The paper was published in the proceedings of the 12th Australia New Zealand Conference on Geomechanics and was edited by Graham Ramsey. The conference was held in Wellington, New Zealand, 22-25 February 2015.

Rock, rumble and roll: DoC high country hut hazard assessment procedures

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ABSTRACT

The National Parks system provides boundless opportunities for adventure in a dynamic and rapidly changing environment. The Department of Conservation maintains over 950 huts. Many are found in areas of spectacular scenery and are exposed to natural conditions that are unique to their environment. Historically, a small number of huts have been impacted by landslide, some with tragic loss of life. In order to mitigate natural hazard risk, the authors present the approach developed over the last 15 years into location and positioning of new huts in varying topographical and geologic settings, from coastal, to sub alpine, to high alpine country. Natural hazard assessment is a fundamental tool used in the positioning of high country structures. In conjunction with GNS, the Department of Conservation has developed a natural hazard assessment approach for use in remote hut sites that is adapted from the AGS 2000 Landslide Risk Management and Guidelines. Assessment procedures into potential effects of strong earthquake shaking, rockfall and landslide risk are presented.

Keywords: hazards, risk, huts, landslide, earthquake, tsunami,

1 INTRODUCTION

The Department of Conservation (DoC) manages over 950 huts throughout New Zealand. The environment in which this network of huts is located is varied, from coastal lowlands, to sub alpine, to alpine settings. The land forms that are present at many of these hut locations create particular challenges in determining appropriate and safe locations. Hut sites commonly are positioned in proximity to very steep, mountainous terrain with rockfall, landsliding, and avalanche part and parcel to the dynamic environment. Many of these huts date back to the 1960's and 1970's when they were commonly used for deer culling. This network of huts came under the management of the New Zealand Forest Service, and ultimately DoC. Hut usage changed through the years to become recreational and conservation based. As user numbers increased and the hut stock grew older, a need to provide new huts and replace older huts with new and in most cases, larger huts arose.

In order to better understand the potential risks from natural hazards to hut assets, DoC engaged GNS Science in 1998 to develop a methodology for the assessment of geological hazard in order to provide information for DoC and District Councils to enable classification of a hut structure as dangerous or not, in terms of the New Zealand Building Act 1991. The methodology was updated and revised in 2000 to include a Danger Rating and again in 2008 to include the previously developed Geological Hazard Rating System (1998), remove the Danger Rating assessment, and to add the Qualitative Risk Assessment process described in the AGS 2000 Landslide Risk Management and Guidelines that had been widely adopted in New Zealand at the time.

In 2007 DoC produced a draft avalanche assessment guideline (Bogie, 2007). Typically avalanche risk assessment is performed by DoC staff who have relevant experience. The specifics of avalanche risk assessment are not discussed further in this paper.

Staff from MWH New Zealand Ltd have conducted natural hazard assessment, and provided geotechnical and structural engineering design to numerous hut sites in varied environmental settings in the South Island over the last 15 years. During the initial part of the hut assessment programme, our natural hazard risk assessment process was developed independent of the GNS approach relying predominantly on interpretation of historic stereo paired aerial photographs of the site and on application of the AGS 2000 Guidelines. In subsequent years, the GNS methodology was amalgamated into our risk assessment process. The purpose of this paper is to present the natural hazard assessment process used for the various challenging environments and geologic conditions that face DoC and hut designers.

2 HISTORY OF NATURAL HAZARD IMPACT ON HUTS

The authors are aware of a number of events where backcountry huts have been severely impacted by natural hazard, some of which have resulted in tragic loss of life. The cause of the events has been reported herein mainly through anecdotal evidence and recollection of news media reports at the time. Approximately 1% of backcountry huts have been damaged or destroyed due to natural hazard impacts. The list provides sobering thought on the risks on hut structures from natural hazard events.

2.1 Bushedge Hut, Motueka Valley Gorge, Richmond Ranges (1995)

A debris flow dammed creek breached and the resulting debris slide/flood destroyed the hut killing two DoC staff that were sheltering there.

2.2 Lake Daniell Fishing Club Hut (1974)

Landslide on the western side of the lake during appalling weather resulted in the loss of life of three trampers. Hut was replaced with a new hut situated away from steep slopes on the south side of the lake.

2.3 Pioneer Hut, WNP (1963)

Located in Westland National Park, Pioneer Hut was impacted by a rockfall which hit the eastern side of the hut in January 1963 whilst eight people were asleep inside. One person was killed, one trapped under a boulder eventually being freed by efforts of the other occupants, and three others were injured. Hut has been replaced and is now situated on a ridge where there is no rockfall hazard.

2.4 Three Johns Hut, MCNP (1997)

Four people died when Three Johns Hut was blown off the Barron Saddle in extremely high winds. The hut was located at the head of the Mueller Glacier at an elevation of 2135m.

2.5 Beetham Hut, MCNP (1996)

A snow avalanche damaged this once popular climber’s hut. The hut has not been replaced as the area is now recognised as being vulnerable to avalanches.

2.6 Welcome Flat Hut, WNP

This hut was severely damaged by a landslide in the 1980’s and has since been replaced by a new hut in a safer location.

2.7 Smyth Hut (2013)

Smyth Hut in the Wanganui Valley, West Coast escaped damage when a landslide created lake at the head of the valley burst through the debris dam and inundated the valley in which the hut is situated.

2.8 Dome Shelter, Mt Ruapehu (2007)

One person seriously injured and the hut was damaged during a hydrothermal eruption from Crater Lake.

2.9 Finlay Face Hut, Havelock River

Hut destroyed by avalanche. Figure 1 captures the extent of avalanche and the impact on the hut.

Figure 1. Finlay Face Hut, Havelock River – Photo DOC Raukapuka

2.10 Gardiner Hut, Hooker Valley, MCNP (2014)

A large rockfall from the South Ridge of Mt Cook enveloped Gardiner Hut with debris, destroyed the toilet on the upslope side of the hut and pushed the hut off its foundations. Figure 2 presents the view eastwards up the Noeline Glacier of the rockfall debris enveloping the hut in the lower left corner of the photograph.

Figure 2. Gardiner Hut rockfall landslide 2014

3 DOC NATURAL HAZARD ASSESSMENT APPROACH

GNS presented a geological baseline inspection approach for backcountry huts in 1998 and updated it in 2000. The approach assessed the geological hazard of a number of factors (eg. slope angle, site geology, strong earthquake shaking, etc) and determined an overall hazard rating for the site. The geological hazard rating was then combined with a hazard activity rating (based on the date of most recent hazard activity) and an exposure rating based on visitor numbers per annum. The combination resulted in a danger rating for the site. This approach was updated in 2008.

The approach that the authors adopted for work done in the period up to 2005 was developed independently from that used by GNS at the time. This early approach was based solely on the AGS 2000 guidelines which were being widely used for qualitative landslide risk assessment in New Zealand. It materially did not differ greatly from the GNS approach as a similar methodology to hazard assessment was used, except for GNS' use of an exposure rating tied to visitor numbers. After 2005 the GNS approach was adopted.

The current natural hazard assessment approach developed by GNS Science in 2008 for DoC is based on a three part approach. The danger rating (exposure rating) from the earlier baseline inspection approach has been removed. The first part identifies the hazards that the hut site may be exposed to and develops the geological hazard rating for the site. The hazards are then assessed using a risk assessment approach based mainly on the AGS 2000 guidelines for landslide risk assessment. Lastly, the risk is prioritised in order to present a summary of the risks with appropriate mitigation strategies. The following sections give a step by step description of the approach required to develop a risk profile for the hut site.

3.1 Desk Study

The natural hazard assessment of a hut or a potential hut site starts with a desk study prior to the site visit. The desk study provides background information such as hut location, general topography, geology, presence of known active faults, geomorphological information, and proximity to watercourses. The tools available for desk study are typically the New Zealand Topographical Map series, Google Earth imagery (present as well as historical), stereo pair aerial photography (if available), DoC file information, geological maps, and the GNS active fault databases.

3.2 Geological Hazard Evaluation

The geological hazard evaluation process rates a series of geological and environmental hazard factors by assessing then assigning a value to each on a sliding scale of zero to five. The lower values reflect more benign conditions and conversely the higher values reflect more challenging conditions that result in a higher hazard rating for the factor under evaluation. Guidance is given in the GNS 2008 report on selecting an appropriate factor value for the hazard factor under assessment. The values are summed to provide the overall geological hazard rating for the hut site with the rating varying from very low to very high. The risk associated with each hazard is then qualitatively assessed following the AGS 2000 guidelines, and mitigation measures are determined. Along with the qualitative risk assessment process, the geological hazard rating is used to compile a final recommendation and prioritise future actions for planning and development of the site. Table 1 below presents the factors that are evaluated for the hut site.

Table 1: Geological Hazard Factor Evaluation (Reproduced from GNS 2008)

GEOLOGICAL HAZARD FACTORS ***(Place X in appropriate cell to indicate Factor Values)***	***FACTOR VALUE***					
	0	***1***	***2***	***3***	***4***	***5***
1. Slope angle and local topographic effects at site.						
2. Site geology and foundation materials.						
3. Proximity to steep slope below site.						
4. Hazard from slopes above site (rock/debris fall, avalanche, slide).						
5. Foundation failure (none, possible, incipient, active).						
6. Strong earthquake shaking (liquefaction, slope failure, seiche, tsunami).						
7. Heavy rainfall, flooding, erosion, debris flows etc.						
8. Other (snow avalanches; faulting; volcanic ash, gas, lahar etc).						
***Sum of Hazard Factor Values**:*						
GEOLOGICAL HAZARD RATING FOR: xxx						
TOTAL FACTOR VALUES FOR GEOLOGICAL HAZARD RATINGS: *Very low: 0-5 Low: 6-12 Moderate: 13-18 High: 19-24 Very High: 25 or greater*						

3.3 Qualitative Risk Assessment

The process for qualitative hazard risk assessment follows the AGS 2000 guidelines approach which has been used extensively by geo professionals in New Zealand for over 10 years. Each hazard identified in the geological hazard evaluation is assessed for risk by qualitatively assessing the likelihood of such an event occurring and assigning a consequence. The likelihood range is from inconceivable to almost certain and are distinguished by the indicative probability of such an event occurring. The consequence range is from insignificant to catastrophic. The combined pair of likelihood and consequence generates a risk level that span from very low to very high risk. Once the risk has been analysed, the individual risk items are given priorities for action by DoC.

The combined pairing of likelihood and consequence is presented in the risk matrix in Table 2:

Table 2: Risk Matrix (Reproduced from AGS 2000)

LIKELIHOOD	CONSEQUENCES to PROPERTY and PEOPLE				
	1: CATASTROPHIC	2: MAJOR	3: MEDIUM	4: MINOR	5: INSIGNIFICANT
A – ALMOST CERTAIN	**VH**	**VH**	**H**	**M**	**M**
B – LIKELY	**VH**	**VH**	**H**	**M**	**L**
C – POSSIBLE	**VH**	**H**	**M**	**L**	**VL**
D – UNLIKELY	**H**	**M**	**L**	**L**	**VL**
E – RARE	**M**	**L**	**L**	**VL**	**VL**
F – INCONCEIVABLE	**L**	**VL**	**VL**	**VL**	**VL**

3.4 Recommendations for Prioritising Geological Hazard

Lastly, guidelines are given to enable DoC asset management staff to prioritise risk items. Priorities are defined by the magnitude of the geological hazard rating or the risk of a particular hazard item. A timeframe for response is provided. The priority rating system gives clearly defined outcomes for how the risk is recommended to be mitigated by DoC. Table 3 summarises the priority ratings system.

Table 3: Priority Rating for Recommendations (Reproduced from GNS 2008)

PRIORITY RATING FOR RECOMMENDATIONS:

*The following **Priority Ratings** are used for rating Recommendations given in this report for mitigating geological hazards at DoC hut sites and camp sites. They are mainly based on the Geological Hazard Rating and Risk Level at a site, and indicate the time frame within which the recommendation should be attended to. Specific time frames for responding to unacceptable risk from any hazard should be specified in the Qualitative Risk Assessment (C8).*

Priority 1: *Recommendation of **very great significance** and URGENT, at a site where there is Very High geological hazard (Rating >25) or **Very High Risk** from one or more hazard. Should be attended to immediately.*

Priority 2: *Recommendation of **great significance**, at a site where there is High geological hazard (Rating 19-24) or **High Risk** from one or more hazard. Should be attended to, as far as reasonably practicable, within the next 12 to 18 months.*

Priority 3: *Recommendation of **considerable significance**, at a site where there is Moderate geological hazard (Rating 13-18), or **Moderate Risk** from one or more hazard. Should be attended to as far as reasonably practicable, within the next three years.*

Priority 4: *Recommendation of **moderate significance**, at a site where there is Low to Moderate geological hazard (Rating 6-18) or **Moderate to Low Risk** from one or more hazards. Should be attended to, as far as reasonably practicable, within the next five years.*

Priority 5: *Recommendation of **some significance**, at a site where there is low or very low geological hazard, or **Low Risk** or **Very Low Risk** from a hazard. Should be attended to within the next ten years.*

4 EXAMPLE OF NATURAL HAZARDS ASSESSMENT PROCESS

4.1 Manson-Nicholls Memorial Hut

The Manson-Nicholls Hut site was assessed in 2012 and is presented as an example to illustrate the current approach to hazard assessment using the GNS 2008 guideline.

The existing Manson-Nicholls Memorial Hut (24 bunks) is located in a grassy clearing on the south shore of Lake Daniell. The clearing is surrounded by mature beech forest. The existing hut replaced an older hut on the western shore of the lake that was destroyed by a landslide in 1974 which led to the loss of three lives. The existing hut is scheduled for replacement, thus the focus of the hazard assessment was to provide DoC with information to enable selection of an appropriate site for the new hut. In this case, the existing site was proposed to be the most likely hut location subject to hazard assessment.

4.1.1 Desk Study

The published geological map of the region (GNS Science Q Map 13 Kaikoura, 1: 250, 000 scale, 2006) records the underlying geology as consisting of Holocene age alluvium ie. deposited in the last 12,000 years.

The hills to the west of Lake Daniell are composed of granite, whilst the hills to the east are composed of schist and greywacke. Large fans have formed along the eastern side of the lake due to uplift and significant erosion of the schist rocks to the east, whilst only very small fans have formed at the mouths of gullies eroded into the granite along the western shore of the lake.

The Alpine Fault has been mapped by GNS Science as being located some 300m southeast of the hut site. The fault is active and severe ground shaking would occur when it next ruptures. The Alpine Fault last ruptured in the year 1717 and GNS have calculated that there is a 50% probability that the fault will rupture within the next 100 years with a likely earthquake magnitude of 7.5 – 8.

The valley is a glacially carved valley with the infilling of the valley floor with glacial till, and outwash gravels having impounded the lake. The lake is very shallow on the eastern side and deepens towards the west with depths of 3 - 5m close to the steeply sloping western bank. At the northern end, a steep sided kettle hole 14m deep forms the deepest part of the lake (Department of Lands and Survey 1979).

Figure 3 shows the approximate position of the hut site relative to the Alpine Fault, while the NZ Topo Map M31 gives a general indication of surface topographical contours at the site.

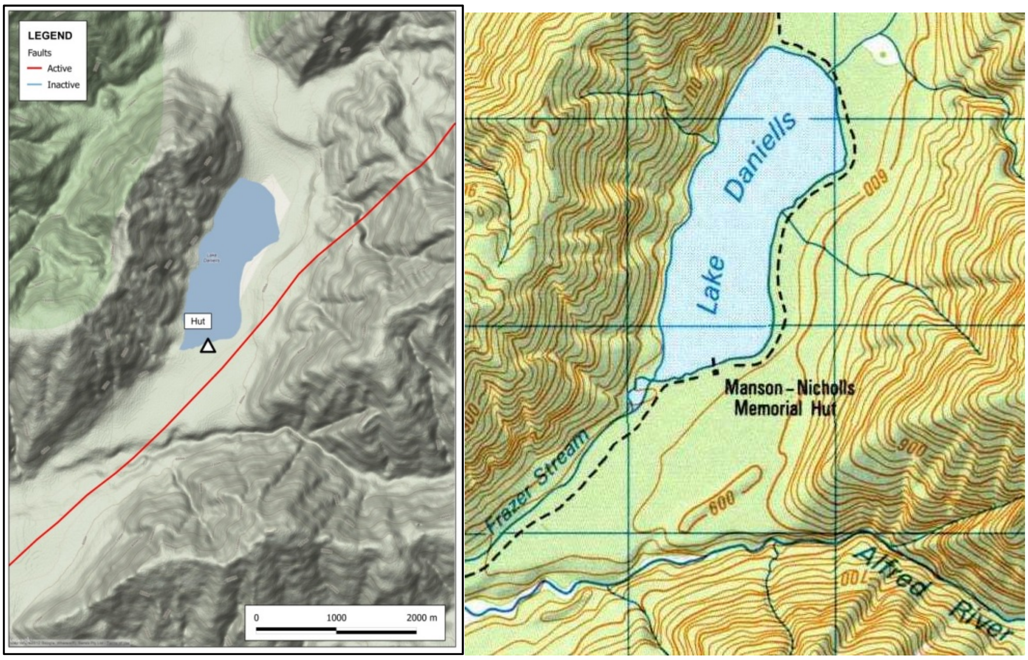

Figure 3. Manson-Nicholls Hut GNS Active Fault Database (left) showing proximity of Alpine Fault to Hut site. NZ Topo Map M31 (right)

4.1.2 Geological Hazard Evaluation and Qualitative Risk Assessment

The Manson-Nicholls Hut site is located on a flat site which is covered in well-established vegetation with surrounding mature beech forest which shows no signs of previous land instability. The hut site is located well away from steep slopes and there is no evidence of significant landslide deposits in the vicinity. We consider there is a low risk to the site from landslides and rockfall related to earthquakes and extreme rainfall events.

The risk of a seiche (tsunami) from the lake affecting the hut site is considered to be low and only conceivable if a very large landslide fell into the lake, and a large seiche is considered a very infrequent (rare) event. The massive nature of the granite bedrock to the west of the lake indicates that it is highly unlikely to be prone to large landslides although smaller debris flows are likely (debris flows are not considered to be able to cause significant seiching). The hills to the east of the lake are far enough away that a large landslide is highly unlikely to reach the lake and the deposits along the eastern shore are fan deposits and not landslide deposits. We have reviewed Google Earth imagery and aerial photographs and these show no signs of present or past significant large landslides.

There is a low risk of flooding with no streams or rivers existing near the hut site. The only conceivable flooding scenario is the lake outlet becoming blocked by a landslide and raising the lake level and this is considered to be unlikely as flood waters would be able to easily spill around the landslide over the flat gradient forest floor to the east of Frazer Stream. The highest known observed flood lake level is approximately midway between the jetty and the existing hut and the site has not been flooded since the hut was built in 1976.

The active Alpine Fault is mapped by GNS Science as being located 300m southeast of the hut site and there is a high risk relating to strong earthquake shaking. The clayey gravels encountered beneath the site have a low susceptibility to liquefaction although there is a possibility of liquefaction prone sand or silt beds existing at depth. There is also a possible hazard of minor lateral spreading, however the risk of significant lateral spreading is considered to be low as the clayey gravels are medium dense and consolidated.

Overall the Manson-Nicholls Hut site is assessed to be subject to a low level of risk related to geological hazards. The hut is assigned a Geological Hazard Rating of Low (9), which is usually acceptable for hut sites. Table 3 and Table 4 summarises the assessment of the hazard rating and geological risk.

Table 3: Geological Hazard Factor Evaluation for Manson-Nicholls Memorial Hut

GEOLOGICAL HAZARD FACTORS (Place X in appropriate cell to indicate Factor Values)	***FACTOR VALUE***					
	0	***1***	***2***	***3***	***4***	***5***
1. Slope angle and local topographic effects at site.	X					
2. Site geology and foundation materials.		X				
3. Proximity to steep slope below site.	X					
4. Hazard from slopes above site (rock/debris fall, avalanche, slide).	X					
5. Foundation failure (none, possible, incipient, active).		X				
6. Strong earthquake shaking (liquefaction, slope failure, seiche, tsunami).						X
7. Heavy rainfall, flooding, erosion, debris flows etc.		X				
8. Other (snow avalanches; faulting; volcanic ash, gas, lahar etc).		X				
***Sum of Hazard Factor Values**:*	*9*					
GEOLOGICAL HAZARD RATING	*LOW*					

Table 4: Risk Matrix for Manson-Nicholls Memorial Hut

QUALITATIVE RISK ASSESSMENT SUMMARY			
Hazard Type	**Consequences**	**Risk Level**	**Comments and Risk Management Options**
Rockfall/ landslides	Catastrophic	Low	Risk *acceptable*. Hut is 500m away from steep hills to the east and 350m away from steep hills to the west.
Seiche (Tsunami)	Medium	Low	Risk *tolerable* and can be accepted. Only a very large landslide into the lake could generate a seiche and there is no evidence of very large landslides into the valley in the past 12,000 years.
Flooding/ debris flows	Minor to Medium	Low	Risk *acceptable.* Flooding could occur if a landslide blocked the lake outlet. Consequences are minor to medium and hut users could evacuate to higher ground. Appropriate signage could be placed at the beginning of the Lake Daniell track informing users of possible flooding in extreme weather conditions.
Liquefaction	Minor	Low	Risk *acceptable*. Liquefiable sands or silts (old lake beds) could occur within 20m depth but appears unlikely. Consequence to building foundations is considered to be *minor,* but consequence to hut users is considered to be *insignificant*.
Significant earthquake ground shaking	Medium	**High**	Moderate damage to hut and foundations can be expected in a large EQ (hut will be designed to resist major damage). Risk related to injuries is considered to be minor. Risk of damage can be mitigated/reduced to an acceptable level by appropriate hut design.
Lateral spreading	Medium	Low	Risk *acceptable*. The high water table at the hut site and proximity to the lake edge could result in minor lateral spreading near lake edge in a very large earthquake, however damage to hut and consequence to hut users likely to be only minor.
Notes and additional comments: *1. Likelihood (%) estimates given as annual probability, or approximate Annual Exceedance Probability (AEP) - Appendix 2.*			

5. CONCLUSION

As presented herein, the environment in which huts are situated is subjected to dynamic environmental processes which in the past have had severe impact and consequences on huts and hut users. The hazard assessment methodology developed by GNS and presented in this paper provides a simple and clear process for evaluating the risk that various geological effects have on particular hut site locations. As a result, this geological hazard and risk assessment methodology provides important input into DoC's wider hut site selection process with the end effect of providing hut users with a safe shelter.

6. ACKNOWLEDGEMENTS

DoC staff who have assisted MWH field staff and Graham Hancox of GNS who has compiled the approach to geological hazard assessment for DoC huts are gratefully acknowledged.

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