The Totara Reserve Regional Park cliff collapse of 15 December 2006

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GNS Science Report 2007/11
April 2007

GNS SCIENCE
TE PŪ AO

BIBLIOGRAPHIC REFERENCE

McSaveney, M. J.; Page, M. J. 2007. The Totara Reserve Regional Park cliff collapse of 15 December, 2006, *GNS Science Report* 2007/11 14 p.

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ISSN 1177-2425
ISBN 978-0-478-09975-1

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EXECUTIVE SUMMARY

At about 6 pm on the 15th December 2006, a section of cliff collapsed on the right bank of the Pohangina River at the Totara Reserve Regional Park[1] camping ground, 30 km northeast of Palmerston North, killing three of four people playing in the river. The collapse was witnessed by others, but occurred with far too little warning for any useful response by the victims or witnesses.

The 50-m high cliff is made of ancient, weakly consolidated, weathered river gravels with sparse thin beds of weakly consolidated silt (Turitea Formation, about a million years old). It is prone to infrequent collapse, largely as slabs of variable thickness separating along cracks subparallel to the cliff face. The typical failures are arch failures producing rockfalls in a wide variety of sizes. The rockfall of 15 December was unusually large for the site, at about 500 cubic metres of mostly weathered gravel. At the site, failure frequency may be exacerbated by an easily eroded silt layer at the base of the cliff within the reach of floodwater, but this weak layer is not the primary cause of the failure of 15 December. The primary cause is the presence of the cliff, which is maintained by scour on the outside of a bend in the Pohangina River. Scour also maintains a water depth suitable for swimming in. There is evidence that scour was particularly severe during flooding in 2004, and the cliff may still be responding with more frequent rockfalls and increased likelihood of large rockfalls. The increase is slight, however, and events such as occurred on 15 December have always been possible. Stability within the cliff has always been deteriorating over time, and a relatively small volume of gravel behind the cliff face reached a critical point of instability at about 6 pm on 15 December 2006, resulting immediately in a rockfall of some 500 cubic metres within seconds.

Evidence of past collapses is plain to see at the foot of the cliff, in the form of several large piles (cones) of debris that are easily interpreted as having fallen from the cliff. Their shape, material and location leave no other possible explanation for anyone wondering how they might have formed. But there was no evidence visible to suggest even to knowledgeable people that the frequency of failure was high enough that the pool beneath the cliff was dangerously unsafe for swimming in. Especially, there was no visible evidence before the event, that collapse was at all imminent — the evidence of slowly propagating cracks behind the face, and slowly changing stresses within the gravel mass was all hidden within the cliff.

As a result of the collapse of 15 December, some open cracks in the gravel are visible, so further rockfalls can be expected over the next few years, but they are not likely to be as large as 500 cubic metres. The next collapse at this site as large as, or larger than the event of 15 December is most likely to be immediately upstream of the last collapse, because this is where the cliff face protrudes furthest from the general line of the cliff. When this event will occur is no more predictable than was the last one — the only visible evidence will be its fall.

This site is not unique along the Pohangina River, and sites with similar characteristics of well used swimming holes below cliffs prone to infrequent, unpredictable collapse are common throughout much of New Zealand. It is impractical to ban swimming at such sites or to expect swimmers or their guardians to usefully evaluate the danger, but it is necessary for

[1] Formerly Totara Reserve. On 5 December 2006, Horizons Regional Council formalised a new partnership with Manawatu District Council on the joint management of Totara Reserve in the first stage of turning it into Totara Reserve Regional Park.

them and not society to assess their risk. The infrequency of such tragedies as occurred on 15 December is an indication that the frequency of such accidents is not a risk to society, it is only a risk to the people involved. People face other comparable dangers in Totara Reserve Regional Park; there is an ever-present danger of falling tress and tree limbs. Witnesses to the rockfall may well have been exposed to a higher risk from falling tree limbs than their children were from falling rock. Greater danger and risk however was faced and accepted in the drive to and from the park.

Sites where similar tragedies could occur can be readily recognised as being unsafe by people with knowledge of slope stability, but the acceptable level of risk can not be determined by society. Like crossing the road, it has to remain an individual responsibility, and so such rare tragedies will not be avoided.

KEYWORDS

Rockfall fatality, Pohangina River, cliff stability, Turitea Formation, Totara Reserve Regional Park, Manawatu

1.0 INTRODUCTION

1.1 Background

On 15 December 2006, at about 6 pm, a large section of cliff on the right bank of the Pohangina River at the Totara Reserve Regional Park camp ground (grid reference Infomap 260-T23 Kimbolton E2753350 N6116890) collapsed without warning. Of four people in the river at the time, Callum Warrick Langley, 10; Keryn Sarah Langley, 8; and Michael Keith Liengme, 13, were killed. Only Kevin Liengme, 10, survived, with minor leg injuries, because he was not in the direct path of the debris. The collapse was seen by the children's' parents, but no one had time to respond before the children were lost from view in a huge dust cloud. The children were not under the collapsing debris, but were hit by the rapid lateral movement of debris after it hit the base of the cliff.

The Reserve formerly was managed by Manawatu District Council. On 5 December 2006, just 10 days before the tragedy, Horizons Regional Council formalised a new partnership with Manawatu District Council on joint management of Totara Reserve in the first stage of turning it into Totara Reserve Regional Park.

1.2 Site Inspection

As part of the GeoNet natural geological hazards monitoring contract between GNS Science and the Earthquake Commission, a response team is to investigate any incident of land instability involving loss of life. This investigation was made under this contract. The response team consisted of Dr Mauri McSaveney and Mike Page of GNS Science. We visited the site on 19 December, and were on site for about an hour. We inspected the site with Alistair Beveridge of Horizons Manawatu, from safe ground on the left bank of Pohangina River adjacent to the fatal rockfall. We did not venture to cross the river to the rockfall deposit; we judged it unstable and too liable to further collapse without warning or adequate time for us to escape.

1.3 Scope of report

This report details our findings concerning the stability of the slope in the vicinity of the fatalities, and the behaviour of the rockfall. It is not directly concerned with the deaths or injuries.

1.4 Acknowledgments

Logistics for this investigation were funded by the Earthquake Commission through the GeoNet project. We gratefully acknowledge information provided by Horizons Regional Council.

2.0 SITE LOCATION, GEOLOGY, GEOMORPHOLOGY AND HYDROLOGY

2.1 Accident location and time of occurrence

The cliff collapse occurred at NZ map grid reference E2753350 N6116890 (Infomap 260-T23 Kimbolton), on the true right bank of the Pohangina River immediately adjacent to the Totara Reserve Regional Park camping ground about 30 km northeast of Palmerston North (Figure 1). River-bank shade from trees, a variety of facilities associated with the camping ground, and a convenient site for recreational swimming in the river, had made this a popular site for picnicking. The two families involved had travelled from Palmerston North to Totara Reserve Regional Park for a summer picnic supper and swim. The four children were playing in the river within sight of their parents at about 6 pm (NZDST) when one parent saw the cliff begin to collapse. Three children appear to have been in the deeper water near to a narrow platform at the base of the cliff, the fourth was standing on the narrow platform immediately below the cliff; he survived with only minor leg injuries. The parents were high on the river bank opposite the collapse, and clear of any flying debris or splash. One of them, while watching the playing children, saw some of the cliff begin to move. He shouted a warning, but it was already too late. There was too little time for the children to escape being hit by the debris.

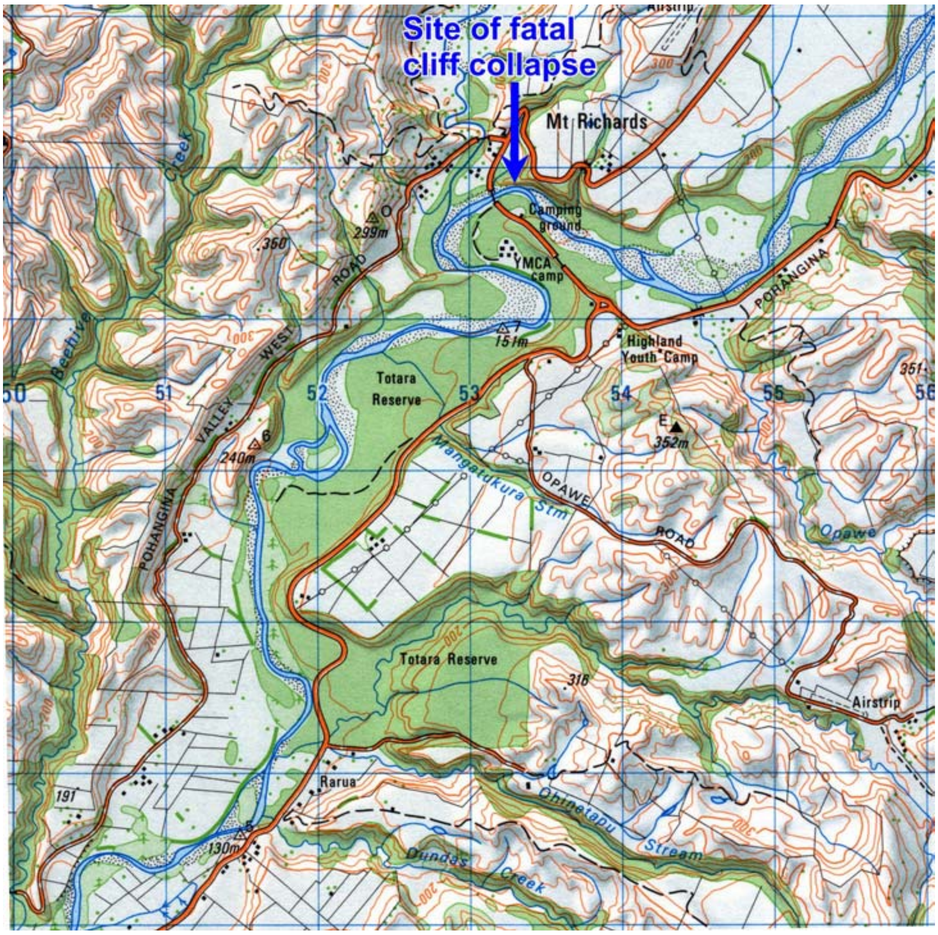

Figure 1 Map of Totara Reserve Regional Park showing location of the camping ground and the site of the rockfall tragedy of 15 December 2006 (arrow). Grid is 1 km square. Contour interval is 20 m. North is uppermost. From Infomap 260-T23 Kimbolton.

The time of occurrence of the collapse is known only approximately; its exact time is immaterial to this report, and of consequence only in relation to its victims.

2.2 Geology, geomorphology and river dynamics

The valley of Pohangina River is deeply incised along the western flank of the Ruahine range, as a result of ongoing uplift along the Pohangina fault, an active fault which forms the western front to the range. Within the valley, there are a series of terraces representing past levels of the river channel as it cut into the rising mountain front. Some terraces are cut in the local bedrock, which is known as the Rapanui Formation, and others are from ice-age aggradation of Pohangina River and are made entirely of river-deposited gravel and layers of sand and silt. These deposits vary in age from a few tens of thousands of years to many hundreds of thousands of years and are known collectively west of the Ruahine Range as the Turitea Formation. The Turitea Formation is a little-studied group of non-marine sandy gravels with layers of sands and silts. These are weakly consolidated, and the older components are moderately weathered. Although long-exposed surfaces on Turitea gravel are grey, on fresh outcrop it is light brown. The collapse occurred entirely in older Turitea Formation. It initiated in a thick brown-weathered gravel horizon and extended the full depth of this horizon into an overlying grey silt layer (Figure 2).

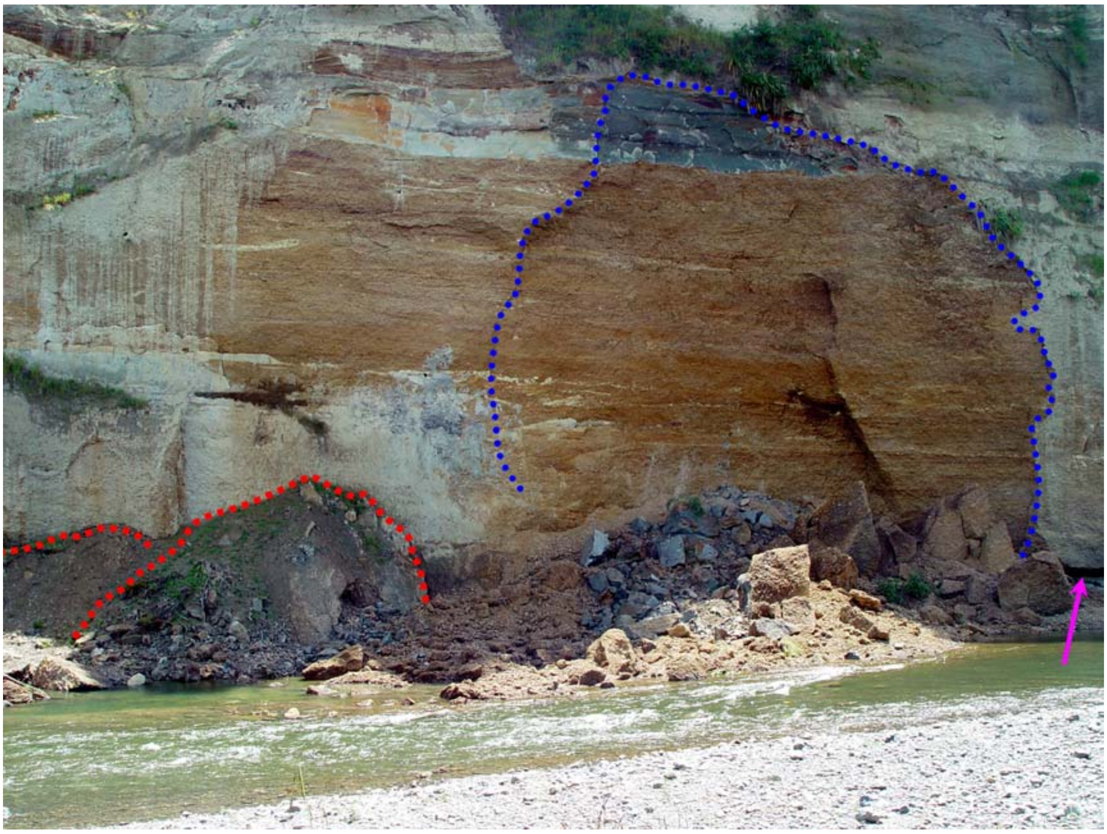

Figure 2 View of the swimming hole at the Totara Reserve Regional Park Camping ground showing the deposit in the Pohangina River from the fatal rockfall of 15 December 2006. The area of the rockfall scar is outlined in blue. The collapsing debris dropped vertically from the cliff, then sprayed outwards as it hit a narrow ledge beside the river. Photograph taken 19 December 2006. Note the piles of debris at left of photograph (outlined) from a past rockfall of several years ago (based on the sparse growth of weedy vegetation on it). Arrow points to eroded silt layer undercutting a small portion of the cliff.

The gravel at the collapse site is underlain by a thin, gently inclined silt layer, which locally has been selectively eroded by the river. The erosion has undercut the gravel by a small amount. The extent to which the undercut might have influenced the size of the collapse has not been evaluated. The collapse was not centred over the undercut, most of which still remains visible beside the rockfall deposit (Figure 2). The selective erosion will have contributed to the loss of stability, but it was not essential to it, and did not play an important role in determining where the failure occurred.

Pohangina River has a low gradient, generally single-thread meandering channel about 15–20 metres wide at normal flow, on a flood plain between 500 metres and a kilometre wide. In the vicinity of Totara Reserve Regional Park, the river flows gently, dropping only about 40 metres in 8 km, through a series of pools and riffles on a fine gravel bed. The swimming hole is one of these pools, with shallow riffles up and down stream. Although many pool-and-riffle systems are migratory, this particular one is fixed in position by other characteristics of the site

The river makes a sharp (90°) bend to the left at the base of the cliff beside the Totara Reserve Regional Park camping ground, maintaining a deep scour hole that is popular in summer for swimming. It is this scour that maintains the cliff in its active state, by slowly clearing any debris that collapses from the cliff. The bend and the scour hole have been there a long time, far longer than there has been a campground at the site. It is certain that debris has been falling from the cliff infrequently throughout its existence, and certainly there have been repeated falls since the hole has been used for swimming in.

It is normal for cliff collapses to occur very irregularly, and unpredictably. It also is common for them to cluster in time at a site, so that the frequency of collapse can appear to vary with no readily apparent cause. At the Totara Reserve Regional Park campground site, however, there appears to have been a cause for an apparent recent increase in rockfall frequency. There was severe flooding in the Pohangina River valley on 15-17th February 2004 in the largest flood on record for the catchment, with widespread channel changes documented (Fuller & Heerdegen 2005). In addition to scouring the foot of the cliff, there also was scour at the outside of the next bend upstream, which is not cliffed. Flood overflow passed through the campground. Some camp sites and parkland forest were lost in this scour, and protective groins were built to prevent further scour of the forest and campground. These structures, prevent further erosion of the outside of this bend, and have indeed promoted deposition of gravel between the groins (Figure 3), further increasing their effectiveness in protecting the forest. The lack of erosion, and induced deposition, locally deprive the river just downstream of bedload that it often has capacity to move. An outcome has been increased scour at the next bend – the swimming hole. Increased scour leads to a bigger hole, but also to increased frequency of cliff collapse, and increased likelihood of larger collapses. It does not, however, change the inevitability of cliff collapse, or make the timing of collapse any more predictable. It has always been only a matter of probability that the timing of a significant collapse, and the presence of swimmers would coincide. This probability is demonstrably very low, not only at the Totara Reserve Regional Park site, but for all such sites in New Zealand rivers.

The situation at the Totara Reserve Regional Park campground is far from unique along the Pohangina River, and at many other New Zealand rivers. The very low level of historical deaths and injuries from similar causes suggests that a certain amount of public awareness and caution may exist and be utilised with respect to swimming in proximity to cliffs. The more dangerous sites evidently are instinctively viewed as threatening, and scour holes tend not to persist in proximity to the more frequently collapsing cliffs. In addition, more cliff collapses will occur when a cliff is wet, because wetting generally weakens the rock mass. This further reduces the likelihood of swimmers being present when collapse occurs.

Figure 3 View of groynes constructed after the floods of 2004 to protect forest and the campground from further river erosion, immediately upstream of the swimming hole. Photograph taken 19 December 2006.

2.3 Landslide terminology in relation to the cliff evolution

In the jargon of the geotechnical profession, the cliff collapse was a rock or debris fall from an arch failure in the very steep cliff face. That is, the mechanism of failure was the action of gravitational forces on the mass of material in the cliff face. These forces placed the outer part of the cliffed rock mass under tension, and a relatively thin slab behind the face began to move outwards (and downwards), as it pulled away from the mass behind it. Rock masses in general, and old weathered river gravels in particular are not very strong in tension, and crack relatively easily, so that the thin slab tends to separate from the rock behind it. The crack can only enlarge, and as it extends over a larger area, the slab loses more and more of the support that is holding it up. As the support lessens, more and more weight is carried by less and less, and collapse is inevitable. The rate at which loss of strength proceeds is extremely variable both from place to place, and from time to time at any place, but the general trend is for support to lessen at an accelerating rate until catastrophic failure occurs.

Most of the process of detachment takes place behind the cliff face, and is unseen; but the unseen displacement is only a few millimetres of movement. It is rare for there to be external signs of impending rapid failure, other than the rapid failure itself. Rarely, the sound of propagating cracks is heard, or a few small rocks are seen to “pop” out from the cliff face, because they become so highly stressed. Such warning signs can occur months to fractions of a second before rapid failure occurs. The Totara Reserve Regional Park rockfall gave no adequate warning, if it gave any warning at all.

3.0 THE COLLAPSE

We have not accurately measured the dimensions of the collapse or the resulting deposit. Our visual assessment of the dimensions of the scar support others’ estimates of the debris volume quoted in the media as being about 500 cubic metres. The scar from which debris had freshly fallen was about 20 metres high, at its maximum, and a similar width. The slab which had peeled off the cliff face was probably less than several metres thick at its thickest, thinning to zero at the edges (sides and top). The thickness at the base was obscured by the remaining cone of debris against the base of the scar where the debris came to rest (Figure 2). The area of freshly fallen rock can be seen clearly between a pair of photographs published on page 1 of the Manawatu Standard of 18 December 2006, where the “before” photograph was taken on 14 December 2006.

The mass that collapsed appears to have protruded beyond the general line of the cliff, and supported a substantial clump of shrubby vegetation on its more gently sloping apex, where now there is a declivity.

The collapse to the foot of the cliff was essentially a free fall. The maximum height that debris fell from is about 20 metres, but most of the mass fell less than 10 metres. The dynamics of such small falls is independent of the mass that fell, so from conversion of potential energy to kinetic energy under gravitational acceleration in a free fall, much of the debris was travelling at about 14 m/s (50 km/hr) on impact with the base of the cliff, and some may have been travelling at about 70 km/hr. A free fall of 10 to 20 metres would have been completed in 1.4 to 2 seconds, and much did not have so far to fall.

At impact with the foot of the cliff, the debris was deflected horizontally at essentially these speeds, and spread about 20 metres from the base of the cliff into the river on ballistic trajectories. The four children were within the zone of flying debris, but the three killed evidently were more directly in the path of the flying debris than the survivor, who also may have been standing high enough in the landscape so that flying debris missed his vital organs.

The four had less than 2 seconds to notice what was happening, and to react to it. They obviously noticed, but had too little time to escape.

The survivor was standing on a riverside ledge beneath the cliff, and this probably was all that saved him from sudden death or serious injury. He was beyond one side of the collapse, and not in any position to have contributed to its timing. His close proximity to the slightly concave cliff face is probably good evidence that the collapse took place with no precursory noise or falling rocks to warn anyone.

3.1 Past collapses

There is an unconfirmed report of a witnessed collapse at the site of some decades ago, but there have been no previously reported deaths or injuries. Witnessed collapses should not be a surprise, because there is clear evidence along the foot of the cliff for a number of previous rockfalls of a similar type to event of December 2006 (Figure 2, 4), although the latter is obviously the largest collapse that still leaves a deposit in the river. Although smaller, any of the previous rockfalls could have killed people had they been present near them at the time.

Figure 4 View of blocks of debris from past rockfalls (outlined) along the cliff immediately downstream of the Camping-ground swimming hole. The grey-brown cliff above them and the weedy plant growth among the blocks indicate that these fell some years ago. Compare with the fresh brown scar surface on Figure 2 from 15 December 2006.

In addition to the evidence of past deposits, there is evidence for earlier rockfalls in the form of old scar outlines without associated deposits, because the deposits have been carried away by the river. Long-continued erosion of debris from the base of the cliff, and episodic rapid collapse of rockfalls, is the mechanism by which the cliff formed and is maintained. All riverside cliffs form and are maintained by this mechanism, it is only the frequency and size distribution of rockfalls that varies between sites. Even apparently long-stable cliffs can and do fail. This potential to fail in rapid rockfalls is only lost when the debris pile at the base is high enough, and the slope of the collapsing part low enough, that further free-fall collapse becomes impossible. This can only begin to develop at the site when the scour hole is no longer present. As mentioned earlier, the scour hole currently is locked in position by upstream engineering work to prevent another river bend from migrating downstream and removing more of the forest and camping ground.

There is abundant evidence that a potential for future rockfalls remains at the site. This potential currently is heightened by the exposure of cracks in the cliff (Figure 5) and the significant reduction in support afforded to some remaining, smaller slabs on the face, by failure of the larger slabs on 15 December. There is little indication of when these might fall, but we expect them to fall sooner, in the next few years, rather than later.

Figure 5 An open crack in the cliff. A thin slab of rock on the left still clings to the cliff face after the collapse of 15 December 2006. Prior to 15 December, such cracks, little wider than a credit-card thickness, were hidden so that there were no external signs of the progressive weakening of the cliff face.

The collapse of 15 December has left a portion of the cliff face protruding beyond the general trend of the cliffline. This portion is immediately upstream of the last collapse. Because it protrudes furthest from the line of the cliff, it is likely that internal stresses are higher in this section then elsewhere, and other things being equal, it is more likely to collapse sooner there than elsewhere. As with the last rockfall, it is far simpler to predict generally where the next fall is likely to occur, than generally when it is likely to occur. As best the geotechnical profession might predict, the event of 15 December was no more likely to occur then than it was a week or so earlier or a week or so later; In point of fact, it was unlikely to occur at about 6 pm on 15 December 2006, but it did occur then.

3.2 Potential for cliff collapse elsewhere

Any rockfall is a danger if people are present at the time; how then are people to assess whether they might be in danger from rockfalls while playing in a river? We have already discussed that the presence of the cliff itself is evidence of some potential for rockfall collapse, even if there is no debris cone at its base. A debris cone is only indicative of recent rockfall, and a number of cones is evidence of a significant frequency of recent rockfalls. The number and freshness of debris cones (how much remains of them, and how much vegetation had grown of them since they fell) are an indication of whether the rockfall frequency might be unacceptably high.

Although our society regulates where people may put structures to avoid such hazards, it does not regulate where people may go of their own volition and free will; it can only alert them to the dangers they might encounter. In this respect, swimming beneath a cliff is much like crossing a rural road.

Horizons Regional Council staff have identified an alternative site for swimming several hundreds of metres downstream of the campground with a clearly lesser rockfall hazard. This site, however, is still beside a cliff, and so it still has a rockfall hazard. The absence of rockfall debris at its base, its lack of evidence of a sequence of past rockfall scars, colour (grey) and texture of its weathered surface all indicate that the rockfall hazard is low enough to not be of immediate concern to swimmers. The cliff also is much lower than at the camping ground, and so there is little potential for large rockfalls, should the cliff become active. There is however no constraint for permanence for the pool or the pool-and-riffle system at this site. Constant migration of the hole may account for the apparent long-term stability of the cliff. If this is a problem, it will become apparent over time, and usage will reveal if the trade-off between ambiance, convenience and safety between the sites was acceptable.

3.3 Other comparable dangers

Falling rocks are not the only dangers people face in Totara Reserve Regional Park. In a forest reserve there is an ever-present danger of falling tress and tree limbs. Depending on where witnesses to the rockfall of 15 December were seated, they may have been exposed to a higher risk from falling tree limbs than their children were from falling rock. In a forested campground, the average duration of exposure to this danger also is greater, and more likely to occur in adverse weather, than exposure of swimmers to rockfall hazard. Greater danger and risk however is faced and accepted in the drive to and from the park.

4.0 CONCLUSIONS

Prior to the collapse of the cliff at the Totara Reserve Regional Park campground site there was clear evidence that collapse of the cliff into the swimming hole was possible, but there was no evidence of when this collapse might occur. Hence it was only a matter of time before a collapse, and the presence of swimmers coincided.

The collapse occurred without warning and with far too little time for anyone in its proximity to escape.

Cracks in the cliff suggest that there is a heightened danger of further collapses in the immediate future, but the cliff has always been prone to sudden collapse because this is part of the mechanism by which the cliff was formed and persists.

There are nearby sites where cliff collapse currently is much less frequent, but it may be that the current scour hole there is mobile, and that site’s acceptability for safe swimming may not persist in the long term.

5.0 REFERENCE

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