

4.3 Current Modelling

4.3.1 Model Overview

The GNS modelling discussed in sections 4.2.2 and 4.2.3 is considered the best assessment of cliff behaviour in the vicinity of Redcliffs School and has been used as the primary basis of decision making regarding potential mitigation. In support of the modelling from GNS, MWH has given further consideration to potential large scale cliff failures to assist in the planning of mitigation works.

Based on the risk assessment presented in figure 4-1 to 4-3 and the red zones illustrated in figure 4-4 it has been determined in consultation with the MoE that the most at risk portion of the school site will be abandoned. The model considered by MWH focusses on what rock may reach the revised school boundary, which is shown highlighted by the red lines in the figure below.

Figure 4-5 – Revised School Boundaries adopted in Modelling.



4.3.2 Model Set Up

Figure 4-6 shows the conceptual model development which is based on the cross section to the south of the existing school hall (Figure 1 in MWH March 2011 report). The hypothetical stages of cliff failure taken into account in the model are:

- The slope profile following the February 2011 earthquake is shown by the green line and resulted from material from the upper cliff face falling and enlarging the existing talus slope at the base of the cliffs. Minor changes to this profile occurred following the June 2011 event; however, comparison of LIDAR between the two events indicated little change in the modeled cross section. Relative to the extreme design case being considered, the changes to the slope between February and June are not considered significant to the subsequent analysis.
- A future potential large scale failure at the top of the cliffs similar in scale to observed failures on other cliffs in the Sumner/Redcliffs area (refer to the hatched area on figure 4-4 below). A conservative estimate is that failed material may tip to form a loose deposit with 50% voids, therefore bulking to fill approximately twice the volume at the base of the cliff than that displaced at the top.

- Progressive failure of the slope, either over a series of events or most conservatively one event until the slope regresses to a residual angle. Figure 4-4 presumes a 27 degree (approximately 2H:1V) angle and establishes the geometry of the slope assuming that the fallen material bulking to twice its original volume (i.e. the volume that has fallen from top of the slope is half of the volume that accumulates at the base of the slope). The 2H:1V slope selected is similar to the shallowest slope present within the boulder field on the lower slopes.

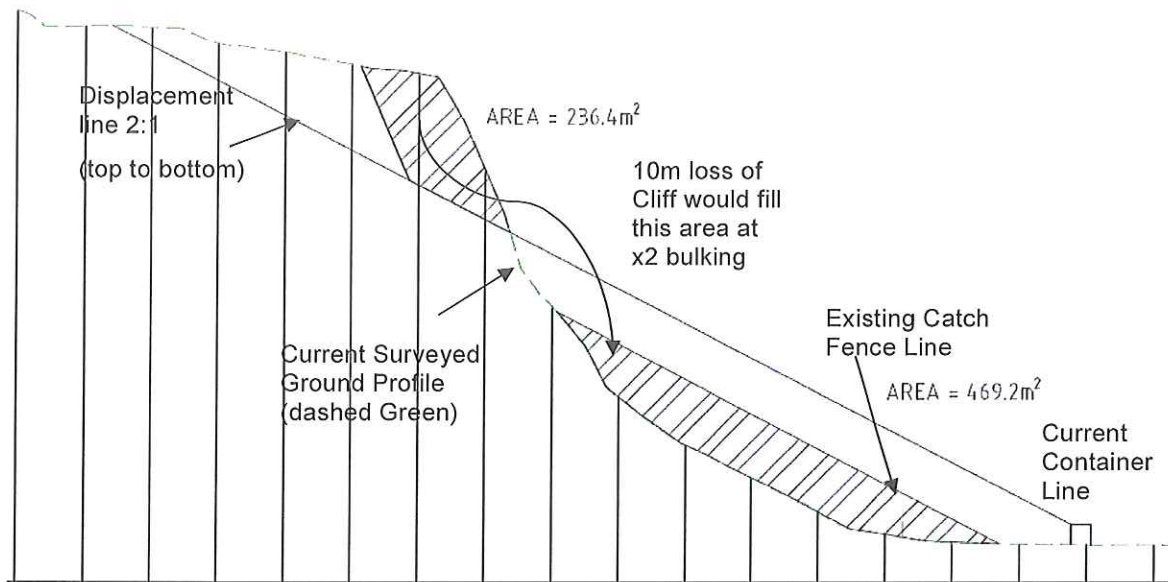


Figure 4-6: Modelled Potential Cross Section with Notes

It is noted that this model is highly idealised and that in reality defects in the rock mass will control the failure volumes and deposition at the toe will be more irregular. However, it is still considered useful as a secondary check to the GNS modelling to assist in understanding the overall scale of future large scale rockfall events that may occur.

The following design cases were considered:

- Case 1 - Rockfalls from the current slope (as measured by LIDAR survey flown after the major rockfalls in February 2011)
- Case 2- An intermediate case where there has been a partial regression of the slope as shown in the shaded areas of figure 4-6 above, extending the talus slope closer to the existing container protection works.
- Case 3 - A volumetric assessment at three cross sections to determine whether, in the case of full regression of the slope a sufficient volume of rock could fall to inundate the area behind the revised school boundaries shown in figure 4-5.

4.3.3 Results

4.3.3.1 Case 1 - Current Slope

LIDAR data collected on 24 February 2011 was utilised to provide more accurate cross sections through the area behind the school and confirm the validity of the abney level cross-section used previously (MWH, March 2011). The assessment of these cross sections confirmed that the earlier measurements using abney level were very close to those from LIDAR following both the February and June 2011 earthquakes.

This analysis case confirmed that the earlier assessment presented in our March 2011 report that "rocks may breach the protection works installed after the September 2010 earthquake but would not be expected to reach the post February 2011 container line" is still considered valid.

Because of the similarity of this scenario to that presented in our March 2011 report, and subsequent consideration of more adverse scenarios in the following sections, detailed outputs from this modelling have not been provided.

4.3.3.2 Case 2 - Intermediate Condition

The model assumed the same conditions of relative roughness, and elasticity for the slope as was modelled in Case 1 but assuming failure of the slope in accordance with the shaded areas in Figure 4-6. In this instance we modelled the largest of the three boulder sizes trailed as previous modelling confirmed that this produced the highest bounces, velocities and travel distances. The modelling is outlined in more detail in Appendix C.

Rockfall modelling of the intermediate case indicated that 6% of the boulders would reach the base of the slope, and would have a maximum height of 1.2 m at this point. Of these rockfalls, none ($< 1/10,000$) had sufficient velocity to reach the line of the existing containers (installed in March 2011 located at 130 m in the model presented in Appendix). The proposed revised school boundary is approximately 30m further beyond this line of containers.

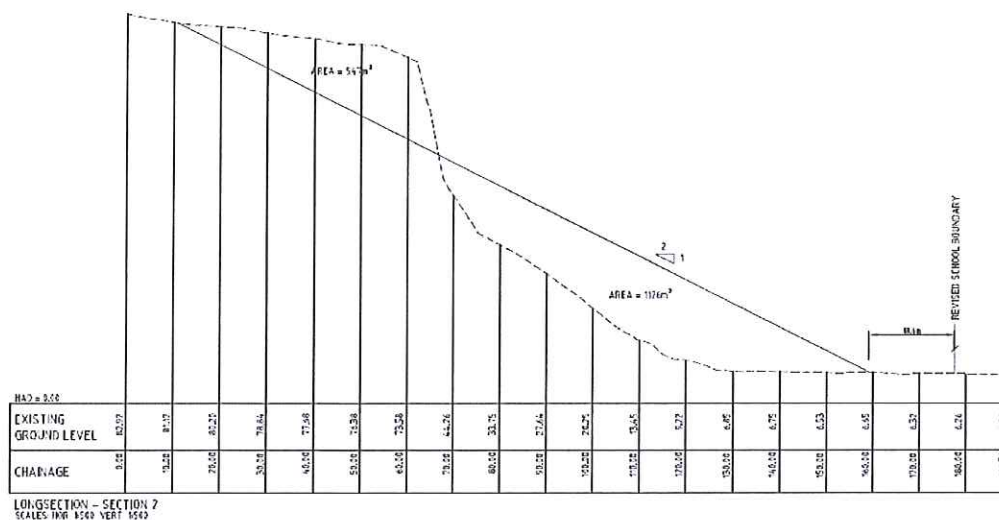
The sensitivity of the model was further tested by considering artificially smooth talus properties (i.e. properties that are consistent with a smooth loess slope rather than a boulder field) to develop an extreme case. Under these assumptions boulders were found to roll further, attaining a maximum velocity of 18 m/s at the revised school boundary (at a distance of 160 m in the appended model under the "extreme case"). GNS in their August 2014 report note that "Based on the results of the two dimensional rockfall modelling, it is possible that individual boulders (rockfalls) could exceed the run out limits of the of the empirical and numerical RAMMS models used to estimate the risk in the study area".

4.3.3.3 Case 3 - Volumetric Assessment

Three cross sections were considered as part of this case, located as shown in the following figure. The model considers the potential for a large scale regression of the slope to a residual 2H:1V slope. Material falling from the top of the slope is assumed to double in volume at the base of the slope (bulking factor of 2). The assessment is undertaken based on LIDAR data collected after the June 2011 event and is considered a good approximation to the current slope geometry.



Figure 4-7: Location of Cross Sections.

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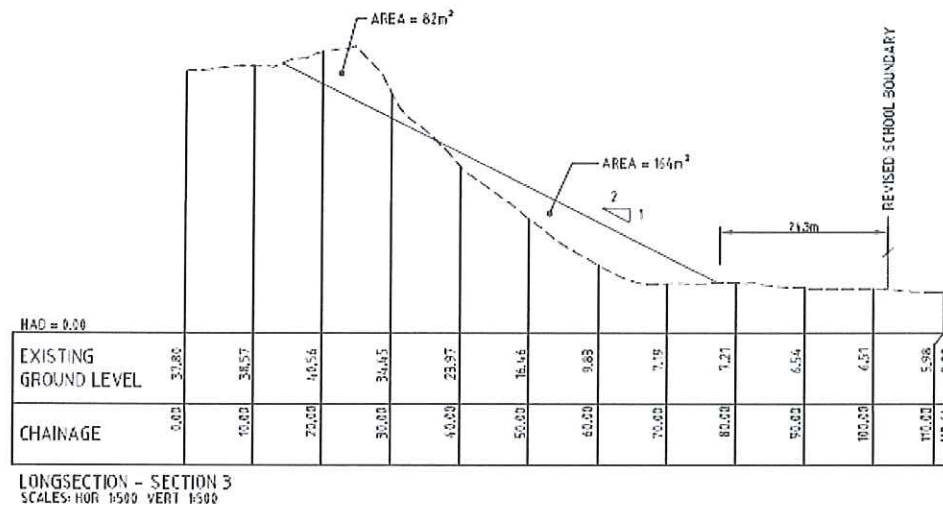


Figure 4-8: Hypothetical and simplified volumetric assessment

It is noted that the GNS RAMMS modelling discussed in section 4.2.2 is considered the definitive assessment of potential large scale future cliff collapse events. As a secondary check the situation shown in figure 4-8 indicates similar trends to the GNS modelling with the talus slope stopping some distance short of the revised school boundary. It is acknowledged that the 2H:1V slope regression angle shown in figure 4-8 may not necessarily represent the largest volume that may fall (the volume being controlled by defects in the rock mass and the buttressing effect of the talus slope). However, it can be seen from the figure that there is the potential for a considerably larger volume than that shown to fall at each cross section before the talus slope would fill the volume available behind the revised school boundary.