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The need for NZ geotechnical emergency response guidelines

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ABSTRACT

New Zealand has experienced a number of significant natural disasters in the past few years, as a result of its unique geological and meteorological setting. These events have invoked Civil Emergency declarations and required significant input from the professional engineering community to assist in rapid responses and the following recovery operations. Along with input to the efforts in Christchurch following a series of earthquakes, MWH played a key role in the Civil Defence responses to the significant storm event that hit Nelson/Tasman in 2011. Based on observations from these events, the authors believe that there is a clear need for New Zealand to develop national guidance for geotechnical input to emergency responses. This paper sets out to provide observations from the two specific events, overview existing guidelines and documents and make comment on the specific requirements for a New Zealand document. This document should include a field assessment process to establish consistencies, data collection forms and triage and recovery guidelines.

Keywords: Civil Defence, Risk Management, Emergency Response

1 INTRODUCTION

Natural disasters that have occurred since 2010 have arguably thrust geotechnical engineering into the public consciousness more than any time in recent history and required large numbers of the profession to participate in civil defence emergency situations. The authors' experience during this period has identified what we perceive as opportunities for improvement in the way that civil defence emergencies are dealt with to the benefit of the public and the engineering profession.

In this paper we set out our key observations from the events including two case histories, discuss international literature that we have reviewed and discuss how we believe that practices from the literature could be implemented to improve civil defence response. The benefits extend beyond the emergency phase into the recovery where collated data can jumpstart redevelopment.

We believe the key elements to improving the emergency response are improved pre-planning, standardised methods for on-site data collection and tools to assist on-site assessors reach consistent conclusions. Because landslides, in the broad sense inclusive of ground displacement, rockfall and debris flows, represent the greatest risk to life in an emergency situation, the focus of this paper is on landslide response rather than the response to other geotechnical issues such as flat ground liquefaction.

2 BACKGROUND TO THE EVENTS

2.1 The 2010/2011 Canterbury Earthquakes

The Canterbury earthquake sequence started with a M7.1 event on 4 September 2010. The event caused localised damage throughout the city of Christchurch, most notably pockets of liquefaction with associated damage to residential dwellings and damage to older unreinforced masonry buildings in the CBD. Slope instability on the Port Hills immediately to the south of the city was generally of a small and localised scale. The event acted as a trigger to the event on 22 February 2011, a M6.3

event with its epicentre located beneath the Port Hills that generated peak horizontal and vertical accelerations in excess of 2g. Damage throughout the CBD and eastern suburbs was extensive and many rockfalls, cliff collapses and large scale landslides were triggered.

Figure 1. Example of rockfall on Port Hills of Christchurch following 22 Feb 2011 Earthquake

Many thousands of aftershocks have occurred since the initial event, the most notable on 13 June 2011 generating peak ground accelerations in excess of 2g in the Port Hills region and initiating several large rockfall and cliff collapse events. Current estimates of the cost of repairs to Christchurch and surrounding areas is in excess of $NZ40 Billion.

2.2 The 2011 Tasman Floods

Between the 13 and 15 of December 2011 intense rainfall fell on the Tasman District with rainfall totals in excess of 250mm over the 48 hour period. The event represented an estimated 1 in 250 annual exceedence probability event in Nelson and 1 in 500 further west in Golden Bay. The effect was large scale flooding of local river system, hundreds of slips on the hillsides around the district and large scale debris flows. Damage to the road network and residential property was extensive with estimated costs from the event of $NZ40 Million.

Figure 2. Example of large scale flooding and debris flows in Golden Bay

3 OBSERVATIONS FROM THE TWO EVENTS

After discussing our collective observations from the events, the authors agreed on a number of key themes that were common between the events and our own observations. These points are summarised in the following section. This is not an exhaustive list of observations, but sets out a number of points we believe supports the case for better guidance.

The initial responses and assessments made by engineers are generally conservative as is prudent following a major event. Following the initial response pressure quickly emerges to make decisions to allow re-occupation of structures and operation of infrastructure. In both events it is our observation that within a matter of days, or sooner, following an event peoples focus quickly turns from the shock of the event to consideration of how the events affects their normal life and livelihood. Decision making around reoccupation of structures quickly changes from initial rapid assessment and best judgement to a more considered review of the risks going forward. These ongoing decisions around risk are often completed by engineers from different companies, backgrounds and experiences without a complete understanding of the risk level that existed before the event.

There will be many situations where in all likelihood the risk to occupants is very low but the possibility can't be discounted under extreme conditions. Our observation is that the general attitude of most engineers is to try and not be overly conservative to aid recovery. In doing so they are often placing themselves at risk of liability and potentially criminal charges. For example, during Royal Commission hearings into fatalities resulting from the February 2011 earthquake, several engineers were questioned about barriers placed around buildings that proved inadequate given the extreme event that occurred. The questioning around these issues often focussed on why, if there was any risk, was the barrier not further away.

Do not underestimate the emotional impact of displacing people from their homes and businesses. Our observation and experience is that it is extremely difficult not to have your judgement affected when the consequences of a decision is to remove someone from their home or business. This often results in non-conservative decision making about reoccupation of structures.

Formal guidance on complex and unique engineering issues may take months or years to develop. Following the Canterbury earthquake events guidance on repairing houses in the worst affected areas took over a year to be produced, while knowledge around aspects such as rockfall risk is still being developed.

'Safe' to engineers generally means acceptably low risk of failure while to the public it means no risk of failure. Many statements were made that structures or slopes were safe following the Christchurch events, which gave members of the public a false sense of security and no appreciation of the on-going level of risk. Our view is that geo-professionals should never use the term safe as it implies to the public no level of risk and in reality there is always a residual level of risk in any situation.

There will be many different opinions of what is and isn't acceptable by different geo-professionals. Our observation is that given different peoples background, experiences and often without guidance on what is and isn't acceptable, different assessments and views will result from different geo-professionals. At each of the events attended by the authors, regular meetings were held with assessors to discuss the approach to decision making, however, even with these efforts we found that gaining commonality in assessments was not straightforward.

4 CASE HISTORIES

The 2011 Tasman floods caused numerous slips on Abel Tasman Drive, an important local road that provides the only road access into the Abel Tasman National Park. Following initial emergency works to remove debris and erect barriers, the road was passable but clearly users would be at an increased level of vulnerability to landslide issues with numerous 'dropouts' on the downslope side of the road and some creep and small quantities of material reaching the road shoulder from upslope slips. Further works to substantially improve the stability of the slopes would take many weeks and in some cases months to implement. Given the timing of the event only days before the peak Christmas season and the reliance of the local economy on tourist trade during this period there was considerable pressure to keep the road open, despite there clearly being an elevated risk to road users from landslides than under normal conditions.

Figure 3. Example of slip on Abel Tasman Drive following December 2011 Floods

Following a meeting between geotechnical and transportation staff it was decided to implement mitigation strategies such as night closure of the road, a morning sweep of the road to check for changes overnight before re-opening and improved temporary warning signage and speed restrictions to manage the increased level of risk. The decision making process was done on a best judgement basis, attempting to reasonably balance the increased level of risk with the social and economic consequences of road closure.

The February 2011 earthquake generated extensive rockfall throughout the Port Hills of Christchurch. Two of the three authors of this paper were involved in development of rockfall remediation strategies for a school, commercial property and roads located beneath cliffs, which generally involved the erection of temporary protection barriers, usually in the form of shipping containers. Our experience is that decisions around these remediation works were made on a combination of judgement and limited computer modelling, with a general philosophy of attempting to enable recovery while managing risk. Due to the level of uncertainty and judgement involved in the work, peer review was sought as an additional risk mitigation measure. Since the initial remedial works were implemented, ongoing research has been undertaken resulting in numerical estimates of risk based on distance from the cliffs. Understanding of this risk is evolving, with work as recent as August 2014 indicating an increase in risk in some areas, compared to earlier estimates.

In both examples a considerable level of judgement in the level of allowable risk was made. The process in both cases would have benefitted from guidance on issues such as:

- The best standardised approach to collecting data on sites.
- Is any increase in risk acceptable in a post emergency situation, compared to the level that existed before the emergency?
- How much weight should be placed on the social and economic consequences of closing infrastructure in allowing it to re-open?
- If uncertainty exists, and is unlikely to be resolved for many months or longer, should best judgement be used to allow recovery to continue?
- Should mitigation aim to reduce the level of risk as the same level as before the emergency event or some absolute level of risk?

In the case of both road assessments discussed above, the effects of a major weather or seismic event were largely predictable and given their role as the only road link to communities, the consequences of losing these links was understood. In both cases the response to an emergency event could have been better pre-planned, with an agreed positioned with the local road authority gained on the questions posed above agreed in advance. Such pre-planning would also allow local authorities to better understand vulnerability in their network, and therefore consider upgrades or alternative routes to reduce this vulnerability over time.

5 REVIEW OF AVAILABLE LITERATURE

5.1 International Review

In order to identify existing literature that could assist with the issues discussed in sections 3 and 4, a number of references were reviewed. In reviewing the documents the authors identified risk management documents that related to large scale assessment of existing risk and planning for future development. Guidance was also identified for first responders dealing with rescue operations. However, limited specific advice concerning the type of rapid, initial infrastructure assessments common in civil defence situations was identified.

The overall trends that we noted from review of these documents were:

- Documents from the United States defined roles and responsibilities in some detail but specific guidance on individual event responses were not identified.
- Australian and Canadian practice appeared strongly aligned with the use of quantitative and semi-quantitative risk assessment procedures for assessing landslide risk.
- Transportation agencies from Australia and the United States were found to have pragmatic points and probability based systems for identifying acceptable risk on road networks.
- Guidance on immediate response was found from Sweden, however, it did not extend to guidance around re-occupation or re-use of infrastructure.
- Dam safety practice includes a strong element of pre-emergency response planning that appeared to offer elements that could be adopted for other types of infrastructure. The Christchurch City Council has made progress in producing pre-planning documents on how to respond to further movements on the earthquake affected Port Hills of Christchurch.

From our review of these documents we were not able to identify an existing guideline(s) that could be directly adopted in New Zealand. However, we believe that existing guidance documents could provide a good starting point for development of New Zealand specific guidance. In our opinion Australian and Canadian landslide guidelines and dam safety practice are the most appropriate reference documents for adaption to New Zealand practice and are discussed in more detail in the following sections.

5.2 Risk Assessment Systems

The Australian Geomechanics Society and Geological Survey of Canada have published guidance on landslide risk management and among other techniques proposes a semi-quantitative matrix based approach to assessment based on likelihood and consequence (refer Figure 4a and 4b below). In order to use such a system in a post emergency situation it would be necessary to define which different combinations of consequence and likelihood would be acceptable. In civil defence terms it would be necessary to define which parts of the matrix would allow green (no restriction on use), yellow (limited use) or red (restricted use) placards to be applied to buildings.

Table 7: Recommended descriptors for risk zoning using property loss criteria (AGS 2007c).

Likelihood		**Consequences to property (With indicative approximate cost of damage)** (1)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (2)
B LIKELY	10^{-2}	VH	VH	H	M	**L**
C -POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Figure 4a. Extract from Australian Geomechanics Society Landslide Risk Management Guidelines

Multi-hazard Risk Evaluation Matrix (SAMPLE)

For the Qualitative Assessment of Natural Hazards

Risk Evaluation and Response		
VH	Very High	Risk is imminent; short-term risk reduction required; long-term risk reduction plan must be developed and implemented
H	High	Risk is unacceptable; long-term risk reduction plan must be developed and implemented in a reasonable time frame. Planning should begin immediately
M	Moderate	Risk may be tolerable; more detailed review required; reduce risk to As Low As Reasonably Practicable (ALARP)
L	Low	Risk is tolerable; continue to monitor and reduce risk to As Low As Reasonably Practicable (ALARP)
VL	Very Low	Risk is broadly acceptable; no further review or risk reduction required

Partial Risk (annual probability)

Likelihood Descriptions	Indices		Probability Range	1	2	3	4	5	6
Event typically occurs at least once per year	F	Almost certain	>0.9	M	H	H	VH	VH	VH
Event typically occurs every few years	E	Very Likely	0.1 to 0.9	L	M	H	H	VH	VH
Event expected to occur every 10 to 100 years	D	Likely	0.01 to 0.1	L	L	M	H	H	VH
Event expected to occur every 100 to 1,000 years	C	Possible	0.001 to 0.01	VL	L	L	M	H	H
Event expected to occur every 1,000 to 10,000 years	B	Unlikely	0.0001 to 0.001	VL	VL	L	L	M	H
Event is possible but expected to occur less than once every 10,000 years	A	Very Unlikely	<0.0001	VL	VL	VL	L	L	M

Description of expected negative outcome (Consequence)

Indices	1 Incidental	2 Minor	3 Moderate	4 Major	5 Severe	6 Catastrophic
Health and Safety	No impact	Slight impact; recoverable within days	Minor injury or personal hardship; recoverable within days or weeks	Serious injury or personal hardship; recoverable within weeks or months	Fatality or serious personal long-term hardship	Multiple fatalities
Environment	Insignificant	Localized short-term impact; recovery within days or weeks	Localized long-term impact; recoverable within weeks or months	Widespread long-term impact; recoverable within months or years	Widespread impact; not recoverable within the lifetime of the project	Irreparable loss of a species
Social & Cultural	Negligible impact	Slight impact to social & cultural values; recoverable within days or weeks	Moderate impact to social & cultural values; recoverable within weeks or months	Significant impact to social & cultural values; recoverable within months or years	Partial loss of social & cultural values; not recoverable within the lifetime of the project	Complete loss of social & cultural values
Economic	Negligible; no business interruption	<$10,000 business interruption loss or damage to public or private property	<$100,000 business interruption loss or damage to public or private property	<$1M business interruption loss or damage to public or private property	<$10M business interruption loss or damage to public or private property	>$10M business interruption loss or damage to public or private property

Figure 4b. Extract from Canadian Technical Guidelines and Best Practices related to Landslides

More specific guidance for particular situations has also been developed in Australia. The Roads and Traffic Authority of New South Wales has produced a Guide to Slope Risk Analysis. Included in this guide is a semi-quantitative assessment system for slopes that impact on roads. The assessment uses a points system based on the potential impact the slope could have on the road and consideration of likely traffic volumes. Based on these considerations it is possible to derive an overall score that can be used as the basis for whether the slope in its current state is deemed to be at an acceptable level of risk. Again a customised assessment tool could be developed for post emergency situations using such a system.

5.3 Emergency Action Planning

It is common in most countries, including New Zealand, to undertake Emergency Action Planning for dams. The New Zealand Dam Safety Guidelines note that “the plan is designed to limit damage to the dam and areas downstream, and prevent loss of life. It should take into account conceivable failure scenarios applicable to the dam, the potential downstream consequences, and what realistically may be achieved to safe guard lives at risk and generally minimise damage”.

In the authors opinion such preplanning could equally be applied to important slopes and subdivisions to define potential failure modes, expected behaviour in a range of events, triggering points for evacuation and potential downslope risks. The availability of such information and forethought involved in producing it would assist in both the immediate response phase by:

- giving a basis for pre-planned responses to site observations
- collating the background rational for acceptability of the slope at the time of design and allowing an changes to be assessed in the recovery phase.

In general terms it would allow a more considered response to emergency situations rather than a "heat of the moment" decision.

The Christchurch City Council and GNS have produced documents similar in intent to emergency action plans in order to manage potential evacuation of the earthquake degraded Port Hills of Christchurch. These set out roles and responsibilities, triggering criteria and the appropriate responses to different events. Although these documents benefit from the intense level of study undertaken on the Port Hills, similar documentation could be prepared for important existing and new slopes and other landforms.

6 SUGGESTED ELEMENTS OF GEOTECHNICAL EMERGENCY RESPONSE GUIDELINES

Based on our experiences following major civil defence events in Christchurch and Nelson and following review of a number of international risk management procedures, we believe the key elements of post-earthquake risk assessment guidelines are:

- Development of emergency action plans for important existing slopes, particularly in situations where failure would place downslope infrastructure at risk e.g. slopes above major transport links.
- Development of emergency action plans for new engineered landforms e.g. subdivisions.
- Adoption of a standardised assessment system that leads assessors through a decision making process to deliver a justified decision on whether the risk of continued occupation or use of a piece of infrastructure is acceptable. Such a system would use a matrix or points based system to justify a decision.

The benefits of such documentation are considered to be threefold:

Better Preparedness

- Preparation of emergency action plans would force improved pre-emergency planning and thereby highlight areas of existing risk to policymakers.
- Preparation of emergency action plans would highlight areas to policymakers where the level of understanding of existing risk is poor and/or there is insufficient design guidance available.
- Preparation of guidelines around acceptability of risk in a post emergency situation would highlight to policymakers the difficult decisions and balance that needs to be struck between post emergency safety and post emergency speed of recovery.
- Understanding of the level of risk inherent in existing infrastructure may shape future planning of infrastructure upgrades to address those risks.
- If a standardised approach to dealing with post emergency situations was developed better training tools for professionals could be developed.
- A better baseline for developing tools to communicate risk to the public.

Better Response

- Critical decisions about keeping key infrastructure in operation could be assisted by forethought rather than 'heat of the moment' decision making.
- Quicker response to areas that already have pre-planning via emergency action plans.
- Better consistency in assessment of risk and response to that risk.
- Ability to collect data for future use in a standardised way reducing repeat site visits.

Advancement of Geo-practice

- Catalyst for preparation of better design guidance by identification of deficiencies in existing practice.
- Raising the standard of risk assessment by encouraging pre-planning of potential failure modes.
- Reaffirming the need for policymakers to set acceptable levels of risk rather than relying on individual engineering judgements.
- Reducing the potential for criminal conviction or 'trial by media' by providing a defendable basis for post emergency decision making.

7 CONCLUSION

Responses to civil defence emergencies in 2010 and 2011 have highlighted there is the potential to improve the response to such events in the future. The authors' observations from these events was that there are a number of judgements that need to be made in assessing issues such as slope instability and that without guidance there is likely to be considerable inconsistency in decision making.

A review of international literature indicates that, while there is much available information on risk management, specific guidance for first response assessors was limited. Based on our review, our opinion was that Australian and Canadian landslide practice and international dam safety practice were the best starting points for development of guidance and tools. We believe the priority is for the development of tools to assist in decision making in situations where infrastructure will potentially be affected by slope instability and emergency action planning for important infrastructure.

We believe that the benefits of development of guidance will be threefold:

- Better preparedness by allowing policymakers to understand existing levels of risk through emergency action response.
- Better response by bringing greater consistency of data collection and decision making between different assessors.
- Advancement of Geo-practice by highlighting areas where existing understanding of risk is poor and design guidance is limited.

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