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Dear Kristine

Naval Point Hazard Assessment

1.0 Introduction & Scope

Christchurch City Council (CCC) has engaged AECOM New Zealand Limited (AECOM) to undertake a rockfall hazard assessment at Naval Point, Lyttleton as part of the Naval Point Development Plan. As part of the development plan, CCC are looking at utilising the western boundary of the site adjacent to a known rockfall area (outlined in yellow in Figure 1) to allow public access to the Magazine Bay Marina.

The scope of the assessment consists of:

- Review of existing hazard zoning and background information for the site
- Review of proposed public use of the site in the Draft Naval Point Development Plan
- Identification of mitigation / protection measures to allow for Development Plan uses
- High-level costs for mitigation / protection measures for the site.

This letter presents the existing information available relating to the rockfall hazard, the outcome of the site inspection and recommendations and costs of potential mitigation options.

Figure 1 Naval Point development plan. Site boundary outlined in red, approximate site inspection area outlined in yellow.

2.0 Background

Naval Point is a steep sided prominent basalt outcrop that protrudes into the Lyttelton Harbour, demarking the south western extent of the Port (Figure 1). The outcrop rises up to 21 m above the surrounding reclaimed flat land of the port, and is comprised of Lyttelton Basalts intruded by trachytic dykes. The Naval Point Yacht club is situated approximately 4m from the base of the cliff.

The September 2010 Canterbury Earthquake caused significant rockfall at Naval Point that damaged the clubhouse and blocked the vehicle access way behind the club. An initial geotechnical inspection of this area by Geotech Consulting Ltd on 24 September 2010 identified that a large wedge failure had occurred; the resulting debris struck the back wall of the clubhouse. A smaller wedge failure is understood to have occurred at the same location prior to the earthquake. The wedge failure (visible in Figure 4) was related to the intrusion of one of the trachyte dykes into the surround basalts of the outcrop. Joints formed between the dyke and the surrounding rockmass acted as failure surfaces. At the same time as the Geotech Consulting site inspection, scaling of loose material on Naval Point was undertaken by ropes access contractors Geovert. While this reduced the imminent hazard, further recommendations were made in the subsequent report by Geotech Consulting Ltd, including:

- Stabilisation of the cliff face by meshing and rock bolting
- Reforming the earth bund at the base of the cliff and relocating it slightly further out from the cliff base (a temporary earth bund was created from fallen debris after the 2010 earthquake).

Further damage was sustained at Naval Point as a consequence of the February and June 2011 earthquakes (Figure 2). Rockfall again struck the yacht club. Cliff collapse modelling by GNS Science put the yacht club into the highest risk category (10^{-1} to 10^{-2} AIFR), however it should be noted that this was based solely on suburb-wide assessments of cliff heights and potential debris travel distances. We are not aware of any quantitative risk assessments at this site. Nevertheless, this does reinforce the fact that the yacht club is positioned extremely close to the rockface.

In May-June 2012 URS (now an AECOM company) investigated remediation options at the site. Several options were put forward, including rock anchoring and mesh installation, which was seen as a robust, cost effective solution, allowing the public walkway to remain open. No permanent remediation works were undertaken. Instead, a temporary solution was proposed as the building was set to be demolished, with a permanent solution deferred until a new building design could be completed.

Temporary rockfall mitigation undertaken at Naval Point initially consisted of scaling the rockface and removing unstable concrete components of the Naval Point gun emplacement. Additionally, a concrete block wall was installed between the Naval Point Yacht Club building and the cliff, and signage warning of rockfall was erected. The bund adjacent to the carpark and accessway had already been constructed, but was extended and modified, joining it to the concrete wall. Monitoring equipment was installed on the cliff face and on the gun emplacement itself. This consisted of:

- Five trilex crack gauge monitors on the gun emplacement located at the top of the cliff behind the yacht club;
- Three monitoring bolts across selected defects on the rockface behind the yacht club (Figure 3).

In 2013 a baseline 3D model of the cliff was created from a laser survey, with the intention of using repeat survey to detect movement over time and/or after significant events. Defect mapping was also carried out. Monitoring points had been periodically checked during this time. The 2013 URS monitoring records indicate there was no significant movement observed during this period.

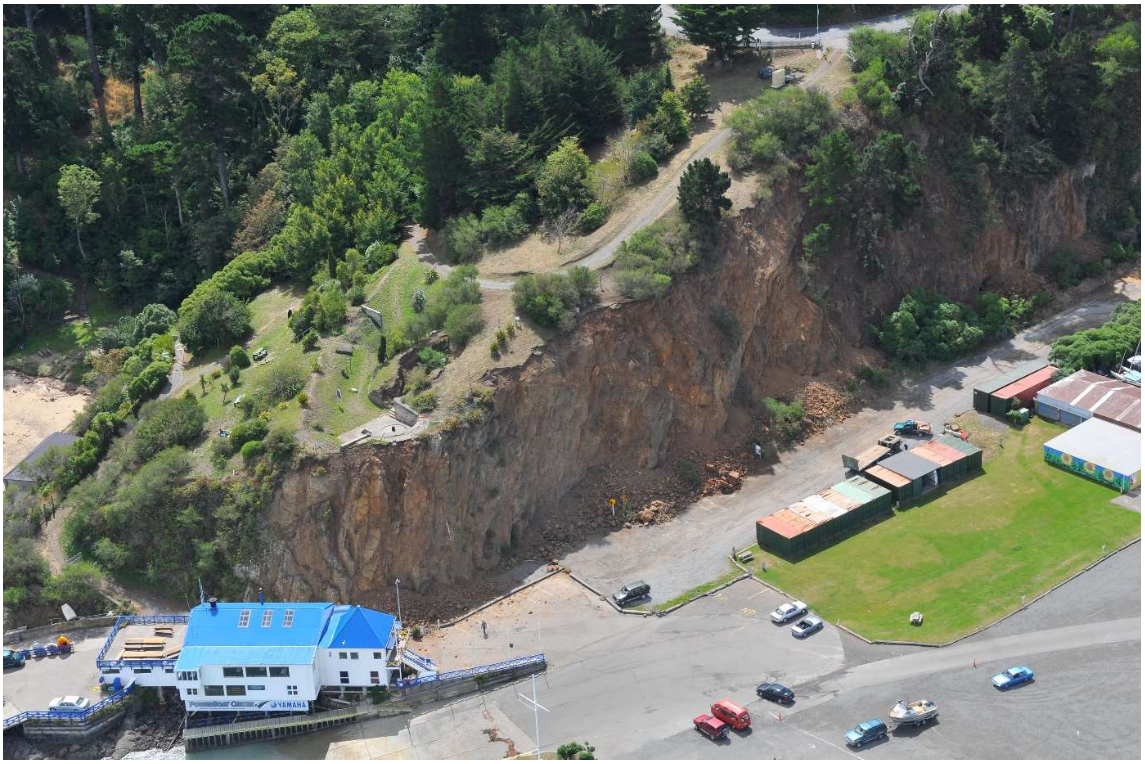

Figure 2 Naval Point on February 24, 2011. Fresh rockfall can be seen in the car park adjacent to the yacht club (blue roofed building). Much of the rockfall visible at the base of the cliffs is fresh, though some is likely to have been present already. Photograph by G Hancox, GNS Science.

Since the work carried out in 2011-2013 there has been no work of note carried out by AECOM at Naval Point. We are unaware of any other official works being undertaken by CCC or external consultancies. The yacht club building has not been demolished and, based on a conversation with yacht club members, AECOM understands that the section of cliff behind the yacht club building has been sluiced with a high pressure hose twice in the intervening period (one of those times using a water cannon on a fire fighting appliance). This was carried out as the cliffs continued to fret, with loose material periodically falling. The sluicing acted to remove additional loose material.

3.0 Site Inspection

A site inspection of the area was carried out by AECOM in September 2020. This consisted of a walkover inspection and a roped abseil inspection of the cliff. The roped abseil inspection was focused on the area behind the yacht club, in part to examine the existing monitoring bolts to look for any signs of movement. Dense vegetation on the cliff restricted ropes access and obscured observation of the rock face in some locations. The remainder of the cliff was inspected from the accessway at the base of the cliff. Multiple signs warning of rockfall and cliff collapse were noted at both the top and bottom of the cliff. The walkover inspection covered the gun emplacement and top of the cliff, the base of the cliff and the south east facing side of the outcrop.

3.1 Observations

3.1.1 South West Face

Overall, no large-scale instability was observed, however ongoing erosion and fretting of small rocks is evident. Small fallen rocks (typically no more than 0.25 m diameter) were observed along the base of the cliff. A notable exception to this was beneath the previously identified wedge failure behind the yacht club. Three large blocks (the largest being 0.6 x 0.4 x 0.2 metres) had fallen from this site and landed behind the concrete block wall. Yacht club members indicated these had fallen 3-4 years ago (possibly as a result of shaking caused by the 2016 Kaikoura Earthquake).

Loose rock on the outcrop surface was observed in several locations along the length of the cliff. These loose blocks were generally quite small (<0.2m on their largest axis). Multiple persistent defects remain visible on the rockface. Overall these do not appear to have dilated or otherwise moved. The monitoring bolts installed on the rockface show no signs of movement (Figure 3). There was no evidence of tension cracks or movement at the top of the cliff.

Figure 3 Current condition of two of the monitoring bolts installed at Naval Point in 2012

The five Trilex crack gauge monitors installed on the gun emplacement itself have all long since been removed - presumably by members of the public. These were in visible locations in a publicly accessible area. Removal of such items is common. Despite their removal it was clear that the cracks they had been monitoring had not undergone any significant movement.

One site of questionable stability was identified and assessed during the roped inspection (Figure 4). This potentially unstable site is located on the previous wedge failure that occurred as a result of the September 2010 earthquake. It consists of 2 blocks that appear to be largely held in place by friction, with persistent defects separating them from the rockmass (Figure 4). The base of the blocks is located approximately 6m up the face. The block on the right (2) is located above the failure that occurred in late 2016 or early 2017. As such it is reasonable to assume that some of its support was removed at that time. The block is of marginal stability as it appears to only be supported by a small piece of rock at the base, and the friction between that block and the outcrop. This block is in the order of 2 x 1 x 0.25 m. Adjacent to and partially supported by this block is another potentially unstable block, in this case measuring 2.5 x 0.6 x 0.5 m and at least partially detached from the surrounding rockmass.

Figure 4 Left image - unstable site (previous wedge failure), red lines indicate location of persistent defects on each block, arrows indicate the direction that the close up photo has been taken. Right images – images to illustrate the defects outlined in the left image.

3.1.2 South East Face

Parts of the cliff face on this side are covered in vegetation. The bund itself is now largely covered in Tree Lucerne (Tagasaste). At the north-eastern end of the cliff, pine tree roots were observed throughout the rockmass within the joints, it was evident that previous failures have occurred around the roots likely due to ‘root jacking’.

The site inspection revealed evidence to suggest there is ongoing rockfall on the south east side of the site. Figure 5 illustrates some of the rockfall that was observed; the majority was seen to be behind the bund, with one rock observed on top of the bund. Due to the dense vegetation between the cliff and the bund/on the bund restricting access, this area was not inspected extensively. Although there was no evidence to suggest that rocks have travelled over the bund, we cannot be certain this is the case. As there is a vehicle access way situated directly to the east of the bund, any rocks that may have travelled over the bund would likely have been cleared away.

We note that the area behind the bund is slowly decreasing, as this area accumulates debris. This is not just rocks, but organic matter from dead and fallen vegetation, and not least illegally dumped rubbish. Car tyres have been dumped in large quantities behind the bund. While these weren’t counted, there were at least 3 large piles of tyres, the largest of which may have had up to 100 tyres in it. The accumulation of debris behind the bund will gradually lessen its effectiveness, as its height relative to the height of the catch area behind it decreases.

Figure 5 **Left image - rockfall observed on the top of the bund. Right image – rockfall observed on the upslope side of the bund.**

3.2 Existing Bund & Concrete Block Wall

At the base of the cliff a non-engineered earth fill bund, approximately 3 m to 4 m in height (on the downslope side) is present along the south eastern extent of the cliff. Due to debris and vegetation the upslope side of the bund, it is typically approximately 2 m in height. The offset of the bund from the base of the cliff varies along its length, but is generally 2 m to 4 m. A typical section to illustrate the bund is presented in Figure 6. The bund stops approximately 20 m to the south of the stone masons' yard. At the back of the stone masons' yard a separate non-engineered earth bund was observed at the base of the cliff approximately 1.5 m high.

At the southern end of the earth fill bund a concrete block wall, typically 3 blocks high (approx. 1.8 m), extends behind the Naval Point Yacht Club (Figure 7). At the location where the bund and concrete block wall meet, both of these structures taper down to a reduced height creating a low point. Aside from this low point, observations during the site inspection suggest the bund and concrete wall have been an effective mitigation measure due to the fallen rocks observed on the upslope slide of the protection structures.

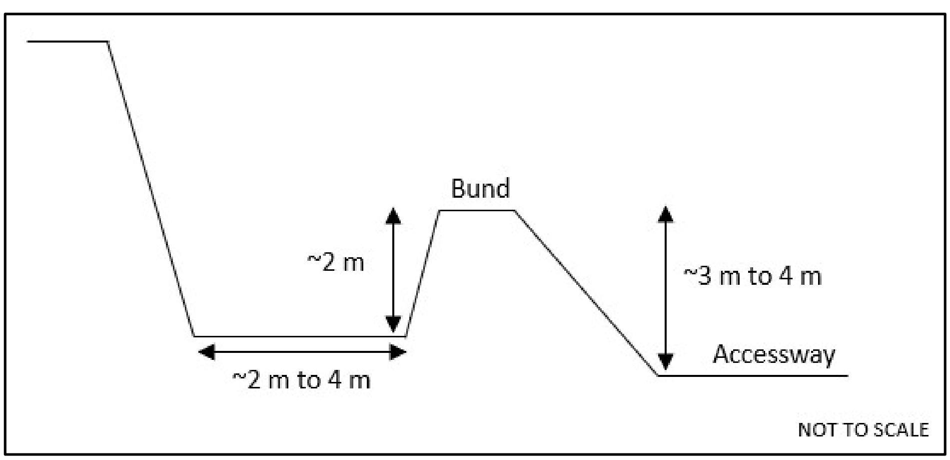

Figure 6 Schematic cross section of the non-engineered earth fill bund

Figure 7 Concrete block wall behind the Yacht Club and the earth bund adjoining it on the right of the photo.

4.0 Assessment

Rockfall is a known hazard at Naval Point and based on the recent site inspection it is evident that 'fretting' of the cliff face is actively occurring and is likely to continue due to the nature of the rock. The rockfall hazard is assessed to be medium to high in accordance with the criteria summarised in Table 1.

The current earth bund and concrete block wall have to date acted as an effective mitigation method that has contained a large amount of rocks that have released from the cliff.

We have not conducted a quantitative risk assessment (QRA), as there is insufficient data available to accurately undertake such an assessment; neither the frequency of rockfall nor an accurate estimate of visitor numbers using the pathway are available. Our assessment is based on existing information from the site, our knowledge and observations of the site, evidence of ongoing rockfall and the topography of the site. While we do not believe a QRA is currently required, undertaking one may be useful in helping to decide what form of mitigation CCC would like to implement. This would inform CCC of what the actual risk of injury/death may be. An estimate of visitor numbers using the area would be needed to conduct this task. Alternatively, a decision could also be made without undertaking this - all forms of mitigation suggested will be effective in mitigating the hazard.

We believe that the use of land adjacent to the rockfall hazard as seen in the proposed Naval Point Development Plan (Appendix 1), can be managed with appropriate rockfall mitigation.

Table 1 Criteria for Hazard Zoning

Hazard Zone	Criteria
Low	Very limited rockfall source area above zone. Potential source rock is not currently unstable and is judged to be at low risk of failure.
Medium	Potential rock source above zone. Source rock may have undergone previous failures. The source area contains loose and/or detached rock blocks that are not judged to be at imminent risk of failure, however rockfall may occur during trigger events.
High	Rockfall actively occurring in this zone and/or rock source area comprises loose and/or detached blocks that are highly unstable or judged to be at imminent risk of failure.

5.0 Rockfall Hazard Mitigation Options & Cost

Based on the assessment above we have evaluated four options to manage the rockfall hazard at Naval Point as part of the Naval Point Development Plan. These are presented in Table 2. Option 1 would be the most cost-effective solution. It would also limit the exposure time of contractors to the rockfall hazard due to a reduced amount of construction time. The remaining options present differing degrees of protection, and cost. The order they are presented in reflects an increasing level of protection.

In addition to the options presented below, we recommend removal of the two unstable blocks identified as part of the previous wedge failure illustrated in Figure 4. Removal of these blocks will likely be able to be completed with hand tools via ropes access.

Table 2 Rockfall hazard mitigation options and costs

Option		Description/Comments	Cost Estimate
1	Leave existing bund in place with additional extensions	Leave the existing non-engineered bund and concrete block wall in place at the base of the cliff. Close the gap between the northern extent of the wall and the bund with either additional concrete blocks or earth fill. Extend the northern end of the bund to the northern boundary of the proposed development. Extend the southern portion of the concrete block wall by approximately 5 m adjacent to the current walkway and ensure separation is maintained between the track and the cliff (as it is currently) beyond this point. Remove large unstable blocks identified on the south western face.	$7,000
2	Install a mesh drape along the cliff above the footpath	Install a mesh drape across the south west length of the cliff. Leave the earth bund in place on the south east side. A minimum separation from the base of the cliff to the proposed accessway will still need to be maintained, and low (~1m) earth bund would be needed at the base of the drape (or leave the concrete blocks in place as well as the mesh). Remove large unstable blocks identified on the south western face.	$35,000 - $50,000
3	Pattern bolt and mesh the face	Pattern bolt and mesh the south west face above the footpath, remove the concrete block wall. Leave earth bund in place below the south east face. Remove large unstable blocks identified on the south western face.	$100,000-120,000
4	Replace and extend existing bund	Replace the existing non-engineered bund and concrete block wall at the base of the cliff with an engineered bund. This option would allow a more aesthetically pleasing structure to be constructed. It would have a design life of at least 100 years. The minimum separation from the base of the cliff to the existing bund should be maintained and have the same total length as the works described in Option 1. In addition, remove large unstable blocks identified on the south western face.	$400,000-$600,000 depending on height of bund

The use of bunds will come with some maintenance requirements, as debris may accumulate behind them – from both rockfall and illegal dumping of rubbish. Any bund on site should be inspected every 5 years, and clearing undertaken if required. In the event of a locally felt earthquake over MM7 an inspection would also be advised.

Any of the mitigation options suggested in Table 2 will act to significantly reduce the hazard, allowing the areas to be used at no greater risk than currently exists at the site (assuming the same level of use). Option 1 will require the most maintenance, as the non-engineered bund is more likely to require repair in the event of a large failure form the cliffs. It may also require weed control. The structure of it could be compromised by the Tagasaste which currently grow on it, in the event of those plants dying or falling. Repairs to the non-engineered bund would however be comparatively cheap to undertake. The engineered bund (option 4) is the most robust and most effective option, preventing even large failures from impacting the public areas, and requiring very little upkeep other than occasional clearing from behind it.

Aesthetics may also come into decisions on how the hazard is treated. Option 1 is cost effective, but perhaps less aesthetically pleasing than other options. The comparative attractiveness of mesh on the face or a bund is likely to divide opinion. Examples of engineered bunds vs meshed faces are readily available in Christchurch, particularly in Sumner.

We are happy to be contacted to answer any questions regarding this assessment. AECOM would also be pleased to assist CCC with any further assessments required following future movements or failures at Naval Point.

Kind regards

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Appendix 1

Naval Point Development Plan

DRAFT

Prepared for planning purposes only

NAVAL POINT

DRAFT Development Plan

02.09.2020