Woodstock Quarries Ltd

Attention Darryn Shepherd

11 February 2022

Woodstock Quarry RFI - response to geological questions

A number of geological and/or hydrogeological questions have been raised by Ecan's reviewers. As requested, I have considered these questions and have summarised the questions and my responses below.

Item 1.1 (a) Please provide responses to all question in Section 5 of the attached *CRC214073 Landfill Compliance Review Woodstock Quarries Limited* letter, dated 31 May 2021, and address all the issues identified, particularly in relation to the recommendation to reconsider or further justify the proposed cut slope profile.

Q21 Section 62 of the AEE application states that fresh greywacke would be suitable for use as a low permeability liner and for capping or drainage layers. This is unlikely to be the case. Possibly the author should be referring to the overlying weathered greywacke which is likely to be more soil-like and may prove suitable as a low permeability layer? Fresh greywacke material is likely to be a crushed rock and to form a high permeability product, which would also not be compatible with the proposed geosynthetic liners.

Response: The first sentence of Section 62 should be reworded to read "Weathered rock occurs in the upper 10-15m below ground level." Remainder of Section 62 is then OK.

Q22 Several sections of the report suggest that the proposed bench with of 2 m in the cut highwalls may prove insufficient to control the release of rockfall from a safety perspective. Those sections of the report referring to the cut slope design and require clarification or amendment are provided below:

a. The Geology report, Figure 6, shows greywacke bedding, which the caption states is dipping "approximately 40-45 degrees to the right" into the face with conjugate joints dipping at 45-50 degrees into the pit. This seems at variance with statements in Section 3.1.3 of the report where the bedding dip is "(commonly > 80°)" which would give a conjugate joint set dip set of 10 degrees. Drawing 02 and 03 in Appendix 2 show cut slopes on the section that are much steeper than 45 degrees with minimal bench width. Figure 13 in the Geology report shows cut batter slopes in fresh greywacke that appear to be dictated by the bedding angles. Later comment suggests the issue of the cut highwall designs needing further work to confirm the proposed design profiles in each wall. As the angle that the slopes can be cut at is key to landfill airspace, stability and operations, this aspect requires clarification.

Response: The reviewer appears to have mis-read Figure 6. The caption clearly states that the greywacke is steeply dipping and that there are <u>joints</u> dipping 40-45° to the right. For clarification, the bedding dips ~80° to the left in the photo.

b. In Section 5.5 of the Geology Report the first paragraph states that the quarry walls will be cut at an unstated angle (presumably dictated by rock defect dip in each wall) with 10 m high inter-bench heights and a 2 m bench. Firstly, this gives an overall angle of 79 degrees which is steeper than the Joint sets J1 and J3 in Table 1 of the Geology report and those shown in Figure 6. Depending on wall vs Joint orientation rock blocks underlain by J1 and J3 will daylight in the proposed cut face and are likely to be unstable as indicated in Appendix C. This could lead to local cut slope failure and represent a danger of rockfall to site staff. Has this risk been considered in the selection of bench width design?

Response: This is a valid point. Response 23 below provides details of a slope redesign.

c. The cross-sections in Drawing B4 illustrate the proposed cut wall slopes. The scale is uncertain but one of the cut walls may be 80 m high if the height intervals are 10 m. This highlights the potential safety issue and the need to ensure the rockfall risk is adequately managed for staff safety. One example from open cast NZ coal mines, is the use of a highwall profile with a 15 m inter-bench height and 8 m bench width to manage rockfall and to provide maintenance access. This gives an overall wall angle of 62 degrees. This angle may better manage both wedge and toppling failure types at Woodstock.

Response: This is a useful comment that has been considered in the slope redesign described below in the response to Q23.

d. The kinematic analyses of the joints and cut slope interactions presented in Appendix C of the Geology report highlight that a high number of failure possibilities for the East and South wall for both wedge sliding and toppling failure modes reinforcing the importance of a sound design cut profile.

Q23 Overall, considering the above points, the applicant should either reconsider or further justify the proposed cut slope profile, particularly with respect to the design cut slope angles and 2 m inter-bench width to ensure consistency with the geological defect orientations, the adequacy of the proposed bench width and its ability to control rockfall from a safety perspective.

Response: Based on the above helpful comments and suggestions, the slope design has been reconfigured to improve safety. The revised proposed design is provided as an attachment. The design philosophy, as noted on the drawing, is

- 10m vertical separation between benches
- Bench widths of 2m and 5m (alternating)
- 5m wide bench within weathered zone (exact base of weathering unknown and expected to vary)
- Overall slope angle ~70°

Q24 Is the stripped overburden material stockpiled around the quarry area an instability threat to the landfill, and to the safety of people working in the pit area?

Response: Management of stripped overburden is not an engineering geological issue. I have recommended that the stockpiled material should be removed to be at least 10m from the top of any long term batter.

Item 1.2. The monitoring wells (MWs) do not appear to have been placed to intercept fault/shear zones. The highest groundwater conductivity (K) values would be expected in the faulted/fractured rock. Groundwater levels may also be most critical near these structures, i.e., if the faults/shears act as drains then the hydraulic gradient may increase significantly near these features. Further, it is understood that drilling of MWs was carried out without extracting a core, which would have been useful to characterise the fractures below the site (i.e., are they clean/infilled, open/tight, etc.?).

Please provide an investigation of fractures and joints of the exposed pit walls to get an understanding of the fracture characterisation for the site.

Response: It is correct that the MW's were not specifically sited to intersect fault/shear zones. A hydrogeologist might do that, an engineering geologist working on a dam investigation would more likely recommend angled holes across known or suspected faults to do packer tests.

Drill core from greywacke typically breaks along joints and it is hard to confidently demonstrate that they are tightly closed from drilling. Generally, below the weathered zone the joints in undisturbed greywacke are kept tightly closed by the weight of the overlying rock.

Field mapping has shown that the greywacke rock at the site is (as is typical of Canterbury greywacke) highly jointed with multiple joint sets and variable spacing. In exposures within the quarry, the joints below the weathered zone are typically either clean and tightly closed except for superficial opening due to blast damage and rockmass relaxation, or they are healed with quartz (forming veins).

Please also consider whether or not further investigations are necessary to confirm conductivity of the underlying rock and whether there are fault/shear zones within the site of the proposed landfill.

Response: This matter is addressed in Appendix 4A Hydrogeology Report 2, which forms part of the response to the RFI.

Item 1.5. The Geology Report notes “minor rock types that may be found interbedded with, or faulted into, the greywacke include limestone, chert, and conglomerate, none of which have been observed on site”. The geologist confirmed in the site visit that there is no limestone onsite.

Please confirm this in writing and whether this statement applies to all areas and depths to be quarried and filled.

Response: There is no evidence of other rock types interbedded with the greywacke in exposures at the site. A review of the literature found no reference to limestone within greywacke anywhere in the South Island.

We will never know for certain until the rocks are excavated and we can see the quarry walls and floor. This is true of any excavation in any material – we can be 99% sure but never 100% of what we will find in the ground. I’m happy to say I’m 99% sure and that the depositional environment suggests deep water sediments (limestone only forms in shallow water).

Please confirm whether or not the argillite beds are calcareous as carbonates can dissolve in weak acids such as rainwater over long periods of time, or very quickly with stronger acids (i.e. potential leachate from the landfill).

Response: I have never come across calcareous argillite and found no reference to it in a review of the literature. We tested this concern by putting a few drops of 10% hydrochloric acid onto unweathered argillite exposures at 10 locations in the existing quarry. The rocks would fizz if they contain calcite. None of the test sites indicated any response suggestive of calcite. From this I conclude that the rocks at the site are non-calcareous and at worst may contain only trace amounts of calcite as secondary minerals in veins.

Item 1.7. We agree with the description given for the expected groundwater behaviour, i.e. the intact rock has a low conductivity, and groundwater flow is likely to be dominantly fracture flow or along bedding planes. However, to predict where potential contaminant may flow, it is recommended that structural mapping of faults/shear zones in the area (local to pit, not just regional). This would help with placement of monitoring wells (also see Question 5.9 below).

Please provide a conceptual model of the groundwater system specific to this site, considering local structure, geology, recharge, and specifically discharge mechanisms.

Response: As indicated in the Geology report, in addition to bedding shears in the pit, I observed one sheared zone near MW3/MW4 (in the side of the pond – see Figure 11) and inferred two others from the topography, one of them passing very close to MW7/MW8 (as shown on Drawings G-02 and G-03)

Item 1.8. Blasting is currently used as part of pit excavation. This is expected to increase fracturing and potentially increase permeability in the rock surrounding the pit.

Please confirm how fracturing and increase in permeability in surrounding rock will be monitored and managed throughout the quarrying operation and how the proposed landfill cell design will be informed by this information.

Response: Blasting may loosen rock to shallow depth (generally less than 1 m) in the side walls or base of the excavation. In my experience the degree of damage depends on the blast design and can easily be controlled.

T+T Review

Q30 The geological report describes a high groundwater level surrounding the landfill. Please provide details of the expected groundwater inflow through the unlined side slopes of the landfill and the expected impact of this on the liner system, leachate containment, leachate quantities and the overall design of the leachate management system.

Response: This is separately addressed by the hydrogeologist. The geology report was a 'first pass' that inferred a groundwater table based on the topography and streams. As stated on page 12 in the report, the monitoring data appears to show that the unweathered and slightly weathered rock is virtually impermeable and that groundwater infiltration and flow occurs within the upper weathered rock zone where it will be recharged by rainfall and runoff.

T+T Review, Appendix A

Item 17 The geology reporting highlights the risk of rockfall both small and large scale. Please provide further clarification on how this will be managed in terms of landfill worker safety, overall slope stability, adopted benching profiles and protection of the landfill liner.

Item 18 Weathered rock is located above the hard greywacke rock, however proposed excavation profiles do not appear to take into consideration this weather rock with the same 10 m high 2 m width benching profiles adopted. Please provide technical justification and analyse for this design.

Response: The proposed bench widths, batter slope angles and height between benches are conservative and are designed based on kinematic analysis (presented in the report – p16-17 and Appendix C). Following initial review comments by T+T, the bench widths were increased to 5m, thus reducing the overall slope angle, as detailed above, to improve overall stability and reduce the risk of rockfall to workers.

Closing

I trust that these notes provide sufficiently detailed responses to the geological questions raised by ECan. Please do not hesitate to contact me if additional explanation is required.

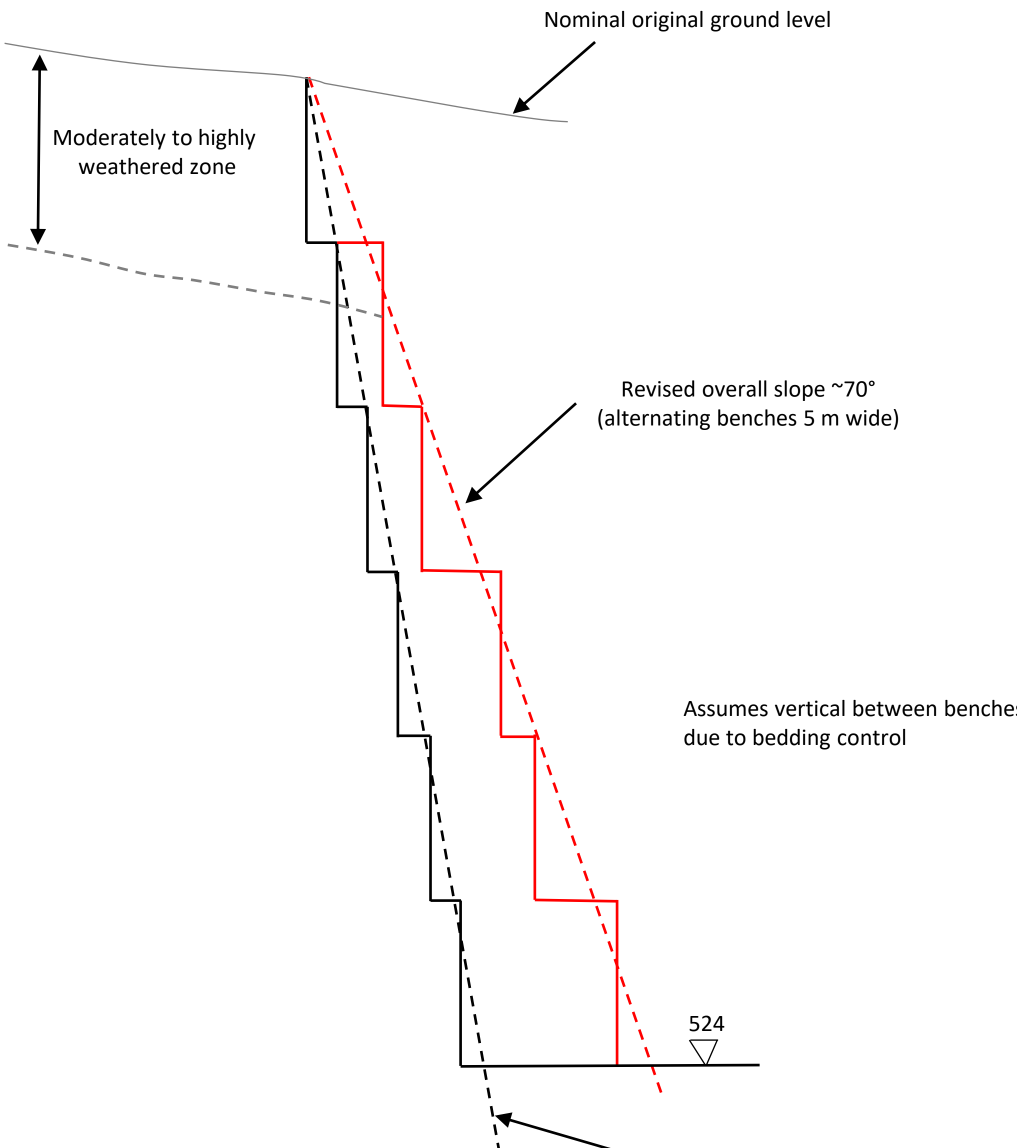
Yours faithfully

D Macfarlane

Don Macfarlane
Consultant Engineering Geologist

2 Attachments

Woodstock Quarry – Revised Pit Slope Design



Design Basis

1. 10 m vertical between benches
2. Bench width 2 m and 5 m alternating
3. Overall slope ~70°

	Bench Width (m)	Overall Slope (°)
Original slope design	2 m	~80°
Revised slope design 1	2 m and 5 m (alternating)	~70°