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Dear Logen

Kiwi Point Quarry - Review of Geotechnical Information

1 Introduction and Background

Kiwi Point Quarry has been owned by Wellington City Council (WCC) and was operating as a Council Business Unit until 2006, when it was contracted out for operation. Holcim (NZ) Ltd (Holcim) is the current operator of the quarry.

The current quarry operation is proceeding at the area referred to as the Northern Face (Areas A, B, and C) and the availability of good quality resource is expected to last for another 3 to 4 years, at present rate of consumption. In the view of this, Holcim are suggesting to expand their quarry operations to the so-called Southern Face and specifically Area H, which is an approved quarrying area under the current District Plan.

Due to safe design of quarry slopes requirements and in order to make the development of the quarry economically viable, Holcim are proposing to expand the quarry operation to the west of Area H, which is designated as Open Space B, under the current District Plan. As a result of this, a change of the current District Plan is required.

Apart from the above, the current Northern Face slopes of the active quarry have presented instabilities over the years and require laying back at a more stable angle. This laying back will result in encroaching into the northern buffer area which is also designated as Open Space B under the current District Plan.

Holcim have carried out geotechnical investigation and prepared a number of geotechnical reports to support the proposed changes of the District Plan. For the preparation of the reports Holcim engaged Geoscience (ENGEO) and Ormiston Associates Ltd.

Wellington City Council engaged Opus International Consultants to review the available geotechnical reports with the aim to ensure that all the appropriate geological and geotechnical information and assessment is in place to support the proposed change of the District Plan.

This letter presents the comments and observations of the review of the geological geotechnical information relevant to the existing and proposed development of Kiwi Point Quarry (KPQ).

2 List of reports reviewed

The following documents were initially provided by Wellington City Council on 13 June 2016:

1. Wellington City Council (2015), Proposed Kiwi Point Quarry Extension 2015, Memorandum by Logen Logeswaran, January 2015
2. Incite (2016), Kiwi Point quarry Expansion Issues and Options Report, April 2016.
3. Ormiston Associates Ltd. (2016), Report on the proposed development for the Business Centre Area, South Ridge, Kiwi Point Quarry, February 2016.
4. Ormiston Associates Ltd. (2016), Report on the proposed development for Open Space B Area, South Ridge, Kiwi Point Quarry, February 2016.

Following the review of the above documents and the attendance of a workshop in Wellington City Council on 23 June 2016, additional geological – geotechnical information was requested from WCC, which was received on 28 June 2016. The additional information includes the following:

5. Ormiston Associates Ltd. (2016), Southern Ridge Queries Response for Wellington City Council, Memorandum by Sandy Ormiston et al., 27 June 2016.
6. Geoscience Consulting (NZ) Limited (2015), Slope Stability Review, Kiwi Point Quarry, Ngauranga Gorge, Wellington, 24 February 2015.
7. Ormiston Associates Ltd. (2014), Site Plan – Southern Ridge – Borehole Locations, Dwg. No. 3655–SR-1, 4 August 2014.
8. Ormiston Associates Ltd. (2014), Geological Section SR1 – SR1' Revised 16-10-14, Dwg. No. 3655–SR-1, 16 October 2014.
9. Ormiston Associates Ltd. (2014), Geological Section SR2 – SR2' Revised 16-10-14, Dwg. No. 3655–SR-2, 16 October 2014.
10. Ormiston Associates Ltd. (2014), Borehole Logs, BH 406 to BH 412, June – July 2014.

3 Review comments

3.1 General

Our review is at a high level and no independent calculations or site visits were carried out at this stage. Our review comments are focused on the following objectives:

- To ensure that the appropriate geotechnical information and assessment are in place to support the proposed change of the District Plan.
- To ensure that the slope stability and other geotechnical risks imposed to the surrounding environment by the quarry operations are low.
- To ensure that the long term stability of the final slopes to be returned to WCC is satisfactory, without the need to implement extensive stabilisation and risk mitigation measures, or additional change of the District Plan for laying back.

As the information collected and assessed for the stability assessment and operational safety of the existing quarry slopes by Geoscience (Geoscience, 2015) was used for planning of the new proposed development in Area H and Open Space B, this report was also taken into account in our review.

3.2 Slope description and context

It is noted that the existing quarry slopes (Northern Face) are estimated to be of a height of the order of 80 - 90 m (based on the analysis outputs provided in the appendices of the Geoscience report) and appear to be at an overall angle of 60 degrees, consisting of intermediate slopes (batters) at 80 degrees 22 m high and benches of a width less than 4 m. The proposed laying back is at an overall slope angle of about 40 degrees, with intermediate slopes (batters) at 55 degrees, which will result at slope heights of about 100 m.

Dwellings of the residential area of Johnsonville are located above (upslope) of the Northern Face slopes, at a distance of 50 m to 80 m approximately from the crest of the existing slopes. This distance will be reduced by the proposed laying back of the slope to about 40 m from the crest of the existing slope.

The height of the quarry slopes of the proposed new development (Southern Face, i.e. Area H and Open Space B) vary at the different stages of the proposed quarry development, with the final slope height to be of the order of 170 m (Section SR2-SR2', Drawing no 3655-SR-2, Ormiston 2014). The overall slope angle proposed for these slopes are 40 degrees approximately, consisting of intermediate slopes (batters) at 45 degrees in brown rock and 55 degrees in blue rock, 15 m high, and benches 5 m wide.

Existing infrastructure adjacent to the new development is State Highway 1 at the northeast and the Commercial Centre at the southeast. The residential area of Kandallah, which is located upslope at the southwest of the proposed development, appears to be at a distance of ~100 m from the final proposed slopes and is not considered to be affected.

3.3 Review comments

The key points of our review are presented below:

Proposed Slope Angles

In Section 5.1.1 of the Geoscience report it is mentioned that 55 degrees is the commonly accepted long term maximum batter slope angle of Greywacke in the Wellington Region and 45 degrees are referred to as a conservative recommendation. These slope angles appear to have been adopted in the design of the new development at the Southern Face.

We note that the long term adequacy of slope angles proposed for each slope depends on local rock mass quality, orientation of rock defects, slope height, the wider context of slope, and acceptable risks. As a result, the adequacy of the slope angle, especially for so high slopes, should be thoroughly examined.

Slope Stability Analysis

Slope stability analysis was mainly carried out for the existing quarry slopes (Northern Face) by Geoscience (Geoscience, 2015). We understand that the slope angles recommended for the new quarry development at the Southern Face (Area H and Open Space B) are based on this analysis. The comments referred for the analysis of the Northern Face should be appropriately taken into account in the design of the new slopes.

We note that the global stability of the Northern Face quarry slopes (existing and new proposed configurations) are only examined against circular failure through rock mass, which is not considered to be the most critical for greywacke rock. The possible presence of persistent rock defects such as shear zones and crush zones, or combined failures through such defects and poor quality rock mass have not been examined. *These types of failures are considered to be the most critical for the long term stability of the slopes in Greywacke rock, especially under seismic loading*.

Further, the Factor of Safety (FoS) against circular failure through moderately weathered rock for the Northern Face slopes for Scenario 3 (55 degrees batters) for the 1:500 years earthquake is <1. The implications of such a type possible failure and the risk imposed to the areas above and below the slopes need to be further discussed for the long term use of the land. The slope stability analysis and the possible mechanisms of failure identified will confirm the adequacy of the distance to the residential area above the existing slope, as well as the width of the no built zone from the base of North Face slopes (currently proposed 5 m no build zone for a 100 m high slope, see Table 5 in Geoscience Report, 2015).

In the slope stability models, the presence of soil overburden and highly weathered rock should be also taken into account. A slope angle of 45 or 55 degrees in such material may not be adequate. Ormiston memorandum provided following our request for additional information, suggests a 30 degree angle in such material. The adequacy of this angle should be examined by analysis and the areas of application of this slope angle should be specifically shown on the drawings.

Further, the excavation methodology and slope stability of temporary slopes during staged excavation of the quarry affecting existing infrastructure (e.g. SH1) should be examined in more detail.

Geological mapping and assessment - investigation of rock defects

Persistent defects in Greywacke rock are critical for slope stability and eventually govern the stable slope angle in this material. As mentioned in the previous comment these defects are not taken into account in the slope stability analysis.

It is not clear if such persistent critical defects (e.g. shears) were found on the existing Northern Face slopes during geological mapping. We note that such defects are not easily identified on the slope face during mapping, especially if they are adversely oriented. They can be spotted though by mapping a slope face perpendicular to the existing face or with downhole geophysical survey in boreholes, which has not been carried out in the boreholes for the new development. Such downhole survey is relatively quick and cheap and can provide valuable information on rock quality and defects.

In Section 4.2 of the Geoscience report the presence of “greasy back” structures are observed at the northeast and the northwest of the North Face (domains N1 and N2). These structures are described as stress-relief induced, parallel to the original ground surface (are they parallel to the excavated slope face?) and “more persistent” than the ones in the rock mass beneath. The location, orientation and persistence of these defects with respect to the existing slopes of the North Face, as well as their possible effect on the stability of the slopes and the surrounding environment above and below the quarry slopes in the short and long term should be further explained and examined.

Could the above defects systematically appear in the entire area (Area H and Open Space B)? This may be demonstrated by a more detailed assessment of available defect mapping information from the entire area.

Further, planar failure was observed on the West Wall of the existing Northern Face slopes (Geoscience, 2015). This failure should be further explained and assessed (mechanism - size – conditions) and the findings should be taken into account in the stability analysis. Is the failure along one of the inferred as key discontinuity sets and what would that mean for similar failures occurring in the future or in new developments?

An inactive fault is mentioned to be suspected between the West and the North Wall. It is mentioned that it is unlikely that the rock mass consisting the proposed slopes are affected by this feature. What are the dip and orientation of this feature, can they be measured on site? We believe that this feature and the effect on rock mass and slope stability should be investigated further, especially for the new developments proposed in Area H and Open Space B.

We believe that further assessment of general published information relative to the site and of the existing mapping information could provide a better understanding of possible systematic appearance of predominant critical defects for the entire site.

Geological interpretation of Southern face (Area H and Open Space B)

The inferred depth of resource (blue rock) presented in the geological sections SR1-SR1’ and Sr2-SR2’ appears to be reasonable, based on the borehole logs. Some fluctuation of the depth of the resource along the entire area of proposed quarrying could be expected, as indicated by BH 407.

However, we note that the geological interpretation of the collected information is at a relatively high level. The sections should provide more detail of geology and tectonics expected in the area of the pit, i.e. presence of faults, interlayers of argillite or the rock quality of the overburden. These elements could influence slope design and estimated quantities of overburden and resource.

The possible presence of a fault zone is inferred in the area (shown in the 1:50,000 Geological Map of the Wellington region, observed during mapping as part of the Geoscience report and also possibly inferred from the quality of rock mass in BH409). The presence of a fault zone could influence both the stable slope batters (for temporary excavations as well) and the quantity of available resource, as a result the presence, extent and orientation of such a zone should be investigated further.

Rock fall analysis for Northern Face

The recommended slope batter angles in Table 1 (Geoscience, 2015), based on kinematic analysis results and structurally controlled failures in the rock, are between 35 and 50 degrees, depending on the slope aspect. The suggested slope angles of 45 and 55 degrees, obviously allow some failures to occur, which will be contained in the benches temporarily and eventually generate rock fall.

Rock fall stability analysis was carried out in the Geoscience report, however the material used on the bench surface and at the bottom of the slopes do not appear to allow bouncing of rocks away from the slope. This implies that the distance from the toe of the slope affected by rock fall has not been examined. This should be further explained. Further, seismic loading should be accounted for in the rock fall analysis to assess the long term rock fall risk.

Following the above comments the adequacy of the rock fall protection measures proposed in the Geoscience report (Table 5) should be confirmed against all possible rock fall for the final long term configuration of the slope.

4 Recommendations

The proposed District Plan changes are more likely to be accepted if they are supported by a robust geotechnical assessment and proposal. An adequate geotechnical assessment will provide confidence that the proposed new District Plan boundaries are appropriate to accommodate the long term stable slope angles and further change will not be required in the future. A possible change in slope angles to fit within the approved boundaries could compromise the quantity of useful resource extracted.

A better understanding of the rock structure and presence of defects in the entire area is required to provide confidence on the proposed slope angles for both the Northern Face and new development at the Southern Face. The assessment should be carried out with a focus on the Northern Face, where there is abundancy of rock exposure, and the results adequately extrapolated to the proposed areas for new development, Area H and Open Space B. The following supplementary assessment is recommended to be carried out to support the district plan change, points 1 to 9 below:

1. There is indication that persistent rock defects are present in the area of Northern Face ("greasy back structures, inactive fault etc.). A more thorough assessment of these and other defects, which could possibly be critical for the stability of the slopes in the entire area, should be carried out.
2. The defect assessment could initially include a desktop interpretation of ground models obtained using best practice modern surveying and inspection techniques,

such as Unmanned Aerial Vehicles (UAV), that have good application on slope stability problems, especially at steep and inaccessible sites. Older aerial photographs could be also studied. Alternatively, laser scan could be used. The techniques mentioned (especially UAV) are cheap and quick and can provide invaluable information regarding location and orientation of persistent defects.

3. Supplementary geological mapping is recommended to be carried out on site, following the desk top study to supplement the information. The mapping could be focused on the Northern Face, possible existing excavations perpendicular to the North Face slope and rock exposures near and around Area H and Open Space B. The mapping should aim at confirming the critical defects identified in the desk top study, and to assist adequate extrapolation of defects at the entire area. Past failures (e.g. the planar failure on the west slope and others) should be adequately assessed to provide insight on the possible critical defects.
4. Mapping or digital terrain models interpretation should also identify areas of poor quality rock (HW or highly fractured) on the slope faces as well as the extent and depth of soil overburden or highly weathered rock at the top of the slope on the Northern Face.
5. The results of the above supplementary assessment, especially in terms of defects, should be taken into account in the stability analysis of the Northern Face. Defect controlled large scale mechanisms should be examined (formed by defects only or combined defect – poor quality rock mass) for the long term condition and the slope angles revised accordingly, if required.
6. Potential instabilities and risk should be assessed in relation to the long term use of land, i.e. for the final slopes to be returned to the Council, taking into account the existing and intended infrastructure above and below the slopes.
7. Rock fall risk should be examined for the final proposed slope, allowing bouncing of the rocks on the benches and ground at the bottom of the slope, to determine the adequate width of no-build zone and possible additional protection measures, if required.
8. The geological long section of the new proposed development (Area H and Open Space B) should be supplemented with more detailed information (all boreholes carried out, information on rock quality, brecciated material, any critical defects identified by the supplementary assessment). The slope angles recommendations should be revised according to the results of the additional assessment (if required).
9. The upper part of the slopes possibly formed in soil overburden or highly weathered material may need to be designed at a shallower angle. This will be demonstrated by stability analysis. The flatter angle proposed should be shown on the drawings supporting the District Plan change proposal.

For the design of the proposed new development (Area H and Open Space B) we propose the following:

1. Detailed assessment of defects and rock mass quality. The defect assessment could be carried out with detailed geological mapping, when more accesses are formed. Downhole geophysical survey in any new boreholes to be carried out is recommended. The investigation should be focused in identifying the persistent defects that could be critical for the overall stability of the slopes (temporary and permanent).
2. The extent and depth of the possible fault zone should be investigated further, as it could affect slope stability as well as the quantities of resource / overburden.

3. The proposed stages of excavation should be shown in drawings. Proposed slope angles should be confirmed by appropriate stability analysis for all possible modes of failure (rock mass, defect controlled small and large scale and combined defect- poor quality rock mass), following the recommendations of Worksafe best practice guidelines (Worksafe, 2015) for the design of new excavations in quarries.
4. The potential failures for each stage of excavation should be assessed in terms of the risks imposed to the operation of the quarry but also to any adjacent infrastructure temporarily or permanently affected (e.g. the Motorway).
5. The long term stability and possible landscaping or rehabilitation requirements of the final slope to be returned to the Council should be taken into account in the design of the new development.

We remain at your disposition for any clarification and additional information may be required.

Sincerely yours,

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