20 December 2018 Reference No. 1773474_7407-001-LR-Rev0-1023_0003

2016 Kaikoura Earthquake Recovery Manager
Kaikoura District Council
PO Box 6
Kaikoura 7340

1800, 1802 SH1, BOAT HARBOUR, KAIKOURA – DANGEROUS BUILDING RISK ASSESSMENT

Dear Recovery Manager

1.0 INTRODUCTION

This letter report[1] documents a dangerous building risk re-assessment for the residential buildings located at 1800 and 1802 SH1, Boat Harbour, Kaikoura, undertaken by Golder Associates (NZ) Limited (Golder). Golder has conducted several previous studies of these properties including:

- Golder 2017a[2]
- Golder 2017b[3]

These buildings were issued with Section 124 notices in August 2017 because of slope instability hazard following the 14 November 2016 Kaikoura earthquake. This letter report builds on that previous knowledge considering 20 months of observed performance since the earthquake.

The current report:

- Draws together dangerous building risk assessment criteria
- Re-assesses the likelihood and consequences of slope instability hazard, accounting for uncertainty
- Compares dangerous building risk criteria to the assessed likelihood and consequences
- Identifies potential slope instability risk mitigation options

This report does not make a recommendation on whether buildings on these properties should or should not be considered a dangerous building, but rather provides the information to assist Kaikoura District Council when making their assessment.

This work has been undertaken under the existing agreement between Kaikoura District Council and Golder. This report does not assess all possible natural hazards that may affect the site – only those that have been identified on the Civil Defence Emergency Management placards placed on the buildings following the November 2016 earthquake. The scope for the assessment of hazards in this report is focused on providing

[1] This letter report is provided subject to the attached Report Limitations.

[2] Golder (2017a): Boat Harbour Slope Hazard Study – Stage1: Report 1773474_7407-001-R-Rev1-1017 to Kaikoura District Council, dated July 2017.

[3] Golder (2017b): 1800 and 1802 (Two Buildings) State Highway 1, Boat Harbour, Kaikoura – CDEM Placard Reassessment and Section 124 Notice. Report 1773474_7407-001-LR-Rev1-1018_006-1800_1802-SH1 to Kaikoura District Council, dated 20 August 2017.

Kaikoura District Council with information so that they can make an informed dangerous building assessment. A more detailed analysis may result in alternative recommendations.

2.0 OBSERVATIONS OF ROCKFALL AFFECTING THE PROPERITES

Rockfall affecting the occupied buildings on the properties, as a result of the 2016 Kaikoura earthquake was described in Golder 2017a. The key observations were that at least one boulder penetrated the roof of 1800 SH1 and many boulders either hit, or had trajectories that could have hit, the occupied buildings. No occupant was injured or killed because of this rockfall.

Observations from new site visit

An engineering geologist from Golder visited the site on 27 August 2018. The objective of the site visit was to observe and record any evidence of ongoing slope instability that has affected the site since the last site visit in August 2017.

The following observations were made during the site visit:

- The buildings on both sites have a red notice taped to the window indicating that each is a dangerous building in accordance with Section 124 of the Building Act 2004 due to *'very high risk of rockfall'*.
- The buildings were unoccupied at the time of the visit.
- No evidence was observed of new rockfall boulders having hit or travelled past the buildings on these properties.
- Several boulders were observed around the buildings and the railway formation between the properties and the toe of the adjacent slope. While many of the observed boulders are believed to have fallen during the 2016 Kaikoura earthquake, some are located against the rockfall monitoring fence constructed along the railway indicating that they fell during approximately the least 12 months. In addition, we are aware of at least one occasion when rockfall boulders fell on the railway tracks.
- Anecdotal photographic evidence provided to KDC indicates that a rockfall boulder reached the back wall of 1802 SH1 in July 2017.
- Many rockfall boulders were observed on the slope above the properties and, along with the heavily dilated rock outcropping in the upper part of the slope, represent a significant source area for ongoing rockfall.

During the period of nearly two years since the 2016 Kaikoura earthquake several factors relevant to rockfall hazard at the site are evident:

- **Aftershock sequence:** Kaikoura has moved through a period of heightened earthquake aftershock activity immediately following the 2016 Kaikoura earthquake and earthquake likelihood is now approaching the background level[4]. Earthquakes are a common trigger for slope instability.
- **Heavy rainfall events:** Several heavy rainfall events have affected the Kaikoura Coast since the 2016 Kaikoura earthquake. The nearest rain fall gauge is located at Rosy Morn[5], about 5 km from the site. Several significant rainfall events have been recorded since November 2016, including ex-tropical

[4] https://www.geonet.org.nz/earthquake/forecast/.

[5] https://ecan.govt.nz/data/rainfall-data/.

cyclone Gita (20 February 2018) which resulted in about 300 mm of rainfall in 24 hours at the Rosy Morn rain gauge. This is estimated to have a return period in excess of 100 years. We note that this is useful information but that there is likely a high degree of spatial variation in rainfall events due to the geography of the region and the nature of the storms.

It is unclear whether the additional rockfall activity that appears to have affected the properties since the earthquake is the result of any of the heavy rainfall events. Potential additional trigger mechanisms that could have generated rockfall during the period or could generate future rockfall include:

- Livestock on the slope
- Scour of supporting material
- Impact from a smaller boulder
- Fire
- Earthworks or other human activities on the slope.

3.0 EVALUATION CRITERIA FOR *DANGEROUS* BUILDINGS

Under the Building Act 2004:

- Section 121, a building is dangerous if… "*in the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause injury or death (whether by collapse or otherwise) to any persons in it or to persons on other property or damage to other property."*
- If a territorial authority is satisfied that a building is dangerous it may issue a Section 124 notice to prevent people from occupying or approaching the building.
- In the context of the Building Act, '*in the ordinary course of events*' has been interpreted as '…*likely to be encountered in the course of a year… but would exclude incidents not normally occurring, such as, for example, 50-year floods and cyclones*.' (Judge McGuire, DC Rotorua NP966/97). Likely in the context of the Building Act has been interpreted as: '*likely does not mean probable, as that puts the test too high. On the other hand, a mere possibility is not enough. What is required is "a reasonable consequence or [something which] could well happen".*' (Judge Boshier, DC Auckland NP2627/95, [196] DCR 635).
- Golder refers to the test for "likely", as per the 2012 High Court judgement of The Wanaka Gym Limited v Queenstown Lake District Council[6], which upholds an earlier judgement by the District Court.

> "In *Weldon Properties Ltd v Auckland City Council* this Court upheld a District Court judgement in which it was stated that "likely" for the purposes of the predecessor section to s 121 does not mean "probably", as that puts the test too high. On the other hand, a mere possibility is not enough, so it has to be a reasonable consequence or something that could well happen".

While we are unable to provide advice on the legal interpretation of the test, from a geotechnical perspective we interpret that a reasonable definition of probability of injury or death consistent with the legal interpretations above of 'likely in the ordinary course of events' is between 10 % and 50 % probability in 50 years, which equates to annual probability of 1/475 and 1/73 respectively.

[6] High Court of New Zealand, Invercargill Registry. The Wanaka Gym Limited v Queenstown Lakes District Council. CRI-2011-425-00002, CRI-2011-425-00003 [2012] NZHC 284, dated 27 February 2012.

These criteria are shown graphically on Figure 1 using the likelihood and consequence tables in Attachment B that have been developed for this study.

- The guidance is unequivocal that the consequence must exceed minor injuries, so risk of minor injuries and lesser consequences are not considered as slope instability risk for dangerous building assessment.

  The heavy black vertical line on Figure 1 represents the boundary between where the consequence exceeds a minor injury and where hospitalisation may be required. Therefore, the area to the right of that line can be considered to exceed the consequence criteria.

- The two heavy black horizontal lines represent annual probabilities of 1/475 (dashed line) and 1/73 (solid line) likelihood criteria. The area of the graph above each of these criteria can be considered to exceed each likelihood criteria.

- The dashed and solid red lines are lines of constant slope instability risk derived using the intersection of the two likelihood acceptance criteria and the consequence acceptance criterion.

4.0 SLOPE INSTABILITY RISK ASSESSMENT

For this study, the risk to the building occupants from slope instability, has been estimated by presenting a judgement-based assessment of the likelihood and consequences of slope instability. Slope instability is dominated by rockfall at these properties. The uncertainty in the likelihood and consequence estimates is accounted for by assigning a range of values for each parameter as per the likelihood and consequence tables in Attachment B.

Our estimated likelihood of slope instability impacting on the buildings on the properties could be as low as 1/50 or as high as 1/2, with a most likely probability of 1/5.

The consequences of slope instability impacting on the buildings could range from some damage but no injuries (*0.20)* through to significant damage with injuries and the potential for a fatality (*0.83).* We think the most likely consequence of slope instability hitting either building is significant damage but without injury or death occurring (*0.57*).

This assessment is shown on Figure 1 as the coloured map that presents the combined probability distribution of the estimated consequence and likelihood.

- The horizontal axis labelled at the bottom represents the consequences and a green line graph inside that axis shows the assessed distribution of consequence described above.

- The vertical axis labelled on the left represents the likelihood and a green line graph inside that axis shows the assessed distribution of likelihood described above.

- The slope instability risk distribution is defined as the likelihood multiplied by the consequence so at each point in the field presented in Figure 1 the probability is shown as a colour. The risk probability is calculated in a 100x100 bin matrix.

5.0 SLOPE INSTABILITY RISK ASSESSMENT COMPARED TO DANGEROUS BUILDING CRITERIA

By combining the estimates of likelihood and consequence presented in Section 4.0, we calculated a risk distribution that can be compared to the dangerous building criteria (presented in Section 3.0) as illustrated in

Figure 1. Based on this assessment we calculate there is a 34 % probability that the slope instability risk exceeds the dangerous building criteria for 1800 and 1802 SH1.

This dangerous building risk assessment is not definitive and accounts for the fact that we have imperfect knowledge of the likelihood and consequences of the slope instability hazard affecting these properties. Further investigations and analysis may reduce the uncertainty. We would expect that the risk would still fall within the uncertainty range described in this study unless the hazard changes, which could occur over time as our understanding of hazards change or as the slope evolves.

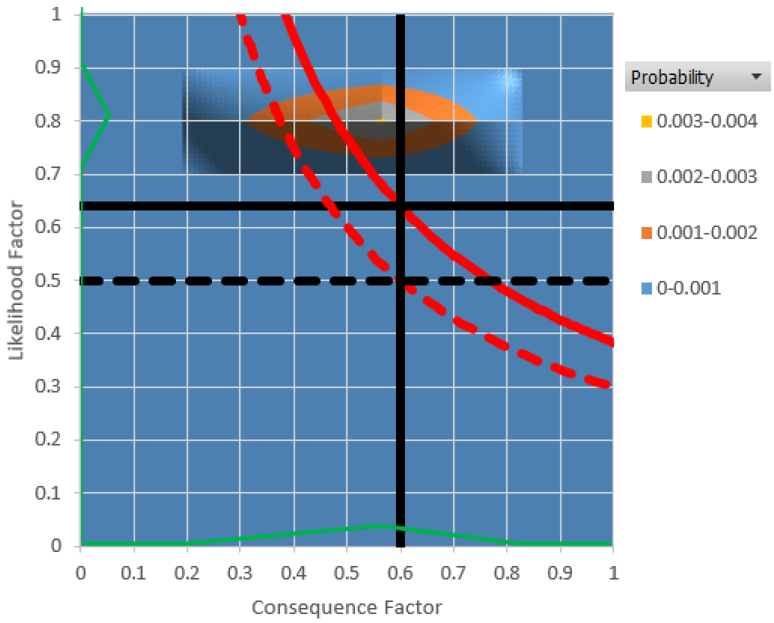

Figure 1: Criteria and assessment for dangerous building assessment. Likelihood and consequence factors are defined in Attachment B. Criteria are shown as black and red lines. The assessed range of likelihood- and consequence- factors are shown as green lines on the left and bottom axes, the combined probability of the assessed likelihood and consequence is shown as probability by colour bands.

6.0 MITIGATION OPTIONS

Given the layout of the properties and the location of the potentially occupied buildings relative to the slope and the distribution of rockfall boulders, we believe that mitigation of the rockfall hazard could be effective and result in a reduced level of risk for occupants. In this case, a high energy rockfall catch fence could be constructed on the slope above the occupied buildings. Any rockfall mitigation such as a catch fence will require a building consent. Alternatively, the buildings could be moved away from the toe of the slope and outside the area identified in Golder 2017a as the ‘rockfall hazard zone’. It is our opinion that if such measures are implemented, the risk to occupants of the buildings could be reduced.

7.0 CLOSURE

We trust this meets your current requirements. Should you have any queries, or require further clarification, please do not hesitate to contact the undersigned.

Yours sincerely

GOLDER ASSOCIATES (NZ) LIMITED

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Attachments: Attachment A – Report Limitations
Attachment B – Dangerous Building Assessment Criteria

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Attachment B – Dangerous Building Assessment Criteria

Table 1: Likelihood criteria.

Likelihood	Probability of occurring in each year		Probability of occurring in 50 years	Likelihood Factor
	100%	1/1	100%	
Almost certain				0.9-1.0
	20%	1/5	99.999%	
Very likely				0.8-0.9
	5%	1/20	92%	
Likely				0.7-0.8
	1%	1/100	39%	
Possible				0.6-0.7
	0.4%	1/250	18%	
Unlikely				0.5-0.6
	0.2%	1/500	10%	
Very unlikely				0.4-0.5
	0.1%	1/1000	5%	
Rare				0.3-0.4
	0.04%	1/2500	2%	
Very rare				0.2-03
	0.02%	1/5000	1%	
Extremely rare				0.1-0.2
	0.01%	1/10000	0.5%	
Almost impossible				0.0-0.1

Table 2: Consequence criteria

General descriptor	Example consequence to persons	Consequence Factor
	Loss of hundreds of lives	
Cataclysmic		0.9-1.0
	Loss of tens of lives or 100 serious injuries	
Catastrophic		0.8-0.9
	Loss of 1 life or 10 serious injuries	
Disastrous		0.7-0.8
	1 Serious injury requiring hospitalization or 10 minor injuries	
Major		0.6-0.7
	Minor injury to person	
Moderate		0.5-0.6
	Highly inconvenient	
Low-Moderate		0.4-0.5
	Inconvenient	
Low		0.3-0.4
	Slightly inconvenient	
Minor		0.2-03
	Noticed	
Very Minor		0.1-0.2
	Unnoticeable	
Negligible		0-0.1