic criteria outlined in the 2021 Geotechnical Review.

33. For an earthquake event larger than the design event such as a 1 in 500 year return period earthquake estimates of permanent displacements are expected to remain minor (e.g. <0.15 m).

34. Overall, it is my view that even if the ELF is disturbed by an earthquake similar to the design event the construction technique of the ELF will allow a

[9] CCM – Final Engineered Landform Geotechnical Review 2021, Section 8.2.3, Page 14.

degree of distributed deformation without compromising the integrity of the contained PAF material.

RESPONSE TO SECTION 42A REPORTS

35. I agree with the conclusions of Mr Donald Macfarlane in the final landform and slope stability review which found: *“there to be a very low risk of future instability of the final engineered landform assuming the adopted design geometries and stability criteria are implemented and the slopes are not fundamentally changed by post mining land users”*.

36. I agree with Mr Macfarlane the appropriate seismic hazard has been used for the final landform and stability assessment of the site[10].

37. The Section 42A reports of Mr Andrew Henderson and Ms Adele Dawson rely on the findings of Mr Macfarlane[11]. Ms Dawson agrees that the design earthquake adopted is reasonable in terms of risk to human life and property and the consequences of slope failure at the site being low. I agree with this conclusion[12].

38. In terms of the proposed conditions discussed in the Section 42A report of Ms Dawson[13], I agree the final landform will require monitoring during and following construction as detailed in the 2021 Geotechnical Review. I agree with the recommended inspection details for during construction and post construction monitoring and the use of a trigger action response plan in the event of a specified seismic event or high intensity / prolonged rainfall event above a trigger level. However, it is my view that the post-construction monitoring period of 12 months outlined in the 2021 Geotechnical Review is of sufficient duration to confirm design assumptions and predicted slope stability performance given the knowledge of existing onsite monitoring and inspections undertaken during the operational phase of the mine. Should settlement or field observations of slope performance be outside of design assumptions an extended period of an additional 12 months monitoring

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[10] Section 42A Officer’s Report, 24 September 2021, Appendix 3: Section 42A Report of Don Macfarlane.
[11] Section 42A Officer’s Report, 24 September 2021, Appendix 3: Section 42A Report of Don Macfarlane.
[12] Section 42A Officer’s Report, 24 September 2021 at [270].
[13] Section 42A Officer’s Report, 24 September 2021 at [288(b)] and [289].

would be recommended. Following the monitoring period to demonstrate long-term stability there should be no requirement for the land-owner to continue monitoring.

Michael James Begbie
1 October 2021