The 23rd January 2019 Cape Kidnappers Coastal Cliff Collapse, Hawke's Bay, New Zealand

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GNS Science Report 2019/26
May 2019

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BIBLIOGRAPHIC REFERENCE

de Vilder S, Dellow GD, Archibald GC, Morgenstern R. 2019. The 23rd January 2019 Cape Kidnappers coastal cliff collapse, Hawke's Bay, New Zealand. Lower Hutt (NZ): GNS Science. 11 p. (GNS Science report; 2019/26). doi:10.21420/CT0N-7284.

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ISSN 2350-3424 (online)
ISBN 978-1-98-856947-5 (online)
http://dx.doi.org/10.21420/CT0N-7284

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ABSTRACT

An approximately 25,500 m³ debris avalanche occurred on the 23rd January 2019 from the coastal cliffs of Cape Kidnappers, Hawke's Bay. The debris avalanche was observed by multiple bystanders, and seriously injured two tourists. The tourists were walking along the beach, which forms the public accessway to the Gannet Colony at Cape Kidnappers – a popular tourist attraction in the Hawke's Bay.

The cliff collapse occurred within a conglomerate unit located in the upper 50 m of the cliff. The site has been the location of previous failures with a significant debris avalanche occurring from the lower half of the cliff in the 2015. The remnants of the 2015 debris deposit were still present at the base of the cliff on the 23rd January 2019, with the 2015 deposit acting as a ramp, allowing the 23rd January 2019 debris avalanche debris to travel further. 'Small' precursory rockfalls were observed sporadically through the week prior to the 23rd January 2019 event.

There was no discernible trigger for the debris avalanche, with no seismicity and limited rainfall recorded in the week prior. Marine erosion at the toe of the slope may have been a contributing factor in the 2015 failure. The most likely cause of 23rd January debris avalanche is upward propagation of cliff failure through time. The final cause of failure would be the culmination of cliff material weakening through time (due to weathering processes such as saltwater wetting and drying and failure surface development in response to ongoing stress relief). As the strength of the material decreases and the failure propagates, 'low' apparently benign environmental stresses can act as a trigger for final failure.

Several smaller rockfalls have occurred after the 23rd January 2019 debris avalanche, including a 10,000 m³ debris avalanche located to the east of the 23rd January debris avalanche. This subsequent cliff failure narrowly missed two tourists who were walking along the beach below (the beach and accessway were closed at the time).

Anecdotal evidence, field observations, and aerial LiDAR analysis all indicate that landslides of a similar size, or smaller, occur regularly along this 7 km long section of coastal cliffs between Clifton and Black Reef. However, the baseline risk users of the beach accessway are exposed to is unknown. As such, the logical next step would be to undertake a quantitative risk assessment to quantify this baseline risk.

KEYWORDS

Debris Avalanche, Rockfall, Coastal Cliffs, Cape Kidnappers, Hawke's Bay.

1.0 INTRODUCTION

On the 23rd January 2019 at approximately 2.30 pm a large debris avalanche (occurred from the coastal cliffs of Cape Kidnappers, Hawke's Bay, New Zealand (Figures 1.1 and 1.2). The debris avalanche injured two tourists, one critically, who were walking along the beach below the cliff at the time. At low tide the beach provides access to the Cape Kidnappers Gannet Colony, a popular tourist attraction. There were several other walkers and a tractor tour group present on the beach nearby at the time of the debris avalanche. These bystanders captured the debris avalanche event with photographs and video, which can be viewed through several media outlets including:

https://www.stuff.co.nz/environment/110134954/images-of-cape-kidnappers-rock-fall-emerge.

https://twitter.com/AnushaBradley/status/1087917915779878912?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E1087917915779878912&ref_url=https%3A%2F%2Fwww.radionz.co.nz%2Fnews%2Fnational%2F380750%2Fwalkers-swept-by-rockfall-into-sea-at-hawke-s-bay-beach.

One of the tourists personal account of the event is also available through several media outlets, including: https://www.tvnz.co.nz/one-news/new-zealand/tourist-recounts-moment-cape-kidnappers-cliff-collapsed-forcing-him-run-sea.

Due to the serious nature of the injuries, a GeoNet landslide response was initiated. A geological reconnaissance visit was undertaken on the 25th January 2019, by GNS staff Sally Dellow, Saskia de Vilder, Garth Archibald and Regine Morgenstern. The visit comprised of a geological walkover of the site and terrestrial laser scan (TLS) survey of the debris avalanche, to evaluate the failure mechanisms, volume of material which had failed, and obtain baseline data for potential future monitoring. This site visit was undertaken in conjunction with Matt Shore (Stantec Ltd.) and the Stantec survey team, who were engaged by Hastings District Council (HDC) to act as their geotechnical advisor in response to this cliff collapse. Unless otherwise stated, all data and photographs within this report were collected by the GNS team. This includes terrestrial laser scan data of the site on the 25th January along with drone imagery.

Figure 1.1 Location of the debris avalanche along the Cape Kidnappers walkway.

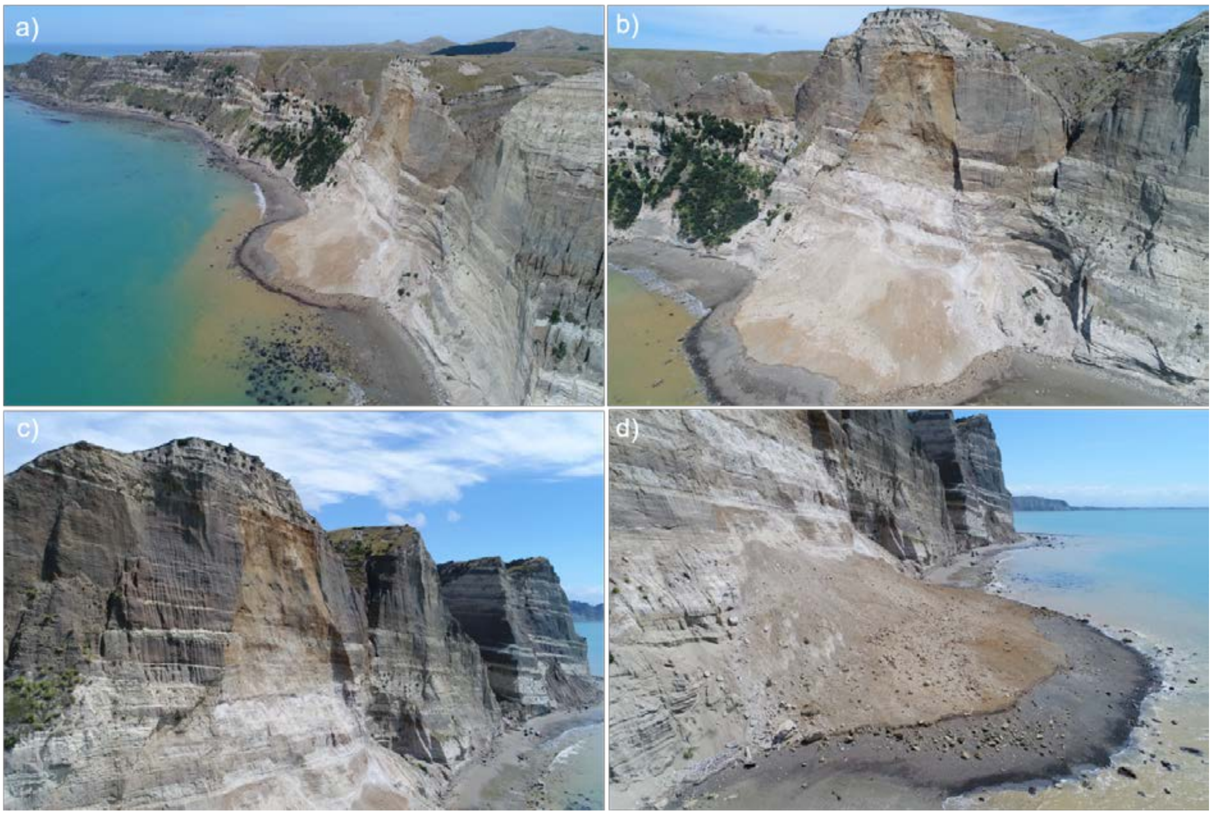

Figure 1.2 Photographs of the Cape Kidnappers debris avalanchecaptured via drone on the 25/01/2019.a) & b) Images of the debris avalanche, c) Source area of the debris avalanche, and d) Deposit of the debris avalanche.

2.0 CLIFF COLLAPSE EVENT

2.1 Site Setting and Geology

The debris avalanche is located on a steep 130 m high coastal cliff, which has a northerly (facing) aspect. At the base of the cliff, the beach width is 25 m at low tide, and 10 m at high tide. The geology of the cliff comprises the early Pleistocene Kidnappers group, described as 'basal fossiliferous sandstone overlain by conglomerate, sandstone, carbonaceous mudstone, tephra and ignimbrite' (Lee *et al*., 2011).

Within the cliff and debris avalanche, four units are identified (Figure 2.6). They are:

- Unit 1: Tuff, with some interbedded conglomerate.
- Unit 2: Conglomerate, with some interbedded tuff.
- Unit 3: Interbedded conglomerate and tuff.
- Unit 4: Sandstone.

All these units are massive, with bedding dipping at 8° towards the north-west out of slope. Few joints are observed within the cliff. Two faults, colloquially known as 2 m and 5 m fault, bound the debris avalanche on either side, dipping into the slope (Figure 2.1). No seepage was observed from the face of the cliff.

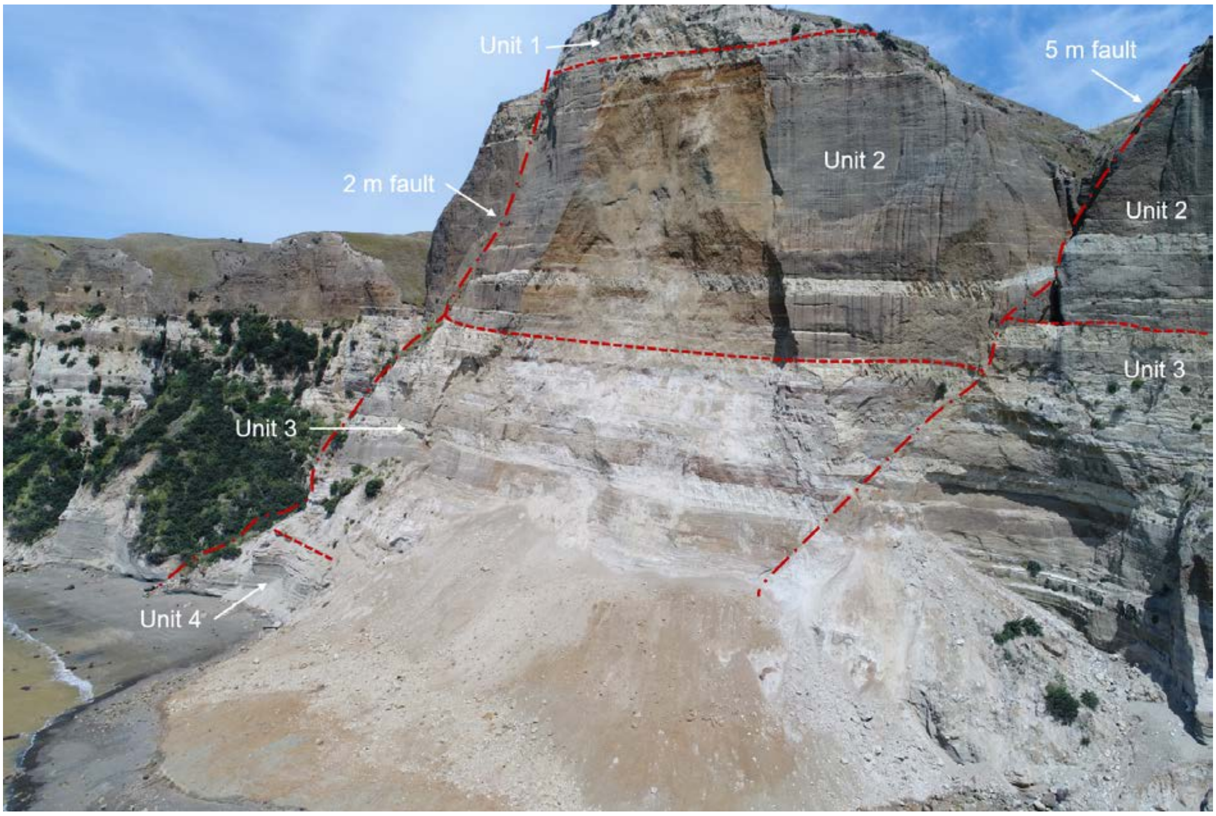

Figure 2.1 Photograph displaying the four different geological units exposed at the cliff surface.

2.2 Description of the debris avalanche

Based on eyewitness accounts and imagery, the upper 50 m of the cliff failed on afternoon of the 23rd January 2019. The source area for the material is mostly within Unit 2 (Figure 2.1). Anecdotal evidence suggests that locally within the wider failure area, toppling may have occurred. Once the debris avalanche initiated it travelled extremely to very rapidly downslope, where the pre-existing debris deposit from a 2015 failure (Figure 2.2) acted as a ramp for the debris, allowing the debris avalanche debris to run-out further into the sea.

The source area scar has a surface area of approximately 1,200 m^2, with a volume of 25,500 m^3 and an average thickness of about 20 m. The deposit is 125 m wide and initially extended out 75 m from the base of the cliff prior to being subjected to erosion from tide and wave action (based on estimates from Stantec Ltd.). To quantify the volume of the debris avalanche, a 2011 aerial LiDAR data-set of the coast has been compared and differenced with the Terrestrial Laser Scanner scan data collected by GNS on the 25th January 2019. This difference model has shown that between 2011 and 2019, 63,000 m^3 has been eroded from the location of the debris avalanche (Figure 2.3). As there was already a substantial debris deposit from 2015 (Figure 2.2), this will account for some of the 63,000 m^3 lost from the cliff face. The Stantec Ltd estimate of 25,500 m^3 for the 23rd January 2019 debris avalanche is within the range of possible failure volumes constrained by this data.

The debris avalanche appears to have involved fracture through intact material of Unit 2 in the source area (Figure 2.1). The surface of the debris avalanche scar is irregular with few joint surfaces visible (Figure 2.4). Bedding does not appear to have been a control on instability and the resulting failure mechanism. Non-persistent planar features within the scar surface may represent pre-existing joint surfaces within the cliff, which potentially contributed to the development of the release surface (Figure 2.4). Additionally, the faults or joints do not appear to control the lateral extents of the debris avalanche (Figure 2.1).

As mentioned above, the site has experienced previous debris avalanche and rockfall activity. Several precursory rockfall events were observed in the week and day prior to the debris avalanche occurring. We outline below the documented events, as determined from anecdotal observations:

- 2015: Debris avalanche, which impeded beach access. This event involved the collapse of the lower half of the cliff within Unit 3, with the resultant deposit still visible on the beach.
- December 2018: Rockfall.
- 21 January 2018: Rockfall.
- 21/22 January 2019: Rockfall, which impeded beach access.

Continued monitoring by Stantec Ltd. following the debris avalanche have shown several rockfall events located on the periphery of the 23rd January failure surface. These include:

- 26/27 January: 330 m^3 rockfall volume located adjacent to the main debris avalanche within Unit 3.
- 2 February: 10,000 m^3 debris avalanche located adjacent to the main debris avalanche within Unit 2 (Figure 2.5). The debris avalanche narrowly missed two tourists walking along the beach (though the beach and the walkway were closed at this time).
- 7 February: 2,500 m^3 rockfall located above the main debris avalanche within Unit 1 (Figure 2.6).

Figure 2.2 a) Photo of the coastline prior to the 23rd January event, displaying the 2015 rockfall deposit in the same region (Source: J Marshall, 13/01/19). b) Photo of the landslide on the 23rd January (Source: Unknown 3rd Party, 23/01/2019).

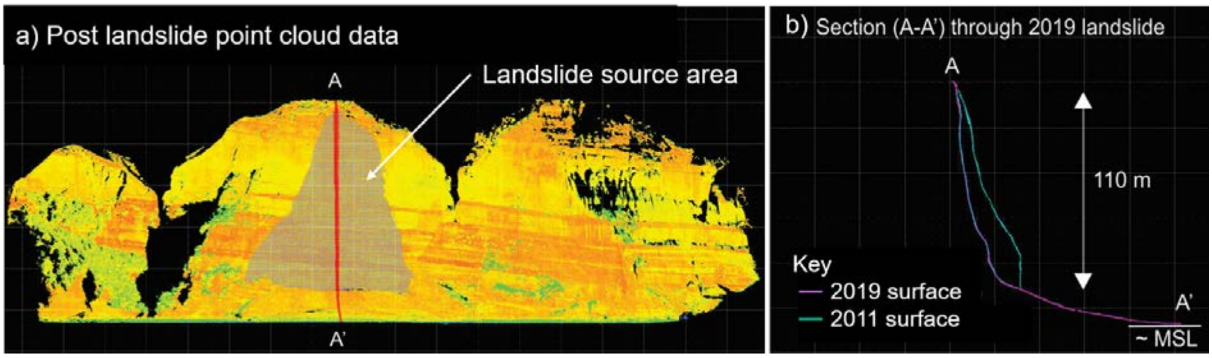

Figure 2.3 a) Point cloud data derived from terrestrial laser scan (TLS) survey conducted on the 25/01/2019. The grey area displays the debris avalanche source, with this area being used to compare between 2019 TLS data and the 2011 Aerial LiDAR (NZ Aerial Mapping for Hawke's Bay Regional Council). b) Cross-section displaying the difference between 2019 cliff surface and 2011 cliff surface.

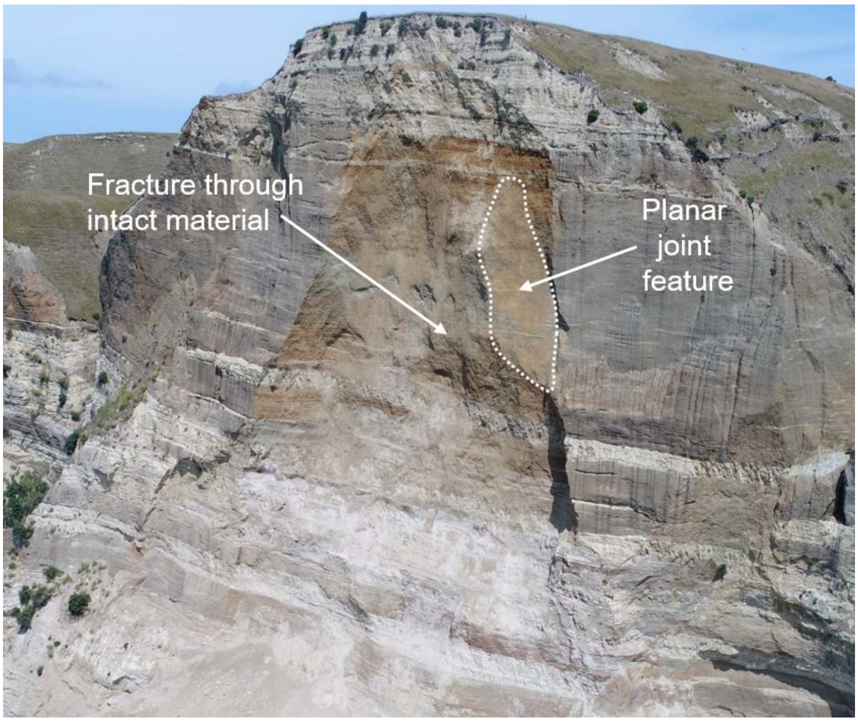

Figure 2.4 Photograph displays the main planar joint features observed within the landslide failure surface. The irregular curved surfaces of the majority of the failure surface is interpreted to be failure through intact material.

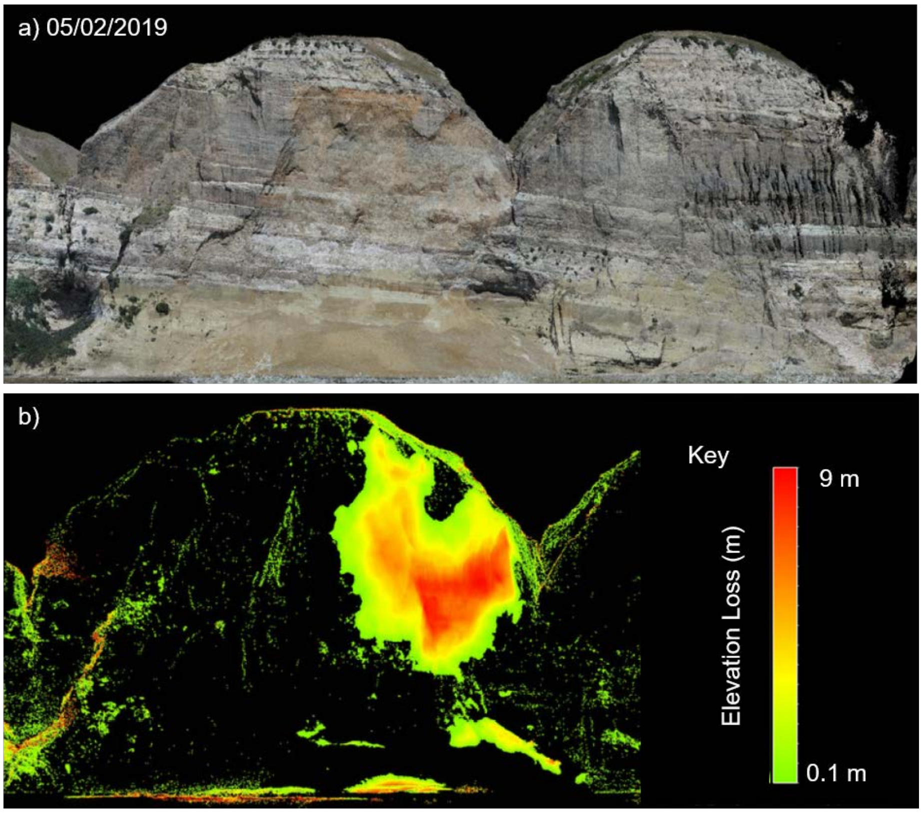

Figure 2.5 a) Drone imagery of a subsequent debris avalanche captured on the 05/02/2019. b) Elevation loss model derived from differencing of the UAV generated point clouds of the 25/01/2019 and 05/02/2019.(Data Source: Stantec Ltd).

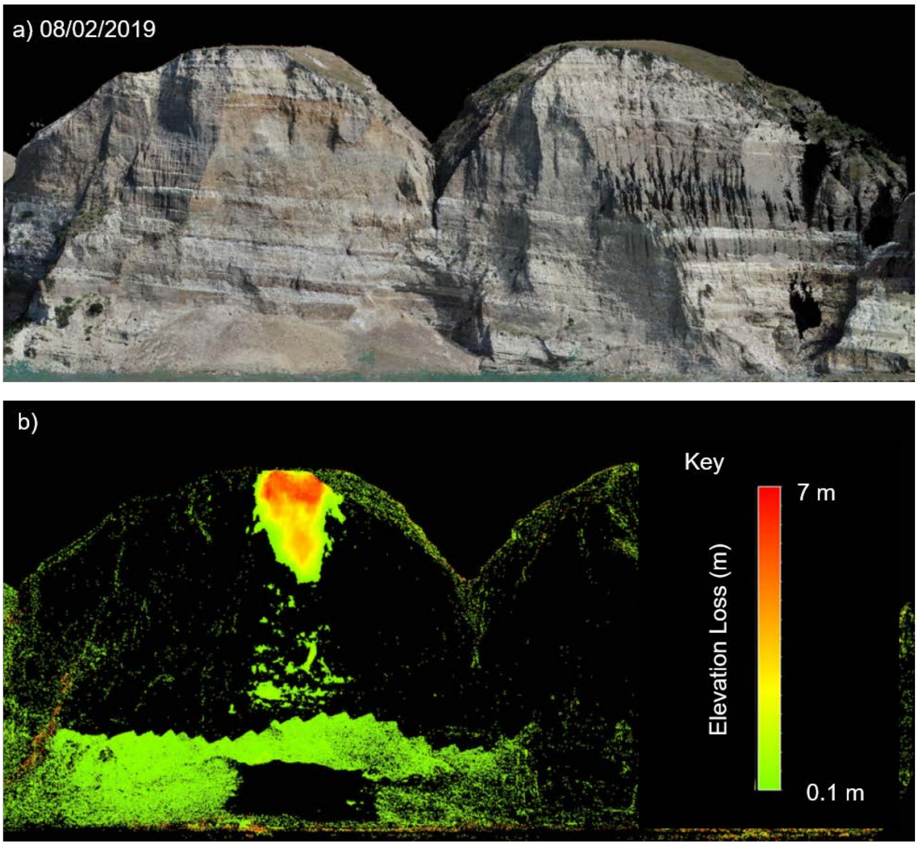

Figure 2.6 a) Drone imagery of another subsequent rockfall captured on the 08/02/2019. b) Elevation loss model derived from differencing of the UAV generated point clouds of the 05/02/2019 and 08/02/2019.(Data Source: Stantec Ltd).

2.3 Triggering factors

There is no apparent trigger for the debris avalanche, in terms of seismicity and rainfall. No seismic activity of a sufficient magnitude (≥ 6) required to generate landslides occurred at the time of the debris avalanche, or in the six weeks prior. No rainfall was recorded on the day of the debris avalanche, though 50 mm of rain was recorded a week prior on the 16th and 17th January. However, no seepage was observed from the cliff face.

The debris avalanche appears to be related to the 2015 event. Marine erosion at the toe of the cliff is likely to have been a contributing factor in this initial 2015 failure at the base of the cliff. Over time, this instability has spread and propagated upwards, with all other recorded rockfalls and the 23rd January event occurring above this 2015 failure.

The 23rd January event may be the cumulative result of strength loss in the cliff materials, so that 'low' or apparently benign environmental conditions on the 23rd January could have acted as a trigger to failure (Viles, 2013). This strength loss through time may be due to weathering, cliff over-steepening, and development of the release surface as cracks propagate in response to small, episodic stress release.

The recorded post-failure debris avalanche and rockfall events may also represent a continuation of this upward movement of failure (in particular, the 7th February rockfall which occurred in Unit 1 at the top of the slope). These subsequent debris avalanche and rockfall events may occur via progressive failure, where a change in the stresses within a slope occurs (i.e. in this case, the 23rd January debris avalanche event), resulting in stress redistribution throughout the surrounding rock mass. As this stress redistributes, this results in further cracking within the material and subsequently the failure of the surrounding rock mass (Eberhardt *et al*., 2004; Rosser *et al*., 2007).

3.0 LANDSLIDE ACTIVITY ALONG THE COAST

The 23rd January 2019 debris avalanche does not represent an unusual event in this area but is consistent with anecdotal evidence of previous failures observed along this stretch of coastline. In 1989 a similar event occurred, resulting in injuries to two tourists. Field observations show that there are multiple debris deposits located at the base of the cliffs, indicating past events of a similar magnitude to the 23rd January 2019 debris avalanche have occurred. Comparison between Aerial LiDAR captured in 2003 and in 2011 (Figure 3.1) records areas of failure along the coast (red colours within Figure 3.1), confirming the field observations of landslide activity.

However, the rates of activity (i.e. how often failures occur along the coast, and how big they are?) are not quantified, and only qualitatively and anecdotally observed. Baseline levels of landslide activity need to be quantified in order to understand the risk they pose to visitors and users of the accessway.

In addition, climate change may result in increased erosion and landslides due to higher sea levels and increased storminess (e.g. Trenhaile, 2011). To understand the future impacts of climate change on the coastal cliffs, we need to understand when, where and how often landslides are occurring along the coast currently.

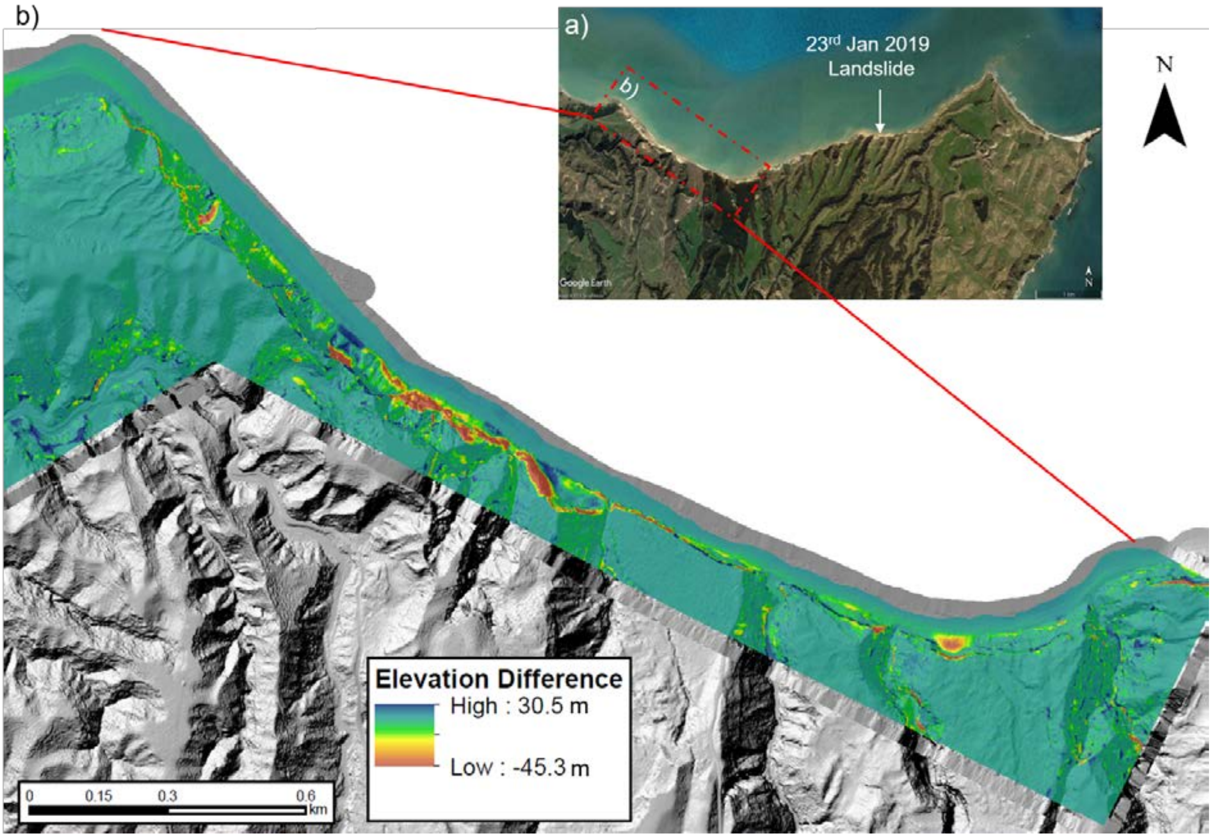

Figure 3.1 a) Location and extent of difference model between Aerial LiDAR collected in 2003 (by AAM Geoscan Ltd for Hawke's Bay Regional Council) and 2011 (Aerial Mapping Ltd for Hawke's Bay Regional Council) is outlined in the red box. The LiDAR does not cover the area of the 23/01/2019 debris avalanche. b) Elevation difference model between 2003 and 2011, where red colours represent erosion and blue colours deposition.

4.0 CONCLUSIONS AND RECOMMENDATIONS

1. On the 23rd January 2019 at 2.30pm an approximately 25,500 m^3 debris avalanche occurred from an upper section of the coastal cliffs near Cape Kidnappers, Hawke's Bay. This event, observed by multiple bystanders, swept two tourists into the sea, seriously injuring them, one critically.
2. There were no discernible seismic or rainfall triggers for the debris avalanche. However, the coastal cliff is the site of previous landsliding with a significant debris avalanche occurring from the lower half of the cliff at this site in 2015, with the debris deposit from that event still present on the beach. The 23rd January 2019 debris avalanche probably represents an upward propagation of failure from initial erosion (as represented by the 2015 event) at the base of the cliff from marine action.
3. In the weeks and days leading up to the failure, multiple 'small' precursory rockfalls were observed near the 23rd January event.
4. Since the 23rd January 2019 debris avalanche, at least three subsequent failure events have occurred, including a 10,000 m^3 debris avalanche located on the periphery of the 23rd January 2019 debris avalanche. This failure event narrowly missed two tourists who were walking along the beach (the beach and accessway were closed).
5. Anecdotal evidence and long-term aerial LiDAR data-sets confirm that landslides events and erosion occur regularly along this stretch of coast. In 1989, a similar debris avalanche event resulted in serious injuries to two tourists. The baseline rate of landslide activity has not been quantified.
6. The potential risk from cliff failures to users of the accessway has not been evaluated as part of this response. Based on the observations within this report, the logical next step would be to undertake a quantitative risk assessment to understand the risk users of the accessway are exposed to.

5.0 ACKNOWLEDGEMENTS

We have appreciated the assistance of: Will Ries (University of Vienna), Matt Shore and the wider Stantec Ltd team with providing and analysing data. Funding was provided through the New Zealand Hazards Platform and GeoNet project (www.geonet.org.nz) landslide immediate response function, supported by the Earthquake Commission and the Ministry of Business, Innovation and Employment. This report was reviewed by: Zane Bruce and Jon Carey.

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