GeoNet Response Report

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Report on the fatal rock fall on the coastal cliff south of Rothesay Bay, Auckland, on 2 July 2011

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1. Introduction

On 2 July 2011, a rock fall from the coastal cliff on Auckland's North Shore killed a woman while walking her dogs on the beach about 350 m south of Rothesay Bay (Figure 1). The woman is reported to have died instantly when rocks hit her around 1pm and was found by another person on the beach, who reported the accident *(Sunday Star Times, 3 July 2011).*

The cliffs on Auckland's eastern coast south of Browns Bay (Figure 1) are well known for erosion, slips, and rock falls, particularly during periods of heavy rain (Hancox and Nelis 2009). A paved walkway at the top of the cliffs along Churchill Road (Figures 2 and 3) was temporarily closed while the scene was investigated by police and geotechnical engineers acting on behalf of the Auckland Council. An Auckland police spokesman (Kevin Loughlin) warned the public to be aware of the danger of rocks falling in the area. Auckland Council's Manager Building Control, Ian McCormick, said that engineers had checked the area and recommended people stay away from the base of the cliff as a precaution. There were already signs along the coast warning people of falling rocks, but not in the immediate area of the fatality. A warning sign was put up in the area on 2 July, soon after the accident occurred.

Figure 1. Map showing the location of the fatal rock fall site on the coastal cliff about 300 m south of the Rothesay Bay car park. *(Base map from LINZ Topo50-BA32)*

Figure 2. Annotated Google Earth Image (January 2008) showing the site of the 2 July 2011 rock fall on the coastal cliff below the cliff-top walkway at 131A Churchill Road.

Consulting Engineers Tonkin & Taylor were commissioned by Auckland Council (AC) to undertake a geotechnical inspection and report on the rock fall site on the Rothesay Bay Cliffs for Auckland Council on 2 July 2011. That report (Tonkin & Taylor 2011) concluded that:
(a) The rock fall was relatively small (up to ~¼ m^3); (b) the slope failure was typical of the progressive natural erosion and small rock falls on Auckland's east coast cliffs; (c) the rock fall risk has always existed, and still exists at the site, but is no greater as a result of the recent rock fall. (d) There is no evidence that discharge of stormwater played a role in the rock fall; (e) additional signs could be erected to warn on the risk of rock falls in the area; (f) rock fall protection measures are possible at the site, but are not thought to be justified given the apparent rarity of the event (it was the first known fatality of its type in the Auckland area).

There was no obvious trigger for the rock fall. It was fine at the time, and no rain fell on the two days prior to the rock fall (30 June and 1 July 2011). However, the previous two weeks from 17–29 June 2011 were very wet, with ~98 mm rain recorded at Auckland Airport *(Metconnect.co.nz)*. A magnitude-2.9 earthquake occurred in Auckland (~MM 4) at 9:09 pm on Friday 1 July 2011 *(GeoNet website).* However, GNS Science believes the earthquake was unlikely to have triggered the rock fall given its relatively small size and considerable time lapse between the two events.

This report presents the results of a Landslide Response inspection of the rock fall site carried out under the GeoNet project by the author, together with Marion Irwin (AC Hazards Manager, Civil Defence and Emergency Management Department) and Rachael Pentney (AC Specialist Hazards, Environmental Strategy and Policy Department) on Friday 15 July 2011. The objective of the site visit was determine the location, nature and mechanism of the fatal rock fall, and to compare the recent failure with the landslides that occurred on Auckland's east coast cliffs during a prolonged wet period from June to August 2008 (Hancox and Nelis 2009).

2. Description of rock fall

2.1 Site location and geology

The rock fall occurred on the ~35 m high, near-vertical coastal cliff about 350 m south of the Rothesay Bay Car Park, about 1 km from the Browns Bay shopping centre (Figure 1). The failure site is about half way (~20 m) up the ~35 m high cliff below the paved cliff-top walkway at 131A Churchill Road (Figures 2 and 3). This section of the cliff comprises interbedded, sub-horizontal to ~3–5° west-dipping (into the cliff face) Tertiary sandstone and siltstone of the Waitemata Group, with a ~1–2 m thick mantle of soil and weathered rock at the top of the cliff. The sandstone and siltstone beds range in thickness from ~0.1–1.5 m. The thinner siltstone beds exposed in the coastal cliffs are typically prone to frittering erosion. This process undercuts the sandstone beds, often leading to joint-controlled sandstone block falls, which is the most common form of instability on the east coast cliffs (Moon and Healy 1994). Figure 3 shows the geology of the coastal cliff, and the location of the rock fall site on the cliff face, and the coastal platform east of (below) 137–131A Churchill Road (houses identified in Figure 2).

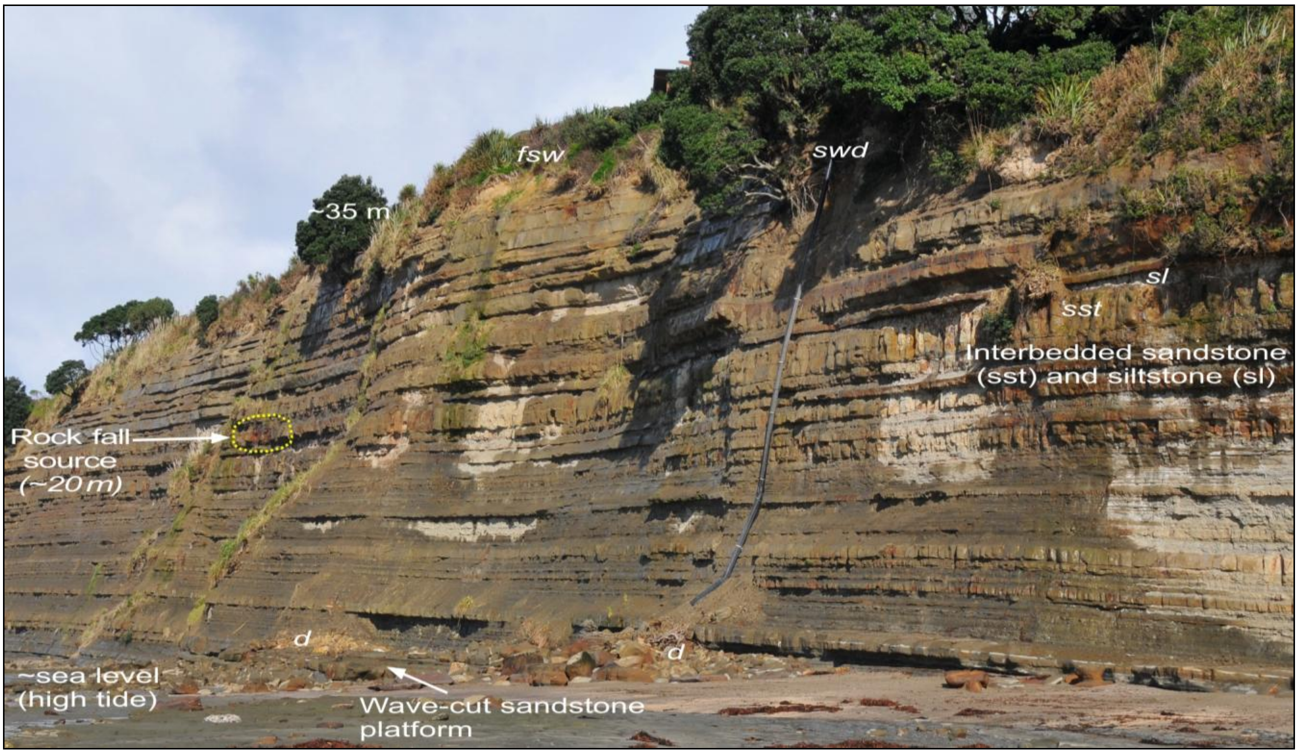

Figure 3. Area of the 2 July 2011 rock fall site on the near vertical ~35 m high coastal cliff at Rothesay Bay. This view, from the north at low tide, shows interbedded sub-horizontal sandstone *(sst)* and siltstone *(sl)* beds forming the cliff, with a thin (1–2 m) layer of soil and weathered rock at the top of the cliff face. Other features shown are a prominent sandstone wave-cut platform, an existing storm water drain *(swd)* and the site of former drain *(fsw)* ~50–100 m north of the rock fall site, and old rock and soil debris *(d)* at the base of the cliff below the storm water drain outlets.

As shown in Figure 3, the rock fall source area is located about 20 m above the base of the cliff. There are no storm water outlets in the immediate vicinity of the rock fall site. However, ~100 m north of the rock fall site a polythene storm water drain discharges water at the base of the cliff onto old rock and soil debris. Another drain outlet was previously located at the top of the cliff above an area of grass and algae growth, suggesting a greater water flow on that part of the cliff. The drain is visible in an aerial photo taken by the author in September 2008 (Figure 4). There is no evidence that these drains affected the 2 July rock fall site or contributed to the recent slope failure. However, they do appear to have caused or at least contributed to earlier small rock and debris falls in the immediate vicinity of the drain outlets (Figure 3).

Figure 4. Aerial view of the area about 50 m north of the 2 July 2011 rock fall site (out of view to the left), showing two storm water drains *(swd1, swd2)* which discharged water down the cliff face south of Rothesay Bay in September 2008. The northern drain *(swd1)* now extends to the bottom of the cliff. Small rock falls (~0.5-1 m^3) have since occurred at the site of the southern *(swd2)* drain (see Figure 3).

2.2 The rock fall

The rock fall occurred at around the middle of the near-vertical coastal cliff within a ~800 mm thick sandstone bed. The ~3 m long source area is clearly recognisable on the cliff face by the fresh iron-stained, joint-controlled scar (Figure 5). Details of the rock fall source are more clearly shown in a close up view of the scar (Figure 6).

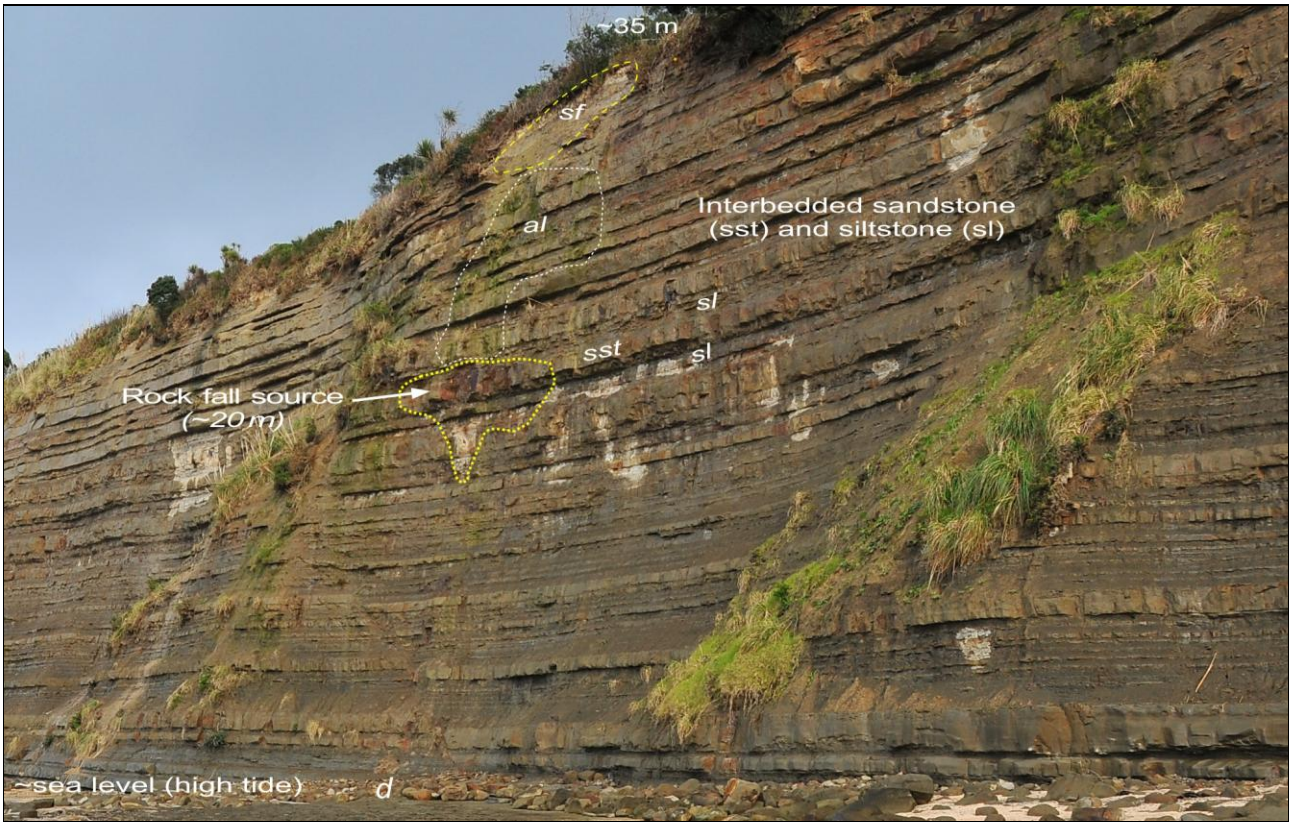

Figure 5. Closer view of the source of the 2 July 2011 rock fall in a ~800 mm thick sandstone bed *(sst)* about 20 m above the base of the 35 m high cliff. Grass and algal growth *(al)* above the rock fall scar, and the recent shallow soil failure *(sf)* at the top of the cliff suggests there has probably been more concentrated flow of natural run-off water down the cliff face at this location. Most of the debris *(d)* from the 2 July rock fall had been washed away or redistributed by wave action when this photo was taken on 15 July.

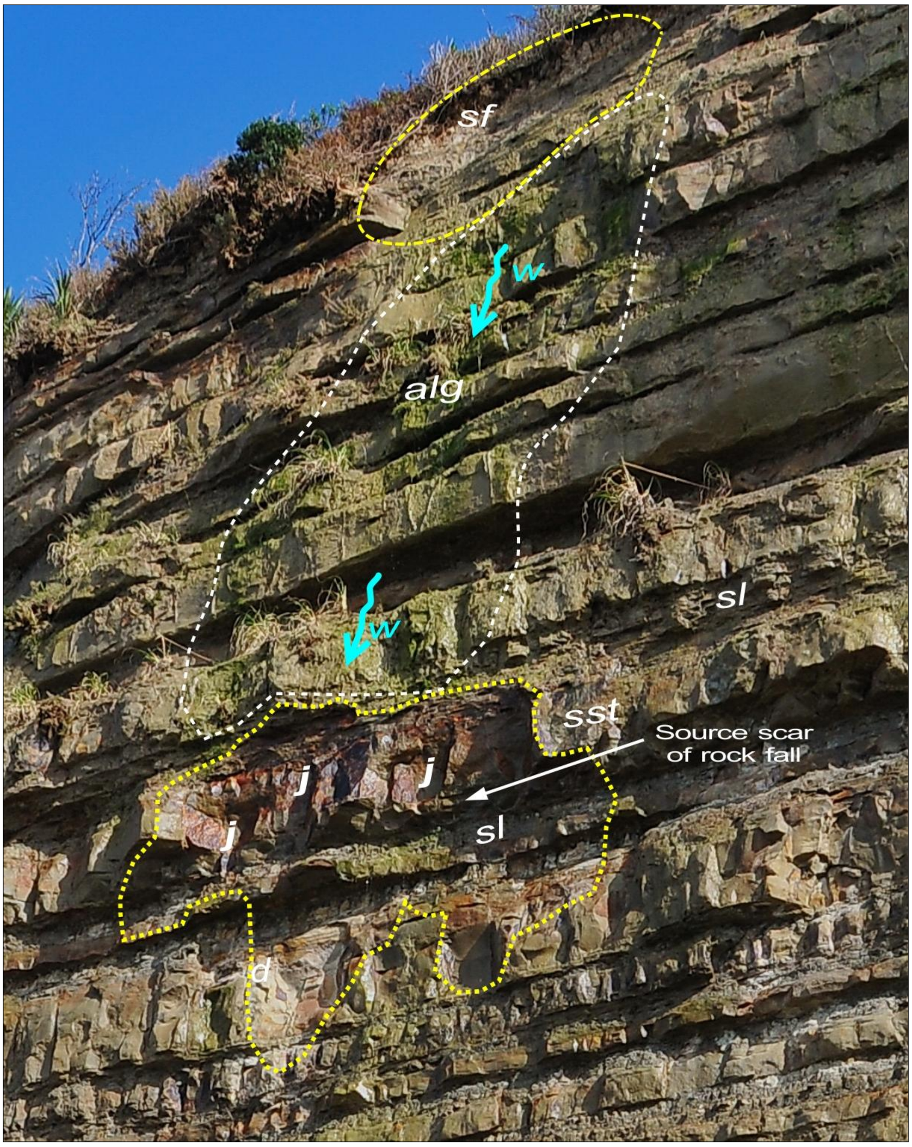

Figure 6. Closer view of the 2 July rock fall scar in the thick sandstone bed showing the iron stained joints *(j)* on which the break-out occurred, and obvious undercutting of the sandstone bed caused by erosion of the underlying siltstone *(sl)* layer. The strong algae and grass *(alg)* growth above the scar, and the shallow soil failure *(sf)* at the top of the cliff face, are both indicative of greater water flow *(w)* down the cliff at this location, as is the heavy iron staining of joints exposed in the rock fall scar.

Most of the material in the 2 July rock fall was clearly derived from a ~800 mm thick sandstone bed, with a minor amount from the underlying siltstone and sandstone beds. The rock fall source scar shows that it was a typical block failure, with break-out controlled by prominent, near vertical iron stained joints (Figure 6). Locally greater water flow down the cliff face at the rock fall site, as shown by algae and grass on the cliff above the source scar, is thought to have been responsible for iron staining of the joint surfaces, and hence reduced joint strength and increased likelihood of slope failure at this particular location. The source of the water is more likely to be from natural run-off. Construction of houses and the walkway along the cliff edge may have affected natural drainage paths on the cliff face, but there is no direct evidence of this. There are no storm water drains in the immediate vicinity of the site, and I therefore agree with Tonkin & Taylors (2011) conclusion that there is no evidence that stormwater discharge was a factor in the failure.

Although the source area of the rock fall was still clearly visible during the 15 July site visit, most of the rock fall debris had been washed away or redistributed by wave action (Figure 5). However, from inspections carried on the day of the failure the total volume of fresh angular rock fall debris (~200-300 mm boulders) at the site is estimated to have been less than ~¼ m^3, which extended up to ~7 m out from the cliff face (Tonkin & Taylor 2011). The woman killed by the rock fall was found within the area of new debris at about 1 pm on 2 July 2011 (low tide was at 1:49 pm), approximately 7 m from the base of the cliff (pers. comm. Ian McCormick, AC).

3. Discussion

The rock fall at Rothesay Bay on 2 July 2011 was a typical joint-controlled sandstone block fall, which is the most common form of slope failure on Auckland's east coast cliffs. In terms of volume the 2 July rock fall was relatively small (up to ¼ m^3 or less), which ran out about 7 m from the base of the cliff. There are many old rock fall sites of a similar size and nature on the cliff face south of Rothesay Bay. The characteristic block failure mechanism described by Moon and Healy (1994) involves loss of support to a sandstone layer by frittering, slaking, and erosion of the underlying siltstone bed by waves, surface water, and wind-blown silt. Undercutting of the sandstone beds and opening of joints allows blocks to fall from the face. This process is exacerbated by water flowing down joint planes, as shown by wet surfaces and extensive iron staining on newly-exposed joint surfaces. These features are clearly shown in the scar of the 2 July rock fall, notably the prominent iron stained joints, and evidence of water flow on the cliff face above the scar (Figure 6). A concentration of natural run-off on the cliff face is therefore believed to have increased the likelihood of slope failure at the rock fall location. There is no evidence that discharge of stormwater was a causative factor in the failure, or that construction of houses and a walkway at the top of the cliff caused increased run-off on the cliff face above the rock fall site.

There was no obvious trigger for the rock fall, which occurred during two days of fine weather. However, two factors may have influenced when it occurred. Given the apparent concentration of natural runoff at the rock fall site it is possible that two weeks of wet weather (~98 mm of rain) prior to a brief fine spell may have influenced the timing of the failure. Another possibility to be considered is the magnitude 2.9 earthquake that shook Auckland at 9:09 pm on Friday 1 July. There was a significant time lapse between the two events, so the relatively small earthquake clearly did not directly trigger the rock fall, or any others in the Auckland area. Nevertheless, it is possible the low to moderate (~MM 4) shaking that occurred on Friday night could have loosened the weathered, iron-stained joint-bounded blocks of sandstone on the cliff face, and thus made it more prone to the sudden collapse that occurred some 16 hours later. It is likely therefore, that both rainfall and earthquake shaking had some bearing on the timing of the failure.

Rock falls of the size and type that occurred on 2 July 2011 are a relatively common occurrence on the coastal cliffs south of Rothesay Bay. That particular failure was much more significant, however, because it tragically resulted in a fatality on a stretch of coastline that is often used by people walking along the beach at low tide. Reports of the incident suggest that the rock fall fatality occurred about 7 m from the base of the cliff at about 1pm, around 50 minutes before low tide. At this time of day the tide would have been a long way out, allowing walkers to keep well clear of the cliff face, and this made us wonder why the woman killed by the rock fall was walking so close to the cliff. We gained some insight into the possible reason for this during our site visit. As observed by others (Tonkin & Taylor 2011), the sandstone wave-cut platform close to the cliff offers reasonably good footing, but where it is exposed to tidal action, or is cut in in siltstone, it is very slippery underfoot. Stories abound of people having nasty falls on it. Beach walkers therefore appear to prefer to use the less slippery route close to the cliff, which places them within the rock fall hazard zone that extends 10–15 m out from the base of the cliff.

Historically, the 2 July rock fall fatality is believed to be the only known fatality of its type in the Auckland area, and is therefore considered to be a very low probability event. It appears to be a tragic case of a person being in the wrong place at the wrong time, or in this instance at the rock fall site exactly when it happened. Given the small exposure time for a person walking below a cliff face subject to periodic rock falls, the probability of being hit by a rock fall precisely when it occurs is considered to be extremely low. Although occasional rock falls will continue to occur on the cliff face south of Rothesay Bay, I agree with Tonkin & Taylor's (2011) conclusions that the risk to the public from such rock falls is probably low, and that extensive rock fall protection or slope stabilisation measures are not justified. However, better control of drainage on the cliff face, for example by ensuring that storm water drains discharge at the bottom of the cliff, rather than at the top or halfway down, may improve its stability and reduce the incidence of rock and soil falls.

Restricting access to the beach along the base of the cliffs to low tide is also likely to be ineffective as it would be difficult to police, and there is no guarantee that it would achieve the main objective of keeping people away from the rock fall zone 10–15 m out from the base of the cliff. This is probably best done by placing rock fall warning signs along the beach in potentially hazardous areas. It is also possible that sites of future rock falls on the cliff face can be identified, such as the area of under-cut sandstone beds and water flow on the cliff face above the 2 July rock fall site (Figure 6). This could be achieved by means of a detailed visual geotechnical inspection, enabling warning signs to be strategically placed along the beach near the base of the cliff at potential rock fall sites, as well as at the entry and exit points of beach walking routes.

4. Conclusions

Based on a ground inspection of the site of the fatal rock fall which occurred on 2 July 2011, and consideration of its location, nature, and failure mechanism my conclusions are as follows:

(1) The rock fall was a relatively small (~¼ m^3 or less) joint-controlled, sandstone block failure, which is the most common form of slope instability on Auckland's east coast cliffs. The failure is attributed to erosional undercutting of a sandstone bed, water flow on the cliff face, and joint opening, leading to the sudden collapse of loosened blocks of sandstone.

(2) A concentration of natural run-off on the cliff face is believed to have increased the likelihood of this type of slope failure at the rock fall location. There is no evidence that discharge of stormwater was a causative factor in the failure, or that construction of houses and a walkway at the top of the cliff caused increased run-off on the cliff face above the rock fall site.

(3) There was no obvious trigger for the rock fall. However, ~98 mm of rain over two weeks prior to the rock fall, together with low to moderate (~MM 4) earthquake shaking 16 hours before it occurred are likely to have influenced the timing of the fatal event.

(4) The 2 July rock fall fatality is the only known event of its type in the Auckland area, and is considered to be a very low probability event. The possibility of similar rock falls occurring in the future presents a potential hazard to the public from, but the risk is thought to be low.

(5) The risk to the public from future rock falls on Auckland's coastal cliffs is probably best addressed by placing rock fall warning signs along the beach at potential sites of future rock fall, as well as the entry and exit points of beach walking routes. These signs should warn people to keep well clear of the rock fall hazard zone ~10–15 m out from the base of the cliff.

(6) Better control of drainage on the cliff face, for example by ensuring that storm water drains discharge at the bottom of the cliff, rather than at the top or halfway down, may improve its stability and reduce the incidence of rock and soil falls.

References

Hancox, G.T., Nelis, S., 2009. Landslides caused by the June–August 2008 rainfall in Auckland and Wellington, New Zealand. *GNS Science Report 2009/04. 30pp.*

Moon, V.G., Healy, T.R., 1994. Mechanisms of coastal cliff retreat and hazard zone delineation in soft flysch deposits. *Journal of Coastal Research 10:663–680.*

Tonkin & Taylor, 2011. Emergency Geotechnical Inspection of Rockfall, Rothesay Bay Cliffs, Auckland. *Tonkin &Taylor Report (by Stephen Crawford) Ref. 28050 for Auckland Council, 7 July 2011.*

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