



**Cathedral Cove Basic Level
Landslide Risk Assessment**

Prepared for
Department of Conservation
Prepared by
Tonkin & Taylor Ltd
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1 Introduction

Tonkin & Taylor Ltd has been engaged¹ by the Department of Conservation (DoC) to undertake a landslide risk assessment of the Cathedral Cove Track. The landslide risk assessment includes the track from Hahei Beach to Cathedral Cove Beach, Cathedral Cove Beach, Stingray Bay and Gemstone Bay, see Figure 1.1.

DoC has requested the landslide risk assessment in response to severe weather events occurring in February 2023 causing multiple landslides damaging the track and beach access. DoC wish to understand their risk exposure and use this assessment to inform their decision making.

Damage to the track and beach access has made several sections impassable without reinstatement, track realignment, or other mitigations. In addition to the risk assessment, this report also provides potential mitigation options for DoC to consider in these areas.

The risk assessment does not consider that multiple sections of the track are currently damaged. These damaged track sections are more hazardous than the risk estimates presented and these areas should be avoided or mitigated prior to opening the track.



Figure 1.1: Site plan showing extent of the risk assessment area.

¹ Tonkin & Taylor Ltd (6 March 2023) *Letter of Engagement Cathedral Cove Track and Beach Risk Assessment Options*, Ref 1007838.3000.

2 Scope

2.1 Purpose

The purpose of the landslide risk assessment is to provide DoC with an understanding of the landslide hazards across the site and estimate risk metrics to inform DoC's planning and management of the track.

2.2 Study area

The study area for the landslide risk assessment is approximately shown on Figure 1.1 and is focused on the track and relevant point locations frequented by visitors (toilet block, seating benches, etc.). The mapped area extends from Hahei Beach to the northern end of Cathedral Cove Beach and extends from the coast to approximately 300 m inland to the west. The total track length assessed is approximately 3.8 km. Further details on the track and point locations are provided in Section 4.2.

2.3 Methodology

This landslide risk assessment adopts the Natural Hazard Risk Analysis guidelines² (Parts 1 to 4) (NHRA) developed by GNS Science for DoC. There are three levels of assessment within the guidelines, Preliminary Screening, Basic and Advanced, and DoC has requested that a Basic Level assessment is undertaken.

A Basic Level Assessment *"involves an initial quantitative estimate of the landslide risk that workers or visitors are exposed to using simple and limited input datasets and data analysis."*²

The main steps in a basic level risk analysis include the following:

- 1 Identify hazard types.
- 2 Estimate likelihood of hazards.
- 3 Estimate consequences if the hazard were to occur.
- 4 Derive appropriate risk metrics.

Our specific scope of work has included the following items:

- Review readily available background information (historical aerials, past reports, published information).
- Undertake site inspections recording key site features, evidence of landslides and delineate landscape units.
- To support the site inspections, UAV capturing aerial imagery was undertaken.
- Develop a conceptual geotechnical model including landslide failure modes and geotechnical hazards.
- Develop a landslide inventory.
- Undertake a Basic Level Geotechnical Risk Assessment.
- Prepare conceptual mitigation options for the relevant damaged sections of track.

² de Vilder SJ, Massey CI, Power WL, Burbidge DR, Deligne NI, Leonard GS. 2020. Guidelines for natural hazard risk analysis – Part 1: risk analysis framework . Lower Hutt (NZ): GNS Science. 22 p. Consultancy Report 2020/50

3 Background reports

T+T have undertaken a number of reports for DoC on the Cathedral Cove since 2009. A review and summary of relevant key findings of the previous reports are presented in Appendix A Table 1.

4 Setting

4.1 General

The site area is situated on the east coast of the Coromandel. It is a very popular tourist location and is accessed by walking tracks from Hahei beach, Lees Road, or a carpark at the end of Grange Road, see Figure 4.1. The Lees Road track is excluded from our assessment.

The coast comprises a series of near vertical coastal cliffs interspersed with a series of bays including Gemstone Bay, Stingray Bay and Cathedral Cove (including Mares Leg Cove). The main walking track is situated above the coastal cliffs and bays along hilly, often steep topography. To the west of the track further inland are prominent escarpments of outcropping rock. These are situated south of Gemstone Bay and directly above Cathedral Cove. The site geomorphology is further discussed in Section 7.



Figure 4.1: 1:50:000 Topo map (Source Topomap.co.nz / LINZ). Blue grid lines are spaced 1 km and vertical blue lines are oriented to grid north.

4.2 Cathedral Cove track and point locations

The tracks, beaches and point locations included in our assessment are presented in Figure 4.2 and Figure B1 in Appendix B. The tracks have been divided spatially based on the landscape units and failure modes. Landscape units are further discussed in Section 7 and landslide failure modes in Section 5.2.

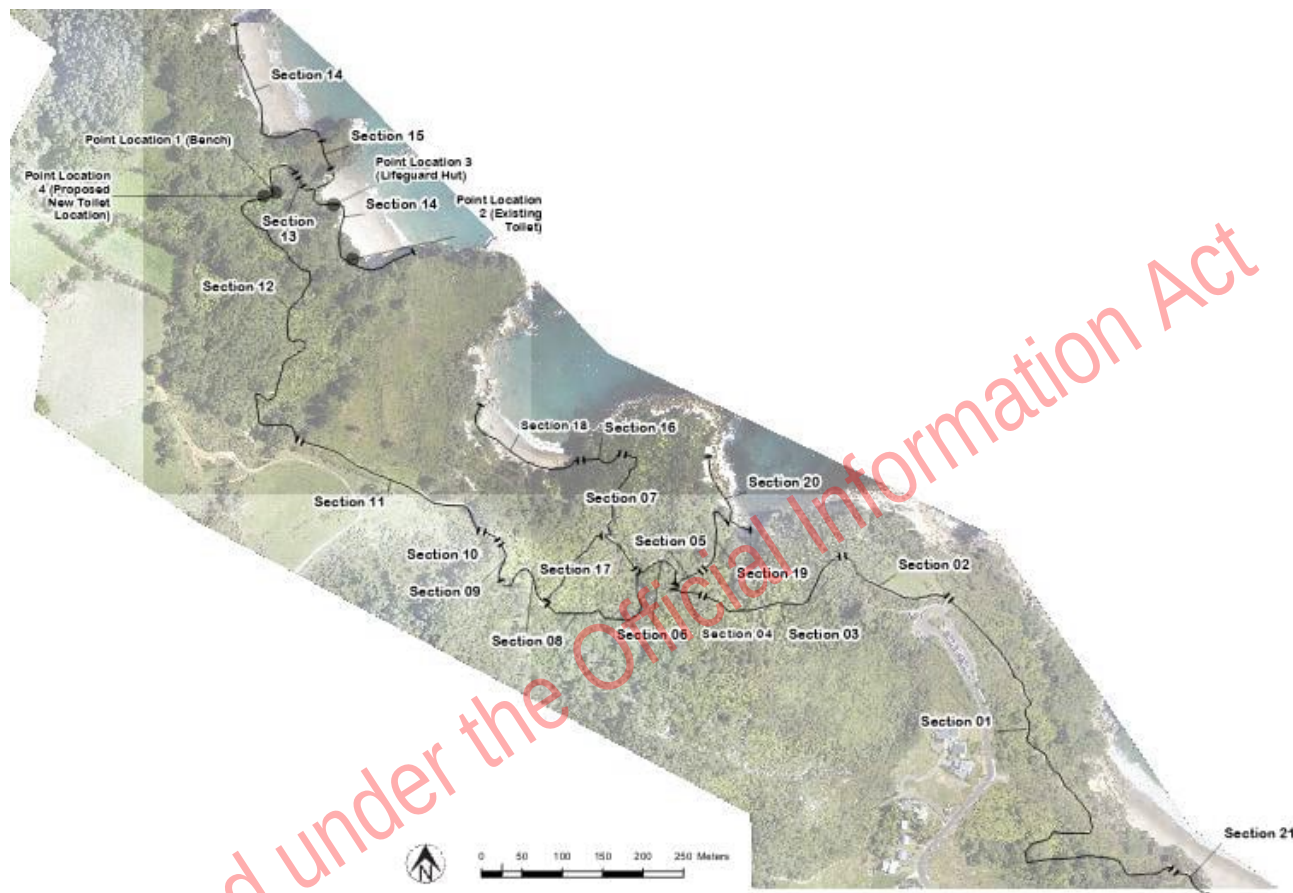


Figure 4.2: Track and point locations

4.3 Topography and elevation information

The site is covered by the Coromandel Digital Elevation Model 2012/2013³ undertaken by Waikato Regional Council which has been utilised for this assessment.

Additional site-specific surface models were developed using photogrammetry from aerial photographs taken by an unmanned aerial vehicle flown during the site inspection. These models have approximate accuracy only and were utilised for visualisation and landslide identification.

³ Waikato Regional Council 2012/2013. *Coromandel Digital Elevation Model*

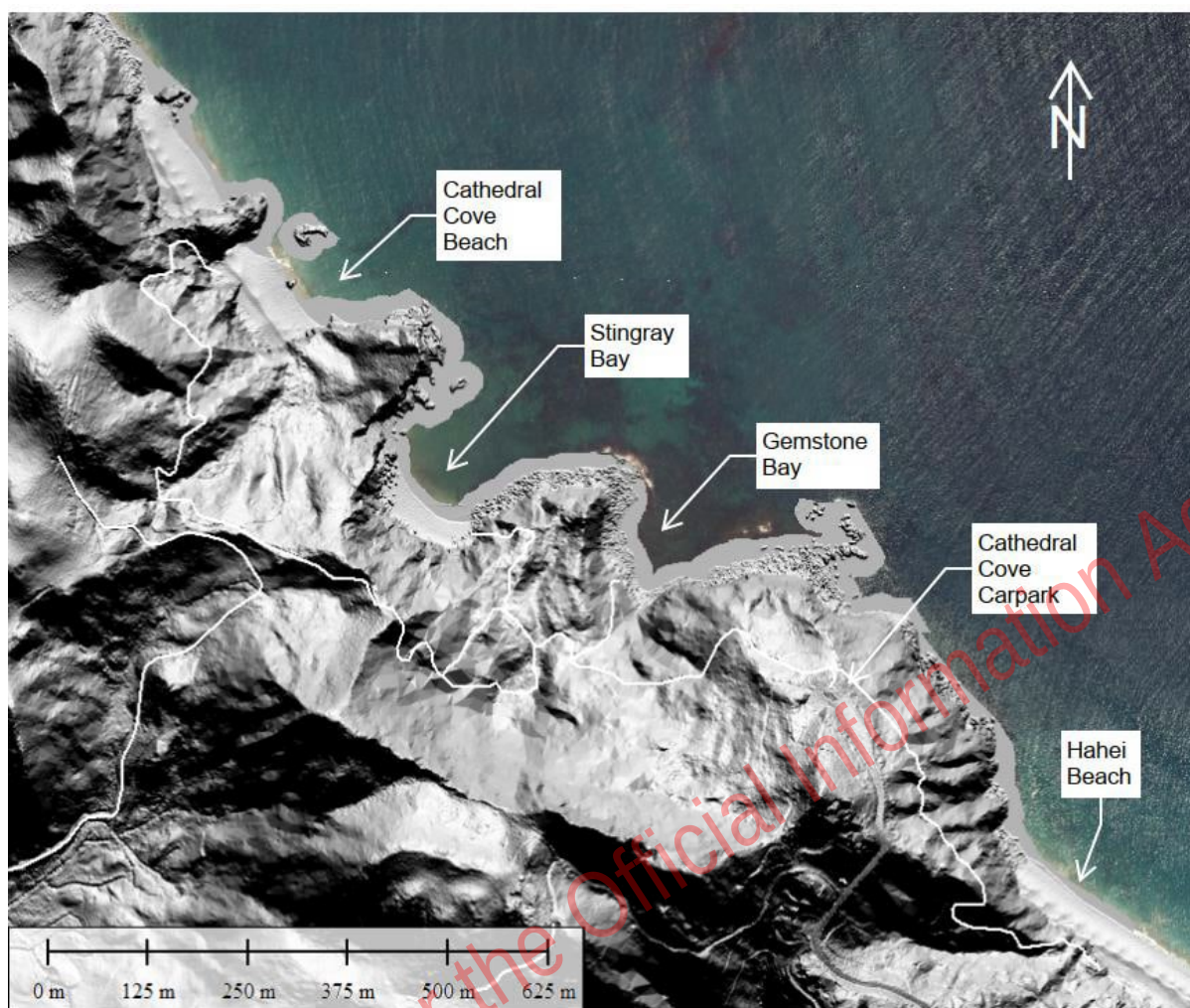


Figure 4.3: Site plan showing hillshade based on the 2012/2013 Digital Elevation Model of Coromandel.

4.4 Geological setting

Published geological information⁴ indicates that the site comprises four main geological units. The Wharepapa Ignimbrite (wr) (Coroglen Subgroup) forms the white coastal cliffs at Cathedral Cove beach and Stingray Bay. To the north, south and west, the site has been overprinted by a series of rhyolite dome, see Figure 4.4. The oldest of these domes is the Grange Dome comprising Rangihau Rhyolite (mgi). Overlying Grange Dome is the Hahei Dome comprising Ruahine Rhyolite (mhh). To the west of Cathedral Cove is Bluff Centre Flows comprising Purangi Rhyolite (mpl).

The broad arrangement of these units is shown on Figure 4.5.

The 1:50 000 geology map also highlights deep seated land instability along the eastern and western margins of the Hahei Dome, noted by the triangle pointed lines. These areas are outside of the study area.

⁴ Skinner, D.N.B 1995. Geology of the Mercury Bay area, scale 1:50 000. Institute of Geological & Nuclear Sciences geological map 17. 1 sheet + 56 p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

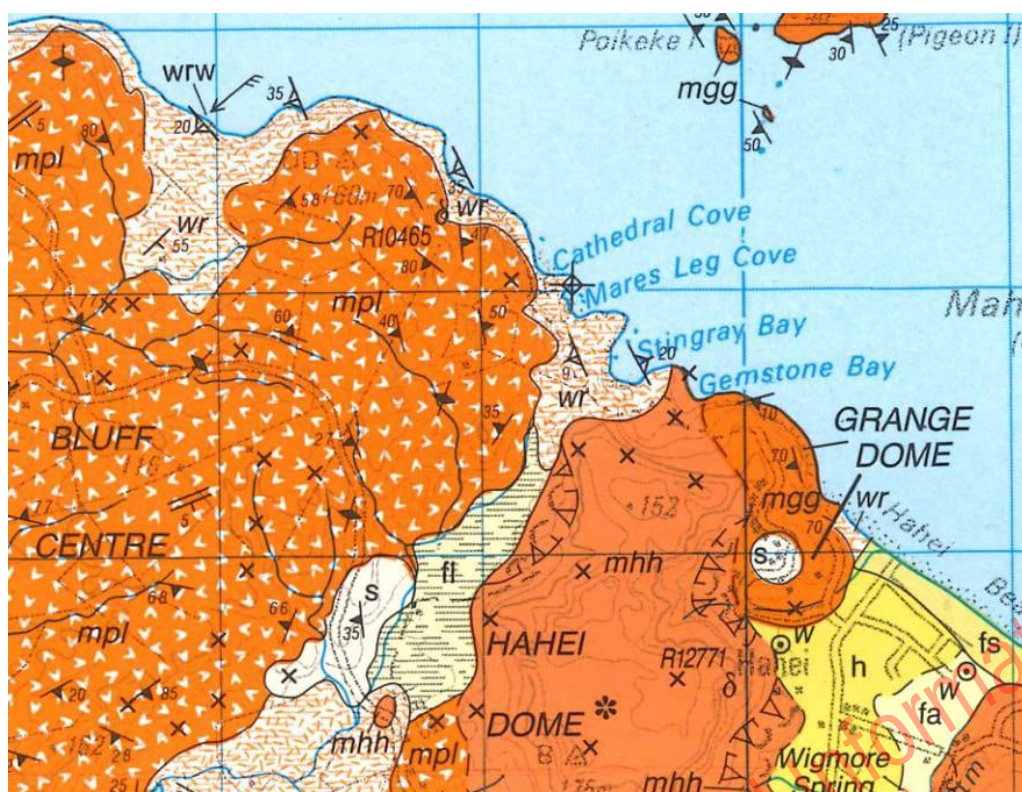


Figure 4.4: Excerpt of the 1:50 000 Geology of the Mercury Bay Area. Blue grid lines are spaced 1 km. Vertical blue grid lines are oriented to grid north. Relevant mapping abbreviations include: Wharepapa Ignimbrite (wr), Rangihau Rhyolite (mhh), Purangi Rhyolite (mpl).



Figure 4.5: Aerial photograph of the coastal cliffs from Cathedral Cove (bottom right foreground) to Hahei (background). Photograph and interpretation after Skinner⁴.

4.5 Aerial photography

Historical aerial photography has been reviewed as part of the landslide mapping (Section 6). Historical aerial photographs were sourced from Retrolens and Google Earth and include photographs dated 1944, 1966, 1971, 1984, 2002, 2004, 2007, 2008, 2009, 2010, 2011 and multiple photographs between 2015 and 2021.

Where landslides were identified in the aerial imagery these were mapped and added to the inventory including the date of the aerial image.

4.6 Rainfall

Rainfall data from the rain gauges in Whitianga have been reviewed as part of the assessment. The rainfall dataset includes daily rainfall for the period between 1949 to 2023 includes daily rainfall (Station 1520 and Station 1522), noting that there are several month long data gaps in the dataset.

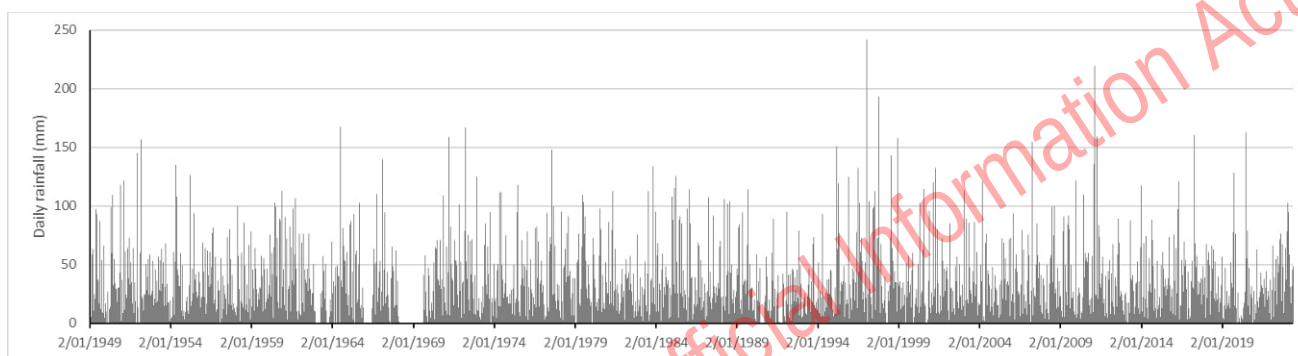


Figure 4.6: Daily rainfall (Source: Cliflo, stations: Whitianga 1522 and Whitianga Aero Aws 1520).

4.7 Seismicity

Following guidance in the NRHA Part 3, Peak Ground Acceleration (PGA) at Cathedral Cove has been compared with earthquake induced landslide opportunity (Figure 4.8 in NRHA Part 3). Similar to Figure 4.2 in NRHA Part 3, we have adopted a 1 in 500-year seismic event and utilised PGAs from the National Seismic Hazard Model⁵ updated in 2022. This corresponds to a PGA of 0.17 g for the Cathedral Cove area, as shown in Figure 4.7.

The earthquake induced landslide opportunity is 'Low to Moderate' in Figure 4.8 in NRHA Part 3.

⁵ GNS Science, National Seismic Hazard Model website: <https://nshm.gns.cri.nz/>

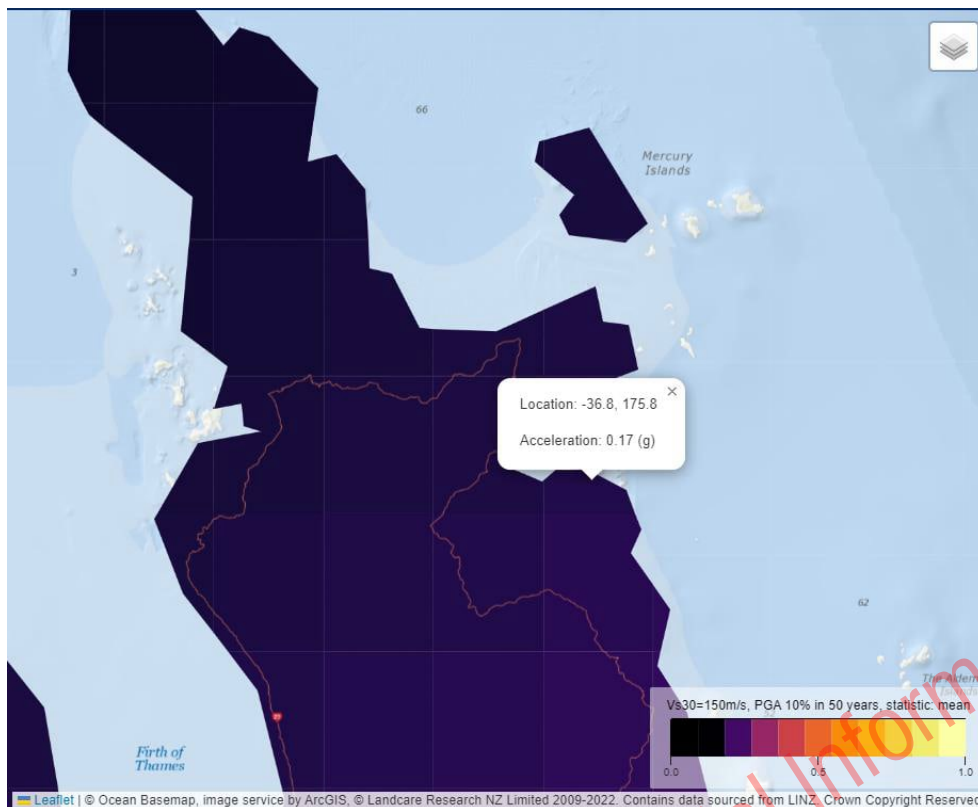


Figure 4.7: Peak Ground Acceleration for 1 in 500 based on the National Seismic Hazard Model 2022.

Table 4.8 Landslide- and rockfall-triggering thresholds for earthquake-induced ground shaking, earthquake-induced landslide (EIL) opportunity (modified from Hancox et al. 2002) and description of impacts.

Peak Ground Acceleration (PGA)*	Approximate MMI Range	EIL Opportunity	Description (Modified from Hancox et al. 2002)
<0.1 g	5–6	Very low	Very small rock and soil falls on the most susceptible slopes.
≥0.1–0.2 g	6–7	Low to moderate	Small landslides, soil and rock falls may occur on more susceptible slopes (particularly road cuts and other excavations), along with minor liquefaction effects (sand boils) in susceptible soils.
≥0.2–0.5 g	7–8	Moderate	Widespread small-scale landsliding expected, with a few moderate to very large landslides and possibly landslide-dammed lakes; many sand boils and lateral spreads likely in susceptible soils. Severe damage to roads, with many failures of steep high cuts and road-edge fills.
≥0.5–1.1 g	8–9	High	Widespread small-scale landsliding expected, with a few moderate to very large landslides and landslide-dammed lakes; many sand boils and lateral spreads likely. Severe damage to roads, with many failures of steep high cuts and road-edge fills.
>1.1 g	>9	Very high	Widespread landslide damage expected. Many large to extremely large landslides; sand boils and lateral spreads are widespread in susceptible materials and along stream and river banks. Landslide-dammed lakes are widespread in areas of steep terrain. Extensive very severe damage to roads – failures of steep high cuts and road-edge fills are widespread.

* Adopts the PGA to MMI relationship of Moratalla et al. (2020).

Figure 4.8: Table 4.8 of NRHA Part 3 with the EIL Opportunity category highlighted corresponding to the 1 in 500 year PGA for Cathedral Cove.

4.8 Track count data

An uncalibrated track count summary report has been provided by DoC for the Hahei Beach Walk, and the Cathedral Cove Track for periods between 23 May 2016 and 10 January 2022 in Appendix C. Hourly track count data has also been provided for between 2017 and 2019.

Approximately 250,000 visitors trigger the Cathedral Cove access track counter which is situated at the top of the beach access stairs (visitors trigger the counter twice on a return trip). This figure does not include visitors accessing the cove via boat or differential visitors from Lees Rd track. Annual count for the Hahei to Carpark track is more variable with approximately 25,000 to 40,000 visitors triggering the counter.

Comparison of daily track counts with rainfall data is presented in Table 4.1 and highlights that increased rainfall generally reduces daily visitor numbers but not completely.

Table 4.1: Summary of daily track count data with daily rainfall for Cathedral Cove Track 2017 to 2018 (note track counts not visitor numbers are presented)

	All count data	Daily rainfall			
		< 10 mm per day	10 to 50 mm per day	50 to 100 mm per day	> 100 mm per day
Average daily count	1490	1601	941	697	499
Maximum daily count	6315	6315	2675	1859	917
Number of days where there are no visitor counts	23	23	0	0	0
Total days	730	615	95	15	2

5 Site mapping

5.1 General

To understand the types and extent of recent and historical landslides and how they are distributed within the landscape, site mapping and aerial photography review were undertaken. Landslides were mapped and categorised into a landslide inventory. Landforms were categorised into landscape units.

Site mapping was undertaken on 21 and 22 March 2023 and 17 May 2023 by T+T engineering geologists. Mapping was generally limited to land near the existing tracks and coastal cliffs were visible from the beaches. The site mapping was aided by aerial photographs taken by an unmanned aerial vehicle flown during the site inspection. Historical and recent landslides were identified and added to the landslide inventory. Landscape units and other site features were also mapped.

The extent of the mapped area is shown on the site plan in Appendix A.

5.2 Landslide types

A number of different landslide types were observed across the site in different areas. These include rockfalls, rock/debris/earth slides, and Earth flows. These different types are summarised in Table 5.1. Additional site photographs are presented in Appendix D.

Table 5.1: Summary of observed landslide types

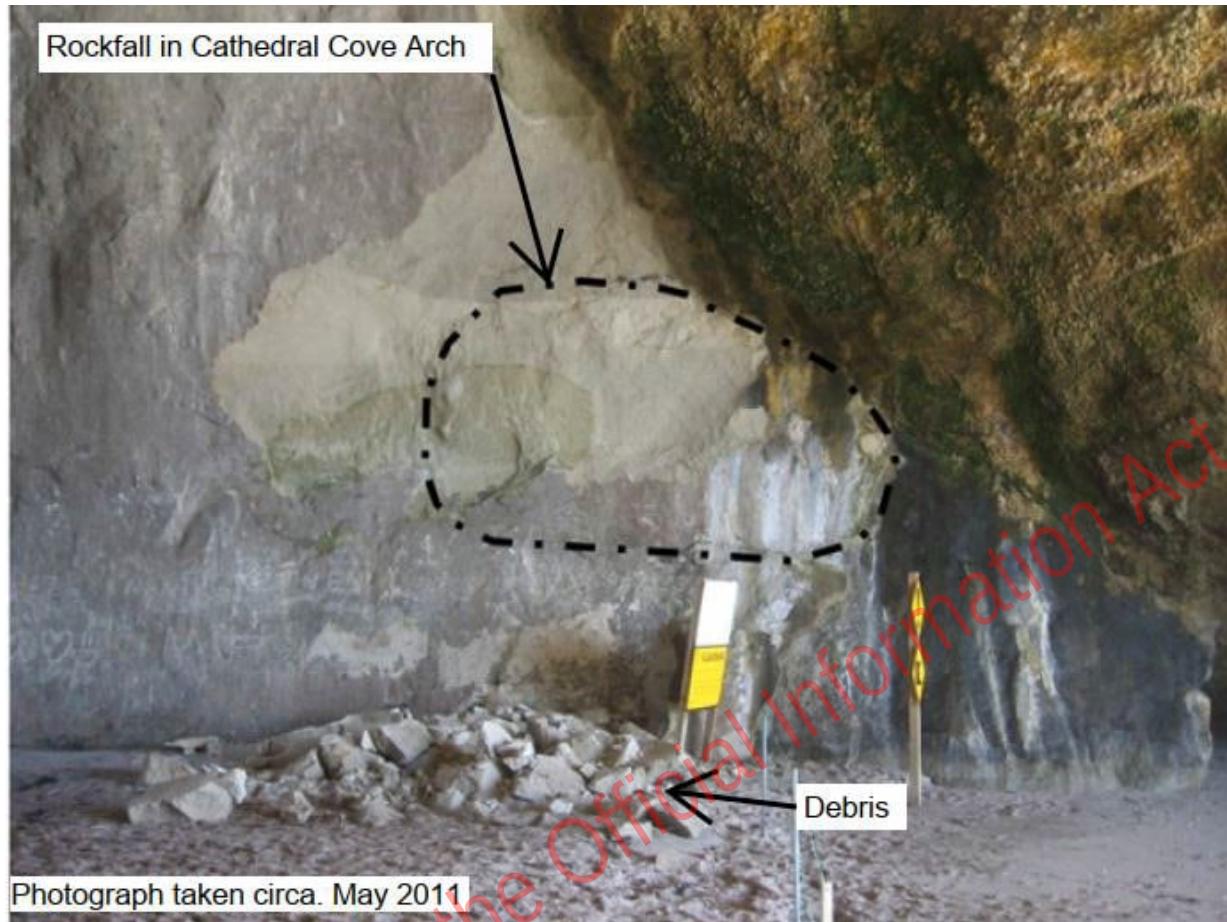
	Debris/earth flow Recent debris flows are observed on the saddle above Cathedral Cove Beach, and on the western side of Hahei Dome. The recent flow below the track (foreground in photo) initiated as a complex rotational landslide. The mobilised material appears to have reached the clifftop near the waterfall of Cathedral Cove Beach, however no debris was observed on the beach. DoC staff noted that they did not observe any debris on the beach following the storm event, however it may have washed away during high tide. Debris was typically silt and sand soil. Geomorphology suggests debris flows may have occurred in this area in the past.
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Debris/rock slide

Common along the coastal cliffs and escarpments often within moderately to completely weathered ignimbrite and rhyolite.

Often large trees were observed within the landslide debris. These trees typically extended further from the cliff toe than the main debris.



Rockfall

Cathedral Cove and Coastal Cliffs:

Typically occur on the ignimbrite cliffs, particularly at Cathedral Cove coastal cliffs and the Arch. Typically within Wharepapa Ignimbrite.

Typically run out length is in the order of 1 to 5 m from the base of the cliff. These cliffs are near subvertical or in some cases overhanging and debris runout is limited on beach sand.

Failures are often $<1 \text{ m}^3$ in volume and in some cases larger approximately 5 m^3 .

The ignimbrite rockfalls often fail as tabular slabs in the order of 0.1 to 0.3 m thick. In the Arch, there are limited defects within the in-situ rock mass and the failures typically occur through short impersistent defects subparallel to the cliff/arch face combined with breakage through intact ignimbrite (which is relatively soft).

Observed failed debris are typically cubic blocks in the order of 0.3 m diameter, however it is likely that these blocks have broken on impact and larger block sizes have fallen from the arch.

	Escarpment rockfall Columnar jointed rock, inferred as rhyolite, is visible on the escarpment. These columns have the potential for rockfall / toppling type failures. Boulders at the toe of the escarpment, near the Puriri Grove, are in the order of 1 to 4 m diameter. Multiple boulders also are present from Gemstone Bay, inland up to the escarpment. Site mapping did not indicate that these boulders were from recent rockfall, e.g. no upslope vegetation damage or fresh-looking rock. Escarpment rockfall is further discussed in Table 7.1.
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Translational landslides

Translational landslides occur throughout the site and vary considerably in size. Typically, they occur within soil rather than rock, including residual soil, ash and colluvium.

Run out varies from several meters to 10's of meters from the source.



Creep/tension cracks

Cracks are distinctly visible in the bitumen sections of track. Discussions with DoC highlight that this has been an ongoing issue for maintenance of the track. Some cracks have developed in the past; however many have developed following the recent 2023 rainfall events.

The failure mode of these cracks is likely to vary from a precursor to fast moving landslides to slow moving creep.

Crack aperture is typically less than 50 mm wide.

6 Landslide inventory

The landslide inventory has generally followed guidance from the NHRA, and incorporated events identified in field mapping and historical aerial photograph interpretation.

The landslide inventory is presented in Appendix E and corresponding Figure B1, Figure B2 in Appendix B.

For the purposes of the risk assessment, we have simplified landslide types into three main categories. For sites mapped from aerial photography, typically these were mapped as landslide unless there was clear evidence of rockfall. Detailed field notes of the landslide types are also provided.

- Rockfall.
- Landslide (including earth, debris and rockslides).
- Creep.

Where possible on site, we have identified the landslide parent material, basic geometry, date of failure and landscape unit.

The landslide inventory includes features mapped from the 1944 aerial imagery onward. For Cathedral Cove Arch, rockfalls have been based on previous reporting from 2009 onward.

Landslide, rockfall and creep failure types summarised for each landscape unit in Figure 7.1.

Table 6.1: Landslide inventory summary over the mapping area

Landslide Type	Count
Rockfall	30
Landslide	141
Creep	9
Total	180

7 Landscape units

The site has been divided into landscape units to support dividing the track into separate sections in terms of risk. The landscape units have considered geomorphology, geology and landslide distribution / type, and are summarised in Table 7.1 and shown on Figure B1 in Appendix B. Slope angle is shown in Figure B3 in Appendix B.

Table 7.1: Landscape unit summary

Landscape unit	Description	Extent
Beach (at toe of cliff)	Cathedral Cove, Gemstone Bay and Stingray Bay Beaches. For the purpose of this assessment these have been included as one landscape unit.	The extent of the beaches includes areas which are accessible to the general public without significant clambering over rocks, e.g., the headlands between Cathedral Cove, Stingray Bay and Gemstone have been excluded. The beach unit has been mapped from the cliff toe and extending seaward approximately 10 to 15 m. This is typically the runout distance from large landslide events including treefall). The mapped extent has been increased where rock / tree debris has been identified.
Coastal Cliff	Coastal Cliffs include the near vertical cliff which are present along most of the coastline in the site area. The coastal cliff includes rockfall and landslide type failures.	Judgement has been made as to where the coastal cliff crest is positioned in the topography as thick vegetation and steep slopes are sometimes present above the cliffs and there is not easily defined transition. In these cases, a slope of angle of approximately 45° or steeper was used to distinguish this transition.
Steep Coastal Hills	Coastal Hills have been divided into 'Steep Coastal Hills' and 'Coastal Hills'. Steep Coastal Hills are typically inland areas where the slope is greater than 25° from horizontal. This slope division tends group most landslide features from the flatter 'Coastal Hills' unit.	Steep Coastal Hills are generally present up slope of the Coastal Cliffs across the site. Generally Steep Coastal Hills have been separated from Coastal Cliffs based the coastal cliff crest (approximately 45° or steeper), and the presence of a near vertical cliff below.
Coastal Hills	Coastal Hills are typically hilly areas where the slope is less than 25° from horizontal.	Coastal Hills are present across much of the tracks between the carpark area to the Cathedral Cove beach.
Cathedral Cove Arch	Cathedral Cove Arch is a natural tunnel formed from coastal processes. For the purposes of this assessment, we have not separated out the arch into different zones.	The arch varies between 8 m to 30 m wide, 7 m to 11 m high and is approximately 50 m long.
Escarpment	There is one mapped escarpment within the site which is inland to the southwest of the track. The escarpment is a prominent bluff of outcropping rock inferred as rhyolite from the Hahei Dome.	The escarpment extends for approximately 500 m across the southwest half of the site.

Landscape unit	Description	Extent
	Rockfalls are possible from the columnar rhyolite outcropping. Multiple boulders were observed on the Coastal Hills below the escarpment down to Gemstone Bay. It is not clear if these boulders were eroded in place, travelled to current positions from very large landslides over geological timeframes, or potentially smaller landslide events in more recent historical time were able. Site mapping of land adjacent to the track did not identify evidence recent rockfall reaching the track such as vegetation damage or fresh looking rock. The area from Gemstone Bay to the Escarpment is currently well vegetated including large trees. Historical aerial photographs circa 1944 show the area as being cleared and in scrub or pasture. Potentially rockfalls could have extended further in the past than they do now due to the current vegetation.	
Road Corridor (Grange Road / Carpark)	Grange Road and the Cathedral Cove Carpark have been mapped as 'Road Corridor' for the purposes of this assessment.	Grange Road and the Cathedral Cove Carpark.

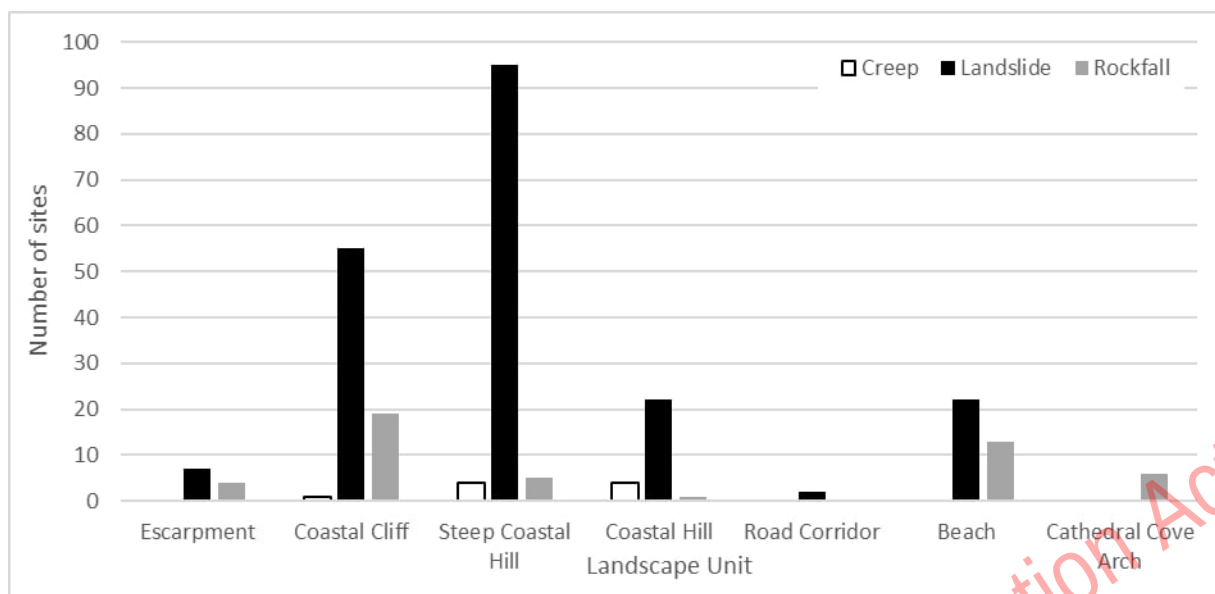


Figure 7.1: Number site landslide/rockfall/creep sites within landscape units. Note that sites can be counted twice if debris travel through multiple areas.

8 Landslide inventory analysis

8.1 Landslide size

Landslide/rockfall volume and area has been considered as part of the assessment using all landslide and rockfall data from the landslide inventory. Volume was estimated during field mapping using handheld range finder measurements, where accessible. Area was measured from mapping aerial photographs of landslide/rockfall features. This information is summarised in Figure 8.1 for landslide and rockfall types.

Creep failure type, largely manifested as cracking in the walkway pavement has not been considered further in the risk assessment. The failure mode of these cracks is likely to vary from a precursor to fast moving landslides to slow moving creep. However, it is difficult to quantify or separate these potential effects, particularly as the walkway pavement is relatively brittle and the cracks have been an ongoing maintenance issue for DoC since installation.

Maximum credible and most likely size landslide/rockfall events are summarised in Table 8.1 for rockfalls within Cathedral Cove Arch, and landslide/rockfalls elsewhere. These divisions are based on qualitative judgment and broadly align with 90 % threshold, i.e., maximum credible event size is approximately the 90th percentile or above.

Landslide and rockfall event sizes, except Cathedral Cove Arch Rockfall, are based on mapped *areas* because nearly all features have this data. Not many features have an estimated volume mapped, with the exception of Cathedral Cove Arch Rockfalls. Estimating event *volume* from the mapped *area* has not been undertaken given the small data set of volume/area pairs available, and those pairs that are available do not fit well with correlations published in the NHRA.

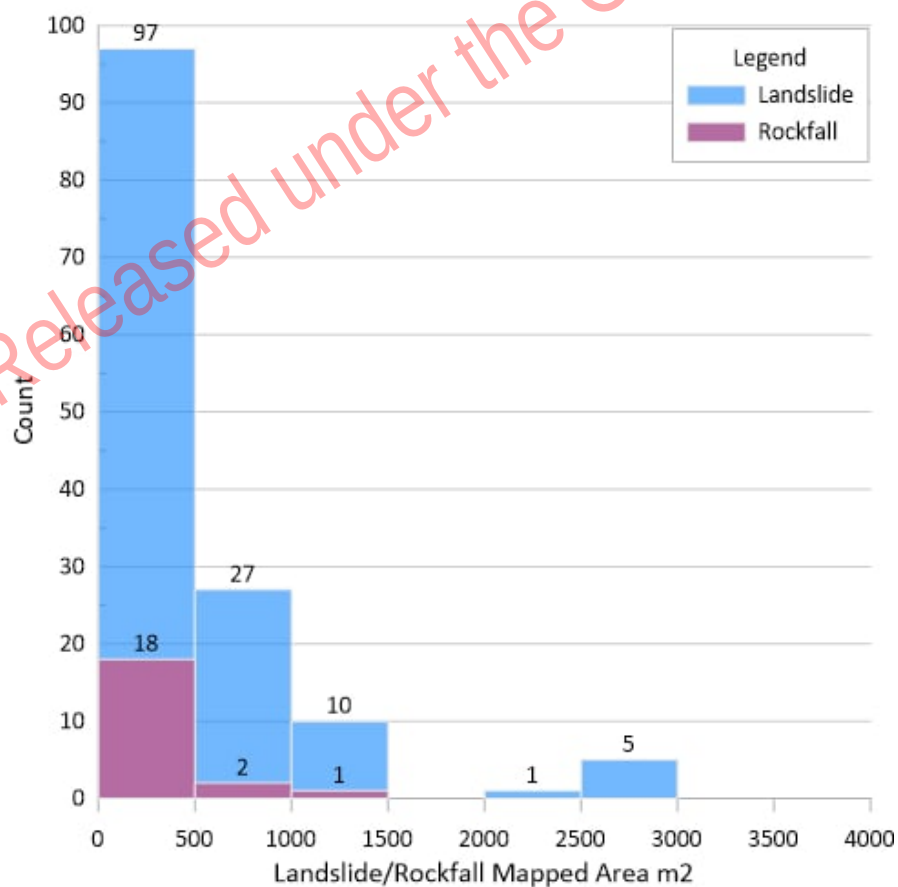


Figure 8.1: Histogram of landslide and rockfall mapped area (m²) (excluding Cathedral Cove Arch rockfalls)

Table 8.1: Landslide and rockfall size classes adopted for this assessment

	Landscape Unit	Most Likely	Maximum Credible Size
Landslides	All except Cathedral Cove Arch	<1000 m ² (In terms of area)	1000-10,000m ² (In terms of area)
Rockfall except Cathedral Cove Arch	All except Cathedral Cove Arch	<500m ² (In terms of area)	500-1000m ² (In terms of area)
Rockfall Cathedral Cove	Cathedral Cove Arch	≤3m ³ (In terms of volume)	4-5m ³ (In terms of volume)

8.2 Landslide frequency and triggering

Triggering of landslides/rockfall across the site is assumed to be primarily due to elevated groundwater conditions as a result of prolonged and/or intense rainfall. No known landslides/rockfall within the inventory are known to have occurred as a result of earthquakes.

Within Cathedral Cove Arch, anecdotal evidence from monitoring suggests rockfalls often occur in the days following heavy rainfall. Possibility this is due to a wetting/drying of the rock or delayed pore-pressure building up.

Landslide frequency is estimated for each landscape unit and summarised in Table 8.2. The estimate is based on the known or estimated date of the events within the landslide inventory. The estimated frequency excludes events mapped on the 1944 aerial photograph, i.e., only events occurring after 1944 are included. The estimate considers that a single event could travel across the site and effect multiple landscape units (i.e., some landslide/rockfall features are considered in more than one landscape unit).

For Cathedral Cove Arch rockfalls, the time period has been taken from 2009, the earliest monitoring report for the Cove.

A plot of the number of landslides and daily rainfall is shown in Figure 8.2. The recent February 2023 weather events appear to have resulted in a relatively large number of landslides/rockfall compared with mapping of historical aerial photographs.

Table 8.2: Landslide/Rockfall mean recurrence interval for each landscape unit.

Landscape unit	Size class	Type	Count	Time period (years)	Mean recurrence interval (Time period/ count)	Area mapped (km ²)
Escarpment	Most likely	Landslides	3	79	26	0.059
		Rockfall	3	79	26	
	Maximum Credible	Landslides	0	79	-	
		Rockfall	1	79	79	
Coastal Cliff	Most likely	Landslides	27	79	3	0.042
		Rockfall	17	79	5	
	Maximum Credible	Landslides	2	79	40	
		Rockfall	2	79	40	
Steep Coastal Hill	Most likely	Landslides	40	79	2	0.174
		Rockfall	5	79	16	
	Maximum Credible	Landslides	1	79	79	
		Rockfall	0	79	-	
Coastal Hill	Most likely	Landslides	4	79	20	0.150
		Rockfall	1	79	79	
	Maximum Credible	Landslides	1	79	79	
		Rockfall	0	79	-	
Road Corridor	Most likely	Landslides	0	79	-	0.006
		Rockfall	0	79	-	
	Maximum Credible	Landslides	0	79	-	
		Rockfall	0	79	-	
Beach	Most likely	Landslides	12	79	7	0.015
		Rockfall	12	79	7	
	Maximum Credible	Landslides	1	79	79	
		Rockfall	1	79	79	
Cathedral Cove Arch	Most likely	Landslides	0	14	-	780 m
		Rockfall	5	14	3	
	Maximum Credible	Landslides	0	14	-	
		Rockfall	1	14	14	

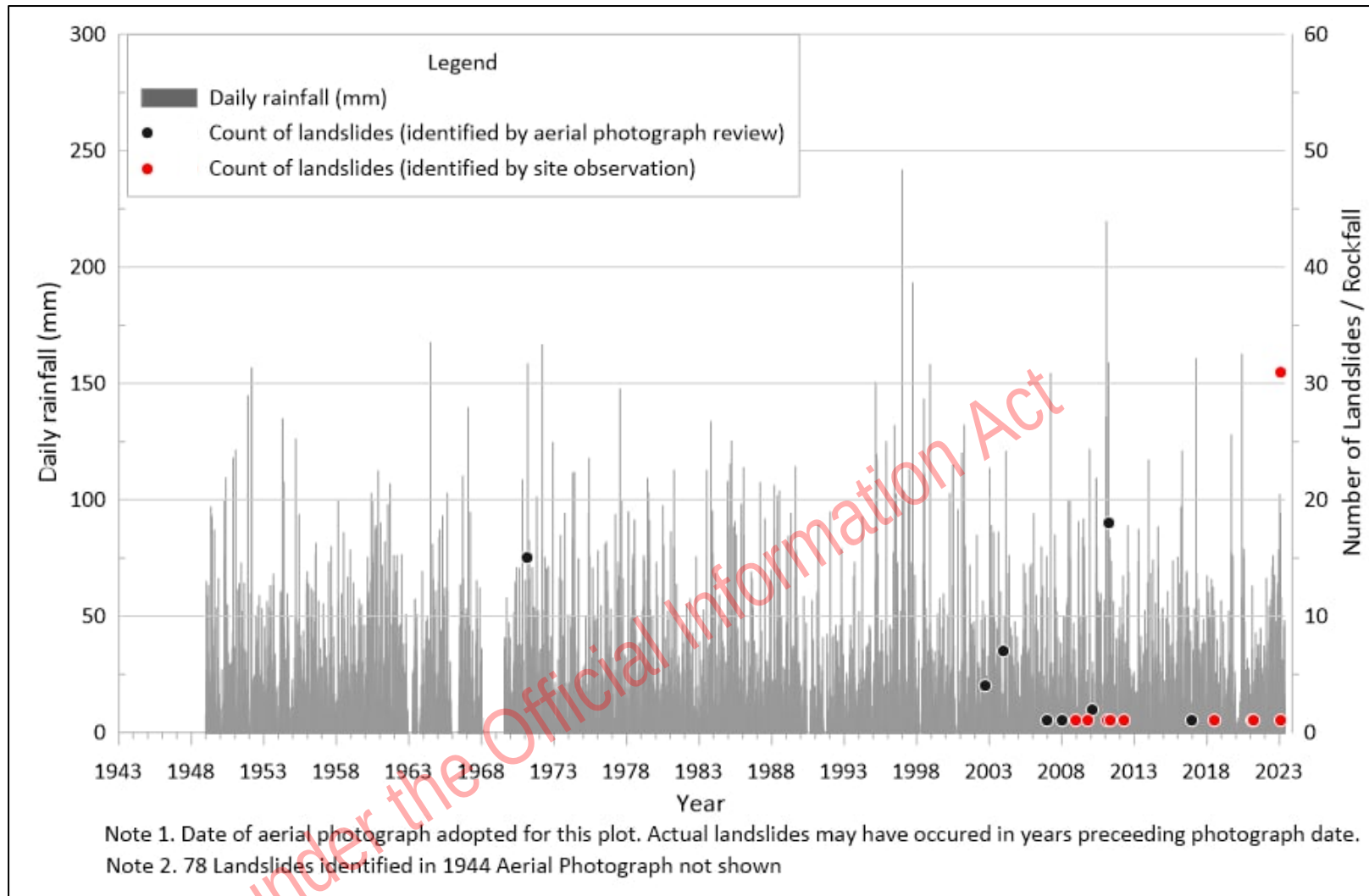


Figure 8.2: Daily rainfall (mm) and count of mapped landslides / rockfall.

9 Risk assessment

9.1 General

Risk assessment have been undertaken following guidance from the NHRA to provide DoC with an understanding of their risk exposure from the site and to inform their decision making. The following risk metrics have been assessed.

- 1 **Annual individual fatality risk (AIFR).** This has been calculated in terms of the fatality risk experienced by an individual over one year. This has been calculated for a single visit over one year (e.g., **Visitor Risk**). This has also been calculated for the most at risk DoC worker who visits the site multiple time in a year.
- 2 **Societal risk.** This metric provides the relationship between the frequency of occurrence of a specified hazard and the number of fatalities in a given population if the hazard were to occur.

The following sections detail the risk assessment methodology and results.

DoC has provided details of their risk thresholds which are presented in Section 9.4.

9.2 General landslide risk analysis calculation

The landslide risk analysis calculation for annual probability that a person may lose their life follows NHRA Part 3 Equation 2.1, as outlined below.

$$P_{(LOL)} = P_{(L)} \times P_{(T:L)} \times P_{(S:T)} \times V_{(D:T)}$$

Where:

$P_{(LOL)}$ is the annual probability at the person will be killed.

$P_{(L)}$ is the annual probability of the landslide occurring.

$P_{(T:L)}$ is the probability of the landslide reaching the element at risk (e.g. the debris from a landslide reaching the track)

$P_{(S:T)}$ is the spatio-temporal probability of the person at risk (the proportion of a year that the person is in the path of the landslide when it reaches or passes the element at risk).

$V_{(D:T)}$ is the vulnerability of the person to the landslide event (The probability that the person will be killed if impacted by the landslide).

This equation has been undertaken for the track and point locations considering each of the landscape units and landslide/rockfall event types and the product of each scenario summed to determine the overall risk.

9.3 Inputs to risk assessment

9.3.1 Probability of the event occurring $P_{(L)}$

The probability of landslide and rockfall events occurring over a year for each track section and size class are outlined in Table 9.1. These have been estimated following guidance in Part 3 and Part 4 of the NHRA guidelines. The mean recurrence interval from Table 8.2 has been utilised with the following equation below.

AEP, Probability that one or more landslides will occur annually = $1 - e^{(-t/m)}$

Where $t = 1$ year and $m =$ mean recurrence interval.

As some track sections are relatively short with limited landslide inventory data nearby, we have considered the AEP from each landscape unit and then scaled this for each track section based on the area contributing to the landslide/rockfall hazard. This allows a larger landslide inventory dataset to be utilised to determine $P_{(L)}$ for each track section, and to provide a $P_{(L)}$ for each track section rather than considering a site wide value for each track. Equation below:

$$\frac{\text{AEP of each Landscape Unit}}{\text{Area of Landscape Unit}} \times \text{Area contributing to landslide hazard for track section}$$

The working for these calculations are shown in Appendix F.

Table 9.1: Probability of landslide/rockfall occurring for each landscape unit

Track	Case	Probability that one or more landslides will occur in time 't = 1 year' ($1 - e^{-t/m}$)	
		Landslide	Rock fall
Section 1	Most likely	9.2E-02	1.4E-02
	Max credible	2.9E-03	-
Section 2	Most likely	2.6E-02	1.3E-03
	Max credible	3.2E-04	-
Section 3	Most likely	1.2E-02	1.8E-03
	Max credible	3.7E-04	-
Section 4	Most likely	1.1E-02	5.4E-04
	Max credible	1.4E-04	-
Section 5	Most likely	2.3E-02	1.1E-03
	Max credible	2.8E-04	-
Section 6	Most likely	2.5E-02	1.2E-03
	Max credible	3.0E-04	-
Section 7	Most likely	5.9E-02	2.9E-03
	Max credible	7.3E-04	-
Section 08	Most likely	4.5E-02	2.2E-03
	Max credible	5.5E-04	-
Section 09	Most likely	2.3E-03	2.3E-03
	Max credible	-	7.9E-04
Section 10	Most likely	4.9E-03	7.6E-04
	Max credible	1.6E-04	-
Section 11	Most likely	8.8E-02	4.2E-03
	Max credible	1.1E-03	-
Section 12	Most likely	1.2E-01	1.9E-02
	Max credible	4.0E-03	-
Section 13	Most likely	4.2E-03	2.8E-03
	Max credible	3.7E-04	3.7E-04
Section 14	Most likely	4.9E-02	4.9E-02
	Max credible	4.3E-03	4.3E-03
Section 15	Most likely	-	3.0E-01
	Max credible	-	6.9E-02
Section 16	Most likely	8.1E-03	5.4E-03

Track	Case	Probability that one or more landslides will occur in time 't = 1 year' ($1 - e^{-t/m}$)	
		Landslide	Rockfall
	Max credible	7.0E-04	7.0E-04
Section 17	Most likely	1.5E-02	7.1E-04
	Max credible	1.8E-04	-
Section 18	Most likely	1.5E-02	1.5E-02
	Max credible	1.4E-03	1.4E-03
Section 19	Most likely	7.8E-03	1.2E-03
	Max credible	2.5E-04	-
Section 20	Most likely	9.8E-03	9.8E-03
	Max credible	8.7E-04	8.7E-04
Section 21	Most likely	8.5E-03	4.1E-04
	Max credible	1.0E-04	-
Point Location 1 (Bench)	Most likely	1.7E-03	2.7E-04
	Max credible	5.5E-05	-
Point Location 2 (Existing Toilet)	Most likely	6.6E-03	6.6E-03
	Max credible	5.9E-04	5.9E-04
Point Location 3 (Lifeguard Hut)	Most likely	3.8E-03	3.8E-03
	Max credible	3.4E-04	3.4E-04
Point Location 4 (Proposed New Toilet Location)	Most likely	3.0E-03	4.6E-04
	Max credible	9.5E-05	-

9.3.2 Probability of the landslide reaching the walkway or point locations at risk $P_{(T:L)}$

Landslides and rockfalls could impact the track and users through inundation (e.g., traveling debris hitting a person) and loss of supporting land (e.g., undermining the track and creating a fall hazard). Landslides and rockfalls affect different sections of the track depending on the landscape unit. We have utilised the following equation to determine $P_{(T:L)}$ as outlined in NHRA Part 3, as the proportion of the walkway affected for each event.

$$P_{(T:L)} = D + d / L$$

Where:

D is diameter of the event (m) (block size for rockfall or width of falling debris). Estimated for each landscape unit based on mapped size information for rockfall and landslide widths.

d is diameter of a person (m). Assumed to be 0.8 m.

L is the length (m) of track along which the landslide/rockfall could occur. Based on observations and simplicity, we have assumed landslide / rockfall could occur along the entire track length.

For each section of the track and point location $P_{(T:L)}$ has been estimated in Table 9.2. Where the event width is larger than the individual section track length, $P_{(T:L)}$ has been capped at 1.

Table 9.2: Proportion of the walkway affected for each event.

Location	Size Class	Landscape Unit	Total length of zone	Rockfall Event Width	Landslide Width	P T:L
Section 1	Max credible	Steep Coastal Hills	667	0	31	4.7E-02
	Most likely	Steep Coastal Hills	667	9	13	3.4E-02
Section 2	Max credible	Coastal Hill	153	N/A	28	1.9E-01
	Most likely	Coastal Hill	153	N/A	18	1.2E-01
Section 3	Max credible	Steep Coastal Hills	212	0	31	1.5E-01
	Most likely	Steep Coastal Hills	212	9	13	1.1E-01
Section 4	Max credible	Coastal Hill	39	N/A	28	7.4E-01
	Most likely	Coastal Hill	39	N/A	18	4.9E-01
Section 5	Max credible	Coastal Hill	41	N/A	28	7.0E-01
	Most likely	Coastal Hill	41	N/A	18	4.6E-01
Section 6	Max credible	Coastal Hill	79	N/A	28	3.6E-01
	Most likely	Coastal Hill	79	N/A	18	2.4E-01
Section 7	Max credible	Coastal Hill	194	N/A	28	1.5E-01
	Most likely	Coastal Hill	194	N/A	18	9.8E-02
Section 08	Max credible	Coastal Hill	279	N/A	28	1.0E-01
	Most likely	Coastal Hill	279	N/A	18	6.8E-02
Section 09	Maximum Credible	Escarpment	56	30	30	1
	Most Likely	Escarpment	56	7	9	3.0E-01
Section 10	Maximum Credible	Steep Coastal Hills	27	0	31	1
	Most Likely	Steep Coastal Hills	27	9	13	8.3E-01
Section 11	Maximum Credible	Coastal Hill	262	N/A	28	1.1E-01
	Most Likely	Coastal Hill	262	N/A	18	7.2E-02
Section 12	Maximum Credible	Steep Coastal Hills	562	0	31	5.6E-02
	Most Likely	Steep Coastal Hills	562	9	13	4.0E-02
Section 13	Maximum Credible	Coastal Cliffs	18	41	31	1
	Most Likely	Coastal Cliffs	18	12	15	1
Section 14	Maximum Credible	Beach	497	15	36	1.0E-01
	Most Likely	Beach	497	12	18	6.3E-02
Section 15	Maximum Credible	Cathedral Cove Arch	44	8	N/A	1.9E-01
	Most Likely	Cathedral Cove Arch	44	3	N/A	8.1E-02
Section 16	Maximum Credible	Coastal Cliffs	58	41	31	1
	Most Likely	Coastal Cliffs	58	12	15	4.7E-01
Section 17	Maximum Credible	Coastal Hill	115	N/A	28	2.5E-01
	Most Likely	Coastal Hill	115	N/A	18	1.6E-01
Section 18	Max credible	Beach	181	15	36	2.9E-01
	Most likely	Beach	181	12	18	1.7E-01
Section 19	Maximum Credible	Steep Coastal Hills	105	0	31	3.0E-01
	Most Likely	Steep Coastal Hills	105	9	13	2.1E-01
Section 20	Max credible	Beach	123	15	36	4.2E-01
	Most likely	Beach	123	12	18	2.5E-01

Location	Size Class	Landscape Unit	Total length of zone	Rockfall Event Width	Landslide Width	P T:L
Section 21	Maximum Credible	Coastal Hill	57		28	5.0E-01
	Most Likely	Coastal Hill	57	N/A	18	3.3E-01
Point Location 1 (Bench)	Maximum Credible	Steep Coastal Hills	2	0	31	1
	Most Likely	Steep Coastal Hills	2	9	13	1
Point Location 2 (Existing Toilet)	Max credible	Beach	5	15	36	1
	Most likely	Beach	5	12	18	1
Point Location 3 (Lifeguard Hut)	Max credible	Beach	3	15	36	1
	Most likely	Beach	3	12	18	1
Point Location 4 (Proposed New Toilet Location)	Max credible	Steep Coastal Hills	5	0	31	1
	Most likely	Steep Coastal Hills	5	9	13	1

9.3.3 Spatio-temporal probability $P_{(S:T)}$

The spatio-temporal probability is the exposure of a person to the hazard in a given year. This is expressed in the equation below and summarised in Table 9.3 for each of the walking trips considered.

$P_{(S:T)} = \text{Passes} \times \text{Travel time} / \text{seconds per year.}$

We have assuming a travel time of 0.5 m per second for this assessment.

We have assumed stoppage times for each of the relevant point locations.

Table 9.3: Spatio-temporal probability summary

Track ID	Track length	Seconds on track (assuming walking 0.5 m/s)	P (S:T) proportion of time on track per year		
			Two ways / return	One way	Ranger walking track 3 times per week, 40 weeks per year
Section 01	667	1335	8.5E-05	4.2E-05	1.0E-02
Section 02	153	305	1.9E-05	9.7E-06	2.3E-03
Section 03	212	424	2.7E-05	1.3E-05	3.2E-03
Section 04	39	78	4.9E-06	2.5E-06	5.9E-04
Section 05	41	82	5.2E-06	2.6E-06	6.2E-04
Section 06	79	158	1.0E-05	5.0E-06	1.2E-03
Section 07	194	388	2.5E-05	1.2E-05	2.9E-03
Section 08	279	558	3.5E-05	1.8E-05	4.2E-03
Section 09	56	112	7.1E-06	3.5E-06	8.5E-04
Section 10	27	54	3.4E-06	1.7E-06	4.1E-04
Section 11	262	524	3.3E-05	1.7E-05	4.0E-03
Section 12	562	1123	7.1E-05	3.6E-05	8.5E-03
Section 13	18	36	2.3E-06	1.1E-06	2.8E-04
Section 14	497	994	6.3E-05	3.2E-05	7.6E-03
Section 15	44	88	5.6E-06	2.8E-06	6.7E-04
Section 16	58	116	7.4E-06	3.7E-06	8.8E-04
Section 17	115	231	1.5E-05	7.3E-06	1.8E-03
Section 18	181	362	2.3E-05	1.1E-05	2.8E-03
Section 19	105	210	1.3E-05	6.7E-06	1.6E-03
Section 20	123	247	1.6E-05	7.8E-06	1.9E-03
Section 21	57	115	7.3E-06	3.6E-06	8.7E-04
Point Location 1 (Bench)		60	3.8E-06	1.9E-06	4.6E-04
Point Location 2 (Existing Toilet)		120	7.6E-06	3.8E-06	9.1E-04
Point Location 3 (Lifeguard Hut)		-			9.1E-03 Assuming lifeguard on duty for 20 hours in the tower, 4 weeks over summer
Point Location 4 (Proposed New Toilet Location)		120	7.6E-06	3.8E-06	9.1E-04

9.3.4 Vulnerability of the person to the landslide/rockfall event

We have adopted a vulnerability value outlined in Table 9.4 outside and 0.8 for within buildings, following Table 7.1 in NRHA Part 4. A value of 1 assumes a fatality as a result of a rockfall or landslide event.

Table 9.4: Adopted vulnerability values

Event type	Landscape Unit	Size Class	Vulnerability of a person outside	Vulnerability of a person inside a building
Landslides and Rockfalls (except Cathedral Cove Arch)	All units except Cathedral Cove Arch	Most Likely	0.7	0.4
		Maximum Credible	1	0.8
Rockfall Cathedral Cove	Cathedral Cove Arch	Most Likely	0.5	N/A
		Maximum Credible	0.7	N/A

9.4 DoC risk thresholds for Annual Individual Fatality Risk and visitor risk

DoC risk tolerance levels for are presented in Table 9.5 and Table 9.6 based on provided guidance⁶. DoC have different risk tolerance levels for different types of tracks/sites e.g., a back country track has a higher risk tolerance level than a gentle walking track easily accessible to the public.

We understand that DoC use these risk tolerance levels in comparison to the calculate risk metrics to inform their decision making. DoC have specified that the entire track within study site should be considered a 'Lower Risk Site' category, i.e., this is the lowest tolerance for risk within DoCs thresholds.

⁶ Department of Conservation (14 June 2021) *Risk threshold levels for DOC visitor sites*.

Table 9.5: Individual visitor one trip risk threshold. DoC have specified that the entire site should be considered a Lower Risk Site, i.e., the DoC have a low tolerance to risk for this site.

Action Required	Lower Risk site	Medium Risk Site	Higher Risk Site
Halt until risk reduced.	$> 10^{-5}$	$> 3 \times 10^{-5}$	$> 10^{-4}$
Continue only after high level review.	$> 10^{-6}$	$> 3 \times 10^{-6}$	$> 3 \times 10^{-5}$
Explore practicable risk reduction options.	10^{-7} to 10^{-6}	3×10^{-7} to 3×10^{-6}	3×10^{-6} to 3×10^{-5}
Explore practicable risk reduction options (lower priority)	n/a	10^{-7} to 3×10^{-7}	3×10^{-7} to 3×10^{-6}
Monitor situation.	$< 10^{-7}$	$< 10^{-7}$	$< 3 \times 10^{-7}$

Table 9.6: Person most at risk (DoC staff)

Action	Annual Fatality Risk For staff regularly exposed to natural hazards	Daily Fatality Risk For one off or occasional exposure to natural hazards
Halt until risk reduced.	$> 3 \times 10^{-4}$	$> 3 \times 10^{-5}$
Continue only after high level review.	$> 10^{-4}$	$> 3 \times 10^{-6}$
Explore practicable risk reduction options.	10^{-5} to 10^{-4}	3×10^{-7} to 3×10^{-6}
Explore practicable risk reduction options (lower priority)	10^{-6} to 10^{-5}	10^{-7} to 3×10^{-7}
Monitor situation.	$< 10^{-6}$	$< 10^{-7}$

9.5 Annual Individual Fatality Risk and visitor risk results

The Annual Individual Fatality Risk (AIFR) has been calculated for an individual member of public visiting the site once in a year (visitor risk) and for a typical DoC worker using the calculation outlined in Section 9.2.

AIFR has been calculated for each track section. This then allows AIFR to be considered for walking trips to Cathedral Cove, Gemstone Bay and Stingray Bay separately.

The AIFR calculation for each track section is presented in Appendix G Table 1.

A summary of the AIFR for trips to Cathedral Cove, Stingray Bay and Gemstone Bay is presented in Table 9.7 for an individual member of public visiting the site once in a year.

The AIFR does not take into account the condition of the walking track or that currently some sections of track are damaged and likely more at risk than estimated. We have assumed that these sections will be repaired or realigned.

Table 9.7: Summary of the Annual Individual Fatality Risk for an individual member of public visiting the site once in a year. Colour codes as per DoC thresholds in Table 9.5.

	Hahei to Cathedral Cove Return	Hahei to Stingray Bay Return	Hahei to Gemstone Bay Return
Total Annual Individual Fatality Risk	1.5E-06	6.7E-07	4.6E-07
	Comprises the sum of the following sections below:		
Section 01	2.2E-07	2.2E-07	2.2E-07
Section 02	4.7E-08	4.7E-08	4.7E-08
Section 03	2.8E-08	2.8E-08	2.8E-08
Section 04	2.0E-08	2.0E-08	2.0E-08
Section 05	4.2E-08	4.2E-08	4.2E-08
Section 06	4.4E-08	4.4E-08	N/A
Section 07	N/A	1.1E-07	N/A
Section 08	8.1E-08	N/A	N/A
Section 09	1.3E-08	N/A	N/A
Section 10	1.2E-08	N/A	N/A
Section 11	1.6E-07	N/A	N/A
Section 12	3.1E-07	N/A	N/A
Section 13	1.3E-08	N/A	N/A
Section 14	3.3E-07	N/A	N/A
Section 15	1.2E-07	N/A	N/A
Section 16	N/A	4.3E-08	N/A
Section 17	N/A	N/A	N/A
Section 18	N/A	1.0E-07	N/A
Section 19	N/A	N/A	1.9E-08
Section 20	N/A	N/A	6.6E-08
Section 21	1.5E-08	1.5E-08	1.5E-08
Point Location 1 (Bench)	5.6E-09	N/A	N/A
Point Location 2 (Existing Toilet)	4.8E-08	N/A	N/A

Table 9.8: Summary of the Annual Individual Fatality Risk for DoC worker visiting the site three times per week for 40 weeks in a year. Colour codes as per DoC thresholds in Table 9.6.

	Hahei to Cathedral Cove Return	Hahei to Stingray Bay Return	Hahei to Gemstone Bay Return
Total Annual Individual Fatality Risk	1.8E-04	8.1E-05	5.5E-05
	Comprises the sum of the following sections below:		
Section 01	2.7E-05	2.7E-05	2.7E-05
Section 02	5.7E-06	5.7E-06	5.7E-06
Section 03	3.4E-06	3.4E-06	3.4E-06
Section 04	2.4E-06	2.4E-06	2.4E-06
Section 05	5.0E-06	5.0E-06	5.0E-06
Section 06	5.3E-06	5.3E-06	N/A
Section 07	N/A	1.3E-05	N/A
Section 08	9.7E-06	N/A	N/A
Section 09	1.5E-06	N/A	N/A
Section 10	1.4E-06	N/A	N/A
Section 11	1.9E-05	N/A	N/A
Section 12	3.7E-05	N/A	N/A
Section 13	1.6E-06	N/A	N/A
Section 14	3.9E-05	N/A	N/A
Section 15	1.4E-05	N/A	N/A
Section 16	N/A	5.2E-06	N/A
Section 17	N/A	N/A	N/A
Section 18	N/A	1.2E-05	N/A
Section 19	N/A	N/A	2.3E-06
Section 20	N/A	N/A	7.9E-06
Section 21	1.9E-06	1.9E-06	1.9E-06
Point Location 1 (Bench)	N/A	N/A	N/A
Point Location 2 (Existing Toilet)	5.7E-06	N/A	N/A

9.6 Discussion of Annual Individual Fatality Risk and visitor risk

A comparison of DoC's thresholds and the estimated Annual Individual Fatality Risk (Table 9.8) for visitors (individual one trip) and DoC workers indicate DoC should '*Continue only after high level review*' for Hahei to Cathedral Cove Return track. For tracks to Stingray Bay and Gemstone Bay the thresholds indicate DoC should '*Explore practicable risk reduction options*'. This is illustrated in Figure 9.1.

The risk assessment also highlights that several sections of track have a higher risk than others, namely track Sections 1, 7, 11, 12, 14, 15 and 18 (see site plan in Appendix B for reference). These sections generally have a higher density of landslide/rockfall potentially affecting them.

The risk metrics do not consider that the track is less used during large rainfall events which are more likely to trigger landslide/rockfall. Review of daily rainfall with daily track counts in Section 4.8

shows this reduction in visitor numbers when wet and therefore the metrics may be the conservative in this respect.

The risk estimates have been undertaken at a site wide scale, considering individual track sections and relevant hazard metrics where possible. The estimates do not consider that multiple sections of the track are currently damaged. These damaged track sections are more hazardous than the risk estimates presented, and these areas should be avoided or mitigated prior to opening the track.

DoC should consider the estimated risk metrics, their thresholds and determine a mitigation approach in line with their strategy, the cost and risk they are willing to accept. Mitigation options are further discussed in Section 10.

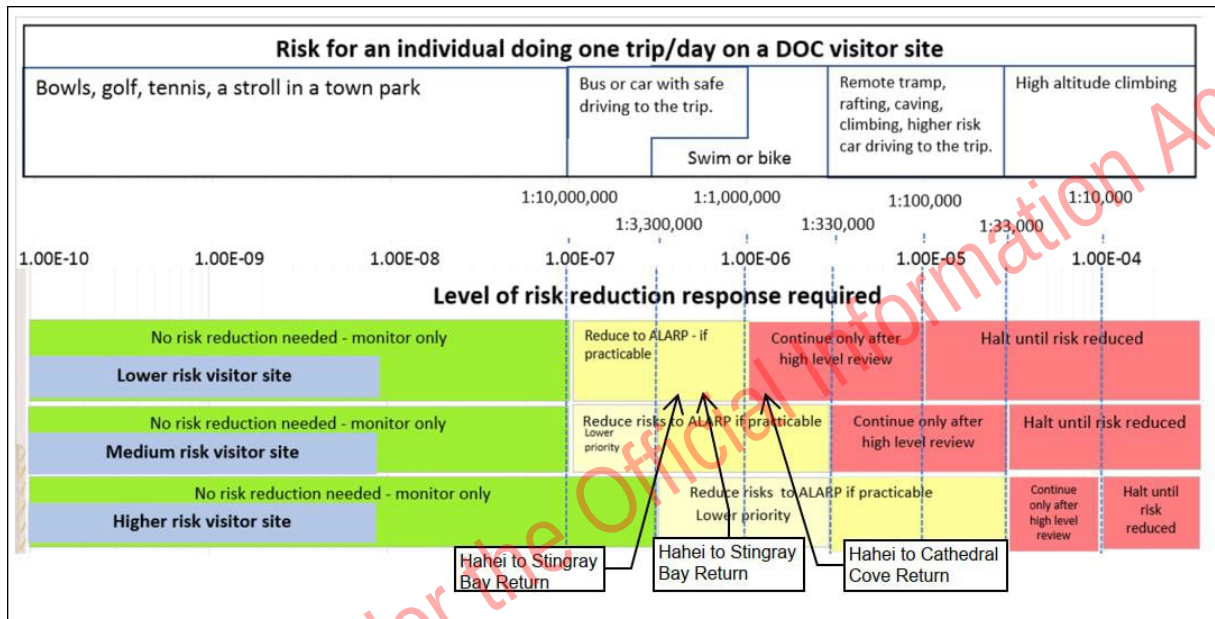


Figure 9.1: DoC visitor site risk levels and the estimated annual individual fatality risks from this assessment. After DoC⁷.

9.7 Societal risk

9.7.1 General

Societal risk has been calculated in terms of the likelihood of 1 or more fatalities per annum, 5 or more fatalities per annum and a worst-case scenario, following guidance in NHRA Part 3 and Part 4.

The calculation follows the generalised landslide risk equation in Section 9.2. Further consideration has been made to the Temporal Spatial Probability, $P_{(S,T)}$, i.e., the proportion of the year the track is occupied to account for multiple users accessing the track. And consideration to the event size class that may result in multiple fatalities. These two considerations, and the Societal Risk are discussed in the following sections.

9.7.2 Event size class, vulnerability and group numbers

Vulnerability of fatality has been estimated in Section 9.3.4. Based on these vulnerability estimates, the minimum group number needed for 1 or more fatality, 5 or more fatalities and a worst-case scenario are estimated in Table 9.5 using the following equation:

$$\text{Minimum group number} = N \text{ fatalities} / \text{Vulnerability}$$

⁷ Department of Conservation (undated) *Visitor site risk levels*, DoC Document no. 6708120.

In some cases the minimum group number is not credible considering the event size class.

Table 9.5 shows the following group numbers need to be considered:

- Minimum Number of people in group for 1 or more fatalities: Approximately 1 to 2 people
- Minimum Number of people in group for 5 or more fatalities: Approximately 5 to 7 people
- Minimum Number of people in group for 30 or more fatalities (worst-case): 30 people

The worst-case scenario is assumed to be a 30 to 40 m wide landslide or rockfall completely inundating a group of 30 people, such as a large walking group, or people sheltering below a beach cliff.

The proportion of the year that these estimated group numbers potentially occupy the track are determined in Section 9.7.3.

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Table 9.9: Group number estimates

Event Type	Event Class	Vulnerability	Minimum Number of people in group for: 1 or more fatality	Minimum Number of people in group for: 5 or more fatalities	Minimum Number of people in group for worst-case scenario of: 30 or more fatalities
Landslide / Rockfall (except Cathedral Cove Arch)	Most Likely	0.7	2	7 – Marginal if the event size is large enough in some cases.	(43) Not credible given event size
	Maximum Credible	1	1	5	30
Rockfall Cathedral Cove Arch	Most Likely	0.5	2	(10) Not credible given event size	Not credible given event size
	Maximum Credible	0.7	2	(7) Not credible given event size	N/A

9.7.3 Societal Risk Temporal Spatial Probability

The Temporal Spatial Probability, $P_{(S:T)}$, is the proportion of the year the track is occupied to account for multiple users accessing the track.

DoC have provided hourly track count data for Cathedral Cove and Hahei between 2017 and 2019 (recent pre-covid years). This data shows the following:

- 98 % of all track users were counted between 7 am and 7 pm, highlighting that for at least 50 % of the year the track is generally not occupied.
- 70 % of track users visit Cathedral Cove between the months of October to February.
- The track counter on Cathedral Cove track is triggered approximately 500,000 times in a year. A user triggers the counter twice during a return trip therefore approximately 250,000 people visit cathedral cove via the track each year.
- The statistics above highlight that the track is frequented by a large number of people over relatively short periods of the year, e.g., daylight hours and peak months.

The $P_{(S:T)}$ estimates are presented in Table 9.10 along with the assumptions used to determine the values. We have considered upper bound values for $P_{(S:T)}$ using high level assumptions rather than detailed analysis for this assessment of Societal Risk. This parameter could be further refined if the Societal Risk values require further assessment.

Table 9.10: Societal risk temporal spatial probability

	Adopted $P_{(S,T)}$	Assumptions
Group of 1 or more fatalities	0.5	Assuming the track is occupied for 50 % of the year i.e., from 7 am to 7 pm all year round.
Group of 5 or more fatalities	0.25	Assuming the track is occupied for 25 % of the year by a group of approximately 5/7 people i.e., from 7 am to 7 pm, 6 months of the year.
Group of 30 or more fatalities	0.25	Assuming the track is occupied for 25 % of the year by a group of approximately 30 people i.e., from 7 am to 7 pm, 6 months of the year.

9.7.4 DoC risk thresholds for Societal risk

DoC risk tolerance levels for societal risk are presented in Table 9.11 based on provided guidance⁸. DoC have provided guidance for events with 5 or more fatalities only.

We understand that DoC use these risk tolerance levels in comparison to the calculate risk metrics to inform their decision making.

Table 9.11: Societal risk threshold

Action	Annual Fatality Risk For events with 5 or more fatalities
Halt until risk reduced	$> 10^{-1}$
Continue only after high level review	10^{-1} to 10^{-2}
Explore practicable risk reduction options	10^{-2} to 10^{-3}
Explore practicable risk reduction options (lower priority)	10^{-3} to 10^{-4}
Monitor situation	$< 10^{-4}$

9.7.5 Societal risk results

The results for societal risk metrics are presented in Table 9.12 for each case. These are the sum of the contributing track sections which are set out in Appendix H Table 1.

⁸ Department of Conservation (14 June 2021) *Risk threshold levels for DOC visitor sites*.

Table 9.12: Societal risk results. Colour codes as per DoC thresholds in Table 9.11

Scenario	Societal risk		
	Hahei to Cathedral Cove Return	Hahei to Stingray Bay Return	Hahei to Gemstone Bay Return
1 or more fatalities	3.9E-02	1.9E-02	1.2E-02
5 or more fatalities	7.4E-03	3.3E-03	2.0E-03
30 or more fatalities	1.1E-03	7.3E-04	3.3E-04

9.8 Discussion of societal risk

A comparison of DoC's societal risk thresholds and the societal risk results for events with 5 or more fatalities indicate DoC should '*Explore practicable risk reduction options*'. This metric is broadly similar to the results of the annual individual risk results discussed in Section 9.5 and Section 9.6.

A number of assumptions have been made to determine the societal risk regarding event sizes, vulnerability and temporal-spatial probability. These parameters could be further refined if the Societal Risk values require further assessment.

With this in mind, DoC should consider the estimated risk metrics, their thresholds and determine a mitigation approach in line with their strategy, the cost and risk they are willing to accept. Mitigation options are discussed in Section 10.

10 Site mitigation options

10.1 Purpose

There are two key purposes of the potential site mitigation options.

- 1 Mitigate track damage resulting from the February rainfall events. These sections of track need to be repaired or avoided prior to opening the track.
- 2 Explore potential for reducing the risk to visitors and DoC workers.

10.2 Risk reduction options

The landslide risk assessment has highlighted DoC should '*Continue only after high level review*' for Hahei to Cathedral Cove Return track. For tracks to Stingray Bay and Gemstone Bay the thresholds indicate DoC should '*Explore practicable risk reduction options*'.

Several areas stand out as particularly hazardous from the site observations made on site. These include the following:

- **Beach cliffs at Stingray Bay and parts of Cathedral Cove Bay (Track Sections 14 and 18).** Large rockfalls are present and visitors often spend time at the toe of these cliffs. There are few practical mitigations to prevent visitors accessing these areas. Signage could be considered but may have limited effect and barriers will likely be washed away from storm surges. Currently many of the existing rockfall areas have debris piles at the cliff toe which may help prevent access. DoC undertook a review of this hazard previously between 2009 and 2012 and a summary of these reports is provided in Appendix A.
- **Track to Hahei to Cathedral Cove Carpark (Track Section 1).** The existing landslides along this section of track appear relatively small (less than 10 m wide), however the track and potential landslide runout is directly above a very steep section of cliff making these particularly hazardous. Discussion on realignment of this track section is outlined in Section 10.3.

Reducing visitor numbers during and directly after rainfall events could be further encouraged across the site by actively closing the track or providing public warning during heavy rainfalls. This would help to reduce the potential for visitors to be impacted by landslides. It should be noted however that it is likely impossible to practically completely close the track off and there are practicality issues. An appropriate process for DoC rangers would need to be determined.

Practical mitigation measures to reduce risk for DoC workers could include reducing exposure during and after rainfall events, and reducing time spent directly under landslide/rockfall source areas such as the beach cliffs.

A written log of landslide/rockfall events identified by DoC staff could be considered to help inform future landslide risk assessments. As a minimum this should record date, location, a sketch or photograph and approximate size/volume.

10.3 Track and beach access mitigation options

Recent weather events have caused significant damage to a number of the track sections. These include the following:

- 1 Beach access to Cathedral Cove
- 2 Beach access to Gemstone Bay
- 3 Beach access to Stingray Bay
- 4 Hahei Track (Track Section 01)

5 Cathedral Cove (Track Section 12, 13 and 14).

Conceptual management and mitigation approaches are presented in the following tables. Discussions with DoC on some of these mitigation options have been undertaken during our site visits.

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Table 10.1: Track and Beach Access Management Options

Site Location	Site details/damage	Mitigation option description	Additional considerations
Cathedral Cove lower track access (Track Section 12, 13 & 14) (Refer Figure 10.1 and Figure 10.2)	Landslides have damaged a 10 m section of stairs and track. This section is in the steep coastal hill landform. Site observations identified an upper soil profile of colluvium overlying residual soil. The existing landslides have potential to regress and very steep ground adjacent to the track nearby may fail in a similar type of landslide. Furthermore, the current public toilet site on the southern portion of Mare's Leg Beach has been damaged by storm surge in recent weather events. Relocation of the toilet is being considered by DoC.	Option 1 – Alternative track route A potential route option was traversed by T+T and DoC during recent site visits and is shown in Figure 10.2. The proposed route would detour north-west of the current track and re-join the track just above the current beach access structure. The re-route would also present an opportunity to locate a new toilet site in an area of ground over a minor spur at the start of the new route as shown in Figure 10.2.	The coastal cliffs on the northern side of Cathedral Cove are nearby to the potential re-aligned track. A potential fall hazard is possible if public detour off the track northward. While this hazard has always been present, bringing the track closer may mean public access this area. The track could be positioned below a slight rise southward of the cliff crest to help avoid this area. Other mitigation options such as barriers and signage could be considered. Ongoing landslide risk would remain from new or regression of existing landslides, however the re-route would largely avoid the current areas of instability. The option is a relatively a low cost and practical option.
		Option 2 – Reinstate the damaged track. Reinstate the track in its current alignment. This would likely entail a resilient engineered solution, particularly as it would require traversing unstable ground. An engineered solution would likely include slope stabilisation, earthworks, and structures such as stairs and/or bridges.	The option is likely to be costly and subject to further geotechnical considerations including slope stabilisation. If engineered appropriately, the option would provide resilient access for this section of the track. Noting that this may be a higher level of resilience than other track sections. Given the current and potential land instability, a non-engineered track/stairs are not appropriate for this location. The proposed new toilet site could still be utilised with this option.



Figure 10.1 Cathedral Cove lower track landslide damage.

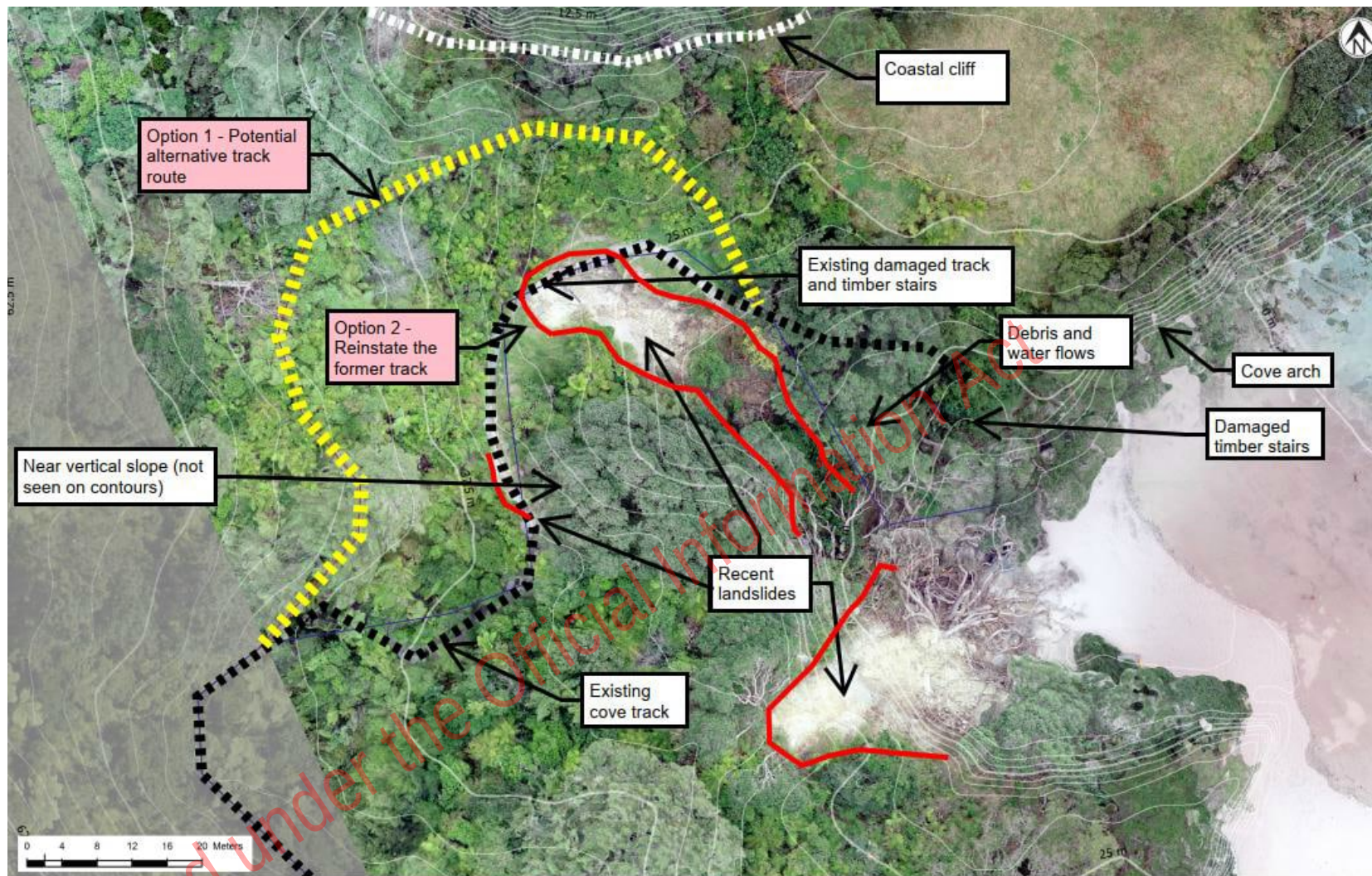


Figure 10.2 Cathedral Cove Lower Track Damage and Mitigation Options (T+T UAV photograph).

Table 10.2: Cathedral Cove Beach Access Management Options

Site Location	Site details/damage	Management and mitigation options	Comments / risks
Cathedral Cove beach access (refer Figure 10.2 and Figure 10.4).	A combination of recent storm surges, landslide debris and scour have contributed to the loss of the timber stairs providing access to Cathedral Cove Beach. The destroyed timber stair section is approximately 4 m high. A challenge for a stair structure is the potential for future storm surges further damaging a new structure.	Option 1 – Reinstate former beach access. Construct new stairs in the location of the former stairs. The stairs alignment would extend down to the beach protruding out away from the coastal cliff above.	We expect that ongoing storm surge, water scour and potential for some landslide debris to interact with the structure potentially causing damage. Resilience will need to be considered and a near permanent stair structure (e.g., 50-year design life) will likely have a significant cost implication with comparison to wooden structure similar to the previous stairs.
		Option 2 – New access via the cliff rock face This option would involve securing a new stair structure to the rock face. Rock anchors would need to be fixed to the cliff face.	This option would likely provide potential resilience to storm surge, washout and landslide debris interactions. This option may encroach into the arch 'view'. Geotechnical and structural considerations would be required. The option would be directly below the cliff face and could be subject to rockfall/landslide hazard.
		Option 3 – New access via a large boulder This option was proposed by DoC and would involve aligning a new timber access way to land further south than the former stairs, secured into a large boulder located on the beach. DoC considered establishing a viewing area/platform along this option so that a view to the Cove Arch could be provided during high tides/storm surge.	This option would be more challenging to provide a resilient structure due to the location being closer to the location of recent beach cliff landslide run-out. Relatively large structures would require structural and geotechnical engineering, and it may be difficult to establish suitable founding materials.

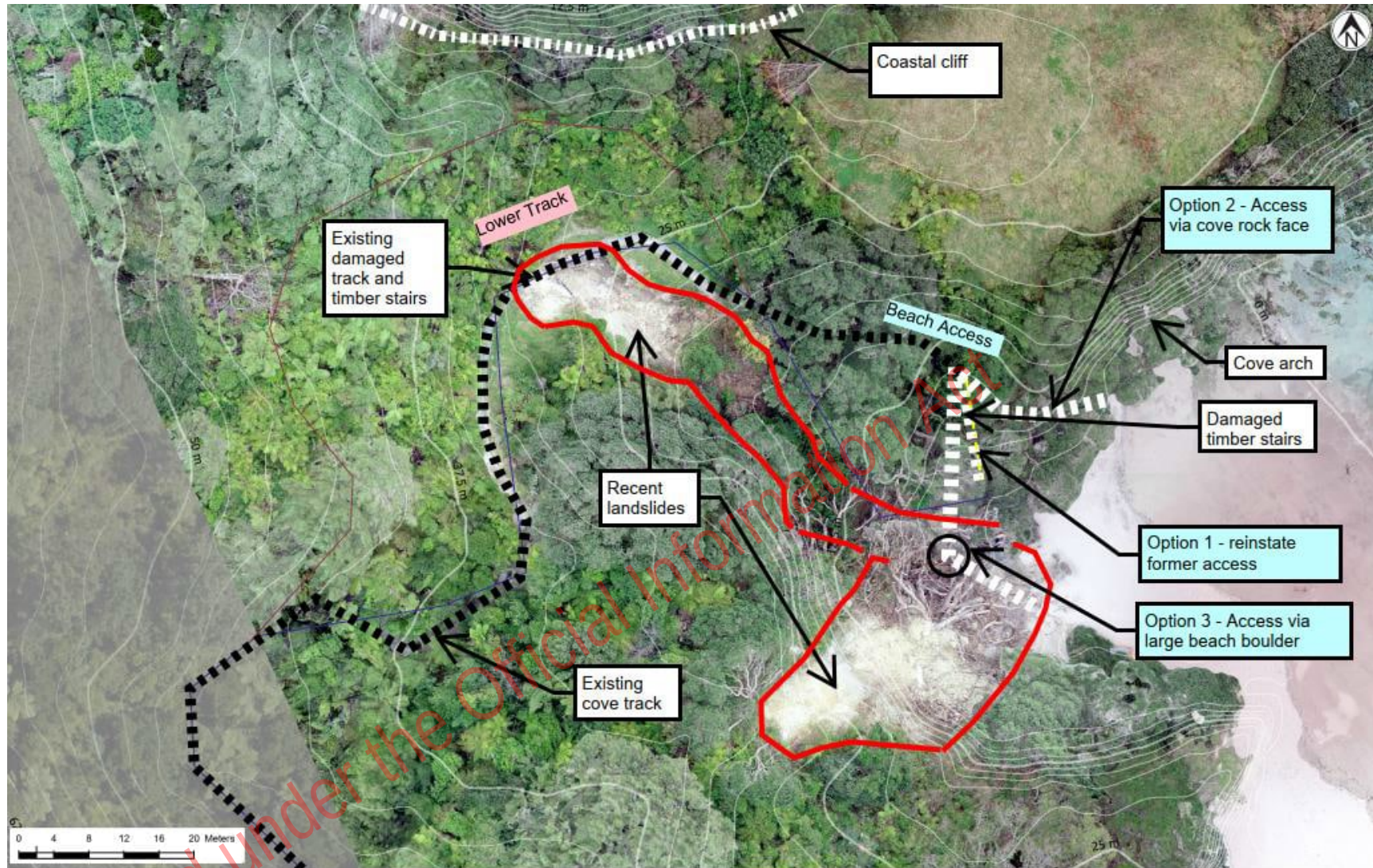


Figure 10.3 Cathedral Cove Beach Access Damage and Mitigation Options (T+T UAV photograph).

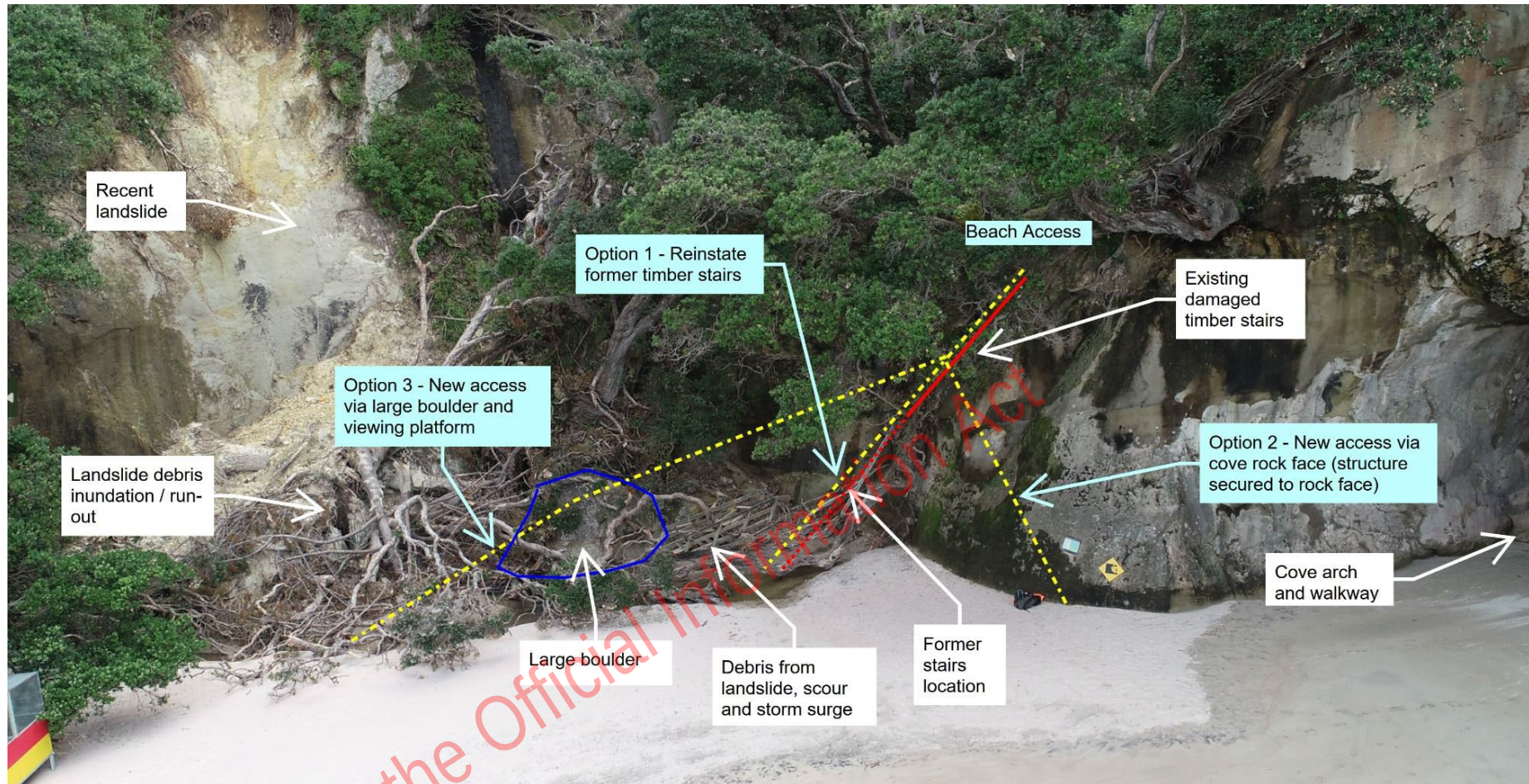


Figure 10.4 Cathedral Cove Beach Access Damage and Mitigation Options (T+T UAV photograph).

Table 10.3: Stingray Bay Beach Access Management Options

Site Location	Site details/damage	Management and mitigation options	Comments/risks
Stingray Bay Beach Access (refer Figure 10.5)	Soil creep has been identified in the lower track and beach access. Recent storm events have exacerbated the impacts of these. Effects include pavement undulations, tension cracks, and minor offsets in structures (stairs and retaining). Functional access remains, and DoC have asked for advice for future mitigations.	Option 1 Monitor and repair as required. Monitor the conditions for future instability. Close the track and repair if/when future creep and or landslides damage the track. As soil creep continues, the track and structure offsets may become significant. If this occurs, local repairs and reinstatement could be carried out on an as required basis.	The current damage is likely not prohibiting track access. It is likely that soil creep will continue, and landslides may occur in these areas. Ongoing monitoring will be required to identify areas that become unstable, and to identify areas requiring repair. This mitigation option is not pro-active management of the onsite hazards, i.e., this will be a reactive mitigation once future instability/damage occurs.
		Option 2 – Stabilisation options Construction of slope stabilisation such as retaining walls or soil nails could help to reduce future instability.	This option will be a relatively high cost. Geotechnical design will be required. The option will provide a high level of resilience for the track.
		Option 3 – Realign track. Realign the track to an area more stable and less likely to be subject to soil creep and slope instability.	Initial mapping of the area did not identify a suitable track realignment. Given the steep coastal hills and cliffs in Stingray Bay there is limited opportunity for realign to significantly improve the track resilience.

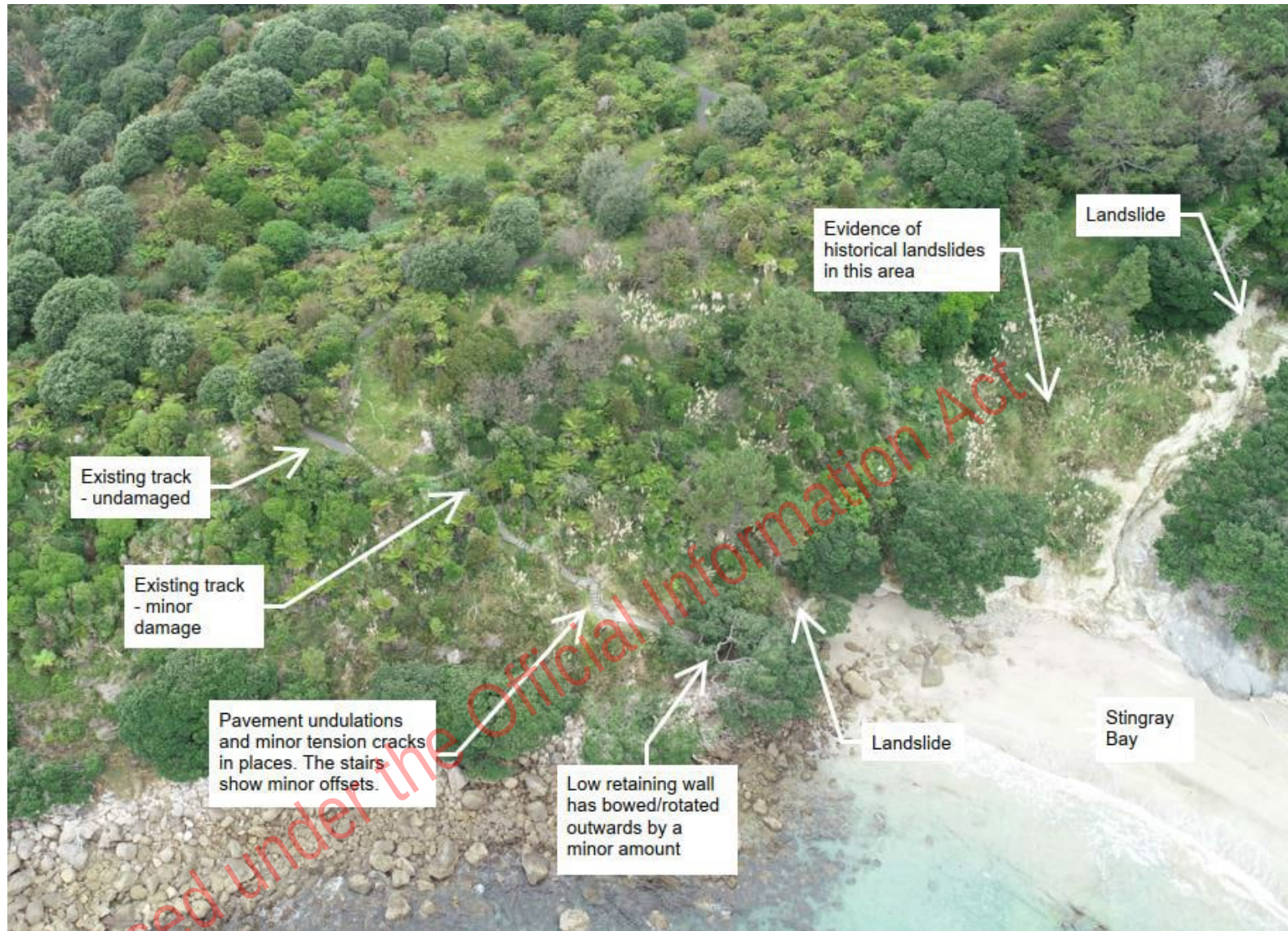


Figure 10.5 Stingray Bay Beach Access Damage (T+T UAV photograph).

Table 10.4: Gemstone Bay Beach Access Management Options

Site Location	Site details/damage	Management and mitigation options	Comments/risks
Gemstone Bay Beach Access (refer Figure 10.6 and Figure 10.7)	The existing timber stairs which lead to the beach have been severely damaged during the February weather events and cannot be used. The cause of the damage is likely from a combination of scour, debris, loose founding materials and storm surge. Options for beach access are required. The track above the stairs shows some tension cracks similar to the Stingray Bay access track. The hill directly above Gemstone Bay appears to comprise colluvium, a mixture of boulders, gravel and fine soils, likely emplaced from very large landslides.	Option 1 – access via alternative route This option involves creating a new route which avoids the current stairs (including the tension cracks) by extending the current track to the south. The track would extend approximately 20 m down the steep coastal hill to the beach. This would entail some minor earthworks to form a suitable track width.	The route would need to work around large existing boulders present on the slope which would make earthworks difficult. This option would not provide resilience to storm surge and beach erosion could create a small cliff prohibiting access. This option would be relatively low cost, provided earthworks can be kept to a minimum. On going track maintenance would be required. There is evidence of past landslides on the hill slope and the realigned track would potentially be affected by future slope instability. Consideration was given to realigning track to the north away from the colluvium/bouldery hill slope, however low coastal cliffs are present, and a large stair structure would be required making the route relatively costly and impractical.
		Option 2 – reinstate former beach access stairs. A new set of stairs could be constructed broadly in the same aligned as the previous stairs. Stabilisation of the slope below the stairs would be required to reduce instability and protect from scour. The previous stairs landed on boulders and an ad hoc concrete structure. This may need to be replaced by an engineered structure.	This option would provide a direct route to the beach and the stair structure if appropriately engineered would be relatively resilient. This option could be relatively high cost. An alternative is to construct a stair access with minimal stabilisation and scour protection, broadly similar to the previous stairs. This option would have reduced resilience to storm events and slope instability. It would likely be damaged after large events and require replacement.

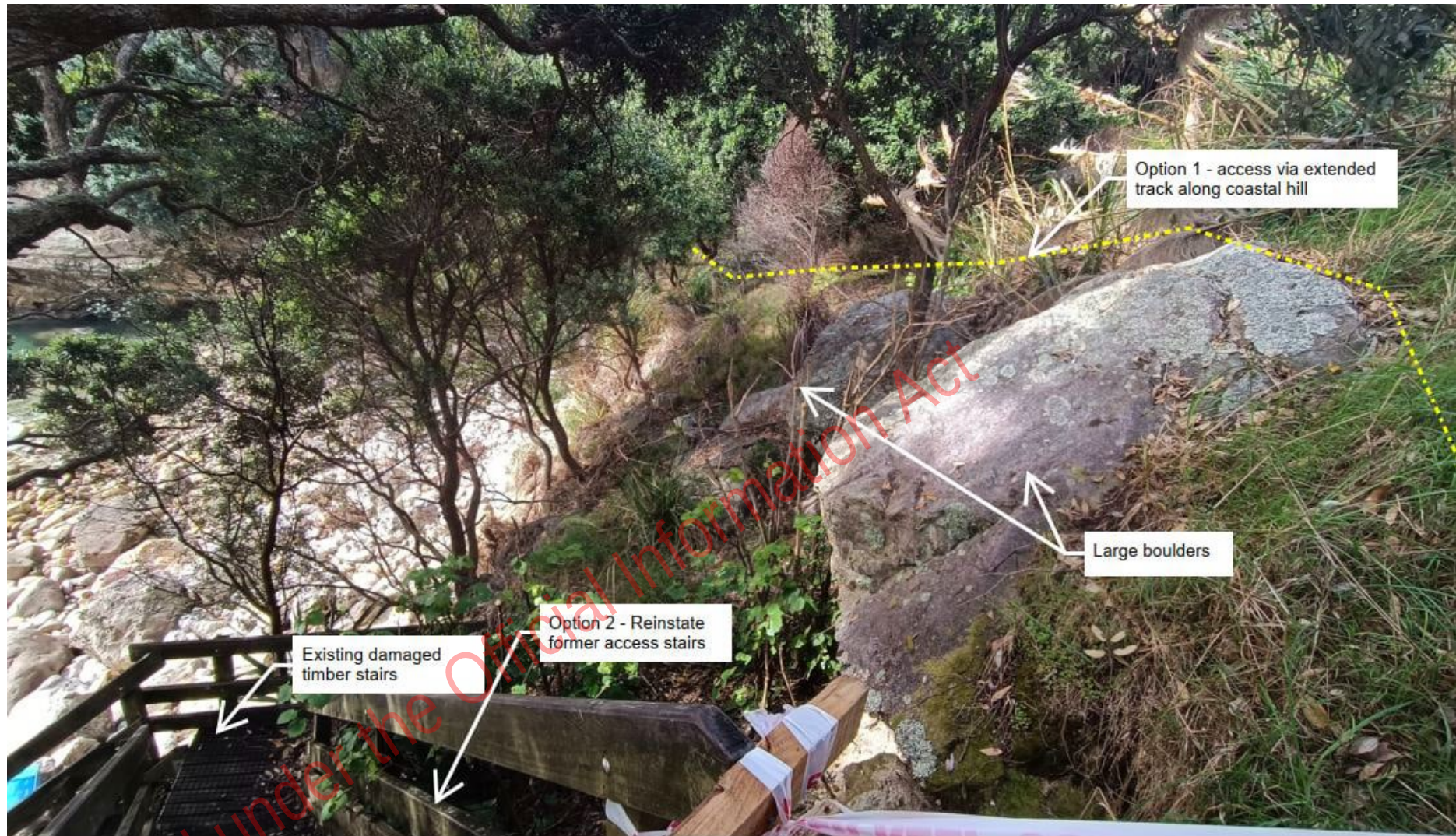


Figure 10.6 Gemstone Bay Beach Access Damage and Mitigation Options (view from top of access stairs).

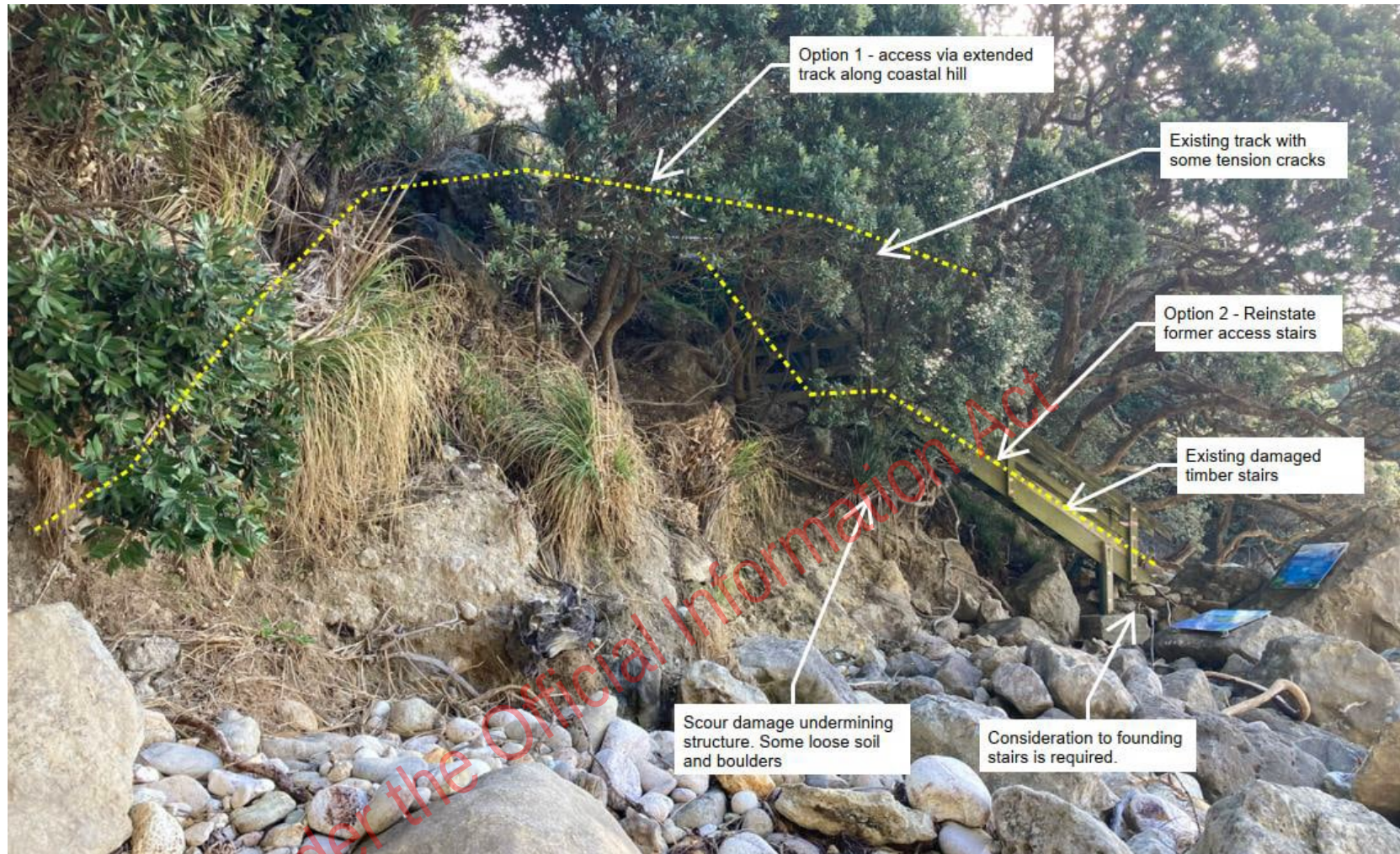


Figure 10.7 Gemstone Bay Beach Access Damage and Mitigation Options (view from beach).

Table 10.5: Hahei Track Management Options

Site Location	Site details/damage	Management and mitigation options	Comments/risks
Hahei Track (refer Figure 10.8, Figure 10.9)	The Hahei Track passes through very steep terrain ground prone to multiple historical and recent landslides. Currently there are several landslides and areas of instability affecting the track. DoC would like to explore options to reduce landslide risks for this portion of the track.	Option 1 – Continue using current track alignment, implement stabilisation where required. To continue use of the current track alignment several locations would need stabilisation or support. This would likely entail engineered solutions such as retaining walls or soil nails. There are other areas along the track which are identified to have historical instability and have a relatively high change of future failure. These areas would need monitoring and future repair if required.	The current alignment crosses a relatively landslide prone area and it will be difficult to mitigate this risk. Engineer stabilisation would be relatively high cost. Geotechnical and structural design would be required. Consideration was also given to realigning the track upslope of the current track alignment and below Grange Road. However, this option would cross similar landslide hazards and not significantly reduce the landslide risk. Stabilisation would still likely be required.
		Option 2 – alternative access via Grange Road and DoC carpark. A potential alternative route option was traversed by T+T and DoC during site visits and is shown in Figure 10.9). The alternative track would connect the existing Hahei Track to Grange Road, a short walk from the existing DoC carpark. The track would pass through a gully with moderate ground slopes and wilding pines.	The track would bypass the steep landslide prone hillslope reducing risk to users. The realigned track does not provide the same views to users. Fallen trees were present within the route of the new track and existing large trees may require removal. Areas of groundwater seepage should be avoided. Consideration is required for traffic safety related issues and confirm whether the current footpath is suitable for the expected visitor numbers.



Figure 10.8: Hahei track realignment option.

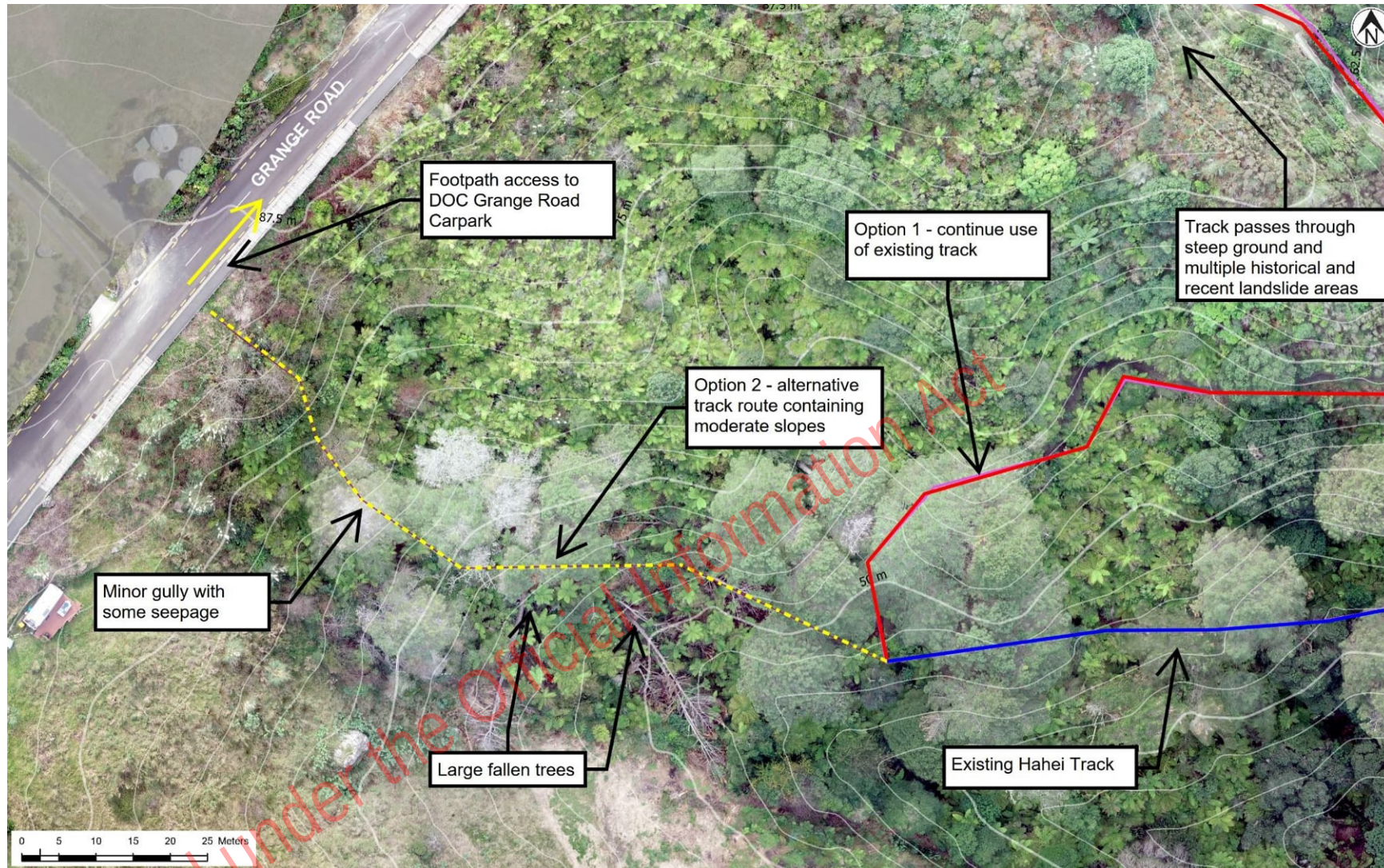


Figure 10.9 Hahei Track Mitigation Options (T+T UAV photography).

11 Conclusions and recommendations

Tonkin & Taylor Ltd has been engaged by the Department of Conservation (DoC) to undertake a landslide risk assessment of the Cathedral Cove Track. The landslide risk assessment includes the track from Hahei Beach to Cathedral Cove Beach, Cathedral Cove Beach, Stingray Bay and Gemstone Bay.

Damage to the track and beach access has made several sections impassable without reinstatement, track realignment, or other mitigations. In addition to the risk assessment, this report also provides potential mitigation options for DoC to consider in these areas.

Conclusions and recommendations are provided below for the two objectives of the report.

Risk Assessment

- 1 The risk assessment metrics indicate DoC should review the site and explore practical risk reduction options. This is based on comparison of the risk assessment metrics with DoC's risk thresholds.
- 2 With this in mind, DoC should consider the estimated risk metrics, their thresholds and determine a mitigation approach in line with their strategy, the cost and risk they are willing to accept.
- 3 Several areas stand out as particularly hazardous from the site observations made on site. These include the following;
- 4 **Beach cliffs at Stingray Bay and parts of Cathedral Cove Bay.** Large rockfalls are present and visitors often spend time at the toe of these cliffs. There are few practical mitigations to be prevent visitors accessing these areas. Signage could be considered but may have limited effect and barriers will likely be washed away from storm surges. Currently many of the existing rockfall areas have debris piles at the cliff toe which may help prevent access.
- 5 **Track to Hahei to Cathedral Cove Carpark.** The existing landslides along this section of track appear relatively small (less than 10 m wide), however the track and potential landslide runout is directly above a very steep section of cliff making these particularly hazardous if occur. Further discussion on realignment of this track is outlined in Section 10.
- 6 Reducing visitor numbers during and directly after rainfall events could be further encouraged across the site by actively closing the track or providing public warning during heavy rainfalls. This would help to reduce the potential for visitors to be impacted by landslides. It should be noted however that it is likely impossible to practically completely close the track off and there are practicality issues. An appropriate process for DoC rangers would need to be determined.
- 7 Practical mitigation measures to reduce risk for DoC workers could include reducing exposure during and after rainfall events, and reducing time spent directly under landslide/rockfall source areas such as the beach cliffs.
- 8 A written log of landslide/rockfall events identified by DoC staff could be considered to help inform future landslide risk assessments. As a minimum this should record date, location, a sketch or photograph and approximate size/volume.
- 9 The risk estimates have been undertaken at a site wide scale, considering individual track sections and relevant hazard metrics where possible. The estimates do not consider that multiple sections of the track are currently damaged. These damaged track sections are more hazardous than the risk estimates presented and these areas should be avoided or mitigated prior to opening the track.

Track mitigation options

- 10 Recent weather events have caused significant damage to a number of the track sections. These include the following.
 - Beach access to Cathedral Cove
 - Beach access to Gemstone Bay
 - Beach access to Stingray Bay
 - Hahei Track (Track Section 01)
 - Cathedral Cove (Track Section 12, 13 and 14).
- 11 A range of conception management and mitigation approaches have been presented for the sections outlined above.
- 12 We recommend DoC appropriately mitigates the hazards for these track sections and beach access prior to opening to the public. DoC should consider the mitigation approach in line with their strategy, the cost and risk they are willing to accept.

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12 Applicability

This report has been prepared for the exclusive use of our client Department of Conservation, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:

Authorised for Tonkin & Taylor Ltd by:

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Appendix A Previous report summary

Appendix A Table 1: Previous report summary

Report Reference	Key summary	Land instability identified
Tonkin & Taylor Ltd, November 2009, <i>Geotechnical Assessment of Cathedral Arch, Hahei</i> . Reference 26920, Prepared for Department of Conservation.	- A geotechnical inspection and assessment of the Cathedral Cove Arch. - Undertaken in response to an ignimbrite rockfall from the Arch, approximately 3 m³ is size. - Recommendation for a safety corridor through the cove and ongoing monitoring/inspection.	26 October 2009: ignimbrite rockfall. Located near southern portal of Cathedral Cove Arch, approximately 3 m³ is volume. - Additional evidence of rockfall from western face of the Arch within approximately 12 months of the inspection. The feature was approximately 6 m long.
Tonkin & Taylor Ltd, May 2010, <i>Cathedral Cove Engineering Options</i> . Reference 26920, Prepared for Department of Conservation.	- Rockfall hazard was assessed using the Rockfall Hazard Rating System⁹ for the Cathedral Cove Arch. - The conclusion of the assessment was that the existing annual probability of fatality from a person being hit by rockfall within the cave is approximately 2×10^{-3} (Note that the methodology used is different to that undertaken in this 2023 report and the risk values may not be comparable). - Hard engineering mitigation options were presented along with an assessment of monitoring and warning systems options.	
Tonkin & Taylor Ltd, October 2010, <i>Cathedral Cove Risk Assessment</i> . Reference 26920, Prepared for Department of Conservation.	- T+T was engaged to undertake further risk assessments for Cathedral Cove Arch. - DoC also requested an assessment of whether an acceptably low risk maybe present for a roped corridor route through the cove. - The risk assessment estimated the annual risk of a death due to rockfall from the roof of the Cathedral Cove Arch is approximately 1 in 25,000 (4×10^{-5}). Note that the methodology used is different to that undertaken in this 2023 report and the risk values may not be comparable.	

⁹ Pierson, Davis and Van Vickie. 1990. Rockfall Hazard Rating System Implementation Manual. Federal Highway Administration Report FHWA-OR-EG-90-01. US Dept of Transportation.

Report Reference	Key summary	Land instability identified
Tonkin & Taylor Ltd, July 2011, <i>Cathedral Cove July 2011 Status Review</i> . Reference 26920, Prepared for Department of Conservation.	- Two rockfalls occurred within the cove prompting further geotechnical inspection and an update to the hazards at Cathedral Cove. - Mitigation options were discussed as part of the report. - Scaling of loose rocks within the cove was recommended and undertaken by a contractor.	- February 2011: Ignimbrite rockfall. Located on the roof area above the southern entrance to the cove and occurred between 4 to 8 February 2011. Approximately 2 m³ in volume. - May 2011: ignimbrite rockfall. Approximately 5 m³ fell from the sidewall of the western face. This area was identified in the 2009 inspection.
Tonkin & Taylor Ltd, December 2011, <i>Cathedral Cove Post-scaling and status Report</i> . Reference 26920, Prepared for Department of Conservation.	- Report summarising the scaling works undertaken to attempt to remove unstable loose rocks within the cove. - In the order of 15 m³ of loose rock was scaled from the cove. - Scaling involved ladders and rope access. The cove apex was not able to be accessed safely to be scaled. - Consideration to seepage, managing subsoil drainage, monitoring and inspection was recommended.	
Tonkin & Taylor Ltd, April 2012 <i>Cathedral Cove Geotechnical Inspection 24 March 2012</i> . Reference 26920.001, Prepared for Department of Conservation.	- Inspection following a heavy rainfall event (111 mm within 48 hr period). - No rockfall was noted.	
Tonkin & Taylor Ltd, August 2012 <i>Cathedral Cove Geotechnical Inspection 26 July 2012</i> . Reference 26920.001, Prepared for Department of Conservation.	- Inspection following a heavy rainfall event (Over 100 mm within 48hr period). - A rockfall was identified near the southern entrance to the cave. This was approximately 1 m³ in volume. - It was not clear at the inspection if this occurred at the time of the heavy rainfall event, but it had occurred since the previous inspection in March 2012.	Between March and July 2012: Ignimbrite rockfall on the cliff near the southern entrance to the cave, approximately 1 m³ in volume.
Tonkin & Taylor Ltd, December 2013, <i>Cathedral Cove Carpark Extension Geotechnical Report</i> . Reference 26920.002/2, Prepared for Department of Conservation.	- Site investigations and slope stability assessment were undertaken to support DoC's proposal for a new carpark approximately 100 m southwest of the existing carpark. - The assessment identified evidence of a large historical landslide at the location of the proposed carpark, and potential for rockfall from the	Large historical landslide. Site investigations suggest the landslide shear surface at the contact between non-welded and welded ignimbrite circa 10 m below ground level.

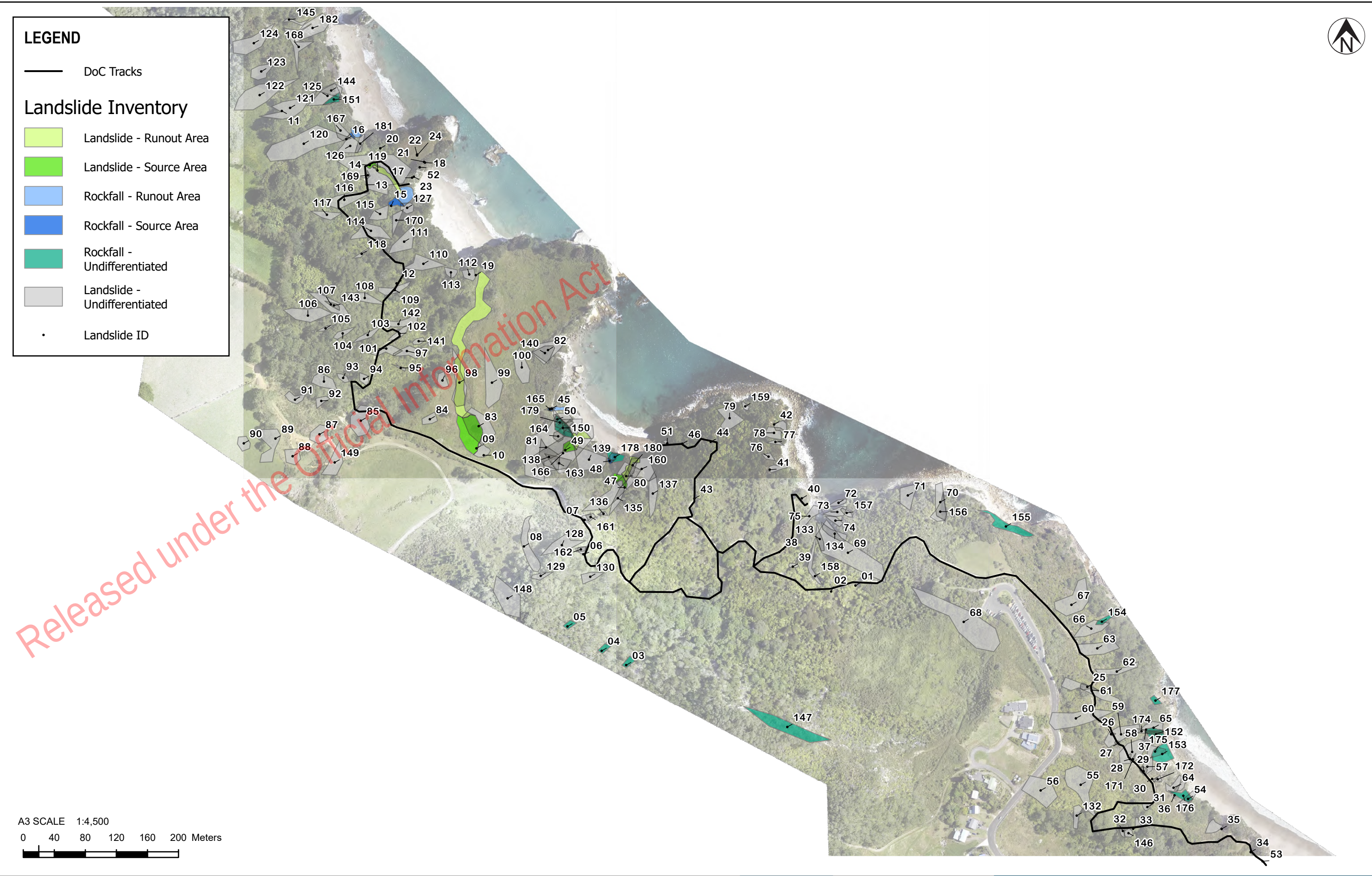
Report Reference	Key summary	Land instability identified
	ignimbrite escarpment above the proposed carpark. Inclinometers installed within the historical landslide did not identify ongoing movement within the monitoring period.	
Tonkin & Taylor Ltd, December 2018, <i>Cathedral Cove Inspection Report</i>. Reference 1007838.0000, Prepared for Department of Conservation.	- Site inspection and reporting was undertaken following a rockfall event in July 2018. - The rockfall occurred in the apex of the arch near the southern entrance. - Scaling of this cove was subsequently undertaken by a contractor, although some areas were unable to be accessed.	July 2018: Ignimbrite rockfall within cove arch. Less than 1 m³ in volume.
Tonkin & Taylor Ltd, August 2019, <i>Cathedral Cove Monitoring: Cathedral Cove Arch and Mare's Leg headland</i>. Reference 1007838.1000, Prepared for Department of Conservation.	- Site inspection and reporting of Cathedral Cove Arch and mare's Leg Headland as part of a routine monitoring programme. - No new rockfalls were identified. - A number of locations were identified which have potential for rockfall due to unfavourably oriented joints, or joints with large aperture. - Scaling was undertaken by a contractor and some of potentially loose blocks were able to be removed.	
Tonkin & Taylor Ltd, December 2020, <i>Cathedral Cove Monitoring December 2020: Cathedral Cove Arch and Mare's Leg headland</i>. Reference 1007838.2000, Prepared for Department of Conservation.	- Site inspection and reporting of Cathedral Cove Arch and mare's Leg Headland as part of a routine monitoring programme. - No new rockfall was identified.	
Tonkin & Taylor Ltd, June 2021, <i>March 2021 Rockfall scaling supervision and rockfall inspection</i>. Reference 1007838.2000, Prepared for Department of Conservation.	- Inspection following scaling work of the cove arch. A minimal amount of rock was able to be scaled – approximately 0.1 m³. - In addition, two rockfalls occurred prompting further inspection and stability appraisal of these areas. These included the beach cliffs on the southern and northern ends the beach.	Early March 2021: Rockfall occurred on the beach cliff near the waterfall at the southern end of cathedral cove beach. Approximately 0.3 m³ of debris was observed. Early May 2021: Rockfall occurred on the north facing beach cliff on the northern end of Cathedral Cove Beach. Approximately 1 m³. Historical rockfall debris identified on the northern end of Cathedral Cove Beach.

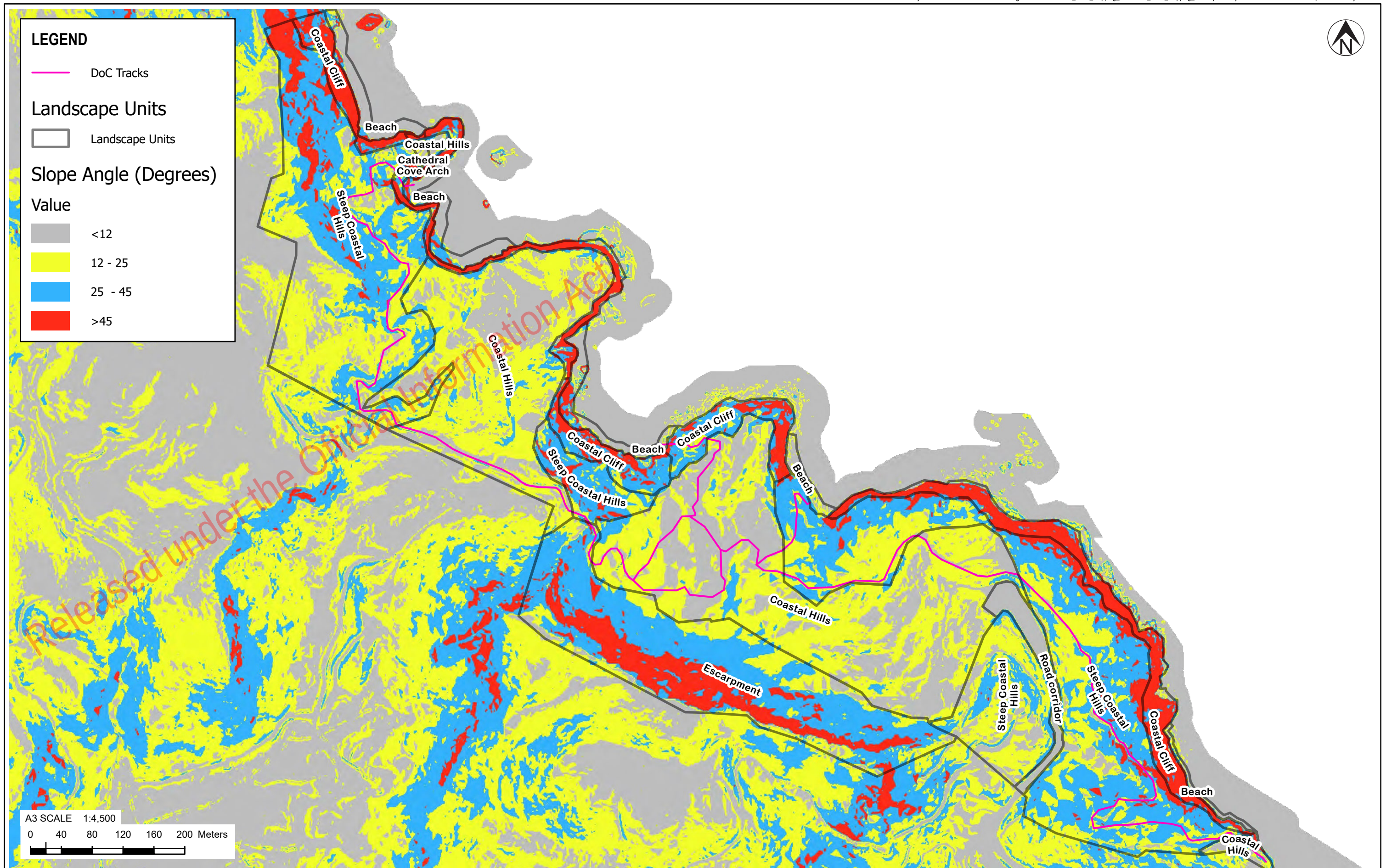
Report Reference	Key summary	Land instability identified
Tonkin & Taylor Ltd, December 2021, <i>December 2021 Cathedral Cove Monitoring.</i> Reference 1007838.2000, Prepared for Department of Conservation.	• Site inspection and reporting of Cathedral Cove Arch and mare's Leg Headland as part of a routine monitoring programme. • No new rockfall was identified.	
Tonkin & Taylor Ltd, August 2022, <i>June 2022 Cathedral Cove Monitoring.</i> Reference 1007838.2000, Prepared for Department of Conservation.	• Site inspection and reporting of Cathedral Cove Arch and mare's Leg Headland as part of a routine monitoring programme. • No new rockfall was identified.	

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Appendix B Figures

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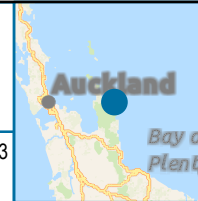




NOTES:
Basemap NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No. 1007038.3000

DESIGNED	TIBO	JUN.23
DRAWN	TIBO	JUN.23
CHECKED	HAMC	JUN.23

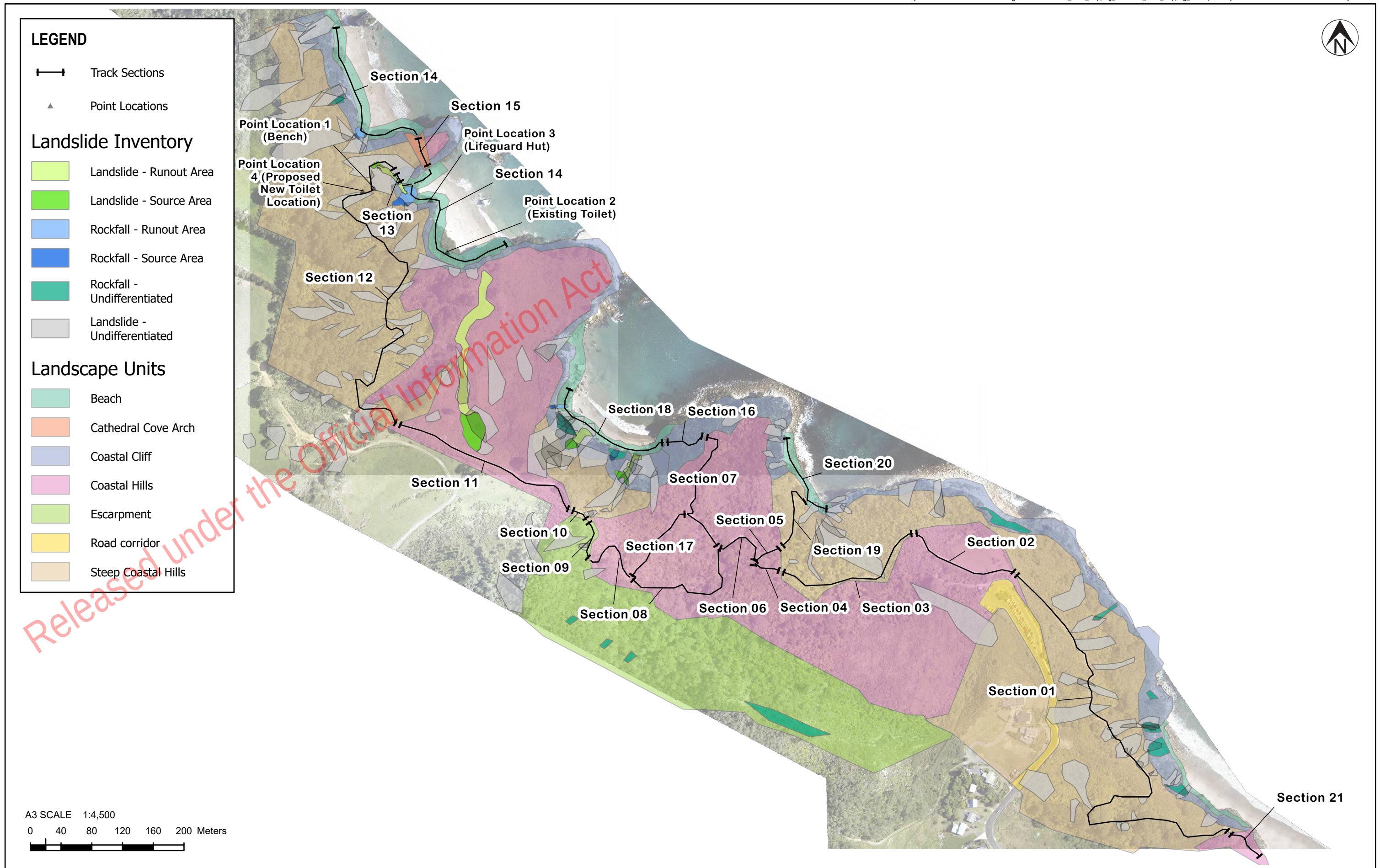
20/07/2023

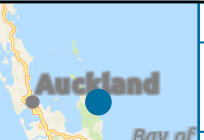
APPROVED DATE

CLIENT DEPARTMENT OF CONSERVATION
PROJECT CATHEDRAL COVE LANDSLIDE RISK ASSESSMENT

TITLE TRACK SETTING
GROUND SLOPE ANGLE AND LANDSCAPE UNITS

SCALE (A3) 1:4,500 FIG No. FIGURE B3 REV 0



 Tonkin+Taylor Exceptional thinking together www.tonkintaylor.co.nz					NOTES: Basemap NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.				PROJECT No. 1007038.3000			CLIENT DEPARTMENT OF CONSERVATION			
			DESIGNED	TIBO	JUN.23	PROJECT CATHEDRAL COVE LANDSLIDE RISK ASSESSMENT									
			DRAWN	TIBO	JUN.23										
			CHECKED	HAMC	JUN.23				TITLE TRACK SETTING						
0 First version			TIBO	HAMC	JUNE 23	 20/07/2023			LANDSLIDES AND INVENTORY REFERENCES						
REV	DESCRIPTION		GIS	CHK	DATE	LOCATION PLAN		APPROVED	DATE	SCALE (A3)	1:4,500	FIG No.	FIGURE A2	REV	0

Appendix C DoC Activity Counter

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DOC Activity Counter Network: Visitor Asset Utilisation Report



Technical Report

For equipment number 100102439
at Cathedral Cove Track
September 23, 2022

This uncalibrated counter data set ranges between 23/05/2016 and 10/01/2022 with a total count of 2188221 in 49395 hourly observations. This document is set up to view the number of counts at an hourly scale, then to view the patterns there are over time (year, month, and day). At the daily level we fit a model that shows the relationship of the counts with time, month, and the Christmas holidays which seem to be the peak time at many sites. These reports are automated, so this trend needs to be evaluated by how well the model in red on Figure 1b matches with the the data.

We estimate that there was a decrease in the number of visitors over time. The busiest 10 days are shown in Table 1 and the longest 10 occasions without any visitors are shown in Table 2. This should give a rough idea of the strength and validity of the data.

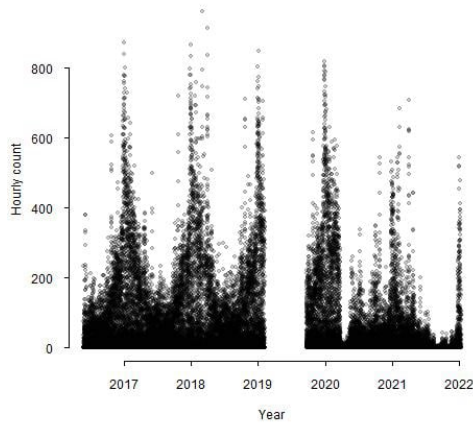
Date	Count
2019-01-02	6407
2017-12-30	6315
2019-12-29	6221
2020-01-02	6203
2016-12-30	6142
2017-01-02	5977
2018-12-30	5905
2017-12-25	5903
2017-01-05	5847
2017-12-31	5774

Table 1: Busiest 10 days in the dataset

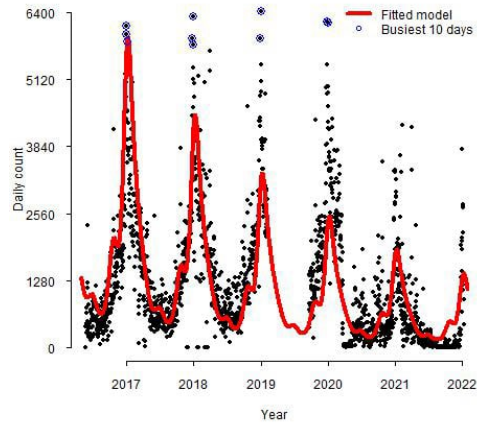
Date	Days no visits
2018-03-03	6.38
2017-11-28	6.29
2018-01-20	5.29
2018-03-17	5.29
2016-05-23	2.00
2021-08-30	2.00
2021-09-15	1.79
2021-09-06	1.75
2021-11-02	1.50
2017-11-25	1.42

Table 2: The 10 Longest times without any visitors for a period.

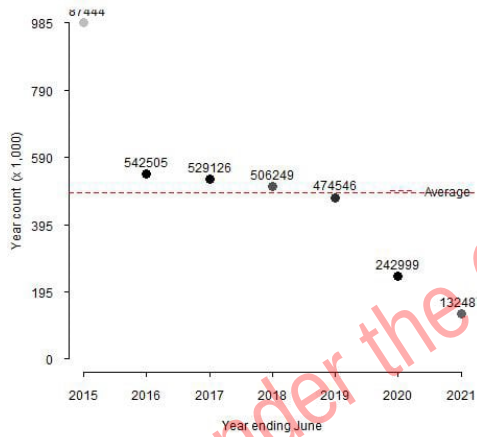
Page created by: Design & Evaluation Team (D&E), Biodiversity Group.
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Jeff Dalley at jdalley@doc.govt.nz



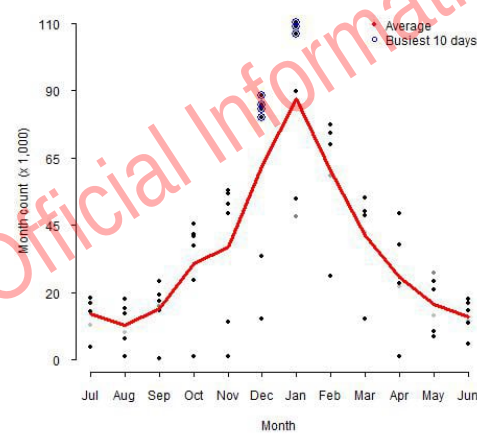
(a) Hourly raw data



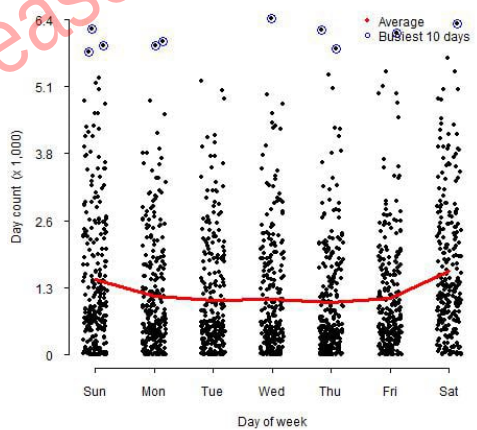
(b) Trends at the daily level



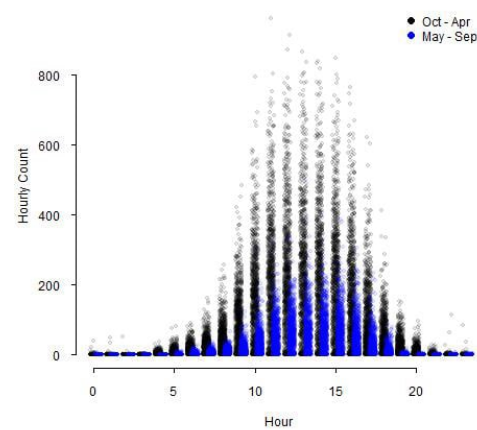
(c) Annual pattern



(d) Seasonal patterns



(e) Day of week patterns



(f) Time of day patterns

Figure 1: Basic trends in visitor counter data shown by (a) the raw hourly data, (b) model of the trend in count by time, season, and, Christmas holiday, (c) sum of counts annually with incomplete years in grey, (d) monthly patterns, (e) weekday patterns, and (f) hourly patterns. If a point was incomplete we filled that month/year with what was predicted to occur and faded the point as a function of the amount of uncertainty.

DOC Activity Counter Network: Visitor Asset Utilisation Report



Technical Report

For equipment number 100093375
at Hahei Beach Walk
September 22, 2022

This uncalibrated counter data set ranges between 31/07/2012 and 17/06/2022 with a total count of 550052 in 86593 hourly observations. This document is set up to view the number of counts at an hourly scale, then to view the patterns there are over time (year, month, and day). At the daily level we fit a model that shows the relationship of the counts with time, month, and the Christmas holidays which seem to be the peak time at many sites. These reports are automated, so this trend needs to be evaluated by how well the model in red on Figure 1b matches with the the data.

We estimate that there was an increase in the number of visitors over time. The busiest 10 days are shown in Table 1 and the longest 10 occasions without any visitors are shown in Table 2. This should give a rough idea of the strength and validity of the data.

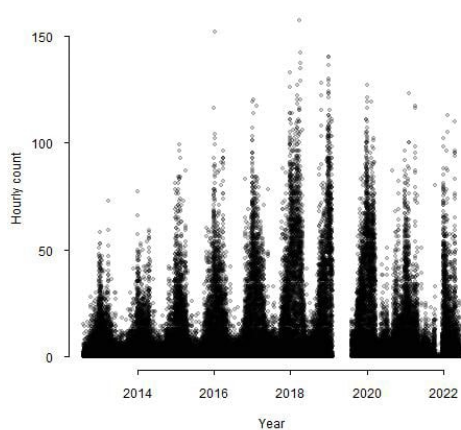
Date	Count
2019-01-02	1258
2019-01-04	1218
2018-12-30	1186
2019-01-05	1135
2018-04-01	1129
2017-12-30	1126
2018-03-31	1069
2018-12-28	1038
2018-12-31	1036
2018-12-29	1018

Table 1: Busiest 10 days in the dataset

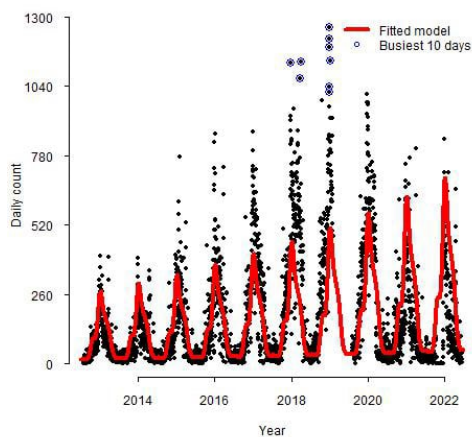
Date	Days no visits
2021-11-15	16.00
2021-10-22	15.12
2021-12-05	10.08
2021-10-12	7.92
2021-11-06	7.92
2021-12-02	3.08
2021-12-17	3.00
2016-08-09	1.92
2018-07-04	1.92
2018-07-10	1.88

Table 2: The 10 Longest times without any visitors for a period.

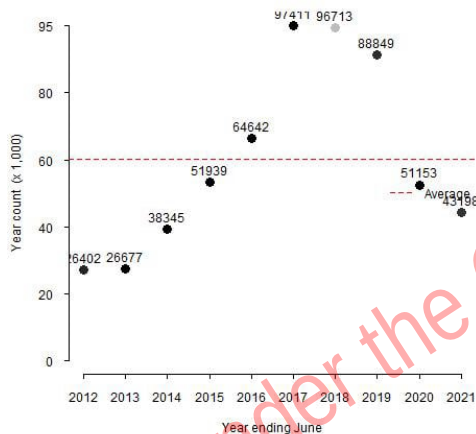
Page created by: Design & Evaluation Team (D&E), Biodiversity Group.
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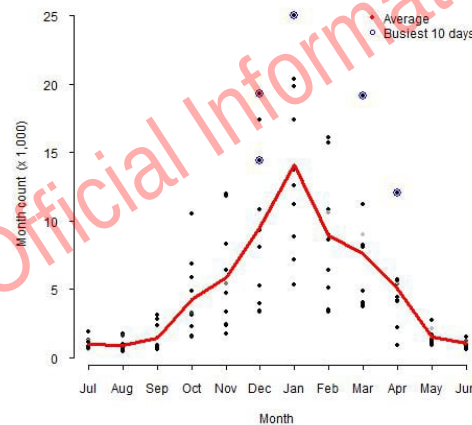
(a) Hourly raw data



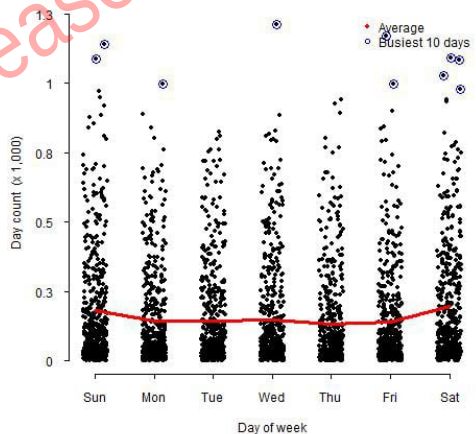
(b) Trends at the daily level



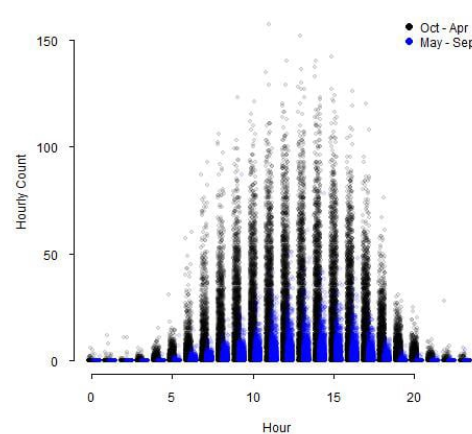
(c) Annual pattern



(d) Seasonal patterns



(e) Day of week patterns



(f) Time of day patterns

Figure 1: Basic trends in visitor counter data shown by (a) the raw hourly data, (b) model of the trend in count by time, season, and, Christmas holiday, (c) sum of counts annually with incomplete years in grey, (d) monthly patterns, (e) weekday patterns, and (f) hourly patterns. If a point was incomplete we filled that month/year with what was predicted to occur and faded the point as a function of the amount of uncertainty.

Appendix D Site photographs

Released under the Official Information Act



Figure C1 Damage to Cathedral Cove Access



Figure C2 Historical debris / talus at the toe of the coastal cliff behind the existing toilet at Cathedral Cove Beach



Figure C3 Recent and historical debris / talus at the toe of the coastal cliff on Cathedral Cove Beach



Figure C4 Aerial view of the damage to Cathedral Cove Track



Figure C5 Aerial view of multiple landslides and rockfall at Cathedral Cove Track



Figure C6 Aerial view of debris flow headscarp.
Tension cracks are visible in grass above headscarp
(directly below track).



Figure C7 Aerial view of landslides at Stingray Bay



Figure C8 View of landslides and rockfall debris at Stingray Bay cliff toe



Figure C9 View of landslides and rockfall debris at
Stingray Bay cliff toe



Figure C10 Rock and landslide debris at north end of Gemstone Bay



Figure C11 Gemstone Bay stair access



Figure C12 Gemstone Bay stair access damage and scour of loose boulders in slope.



Figure C13 Aerial view of Hahei Track close to coastal cliff and recent landslides.



Figure C14 Landslide scarp close to Hahei Track



Figure C14 Tension cracks visible on downslope side of Hahei Track



Figure C15 Landslide behind Hahei Track

Appendix E Landslide Inventory

Released under the Official Information Act

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
1	Creep	Creep	7	2 m visible	-	-	Not Observed	Not Visible	-	Jan Feb 2023	28/01/2023	Site observation		#N/A			1				
2	Creep	Creep	5	2 m visible	-	-	Weathered rhyolite	Not Visible	-	Jan Feb 2023	28/01/2023	Site observation		#N/A			1				
3	Rockfall	Rockfall	7	20 m visible	7 m visible	7	rhyolite	30	30	Jan Feb 2023	28/01/2023	Site observation		115.2	1						
4	Rockfall	Rockfall	5	20	5	5	rhyolite	25	30	Historical		Site observation		103.2	1						
5	Rockfall	Rockfall	10	-	10	10	rhyolite	50-100	100	Jan Feb 2023	28/01/2023	Site observation		97.1	1						
6	Landslide	Translational Earth	5	9	5	5.5	Clayey silt, completely weathered rhyolite.	25	25	Jan Feb 2023	28/01/2023	Site observation		84.04129	1						
7	Landslide	Translational	7	3	-		Track fill and completely weathered rhyolite	Unable to measure	-	Jan Feb 2023	28/01/2023	Site observation		69.90967			1				
8	Landslide	Debris Flow	10	50	30	Unable to measure	Completely weathered rhyolite and ash	100	100	Jan Feb 2023	28/01/2023	Site observation		698.1288	1						
9	Landslide	Tension crack	18	11	2	3	Completely weathered rhyolite	600	600	New / Future	28/01/2023	Site observation		1144.169		1		1			
10	Landslide	Earthflow	40	60 m evacuated, 230 m including runoff	15 m Evacuated area, 50 m overall	3	Completely weathered rhyolite	Unable to measure	-	Jan Feb 2023	28/01/2023	Site observation		271.0586				1			
11	Rockfall	Rockfall	5	-	-	4	Highly weathered to Moderately weathered rhyolite	2.5	2.5	Jan Feb 2023	28/01/2023	Site observation		#N/A			1				
12	Creep	Creep / tension crack	7	1	-	-	Residual soils	-	-	Historical		Site observation		#N/A			1				
13	Landslide	Translational Earth	9	3	2	1.5	Residual soils	7	7	Jan Feb 2023	28/01/2023	Site observation		10.59823			1				
14	Landslide	Debris Flow	13	11 m evac. Total 44 m	19	5	Colluvium (1-2) residual soil	850	850	Jan Feb 2023	28/01/2023	Site observation		80.95499		1	1			1	
15	Rockfall	Rockfall	8	Evac. 10 m / Total 28 m	27	13	Overburden / Ignimbrite	1000	1000	Jan Feb 2023	28/01/2023	Site observation		134.5218		1	1			1	
16	Rockfall	Rockfall	20	Total 25 m, Evac 2-4 m	36	85	Welded Ignimbrite	250	250	Jan Feb 2023	28/01/2023	Site observation		25.74909		1	1			1	
17	Landslide	Overburden Translational	5	1	3	0.5	Soil / ash	1	1	Jan Feb 2023	28/01/2023	Site observation		#N/A		1				1	
18	Rockfall	Rockfall	5	1.5	-	-	Ignimbrite	1	1	Jul-18	1/07/2018	Site observation		#N/A							1
19	Rockfall	Rockfall	0.3	1	-	-	Ignimbrite	0.3	0.3	Jan/Feb 2021	1/02/2021	Site observation		#N/A		1				1	
20	Rockfall	Rockfall	1	1	-	-	Ignimbrite	<1	1	Apr-21	1/04/2021	Site observation		#N/A		1				1	
21	Rockfall	Rockfall	1.4	-	5	-	Ignimbrite	3	3	26/10/2009	26/10/2009	Site observation	T+T Ref 26920 Nov 2009	#N/A							1

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
22	Rockfall	Rockfall	2	-	6	-	Ignimbrite	Not stated in report	3	2008-2009	1/01/2009	Inferred from site observations	T+T Ref 26920 Nov 2009	#N/A							1
23	Rockfall	Rockfall	-	-	-	-	Ignimbrite	2	2	4 to 8 February 2011	4/02/2011	Site observation	T+T Ref 26920 July 2011	#N/A		1				1	1
24	Rockfall	Rockfall	7.5	-	-	-	Ignimbrite	5	5	5 to 19 May 2011	5/05/2011	Site observation	T+T Ref 26920 July 2011	#N/A							1
25	Landslide	Translational	8	20	5	2	Residual soil (rhyolite)	400	400	Historical		Site observation		105.0434			1				
26	Landslide	Translational	4	3	4	1	Residual soil (rhyolite)	6	6	Historical		Site observation		15.17617			1				
27	Landslide	Translational	4	5	5	1	Residual soil (rhyolite)	25	25	Historical		Site observation		23.28973			1				
28	Landslide	Translational	4	6 m visible	5	1.5	Residual soils	25	25	Jan Feb 2023	28/01/2023	Site observation		16.94284			1				
29	Landslide	Translational	10	7 m visible	10	0.5	Residual to extremely weathered rock	50	50	Historical		Site observation		65.60937			1				
30	Landslide	Translational	3.5	5	6	0.5	Residual to extremely weathered rock	10	10	Jan Feb 2023	28/01/2023	Site observation		14.18615			1				
31	Landslide	Translational	10	10	10	2	Residual to extremely weathered rock	100	100	Historical		Site observation		79.70154			1				
32	Landslide	Translational	5	10	5	1	Residual soil	50	50	Historical		Site observation		51.98268			1				
33	Landslide	Translational	6	10	5	1	Residual soil	50	50	Historical		Site observation		57.52497			1				
34	Landslide	Rotational slump	4	3	2	0.5	Residual soil	6	6	Jan Feb 2023	28/01/2023	Site observation		13.26533				1			
35	Landslide	Translational	15	23	18	2	Residual soil or Ignimbrite and rhyolite rock	350 to 750	750	Historical		Site observation		230.4444		1	1				
36	Landslide	Translational	7	16	5	0.5	Residual soil or Ignimbrite and rhyolite rock	50	50	Jan Feb 2023	28/01/2023	Site observation		97.47474		1					
37	Rockfall	Rockfall	8	20	10	1	Rock / rhyolite	80	80	Jan Feb 2023	28/01/2023	Site observation		167.5433		1					
38	Creep	Tension crack	0.02	2	-		Residual soil with boulders	-	-	Jan Feb 2023	28/01/2023	Site observation		#N/A				1			
39	Landslide	Translational	6	11	9	3	Residual soil with boulders	150	150	Historical		Site observation	No debris visible	57.63084			1				
40	Creep	Tension crack	0.02	3	-		Residual soil with boulders	-	-	Jan Feb 2023	28/01/2023	Site observation		#N/A			1				
41	Landslide	Translational debris slide to rockfall	7	10	10	5	Completely weathered Rhyolite with small boulders and cobbles	400	400	Jan Feb 2023	28/01/2023	Site observation		153.7098		1					
42	Landslide	Translational debris slide to rockfall	6	6	12	7	Completely weathered Rhyolite with small boulders and cobbles	250	250	Jan Feb 2023	28/01/2023	Site observation		181.3967		1					
43	Creep	Tension cracks	0.02	2	-		Residual soil / colluvium	-	-	Jan Feb 2023	28/01/2023	Site observation	Two cracks present	#N/A				1			

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
44	Creep	Tension cracks	0.02	3	-		Residual soil / colluvium	-	-	Jan Feb 2023	28/01/2023	Site observation		#N/A				1			
45	Landslide	Translational / slump	7	5	10	4	Rhyolite	150	150	Jan Feb 2023	28/01/2023	Site observation		26.74996		1				1	
46	Creep	Creep and cracking along stairs		25	-		Residual soil / Rhyolite	-	-	Jan Feb 2023	28/01/2023	Site observation		#N/A		1					
47	Landslide	Translational	15	17 m visible	18 m visible	2	Residual soil / Rhyolite	-	-	Historical and recent		Site observation		155.2725		1				1	
48	Rockfall	Rockfall	7	11	25	6	Rhyolite	500	500	Jan Feb 2023	28/01/2023	Site observation		36.61574		1				1	
49	Landslide	Multiple landslides		-	-		Colluvium / residual soil	-	-	Historical and recent		Site observation	Multi failures - very difficult to measure or determine volume / measurements	162.5709		1				1	
50	Landslide	Rotational landslide	30	15	13	4	Talus / colluvium	500	500	Jan Feb 2023	28/01/2023	Site observation		251.3672		1				1	
51	Landslide	Translational landslide	5	5	5	1	Residual soil / colluvium	25	25	Jan Feb 2023	28/01/2023	Site observation		21.17473		1				1	
52	Rockfall	Rockfall		-	-	-	Ignimbrite	1	1	March to July 2012	1/05/2012	Site observation		#N/A							1
53	Creep	Tension crack		2	-	-	Residual soil	-	-	Jan Feb 2023	28/01/2023	Site observation		#N/A				1			
54	Landslide	Landslide	16	11	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	168.3922		1	1			1	
55	Landslide	Landslide	34	60	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, well vegetated	1236.109			1				
56	Landslide	Landslide	30	40	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, well vegetated	1099.907			1		1		
57	Landslide	Landslide	14	25	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	233.5795		1	1				
58	Landslide	Landslide	25	43	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	731.7297			1				
59	Landslide	Landslide	17	49	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	701.4306		1	1				
60	Landslide	Landslide	18	80	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	1235.507			1		1		
61	Landslide	Landslide	10	77	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	709.0507			1				
62	Landslide	Landslide	8	53	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	355.7263			1				
63	Landslide	Landslide	15	50	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	707.2111			1				
64	Landslide	Landslide	10	26	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	226.5941		1	1				
65	Landslide	Landslide	13	25	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	320.2828		1	1				
66	Landslide	Landslide	16	45	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	532.4238			1				

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
67	Landslide	Landslide	25	55	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	1127.847		1	1				
68	Landslide	Landslide	33	130	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	2906.766			1	1			
69	Landslide	Landslide	26	100	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	2528.427			1				
70	Landslide	Landslide	11	43	Unknown	Unknown	Unknown	Unknown		1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe. Smaller movements in 1971, refer H80 and H81.	510.6077		1	1				
71	Landslide	Landslide	18	30	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	487.2801		1	1				
72	Landslide	Landslide	7	25	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	121.6727		1					
73	Landslide	Landslide	12	30	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	223.2416		1					
74	Landslide	Landslide	8	23	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	133.932		1	1				
75	Landslide	Landslide	7	37	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	293.2911			1				
76	Landslide	Landslide	9	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	89.47145		1		1			
77	Landslide	Landslide	6	22	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	73.01027		1					
78	Landslide	Landslide	15	20	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	297.3675		1		1			
79	Landslide	Landslide	19	29	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	546.3643		1		1			
80	Landslide	Landslide	23	110	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, lots of fresh areas	1455.867		1				1	
81	Landslide	Landslide	36	82	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, lots of fresh areas	2764.304		1	1	1		1	
82	Landslide	Landslide	40	46	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	733.0413		1		1		1	
83	Landslide	Landslide	31	45	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	1177.511				1			
84	Landslide	Landslide	11	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	198.2837				1			
85	Landslide	Landslide	22	41	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1945	768.068			1	1			
86	Landslide	Landslide	15	34	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, vegetated	424.8965			1				
87	Landslide	Landslide	22	25	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	417.7191							

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
88	Landslide	Landslide	18	20	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	331.4082							
89	Landslide	Landslide	15	42	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	701.9514							
90	Landslide	Landslide	15	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	231.814							
91	Landslide	Landslide	9	24	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	223.6816							
92	Landslide	Landslide	18	8	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	141.8008			1				
93	Landslide	Landslide	8	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	104.7976			1				
94	Landslide	Landslide	11	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	132.3109			1				
95	Landslide	Landslide	3	18	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	39.31397			1				
96	Landslide	Landslide	20	12	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	209.0404			1	1			
97	Landslide	Landslide	12	35	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	335.2961			1				
98	Landslide	Landslide	15	75	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	792.4166				1			
99	Landslide	Landslide	21	75	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	1037.791				1			
100	Landslide	Landslide	16	43	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	594.856				1			
101	Landslide	Landslide	11	35	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1945	312.3231			1				
102	Landslide	Landslide	8	27	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	192.6023			1				
103	Landslide	Landslide	7	40	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	185.6951			1				
104	Landslide	Landslide	7	30	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	152.9171			1				
105	Landslide	Landslide	4	21	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	64.3071			1				
106	Landslide	Landslide	16	59	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	729.1957			1				
107	Landslide	Landslide	13	59	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	583.1972			1				
108	Landslide	Landslide	11	51	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	359.5067			1				
109	Landslide	Landslide	7	39	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	303.5759			1	1			
110	Landslide	Landslide	17	42	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	549.0347		1	1			1	
111	Landslide	Landslide	20	48	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	574.1612			1				
112	Landslide	Landslide	15	17	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	194.8112		1		1			
113	Landslide	Landslide	15	12	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	151.5108		1		1			
114	Landslide	Landslide	17	55	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh	619.7811			1				

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
													scarp patches maybe								
115	Landslide	Landslide	15	25	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	307.8663			1				
116	Landslide	Landslide	15	57	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	621.9399			1				
117	Landslide	Landslide	10	30	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	242.1851			1				
118	Landslide	Landslide	4	23	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	72.54271			1				
119	Landslide	Landslide zone	53	57	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, large area of previous accumulated slips of about 10 x 20 m size forming a bowl-shaped gully, only minor small potential fresh scarp	2911.616		1	1			1	
120	Landslide	Landslide	26	96	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1945	2338.435			1				
121	Landslide	Landslide	20	55	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	925.5431			1				
122	Landslide	Landslide	25	85	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	1372.115			1				
123	Landslide	Landslide	17	36	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	393.265			1				
124	Landslide	Landslide	18	61	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944, some fresh scarp patches maybe	864.2238			1				
125	Landslide	Landslide	21	43	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	690.7019		1	1			1	
126	Landslide	Landslide	17	29	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	429.4669		1	1				
127	Landslide	Landslide	16	17	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Could be recent to 1944	196.2965		1	1			1	
128	Landslide	Landslide	16	40	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	594.1346	1						
129	Landslide	Landslide	7	26	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	143.195	1						
130	Landslide	Landslide	10	27	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Predates 1944	239.2754	1			1			
132	Landslide	Landslide	9	31	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Sometime between 1944 and 1971 - some fresh scarp patches maybe	214.4924			1				
133	Landslide	Landslide	6	28	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971. Form within the larger footprint of H16	174.343			1				

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
134	Landslide	Landslide	9	37	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Related to H16. Could be recent to 1971. Form within the larger footprint of H16	292.1354			1				
135	Landslide	Landslide	8	45	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971. Some overlap with larger H27	254.498		1	1				
136	Landslide	Landslide	4	9	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	31.84805			1				
137	Landslide	Landslide	10	47	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Older and vegetated. Between 1944 and 1971	476.144		1		1			
138	Landslide	Landslide	36	25	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Related to H28. Could be recent to 1971.	590.4266			1				
139	Landslide	Landslide	42	30	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	876.2897		1	1				
140	Landslide	Landslide	40	46	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Lower portion is still bare, likely small movement in the lower slope	354.3557		1		1		1	
141	Landslide	Landslide	8	16	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	99.23937			1				
142	Landslide	Landslide	40	9	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	353.912			1				
143	Landslide	Landslide	5	20	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971. Small portion within H54 from 1944	74.93646			1				
144	Landslide	Landslide	12	23	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971. Lower portion of H72 from 1944	288.3447		1	1				
145	Landslide	Landslide	4	35	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	100.981		1	1				
146	Landslide	Landslide	11	11	Unknown	Unknown	Unknown	Unknown	-	1971	9/02/1971	Historical Aerial	Could be recent to 1971.	97.9902			1				
147	Rockfall	Rockfall / Landslide	100	15	Unknown	Unknown	Unknown	Unknown	-	2002	7/10/2002	Historical Aerial	Could be recent to 2002. May be rockfall, could be high angle landslide.	1267.258	1						
148	Landslide	Landslide	11	55	Unknown	Unknown	Unknown	Unknown	-	1944	22/05/1944	Historical Aerial	Looks old. Hard to see it the 1941 aerial, but it is there. Can easily see it in the 2002 aerial.	1106.548	1						
149	Landslide	Landslide	16	36	Unknown	Unknown	Unknown	Unknown	-	2002	7/10/2002	Historical Aerial	Could be recent to 2002.	562.9897							
150	Rockfall	Landslide / rockfall	34	13	Unknown	Unknown	Unknown	Unknown	-	2002	7/10/2002	Historical Aerial	Associated with H28.	365.7697		1				1	

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
													Located in the cliff rather than the hill.								
151	Rockfall	Landslide / rockfall	7	18	Unknown	Unknown	Unknown	Unknown	-	2002	7/10/2002	Historical Aerial	Associated with H72 from 1944 and 1972, small movement lower down.	135.1629		1	1				
152	Rockfall	Landslide / rockfall	10	20	Unknown	Unknown	Unknown	Unknown	-	2008	1/01/2008	Historical Aerial	Recent to 2008. Close to H12 - 1944.	188.6011		1				1	
153	Rockfall	Landslide / rockfall	20	25	Unknown	Unknown	Unknown	Unknown	-	2010	1/02/2010	Historical Aerial	Recent to 2010. Close to H12 - 1944.	478.0244		1				1	
154	Rockfall	Landslide / rockfall	5	36	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Down slope of H13 from 1944.	178.2097		1	1				
155	Rockfall	Landslide / rockfall	67	10	Unknown	Unknown	Unknown	Unknown	-	2010	1/02/2010	Historical Aerial	Recent to 2010.	544.1342		1					
156	Landslide	Landslide	15	35	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Further movement within H17 from 1944.	348.2113		1	1				
157	Landslide	Landslide	7	17	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Upslope of H20 from 1944.	88.28574		1	1				
158	Landslide	Landslide	5	53	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	260.8593			1				
159	Landslide	Landslide	5	12	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	58.49867		1					
160	Landslide	Landslide	30	25	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	769.777		1				1	
161	Landslide	Landslide	7	9	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Could be associated with INV 7.	69.92556			1				
162	Landslide	Landslide	5	10	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Could be associated with INV 8.	63.03767	1						
163	Landslide	Landslide	30	19	Unknown	Unknown	Unknown	Unknown	-	2007	1/01/2007	Historical Aerial	Recent to 2007. Eastern side of H85 from 1971	414.9083			1				
164	Landslide	Landslide	12	30	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Associated with H28 1944, and H94 2022.	254.1784		1				1	
165	Landslide	Landslide	4	12	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	28.45341		1				1	
166	Landslide	Landslide	33	73	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004. Associated with H28 from 1944.	2776.815		1	1			1	

ID	Type	Type (From field notes)	Width m	Length overall m	Height overall m	Height of scarp m	Geology	Estimated Volume m3	Adopted volume	Age	Adopted Age	Method of capture	Other	Area from GIS	Landslide/Rockfall Impacts Landscape Unit (1 = Yes)						
															Escarpment	Coastal Cliff	Steep Coastal Hill	Coastal Hill	Road Corridor	Beach	Cathedral Cove Arch
167	Landslide	Landslide	30	11	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004.	277.2046			1				
168	Landslide	Landslide	50	13	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004.	494.8015		1	1				
169	Landslide	Landslide	10	4	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	26.28655		1	1			1	
170	Landslide	Landslide	10	35	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	191.2657			1				
171	Landslide	Landslide	3	12	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Refer H5 1944.	24.08564			1				
172	Landslide	Landslide	5	10	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	59.62399		1	1				
174	Landslide	Landslide	4	41	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004. Close to H6 and H12 - 1944, H95 and H112.	200.2191		1	1				
175	Landslide	Landslide	13	24	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004. Close to H4 - 1944 and H96 - 2010.	266.4777		1	1			1	
176	Rockfall	Landslide / rockfall	17	23	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004. Close to H6 and H12 - 1944, H95 and H112.	208.5361				1			
177	Rockfall	Landslide / rockfall	12	8	Unknown	Unknown	Unknown	Unknown	-	2004	1/01/2004	Historical Aerial	Recent to 2004	91.54762		1					
178	Rockfall	Landslide / rockfall	21	13	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	237.6051		1				1	
179	Rockfall	Landslide / rockfall	26	9	Unknown	Unknown	Unknown	Unknown	-	2017	1/01/2017	Historical Aerial	Recent to 2017. Bit more movement since H94 2002.	238.9106		1					
180	Rockfall	Landslide / rockfall	8	41	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011. Small additional lower end movement of H27 1944.	340.4088		1				1	
181	Rockfall	Landslide / rockfall	6	25	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial	Recent to 2011.	150.2063		1				1	
182	Rockfall	Landslide / rockfall	15	50	Unknown	Unknown	Unknown	Unknown	-	2011	1/04/2011	Historical Aerial		807.1263		1				1	

Appendix F Temporal Probability $P_{(L)}$

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Appendix F Table 1: Determination of Annual Exceedance Probability per km² for each landscape unit

Landscape unit	Size class	Type	Count	Time period (years)	Mean recurrence interval (Time period / count)	Probability (%) of one or more landslides/rockfall occurring based on long-term data $P\{N(t) \geq 1\} = 1 - e^{-t/\mu}$	Landscape unit area mapped (km ²)	Probability (%) of one or more landslides/rockfall occurring based on long-term data per km ² (scaled by landscape unit area)
Escarpment	Most likely	Landslides	3	79	26	3.7E-02	5.912E-02	6.3E-01
		Rockfall	3	79	26	3.7E-02	5.912E-02	6.3E-01
	Maximum Credible	Landslides	0	79	-	-	5.912E-02	-
		Rockfall	1	79	79	1.3E-02	5.912E-02	2.1E-01
Coastal Cliff	Most likely	Landslides	27	79	3	2.9E-01	4.213E-02	6.9E+00
		Rockfall	17	79	5	1.9E-01	4.213E-02	4.6E+00
	Maximum Credible	Landslides	2	79	40	2.5E-02	4.213E-02	5.9E-01
		Rockfall	2	79	40	2.5E-02	4.213E-02	5.9E-01
Steep Coastal Hill	Most likely	Landslides	40	79	2	4.0E-01	1.744E-01	2.3E+00
		Rockfall	5	79	16	6.1E-02	1.744E-01	3.5E-01
	Maximum Credible	Landslides	1	79	79	1.3E-02	1.744E-01	7.2E-02
		Rockfall	0	79	-	-	1.744E-01	-
Coastal Hill	Most likely	Landslides	4	79	20	4.9E-02	1.495E-01	3.3E-01
		Rockfall	1	79	79	1.3E-02	1.495E-01	8.4E-02
	Maximum Credible	Landslides	1	79	79	1.3E-02	1.495E-01	8.4E-02
		Rockfall	0	79	-	-	1.495E-01	-
Road Corridor	Most likely	Landslides	0	79	-	-	5.624E-03	-
		Rockfall	0	79	-	-	5.624E-03	-

	Maximum Credible	Landslides	0	79	-	-	5.624E-03	-
		Rockfall	0	79	-	-	5.624E-03	-
Beach	Most likely	Landslides	12	79	7	1.4E-01	1.540E-02	9.2E+00
		Rockfall	12	79	7	1.4E-01	1.540E-02	9.2E+00
	Maximum Credible	Landslides	1	79	79	1.3E-02	1.540E-02	8.2E-01
		Rockfall	1	79	79	1.3E-02	1.540E-02	8.2E-01
Cathedral Cove Arch	Most likely	Landslides	0	14	-	-	7.809E-04	-
		Rockfall	5	14	3	3.0E-01	7.809E-04	3.8E+02
	Maximum Credible	Landslides	0	14	-	-	7.809E-04	-
		Rockfall	1	14	14	6.9E-02	7.809E-04	8.8E+01

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Appendix F Table 2: Probability (%) of one or more landslides/rockfalls occurring based on long term data – scaled to area contributing to the hazard at each Track Section

Track	Landscape Unit	Case	Probability (%) of one or more events occurring based on long-term data per km2 for corresponding landscape unit		Track hazard area km2	Probability (%) of one or more events occurring based on long-term data - scaled to track hazard area	
			Landslide	Rockfall		Landslide	Rockfall
Section 1	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	4.030E-02	9.2E-02	1.4E-02
	Steep Coastal Hills	Max credible	7.2E-02	-	4.030E-02	2.9E-03	-
Section 2	Coastal Hill	Most likely	6.9E+00	3.3E-01	3.817E-03	2.6E-02	1.3E-03
	Coastal Hill	Max credible	8.4E-02	-	3.817E-03	3.2E-04	-
Section 3	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	5.065E-03	1.2E-02	1.8E-03
	Steep Coastal Hills	Max credible	7.2E-02	-	5.065E-03	3.7E-04	-
Section 4	Coastal Hill	Most likely	6.9E+00	3.3E-01	1.626E-03	1.1E-02	5.4E-04
	Coastal Hill	Max credible	8.4E-02	-	1.626E-03	1.4E-04	-
Section 5	Coastal Hill	Most likely	6.9E+00	3.3E-01	3.364E-03	2.3E-02	1.1E-03
	Coastal Hill	Max credible	8.4E-02	-	3.364E-03	2.8E-04	-
Section 6	Coastal Hill	Most likely	6.9E+00	3.3E-01	3.574E-03	2.5E-02	1.2E-03

Track	Landscape Unit	Case	Probability (%) of one or more events occurring based on long-term data per km2 for corresponding landscape unit		Track hazard area km2	Probability (%) of one or more events occurring based on long-term data - scaled to track hazard area	
			Landslide	Rockfall		Landslide	Rockfall
	Coastal Hill	Max credible	8.4E-02	-	3.574E-03	3.0E-04	-
Section 7	Coastal Hill	Most likely	6.9E+00	3.3E-01	8.632E-03	5.9E-02	2.9E-03
	Coastal Hill	Max credible	8.4E-02	-	8.632E-03	7.3E-04	-
Section 08	Coastal Hill	Most likely	6.9E+00	3.3E-01	6.551E-03	4.5E-02	2.2E-03
	Coastal Hill	Max credible	8.4E-02	-	6.551E-03	5.5E-04	-
Section 09	Escarpment	Most likely	6.3E-01	6.3E-01	3.723E-03	2.3E-03	2.3E-03
	Escarpment	Max credible	-	2.1E-01	3.723E-03	-	7.9E-04
Section 10	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	2.164E-03	4.9E-03	7.6E-04
	Steep Coastal Hills	Max credible	7.2E-02	-	2.164E-03	1.6E-04	-
Section 11	Coastal Hill	Most likely	6.9E+00	3.3E-01	1.279E-02	8.8E-02	4.2E-03
	Coastal Hill	Max credible	8.4E-02	-	1.279E-02	1.1E-03	-
Section 12	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	5.481E-02	1.2E-01	1.9E-02
	Steep Coastal Hills	Max credible	7.2E-02	-	5.481E-02	4.0E-03	-
Section 13	Coastal Cliffs	Most likely	6.9E+00	4.6E+00	6.157E-04	4.2E-03	2.8E-03
	Coastal Cliffs	Max credible	5.9E-01	5.9E-01	6.157E-04	3.7E-04	3.7E-04

Track	Landscape Unit	Case	Probability (%) of one or more events occurring based on long-term data per km2 for corresponding landscape unit		Track hazard area km2	Probability (%) of one or more events occurring based on long-term data - scaled to track hazard area	
			Landslide	Rockfall		Landslide	Rockfall
Section 14	Beach	Most likely	9.2E+00	9.2E+00	5.324E-03	4.9E-02	4.9E-02
	Beach	Max credible	8.2E-01	8.2E-01	5.324E-03	4.3E-03	4.3E-03
Section 15	Cathedral Cove Arch	Most likely	-	3.8E+02	7.800E-04	-	3.0E-01
	Cathedral Cove Arch	Max credible	-	8.8E+01	7.800E-04	-	6.9E-02
Section 16	Coastal Cliffs	Most likely	6.9E+00	4.6E+00	1.174E-03	8.1E-03	5.4E-03
	Coastal Cliffs	Max credible	5.9E-01	5.9E-01	1.174E-03	7.0E-04	7.0E-04
Section 17	Coastal Hill	Most likely	6.9E+00	3.3E-01	2.142E-03	1.5E-02	7.1E-04
	Coastal Hill	Max credible	8.4E-02	-	2.142E-03	1.8E-04	-
Section 18	Beach	Most likely	9.2E+00	9.2E+00	1.658E-03	1.5E-02	1.5E-02
	Beach	Max credible	8.2E-01	8.2E-01	1.658E-03	1.4E-03	1.4E-03
Section 19	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	3.421E-03	7.8E-03	1.2E-03
	Steep Coastal Hills	Max credible	7.2E-02	-	3.421E-03	2.5E-04	-
Section 20	Beach	Most likely	9.2E+00	9.2E+00	1.069E-03	9.8E-03	9.8E-03
	Beach	Max credible	8.2E-01	8.2E-01	1.069E-03	8.7E-04	8.7E-04

Track	Landscape Unit	Case	Probability (%) of one or more events occurring based on long-term data per km2 for corresponding landscape unit		Track hazard area km2	Probability (%) of one or more events occurring based on long-term data - scaled to track hazard area	
			Landslide	Rockfall		Landslide	Rockfall
Section 21	Coastal Hill	Most likely	6.9E+00	3.3E-01	1.244E-03	8.5E-03	4.1E-04
	Coastal Hill	Max credible	8.4E-02	-	1.244E-03	1.0E-04	-
Point Location 1 (Bench)	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	7.650E-04	1.7E-03	2.7E-04
	Steep Coastal Hills	Max credible	7.2E-02	-	7.650E-04	5.5E-05	-
Point Location 2 (Existing Toilet)	Beach	Most likely	9.2E+00	9.2E+00	7.260E-04	6.6E-03	6.6E-03
	Beach	Max credible	8.2E-01	8.2E-01	7.260E-04	5.9E-04	5.9E-04
Point Location 3 (Lifeguard Hut)	Beach	Most likely	9.2E+00	9.2E+00	4.190E-04	3.8E-03	3.8E-03
	Beach	Max credible	8.2E-01	8.2E-01	4.190E-04	3.4E-04	3.4E-04
Point Location 4 (Proposed New Toilet Location)	Steep Coastal Hills	Most likely	2.3E+00	3.5E-01	1.311E-03	3.0E-03	4.6E-04
	Steep Coastal Hills	Max credible	7.2E-02	-	1.311E-03	9.5E-05	-

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Appendix G Annual Individual Fatality Risk

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Appendix G Table 1: Annual Individual Fatality Risk for each track section and point location

Track Section	Corresponding landscape unit	Event	Temporal probability of the event Rockfall	Temporal probability of the event Landslide	Total temporal probability of the event (P _L)	Probability of the landslide/rockfall reaching the track (P _{T:L})	Spatio-temporal probability of the person at risk (P _{S:T}) (Return trip)	Vulnerability of the person (P _{D:T})	Probability of loss of life for visitor P _(LOL)		Spatio-temporal probability of DoC ranger at risk (P _{S:T})	Probability of loss of life P _(LOL) for Ranger
Section 01	Steep Coastal Hills	Most likely	1.4E-02	9.2E-02	1.1E-01	3.4E-02	8.5E-05	0.7	2.1E-07		1.0E-02	2.6E-05
		Maximum Credible	-	2.9E-03	2.9E-03	4.7E-02	8.5E-05	1	1.2E-08		1.0E-02	1.4E-06
								Total	2.2E-07		Total	2.7E-05
Section 02	Coastal Hills	Most likely	1.3E-03	2.6E-02	2.7E-02	1.2E-01	1.9E-05	0.7	4.6E-08		2.3E-03	5.5E-06
		Maximum Credible	-	3.2E-04	3.2E-04	1.9E-01	1.9E-05	1	1.2E-09		2.3E-03	1.4E-07
								Total	4.7E-08		Total	5.7E-06
Section 03	Steep Coastal Hills	Most likely	1.8E-03	1.2E-02	1.3E-02	1.1E-01	2.7E-05	0.7	2.7E-08		3.2E-03	3.2E-06
		Maximum Credible	-	3.7E-04	3.7E-04	1.5E-01	2.7E-05	1	1.5E-09		3.2E-03	1.8E-07
								Total	2.8E-08		Total	3.4E-06
Section 04	Coastal Hills	Most likely	5.4E-04	1.1E-02	1.2E-02	4.9E-01	4.9E-06	0.7	2.0E-08		5.9E-04	2.4E-06
		Maximum Credible	-	1.4E-04	1.4E-04	7.4E-01	4.9E-06	1	5.0E-10		5.9E-04	6.0E-08
								Total	2.0E-08		Total	2.4E-06
Section 05	Coastal Hills	Most likely	1.1E-03	2.3E-02	2.4E-02	4.6E-01	5.2E-06	0.7	4.1E-08		6.2E-04	4.9E-06
		Maximum Credible	-	2.8E-04	2.8E-04	7.0E-01	5.2E-06	1	1.0E-09		6.2E-04	1.2E-07
								Total	4.2E-08		Total	5.0E-06
Section 06	Coastal Hills	Most likely	1.2E-03	2.5E-02	2.6E-02	2.4E-01	1.0E-05	0.7	4.3E-08		1.2E-03	5.2E-06
		Maximum Credible	-	3.0E-04	3.0E-04	3.6E-01	1.0E-05	1	1.1E-09		1.2E-03	1.3E-07
								Total	4.4E-08		Total	5.3E-06
Section 07	Coastal Hills	Most likely	2.9E-03	5.9E-02	6.2E-02	9.8E-02	2.5E-05	0.7	1.0E-07		2.9E-03	1.3E-05
		Maximum Credible	-	7.3E-04	7.3E-04	1.5E-01	2.5E-05	1	2.6E-09		2.9E-03	3.2E-07
								Total	1.1E-07		Total	1.3E-05
Section 08	Coastal Hills	Most likely	2.2E-03	4.5E-02	4.7E-02	6.8E-02	3.5E-05	0.7	7.9E-08		4.2E-03	9.5E-06
		Maximum Credible	-	5.5E-04	5.5E-04	1.0E-01	3.5E-05	1	2.0E-09		4.2E-03	2.4E-07
								Total	8.1E-08		Total	9.7E-06
Section 09	Escarpment	Most likely	2.3E-03	2.3E-03	4.7E-03	3.0E-01	7.1E-06	0.7	7.1E-09		8.5E-04	8.5E-07
		Maximum Credible	7.9E-04	-	7.9E-04	1.0E+00	7.1E-06	1	5.6E-09		8.5E-04	6.7E-07
								Total	1.3E-08		Total	1.5E-06
Section 10	Steep Coastal Hills	Most likely	7.6E-04	4.9E-03	5.7E-03	8.3E-01	3.4E-06	0.7	1.1E-08		4.1E-04	1.4E-06
		Maximum Credible	-	1.6E-04	1.6E-04	1.0E+00	3.4E-06	1	5.4E-10		4.1E-04	6.4E-08
								Total	1.2E-08		Total	1.4E-06
Section 11	Coastal Hill	Most likely	4.2E-03	8.8E-02	9.2E-02	7.2E-02	3.3E-05	0.7	1.5E-07		4.0E-03	1.9E-05
		Maximum Credible	-	1.1E-03	1.1E-03	1.1E-01	3.3E-05	1	3.9E-09		4.0E-03	4.7E-07
								Total	1.6E-07		Total	1.9E-05
Section 12	Steep Coastal Hills	Most likely	1.9E-02	1.2E-01	1.4E-01	4.0E-02	7.1E-05	0.7	2.9E-07		8.5E-03	3.5E-05
		Maximum Credible	-	4.0E-03	4.0E-03	5.6E-02	7.1E-05	1	1.6E-08		8.5E-03	1.9E-06
								Total	3.1E-07		Total	3.7E-05

Section 13	Coastal Cliffs	Most likely	2.8E-03	4.2E-03	7.1E-03	1.0E+00	2.3E-06	0.7	1.1E-08		2.8E-04	1.4E-06
		Maximum Credible	3.7E-04	3.7E-04	7.3E-04	1.0E+00	2.3E-06	1	1.7E-09		2.8E-04	2.0E-07
								Total	1.3E-08		Total	1.6E-06
Section 14	Beach	Most likely	4.9E-02	4.9E-02	9.7E-02	6.3E-02	6.3E-05	0.7	2.7E-07		7.6E-03	3.2E-05
		Maximum Credible	4.3E-03	4.3E-03	8.7E-03	1.0E-01	6.3E-05	1	5.7E-08		7.6E-03	6.9E-06
								Total	3.3E-07		Total	3.9E-05
Section 15	Cathedral Cove Arch	Most likely	3.0E-01	-	3.0E-01	8.1E-02	5.6E-06	0.5	6.8E-08		6.7E-04	8.2E-06
		Maximum Credible	6.9E-02	-	6.9E-02	1.9E-01	5.6E-06	0.7	5.1E-08		6.7E-04	6.1E-06
								Total	1.2E-07		Total	1.4E-05
Section 16	Coastal Cliffs	Most likely	5.4E-03	8.1E-03	1.3E-02	4.7E-01	7.4E-06	0.7	3.3E-08		8.8E-04	4.0E-06
		Maximum Credible	7.0E-04	7.0E-04	1.4E-03	1.0E+00	7.4E-06	1	1.0E-08		8.8E-04	1.2E-06
								Total	4.3E-08		Total	5.2E-06
Section 17	Coastal Cliffs	Most likely	7.1E-04	1.5E-02	1.5E-02	1.6E-01	1.5E-05	0.7	2.6E-08		1.8E-03	3.1E-06
		Maximum Credible	-	1.8E-04	1.8E-04	2.5E-01	1.5E-05	1	6.5E-10		1.8E-03	7.8E-08
								Total	2.7E-08		Total	3.2E-06
Section 18	Beach	Most likely	1.5E-02	1.5E-02	3.0E-02	1.7E-01	2.3E-05	0.7	8.4E-08		2.8E-03	1.0E-05
		Maximum Credible	1.4E-03	1.4E-03	2.7E-03	2.9E-01	2.3E-05	1	1.8E-08		2.8E-03	2.1E-06
			0.0E+00	0.0E+00					1.0E-07		Total	1.2E-05
Section 19	Steep Coastal Hills	Most likely	1.2E-03	7.8E-03	9.0E-03	2.1E-01	1.3E-05	0.7	1.8E-08		1.6E-03	2.2E-06
		Maximum Credible	-	2.5E-04	2.5E-04	3.0E-01	1.3E-05	1	9.9E-10		1.6E-03	1.2E-07
								Total	1.9E-08		Total	2.3E-06
Section 20	Beach	Most likely	9.8E-03	9.8E-03	2.0E-02	2.5E-01	1.6E-05	0.7	5.4E-08		1.9E-03	6.5E-06
		Maximum Credible	8.7E-04	8.7E-04	1.7E-03	4.2E-01	1.6E-05	1	1.2E-08		1.9E-03	1.4E-06
								Total	6.6E-08		Total	7.9E-06
Section 21	Coastal Hills	Most likely	4.1E-04	8.5E-03	9.0E-03	3.3E-01	7.3E-06	0.7	1.5E-08		8.7E-04	1.8E-06
		Maximum Credible	-	1.0E-04	1.0E-04	5.0E-01	7.3E-06	1	3.8E-10		8.7E-04	4.6E-08
								Total	1.5E-08		Total	1.9E-06
Point Location 1 (Bench)	Steep Coastal Hills	Most likely	2.7E-04	1.7E-03	2.0E-03	1.0E+00	3.8E-06	0.7	5.4E-09			
		Maximum Credible	-	5.5E-05	5.5E-05	1.0E+00	3.8E-06	1	2.1E-10			
								Total	5.6E-09			
Point Location 2 (Existing Toilet)	Beach	Most likely	6.6E-03	6.6E-03	1.3E-02	1.0E+00	7.6E-06	0.4	4.0E-08		9.1E-04	4.9E-06
		Maximum Credible	5.9E-04	5.9E-04	1.2E-03	1.0E+00	7.6E-06	0.8	7.2E-09		9.1E-04	8.7E-07
								Total	4.8E-08		Total	5.7E-06
Point Location 3 (Lifeguard Hut)	Beach	Most likely	3.8E-03	3.8E-03	7.7E-03	1.0E+00	9.1E-03	0.4	2.8E-05		9.1E-03	2.8E-05
		Maximum Credible	3.4E-04	3.4E-04	6.8E-04	1.0E+00	9.1E-03	0.8	5.0E-06		9.1E-03	5.0E-06
								Total	3.3E-05		Total	3.3E-05
Point Location 4 (Proposed New Toilet Location)	Steep Coastal Hills	Most likely	4.6E-04	3.0E-03	3.4E-03	1.0E+00	7.6E-06	0.4	1.0E-08		9.1E-04	1.3E-06
		Maximum Credible	-	9.5E-05	9.5E-05	1.0E+00	7.6E-06	0.8	5.8E-10		9.1E-04	6.9E-08
								Total	1.1E-08		Total	1.3E-06

Appendix H Societal risk calculation

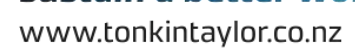
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Appendix H Table 1: Societal risk calculation

Track Section	Corresponding landscape unit	Event	Temporal probability of the event (P_t)	Probability of the landslide/rockfall reaching the track ($P_{T:L}$)	Vulnerability of the person ($P_{D:T}$)	Spatio-temporal probability of Group of 1 or 2	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 5 to 7	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 30	Societal Risk for fatality of 1 or more
Section 01	Steep Coastal Hills	Most likely	1.1E-01	3.4E-02	0.7	0.1	2.5E-04		0.1	2.5E-04		0.1	-
		Maximum Credible	2.9E-03	4.7E-02	1	0.1	1.4E-05		0.1	1.4E-05		0.1	1.4E-05
					Total	Total	2.7E-04		Total	2.7E-04		Total	1.4E-05
Section 02	Coastal Hills	Most likely	2.7E-02	1.2E-01	0.7	0.5	1.2E-03		0.25	-		0.25	-
		Maximum Credible	3.2E-04	1.9E-01	1	0.5	3.0E-05		0.25	1.5E-05		0.25	1.5E-05
					Total	Total	1.2E-03		Total	1.5E-05		Total	1.5E-05
Section 03	Steep Coastal Hills	Most likely	1.3E-02	1.1E-01	0.7	0.5	5.0E-04		0.25	2.5E-04		0.25	-
		Maximum Credible	3.7E-04	1.5E-01	1	0.5	2.7E-05		0.25	1.4E-05		0.25	1.4E-05
					Total	Total	5.2E-04		Total	2.6E-04		Total	1.4E-05
Section 04	Coastal Hills	Most likely	1.2E-02	4.9E-01	0.7	0.5	2.0E-03		0.25	-		0.25	-
		Maximum Credible	1.4E-04	7.4E-01	1	0.5	5.0E-05		0.25	2.5E-05		0.25	2.5E-05
					Total	Total	2.0E-03		Total	2.5E-05		Total	2.5E-05
Section 05	Coastal Hills	Most likely	2.4E-02	4.6E-01	0.7	0.5	3.9E-03		0.25	-		0.25	-
		Maximum Credible	2.8E-04	7.0E-01	1	0.5	9.9E-05		0.25	4.9E-05		0.25	4.9E-05
					Total	Total	4.0E-03		Total	4.9E-05		Total	4.9E-05
Section 06	Coastal Hills	Most likely	2.6E-02	2.4E-01	0.7	0.5	2.2E-03		0.25	-		0.25	-
		Maximum Credible	3.0E-04	3.6E-01	1	0.5	5.4E-05		0.25	2.7E-05		0.25	2.7E-05
					Total	Total	2.2E-03		Total	2.7E-05		Total	2.7E-05
Section 07	Coastal Hills	Most likely	6.2E-02	9.8E-02	0.7	0.5	2.1E-03		0.25	-		0.25	-
		Maximum Credible	7.3E-04	1.5E-01	1	0.5	5.4E-05		0.25	2.7E-05		0.25	2.7E-05
					Total	Total	2.2E-03		Total	2.7E-05		Total	2.7E-05
Section 08	Coastal Hills	Most likely	4.7E-02	6.8E-02	0.7	0.5	1.1E-03		0.25	-		0.25	-
		Maximum Credible	5.5E-04	1.0E-01	1	0.5	2.8E-05		0.25	1.4E-05		0.25	1.4E-05
					Total	Total	1.1E-03		Total	1.4E-05		Total	1.4E-05
Section 09	Escarpment	Most likely	4.7E-03	3.0E-01	0.7	0.5	5.0E-04		0.25	2.5E-04		0.25	-
		Maximum Credible	7.9E-04	1.0E+00	1	0.5	4.0E-04		0.25	2.0E-04		0.25	2.0E-04
					Total	Total	8.9E-04		Total	4.5E-04		Total	2.0E-04
Section 10	Steep Coastal Hills	Most likely	5.7E-03	8.3E-01	0.7	0.5	1.7E-03		0.25	8.3E-04		0.25	-
		Maximum Credible	1.6E-04	1.0E+00	1	0.5	7.8E-05		0.25	3.9E-05		0.25	3.9E-05
					Total	Total	1.7E-03		Total	8.7E-04		Total	3.9E-05
Section 11	Coastal Hill	Most likely	9.2E-02	7.2E-02	0.7	0.5	2.3E-03		0.25	-		0.25	-
		Maximum Credible	1.1E-03	1.1E-01	1	0.5	5.9E-05		0.25	2.9E-05		0.25	2.9E-05
					Total	Total	2.4E-03		Total	2.9E-05		Total	2.9E-05
Section 12	Steep Coastal Hills	Most likely	1.4E-01	4.0E-02	0.7	0.5	2.0E-03		0.25	1.0E-03		0.25	-
		Maximum Credible	4.0E-03	5.6E-02	1	0.5	1.1E-04		0.25	5.6E-05		0.25	5.6E-05
					Total	Total	2.1E-03		Total	1.1E-03		Total	5.6E-05
Section 13	Coastal Cliffs	Most likely	7.1E-03	1.0E+00	0.7	0.5	2.5E-03		0.25	1.2E-03		0.25	-
		Maximum Credible	7.3E-04	1.0E+00	1	0.5	3.7E-04		0.25	1.8E-04		0.25	1.8E-04
					Total	Total	2.8E-03		Total	1.4E-03		Total	1.8E-04
Section 14	Beach	Most likely	9.7E-02	6.3E-02	0.7	0.5	2.1E-03		0.25	1.1E-03		0.25	-

Track Section	Corresponding landscape unit	Event	Temporal probability of the event (P _L)	Probability of the landslide/rockfall reaching the track (P _{T:L})	Vulnerability of the person (P _{D:T})	Spatio-temporal probability of Group of 1 or 2	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 5 to 7	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 30	Societal Risk for fatality of 1 or more
		Maximum Credible	8.7E-03	1.0E-01	1	0.5	4.6E-04		0.25	2.3E-04		0.25	2.3E-04
					Total	Total	2.6E-03		Total	1.3E-03		Total	2.3E-04
Section 15	Cathedral Cove Arch	Most likely	3.0E-01	8.1E-02	0.5	0.5	6.1E-03		0.25			0.25	-
		Maximum Credible	6.9E-02	1.9E-01	0.7	0.5	4.5E-03		0.25			0.25	-
					Total	Total	1.1E-02		Total	0.0E+00		Total	0.0E+00
Section 16	Coastal Cliffs	Most likely	1.3E-02	4.7E-01	0.7	0.5	2.2E-03		0.25	1.1E-03		0.25	-
		Maximum Credible	1.4E-03	1.0E+00	1	0.5	7.0E-04		0.25	3.5E-04		0.25	3.5E-04
					Total	Total	2.9E-03		Total	1.5E-03		Total	3.5E-04
Section 17	Coastal Cliffs	Most likely	1.5E-02	1.6E-01	0.7	0.5	8.8E-04		0.25	4.4E-04		0.25	-
		Maximum Credible	1.8E-04	2.5E-01	1	0.5	2.2E-05		0.25	1.1E-05		0.25	1.1E-05
					Total	Total	9.1E-04		Total	4.5E-04		Total	1.1E-05
Section 18	Beach	Most likely	3.0E-02	1.7E-01	0.7	0.5	1.8E-03		0.25	9.2E-04		0.25	-
		Maximum Credible	2.7E-03	2.9E-01	1	0.5	3.9E-04		0.25	1.9E-04		0.25	1.9E-04
					Total	Total	2.2E-03		Total	1.1E-03		Total	1.9E-04
Section 19	Steep Coastal Hills	Most likely	9.0E-03	2.1E-01	0.7	0.5	6.8E-04		0.25	3.4E-04		0.25	-
		Maximum Credible	2.5E-04	3.0E-01	1	0.5	3.7E-05		0.25	1.9E-05		0.25	1.9E-05
					Total	Total	7.1E-04		Total	3.6E-04		Total	1.9E-05
Section 20	Beach	Most likely	2.0E-02	2.5E-01	0.7	0.5	1.7E-03		0.25	8.7E-04		0.25	-
		Maximum Credible	1.7E-03	4.2E-01	1	0.5	3.7E-04		0.25	1.8E-04		0.25	1.8E-04
					Total	Total	2.1E-03		Total	1.0E-03		Total	1.8E-04
Section 21	Coastal Hills	Most likely	9.0E-03	3.3E-01	0.7	0.5	1.0E-03		0.25	-		0.25	-
		Maximum Credible	1.0E-04	5.0E-01	1	0.5	2.6E-05		0.25	1.3E-05		0.25	1.3E-05
					Total	Total	1.1E-03		Total	1.3E-05		Total	1.3E-05
Point Location 1 (Bench)	Steep Coastal Hills	Most likely	2.0E-03	1.0E+00	0.7	0.5	7.0E-04		0.25	3.5E-04		0.25	-
		Maximum Credible	5.5E-05	1.0E+00	1	0.5	2.8E-05		0.25	1.4E-05		0.25	1.4E-05
					Total	Total	7.3E-04		Total	3.7E-04		Total	1.4E-05
Point Location 2 (Existing Toilet)	Beach	Most likely	1.3E-02	1.0E+00	0.4	0.5	2.7E-03		0.25	1.3E-03		0.25	-
		Maximum Credible	1.2E-03	1.0E+00	0.8	0.5	4.7E-04		0.25	2.4E-04		0.25	2.4E-04
					Total	Total	3.1E-03		Total	1.6E-03		Total	2.4E-04
Point Location 3 (Lifeguard Hut)	Beach	Most likely	7.7E-03	1.0E+00	0.4	0.5	1.5E-03		0.25	7.7E-04		0.25	-
		Maximum Credible	6.8E-04	1.0E+00	0.8	0.5	2.7E-04		0.25	1.4E-04		0.25	1.4E-04
					Total	Total	1.8E-03		Total	9.0E-04		Total	1.4E-04
Point Location 4 (Proposed New Toilet Location)	Steep Coastal Hills	Most likely	3.4E-03	1.0E+00	0.4	0.5	6.9E-04		0.25	3.4E-04		0.25	-
		Maximum Credible	9.5E-05	1.0E+00	0.8	0.5	3.8E-05		0.25	1.9E-05		0.25	1.9E-05
					Total	Total	7.3E-04		Total	3.6E-04		Total	1.9E-05

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Document control

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1 Introduction

Tonkin & Taylor Ltd (T+T) has been engaged¹ by Department of Conservation (DOC) to undertake geotechnical feasibility assessment of proposed track realignments.

Department of Conservation (DoC) wish to reinstate access to Cathedral Cove beach and to understand what potential mitigations are feasible, in light of the significant track damage and landslides from the 2023 storm events. DoC have engaged with Frame Group to help support the concept design/feasibility of potential track realignment and beach access. DOC have requested T+T to support with geotechnical and landslide hazard considerations.

DOC have also requested that T+T undertake a risk assessment of the proposed track realignments and Cathedral Cove Arch following the same methodology as that undertaken by T+T in 2023².

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¹ Tonkin & Taylor Ltd (4 March 2024) *Letter of Engagement Cathedral Cove: Feasibility Assessment*, Ref: 1007838.4000. Prepared for Department of Conservation.

² Tonkin & Taylor Ltd (28 July 2023) *Cathedral Cove Basic Level Landslide Risk Assessment*, Ref 1007838.3000. Prepared for Department of Conservation.

2 2023 storm event damage

The storm events in 2023 resulted in landslides, rockfall and coastal erosion which damaged the Cathedral Cove track in multiple locations, destroyed the beach access stair structure and undermined the beach toilet block. Landslides and rockfalls are discussed in detail in T+T 2023² and summarised in Section 5. Photograph examples of the recent damage are presented below for context.



Figure 2.1: Cathedral Cove lower track landslide damage.



Figure 2.2: 2023 storm event destroyed the stair structure leading to Cathedral Cove Beach.



Figure 2.3: Aerial view showing landslides and rockfall around the track.

3 Proposed track realignment options

The proposed track realignment options proposed by DOC³ are summarised in Figure 3.1 and listed briefly below. Further information for each option is discussed in the Feasibility Assessment Section 6. Frame Group have provided a Feasibility Report presenting track design considerations⁴. Several key drawings of their report relevant to this geotechnical feasibility assessment are presented in Appendix A.

The options proposed by DOC are based on ideas put forward during a site visit on 19 March 2024 which included DOC, Frame Group, T+T and representation from Ngāti Hei. These options considered a number of factors including technical/design, visitor experience, visitor safety and cultural considerations, and have been further developed by Frame Group.

Option 2a Short Term Access. The purpose of Option 2a is to provide short term access to Cathedral Cove, whilst a long-term solution is completed.

Option 2b(i) New Long-Term Access. Provide long term access to Cathedral Cove via a new staircase structure and new short track link.

Option 2b(ii) New Long-Term Access. Provide long term access via a new staircase structure (same as Option 2b(i) above) and construct a longer realigned track section.

Option 3a Hahei Beach Short Walk. Replace 2 no. bridge structures.

Option 3b Hahei Beach Short Walk Reroute. Realigned track to avoid steeper sections of the Hahei Beach Short Walk which requires upgrades and new bridges (i.e., Option 3a above).

Site 1: A short section of track currently affected by significant cracking associated with a slow-moving landslide.

Option 1 and Option 1a are marine access only options and are not part of our scope of work.

³ Department of Conservation (19 March 2024): *Cathedral Cove Site Visit Summary: 19 March 2024 Infrastructure Options Investigation*.

⁴ Frame Group (2 May 2024) *Cathedral Cove Beach Access and Hahei Beach to Grange Road Track – Feasibility Report*, Revision A, Job no 24-020. Prepared for Department of Conservation.

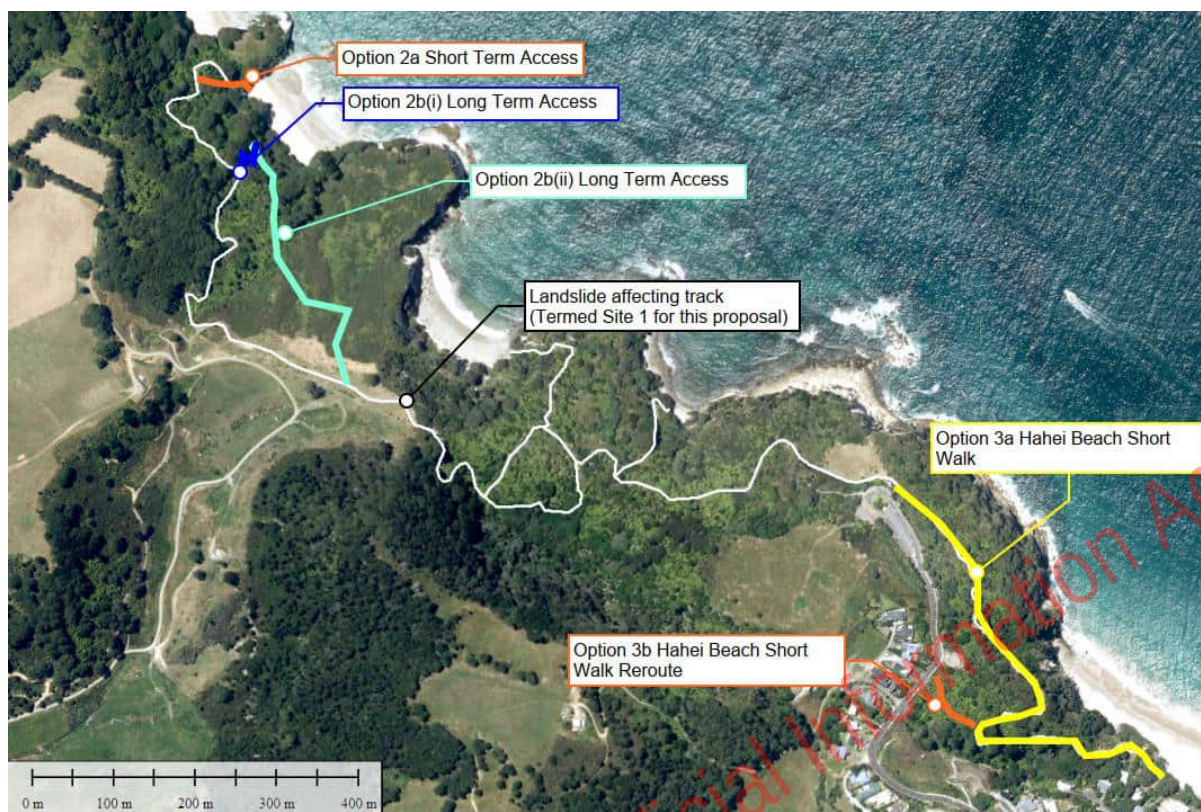


Figure 3.1: Summary plan showing realignment options proposed by DOC.

5 Site inspections and conditions

5.1 General

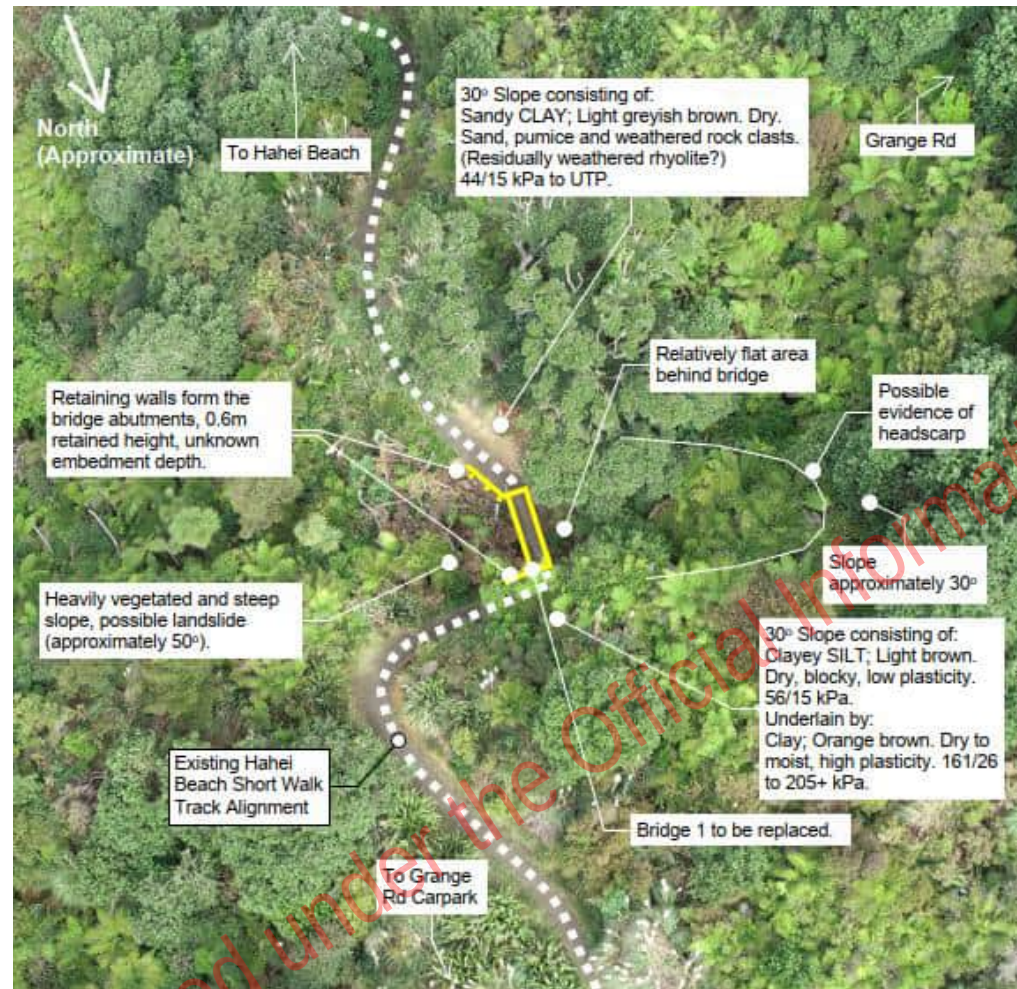
Site inspections and mapping of key site features was undertaken on 18 and 19 March, and 9 and 10 April 2024. This mapping was focused on understanding site conditions at the proposed option locations, identifying geomorphic features and geotechnical hazards and opportunities.

Maps and cross sections sketches are provided in Appendix B and summaries of the site conditions for each option are presented in the following pages.

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Option 3a Hahei Beach Short Walk (Sheet 1 of 2, Bridge 1)

Refer Appendix B Figure 3, Sketch Sections 7 to 9.



Anticipated geology:

- North abutment exposed soil is clayey silt and clay. Currently undetermined if this layer is weathered ash or residual weathered Rhyolite.
- South abutment exposed soil is sandy clay (possibly residually weathered Rhyolite).

Key site features:

- Evidence of a historical landslide upslope and downslope of the bridge (based on topography and historical aerials).
- Land begins to slope steeply beneath the bridge towards the east.
- Small retaining walls (0.6 m retained height) form the abutments on either side of the bridge.
- There is a relatively flat area of land behind the bridge.

Key geotechnical hazards:

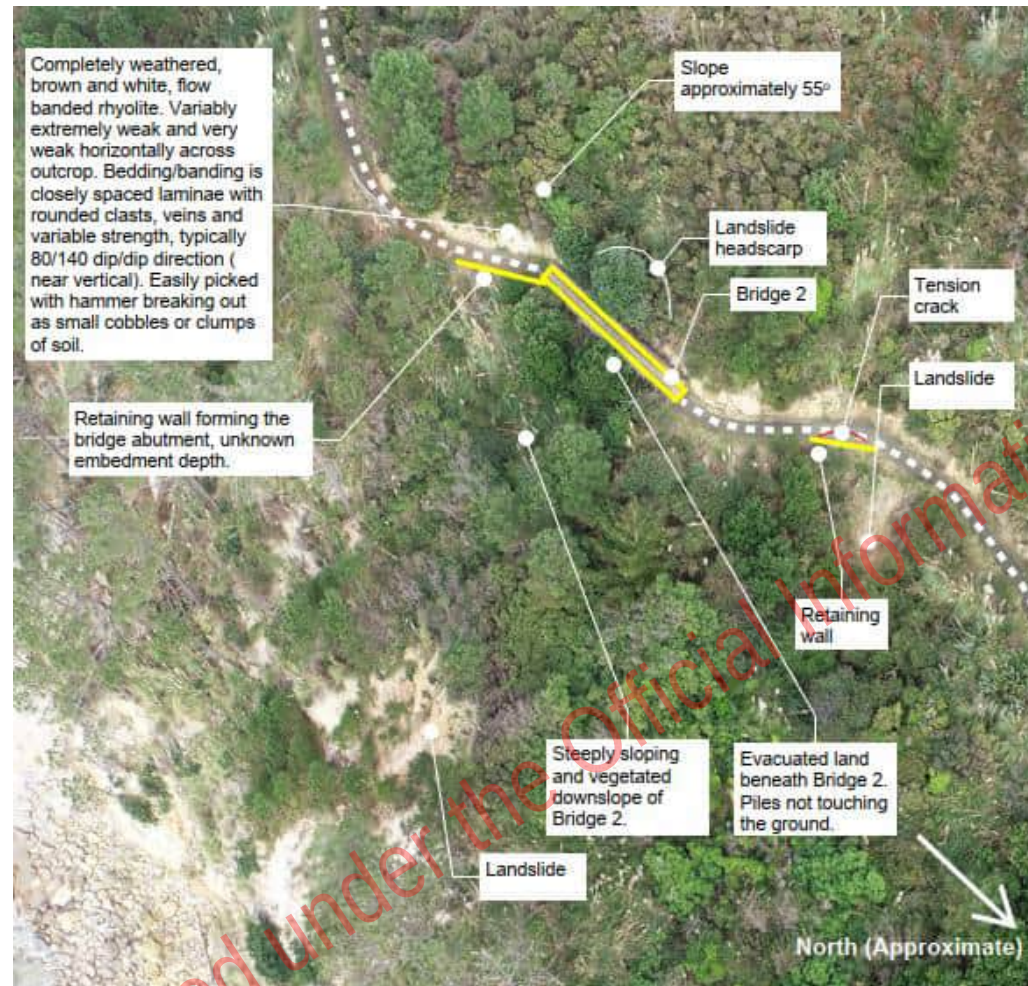
- Potential for future landslides upslope and downslope of the bridge.
- Stability of the bridge abutments and land directly beneath the bridge.

Key uncertainties:

- The embedment depth of the existing retaining wall piles and bridge piles are unknown.
- Ground conditions for the bridge abutments and retaining wall piles.
- Stability of the trees above the bridge.

Option 3a Hahei Beach Short Walk (Sheet 2 of 2, Bridge 2)

Refer Appendix B Figure 4, Sketch Sections 10 to 11.



Anticipated geology:

- Completely weathered to highly weathered andesite exposed at each abutment and headscarp behind the bridge.

Key site features:

- Several landslides located upslope, downslope, and at other locations nearby to the bridge.
- Land slopes steeply above and beneath the bridge towards the east.
- A small retaining wall forms part of the southern bridge abutment.

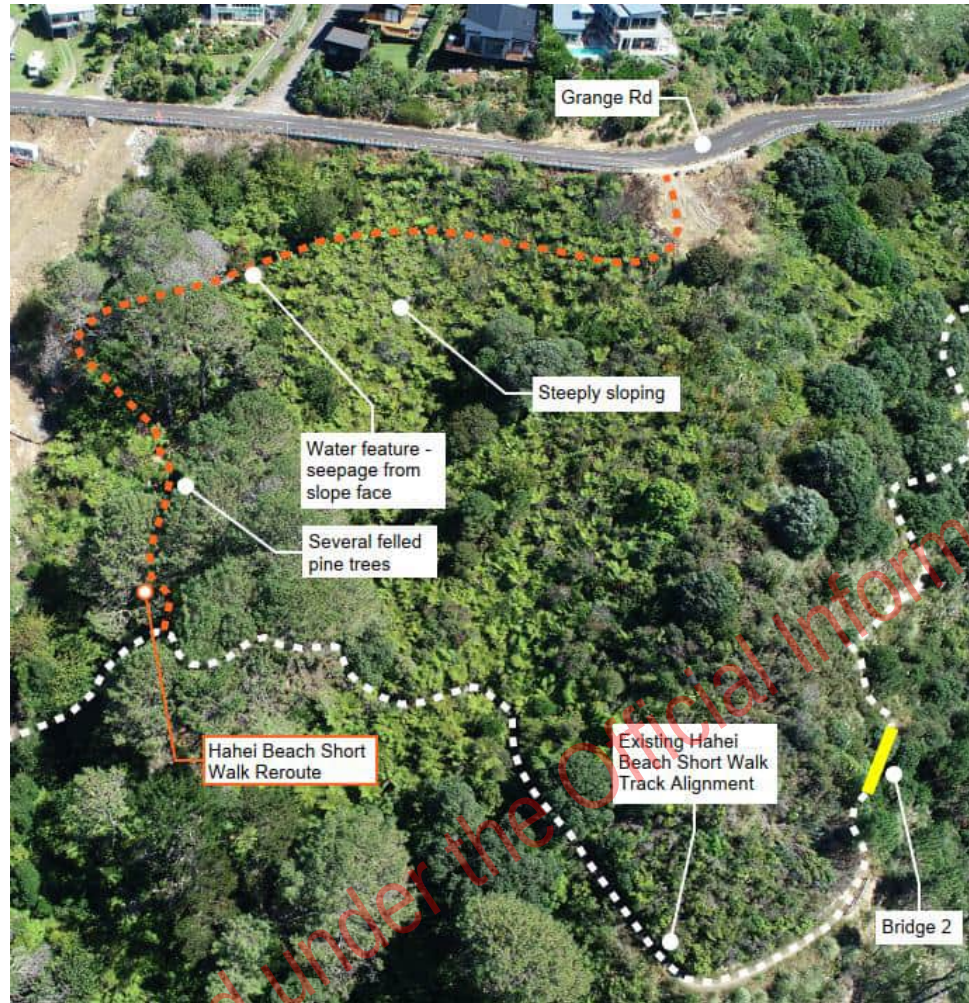
Key geotechnical hazards:

- The bridge piles are not touching the ground. Unclear if this was an intended design or due undermining from past landslides.
- Steeply sloping land at each abutment.
- Potential for future landslides upslope and downslope of the bridge.

Key uncertainties:

- The embedment depth of the existing retaining wall piles is unknown.
- Ground conditions of the bridge abutments.
- Stability of the land above the bridge.
- Stability of the downslope area from the bridge.

Option 3b Hahei Beach Short Walk Reroute



Anticipated geology:

- Topsoil and possibly weathered rhyolite. No soil/rock exposures present along proposed route to determine.

Key site features:

- Several overturned pine trees located near the lower part of the track. Existing pine trees growing in along the route.
- Seepage area observed from the slope face crossing the track alignment.

Key geotechnical hazards:

- Parts of the reroute track alignment are on steeply sloping areas with some potential for future landslides (relatively less concerning than at other track option locations).
- Pine trees overturning.

Key uncertainties:

- While ground conditions are unknown, proposed track comprises relatively low risk structures such as box steps i.e., understanding ground conditions is not critical.

6 Feasibility assessment

6.1 General

A geotechnical feasibility assessment is provided for each option in the subsequent sections. Key considerations we discuss include the following.

- Land stability;
- Ground conditions for foundations (where applicable);
- Constructability; and
- Mitigation solutions to address these potential issues.

6.2 Resilience and design criteria

We understand that DOC wish to have a resilient solution to enable access to Cathedral Cove beach and they have defined resilience as '*secure access with minimal ongoing intervention*'³. Adopting this approach, the following assumptions have informed our assessment.

- 1 Regular tracks and box steps are easily replaced and are relatively low value which are not required to be as resilient to land instability as higher value structures such as staircase/towers and bridges. Land instability around these lower value items is tolerable by DOC and in keeping with many of sections of the existing Cathedral Cove track (and other similar tracks managed by DOC).
- 2 Proposed new stair structures and bridge foundations (i.e., Option 2b(i)/(ii) and Option 3a) need to be designed appropriately and have an appropriate level of resilience to potential land instability.
- 3 Potential for significant land instability upslope of these structures may need to be stabilised to prevent structure damage from landslide debris.
- 4 Other areas of the Cathedral Cove track outside of the 'options' requested by DOC are not considered as part of this feasibility assessment.
- 5 'Short term' solutions (i.e., Option 2a) are intended to last approximately one to two years. We understand DOC is accepting that land instability may damage the 'short term' solutions during their intended design life.
- 6 'Long term' solutions are intended to last approximately 25 to 50 years (subject to final agreed design criteria and notwithstanding extreme events outside or larger than the design criteria).

6.3 Management of surface water

For all options and mitigation solutions discussed below, it is recommended that appropriate surface water management is designed and constructed. This should include appropriately designed track grades, channels, culverts and drainage chutes conveying water down the slope and away from the track, considering downstream affects.

2023 storms appeared to affect the entire beach except for the higher ground at the base of the cliffs where the staircase/towers are proposed.

- 2 Excavatability of ignimbrite rock is expected to be relatively easy however harder rhyolite or andesite boulders were observed within landslide debris. Large boulders of harder rock would be difficult to excavate.

6.7 Option 3a Hahei Short Walk

We understand that Option 3a proposed to replace two bridges, termed Bridge 1 and Bridge 2. These are further discussed in the tables below.

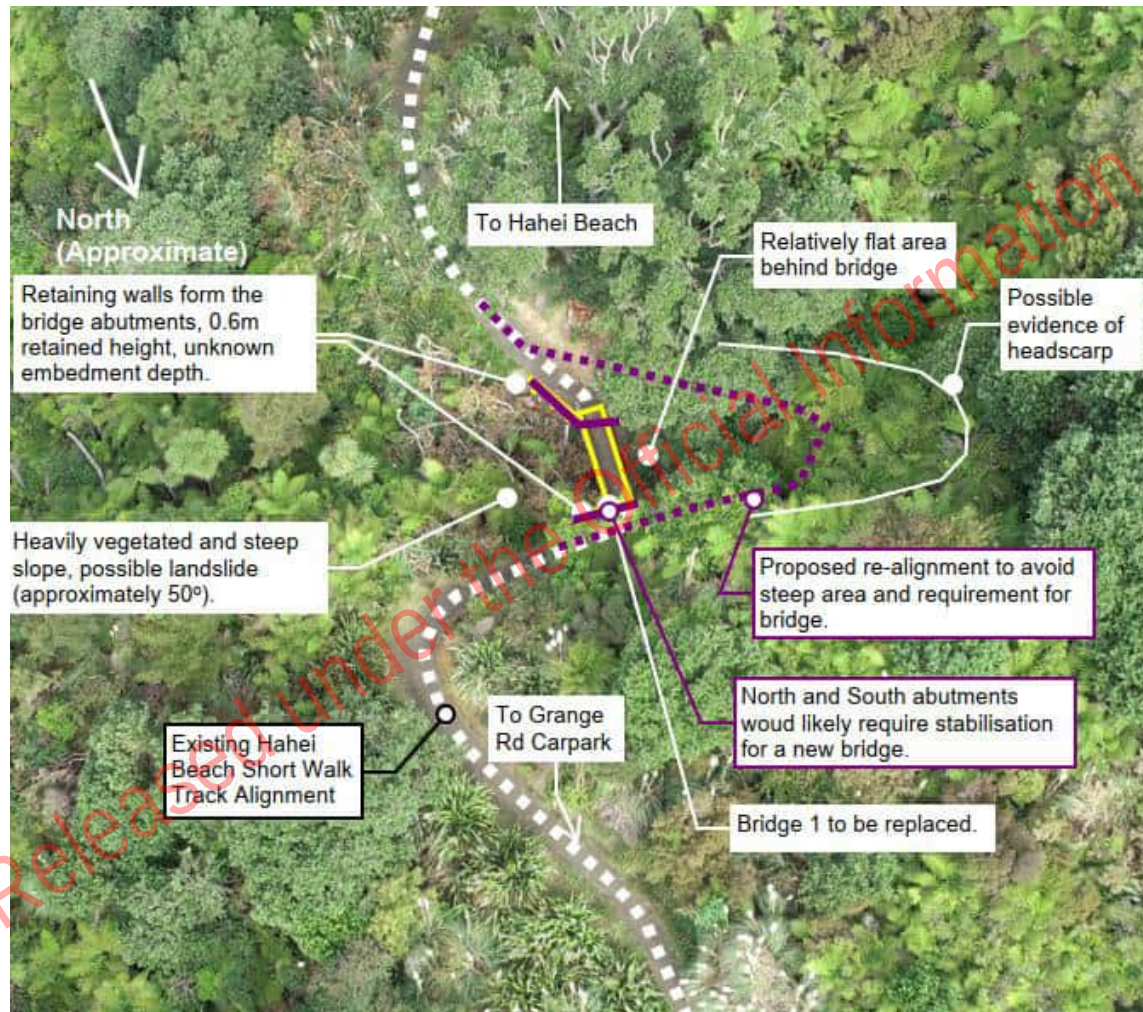


Figure 6.5: Key geotechnical feasibility features of Bridge 1.

Table 6.4: Geotechnical feasibility assessment Bridge 1

Structure	Bridge 1
Key Geotechnical hazards	• Potential for future landslides upslope and downslope of the bridge. • Stability of the bridge abutments and land directly beneath the bridge. • Existing retaining wall design, age and pile embedment depth.
Proposed mitigations and abutment foundations	• Alternative route. We have identified a short alternative route behind the existing bridge which would avoid the existing steep area requiring bridging. This option would not require construction of a bridge or stabilisation measures. • If a new bridge is required, the need to consider stabilisation as the abutments are near a steep slope. Options could include the following: – Utilise the existing retaining wall if design/construction information can be provided by DOC and is assessed suitable for a new bridge. – Design new pile foundations to resist potential lateral loads. – Stabilise the abutments with additional measures such as replacing the retaining wall or ground anchor stabilisation. Shallow bridge foundations rather than piles could be considered in this case.

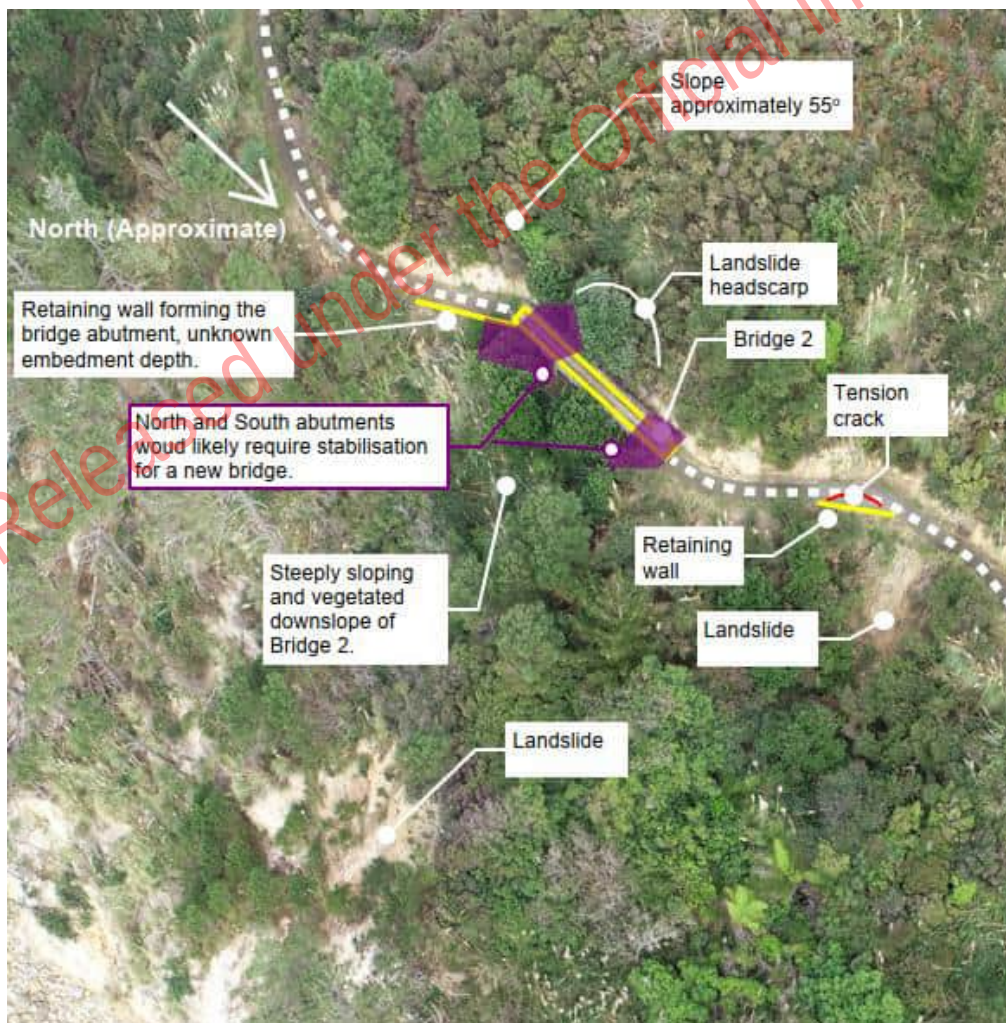


Figure 6.6: Key features of Bridge 2.

Table 6.5: Geotechnical feasibility assessment Bridge 2

Structure	Bridge 2
Key Geotechnical hazards	• Potential for future landslides upslope and downslope of the bridge. • Stability of the bridge abutments and land directly beneath the bridge. • Existing retaining wall design, age and pile embedment depth.
Proposed mitigations and abutment foundations	• Each abutment is likely to require land stabilisation because of the existing landslide likely over steepened the abutment slopes. • Design new pile foundations to resist potential lateral loads. • Stabilise the abutments with additional measures such as ground anchor stabilisation. Stabilisation could include anchors installed in a regular pattern at each abutment. • Mesh could be considered in conjunction with anchors, however initial thoughts are that the ground conditions are relatively hard/strong and mesh may not be required. • We have not considered the current condition of the existing retaining wall on the southern abutment. This wall could potentially be left in place (if ground anchors were installed).

6.8 Option 3b Hahei Beach Short Walk Reroute

The proposed reroute does not include any critical structures such as staircases or bridges. The land is typical of the steep coastal hills in the area which are prone to land sliding.

Provided DOC are accepting of potential land instability (similar to many other sections of the cathedral cove track) then further land stabilisation or geotechnical design of structures are unlikely to be required. This assumption should be reviewed by DOC and geotechnical designers at future project stages as the track design develops.

Large pine trees could be felled to reduce deadfall and potential overturning.

6.9 Ground anchorages and mesh stabilisation

Ground anchorages are proposed for several of the mitigation solutions discussed in Section 6.3. Mesh is proposed for Option 2b also. Based on site mapping and exposed soil/rock outcrops and our experience using ground anchors in similar conditions we have considered this approach could be appropriate.

A summary of key considerations relevant to this feasibility assessment are listed below.

- 1 Soil nail, rock bolt and rock dowel anchorages would be utilised, depending on ground conditions and purpose. Each of these anchorage types broadly use the same materials and differ in installation detail.
- 2 64 mm diameter holes are preferred which can be drilled using handheld drills enabling a high level of efficiency and mobility across the site. Larger hole diameters are not preferred for this site as these may require larger drilling plant (i.e., wire mounted drill rigs), increasing cost and vegetation clearance.
- 3 Exact bar type and lengths will need to be determined and key considerations will include proposed design loads and corrosion resistance. We have assumed 6 m bars for the cost estimate, which are the manufactured lengths. Bars longer than 6 m become difficult to manage on site by hand, increasing installation time and cost.
- 4 Installation of these types of anchorages can be achieved in hard to access and remote locations and are well suited to the terrain at Cathedral Cove.

- 5 Anchorage spacing has not been determined and will be informed by specific design. Typically, anchors are installed in a regular pattern of around 1 m to 3 m spacings, or as spot bolts for specific areas of potentially unstable rock.
- 6 Pull out test investigations would be required to confirm achievable strengths in the site conditions, informing design.
- 7 Mesh (in conjunction with anchorages) is proposed on the slope above Option 2b staircase/towers to help stabilise the soil/rock on the slope crest, reduce surface erosion, and promote small vegetation growth. Mesh sizing has not been undertaken and would need to be considered along with cable sizing.
- 8 Prior to anchorage and mesh installation scaling of loose rock, debris and vegetation would be required.
- 9 Vegetation clearance would typically include scrub, large plants and unwanted trees. Important large trees, such as Pōhutukawa, could remain if required, however there may be a reduction in stability in these areas (Depending on the stability of the tree).



Figure 6.7: Photograph of ground anchorages and Macmat-R mesh during construction at Omanawa Falls. (Source: T+T).

7 Monitoring and maintenance

Maintenance and monitoring of geotechnical stabilisation works will be required and will depend on the final design. Typically ground anchorages and mesh will require annual or two-yearly monitoring 'check up', whereby signs of corrosion and damage are identified and repaired if required. A maintenance manual is normally undertaken as part of detailed design which provides a detailed maintenance schedule.

Monitoring of landslides and signs of instability is recommended across the wider Cathedral Cove site, and at the preferred option locations. The frequency of monitoring may depend on a number of environmental and design considerations which will be determined at later project stages. Typically it may be in the order of annual inspections, and following significant storm or earthquake events. Currently the Cathedral Cove Arch is monitored approximately twice a year which could also continue.

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8 Rough order cost estimate and duration estimate

Rough order cost estimates have been undertaken for relevant geotechnical stabilisation measures and are summarised in the following tables in this report section.

We have engaged with experienced geotechnical stabilisation contractor Avalon Industrial Services Ltd to help prepare the estimates of physical construction works and anchor pullout testing.

The cost estimates have been undertaken to help provide DOC with an indication of possible costs and to compare costs between the various Options. No ground investigations or design has been undertaken to inform the cost estimates and therefore there is a high degree of uncertainty. A 50 % contingency has been applied to the construction cost estimate.

Each option has been estimated as though it was undertaken on its own i.e., we have not allowed for potential efficiency between the different Options. There would likely be programme and cost efficiency if some work stages of the proposed Options are undertaken at the same time (e.g., investigation and design).

Subsequent project stages should aim to revise these estimates.

A duration of each project stage is provided also. The physical stabilisation works would likely need to be undertaken prior to construction of the associated structures, with some works potentially being undertaken concurrently. This may have some effect on the construction programme estimates outlined in Frame Group's assessment⁴.

Table 8.3: Option 3a construction cost summary

Option 3a			
- Slope stabilisation of each bridge abutment for both bridges: Regular pattern anchorages below each abutment.			
Project stage	Cost estimate	Duration estimate	Comments
Concept stage anchor investigations	\$39,000	1 Month	1 no anchor pullout tests (1 in rock).
Shallow investigations for shallow bridge foundations.	\$10,000	Concurrent with above	Up to 4 no hand auger boreholes.
Concept design	\$20,000	1 Month	
Detailed design	\$15,000	2 Month	
Construction	\$130,000	1 Month	Includes both bridges. Subtract \$50,000 if undertaking bridge 2 only.
50 % contingency margin on construction costs	\$65,000		
Construction supervision	\$24,000	Concurrent with above	
Total	\$303,000	5 Months	
Construction cost breakdown			
Establishment and mobilisation	\$5,000		
Labour, plant and access gear	\$80,000		
Project management and accommodation	\$15,000		
Materials	\$20,000		
Quality grout and anchor testing	\$10,000		
Total	\$130,000		

8.1 Cost estimate assumptions and limitations

Key assumptions and limitations of our cost estimate are provided below.

- 1 Cost estimates are based on our initial feasibility assessment and consideration to works that may be required. Estimates are anticipated to be revised following investigation and design stages.
- 2 No allowance has been made for material cost escalation.
- 3 No allowance has been made for the following items.
 - Vegetation clearance – physical works and obtaining permission.
 - Consenting, evidence preparation or attending hearings.
 - Archaeological investigation.
 - Cultural engagement.

- Structure foundations. We have assumed that these are covered in the Frame Group cost estimate.
 - Ongoing maintenance.
- 4 The construction costs for this rough order cost estimate is based on assumed concepts, estimated quantities and early contractor involvement based on their understanding of the site and project.
 - 5 Consequently, a significant margin of uncertainty exists on the cost estimate and the contingency we have allowed should be considered as part of the cost rather than a potential add on.
 - 6 In particular, we have not made any attempt to allow for the potential impact of COVID-19 in this estimate. Also, supply chain disruptions are currently having quickly-changing effects on construction costs and schedules. We recommend you seek up-to-date specialist economic advice on what budgetary allowances you should make for escalation, including for any potential changes in construction costs and timing in relation to both COVID-19 and supply-chain issues.
 - 7 We have not applied contingency on other items within the cost estimates and we recommend DOC apply a contingency that is commensurate with cost estimates for other project components that they have received and in line with the project cost risk they wish to adopt at this stage.
 - 8 Duration estimates and rough order only and assume favourable conditions and weather. No allowance or contingency for delays has been allowed for.

9 Landslide risk assessment

9.1 General

A landslide risk assessment has been undertaken of the proposed track options following a similar methodology of our 2023 risk assessment report².

The risk assessment has considered the proposed re-alignment routes, and additional landslide information from monitoring undertaken since our 2023 assessment.

9.2 Methodology

The landslide analysis follows the general method outlined in our 2023 Basic Level Landslide Risk Assessment report² (2023 Risk Report) which is based on the Natural Hazard Risk Analysis guidelines⁵ (Parts 1 to 4) (NHRA) developed by GNS Science for DoC. For detailed discussion on the methodology refer to these reports and guidelines.

Key steps relevant to this assessment include the following.

- 1 Undertake site inspections recording key site features and evidence of landslides (refer the 2024 monitoring⁶).
- 2 Update the landslide inventory with new information since our 2023 assessment.
- 3 Undertake a Basic Level Geotechnical Risk Assessment for the new track options routes, and the Cathedral Cove Arch.

9.3 Risk assessment

9.3.1 General

Details of the risk assessment analysis and relevant tables are provided in Appendix C. A short summary of key parameters used are provided in the subsequent sections.

9.3.2 Landslide inventory

The site wide landslide inventory has been updated with 2024 observations. The landslide inventory is intended to be provided in a separate monitoring report and is not repeated in this report. Overall, the 2024 observations to date have shown that:

- 11 new landslide, rockfall or creep features have been observed during the 2024 monitoring.
- Four existing features were observed to have additional or larger tension cracks near the landslide/creep headscarps.
- Of the 11 new features, four of these are relatively small (<1 m³ volume) rockfall within the Cathedral Cove Arch. The remaining seven are rockfall, creep and landslides.
- Two of these features were likely associated with the 2023 event but not observed during the initial mapping.

⁵ de Vilder SJ, Massey CI, Power WL, Burbidge DR, Deligne NI, Leonard GS. 2020. Guidelines for natural hazard risk analysis – Part 1: risk analysis framework. Lower Hutt (NZ): GNS Science. 22 p. Consultancy Report 2020/50.

⁶ Email report from T+T 9(2)(a) to Josh Angell (DoC), Subject: February 2024 Monitoring update.

Table 9.1: Landslide inventory summary over the mapping area

Landslide Type	Count
Rockfall	37
Landslide	142
Creep	12
Total	191

9.3.3 Landscape units

No changes to the mapped landscape unit's extent have been undertaken except for subdivision of the Coastal Hills unit into three landscape units: Saddle, Coastal Hills 1 and Coastal Hills 2. This subdivision has been undertaken to help differentiate the landslide hazard between these three areas which are now particularly relevant for DOC and their assessment of the route Options. The mapped extent of the landscape units is presented in Figure 6 in Appendix B. The subdivision of these landscape units has been carried through the risk assessment analysis and calculations.

The recent monitoring has identified new landslide/rockfall events, which in turn has affected parameters for the Cove Arch, Beach and Escarpment landscape units. This has been factored into the new analysis.

Refer to our 2023 risk assessment report² for further details of the landscape units used in the assessment.

9.3.4 Track Sections

The proposed track Option alignments have been divided into new 'Track Sections' to be used for this assessment. These track sections are presented in Figure 6 in Appendix B and listed below.

- Option 2a: Track Sections 22;
- Option 2b(i): Track Sections 11, 23, 24, 25, 28 and Track 12 (2bi);
- Option 2b(ii): Track Sections 24, 25, 26, 27, 28;
- Option 3a: Track Section 01, 21; and
- Option 3b: Track Section 29 and Track 01 (3b).

9.3.5 Analysis

Analysis tables are presented in Appendix C1. Methodology and assumptions related to the analysis is discussed in detail in our 2023 report².

9.4 DoC risk thresholds for Annual Individual Fatality Risk and visitor risk.

DoC risk tolerance levels for are presented in Table 9.2 and Table 9.3 based on provided guidance⁷. DoC have different risk tolerance levels for different types of tracks/sites e.g., a back country track has a higher risk tolerance level than a gentle walking track easily accessible to the public.

We understand that DoC use these risk tolerance levels in comparison to the calculate risk metrics to inform their decision making. DoC have specified that the entire track within study site should be considered a 'Lower Risk Site' category, i.e., this is the lowest tolerance for risk within DoC's thresholds.

⁷ Department of Conservation (14 June 2021) *Risk threshold levels for DOC visitor sites*.

Table 9.2: Individual visitor one trip risk threshold. DoC have specified that the entire site should be considered a Lower Risk Site, i.e., DoC have a low tolerance to risk for this site.

Action Required	Lower Risk site	Medium Risk Site	Higher Risk Site
Halt until risk reduced.	$> 10^{-5}$	$> 3 \times 10^{-5}$	$> 10^{-4}$
Continue only after high level review.	$> 10^{-6}$	$> 3 \times 10^{-6}$	$> 3 \times 10^{-5}$
Explore practicable risk reduction options.	10^{-7} to 10^{-6}	3×10^{-7} to 3×10^{-6}	3×10^{-6} to 3×10^{-5}
Explore practicable risk reduction options (lower priority)	n/a	10^{-7} to 3×10^{-7}	3×10^{-7} to 3×10^{-6}
Monitor situation.	$< 10^{-7}$	$< 10^{-7}$	$< 3 \times 10^{-7}$

Table 9.3: Person most at risk (DoC staff)

Action	Annual Fatality Risk For staff regularly exposed to natural hazards	Daily Fatality Risk For one off or occasional exposure to natural hazards
Halt until risk reduced.	$> 3 \times 10^{-4}$	$> 3 \times 10^{-5}$
Continue only after high level review.	$> 10^{-4}$	$> 3 \times 10^{-6}$
Explore practicable risk reduction options.	10^{-5} to 10^{-4}	3×10^{-7} to 3×10^{-6}
Explore practicable risk reduction options (lower priority).	10^{-6} to 10^{-5}	10^{-7} to 3×10^{-7}
Monitor situation.	$< 10^{-6}$	$< 10^{-7}$

9.5 Risk assessment results

The Annual Individual Fatality Risk (AIFR) has been calculated for an individual member of public visiting the site once in a year (visitor risk) and for a typical DoC worker.

A summary of the AIFR for various route options are presented in Table 9.4, Table 9.5 and Table 9.6 for an individual member of public visiting the site once in a year. The AIFR has been calculated for each track section which allows AIFR to be considered for the walking trips from Hahei to Cathedral Cove separately.

We have presented the AIFR in terms of the following:

- A full trip from Hahei to Cathedral Cove return, utilising the various proposed Track Options and existing tracks. This considers the AIFR of the total track via the new Track Options.
- Similarly, we have considered a full trip from the Grange Road carpark to Cathedral Cove Return.
- We have also summarised the AIFR of the individual Track Options without including the surrounding tracks. This may help with comparing the AIFR of individual Options i.e., Comparing AIFR of Option 3a with Option 3b or Option 2b(i) vs 2b(ii).

Similar AIFR breakdown has been calculated for DOC workers in Table 9.7.

Similar to our 2023 work, the AIFR assumes that the tracks are undamaged. We have also assumed that land stabilisation works proposed for Option 2b(i) and Option 2b(ii) outlined in Section 6 have been undertaken, i.e., reducing the potential landslide/rockfall hazard.

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Table 9.4: Full Trips - Summary of the Annual Individual Fatality Risk for an individual member of public visiting the site once in a year. Colour codes as per DoC thresholds in Table 9.2.

	Hahei to Cathedral Cove Return (Option 2a and Option 3a)	Hahei to Cathedral Cove Return (Option 2bi and Option 3a)	Hahei to Cathedral Cove Return (Option 2bii and Option 3a)	Hahei to Cathedral Cove Return (Option 3b and Option 2a)	Hahei to Cathedral Cove Return (Option 2bi and Option 3b)
Total Annual Individual Fatality Risk	1.1E-06	1.0E-06	8.6E-07	1.0E-06	9.1E-07
	Comprises the sum of the following sections below:				
Section 01	2.3E-07	2.3E-07	2.3E-07	N/A	N/A
Section 02	1.1E-09	1.1E-09	1.1E-09	1.1E-09	1.1E-09
Section 03	2.8E-08	2.8E-08	2.8E-08	2.8E-08	2.8E-08
Section 04	4.5E-10	4.5E-10	4.5E-10	4.5E-10	4.5E-10
Section 05	N/A	N/A	N/A	N/A	N/A
Section 06	9.9E-10	9.9E-10	9.9E-10	9.9E-10	9.9E-10
Section 07	N/A	N/A	N/A	N/A	N/A
Section 08	1.8E-09	1.8E-09	1.8E-09	1.8E-09	1.8E-09
Section 09	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Section 10	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08
Section 11	5.9E-08	5.9E-08	N/A	5.9E-08	5.9E-08
Section 12	3.1E-07	N/A	N/A	3.1E-07	N/A
Section 13	1.3E-08	N/A	N/A	1.3E-08	N/A
Section 14	3.3E-07	3.3E-07	3.3E-07	3.3E-07	3.3E-07
Section 15	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
Section 16	N/A	N/A	N/A	N/A	N/A
Section 17	N/A	N/A	N/A	N/A	N/A
Section 18	N/A	N/A	N/A	N/A	N/A
Section 19	N/A	N/A	N/A	N/A	N/A
Section 20	N/A	N/A	N/A	N/A	N/A
Section 21	3.5E-10	3.5E-10	3.5E-10	3.5E-10	3.5E-10
Point Location 1 (Bench)	5.6E-09	N/A	N/A	5.6E-09	N/A
Section 22	Refer track Section 12. Note 1.	N/A	N/A	N/A	N/A
Section 23	N/A	2.1E-08	N/A	N/A	2.1E-08
Section 24	N/A	2.4E-10	2.4E-10	N/A	2.4E-10
Section 25	N/A	2.4E-08	2.4E-08	N/A	2.4E-08
Section 26	N/A	N/A	2.7E-08	N/A	N/A
Section 27	N/A	N/A	3.0E-08	N/A	N/A
Section 28	N/A	2.1E-08	2.1E-08	N/A	2.1E-08
Section 29	N/A	N/A	N/A	5.5E-08	5.5E-08
Section 30	4.0E-09	4.0E-09	4.0E-09	4.0E-09	4.0E-09
Section 01 (3b)	N/A	N/A	N/A	5.2E-08	5.2E-08
Section 12 (2bi)	N/A	1.5E-07	N/A	N/A	1.5E-07
Note 1: Section 12 has been adopted for Section 22 AIFR because Section 22 has a very similar alignment and length as the existing track Section 12, i.e. same risk profile.					

Table 9.5: Individual Options 1 – Summary of the Annual Individual Fatality Risk for an Individual member of public visiting the site once in a year. Colour codes as per DOC thresholds in Table 9.2

	Grange Road Carpark to Cathedral Cove Return (Option 2a)	Grange Road Carpark to Cathedral Cove Return (Option 2bi)	Grange Road Carpark to Cathedral Cove Return (Option 2bii)	-	-
Total Annual Individual Fatality Risk	9.1E-07	8.1E-07	6.3E-07	-	-
	Comprises the sum of the relevant sections listed in Table 9.4, i.e., doesn't include Section 1, Section 1 3b, Section 21 and Section 29.				

Table 9.6: Individual Options 2 - Summary of the Annual Individual Fatality Risk for an individual member of public visiting the site once in a year. Colour codes as per DoC thresholds in Table 9.2.

	Option 2a from Section 11	Option 2b(i) from Section 11	Option 2b(ii) from Section 27	Option 3a from Hahei Beach	Option 3b from Hahei Beach
Total Annual Individual Fatality Risk	3.8E-07	2.8E-07	1.0E-07	2.3E-07	1.1E-07
	Comprises the sum of the following sections below:				
Section 01	N/A	N/A	N/A	2.3E-07	N/A
Section 02	N/A	N/A	N/A	N/A	N/A
Section 03	N/A	N/A	N/A	N/A	N/A
Section 04	N/A	N/A	N/A	N/A	N/A
Section 05	N/A	N/A	N/A	N/A	N/A
Section 06	N/A	N/A	N/A	N/A	N/A
Section 07	N/A	N/A	N/A	N/A	N/A
Section 08	N/A	N/A	N/A	N/A	N/A
Section 09	N/A	N/A	N/A	N/A	N/A
Section 10	N/A	N/A	N/A	N/A	N/A
Section 11	5.9E-08	5.9E-08	N/A	N/A	N/A
Section 12	3.1E-07	N/A	N/A	N/A	N/A
Section 13	1.3E-08	N/A	N/A	N/A	N/A
Section 14	N/A	N/A	N/A	N/A	N/A
Section 15	N/A	N/A	N/A	N/A	N/A
Section 16	N/A	N/A	N/A	N/A	N/A
Section 17	N/A	N/A	N/A	N/A	N/A
Section 18	N/A	N/A	N/A	N/A	N/A
Section 19	N/A	N/A	N/A	N/A	N/A
Section 20	N/A	N/A	N/A	N/A	N/A
Section 21	N/A	N/A	N/A	3.5E-10	3.5E-10
Point Location 1 (Bench)	N/A	N/A	N/A	N/A	N/A
Section 22	Refer track Section 12	N/A	N/A	N/A	N/A
Section 23	N/A	2.1E-08	N/A	N/A	N/A
Section 24	N/A	2.4E-10	2.4E-10	N/A	N/A
Section 25	N/A	2.4E-08	2.4E-08	N/A	N/A
Section 26	N/A	N/A	2.7E-08	N/A	N/A
Section 27	N/A	N/A	3.0E-08	N/A	N/A
Section 28	N/A	2.1E-08	2.1E-08	N/A	N/A
Section 29	N/A	N/A	N/A	N/A	5.5E-08
Section 30	N/A	N/A	N/A	N/A	N/A
Section 01 (3b)	N/A	N/A	N/A	N/A	5.2E-08
Section 12 (2bi)	N/A	1.5E-07	N/A	N/A	N/A

Table 9.7: Summary of the Annual Individual Fatality Risk for DoC worker visiting the site three times per week for 40 weeks in a year. Colour codes as per DoC thresholds in Table 9.3.

	Hahei to Cathedral Cove Return (Option 2A and 3A)	Hahei to Cathedral Cove Return (Option 2bi and Option 3a)	Hahei to Cathedral Cove Return (Option 2bii and Option 3a)	Hahei to Cathedral Cove Return (Option 2bi and Option 3b)
Total Annual Individual Fatality Risk	1.4E-04	1.2E-04	1.0E-04	1.1E-04
Section 01	2.7E-05	2.7E-05	2.7E-05	N/A
Section 02	1.3E-07	1.3E-07	1.3E-07	1.3E-07
Section 03	3.4E-06	3.4E-06	3.4E-06	3.4E-06
Section 04	5.4E-08	5.4E-08	5.4E-08	5.4E-08
Section 05	N/A	N/A	N/A	N/A
Section 06	1.2E-07	1.2E-07	1.2E-07	1.2E-07
Section 07	N/A	N/A	N/A	N/A
Section 08	2.2E-07	2.2E-07	2.2E-07	2.2E-07
Section 09	1.7E-06	1.7E-06	1.7E-06	1.7E-06
Section 10	1.4E-06	1.4E-06	1.4E-06	1.4E-06
Section 11	7.1E-06	7.1E-06	N/A	7.1E-06
Section 12	3.7E-05	N/A	N/A	N/A
Section 13	1.6E-06	N/A	N/A	N/A
Section 14	4.0E-05	4.0E-05	4.0E-05	4.0E-05
Section 15	1.6E-05	1.6E-05	1.6E-05	1.6E-05
Section 16	N/A	N/A	N/A	N/A
Section 17	N/A	N/A	N/A	N/A
Section 18	N/A	N/A	N/A	N/A
Section 19	N/A	N/A	N/A	N/A
Section 20	N/A	N/A	N/A	N/A
Section 21	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Point Location 1 (Bench)	N/A	N/A	N/A	N/A
Section 22	Refer track Section 12	N/A	N/A	N/A
Section 23	N/A	2.5E-06	N/A	2.5E-06
Section 24	N/A	2.8E-08	2.8E-08	2.8E-08
Section 25	N/A	2.9E-06	2.9E-06	2.9E-06
Section 26	N/A	N/A	3.2E-06	N/A
Section 27	N/A	N/A	3.5E-06	N/A
Section 28	N/A	2.6E-06	2.6E-06	2.6E-06
Section 29	N/A	N/A	N/A	6.6E-06
Section 30	4.8E-07	4.8E-07	4.8E-07	4.8E-07
Section 01 (3b)	N/A	N/A	N/A	6.2E-06
Section 12 (2bi)	N/A	1.8E-05	N/A	1.8E-05

9.6 Risk assessment discussion and summary

A comparison of DoC's thresholds (Section 9.4) and the estimated Annual Individual Fatality Risk (Table 9.4 and Table 9.6) for visitors is illustrated in Figure 9.1. The horizontal scale in Figure 9.1 is logarithmic, which helps to visualise large changes in AIFR but smaller changes, e.g., within one order of magnitude, will appear condensed. It is worthwhile reviewing both the table results and this figure. The comparison highlights the following:

- All proposed Options have broadly similar risk profiles when considering the full route from Hahei to Cathedral Cove Return. Option 2b(i or ii) has the lowest AIFR when combined with Option 3b, of the options considered. See Table 9.4.
- The AIFR results indicate that the long term 2b(i)/3b, and 2b(ii)/3a or 3b options, or starting the walk to Cathedral Cove from the Grange Road carpark all fall within the 'Moderate' risk category and DOC guidance is to '*Reduce to as low as reasonably practicable*'. For the other cases DOC guidance recommends '*Continue only after high level review*'. See Table 9.4 and Section 9.4. The AIFR results for the long-term full trip options are very close to the boundary between these two risk categories and DOC should consider that there is likely some uncertainty in the AIFR metrics.
- Comparing individual track options only (i.e., not the full trip), Option 3b reduces the AIFR compared with Option 3a (AIFR of Option 3a is twice that of Option 3b). Option 2b(i or ii) reduces the AIFR compared with Option 2a. See Table 9.6.
- AIFR results for DOC workers most at risk, indicates DOC guidance is to '*Continue only after high level review*'. However, the AIFR calculation does not factor that DOC workers avoid the track during and after heavy rainstorms, where landslides are more likely to occur, and it is likely that the actual exposure is lower than that estimated.

The risk metrics do not consider that the track is less used during large rainfall events which are more likely to trigger landslide/rockfall. The 2023 Report identified a reduction in visitor numbers when wet and therefore the metrics may be conservative in this respect.

The risk estimates have been undertaken at a site wide scale, considering individual track sections and relevant hazard metrics where possible. The estimates do not consider that multiple sections of the track are currently damaged. These damaged track sections are more hazardous than the risk estimates presented, and mitigations are recommended prior to opening the track.

Land stabilisation mitigation for Option 2b(i and ii) has been assumed for Section 24 of the risk assessment. We accounted for the proposed stabilisation by reducing the Probability of landslide/rockfall occurrence (P_L) by 90 %. This reduction is not based on any specific analysis and is applied only to test sensitivity of the AIFR to this parameter. The AIFR for Track Section 24 was reduced by approximately one order of magnitude as a result. However, this reduction in P_L did not materially change the overall AIFR totals for the relevant Options. The reduction in P_L is for the purpose of this specific risk assessment and should not be taken out of context for other purposes.

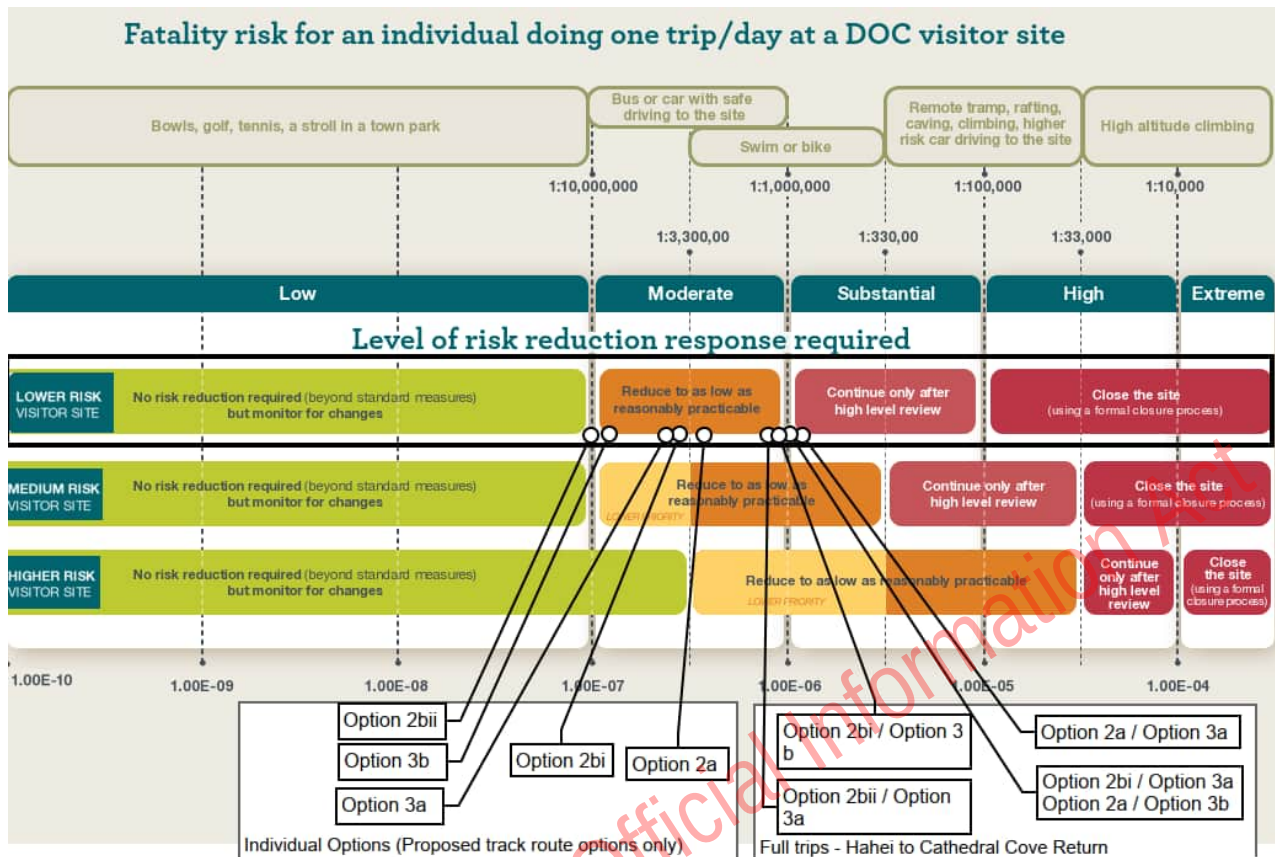


Figure 9.1: DoC visitor site risk levels and the estimated annual individual fatality risks from this assessment. After DoC⁸.

9.7 Societal risk

9.7.1 General

Societal risk has been calculated in terms of the likelihood of one or more fatalities per annum, five or more fatalities per annum and a worst-case scenario, following guidance in NHRA Part 3 and Part 4.

Analysis tables are presented in Appendix C1. Methodology and assumptions related to the analysis is discussed in detail in our 2023 report².

9.7.2 DoC risk thresholds for societal risk

DoC risk tolerance levels for societal risk are presented in Table 9.8 based on provided guidance⁹. DoC have provided guidance for events with five or more fatalities only.

We understand that DoC use these risk tolerance levels in comparison to the calculated risk metrics to inform their decision making.

⁸ Department of Conservation (undated) *DOC Natural Hazard Risk Threshold Chart*, DoC Document no. 7524999.

⁹ Department of Conservation (14 June 2021) *Risk threshold levels for DOC visitor sites*.

Table 9.8: Societal risk threshold

Action	Annual Fatality Risk For events with 5 or more fatalities
Halt until risk reduced.	$> 10^{-1}$
Continue only after high level review.	10^{-1} to 10^{-2}
Explore practicable risk reduction options.	10^{-2} to 10^{-3}
Explore practicable risk reduction options (lower priority).	10^{-3} to 10^{-4}
Monitor situation.	$< 10^{-4}$

9.7.3 Societal risk results

The results for societal risk metrics are presented in Table 9.9 for each case. These are the sum of the contributing track sections calculated in analysis tables in Appendix C2.

Table 9.9: Societal risk results. Colour codes as per DoC thresholds in Table 9.8

Scenario	Societal risk				
	Hahei to Cathedral Cove Return (Option 2a and Option 3a)	Hahei to Cathedral Cove Return (Option 2b(i) and Option 3a)	Hahei to Cathedral Cove Return (Option 2b(ii) and Option 3a)	Hahei to Cathedral Cove Return (Option 3b and Option 2a)	Hahei to Cathedral Cove Return (Option 2b(i) and Option 3b)
1 or more fatalities	2.6E-02	3.3E-02	2.8E-02	2.7E-02	3.3E-02
5 or more fatalities	6.7E-03	1.0E-02	7.7E-03	7.0E-03	1.0E-02
30 or more fatalities	1.3E-03	1.5E-03	9.0E-04	1.3E-03	1.5E-03

9.7.4 Discussion of societal risk

A comparison of DoC's societal risk thresholds and the societal risk results for events with five or more fatalities indicate DoC should '*Explore practicable risk reduction options*'. This metric is broadly similar to the results of the annual individual risk results discussed in Section 9.6.

A number of assumptions have been made to determine the societal risk regarding event sizes, vulnerability and temporal-spatial probability (refer our 2023 report²). These parameters could be further refined if the Societal Risk values require further assessment.

With this in mind, DoC should consider the estimated risk metrics, their thresholds and determine a mitigation approach in line with their strategy.

10 Summary and recommendations

- 1 Tonkin & Taylor Ltd (T+T) has been engaged¹⁰ by Department of Conservation (DOC) to undertake geotechnical feasibility assessment of proposed track realignments.
- 2 Department of Conservation (DoC) wish to reinstate access to Cathedral Cove beach and to understand what potential mitigations are feasible, in light of the significant track damage and landslides from the 2023 storm events. DoC have engaged with Frame Group to help support the concept design/feasibility of potential track realignment and beach access. DOC have requested T+T to support with geotechnical and landslide hazard considerations.
- 3 Site inspections and mapping of key site features was undertaken on 18 and 19 March, and 9 and 10 April 2024. This mapping was focused on understanding site conditions at the proposed track realignment option locations, identifying geomorphic features and geotechnical hazards and opportunities.
- 4 A number of geotechnical hazards and considerations were identified for each option. These are discussed in Section 5 and typically include landslide and rockfall hazards affecting the land below or around the proposed track options, and in some locations uncertain ground conditions for foundations.
- 5 A geotechnical feasibility assessment is provided for each option in Section 6. Key considerations we discuss include the following.
 - Land stability;
 - Ground conditions for foundations (where applicable); and
 - Constructability.
- 6 Mitigation solution options to address the potential issues are provided in Section 6. Land stabilisation in many situations is likely required to provide adequate resilience and could include ground anchorages. Ground anchorages proposed can likely be installed without the requirement for large machinery allowing a relatively high level of mobility across the site.
- 7 Rough order cost estimates have been undertaken for relevant geotechnical stabilisation measures and include engagement with experienced geotechnical stabilisation contractor Avalon Industrial Services Ltd to help prepare the construction cost estimates. These are presented in Section 8.
- 8 An update to our 2023 landslide risk assessment was undertaken, including landslide monitoring data from 2024 and the proposed track options. The assessment identified the following.
 - All proposed Options have broadly similar risk profiles when considering the full route from Hahei to Cathedral Cove Return. Option 2b(i or ii) has the lowest AIFR when combined with Option 3b.
 - The AIFR results indicate that the long term 2b(i)/3b, and 2b(ii)/3a or 3b options, or starting the walk to Cathedral Cove from the Grange Road carpark all fall within the 'Moderate' risk category and DOC guidance is to '*Reduce to as low as reasonably practicable*'. For the other cases DOC guidance recommends '*Continue only after high level review*'. See Table 9.4 and Section 9.4. The AIFR results for the long-term full trip options are very close to the boundary between these two risk categories and DOC should consider that there is likely some uncertainty in the AIFR metrics.
- 9 Recommendations for DOC include the following:

¹⁰ Tonkin & Taylor Ltd (4 March 2024) *Letter of Engagement Cathedral Cove: Feasibility Assessment*, Ref: 1007838.4000. Prepared for Department of Conservation.

- DOC determine the level of resilience required for each track option and adopt a mitigation approach in line with the cost and residual risk DOC are willing to accept i.e., decide which track option and mitigation approach is preferred;
- Geotechnical investigations are undertaken for relevant selected track options and that these are undertaken as early as possible to inform subsequent project stages; and
- Relevant stabilisation and geotechnical design is continued with close collaboration with structural designs and DOC.

Released under the Official Information Act

11 Applicability

This report has been prepared for the exclusive use of our client Department of Conservation, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:

Authorised for Tonkin & Taylor Ltd by:

9(2)(a)

9(2)(a)

9(2)(a)

Engineering Geologist

9(2)(a)

Senior Engineering Geologist

9(2)(a)

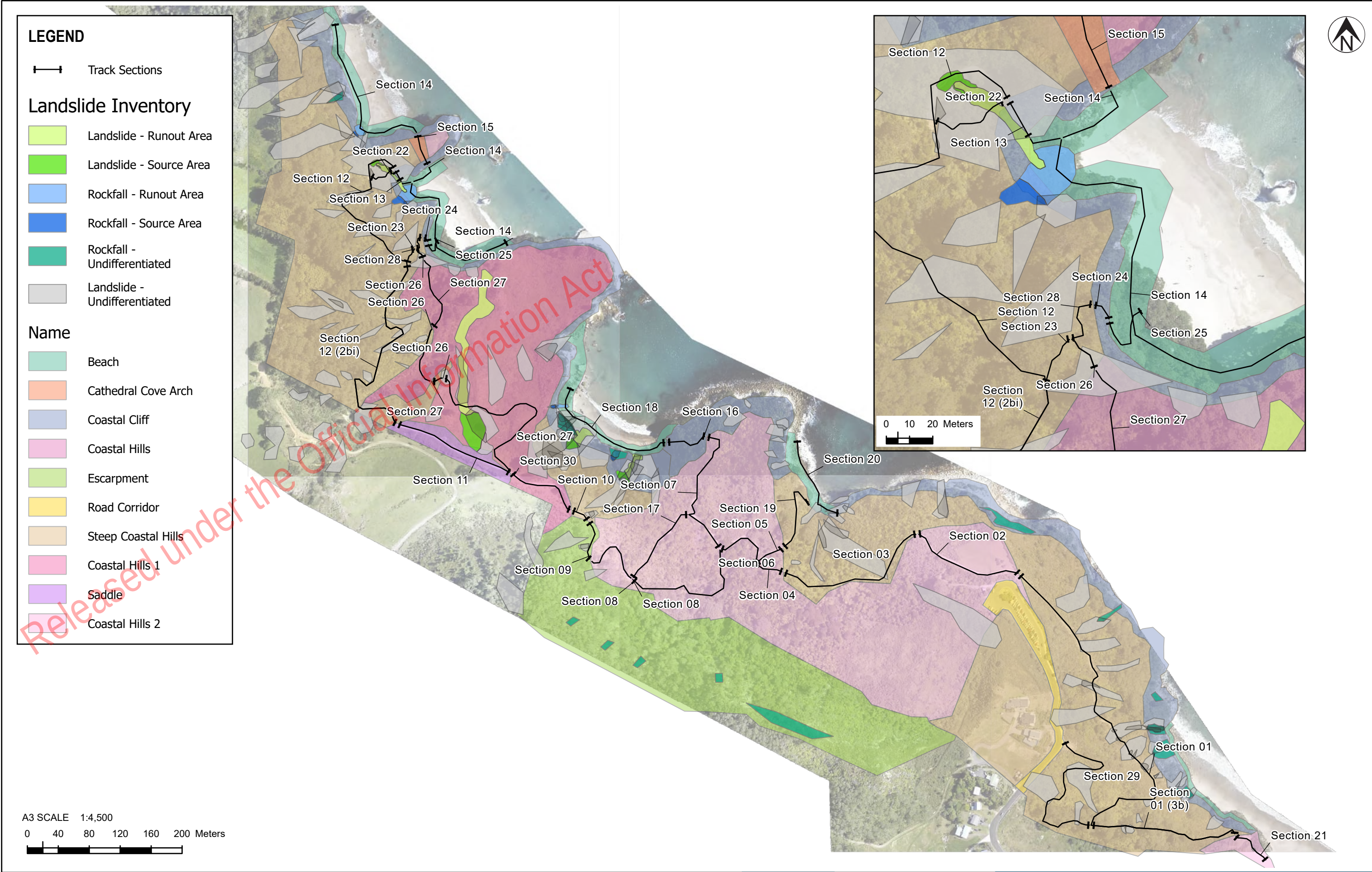
9(2)(a)

Project Director

Technical review undertaken by 9(2)(a) – Principal Geotechnical Engineer

HAMC

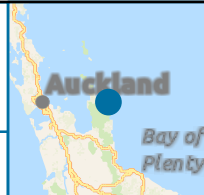
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NOTES:
Basemap NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.
Refer T+T 2023 and 2024 reports for further information

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

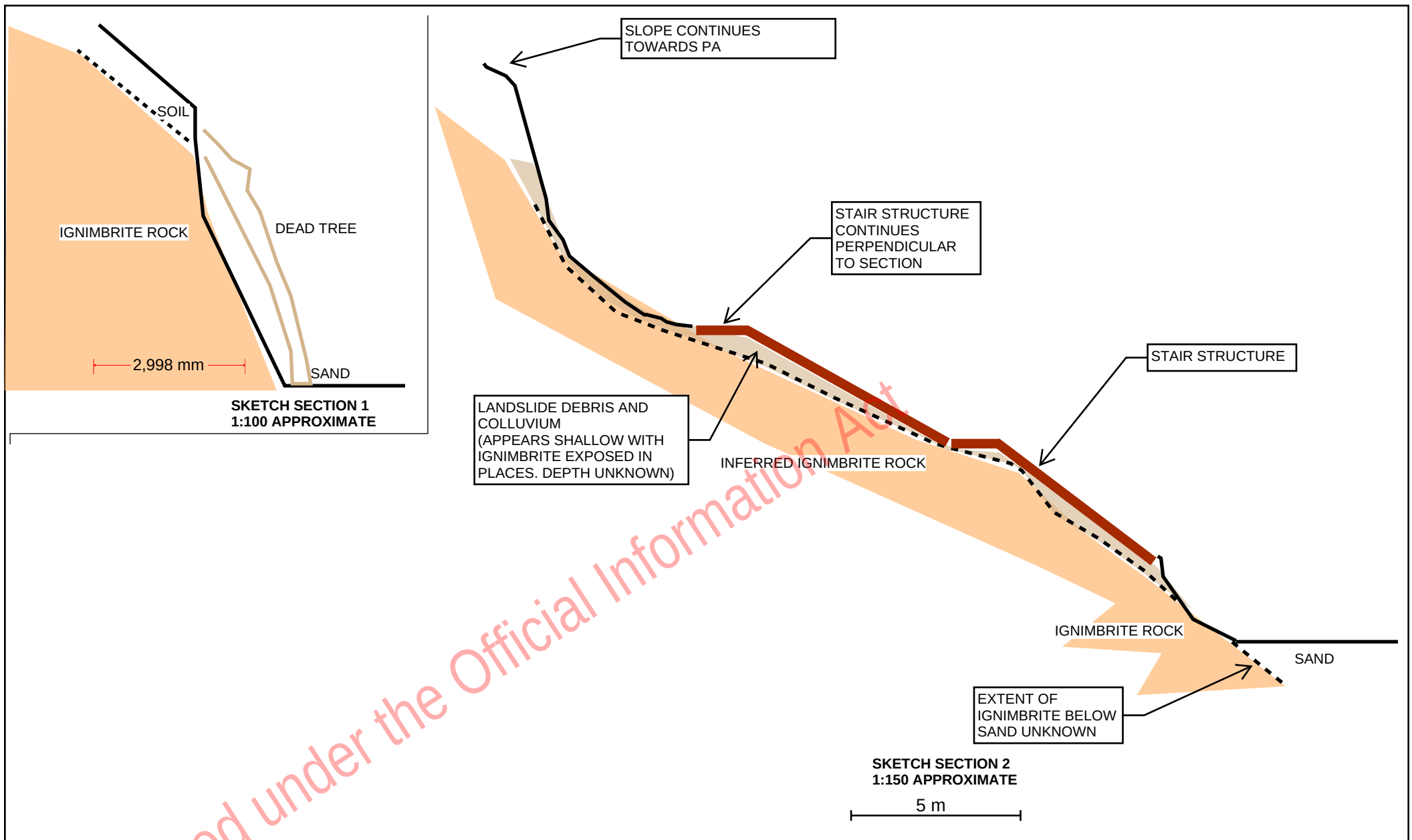
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DRAWN	HAMC	MAY.24
CHECKED	ANDO	MAY.24
27/05/24		

APPROVED	DATE
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CLIENT	DEPARTMENT OF CONSERVATION
PROJECT	CATHEDRAL COVE LANDSLIDE RISK ASSESSMENT

TITLE	TRACK SETTING TRACK SECTIONS USED FOR RISK ASSESSMENT
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SCALE (A3)	1:4,500	FIG No.	FIGURE 6.	REV	0
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Tonkin+Taylor

Project: Cathedral Cove Feasibility Assessment

Description: Section sketches made onsite using hand held range finder. See plan for locations.

Drawn: 9(2)(a)

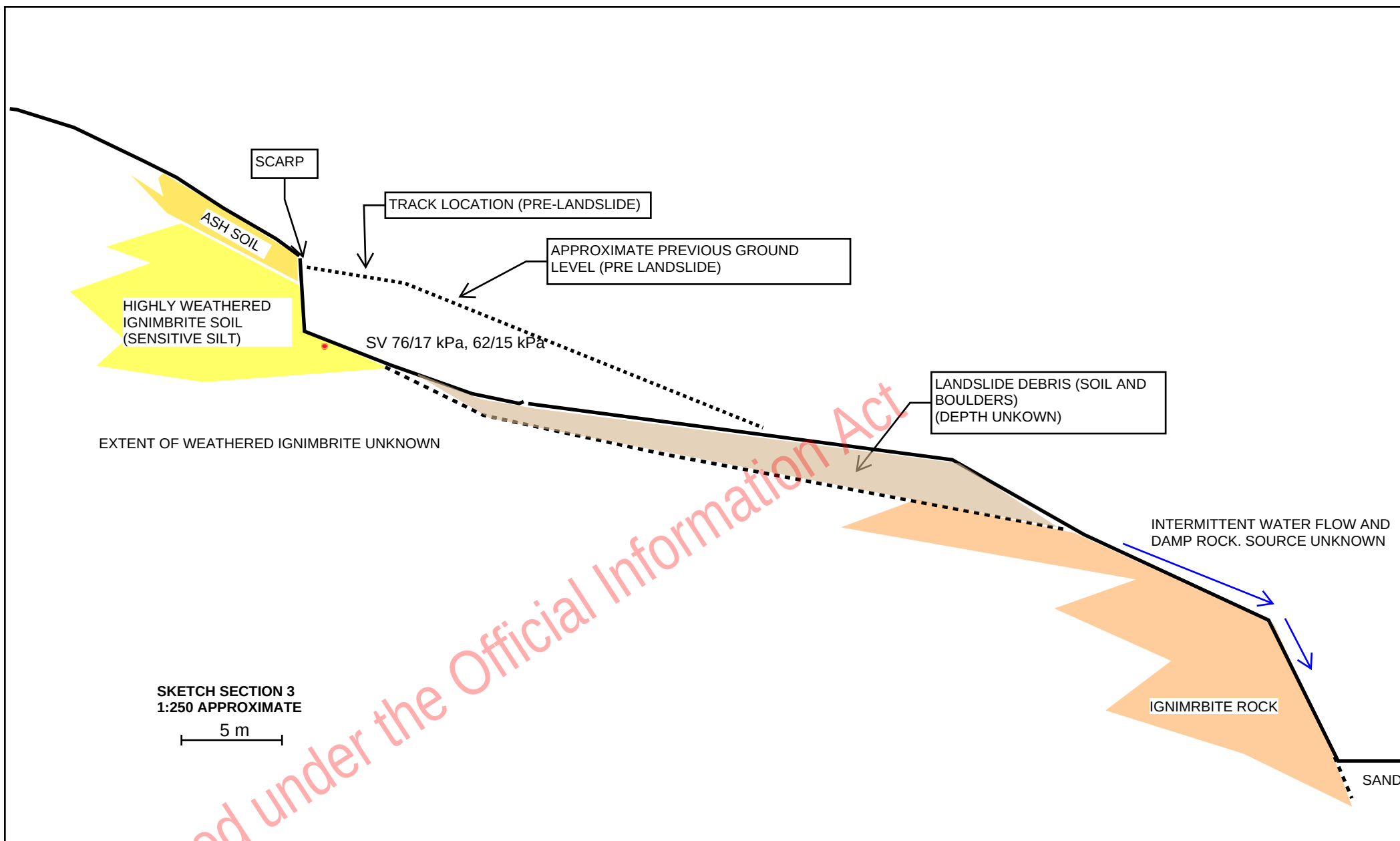
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Office: Hamilton

Job No: 1007838.4000

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Tonkin+Taylor

Project: Cathedral Cove Feasibility Assessment

Description: Section sketches made onsite using hand held range finder. See plan for locations.

Drawn: 9(2)(a)

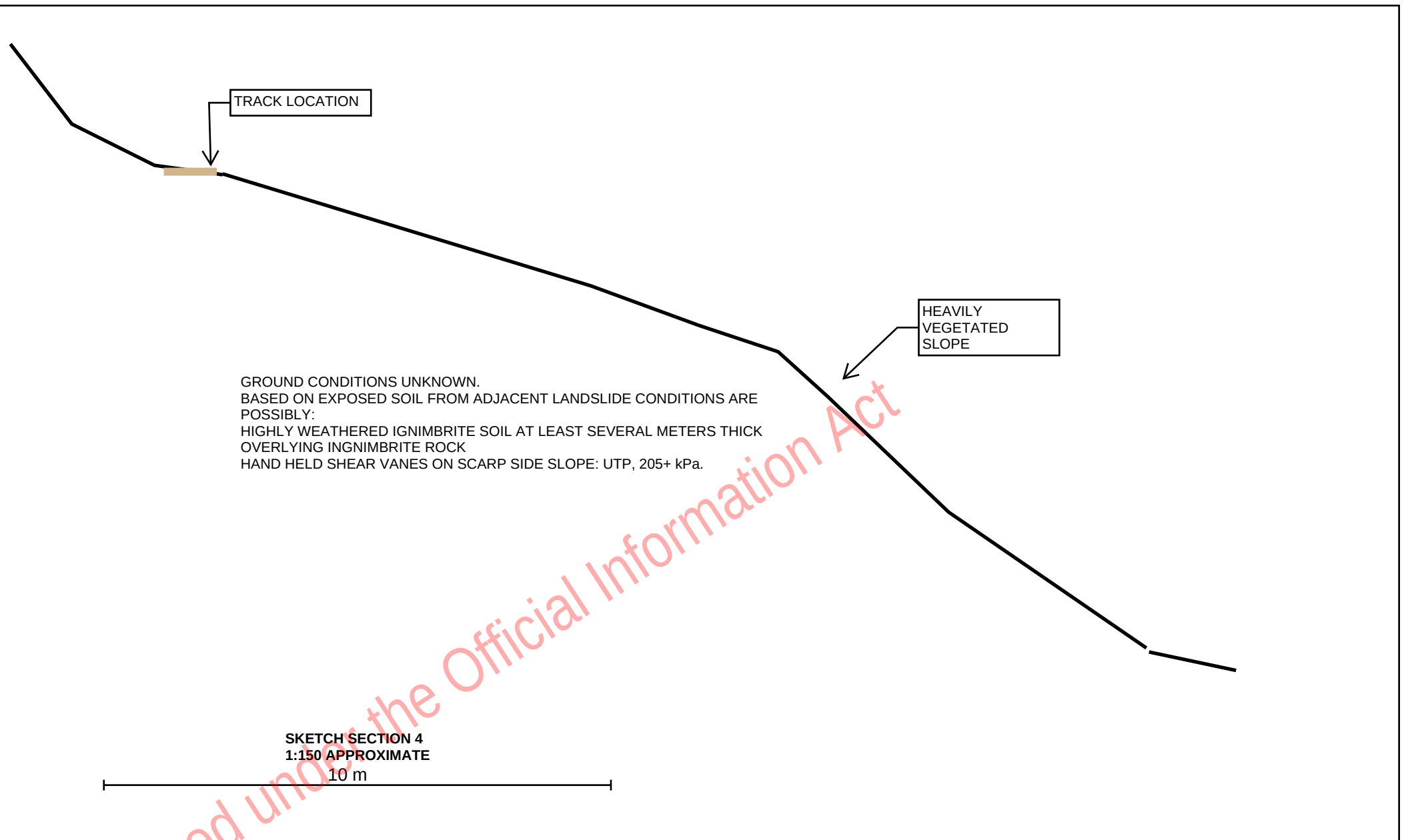
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Sheet: 2



Project: Cathedral Cove Feasibility Assessment

Description: Section sketches made onsite using hand held range finder. See plan for locations.

Drawn: 9(2)(a)

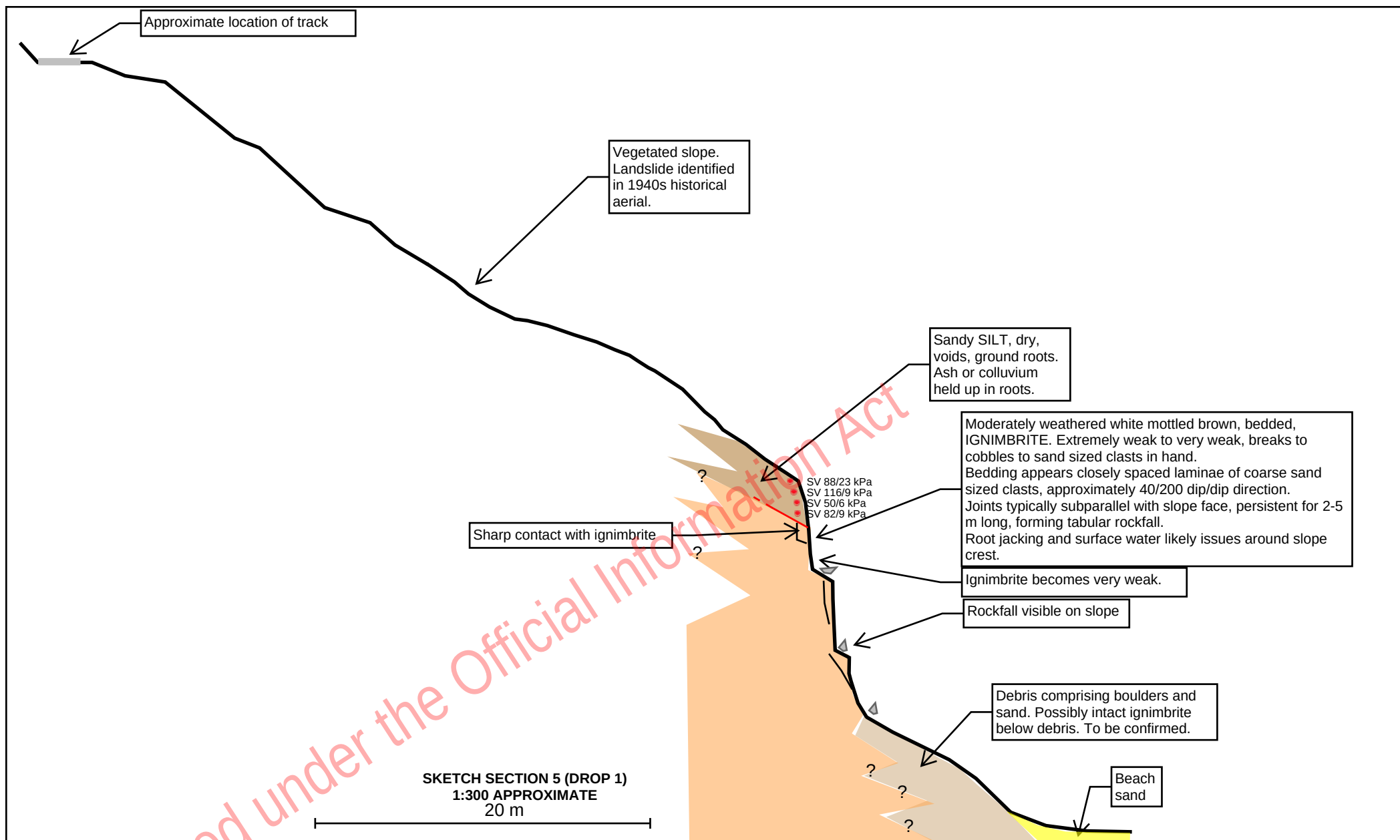
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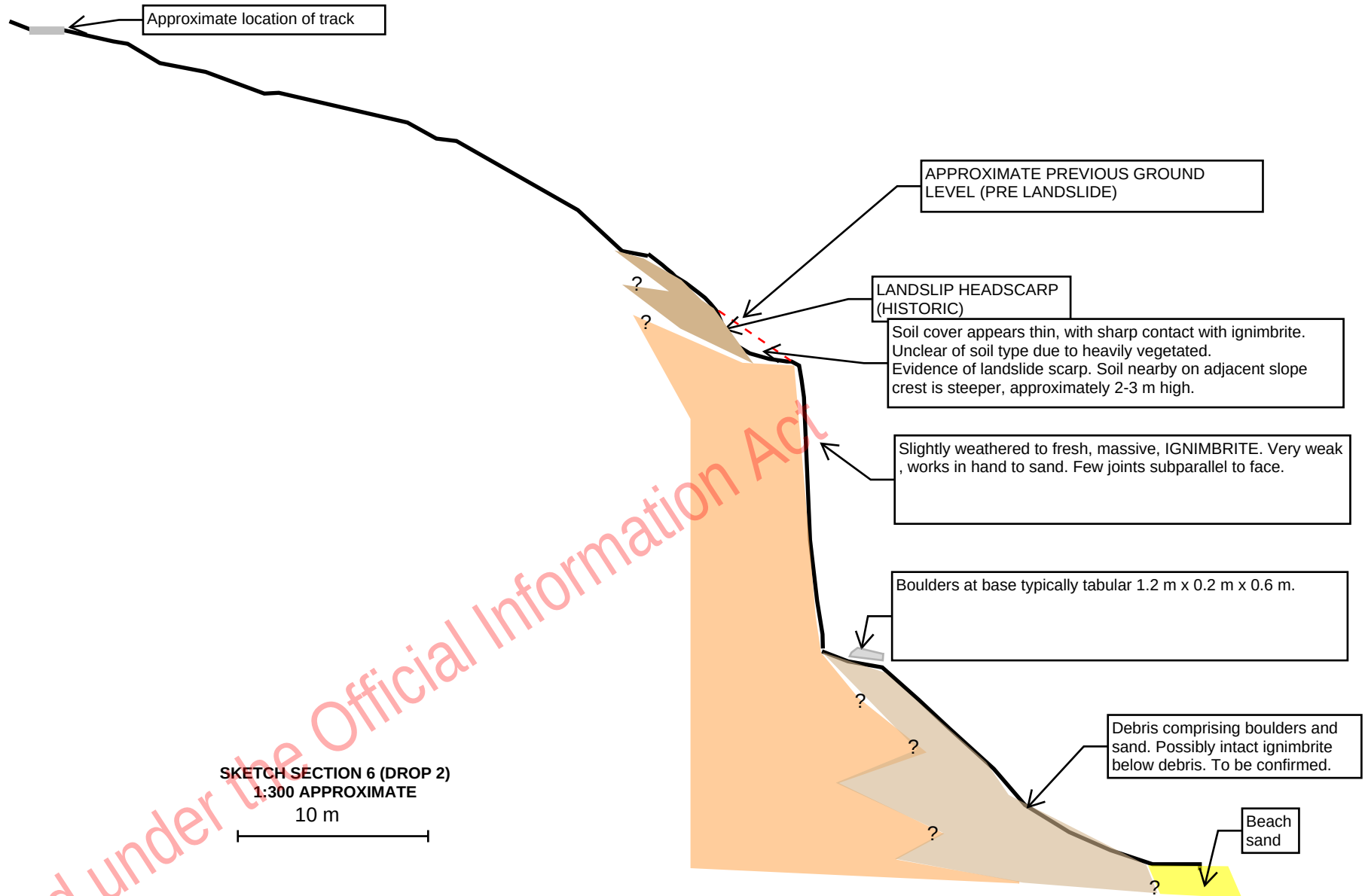
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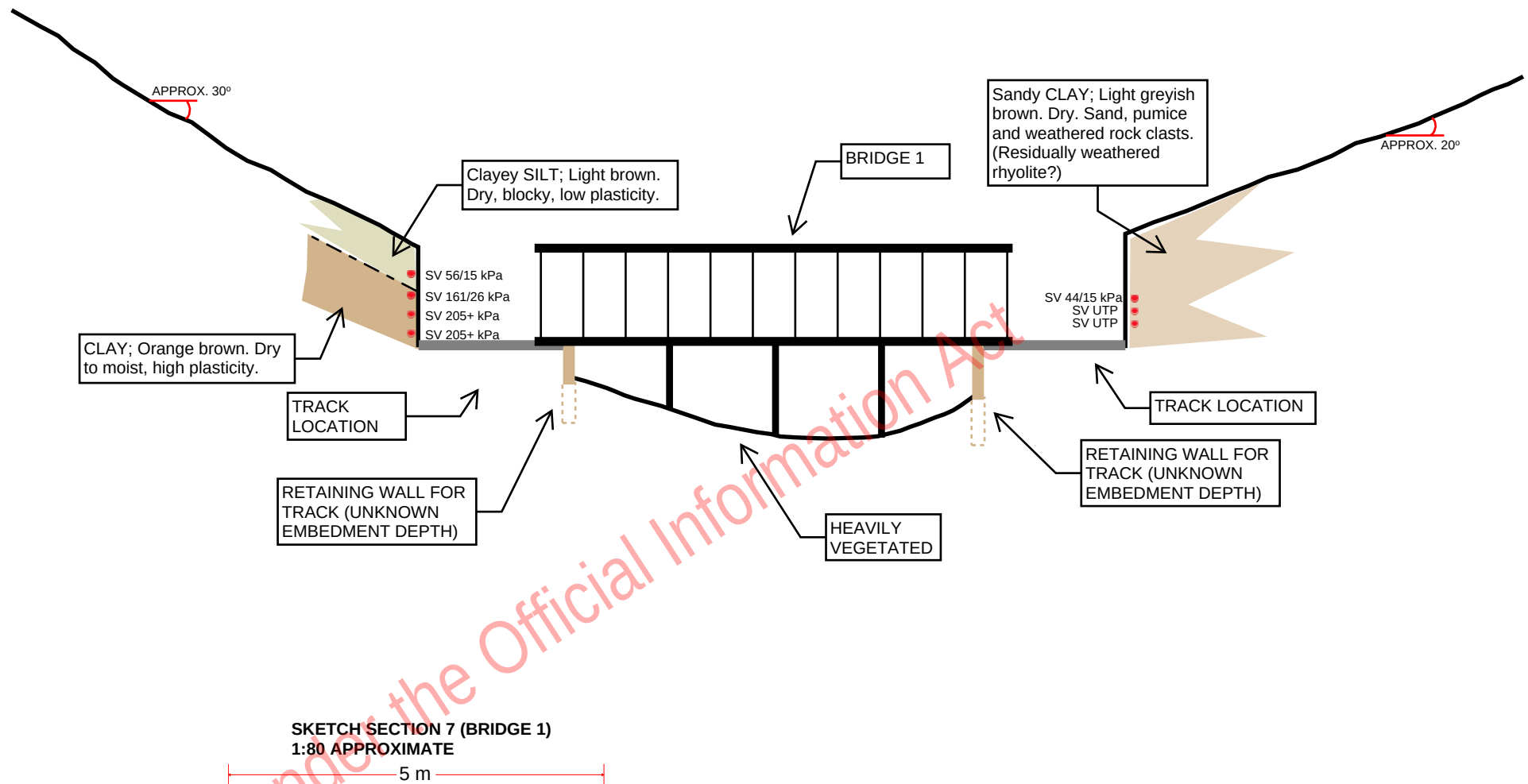
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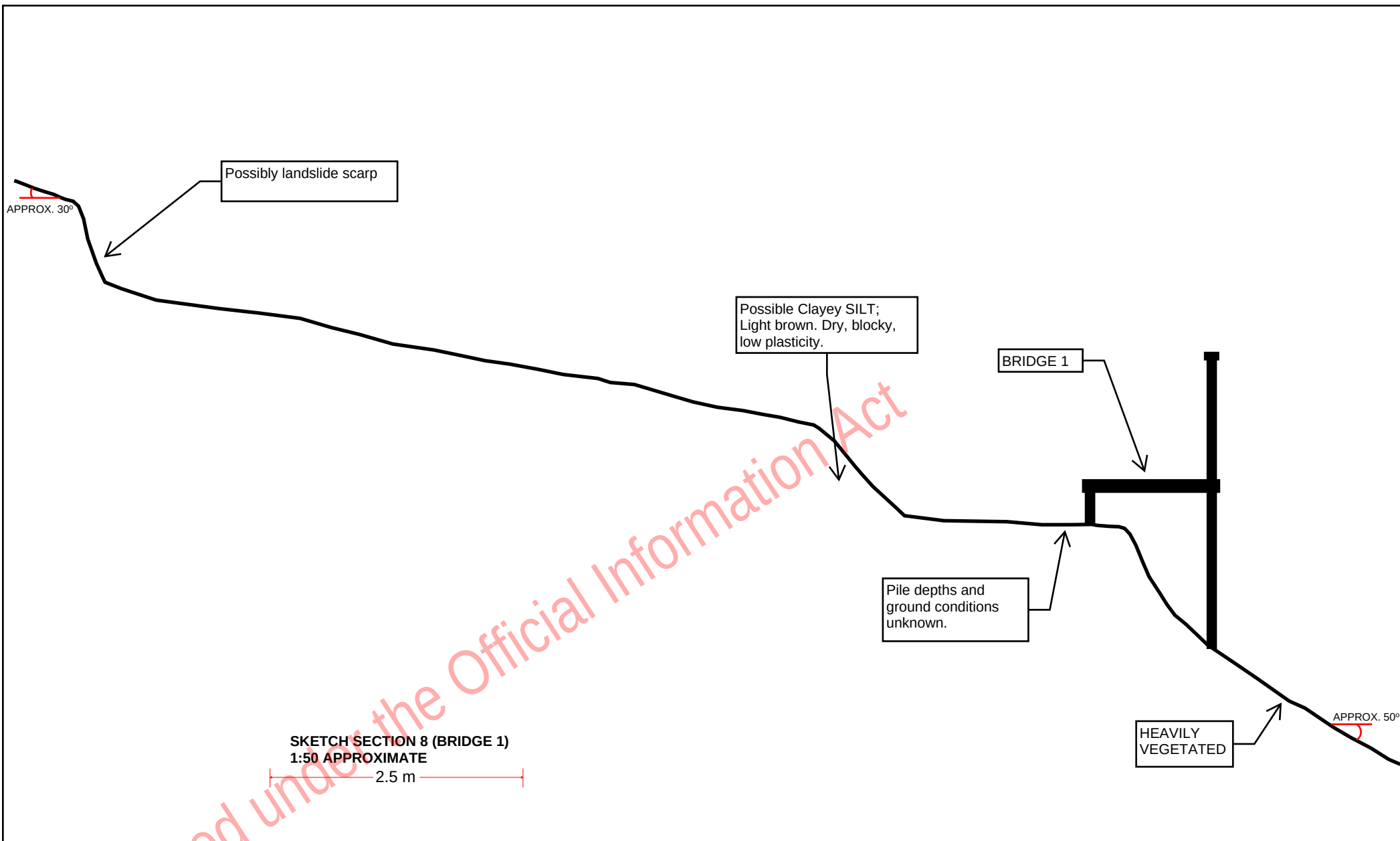
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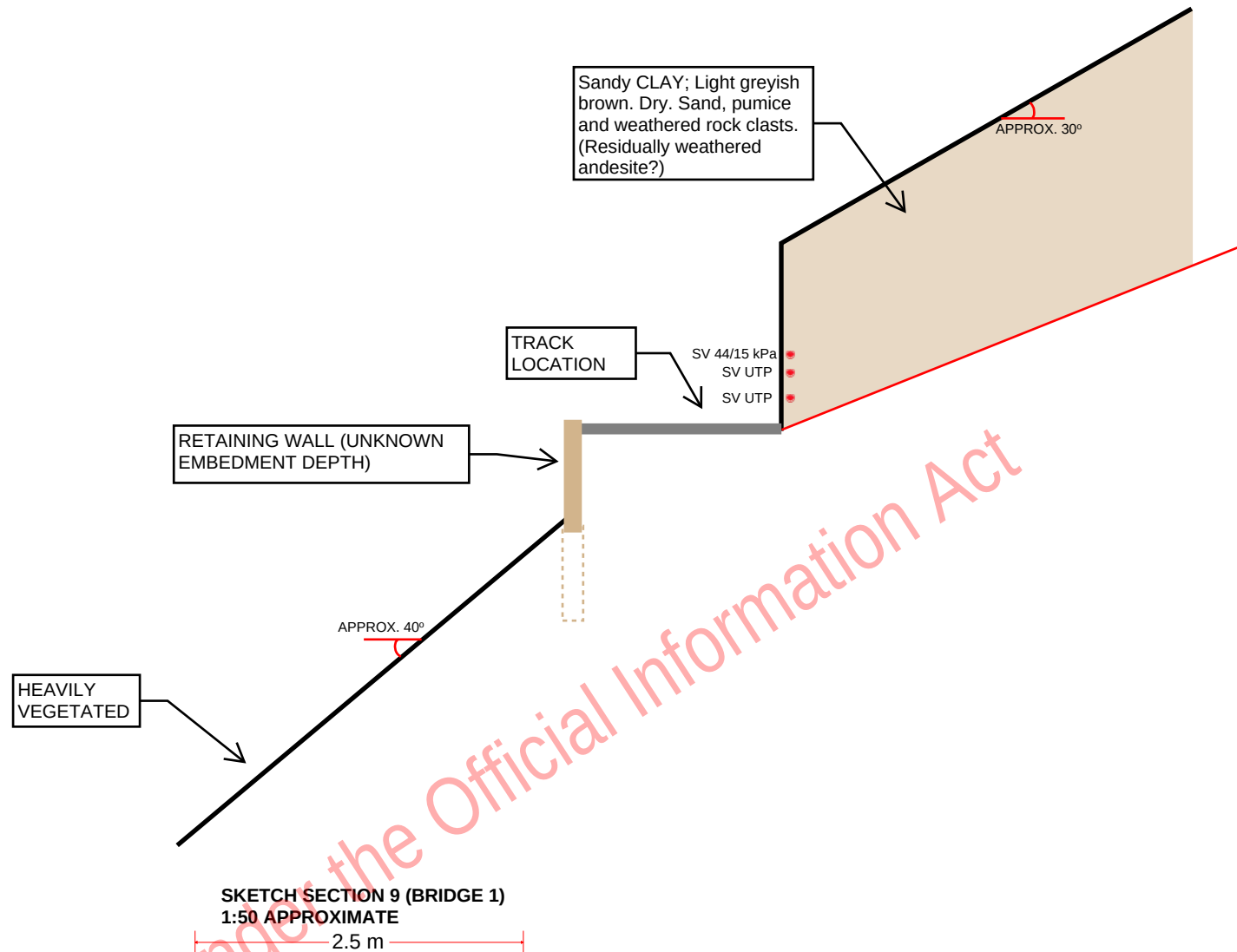
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Completely weathered, brown and white, flow banded ANDESITE.
 Variably extremely weak and very weak horizontally across outcrop.
 Bedding/banding is closely spaced laminae with rounded clasts, veins and variable strength, typically 80/140 dip/dip direction (near vertical).
 Easily picked with hammer breaking out as small cobbles or clumps of soil.

BRIDGE 2

TRACK LOCATION

APPROX. 55°

TRACK LOCATION

Bridge piles not touching ground

SKETCH SECTION 10 (BRIDGE 2)
 1:80 APPROXIMATE

5 m



Drawn: 9(2)(a)

Checked: 9(2)(a)

Office: Hamilton

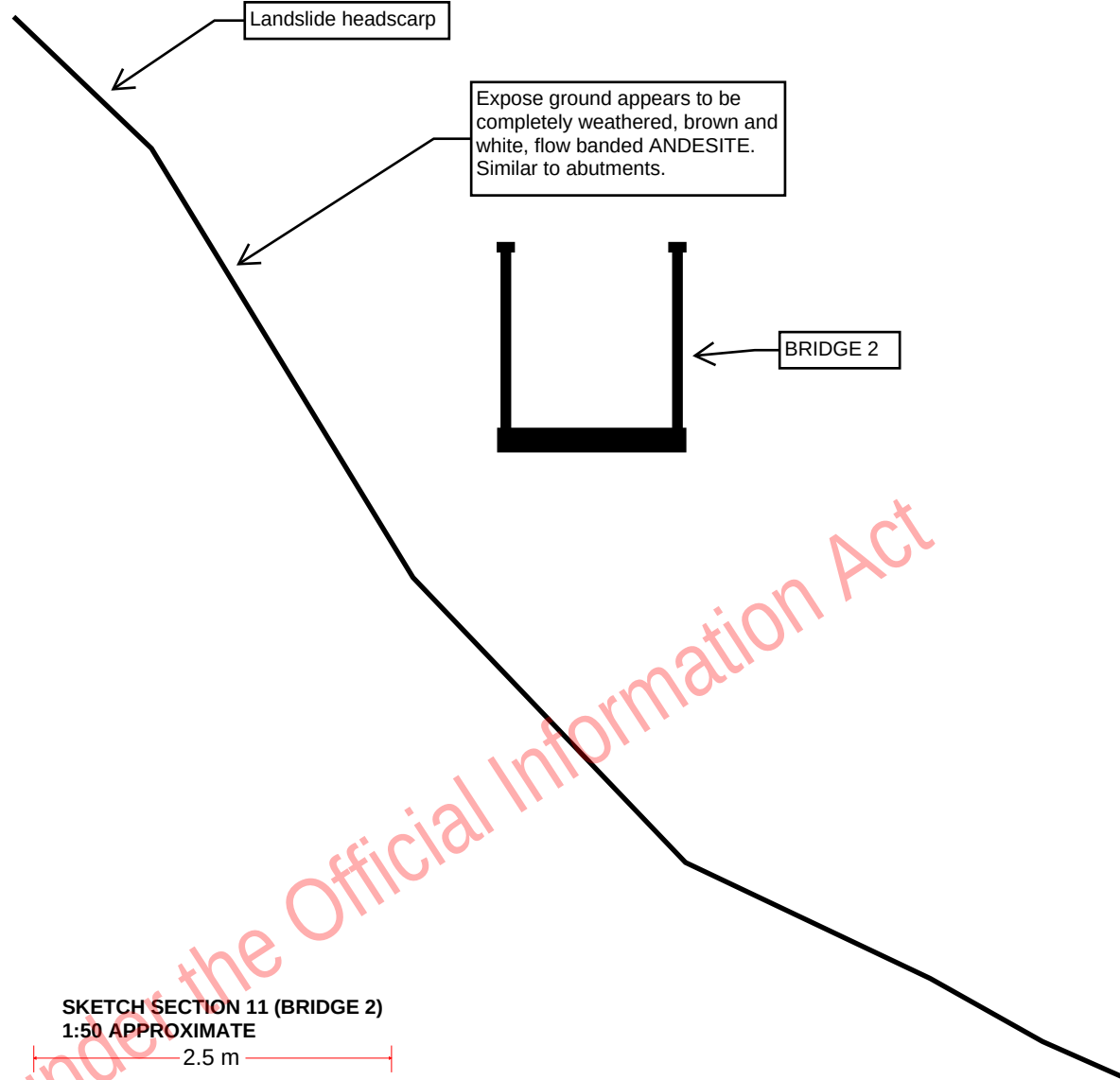
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Sheet: 9

Project:

Description: Section sketches made onsite using hand held range finder. See plan for locations.



Appendix C Risk assessment

C1 Risk assessment analysis tables

Table Appendix C.1 : Landslide and rockfall size classes adopted for this assessment

	Landscape Unit	Most Likely	Maximum Credible Size
Landslides	All except Cathedral Cove Arch	<1000 m ² (In terms of area)	1000-10,000 m ² (In terms of area)
Rockfall except Cathedral Cove Arch	All except Cathedral Cove Arch	<500 m ² (In terms of area)	500-1000 m ² (In terms of area)
Rockfall Cathedral Cove	Cathedral Cove Arch	≤3 m ³ (In terms of volume)	4-5 m ³ (In terms of volume)

Table Appendix C.2 : Landslide/rockfall mean recurrence interval for each landscape unit

Landscape unit	Size class	Type	Count	Time period (years)	Mean recurrence interval (Time period/count)	Area mapped (km ²)
Escarpment	Most likely	Landslides	3	80	27	0.059
		Rockfall	4	80	20	
	Maximum Credible	Landslides	0	80	-	
		Rockfall	1	80	80	
Coastal Cliff	Most likely	Landslides	27	80	3	0.042
		Rockfall	19	80	4	
	Maximum Credible	Landslides	2	80	40	
		Rockfall	2	80	40	
Steep Coastal Hill	Most likely	Landslides	41	80	2	0.174
		Rockfall	5	80	16	
	Maximum Credible	Landslides	1	80	80	
		Rockfall	0	80	-	
Coastal Hill 1	Most likely	Landslides	2	80	40	0.053
		Rockfall	0	80	-	
	Maximum Credible	Landslides	1	80	80	
		Rockfall	0	80	-	
Road Corridor	Most likely	Landslides	0	80	-	0.006
		Rockfall	0	80	-	
	Maximum Credible	Landslides	0	80	-	
		Rockfall	0	80	-	
Beach	Most likely	Landslides	12	80	7	0.015
		Rockfall	14	80	6	
	Maximum Credible	Landslides	1	80	80	

Landscape unit	Size class	Type	Count	Time period (years)	Mean recurrence interval (Time period/count)	Area mapped (km ²)
		Rockfall	1	80	80	
Cathedral Cove Arch	Most likely	Landslides	0	15	-	0.001
		Rockfall	10	15	2	
	Maximum Credible	Landslides	0	15	-	
		Rockfall	1	15	15	
Saddle	Most likely	Landslides	1	80	80	0.004
		Rockfall	0	80	-	
	Maximum Credible	Landslides	1	80	80	
		Rockfall	0	80	-	
Coastal Hill 2	Most likely	Landslides	2	80	40	0.093
		Rockfall	0	80	-	
	Maximum Credible	Landslides	0	80	-	
		Rockfall	0	80	-	

Table Appendix C.3 : Probability of landslide occurring for each landscape unit $P_{(L)}$

Track	Case	Probability that one or more landslides will occur in time 't = 1 year' ($1 - e^{-t/m}$)	
		Landslide	Rockfall
Section 01	Most likely	9.3E-02	1.4E-02
	Max credible	2.9E-03	-
Section 02	Most likely	1.0E-03	-
	Max credible	-	-
Section 03	Most likely	1.2E-02	1.8E-03
	Max credible	3.6E-04	-
Section 04	Most likely	4.3E-04	-
	Max credible	-	-
Section 05	Most likely	8.9E-04	-
	Max credible	-	-
Section 06	Most likely	9.5E-04	-
	Max credible	-	-
Section 07	Most likely	2.3E-03	-
	Max credible	-	-
Section 08	Most likely	1.7E-03	-
	Max credible	-	-
Section 09	Most likely	2.3E-03	3.1E-03
	Max credible	-	7.8E-04
Section 10	Most likely	5.0E-03	7.5E-04
	Max credible	1.5E-04	-

Track	Case	Probability that one or more landslides will occur in time 't = 1 year' ($1 - e^{-t/m}$)	
		Landslide	Rockfall
Section 11	Most likely	8.6E-03	-
	Max credible	8.6E-03	-
Section 12	Most likely	1.3E-01	1.9E-02
	Max credible	3.9E-03	-
Section 13	Most likely	4.2E-03	3.1E-03
	Max credible	3.6E-04	3.6E-04
Section 14	Most likely	4.8E-02	5.6E-02
	Max credible	4.3E-03	4.3E-03
Section 15	Most likely	-	4.9E-01
	Max credible	-	6.4E-02
Section 16	Most likely	8.0E-03	5.9E-03
	Max credible	6.9E-04	6.9E-04
Section 17	Most likely	5.7E-04	-
	Max credible	-	-
Section 18	Most likely	1.5E-02	1.7E-02
	Max credible	1.3E-03	1.3E-03
Section 19	Most likely	7.9E-03	1.2E-03
	Max credible	2.4E-04	-
Section 20	Most likely	9.7E-03	1.1E-02
	Max credible	8.6E-04	8.6E-04
Section 21	Most likely	3.3E-04	-
	Max credible	-	-
Point Location 1 (Bench)	Most likely	1.8E-03	2.7E-04
	Max credible	5.4E-05	-
Point Location 3 (Lifeguard Hut)	Most likely	3.8E-03	4.4E-03
	Max credible	3.4E-04	3.4E-04
Point Location 4 (Proposed New Toilet Location)	Most likely	3.0E-03	4.6E-04
	Max credible	9.3E-05	-
Section 22	No change from track Section 12 (refer note 1, Table Appendix C.3)	-	-
Section 23	Most likely	8.9E-03	1.3E-03
	Max credible	2.7E-04	-
Section 24 Refer Note 2	Most likely	1.2E-04	9.0E-05
	Max credible	1.0E-05	1.0E-05
Section 25	Most likely	3.8E-03	4.3E-03
	Max credible	3.4E-04	3.4E-04
Section 26	Most likely	1.1E-02	1.6E-03
	Max credible	3.4E-04	-
Section 27	Most likely	7.5E-03	-

Track	Case	Probability that one or more landslides will occur in time 't = 1 year' ($1 - e^{-t/m}$)	
		Landslide	Rockfall
	Max credible	3.8E-03	-
Section 28	Most likely	8.9E-03	1.3E-03
	Max credible	2.7E-04	-
Section 29	Most likely	2.3E-02	3.4E-03
	Max credible	7.0E-04	-
Section 01 (3b)	Most likely	2.1E-02	3.2E-03
	Max credible	6.6E-04	-
Section 30	Most likely	1.0E-03	-
	Max credible	5.1E-04	-
Section 12 (2bi)	Most likely	6.3E-02	9.5E-03
	Max credible	1.9E-03	-

Note 1: Section 22 has very similar alignment and length as the existing track Section 12.

Note 2: P_L for track Section 24 has been reduced by 90 % to account for land stabilisation mitigations proposed. This reduction is for the purpose of this specific risk assessment and to understand overall AIFR sensitivity to this parameter. It should not be taken out of context for any other purposes.

Table Appendix C.4 : Proportion of the walkway affected for each event $P_{T:L}$

Location	Size Class	Landscape Unit	Total length of zone	Rockfall Event Width	Landslide Width	$P_{T:L}$
Section 1	Max credible	Steep Coastal Hills	667	0	31	4.7E-02
	Most likely	Steep Coastal Hills	667	9	13	3.4E-02
Section 2	Max credible	Coastal Hill 2	153	N/A	33	2.2E-01
	Most likely	Coastal Hill 2	153	N/A	11	7.7E-02
Section 3	Max credible	Steep Coastal Hills	212	0	31	1.5E-01
	Most likely	Steep Coastal Hills	212	9	13	1.1E-01
Section 4	Max credible	Coastal Hill 2	39	N/A	33	8.7E-01
	Most likely	Coastal Hill 2	39	N/A	11	3.0E-01
Section 5	Max credible	Coastal Hill 2	41	N/A	33	8.2E-01
	Most likely	Coastal Hill 2	41	N/A	11	2.9E-01
Section 6	Max credible	Coastal Hill 2	79	N/A	33	4.3E-01
	Most likely	Coastal Hill 2	79	N/A	11	1.5E-01
Section 7	Max credible	Coastal Hill 2	194	N/A	33	1.7E-01
	Most likely	Coastal Hill 2	194	N/A	11	6.1E-02
Section 08	Max credible	Coastal Hill 2	279	N/A	33	1.2E-01
	Most likely	Coastal Hill 2	279	N/A	11	4.2E-02
Section 09	Maximum Credible	Escarpment	56	30	30	1
	Most Likely	Escarpment	56	8	9	3.2E-01
Section 10	Maximum Credible	Steep Coastal Hills	27	0	31	1
	Most Likely	Steep Coastal Hills	27	9	13	8.3E-01
Section 11	Maximum Credible	Saddle	161	N/A	40	2.5E-01

Location	Size Class	Landscape Unit	Total length of zone	Rockfall Event Width	Landslide Width	P T:L)
	Most Likely	Saddle	161	N/A	18	1.2E-01
Section 12	Maximum Credible	Steep Coastal Hills	562	0	31	5.6E-02
	Most Likely	Steep Coastal Hills	562	9	13	4.0E-02
Section 13	Maximum Credible	Coastal Cliffs	18	41	31	1
	Most Likely	Coastal Cliffs	18	11	15	1
Section 14	Maximum Credible	Beach	497	15	36	1.0E-01
	Most Likely	Beach	497	11	18	6.0E-02
Section 15	Maximum Credible	Cathedral Cove Arch	44	8	N/A	1.9E-01
	Most Likely	Cathedral Cove Arch	44	2	N/A	6.3E-02
Section 16	Maximum Credible	Coastal Cliffs	58	41	31	1
	Most Likely	Coastal Cliffs	58	11	15	4.6E-01
Section 17	Maximum Credible	Coastal Hill 2	115	N/A	33	2.9E-01
	Most Likely	Coastal Hill 2	115	N/A	11	1.0E-01
Section 18	Max credible	Beach	181	15	36	2.9E-01
	Most likely	Beach	181	12	18	1.7E-01
Section 19	Maximum Credible	Steep Coastal Hills	105	0	31	3.0E-01
	Most Likely	Steep Coastal Hills	105	9	13	2.1E-01
Section 20	Max credible	Beach	123	15	36	4.2E-01
	Most likely	Beach	123	12	18	2.5E-01
Section 21	Maximum Credible	Coastal Hill 2	57		33	5.9E-01
	Most Likely	Coastal Hill 2	57	N/A	11	2.1E-01
Point Location 1 (Bench)	Maximum Credible	Steep Coastal Hills	2	0	31	1
	Most Likely	Steep Coastal Hills	2	9	13	1
Point Location 3 (Lifeguard Hut)	Max credible	Beach	3	15	36	1
	Most likely	Beach	3	11	18	1
Point Location 4 (Proposed New Toilet Location)	Max credible	Steep Coastal Hills	5	0	31	1
	Most likely	Steep Coastal Hills	5	9	13	1
Section 22	No change from Section 12 (refer Note 1, Table Appendix C.3)	Steep Coastal Hills	36	-	-	-
Section 23	Max credible	Steep Coastal Hills	23	0	31	1
	Most likely	Steep Coastal Hills	23	9	13	9.8E-01
Section 24	Max credible	Coastal Cliffs	11	41	31	1
	Most likely	Coastal Cliffs	11	11	15	1
Section 25	Max credible	Beach	33	15	36	1
	Most likely	Beach	33	11	18	9.0E-01

Location	Size Class	Landscape Unit	Total length of zone	Rockfall Event Width	Landslide Width	P T:L)
Section 26	Max credible	Steep Coastal Hills	66	0	31	4.8E-01
	Most likely	Steep Coastal Hills	66	9	13	3.4E-01
Section 27	Max credible	Coastal Hill 1	423	-	32	7.8E-02
	Most likely	Coastal Hill 1	423	-	20	4.9E-02
Section 28	Max credible	Steep Coastal Hills	25	0	31	1
	Most likely	Steep Coastal Hills	25	9	13	9.0E-01
Section 29	Max credible	Steep Coastal Hills	266	0	31	1.2E-01
	Most likely	Steep Coastal Hills	266	9	13	8.5E-02
Section 30	Max credible	Coastal Hill 1	101	-	32	3.2E-01
	Most likely	Coastal Hill 1	101	-	20	2.1E-01
Section 12 (2bi)	Max credible	Steep Coastal Hills	323	0	31	9.8E-02
	Most likely	Steep Coastal Hills	323	9	13	7.0E-02
Section 01 (3b)	Max credible	Steep Coastal Hills	197	0	31	1.6E-01
	Most likely	Steep Coastal Hills	197	9	13	1.1E-01

Table Appendix C.5 : Spatio-temporal probability $P_{(s,t)}$

Track ID	Track length	Seconds on track (assuming walking 0.5 m/s)	$P_{(s,t)}$ proportion of time on track per year		
			Two ways / return	One way	Ranger walking track 3 times per week, 40 weeks per year
Section 01	667	1335	8.5E-05	4.2E-05	1.0E-02
Section 02	153	305	1.9E-05	9.7E-06	2.3E-03
Section 03	212	424	2.7E-05	1.3E-05	3.2E-03
Section 04	39	78	4.9E-06	2.5E-06	5.9E-04
Section 05	41	82	5.2E-06	2.6E-06	6.2E-04
Section 06	79	158	1.0E-05	5.0E-06	1.2E-03
Section 07	194	388	2.5E-05	1.2E-05	2.9E-03
Section 08	279	558	3.5E-05	1.8E-05	4.2E-03
Section 09	56	112	7.1E-06	3.5E-06	8.5E-04
Section 10	27	54	3.4E-06	1.7E-06	4.1E-04
Section 11	161	322	2.0E-05	1.0E-05	2.5E-03
Section 12	562	1123	7.1E-05	3.6E-05	8.5E-03
Section 13	18	36	2.3E-06	1.1E-06	2.8E-04
Section 14	497	994	6.3E-05	3.2E-05	7.6E-03
Section 15	44	88	5.6E-06	2.8E-06	6.7E-04
Section 16	58	116	7.4E-06	3.7E-06	8.8E-04
Section 17	115	231	1.5E-05	7.3E-06	1.8E-03

Track ID	Track length	Seconds on track (assuming walking 0.5 m/s)	P _(S,T) proportion of time on track per year		
Section 18	181	362	2.3E-05	1.1E-05	2.8E-03
Section 19	105	210	1.3E-05	6.7E-06	1.6E-03
Section 20	123	247	1.6E-05	7.8E-06	1.9E-03
Section 21	57	115	7.3E-06	3.6E-06	8.7E-04
Point Location 1 (Bench)		60	3.8E-06	1.9E-06	4.6E-04
Point Location 3 (Lifeguard Hut)		-			9.1E-03 Assuming lifeguard on duty for 20 hours in the tower, 4 weeks over summer
Point Location 4 (Proposed New Toilet Location)		120	7.6E-06	3.8E-06	9.1E-04
Section 22	No change from track Section 12 (refer Note 1, Table Appendix C.3)	-	-	-	-
Section 23	23	46	2.9E-06	1.5E-06	3.5E-04
Section 24	11	22	1.4E-06	7.0E-07	1.7E-04
Section 25	33	66	4.2E-06	2.1E-06	5.0E-04
Section 26	66	132	8.4E-06	4.2E-06	1.0E-03
Section 27	423	846	5.4E-05	2.7E-05	6.4E-03
Section 28	25	50	3.2E-06	1.6E-06	3.8E-04
Section 29	266	532	3.4E-05	1.7E-05	4.0E-03
Section 01 (3b)	197	394	2.5E-05	1.2E-05	3.0E-03
Section 30	101	202	1.3E-05	6.4E-06	1.5E-03
Section 12 (2bi)	323	646	4.1E-05	2.0E-05	4.9E-03

Table Appendix C.6 : Adopted vulnerability values

Event type	Landscape Unit	Size Class	Vulnerability of a person outside
Landslides and Rockfalls (except Cathedral Cove Arch)	All units except Cathedral Cove Arch	Most Likely	0.7
		Maximum Credible	1
Rockfall Cathedral Cove	Cathedral Cove Arch	Most Likely	0.5
		Maximum Credible	0.7

Table Appendix C.7 : Societal risk group number estimates

Event Type	Event Class	Vulnerability	Minimum Number of people in group for: 1 or more fatality	Minimum Number of people in group for: 5 or more fatalities	Minimum Number of people in group for worst-case scenario of: 30 or more fatalities
Landslide / Rockfall (except Cathedral Cove Arch)	Most Likely	0.7	2	7 – Marginal if the event size is large enough in some cases.	(43) Not credible given event size
	Maximum Credible	1	1	5	30
Rockfall Cathedral Cove Arch	Most Likely	0.5	2	(10) Not credible given event size	Not credible given event size
	Maximum Credible	0.7	2	(7) Not credible given event size	N/A

Table Appendix C.8 : Societal risk temporal spatial probability

	Adopted $P_{(s,t)}$	Assumptions
Group of 1 or more fatalities	0.5	Assuming the track is occupied for 50 % of the year i.e., from 7 am to 7 pm all year round.
Group of 5 or more fatalities	0.25	Assuming the track is occupied for 25 % of the year by a group of approximately 5/7 people i.e., from 7 am to 7 pm, six months of the year.
Group of 30 or more fatalities	0.25	Assuming the track is occupied for 25 % of the year by a group of approximately 30 people i.e., from 7 am to 7 pm, six months of the year.

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Table Appendix C.9 : Annual Individual Fatality Risk for each track section and point location

Track Section	Corresponding landscape unit	Event	Temporal probability of the event Rockfall	Temporal probability of the event Landslide	Temporal probability of the event (P _L) - combined	Probability of the landslide/rockfall reaching the track (P _{T:L})	Spatio-temporal probability of the person at risk (P _{S:T}) 2 ways/return	Vulnerability of the person (P _{D:T})	Probability of loss of life for a visitor P _(LoL)		Spatio-temporal probability of DoC ranger at risk (P _{S:T})	Probability of loss of life P _(LoL) for Ranger
Section 01	Steep Coastal Hills	Most likely	1.4E-02	9.3E-02	1.1E-01	3.4E-02	8.5E-05	0.7	2.1E-07		1.0E-02	2.6E-05
		Maximum Credible	-	2.9E-03	2.9E-03	4.7E-02	8.5E-05	1	1.2E-08		1.0E-02	1.4E-06
								Total	2.3E-07		Total	2.7E-05
Section 02	Coastal Hill 2	Most likely	-	1.0E-03	1.0E-03	7.73E-02	1.9E-05	0.7	1.1E-09		2.3E-03	1.3E-07
		Maximum Credible	-	-	-	-	-	-	-		-	-
								Total	1.1E-09		Total	1.3E-07
Section 03	Steep Coastal Hills	Most likely	1.8E-03	1.2E-02	1.3E-02	1.1E-01	2.7E-05	0.7	2.7E-08		3.2E-03	3.2E-06
		Maximum Credible	-	3.6E-04	3.6E-04	1.5E-01	2.7E-05	1	1.4E-09		3.2E-03	1.7E-07
								Total	2.8E-08		Total	3.4E-06
Section 04	Coastal Hill 2	Most likely	-	4.3E-04	4.3E-04	3.04E-01	4.9E-06	0.7	4.5E-10		5.9E-04	5.4E-08
		Maximum Credible	-	-	-	-	-	1-	-		-	-
								Total	4.5E-10		Total	5.4E-08
Section 05	Coastal Hill 2	Most likely	-	8.9E-04	8.9E-04	2.88E-01	5.2E-06	0.7	9.4E-10		6.2E-04	1.1E-07
		Maximum Credible	-	-	-	-	-	-	-		-	-
								Total	9.4E-10		Total	1.1E-07
Section 06	Coastal Hill 2	Most likely	-	9.5E-04	9.5E-04	1.49E-01	1.0E-05	0.7	9.9E-10		1.2E-03	1.2E-07
		Maximum Credible	-	-	-	-	-	-	-		-	-
								Total	9.9E-10		Total	1.2E-07
Section 07	Coastal Hill 2	Most likely	-	2.3E-03	2.3E-03	6.09E-02	2.5E-05	0.7	2.4E-09		2.9E-03	2.9E-07
		Maximum Credible	-	-	-	-	-	-	-		-	-
								Total	2.4E-09		Total	2.9E-07
Section 08	Coastal Hill 2	Most likely	-	1.7E-03	1.7E-03	4.23E-02	3.5E-05	0.7	1.8E-09		4.2E-03	2.2E-07
		Maximum Credible	-	-	-	-	-	-	-		-	-
								Total	1.8E-09		Total	2.2E-07
Section 09	Escarpment	Most likely	3.1E-03	2.3E-03	5.4E-03	3.2E-01	7.1E-06	0.7	8.4E-09		8.5E-04	1.0E-06
		Maximum Credible	7.8E-04	-	7.8E-04	1.0E+00	7.1E-06	1	5.5E-09		8.5E-04	6.7E-07
								Total	1.4E-08		Total	1.7E-06
Section 10	Steep Coastal Hills	Most likely	7.5E-04	5.0E-03	5.7E-03	8.3E-01	3.4E-06	0.7	1.1E-08		4.1E-04	1.4E-06
		Maximum Credible	-	1.5E-04	1.5E-04	1.0E+00	3.4E-06	1	5.3E-10		4.1E-04	6.4E-08
								Total	1.2E-08		Total	1.4E-06
Section 11	Saddle	Most likely	-	8.6E-03	8.6E-03	1.18E-01	2.0E-05	0.7	1.4E-08		2.5E-03	1.7E-06
		Maximum Credible	-	8.6E-03	8.6E-03	2.53E-01	2.0E-05	1	4.5E-08		2.5E-03	5.4E-06
								Total	5.9E-08		Total	7.1E-06
Section 12	Steep Coastal Hills	Most likely	1.9E-02	1.3E-01	1.5E-01	4.0E-02	7.1E-05	0.7	2.9E-07		8.5E-03	3.5E-05
		Maximum Credible	-	3.9E-03	3.9E-03	5.6E-02	7.1E-05	1	1.6E-08		8.5E-03	1.9E-06
								Total	3.1E-07		Total	3.7E-05
Section 13	Coastal Cliffs	Most likely	3.1E-03	4.2E-03	7.3E-03	1.0E+00	2.3E-06	0.7	1.2E-08		2.8E-04	1.4E-06

Track Section	Corresponding landscape unit	Event	Temporal probability of the event Rockfall	Temporal probability of the event Landslide	Temporal probability of the event (P _L) - combined	Probability of the landslide/rockfall reaching the track (P _{T:L})	Spatio-temporal probability of the person at risk (P _{S:T}) 2 ways/return	Vulnerability of the person (P _{D:T})	Probability of loss of life for a visitor P _(LoL)		Spatio-temporal probability of DoC ranger at risk (P _{S:T})	Probability of loss of life P _(LoL) for Ranger
		Maximum Credible	3.6E-04	3.6E-04	7.2E-04	1.0E+00	2.3E-06	1	1.7E-09		2.8E-04	2.0E-07
								Total	1.3E-08		Total	1.6E-06
Section 14	Beach	Most likely	5.6E-02	4.8E-02	1.0E-01	6.0E-02	6.3E-05	0.7	2.7E-07		7.6E-03	3.3E-05
		Maximum Credible	4.3E-03	4.3E-03	8.6E-03	1.0E-01	6.3E-05	1	5.7E-08		7.6E-03	6.8E-06
								Total	3.3E-07		Total	4.0E-05
Section 15	Cathedral Cove Arch	Most likely	4.9E-01	-	4.9E-01	6.3E-02	5.6E-06	0.5	8.6E-08		6.7E-04	1.0E-05
		Maximum Credible	6.4E-02	-	6.4E-02	1.9E-01	5.6E-06	0.7	4.7E-08		6.7E-04	5.7E-06
								Total	1.3E-07		Total	1.6E-05
Section 16	Coastal Cliffs	Most likely	5.9E-03	8.0E-03	1.4E-02	4.6E-01	7.4E-06	0.7	3.3E-08		8.8E-04	3.9E-06
		Maximum Credible	6.9E-04	6.9E-04	1.4E-03	1.0E+00	7.4E-06	1	1.0E-08		8.8E-04	1.2E-06
								Total	4.3E-08		Total	5.1E-06
Section 17	Coastal Hill 2	Most likely	-	5.7E-04	5.7E-04	1.02E-01	1.5E-05	0.7	6.0E-10		1.8E-03	7.2E-08
		Maximum Credible	-	-	0.0E+00	2.93E-01	1.5E-05	1	0.0E+00		1.8E-03	0.0E+00
								Total	6.0E-10		Total	7.2E-08
Section 18	Beach	Most likely	1.7E-02	1.5E-02	3.2E-02	1.7E-01	2.3E-05	0.7	8.9E-08		2.8E-03	1.1E-05
		Maximum Credible	1.3E-03	1.3E-03	2.7E-03	2.9E-01	2.3E-05	1	1.8E-08		2.8E-03	2.1E-06
			0.0E+00	0.0E+00					1.1E-07		Total	1.3E-05
Section 19	Steep Coastal Hills	Most likely	1.2E-03	7.9E-03	9.1E-03	2.1E-01	1.3E-05	0.7	1.8E-08		1.6E-03	2.2E-06
		Maximum Credible	-	2.4E-04	2.4E-04	3.0E-01	1.3E-05	1	9.8E-10		1.6E-03	1.2E-07
								Total	1.9E-08		Total	2.3E-06
Section 20	Beach	Most likely	1.1E-02	9.7E-03	2.1E-02	2.5E-01	1.6E-05	0.7	5.8E-08		1.9E-03	6.9E-06
		Maximum Credible	8.6E-04	8.6E-04	1.7E-03	4.2E-01	1.6E-05	1	1.1E-08		1.9E-03	1.4E-06
								Total	6.9E-08		Total	8.3E-06
Section 21	Coastal Hill 2	Most likely	-	3.3E-04	3.3E-04	2.05E-01	7.3E-06	0.7	3.5E-10		8.7E-04	4.2E-08
		Maximum Credible	-	-	0.0E+00	5.88E-01	7.3E-06	1	0.0E+00		8.7E-04	0.0E+00
								Total	3.5E-10		Total	4.2E-08
Point Location 1 (Bench)	Steep Coastal Hills	Most likely	2.7E-04	1.8E-03	2.0E-03	1.0E+00	3.8E-06	0.7	5.4E-09		-	-
		Maximum Credible	-	5.4E-05	5.4E-05	1.0E+00	3.8E-06	1	2.1E-10		-	-
								Total	5.6E-09		-	-
Point Location 3 (Lifeguard Hut)	Beach	Most likely	4.4E-03	3.8E-03	8.2E-03	1.0E+00	9.1E-03	0.4	3.0E-05		9.1E-03	3.0E-05
		Maximum Credible	3.4E-04	3.4E-04	6.8E-04	1.0E+00	9.1E-03	0.8	4.9E-06		9.1E-03	4.9E-06
								Total	3.5E-05		Total	3.5E-05
Section 22	Refer Section 12											
Section 23	Steep Coastal Hills	Most likely	1.3E-03	8.9E-03	1.0E-02	9.8E-01	2.9E-06	0.7	2.0E-08		3.5E-04	2.5E-06

Track Section	Corresponding landscape unit	Event	Temporal probability of the event Rockfall	Temporal probability of the event Landslide	Temporal probability of the event (P _L) - combined	Probability of the landslide/rockfall reaching the track (P _{T:L})	Spatio-temporal probability of the person at risk (P _{S:T}) 2 ways/return	Vulnerability of the person (P _{D:T})	Probability of loss of life for a visitor P _(LoL)		Spatio-temporal probability of DoC ranger at risk (P _{S:T})	Probability of loss of life P _(LoL) for Ranger
		Maximum Credible	-	2.7E-04	2.7E-04	1.0E+00	2.9E-06	1	8.0E-10		3.5E-04	9.6E-08
								Total	2.1E-08		Total	2.5E-06
Section 24	Coastal Cliffs	Most likely	9.0E-05	1.2E-04	2.1E-04	1.0E+00	1.4E-06	0.7	2.1E-10		1.7E-04	2.5E-08
		Maximum Credible	1.0E-05	1.0E-05	2.1E-05	1.0E+00	1.4E-06	1	2.9E-11		1.7E-04	3.5E-09
								Total	2.4E-09		Total	2.8E-07
Section 25	Beach	Most likely	4.3E-03	3.8E-03	8.1E-03	9.0E-01	4.2E-06	0.7	2.1E-08		5.0E-04	2.6E-06
		Maximum Credible	3.4E-04	3.4E-04	6.7E-04	1.0E+00	4.2E-06	1	2.8E-09		5.0E-04	3.4E-07
								Total	2.4E-08		Total	2.9E-06
Section 26	Steep Coastal Hills	Most likely	1.6E-03	1.1E-02	1.3E-02	3.4E-01	8.4E-06	0.7	2.5E-08		1.0E-03	3.0E-06
		Maximum Credible	-	3.4E-04	3.4E-04	4.8E-01	8.4E-06	1	1.4E-09		1.0E-03	1.6E-07
								Total	2.7E-08		Total	3.2E-06
Section 27	Coastal Hill 1	Most likely	-	7.5E-03	7.5E-03	4.92E-02	5.4E-05	0.7	1.4E-08		6.4E-03	1.7E-06
		Maximum Credible	-	3.8E-03	3.8E-03	7.75E-02	5.4E-05	1	1.6E-08		6.4E-03	1.9E-06
								Total	3.0E-08		Total	3.5E-06
Section 28	Steep Coastal Hills	Most likely	1.3E-03	8.9E-03	1.0E-02	9.0E-01	3.2E-06	0.7	2.0E-08		3.8E-04	2.5E-06
		Maximum Credible	-	2.7E-04	2.7E-04	1.0E+00	3.2E-06	1	8.7E-10		3.8E-04	1.0E-07
								Total	2.1E-08		Total	2.6E-06
Section 29	Steep Coastal Hills	Most likely	3.4E-03	2.3E-02	2.6E-02	8.5E-02	3.4E-05	0.7	5.3E-08		4.0E-03	6.3E-06
		Maximum Credible	-	7.0E-04	7.0E-04	1.2E-01	3.4E-05	1	2.8E-09		4.0E-03	3.4E-07
								Total	5.5E-08		Total	6.6E-06
Section 1 (3b)	Steep Coastal Hills	Most likely	3.2E-03	2.1E-02	2.5E-02	1.1E-01	2.5E-05	0.7	4.9E-08		3.0E-03	5.9E-06
		Maximum Credible	-	6.6E-04	6.6E-04	1.6E-01	2.5E-05	1	2.6E-09		3.0E-03	3.2E-07
								Total	5.2E-08		Total	6.2E-06
Section 12 (2bi)	Steep Coastal Hills	Most likely	9.5E-03	6.3E-02	7.2E-02	7.0E-02	4.1E-05	0.7	1.5E-07		4.9E-03	1.7E-05
		Maximum Credible	-	1.9E-03	1.9E-03	9.8E-02	4.1E-05	1	7.8E-09		4.9E-03	9.4E-07
								Total	1.5E-07		Total	1.8E-05
Section 30	Coastal Hill 1	Most likely	-	1.0E-03	1.0E-03	2.06E-01	1.3E-05	0.7	1.9E-09		1.5E-03	2.2E-07
		Maximum Credible	-	5.1E-04	5.1E-04	3.25E-01	1.3E-05	1	2.1E-09		1.5E-03	2.5E-07
								Total	4.0E-09		Total	4.8E-07

Table Appendix C.10 : Societal risk calculation

Track Section	Corresponding landscape unit	Event	Temporal probability of the event (P_t)	Probability of the landslide/rockfall reaching the track (P_{T-L})	Vulnerability of the person (P_{D-T})	Spatio-temporal probability of Group of 1 or 2	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 5 to 7	Societal Risk for group of 5 or more fatalities		Spatio-temporal probability of Group of approx. 30	Societal Risk for group of 30 or more fatalities
Section 01	Steep Coastal Hills	Most likely	1.1E-01	3.39E-02	0.7	0.5	1.3E-03		0.25	6.3E-04		0.25	-
		Maximum Credible	2.9E-03	4.74E-02	1	0.5	6.8E-05		0.25	3.4E-05		0.25	3.4E-05
					Total	Total	1.3E-03		Total	6.7E-04		Total	3.4E-05
Section 02	Coastal Hills 2	Most likely	1.0E-03	7.73E-02	0.7	0.5	2.7E-05		0.25	-		0.25	-
		Maximum Credible	N/A	2.21E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	2.7E-05		Total	0.0E+00		Total	0.0E+00
Section 03	Steep Coastal Hills	Most likely	1.3E-02	1.07E-01	0.7	0.5	5.0E-04		0.25	2.5E-04		0.25	-
		Maximum Credible	3.6E-04	1.49E-01	1	0.5	2.7E-05		0.25	1.3E-05		0.25	1.3E-05
					Total	Total	5.3E-04		Total	2.6E-04		Total	1.3E-05
Section 04	Coastal Hills 2	Most likely	4.3E-04	3.04E-01	0.7	0.5	4.6E-05		0.25	-		0.25	-
		Maximum Credible	N/A	8.70E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	4.6E-05		Total	0.0E+00		Total	0.0E+00
Section 05	Coastal Hills 2	Most likely	8.9E-04	2.88E-01	0.7	0.5	9.0E-05		0.25	-		0.25	-
		Maximum Credible	N/A	8.24E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	9.0E-05		Total	0.0E+00		Total	0.0E+00
Section 06	Coastal Hills 2	Most likely	9.5E-04	1.49E-01	0.7	0.5	5.0E-05		0.25	-		0.25	-
		Maximum Credible	N/A	4.28E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	5.0E-05		Total	0.0E+00		Total	0.0E+00
Section 07	Coastal Hills 2	Most likely	2.3E-03	6.09E-02	0.7	0.5	4.9E-05		0.25	-		0.25	-
		Maximum Credible	N/A	1.74E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	4.9E-05		Total	0.0E+00		Total	0.0E+00
Section 08	Coastal Hills 2	Most likely	1.7E-03	4.23E-02	0.7	0.5	2.6E-05		0.25	-		0.25	-
		Maximum Credible	N/A	1.21E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	2.6E-05		Total	0.0E+00		Total	0.0E+00
Section 09	Escarpment	Most likely	5.4E-03	3.15E-01	0.7	0.5	5.9E-04		0.25	3.0E-04		0.25	-
		Maximum Credible	7.8E-04	1.00E+00	1	0.5	3.9E-04		0.25	2.0E-04		0.25	2.0E-04
					Total	Total	9.9E-04		Total	4.9E-04		Total	2.0E-04
Section 10	Steep Coastal Hills	Most likely	5.7E-03	8.34E-01	0.7	0.5	1.7E-03		0.25	8.4E-04		0.25	-
		Maximum Credible	1.5E-04	1.00E+00	1	0.5	7.7E-05		0.25	3.9E-05		0.25	3.9E-05
					Total	Total	1.7E-03		Total	8.7E-04		Total	3.9E-05
Section 11	Saddle	Most likely	8.6E-03	1.18E-01	0.7	0.5	3.5E-04		0.25	-		0.25	-
		Maximum Credible	8.6E-03	2.53E-01	1	0.5	1.1E-03		0.25	5.5E-04		0.25	5.5E-04
					Total	Total	1.4E-03		Total	5.5E-04		Total	5.5E-04
Section 12	Steep Coastal Hills	Most likely	1.5E-01	4.02E-02	0.7	0.5	2.0E-03		0.25	1.0E-03		0.25	-

Track Section	Corresponding landscape unit	Event	Temporal probability of the event (P _L)	Probability of the landslide/rockfall reaching the track (P _{T-L})	Vulnerability of the person (P _{D-T})	Spatio-temporal probability of Group of 1 or 2	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 5 to 7	Societal Risk for group of 5 or more fatalities		Spatio-temporal probability of Group of approx. 30	Societal Risk for group of 30 or more fatalities
		Maximum Credible	3.9E-03	5.63E-02	1	0.5	1.1E-04		0.25	5.5E-05		0.25	5.5E-05
					Total	Total	2.2E-03		Total	1.1E-03		Total	5.5E-05
Section 13	Coastal Cliffs	Most likely	7.3E-03	1.00E+00	0.7	0.5	2.5E-03		0.25	1.3E-03		0.25	-
		Maximum Credible	7.2E-04	1.00E+00	1	0.5	3.6E-04		0.25	1.8E-04		0.25	1.8E-04
					Total	Total	2.9E-03		Total	1.5E-03		Total	1.8E-04
Section 14	Beach	Most likely	1.0E-01	6.01E-02	0.7	0.5	2.2E-03		0.25	1.1E-03		0.25	-
		Maximum Credible	8.6E-03	1.05E-01	1	0.5	4.5E-04		0.25	2.2E-04		0.25	2.2E-04
					Total	Total	2.6E-03		Total	1.3E-03		Total	2.2E-04
Section 15	Cathedral Cove Arch	Most likely	4.9E-01	6.33E-02	0.5	0.5	7.7E-03		0.25			0.25	-
		Maximum Credible	6.4E-02	1.88E-01	0.7	0.5	4.2E-03		0.25			0.25	-
					Total	Total	1.2E-02		Total	0.0E+00		Total	0.0E+00
Section 16	Coastal Cliffs	Most likely	1.4E-02	4.56E-01	0.7	0.5	2.2E-03		0.25	1.1E-03		0.25	-
		Maximum Credible	1.4E-03	1.00E+00	1	0.5	6.9E-04		0.25	3.4E-04		0.25	3.4E-04
					Total	Total	2.9E-03		Total	1.5E-03		Total	3.4E-04
Section 17	Coastal Hills 2	Most likely	5.7E-04	1.02E-01	0.7	0.5	2.0E-05		0.25	1.0E-05		0.25	-
		Maximum Credible	N/A	2.93E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	2.0E-05		Total	1.0E-05		Total	0.0E+00
Section 18	Beach	Most likely	3.2E-02	1.72E-01	0.7	0.5	1.9E-03		0.25	9.7E-04		0.25	-
		Maximum Credible	2.7E-03	2.88E-01	1	0.5	3.8E-04		0.25	1.9E-04		0.25	1.9E-04
						Total	2.3E-03		Total	1.2E-03		Total	1.9E-04
Section 19	Steep Coastal Hills	Most likely	9.1E-03	2.15E-01	0.7	0.5	6.8E-04		0.25	3.4E-04		0.25	-
		Maximum Credible	2.4E-04	3.01E-01	1	0.5	3.7E-05		0.25	1.8E-05		0.25	1.8E-05
					Total	Total	7.2E-04		Total	3.6E-04		Total	1.8E-05
Section 20	Beach	Most likely	2.1E-02	2.53E-01	0.7	0.5	1.8E-03		0.25	9.2E-04		0.25	-
		Maximum Credible	1.7E-03	4.22E-01	1	0.5	3.6E-04		0.25	1.8E-04		0.25	1.8E-04
					Total	Total	2.2E-03		Total	1.1E-03		Total	1.8E-04
Section 21	Coastal Hills 2	Most likely	3.3E-04	2.05E-01	0.7	0.5	2.4E-05		0.25	-		0.25	-
		Maximum Credible	N/A	5.88E-01	1	0.5	-		0.25	-		0.25	-
					Total	Total	2.4E-05		Total	0.0E+00		Total	0.0E+00
Point Location 1 (Bench)	Steep Coastal Hills	Most likely	2.0E-03	1.00E+00	0.7	0.5	7.1E-04		0.25	3.5E-04		0.25	-
		Maximum Credible	5.4E-05	1.00E+00	1	0.5	2.7E-05		0.25	1.4E-05		0.25	1.4E-05
					Total	Total	7.4E-04		Total	3.7E-04		Total	1.4E-05
Point Location 3 (Lifeguard Hut)	Beach	Most likely	1.4E-02	1.00E+00	0.4	0.5	2.8E-03		0.25	1.4E-03		0.25	-
		Maximum Credible	1.2E-03	1.00E+00	0.8	0.5	4.7E-04		0.25	2.3E-04		0.25	2.3E-04
					Total	Total	3.3E-03		Total	1.6E-03		Total	2.3E-04
Section 22	Refer Section 12												
Section 23	Steep Coastal Hills	Most likely	1.0E-02	9.83E-01	0.7	0.5	3.5E-03		0.25	1.8E-03		0.25	-

Track Section	Corresponding landscape unit	Event	Temporal probability of the event (P _L)	Probability of the landslide/rockfall reaching the track (P _{T:L})	Vulnerability of the person (P _{D:T})	Spatio-temporal probability of Group of 1 or 2	Societal Risk for fatality of 1 or more		Spatio-temporal probability of Group of approx. 5 to 7	Societal Risk for group of 5 or more fatalities		Spatio-temporal probability of Group of approx. 30	Societal Risk for group of 30 or more fatalities
		Maximum Credible	2.7E-04	1.00E+00	1	0.5	1.4E-04		0.25	6.9E-05		0.25	6.9E-05
					Total	Total	3.6E-03		Total	1.8E-03		Total	6.9E-05
Section 24	Coastal Cliffs	Most likely	2.1E-04	1.00E+00	0.7	0.5	7.4E-05		0.25	3.7E-05		0.25	-
		Maximum Credible	2.1E-05	1.00E+00	1	0.5	1.0E-05		0.25	5.2E-06		0.25	5.2E-06
					Total	Total	8.5E-05		Total	4.2E-05		Total	5.2E-06
Section 25	Beach	Most likely	8.1E-03	9.05E-01	0.7	0.5	2.6E-03		0.25	1.3E-03		0.25	-
		Maximum Credible	6.7E-04	1.00E+00	1	0.5	3.4E-04		0.25	1.7E-04		0.25	1.7E-04
					Total	Total	2.9E-03		Total	1.5E-03		Total	1.7E-04
Section 26	Steep Coastal Hills	Most likely	1.3E-02	3.42E-01	0.7	0.5	1.5E-03		0.25	7.5E-04		0.25	-
		Maximum Credible	3.4E-04	4.79E-01	1	0.5	8.1E-05		0.25	4.0E-05		0.25	4.0E-05
					Total	Total	1.6E-03		Total	7.9E-04		Total	4.0E-05
Section 27	Coastal Hills 1	Most likely	7.5E-03	4.92E-02	0.7	0.5	1.3E-04		0.25	-		0.25	-
		Maximum Credible	3.8E-03	7.75E-02	1	0.5	1.5E-04		0.25	7.3E-05		0.25	7.3E-05
					Total	Total	2.8E-04		Total	7.3E-05		Total	7.3E-05
Section 28	Steep Coastal Hills	Most likely	1.0E-02	9.04E-01	0.7	0.5	3.2E-03		0.25	1.6E-03		0.25	-
		Maximum Credible	2.7E-04	1.00E+00	1	0.5	1.4E-04		0.25	6.9E-05		0.25	6.9E-05
					Total	Total	3.4E-03		Total	1.7E-03		Total	6.9E-05
Section 29	Steep Coastal Hills	Most likely	2.6E-02	8.50E-02	0.7	0.5	7.8E-04		0.25	3.9E-04		0.25	-
		Maximum Credible	7.0E-04	1.19E-01	1	0.5	4.2E-05		0.25	2.1E-05		0.25	2.1E-05
					Total	Total	8.2E-04		Total	4.1E-04		Total	2.1E-05
Section 30	Coastal Hills 1	Most likely	1.0E-03	2.06E-01	0.7	0.5	7.2E-05		0.25	-		0.25	-
		Maximum Credible	5.1E-04	3.25E-01	1	0.5	8.2E-05		0.25	4.1E-05		0.25	4.1E-05
					Total	Total	1.5E-04		Total	4.1E-05		Total	4.1E-05
Section 1 (3b)	Steep Coastal Hills	Most likely	2.5E-02	1.1E-01	0.7	0.5	9.9E-04		0.25	4.9E-04		0.25	-
		Maximum Credible	6.6E-04	1.6E-01	1	0.5	5.3E-05		0.25	2.6E-05		0.25	2.6E-05
					Total	Total	1.0E-03		Total	5.2E-04		Total	2.6E-05
Section 12 (2bi)	Steep Coastal Hills	Most likely	7.2E-02	7.0E-02	0.7	0.5	1.8E-03		0.25	8.9E-04		0.25	-
		Maximum Credible	1.9E-03	9.8E-02	1	0.5	9.5E-05		0.25	4.8E-05		0.25	4.8E-05
					Total	Total	1.9E-03		Total	9.3E-04		Total	4.8E-05

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2024 Landslide Monitoring

Prepared for
Department of Conservation

Prepared by
Tonkin & Taylor Ltd

Date
June 2024

Job Number
1007838.3000 v1



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sustain a better world**
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Document control

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1 Introduction

Tonkin & Taylor Ltd (T+T) has been engaged¹ by the Department of Conservation (DoC) to undertake landslide monitoring for the Cathedral Cove and Hahei tracks. The location of these tracks are presented in Figure 1.1 and Appendix A. Stingray Bay and Gemstone Bay tracks are not within the current monitoring scope.

The purpose of the monitoring is to better understand the condition of the existing landslide and rockfall sites affecting the tracks and to inform development of remediation or track realignment options (outside of the scope of this work).

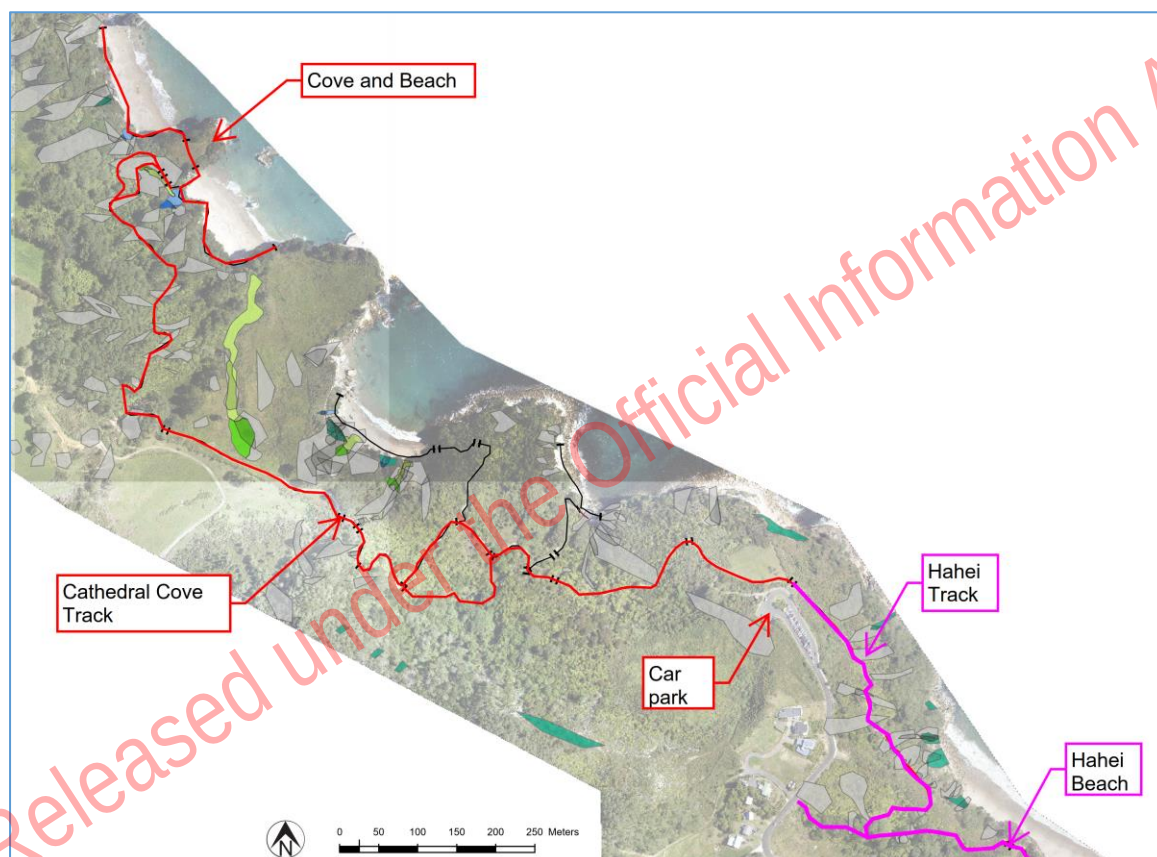


Figure 1.1: Site plan showing proposed monitoring.

2 Monitoring

The key objectives of the landslide monitoring are as follows:

- Document changes and conditions of landslide and rockfall sites affecting the tracks. Particular focus will be placed on the access to the beach areas, Cove arch, and areas of possible mitigation options, as outlined in our 2023 report².
- Provide recommendations for future monitoring, if required.

The monitoring involved walking the extent of the tracks within the scope. This included track from Hahei beach to the Grange Road carpark, and from this carpark to Cathedral Cove beach, including the Cathedral Cove Arch.

¹ Tonkin & Taylor Ltd (7 February 2024). *Variation Order (VO4). Cathedral Cove Monitoring – 2024*, Ref 1007838.3000.

Site observations included the following.

- Condition of existing landslide and rockfall sites.
- Documenting newly observed events.
- In addition to conducting observations on-foot, unmanned aerial vehicle (UAV) imagery was utilised where areas were in dangerous or hard to reach locations.

T+T undertook two rounds of monitoring:

- 28 & 29 February 2024.
- 30 & 31 May 2024.
- Supplementary observations were also made during walkovers and tiltmeter installation in March and April 2024, as part of feasibility assessment work.

The observations taken on the dates listed above were compared with baseline observations taken during our 2023 visits².

3 Landslide inventory

The landslide inventory, produced initially in 2023 as part of our risk assessment², was updated with the results of the monitoring. The landslide inventory is presented in Appendix C.

A selection of photographs, observations and comparisons of the landslide inventory are presented in Appendix B and discussed in Section 5.

4 Tilt meter monitoring results

In addition to undertaking visual observations of the landslide and rockfall events, DOC arranged for tilt meters, supplied by Adroit, to be installed on site. The tilt meters provide near real-time monitoring of possible ground movement at the installed location.

A total of five tilt meters were installed on 11 April 2024 at different locations, as shown on Figure 4.1. These locations were selected where slow moving land instability was possible or where potential for track mitigation/realignment is considered.

² Tonkin & Taylor Ltd (July 2023) *Cathedral Cove basic Level Landslide Risk Assessment*. Reference 1007838.3000, version 3. Prepared for Department of Conservation

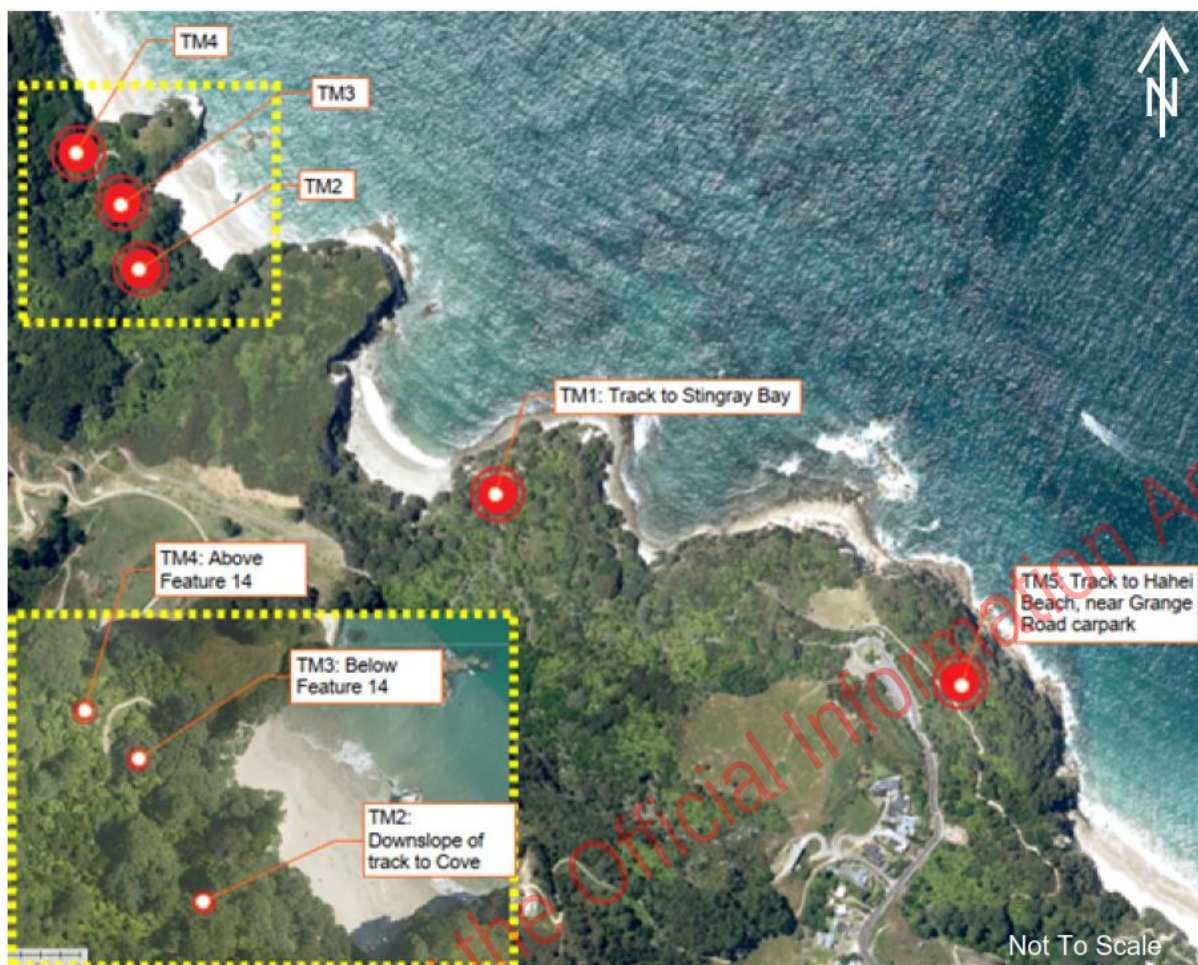


Figure 4.1: Tiltmeter locations.

Continuous logging of data is recorded by the tilt meters. Displacement (movement) of the tiltmeter is calculated by the supplier Adriot using pitch and roll sensors. The displacement recorded by the tilt meters and daily rainfall is illustrated in Figure 4.2. Maximum cumulative displacement observed since installation is approximately 1 to 2 mm in TM1 and TM4. Displacement in other tilt meters has been less than 1 mm. Calculated displacements appear to coincide with rain events.

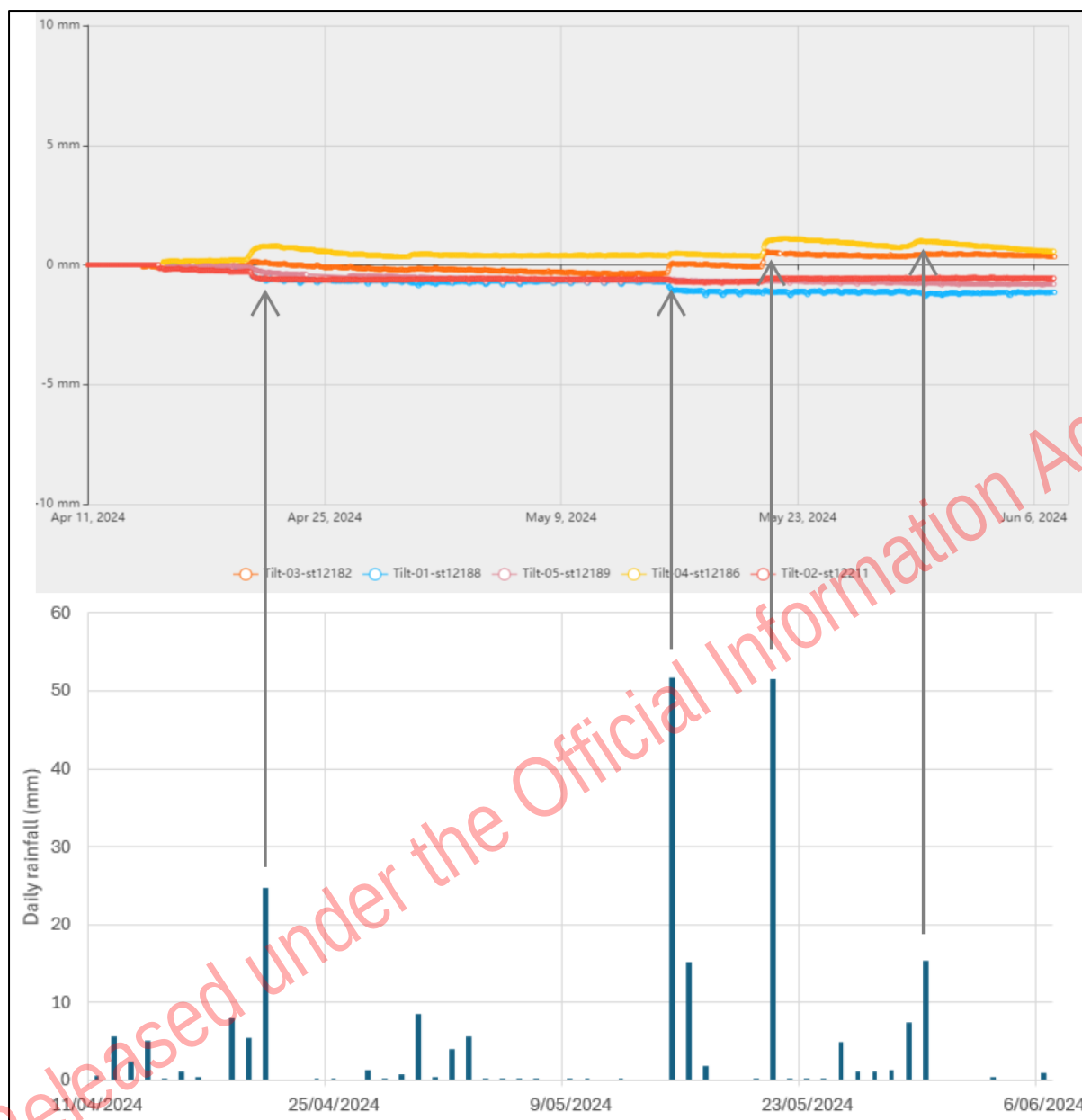


Figure 4.2: Tilt meter calculated displacements and daily rainfall. Tilt meter data supplied by Adroit. Daily rainfall source NIWA CliFlo Whitianga Aero AWS Station 1520.

5 Landslide monitoring results

5.1 General

The aim of the February and May 2024 monitoring rounds was to compare the condition of the landslides and rockfall at the site over time with the baseline observations undertaken during 2023, and to identify any new landslide or rockfall events.

A selection of annotated photographs showing the comparisons between the landslide and rockfall events over the course of the monitoring period are presented in Appendix B. A summary of the findings of the February & May 2024 monitoring rounds are presented below.

5.2 February 2024 monitoring round

Monitoring was carried out on 28 and 29 February 2024 by a T+T engineering geologist and geotechnical engineer and included inspection of the track areas and a series of UAV flights. Supplementary observations were carried out during other site walkovers and tilt meter installation in March and April 2024.

A total of 11 new landslide, rockfall or creep features were observed, and four existing features were observed to have changed since 2023. Key areas of change include small amounts of movement/regression of exposed headscarps, additional tension cracks and additional rockfall. However, many of the existing landslide/rockfall sites remain unchanged. More detail is provided below:

- Cathedral Cove Track:
 - No changes were observed that would suggest significant additional landslide or rockfall movement. This includes the large landslide near the beach access.
 - The changes observed were as follows:
 - o Small amounts of headscarp regression (< 250 mm) from erosion were observed in five landslides.
 - o Small additional movement (less than 25 mm) within the headscarp of the landslide near the viewing platform (Feature 7).
 - Newly observed:
 - o A new landslide was observed by drone in the escarpment distant from the track (Feature 183).
 - o A new tension crack was observed in the track (Feature 184).
 - o Both are likely from the early 2023 storm event.
- Cathedral Cove Beach and Arch:
 - The large rockfall events from 2023 located each side of the cove (Features 15 & 16) showed evidence of small amounts of headscarp regression due to erosion (< 200 mm).
 - Newly observed:
 - o Cove Arch: Evidence of four new rockfall events (ranging from 0.1 to 0.5 m³) observed on the cove arch. These have occurred since the 2023 site visit (Features 185 to 188).
 - o South and north beach sections: Two small rockfalls (<0.1 m³) have occurred in these areas since 2023 (Features 189 and 190).
- Hahei Track and Beach:
 - Changes to existing landslide features:
 - o Small amounts of regression due to erosion was observed in the exposed headscarps of Features 28 and 30. These landslides are close to the track within the steep coastal cliffs. Additional new tension cracks have developed at these two sites (refer newly observed Features 192 and 193 below).
 - o Near the beach access in front of the residential properties, existing tension cracks and slumps are associated with culverts which discharge down slope. Upon further inspection of this area an additional tension crack was observed. The tension crack is likely associated with the early 2023 storm event (i.e., not new) and no additional movement is indicated.
 - Newly observed:

- o A new tension crack (Feature 192) shows movement behind an existing headscarp (Feature 28) and is associated with an existing culvert which discharges to the exposed scarp.
- o A new tension crack (Feature 193) is associated with Feature 30.
- o A newly observed tension crack measuring about 55 m long was observed along the track below the Grange Road carpark (Feature 191).
- Mitigation route (Option 3b):
 - o No new landslides were observed.
 - o Some seepage zones were noted associated within a gully.
 - o Some boulders were observed near the top of slope from the Grange Road access, but these appear to be an old feature.
 - o Large pine trees remain, as well as some large fallen pine which were first observed in 2023. We understand from DOC that some trees have fallen since the 2023 storm event.

5.3 May 2024 monitoring round

Monitoring was carried out on 30 and 31 May 2024 by a T+T engineering geologist and geotechnical engineer, and included inspection of the track areas and a series of UAV flights.

A total of two new rockfall and two new creep features were observed, and two existing features were observed to have changed since February 2024. The key finding is that the existing landslide/rockfall sites remain unchanged compared with February 2024 (and March 2023) with the exception of Feature 7. More detail is provided below:

- Cathedral Cove Track:
 - No changes were observed that would suggest significant additional landslide or rockfall movement. This includes the large landslide near the beach access.
 - The changes observed were as follows:
 - o Some additional small movement (< 25 mm) of the landslide headscarp near the viewing platform (Feature 7).
 - Newly observed:
 - o Two new small tension cracks were observed in the track pavement (Features 194 and 195). Both are likely from the early 2023 storm event.
- Cathedral Cove Beach and Arch:
 - The large rockfall events from 2023 located each side of the cove (Features 15 and 16) showed no change.
 - Newly observed:
 - o Cove Arch: A single small rockfall (< 0.1 m³) observed near the northern portal (Feature 196).
 - o South Beach: A single rockfall (< 1 m³) observed (Feature 197).
- Hahei Track and Beach, including mitigation route 3b: No changes or new features observed.

6 Monitoring summary and recommendations

The results of the monitoring have identified landslide and rockfall features broadly in line with what we would expect from this landscape, and our previous rockfall monitoring undertaken in the Cathedral Cove arch³.

With this in mind, the conclusions of our 2024 feasibility assessment⁴ report remain unchanged. Ongoing regression of the existing landslide headscarps is likely to occur. There is a risk of landslides and rockfalls, particularly after large rainfall events. Rockfalls within the cove area and coastal cliffs are also on going. For further discussion on landslide hazards and risk, see our feasibility assessment report.

Summary points of the monitoring are listed below.

- 1 During the February monitoring a total of 11 new landslide, rockfall or creep features were observed, and four existing features were observed to have changed since 2023. Of the 11 new features, two of these are likely older and associated with the 2023 weather events. The remaining nine are likely new since approximately mid-2023.
- 2 During the May monitoring a total of four new rockfall or creep features were observed and two existing features were observed to have changed since the February monitoring. Of the four new features, two of these are likely older and associated with the 2023 weather events.
- 3 Key areas of change include small amounts of movement/regression of exposed headscarps, additional tension cracks and additional rockfall. However, many of the existing landslide/rockfall sites remain unchanged.
- 4 Feature 7 is continuing to move, and we expect that this slow moving landslide will continue to move downslope. A rapid failure at this location might occur, however we do not know if/when this might eventuate. Based on the ongoing movement observed to date and our judgement only (i.e., not analysed), we might expect a rapid event could occur within a short time period (i.e., next year or two).
- 5 Five rockfalls have occurred within the Cove Arch (Features 185 – 188 and 196). These have been all <1 m³ of debris.
- 6 A new tension crack (Feature 192) shows movement behind an existing headscarp (Feature 28) and is associated with an existing culvert which discharges to the exposed scarp.
- 7 DOC arranged for tilt meters to be installed on site to provide continuous real-time monitoring of possible ground movement. Maximum cumulative displacement observed from the five tilt meters since installation is approximately 1 to 2 mm in TM1 and TM4. Displacement in other tilt meters has been less than 1 mm. Calculated displacements appear to coincide with rain events.

We recommend the following:

- Similar to our previous reporting, we recommend that routine inspections by DOC staff are undertaken three monthly and after heavy rainfall (more than 100 mm of rain in 24 hours) and significant earthquake events (M5 or greater within 200 km). If landslides or rockfall may have occurred, we recommend an inspection is undertaken by a geotechnical professional to understand the potential associated hazards.
- We suggest that six monthly inspections of the Cathedral Cove Arch, continue to be undertaken by a geotechnical professional to ensure regular and consistent monitoring of the cove is taking place. We understand from DOC that their planned inspections can be

³ Tonkin & Taylor Ltd (15 August 2023). *June 2022 Cathedral Cove Monitoring*, Reference 2007838.2000

⁴ Tonkin & Taylor Ltd (May 2024). *Cathedral Cove Track Feasibility Assessment*. Reference 1007838.4000, version 3.

Prepared for Department of Conservation

interrupted by other work requirements and/or staff may not have the experience/training to undertake these inspections. The suggested six-monthly site inspections could be undertaken in spring prior to the summer peak period, and in autumn.

- Continue monitoring the tilt meter data. If DOC wish to continue with the monitoring, we can discuss with you and agree a suitable approach, and whether review of the monitoring data is best placed with DOC or with T+T (Adriot also may be able to place notification emails at specified triggering amounts of movement). Where tilt meters have exceeded more than 2 mm calculated displacement from the baseline 'zero', a geo-professional should be engaged to review the data and to assess conditions on site.
- Management of culvert outlets is implemented to reduce potential for stormwater destabilising existing landslide features. This could be considered for Features 9, 29 and 192 where culverts have been identified nearby. We could discuss potential practical solutions with you, which may include level spreaders and/or pipe/flume drop structures.
- Mitigations to prevent public access to Feature 7 are implemented. This could be a temporary barrier fence.

7 Applicability

This report has been prepared for the exclusive use of our client Department of Conservation, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by:

Authorised for Tonkin & Taylor Ltd by:

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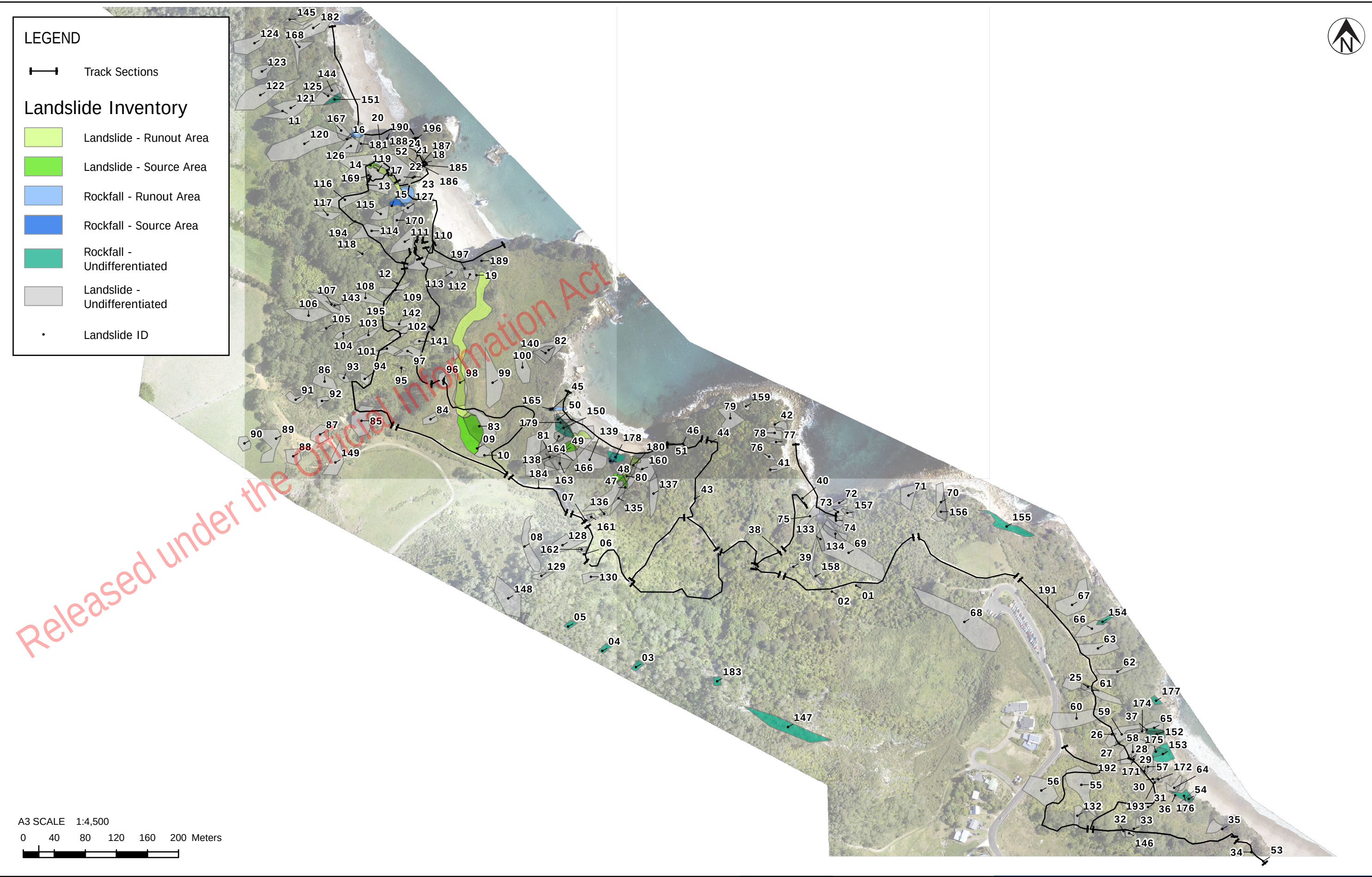
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Appendix A Figures

- Figure A1: Track setting, landslides, and inventory references

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Appendix B Monitoring comparisons

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Feature 1 - Two sets of tension cracks
No new movement

21/03/2023



21/03/2023



28/02/2024



28/02/2024



Feature 1 Continued - Two sets of tension cracks
No new movement

30/05/2024



30/05/2024



Feature 2 - One set of tension cracks. No new movement.



Feature 3 - Rockfall. No new movement



Feature 4 - Rockfall. No new movement

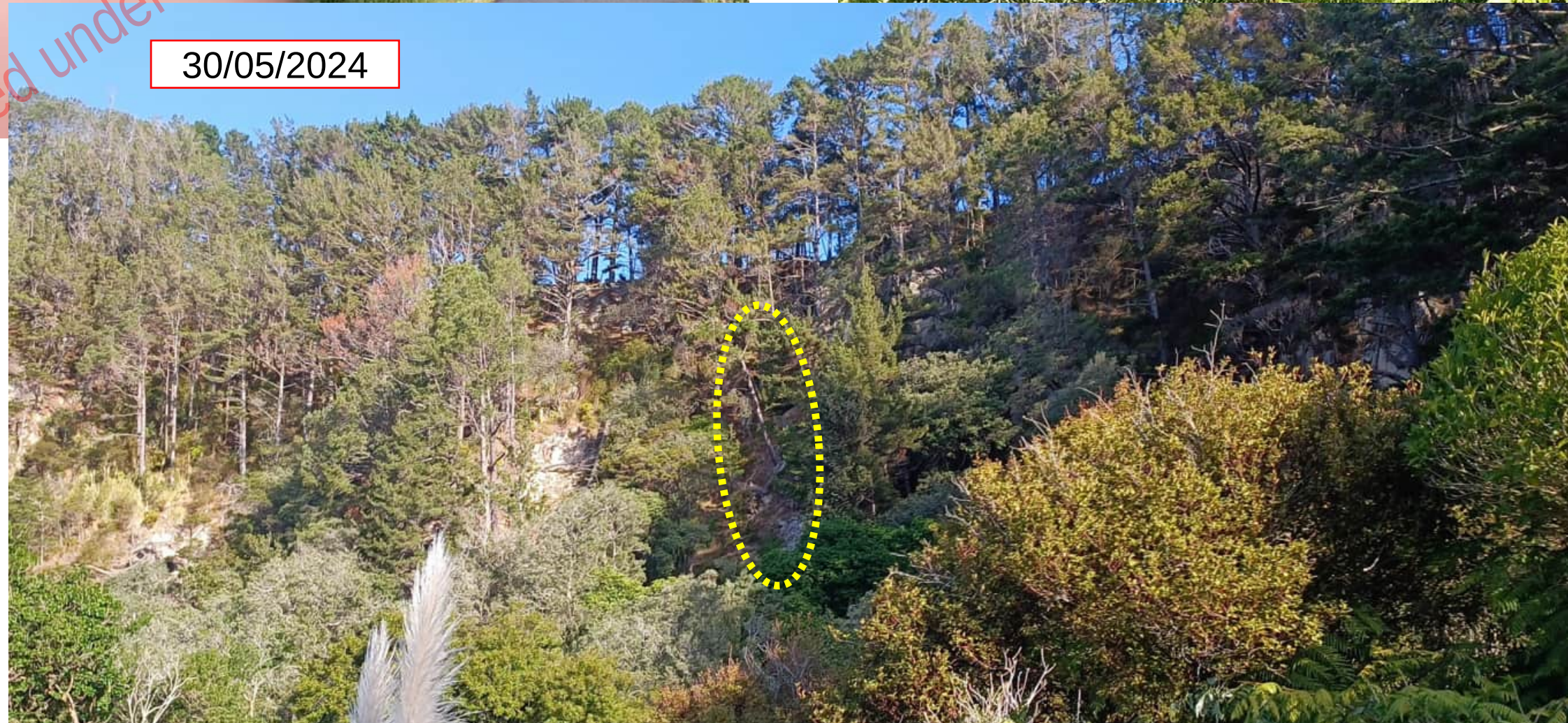
21/03/2023



28/02/2024



30/05/2024



Feature 5 - Rockfall. No new movement

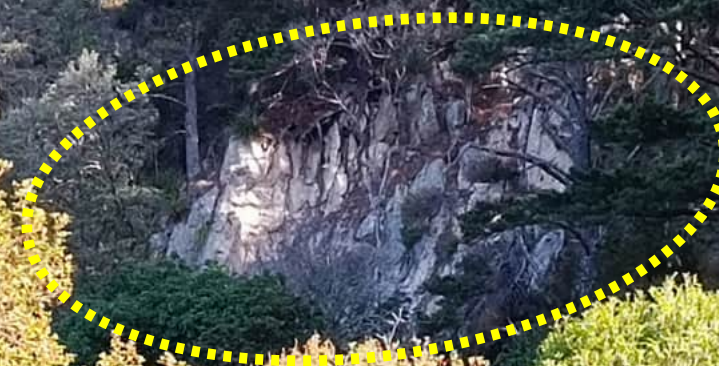
21/03/2023



28/02/2024



30/05/2024



Feature 3,4,5 - Rockfall
No new movement.

28/02/2024

Likely associated with
2023 storm event. Not
visible from the track.

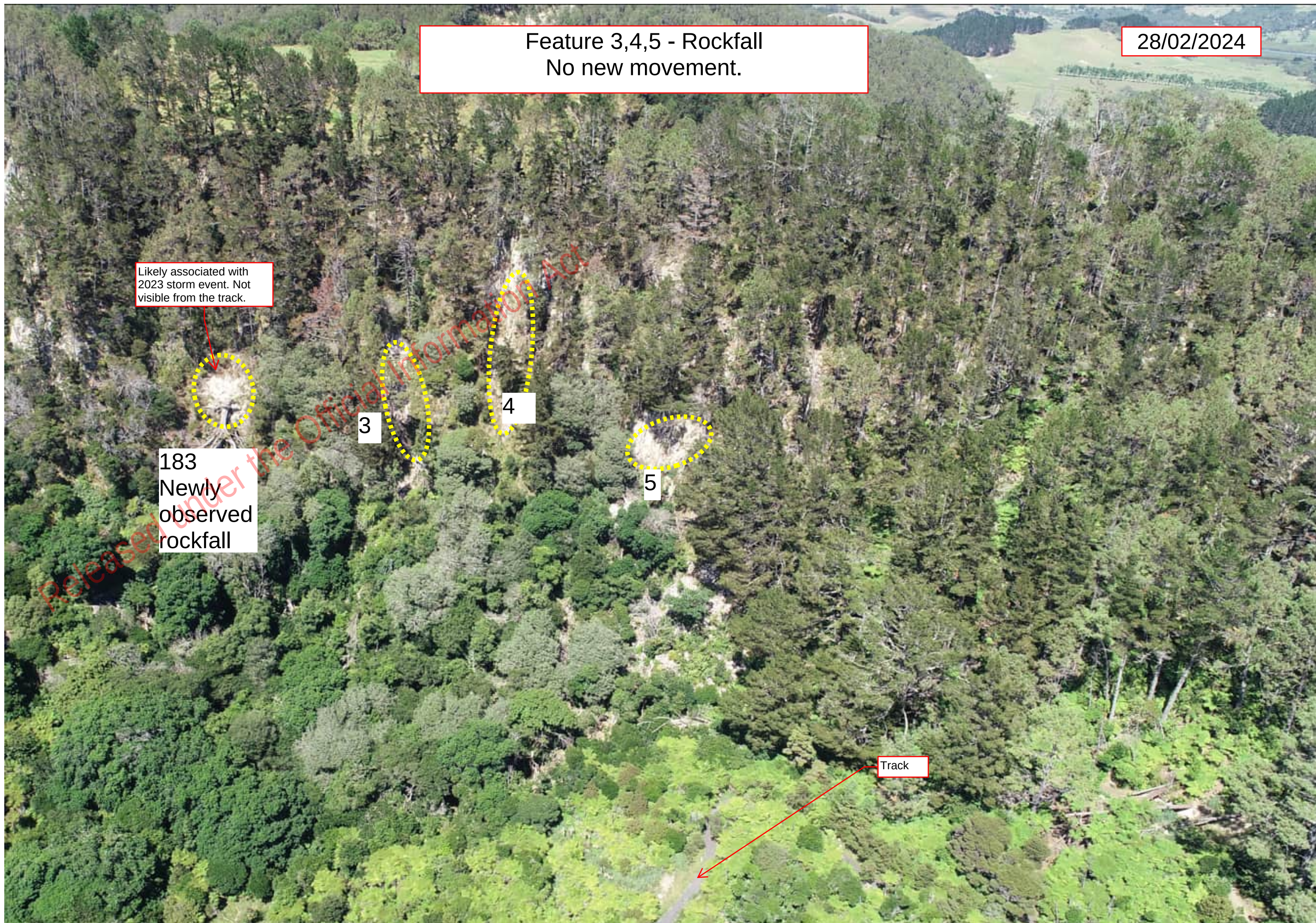
183
Newly
observed
rockfall

3

4

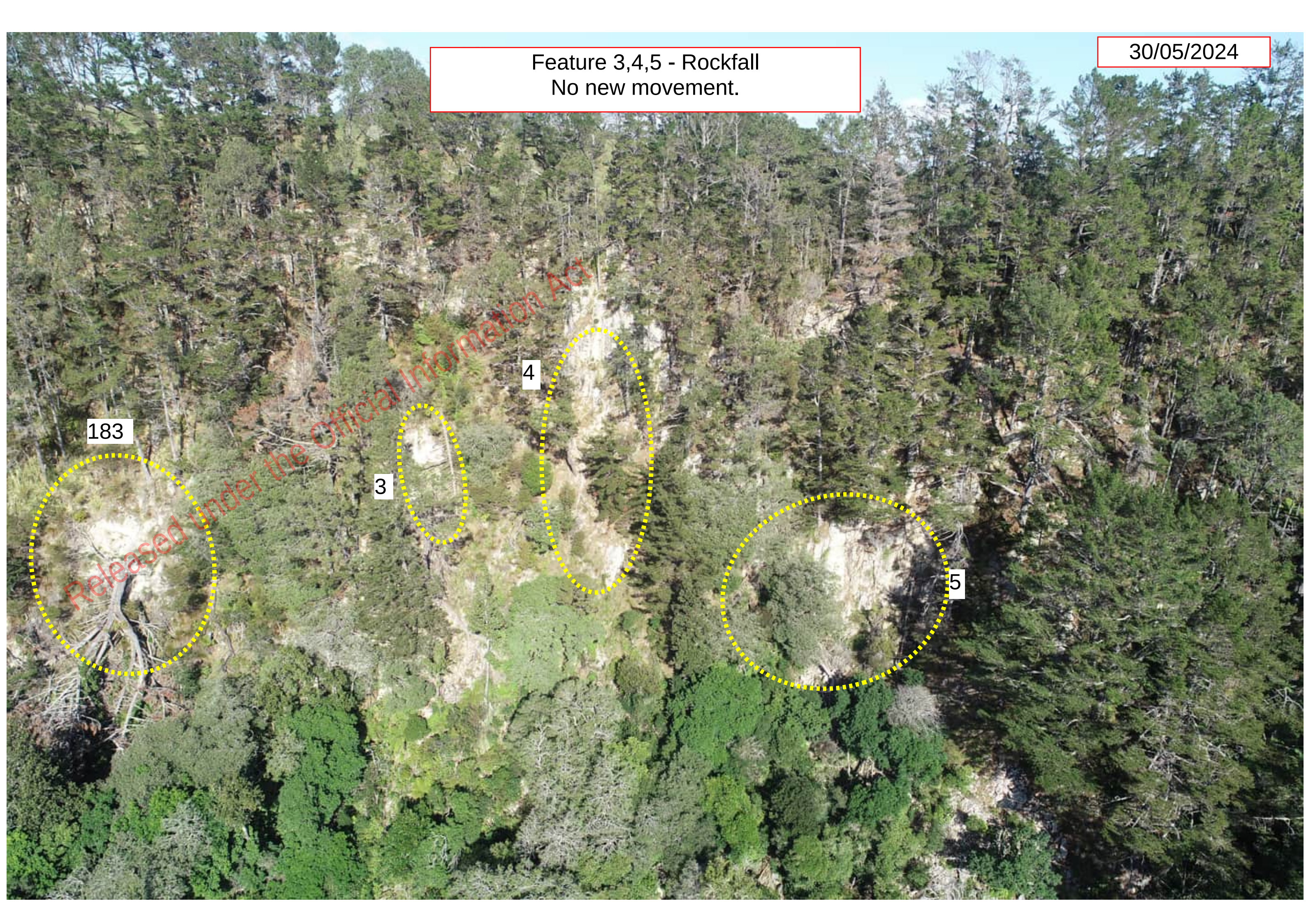
5

Track



30/05/2024

Feature 3,4,5 - Rockfall
No new movement.



183

3

4

5

Feature 6 - Translational landslide. No new movement.



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Feature 7 - Translational landslide
Small amounts of additional deflection
in the scarp observed during Feb 2024
visit.

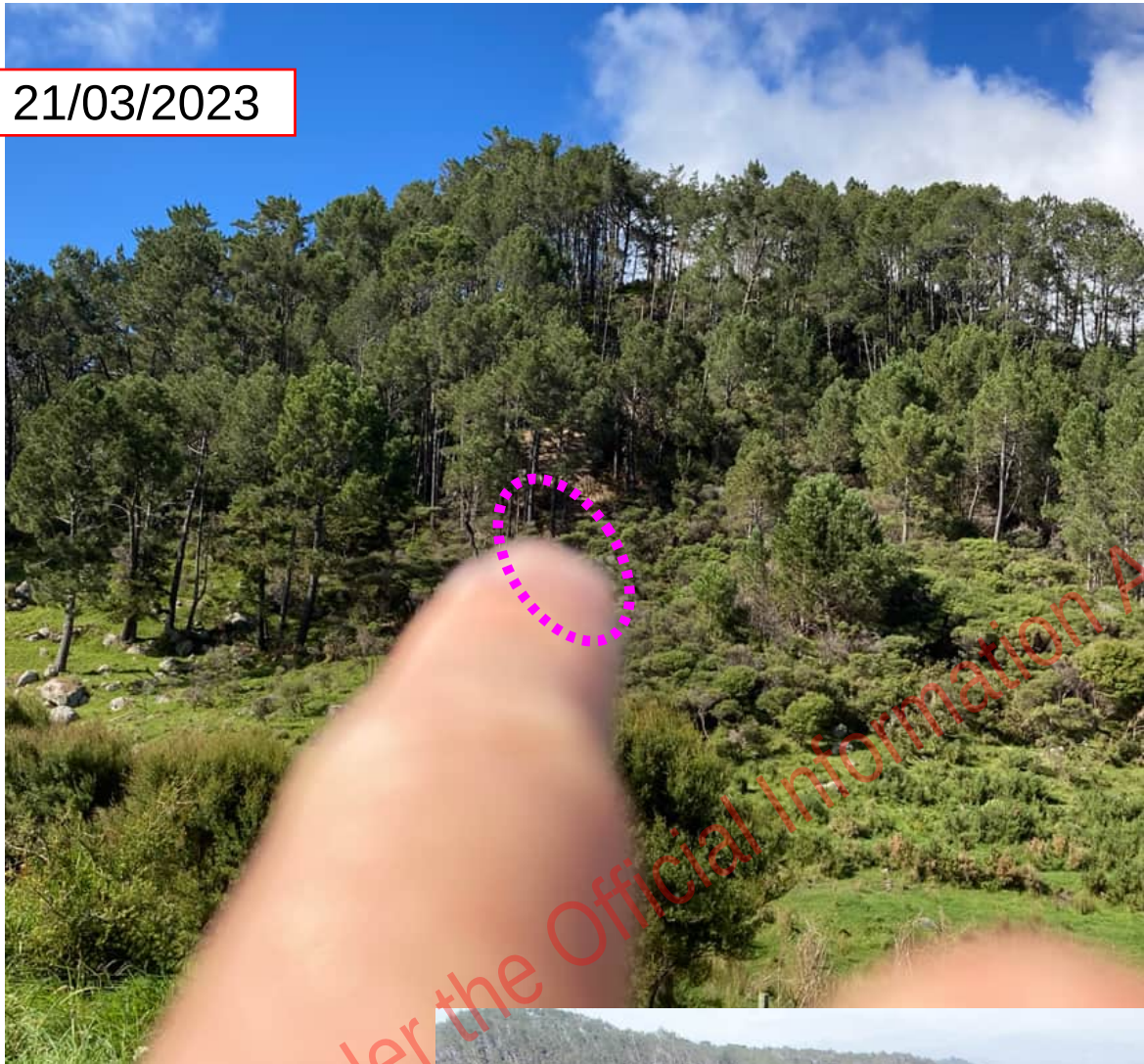


Feature 7 Cont. - Translational landslide
Small additional deflection in the scarp
observed during May 2024 visit.



Feature 8 - Debris flow landslide. No new movement

21/03/2023



28/02/2024



30/05/2024



28/02/2024



~6 m long and 1 cm aperture, does not look fresh.

28/02/2024



184 New Feature - Tension crack on west side of track in moderately sloping ground.
No new movement.

30/05/2024



Feature 9 and 10 - Landslide earth flow and tension crack. No new significant damage observed during Feb 2024 visit. Erosion (< 0.25 m) of headscarp.

A culvert discharges to the vicinity of the headscarp

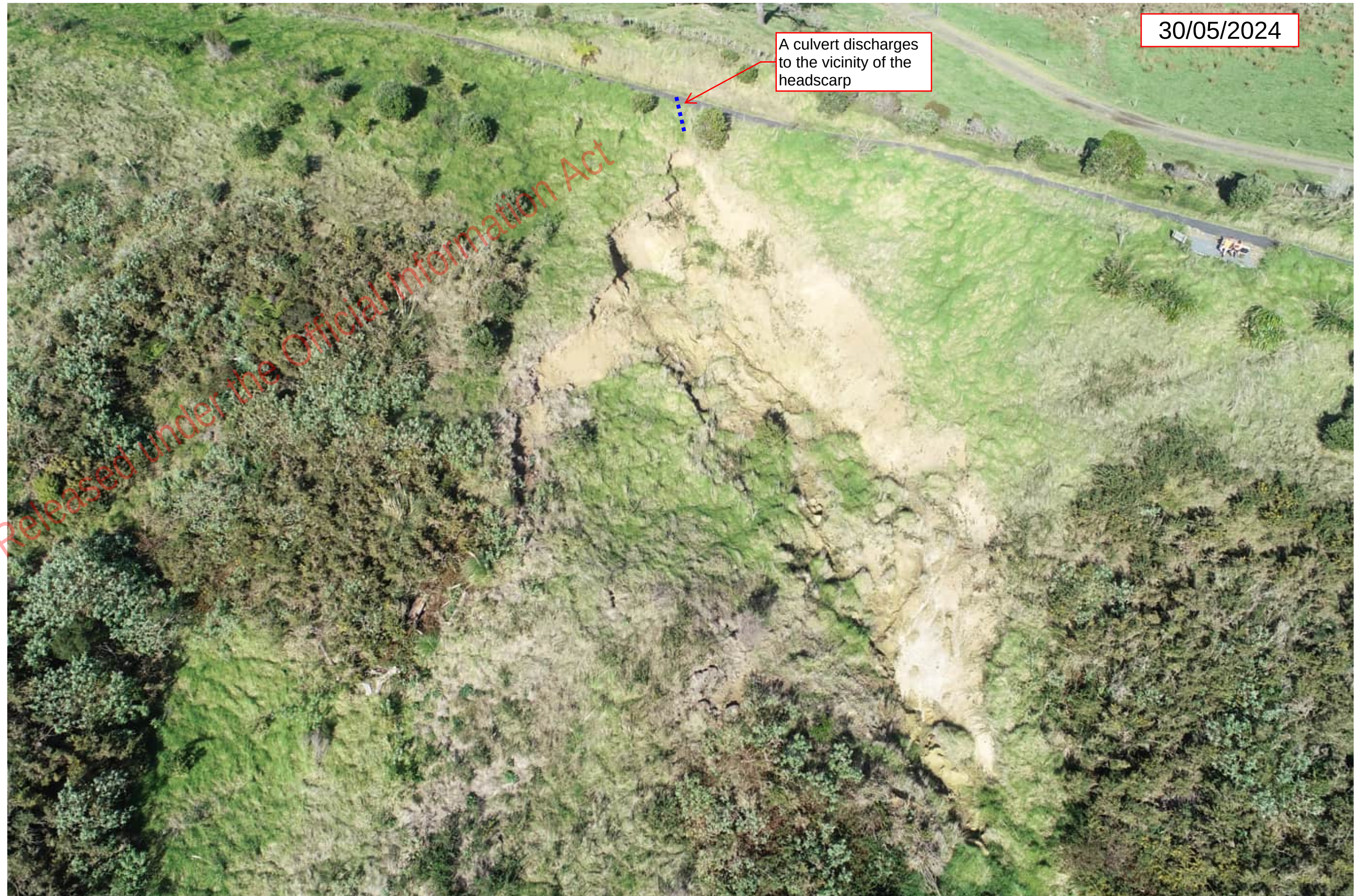
A culvert discharges to the vicinity of the headscarp

21/03/2023

28/02/2024



Feature 9 and 10 - Landslide earth flow
and tension crack.
No new movement since Feb 2024.



Feature 12 - Creep/tension crack
No evidence of new movement. Total
current aperture of ~10 mm.

21/03/2023



28/02/2024



Feature 13 - Translational landslide
No new landslide movement. Some erosion
(<100 mm) of the head scarp.
An older associated scarp was observed
encroaching into the ground adjacent to the
proposed new toilet block location.



Feature 14 - Debris flow landslide
No new significant damage. Some regression of the head scarp
has occurred (approximately $< 200\text{mm}$) due to erosion
(observed during Feb 2024 visit).

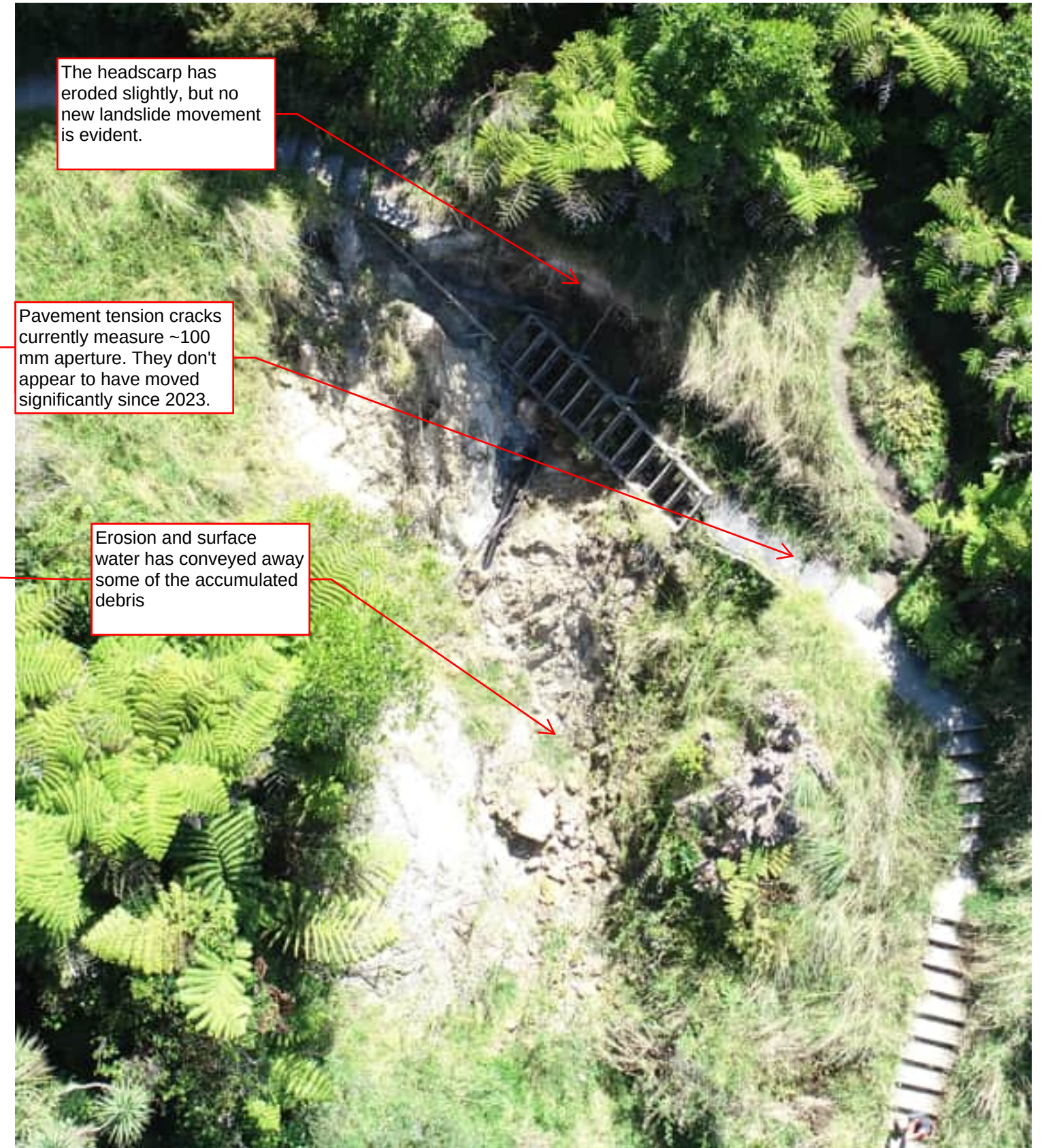


Feature 14 continued

21/03/2023



28/02/2024



Feature 14 continued.
No new movement
observed during May
2024 visit.

30/05/2024



Cove access area. No significant changes observed

21/03/2023



28/02/2024



30/05/2024



Note change in sand level since 2023 storm event.

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Feature 15 - Rockfall

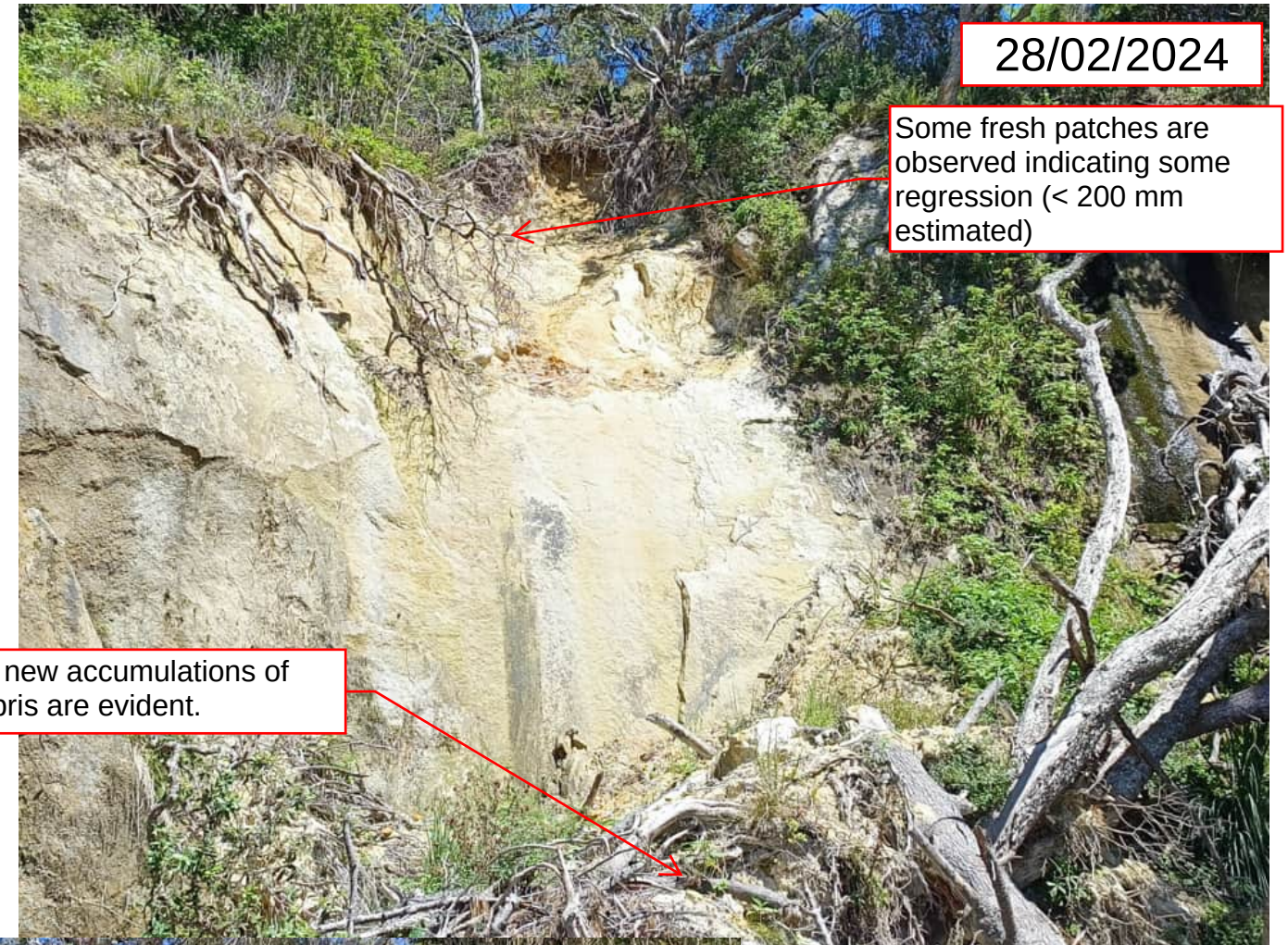
No new significant damage from landslide or rockfall movement.
Regression of the headscarp within the soil/rock overburden due to erosion.

21/03/2023



28/02/2024

Some fresh patches are observed indicating some regression (< 200 mm estimated)



No new accumulations of debris are evident.

30/05/2024



Released under the Official Information Act

Feature 16 - Rockfall
Regression of the head scarp at the
overburden level due to erosion (<200 mm)
observed during Feb 2024 visit. No
significant new inundation.

Feature 16 - Rockfall
Regression of the head scarp at the
overburden level due to erosion (<200 mm)
observed during Feb 2024 visit. No
significant new inundation.

21/03/2023



Released under the Official Information Act

28/02/2024

Some small loose blocks remain on the near vertical face

28/02/2024

Some small loose blocks remain on the near vertical face

Feature 16 Continued - Rockfall
No significant new inundation.

30/05/2024



Released under the Official Information Act

185, 186, 187 Cathedral Cove arch. New rockfall observed near the southern cove portal on the apex of the cove arch during Feb 2024 visit. No new damage observed during May 2024 visit.

21/03/2023

Historical rockfall location

Portal block location

New rockfall locations in the apex ~ 0.1 to 0.2 m³ for each event estimated

28/02/2024

187

185

186

Some rockfall has occurred in the location of the portal block

30/05/2024

Released under the Official Information Act

188 Cathedral Cove arch, above western wall middle section near cove apex. No change observed during May 2024 visit.

21/03/2023

Additional rockfall from previous rockfall areas (~0.5 m³)

28/02/2024

188

30/05/2024

Released under the Official Information Act

Cathedral Cove arch. North portal cubic block remains.
Small rockfall observed during May 2024 visit.

21/03/2023

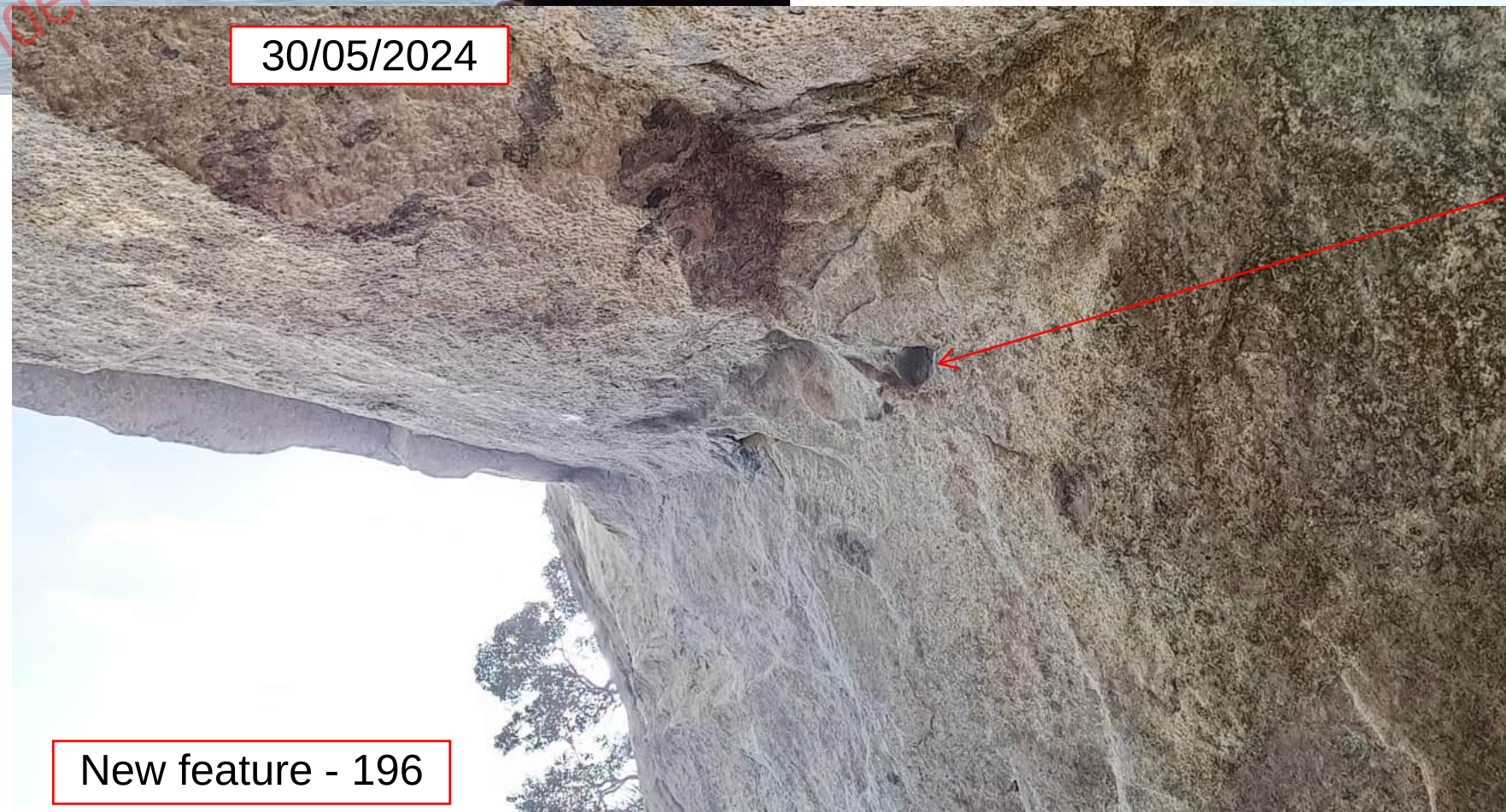


28/02/2024



Cubic block

30/05/2024

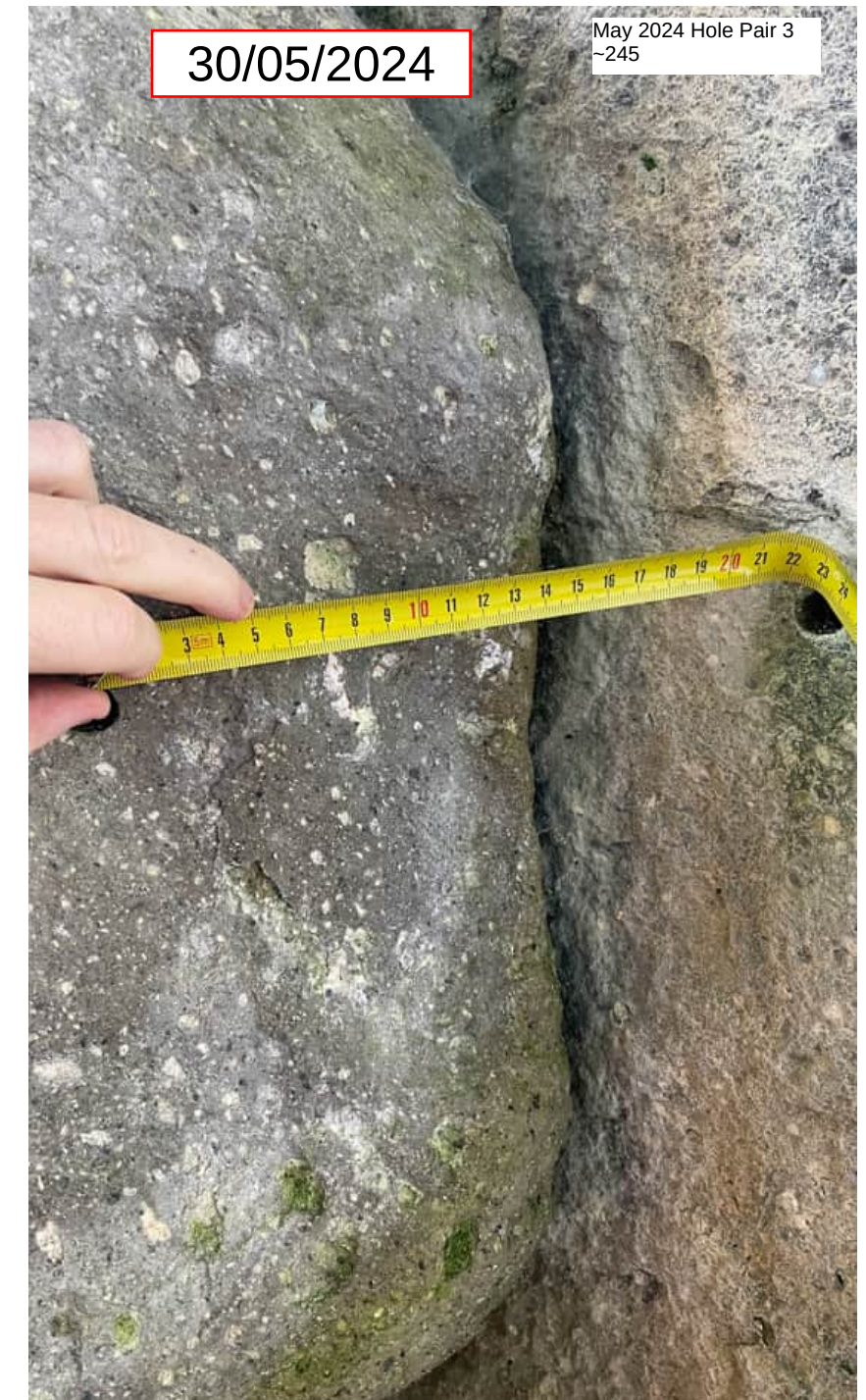


Small rockfall - less than
0.01m3.

New feature - 196

Released under the Official Information Act

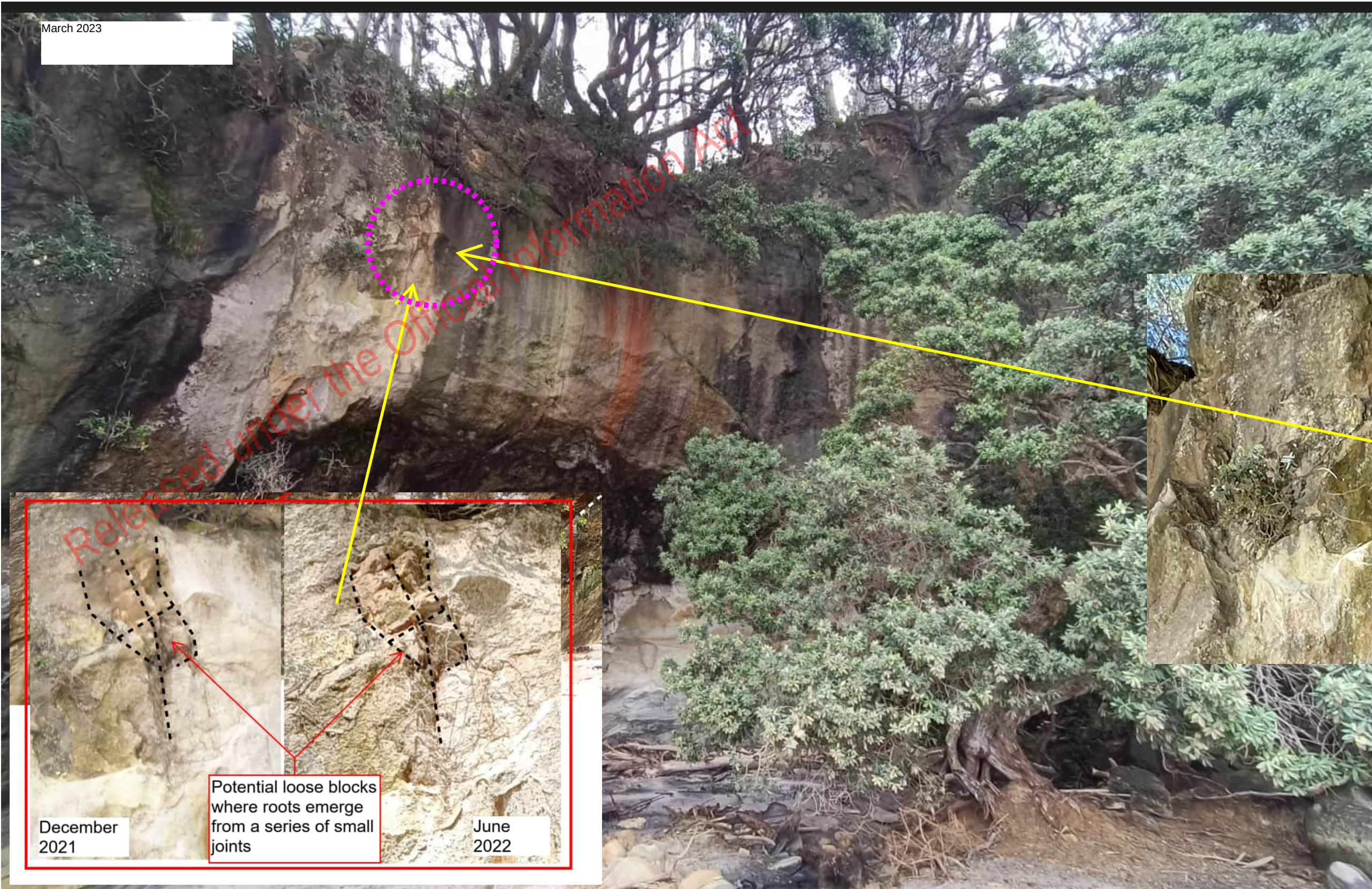
Cathedral Cove arch. Drilled holes. No change.



Notes:
seepage on the cove apex and eastern
wall. Lots of recent rain.

189 South Cliff Section
Additional rockfall (<0.1 m3)
observed in Feb 2024

March 2023



Feb 2024, small rockfall from area with roots.

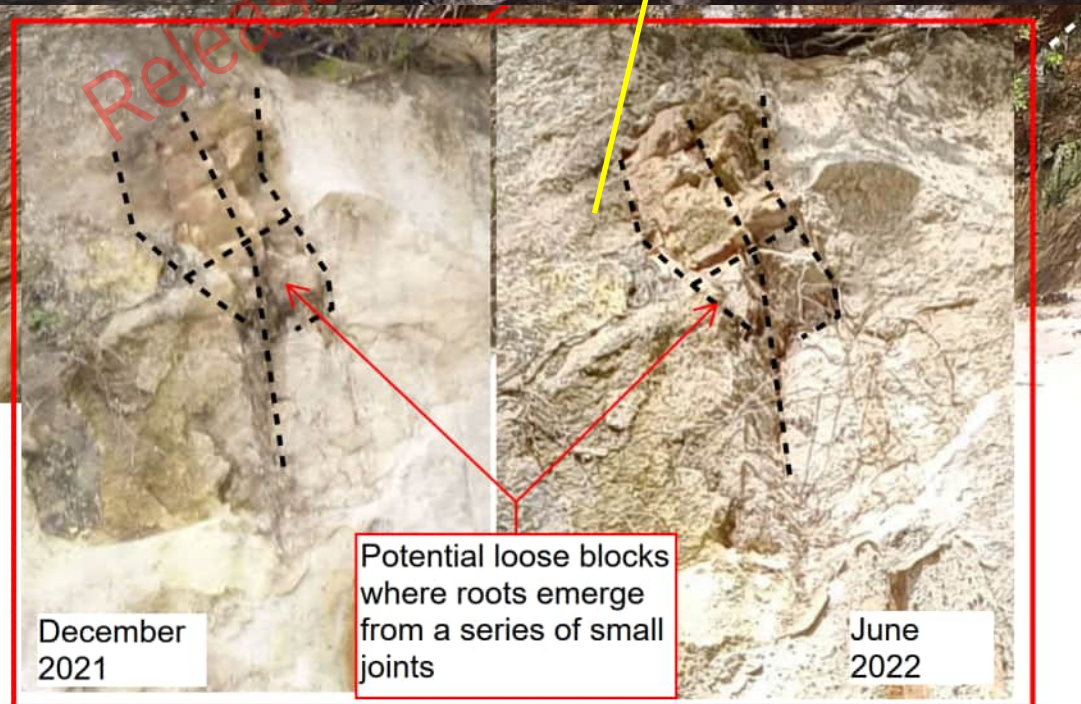
189



Potential loose blocks where roots emerge from a series of small joints

December 2021

June 2022



189 South Cliff Section
Continued. 1 x small rockfall
observed (<1m³) during May
2024 visit.

30/05/2024



Small rockfall with
roots emerging, far
right hand side of
south beach section
towards cliff top.

South cliff area - New feature (197)



30/05/2024

New rockfall observed

Released under the Official Information Act

190 Northern Cliff Section

March 2023



Feb 2024



Subparallel Joints containing roots. Similar inferred conditions to April 2021 rock fall area.

Potential Tabular Block containing roots. Refer Figure A9

Areas of potential rock fall indicated by observed joints, which typically contain roots. Other areas on the cliff may fail without observable joints being present.

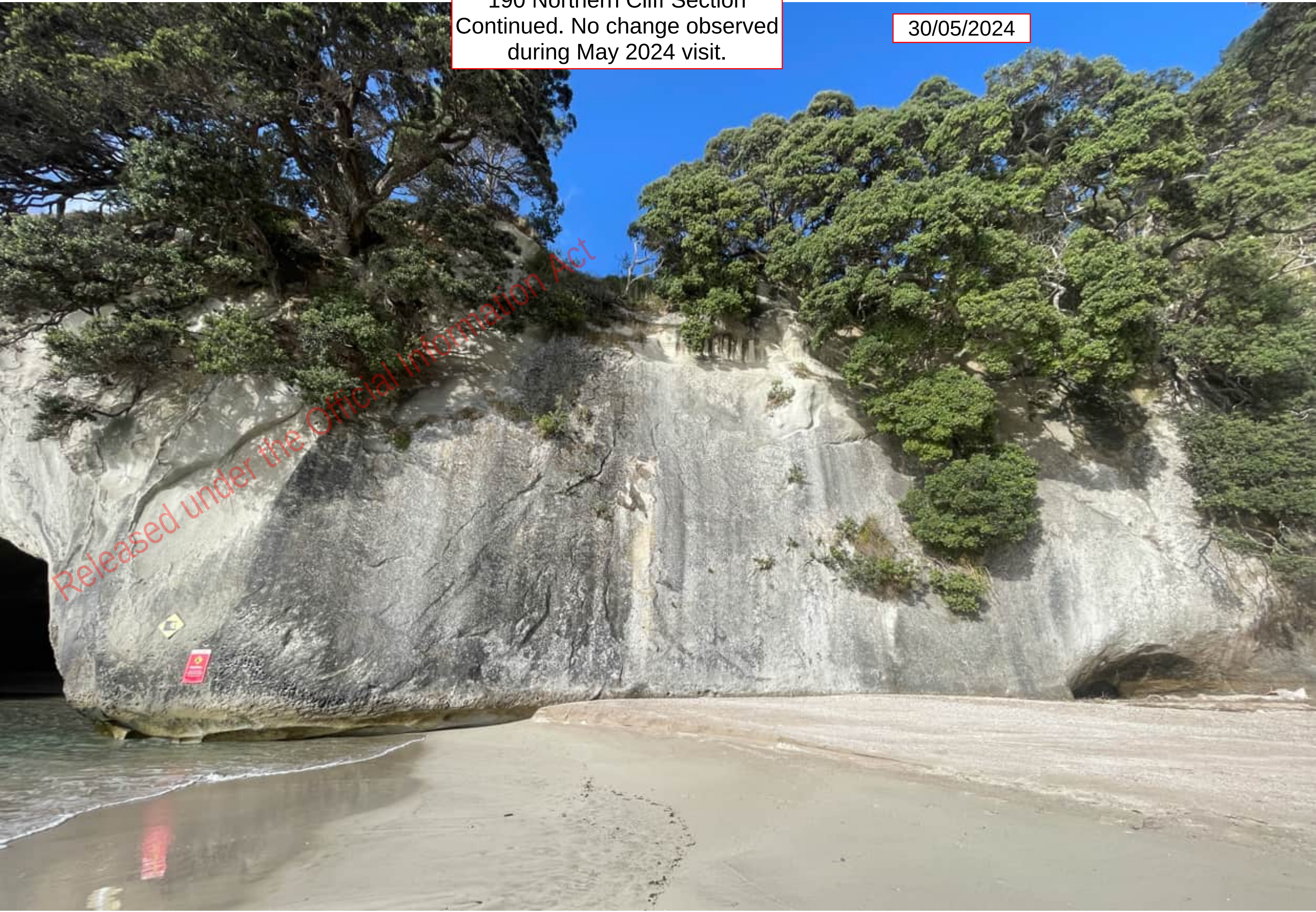
Figure A17: Location 4.1
North Cliff Section
June 2022

Released under the Official Information Act

190 Northern Cliff Section
Continued. No change observed
during May 2024 visit.

30/05/2024

Released under the Official Information Act

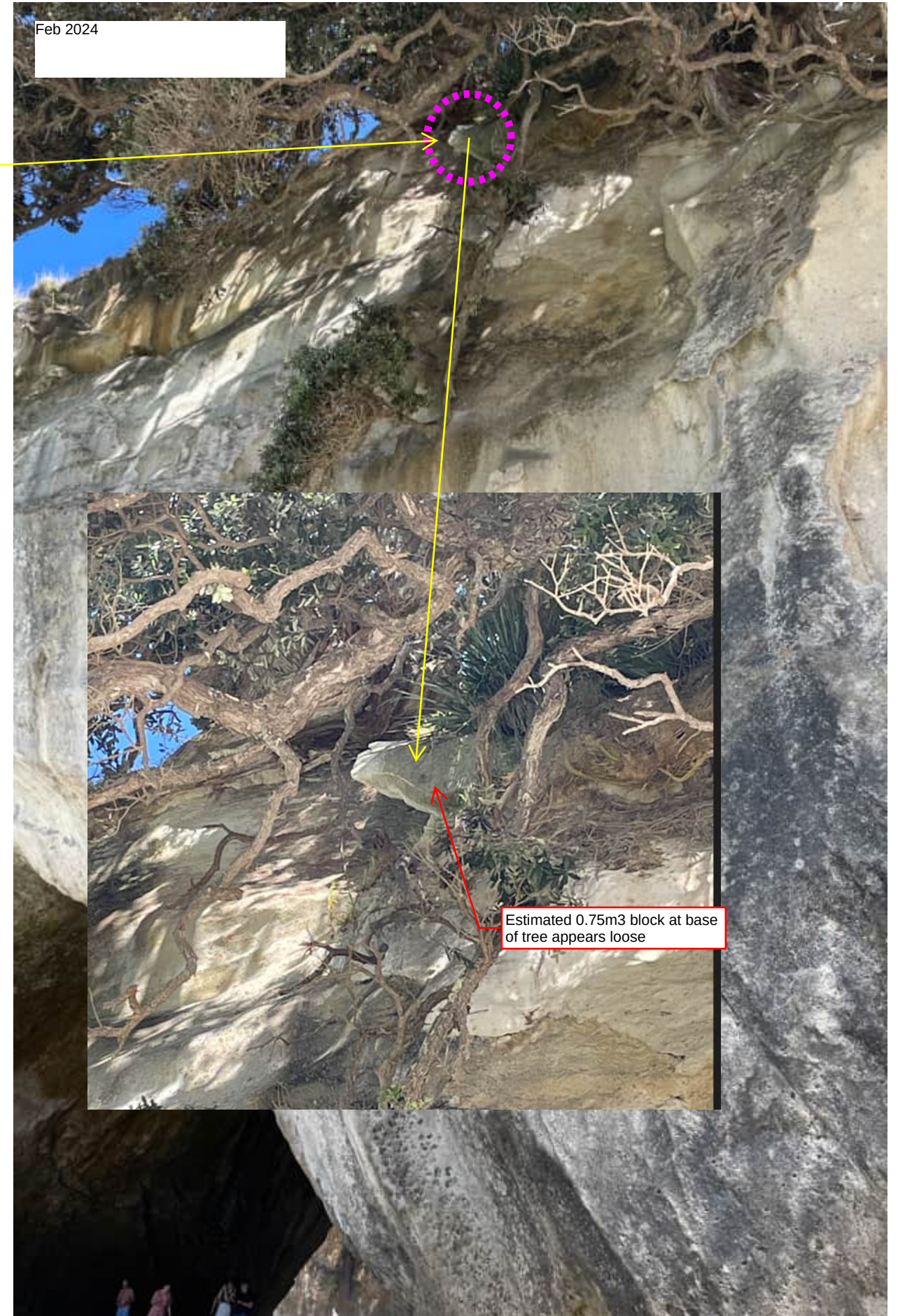


Northern portal

March 2023



Feb 2024



Northern portal Continued. No change
observed during May 2024 visit.

30/05/2024



30/05/2024



Feature 194 - Tension crack. Newly observed in May 2024 visit.
This event is difficult to see and likely to be historical.



Feature 195 - Tension crack. Newly observed in May 2024 visit.
The event may be historical.



17/05/2023

Feature 25 - Translational landslide. No new movement, historical landslide

29/02/2024



30/05/2024

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Feature 26 - Translational landslide. Some erosion (<50 mm) of landslip headscarp observed during Feb 2024 visit. No new movement observed during May 2024 visit.

17/05/2023



29/02/2024



30/05/2024



Released under the Official Information Act

Feature 27 - Translational landslide. Very thickly vegetated, no new movement observed. Historical

17/05/2023



29/02/2024



30/05/2024

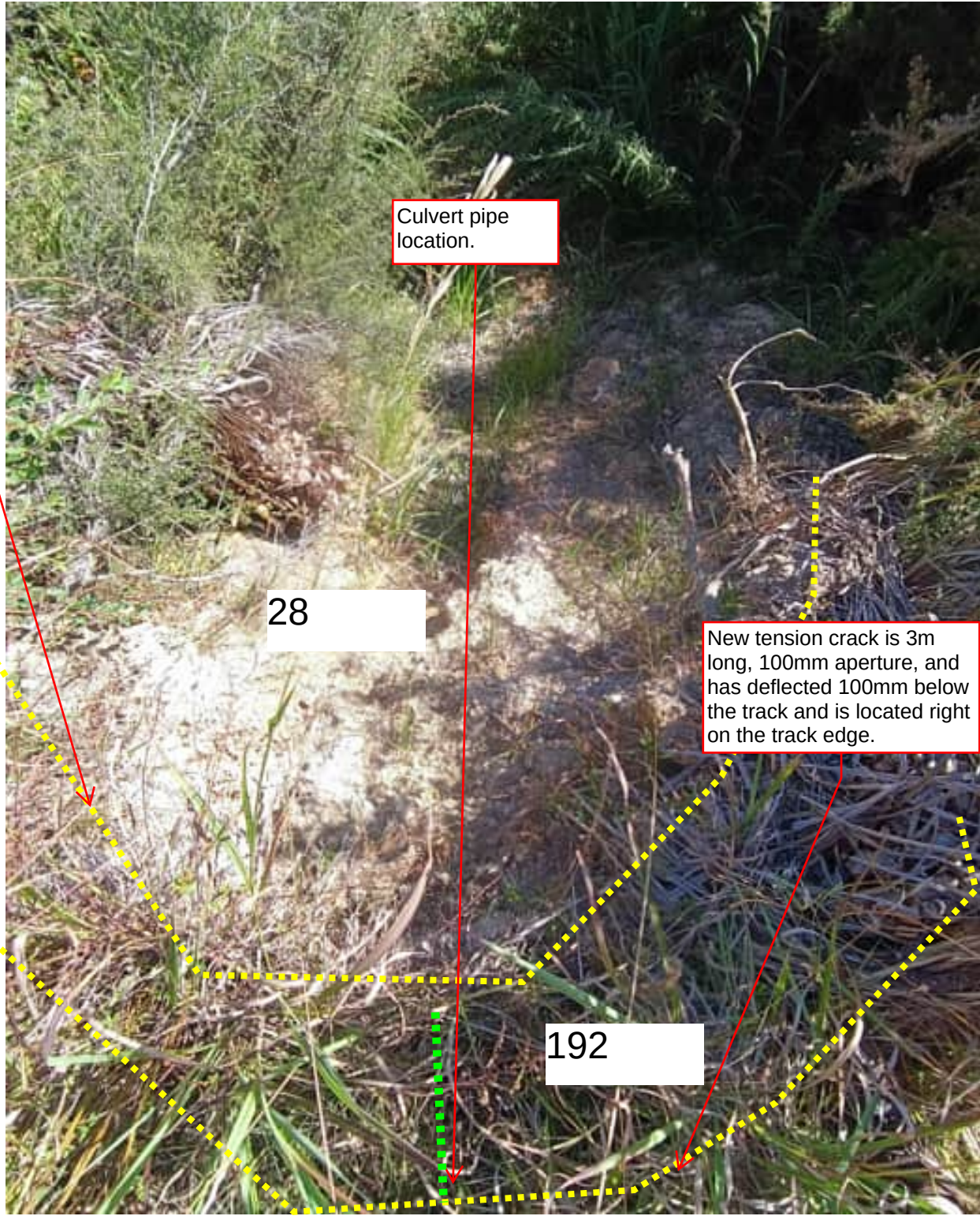


Feature 28 - Translational landslide.
A new tension crack developed (observed Feb 2024) approximately
300mm behind the headscarp (192)

17/05/2023



29/02/2024



Feature 28 Continued - Translational landslide
No new damage observed during May 2024 visit.



Feature 29 - Historical translational landslide. No new movement of historical landslide. Adjacent slope shows some loose roots

17/05/2023



29/02/2024



30/05/2024



Feature 30 - Translational landslide
Headscarp is now 150mm away from the
fence. A new tension crack has formed
near the Southern end of the fence (193).
(Observed during Feb 2024 visit).



Feature 30 - Translational landslide
No new movement observed during May 2024 visit.



Feature 31 - Historical Translational landslide. No new damage. Well vegetated.

17/05/2023



29/02/2024



Headscarp is ~100mm from the track.

30/05/2024



Feature 32 - Historical translational landslide. No new damage, well vegetated.

17/05/2023



29/02/2024



30/05/2024



Released under the Official Information Act

Feature 33 - Historical translational landslide. No new damage, well vegetated.

17/05/2023



29/02/2024



30/05/2024

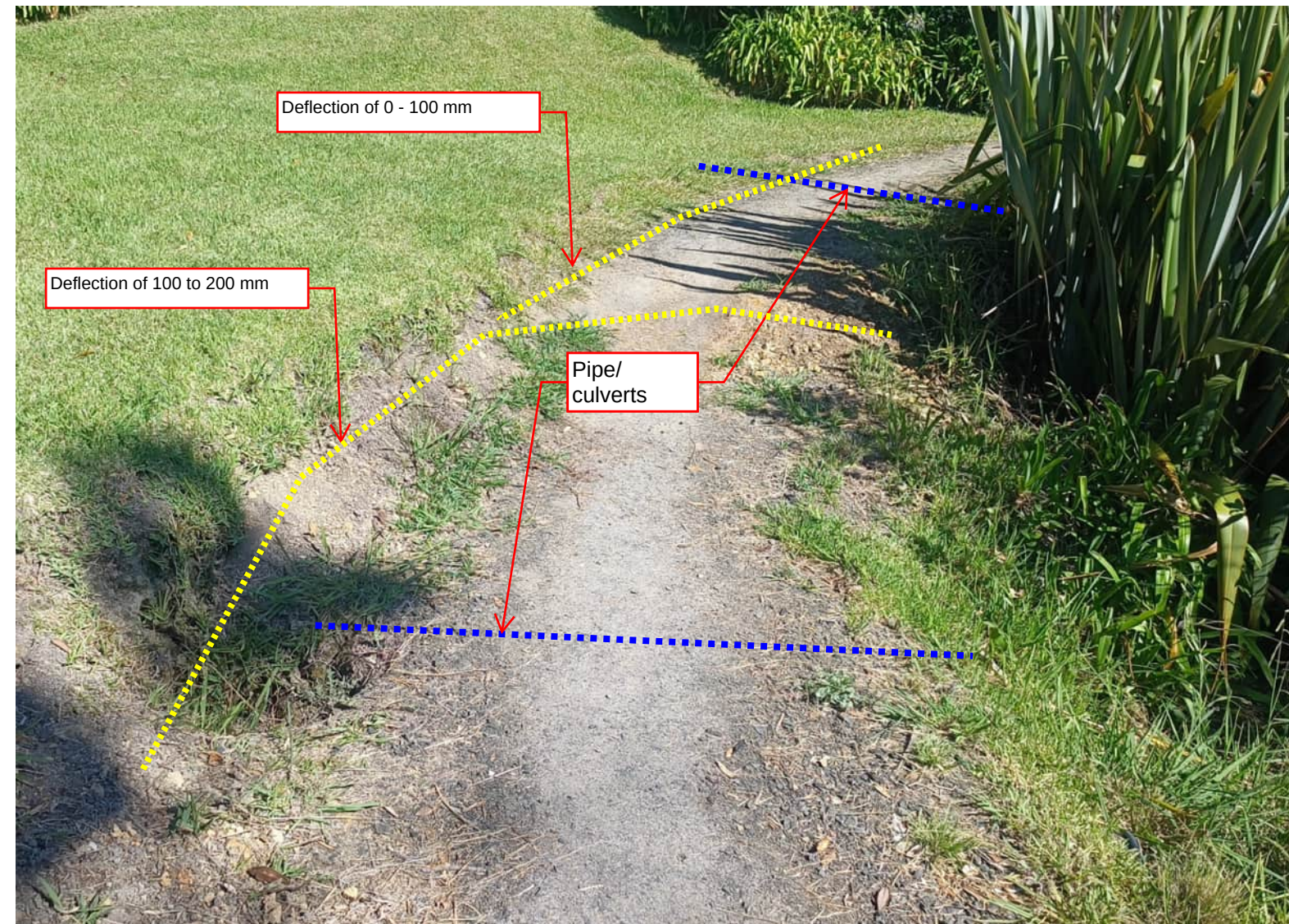


Feature 34 - Rotational slump.
No new movement observed.

17/05/2023



29/02/2024



Feature 34 - Rotational slump.
No new movement observed.

30/05/2024



Feature 35 - Translational landslide where ignimbrite abuts rhyolite.
No new movement observed.



Feature 39 - Translational landslide
No new movement, scrubby and vegetated

21/03/2023



28/02/2024



Feature 53 - Tension crack/creep.
No new movement of the tension crack
observed. Current aperture
approximately 50mm, no deflection.
(Observed during Feb 2024 visit).

17/05/2023



Wall has bowed out slightly. No
new movement is observed.

Culvert



29/02/2024



Feature 53 Continued - No new damage
observed during May 2024 visit.

30/05/2024



Appendix C Landslide inventory

- Landslide Inventory – May 2024

Released under the Official Information Act

ID	Type_II_Fieldnotes	Type_II	Width_m	Length_overall	Height_overall	Height_of_scarp	Geology	Adopted_volume	Adopted_Age	Method_of_capture	February 2024 monitoring round comments	Feb 2024 Change?	May 2024 monitoring round comments	May 2024 change?
1	Creep	Creep	7	2 m visible	-	-	Not Observed	-	28/01/2023	Site observation				
2	Creep	Creep	5	2 m visible	-	-	Weathered rhyolite	-	28/01/2023	Site observation				
3	Rockfall	Rockfall	7	20 m visible	7 m visible	7	rhyolite	30	28/01/2023	Site observation				
4	Rockfall	Rockfall	5	20	5	5	rhyolite	30		Site observation				
5	Rockfall	Rockfall	10	-	10	10	rhyolite	100	28/01/2023	Site observation				
6	Translational Earth	Landslide	5	9	5	5.5	Clayey silt, completely weathered rhyolite.	25	28/01/2023	Site observation				
7	Translational	Landslide	7	3	-	-	Track fill and completely weathered rhyolite	-	28/01/2023	Site observation	Trace additional movement (<25 mm) of the asphalt offset/deflection	Y	Trace additional movement (<25 mm) of the asphalt offset/deflection	Y
8	Debris Flow	Landslide	10	50	30	Unable to measure	Completely weathered rhyolite and ash	100	28/01/2023	Site observation				
9	Tension crack	Landslide	18	11	2	3	Completely weathered rhyolite	600	28/01/2023	Site observation				
10	Earthflow	Landslide	40	60 m evacuated	15 m Evacuated	3	Completely weathered rhyolite	-	28/01/2023	Site observation	Minor erosion of headscarp (<250 mm)	Y		
11	Rockfall	Rockfall	5	-	-	4	Highly weathered to Moderately weathered rhyolite	2.5	28/01/2023	Site observation				
12	Creep / tension crack	Creep	7	1	-	-	Residual soils	-		Site observation		Y		
13	Translational Earth	z	9	3	2	1.5	Residual soils	7	28/01/2023	Site observation	Minor erosion of headscarp (<100 mm)	Y		
14	Debris Flow	Landslide	13	11 m evac. Total	19	5	Colluvium (1-2) residual soil	850	28/01/2023	Site observation	Minor erosion of headscarp (<200 mm)			
15	Rockfall	Rockfall	8	Evac. 10 m / Total	27	13	Overburden / Ignimbrite	1000	28/01/2023	Site observation	Minor erosion of headscarp (<200 mm)	Y		
16	Rockfall	Rockfall	20	Total 25 m, Evacuated	36	85	Welded Ignimbrite	250	28/01/2023	Site observation	Minor erosion of headscarp (<200 mm)	Y		
17	Overburden Translational	Landslide	5	1	3	0.5	Soil / ash	1	28/01/2023	Site observation				
18	Rockfall	Rockfall	5	1.5	-	-	Ignimbrite	1	1/07/2018	Site observation				
19	Rockfall	Rockfall	0.3	1	-	-	Ignimbrite	0.3	1/02/2021	Site observation				
20	Rockfall	Rockfall	1	1	-	-	Ignimbrite	1	1/04/2021	Site observation				
21	Rockfall	Rockfall	1.4	-	5	-	Ignimbrite	3	26/10/2009	Site observation				
22	Rockfall	Rockfall	2	-	6	-	Ignimbrite	3	1/01/2009	Inferred from site obs				
23	Rockfall	Rockfall	-	-	-	-	Ignimbrite	2	4/02/2011	Site observation				
24	Rockfall	Rockfall	7.5	-	-	-	Ignimbrite	5	5/05/2011	Site observation				
25	Translational	Landslide	8	20	5	2	Residual soil (rhyolite)	400		Site observation				
26	Translational	Landslide	4	3	4	1	Residual soil (rhyolite)	6		Site observation	Minor erosion (<50 mm)	Y		
27	Translational	Landslide	4	5	5	1	Residual soil (rhyolite)	25		Site observation				
28	Translational	Landslide	4	6 m visible	5	1.5	Residual soils	25	28/01/2023	Site observation	New nearby tension crack developed (refer 192). Culvert pipe discharges here.	Y		
29	Translational	Landslide	10	7 m visible	10	0.5	Residual to extremely weathered rock	50		Site observation				
30	Translational	Landslide	3.5	5	6	0.5	Residual to extremely weathered rock	10	28/01/2023	Site observation	New nearby tension crack developed (refer 193).	Y		
31	Translational	Landslide	10	10	10	2	Residual to extremely weathered rock	100		Site observation				
32	Translational	Landslide	5	10	5	1	Residual soil	50		Site observation				
33	Translational	Landslide	6	10	5	1	Residual soil	50		Site observation				
34	Rotational slump	Landslide	4	3	2	0.5	Residual soil	6	28/01/2023	Site observation	Likely no change. Total existing deflection up to 200 mm. 2 x culverts discharge below track near cracks.	N		
35	Translational	Landslide	15	23	18	2	Residual soil or Ignimbrite and rhyolite rock	750		Site observation				
36	Translational	Landslide	7	16	5	0.5	Residual soil or Ignimbrite and rhyolite rock	50	28/01/2023	Site observation				
37	Rockfall	Rockfall	8	20	10	1	Rock / rhyolite	80	28/01/2023	Site observation				
38	Tension crack	Creep	0.02	2	-	-	Residual soil with boulders	-	28/01/2023	Site observation				
39	Translational	Landslide	6	11	9	3	Residual soil with boulders	150		Site observation				
40	Tension crack	Creep	0.02	3	-	-	Residual soil with boulders	-	28/01/2023	Site observation				
41	Translational debris slide to road	Landslide	7	10	10	5	Completely weathered Rhyolite with small boulders	400	28/01/2023	Site observation				
42	Translational debris slide to road	Landslide	6	6	12	7	Completely weathered Rhyolite with small boulders	250	28/01/2023	Site observation				
43	Tension cracks	Creep	0.02	2	-	-	Residual soil / colluvium	-	28/01/2023	Site observation				
44	Tension cracks	Creep	0.02	3	-	-	Residual soil / colluvium	-	28/01/2023	Site observation				
45	Translational / slump	Landslide	7	5	10	4	Rhyolite	150	28/01/2023	Site observation				
46	Creep and cracking along station	Creep		25	-	-	Residual soil / Rhyolite	-	28/01/2023	Site observation				
47	Translational	Landslide	15	17 m visible	18 m visible	2	Residual soil / Rhyolite	-		Site observation				
48	Rockfall	Rockfall	7	11	25	6	Rhyolite	500	28/01/2023	Site observation				
49	Multiple landslides	Landslide	-	-	-	-	Colluvium / residual soil	-		Site observation				
50	Rotational landslide	Landslide	30	15	13	4	Talus / colluvium	500	28/01/2023	Site observation				
51	Translational landslide	Landslide	5	5	5	1	Residual soil / colluvium	25	28/01/2023	Site observation				
52	Rockfall	Rockfall	-	-	-	-	Ignimbrite	1	1/05/2012	Site observation				
53	Tension crack	Creep	0.05	10	1	1	Residual soil	-	28/01/2023	Site observation	2 x cracks at each end (1 additional) suggest the creep is wider (10m wider than thought and has bowed out toward RTW). These are likely associated with 2023 events.	N		
54	Landslide	Landslide	16	11	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
55	Landslide	Landslide	34	60	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
56	Landslide	Landslide	30	40	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
57	Landslide	Landslide	14	25	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
58	Landslide	Landslide	25	43	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				

59	Landslide	Landslide	17	49	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
60	Landslide	Landslide	18	80	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
61	Landslide	Landslide	10	77	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
62	Landslide	Landslide	8	53	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
63	Landslide	Landslide	15	50	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
64	Landslide	Landslide	10	26	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
65	Landslide	Landslide	13	25	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
66	Landslide	Landslide	16	45	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
67	Landslide	Landslide	25	55	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
68	Landslide	Landslide	33	130	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
69	Landslide	Landslide	26	100	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
70	Landslide	Landslide	11	43	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
71	Landslide	Landslide	18	30	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
72	Landslide	Landslide	7	25	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
73	Landslide	Landslide	12	30	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
74	Landslide	Landslide	8	23	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
75	Landslide	Landslide	7	37	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
76	Landslide	Landslide	9	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
77	Landslide	Landslide	6	22	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
78	Landslide	Landslide	15	20	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
79	Landslide	Landslide	19	29	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
80	Landslide	Landslide	23	110	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
81	Landslide	Landslide	36	82	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
82	Landslide	Landslide	40	46	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
83	Landslide	Landslide	31	45	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
84	Landslide	Landslide	11	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
85	Landslide	Landslide	22	41	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
86	Landslide	Landslide	15	34	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
87	Landslide	Landslide	22	25	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
88	Landslide	Landslide	18	20	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
89	Landslide	Landslide	15	42	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
90	Landslide	Landslide	15	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
91	Landslide	Landslide	9	24	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
92	Landslide	Landslide	18	8	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
93	Landslide	Landslide	8	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
94	Landslide	Landslide	11	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
95	Landslide	Landslide	3	18	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
96	Landslide	Landslide	20	12	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
97	Landslide	Landslide	12	35	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
98	Landslide	Landslide	15	75	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
99	Landslide	Landslide	21	75	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
100	Landslide	Landslide	16	43	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
101	Landslide	Landslide	11	35	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
102	Landslide	Landslide	8	27	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
103	Landslide	Landslide	7	40	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
104	Landslide	Landslide	7	30	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
105	Landslide	Landslide	4	21	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
106	Landslide	Landslide	16	59	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
107	Landslide	Landslide	13	59	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
108	Landslide	Landslide	11	51	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
109	Landslide	Landslide	7	39	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
110	Landslide	Landslide	17	42	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
111	Landslide	Landslide	20	48	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
112	Landslide	Landslide	15	17	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
113	Landslide	Landslide	15	12	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
114	Landslide	Landslide	17	55	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
115	Landslide	Landslide	15	25	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
116	Landslide	Landslide	15	57	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
117	Landslide	Landslide	10	30	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				
118	Landslide	Landslide	4	23	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial				

119	Landslide zone	Landslide	53	57	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
120	Landslide	Landslide	26	96	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
121	Landslide	Landslide	20	55	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
122	Landslide	Landslide	25	85	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
123	Landslide	Landslide	17	36	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
124	Landslide	Landslide	18	61	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
125	Landslide	Landslide	21	43	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
126	Landslide	Landslide	17	29	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
127	Landslide	Landslide	16	17	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
128	Landslide	Landslide	16	40	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
129	Landslide	Landslide	7	26	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
130	Landslide	Landslide	10	27	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
132	Landslide	Landslide	9	31	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
133	Landslide	Landslide	6	28	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
134	Landslide	Landslide	9	37	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
135	Landslide	Landslide	8	45	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
136	Landslide	Landslide	4	9	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
137	Landslide	Landslide	10	47	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
138	Landslide	Landslide	36	25	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
139	Landslide	Landslide	42	30	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
140	Landslide	Landslide	40	46	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
141	Landslide	Landslide	8	16	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
142	Landslide	Landslide	40	9	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
143	Landslide	Landslide	5	20	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
144	Landslide	Landslide	12	23	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
145	Landslide	Landslide	4	35	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
146	Landslide	Landslide	11	11	Unknown	Unknown	Unknown	-	9/02/1971	Historical Aerial			
147	Rockfall / Landslide	Rockfall	100	15	Unknown	Unknown	Unknown	-	7/10/2002	Historical Aerial			
148	Landslide	Landslide	11	55	Unknown	Unknown	Unknown	-	22/05/1944	Historical Aerial			
149	Landslide	Landslide	16	36	Unknown	Unknown	Unknown	-	7/10/2002	Historical Aerial			
150	Landslide / rockfall	Rockfall	34	13	Unknown	Unknown	Unknown	-	7/10/2002	Historical Aerial			
151	Landslide / rockfall	Rockfall	7	18	Unknown	Unknown	Unknown	-	7/10/2002	Historical Aerial			
152	Landslide / rockfall	Rockfall	10	20	Unknown	Unknown	Unknown	-	1/01/2008	Historical Aerial			
153	Landslide / rockfall	Rockfall	20	25	Unknown	Unknown	Unknown	-	1/02/2010	Historical Aerial			
154	Landslide / rockfall	Rockfall	5	36	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial			
155	Landslide / rockfall	Rockfall	67	10	Unknown	Unknown	Unknown	-	1/02/2010	Historical Aerial			
156	Landslide	Landslide	15	35	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial			
157	Landslide	Landslide	7	17	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial			
158	Landslide	Landslide	5	53	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial			
159	Landslide	Landslide	5	12	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial			

160	Landslide	Landslide	30	25	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
161	Landslide	Landslide	7	9	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
162	Landslide	Landslide	5	10	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
163	Landslide	Landslide	30	19	Unknown	Unknown	Unknown	-	1/01/2007	Historical Aerial				
164	Landslide	Landslide	12	30	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
165	Landslide	Landslide	4	12	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
166	Landslide	Landslide	33	73	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
167	Landslide	Landslide	30	11	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
168	Landslide	Landslide	50	13	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
169	Landslide	Landslide	10	4	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
170	Landslide	Landslide	10	35	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
171	Landslide	Landslide	3	12	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
172	Landslide	Landslide	5	10	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
174	Landslide	Landslide	4	41	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
175	Landslide	Landslide	13	24	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
176	Landslide / rockfall	Rockfall	17	23	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
177	Landslide / rockfall	Rockfall	12	8	Unknown	Unknown	Unknown	-	1/01/2004	Historical Aerial				
178	Landslide / rockfall	Rockfall	21	13	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
179	Landslide / rockfall	Rockfall	26	9	Unknown	Unknown	Unknown	-	1/01/2017	Historical Aerial				
180	Landslide / rockfall	Rockfall	8	41	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
181	Landslide / rockfall	Rockfall	6	25	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
182	Landslide / rockfall	Rockfall	15	50	Unknown	Unknown	Unknown	-	1/04/2011	Historical Aerial				
183	Rockfall	Rockfall	10	10	5	5	rhyolite	30	28/01/2023	Site observation (drone)	Likely from early 2023 storm event (not confirmed). Not visible from the track, and was missed in 2023 (we didn't fly the drone here).	N		
184	Tension crack	Creep	0.01	6	-	-	Completely weathered rhyolite	-	28/01/2023	Site observation	Likely from early 2023 storm event (not confirmed). The aperture is <1cm, hard to spot	Y		
185	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
186	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
187	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
188	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
189	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
190	Rockfall	Rockfall	<1	<1	-	-	Iglimbrite	1	1/02/2024	Site observation	New event	Y		
191	Tension crack	Creep	55	0.02	-	-	Completely weathered rhyolite	-	1/02/2024	Site observation	Hard to know if recent or not. Possibly post 2023 storm event. It is parallel to the track, it may be a shrinkage crack or larger creep event	Y		
192	Tension crack / Translational	Landslide	3	0.3	1	1	Track fill and residual soils	1	1/02/2024	Site observation	New event. TC has deflection of 100 mm, it is related to event 28	Y		
193	Tension crack	Creep	3	0.2	-	-	Residual to extremely weathered rock	-	1/02/2024	Site observation	New event (related to event 30)	Y		

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Date: October 2025

To: Tania Short, Principal Advisor

CC: Cat Wilson, Heritage and Visitor Director
Tinaka Mearns, Regional Director HWT
Lynnell Greer, Visitor Advice Manager

From: Rachael McMillan, Senior Visitor Advisor, Heritage and Visitor Directorate

Subject: Draft Mautohe Cathedral Cove Adaptation Plan

Executive Summary

1. The Cathedral Cove Recreation Reserve is a nationally significant visitor destination facing increasing infrastructure vulnerability due to landscape instability and extreme weather events.
2. This adaptation plan provides a plan for agile infrastructure decision making, now and in the future for Mautohe Cathedral Cove, using a modified Dynamic Adaptive Pathways Planning (DAPP) methodology.
3. The core issue to address at Mautohe Cathedral Cove is how to sustainably maintain safe visitor access and infrastructure in a highly unstable coastal landscape that is increasingly vulnerable to landslides and storm damage, while balancing environmental, cultural, social and economic values.
4. The plan is informed by geotechnical investigations, predictive landslide modelling, statutory obligations, iwi and community expectations. It explores a series of trigger-based pathways to guide future infrastructure responses, balancing cost-effectiveness, environmental impact, cultural values, and visitor safety.
5. The final adaptation plan is built on the following key conclusions drawn from knowledge to date:
 - a. The archway at Mautohe Cathedral Cove is the primary visitor drawcard.
 - b. Track and structure damage will continue due to landscape instability and high likelihood of storm events.
 - c. Low-cost, lightweight infrastructure is more viable than high-cost resilient solutions.
 - d. Repairs should be prioritised if safe and cost-effective.
 - e. Grange Road remains the preferred entry point, but marine access may become necessary.
6. The plan sets clear objectives: maintain the overland access as long as feasible, reopen quickly after storm events, and retreat to marine-only access if land-based options become unachievable. It includes criteria for implementation testing and recommends ongoing community engagement to prepare for future changes.

7. This adaptation plan supports DOC's strategic outcomes and provides a transparent, flexible approach to managing infrastructure at Mautohe Cathedral Cove in the face of ongoing environmental challenges.

Introduction

8. DOC is currently developing an operating model and visitor management plan for the Cathedral Cove Recreation Reserve. As part of this broader strategic work, this paper has been commissioned to support future decisions regarding Mautohe Cathedral Cove, so they are informed by a comprehensive infrastructure adaptation plan. The approach recognises that resilience challenges must be addressed upfront to ensure the long-term viability and effectiveness of any management approach.
9. This adaptation plan provides a structured approach to making future infrastructure investment decisions at the site. It is intended to support the DOC Senior Leadership Team, district-level planning, and engagement with the local community regarding the future of access and the visitor experience at the Cove.
10. The plan draws on several years of investigations and learnings from repeated infrastructure damage caused by extreme weather events—both at Cathedral Cove and across other vulnerable DOC-managed sites nationwide. It offers a proactive framework to navigate uncertainty, manage risk, and ensure that infrastructure decisions remain responsive to environmental, cultural, and visitor needs.

What is an adaptation plan?

11. An adaptation plan is a method for decision making under uncertain change. I have used a Dynamic Adaptive Pathway Planning (DAPP) methodology but have modified it to make it more understandable by using visual mapping (see Figure 2). The pathway approach uses all knowledge to date to provide insights into developing options, defining possibilities and understanding path dependencies to allow DOC to adapt over time to meet changing circumstances. Triggers are used to indicate when a new action should come into force¹.
12. This method creates a strategic vision of the future, recommends short-term actions, and establishes a framework to guide future actions.
 - Step 1 – current situation and problem analysis
 - Step 2 – defining success
 - Step 3 – possible actions to meet the definition of success
 - Step 4 – evaluate the actions
 - Step 5 – assemble the preferred pathways
 - Step 6 – describe implementation testing for when triggers occur
 - Step 7 – recommend actions to be taken in the immediate future
13. This adaptation plan is informed by:

¹ Haasnoot, Kwakkel, Walker & Maat. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environment Change* Vol.23, Issue 2, p485-498.
[Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world - ScienceDirect](#)
[Attachment](#)

- a. the landscape resilience and infrastructure vulnerability from geotechnical investigations and landslide predictive modelling
 - b. site importance, visitor type and behaviour, community and political interest etc.
 - c. the land status and statutory intended use
 - d. cultural, environmental, social and economic impact assessments
 - e. an assessment of potential events where infrastructure and access are damaged which would trigger decision points
 - f. likelihood and consequence of events and potential mitigations.
14. This paper has been developed at the same time as the VMP and serves both as a record of the process undertaken to date and as a foundation for future decision-making. While the adaptation plan looks ahead to how infrastructure and access might need to evolve in response to environmental pressures, it has been an essential part of the operating model and visitor management plan development. Both the VMP and the operating model have been developed with full awareness of the landscape instability and infrastructure vulnerability—particularly to storm damage. These resilience issues have informed decisions now, including the level of investment in infrastructure, and the design approach, with the learnings to date embedded in the recommendations that fall out of this paper.
15. Having a strategic decision pathway for the future also means we can socialise with the community that things may change in the future so when a decision needs to be made to retreat from walking access this does not come as a surprise.

Steps 1 and 2: Current situation, analysing the problem and defining success

16. This section establishes the foundation for the adaptation plan at Mautohe Cathedral Cove and identifies the core challenges that must be addressed through adaptation planning. It examines the unstable nature of the landscape, the significance of the Cove as the primary visitor destination, the importance of the site and the increasing likelihood of infrastructure damage due to natural hazards. These insights form the basis for understanding what is at risk, what success would look like, and what constraints must shape future decisions.

Landscape resilience and risk

17. The landscape instability of the Mautohe Cathedral Cove Recreation Reserve is a critical factor influencing the visitor experience and must be considered in all investment and adaptation planning.
18. Significant storms in 2023 and six months of rain that broke records since 1961 caused damage to assets in the Recreation Reserve:
- a. the track and steps leading to the Cove adjacent to Mautohe Pa destroyed by a landslide
 - b. and stairs down to the Cove destroyed by storm surge in Mare's Leg Cove
 - c. Waimata Gemstone Bay stairs destroyed by storm surge and a slow slip landslide threatening the track access to the bay
 - d. Cracking and fracturing on the Hahei Beach Walk with landslides over the cliffs adjacent to the walk.

- e. Stingray Bay steps twisted by a slow slip landslide and numerous rockfalls behind the bay onto the narrow strip of land that forms the beach.
19. The initial focus post cyclone was to find a way to reinstate overland access to the Cove as the primary consideration. The overland track to the Cove was reopened in December 2024 using a temporary reroute of the track and rebuilding the stairs to the beach that were destroyed by storm surge.
20. Over the last year several infrastructure feasibility studies have been undertaken to explore alternative access points to the Cove to attempt to make a more resilient access. The following conclusions are drawn from geotechnical reports in 2023, follow up monitoring reports in 2024 of the more vulnerable landscape areas identified in 2023, investigations of potential alternative access routes to the Cove and investigations into the ability to stabilise the existing temporary track access.

Landscape instability is a critical constraint

21. The unstable terrain of the Cathedral Cove Recreation Reserve significantly limits the type and quality of visitor infrastructure that can be safely provided. This must be a central consideration in all future infrastructure investment decisions.

Future landslides and storm damage are highly likely

22. Geotechnical assessments and predictive modelling (e.g., Tonkin + Taylor 2023²) confirm a high probability of future landslides and rockfalls, especially during high rainfall events.

High-risk zones are well-identified

23. Specific areas—including the approach to the Cove, cliffs behind Stingray Bay, below the Grange Road carpark, and the Hahei Beach Walk—are particularly vulnerable and should be factored into planning.

Track failure is expected under severe storm conditions

24. The current track to the Cove adjacent to Mautohe Pa has an 80–100% likelihood of landslides under a 100-year storm scenario and 50–70% under a 50-year scenario. Any infrastructure built on this landscape should have a minimal footprint and limit impermeable surfaces to reduce water issues.

Ongoing infrastructure damage is inevitable

25. Technical evidence confirms that track and structure damage will continue. This reinforces the need for a flexible, trigger-based adaptation strategy that avoids over-investment in high-risk areas.

Resilient highly engineered infrastructure options are high impact and not appropriate for this landscape

26. Investigations considered environmental, cultural, visual, financial, and technical factors. The environmental and cultural impact of construction (e.g., barging equipment, cliff drilling) and the high cost of stabilisation made resilient solutions infeasible so low-cost solutions should be prioritised. These can be rebuilt more quickly if they are designed simply. Replacing assets is more cost effective than building high-cost resilient infrastructure.

² Tonkin & Taylor Ltd. July 2023. Cathedral Cove Basic Level Landslide Risk Assessment. Department of Conservation.

27. The visual impact of the stair structure and geotechnical stabilisation of the cliffs were not consistent with the Waikato Conservation Management Strategy.

Drainage and planting offer the most viable stabilisation strategy

28. The most achievable and least impactful option to improve stability of the temporary track access is targeted drainage and strategic planting on the slip area affected by Cyclone Gabrielle. While not a long-term fix, it improves resilience in the short to medium term. Following investigations into a more resilient walking access route it was determined the temporary track access is the only option for access to the Cove.

Strongly engineered solutions are not viable across the landscape

29. Across all access route investigations, the findings were consistent: strongly engineered solutions are not viable in this landscape. Even if one section is reinforced, other parts of the track remain vulnerable. This confirms that a piecemeal engineering approach is not sustainable and reinforces the need for a broader adaptation strategy.

Limits of access and the need to plan for retreat

30. From investigations there is only one viable descent from the reserve to the beach. Other descents were explored and discarded due to the geological constraints of the landscape, cultural heritage in that location, visitor risk, size, cost and impacts of structures required in other potential descent locations. While minor rerouting may be possible, the terrain's instability means that future damage is likely to reach a point where rebuilding the descent is no longer feasible. At that stage, the adaptation plan must support a strategic retreat from walking access and shift toward alternative visitor experiences, such as marine-only access and landscape viewing opportunities.

Land status and intended use

31. The following conclusions are drawn from an assessment of the statutory framework:

Infrastructure decisions must align with statutory and policy frameworks

32. All actions at Mautohe Cathedral Cove must comply with the Recreation Reserve and Marine Reserve in accordance with the Reserves Act 1977, Marine Reserves Act 1971, Heritage New Zealand Pouhere Taonga Act 2014, Conservation General Policy (CGP) and the Waikato Conservation Management Strategy (CMS) and Coromandel Peninsula Land Management Plan (CPLMP). The CMS recognises the Recreation Reserve track network as a regionally (if not nationally) significant icon destination.

33. In addition an Overlay classification for the Cathedral Cove Recreation Reserve has been provided within Deed of Settlement to reflect the traditional, cultural and historical association that Ngāti Hei has with this area. When the statutory process is complete, the Minister of Conservation and Ngāti Hei will commit to "*develop and publicise a set of principles that will assist the Minister to avoid harming or diminishing values of the settling group with regard to that land*". Up until that time, a variety of obligations already exist under section 4 of the Conservation Act and through the Heritage New Zealand Pouhere Taonga Act 2014 to protect Māori interests and archaeological sites.

The site is recognised as a nationally significant destination

34. The CMS identifies the track network within the Recreation Reserve as a regionally and nationally iconic visitor experience, reinforcing the importance of maintaining access.

Walking access is generally supported—if consistent with coastal values

35. Both the CMS and CPLMP favour restoration and retention of permanent walking access, provided it protects the natural character and supports a relatively undeveloped visitor experience.

Infrastructure design must protect the site's natural and recreational values

36. Any new or replacement infrastructure must avoid diminishing the landscape's visual appeal and the quality of the visitor experience for which the site is internationally renowned.

Repairs should be prioritised if safe and cost-effective

37. There is a strong policy expectation that storm damage will be addressed promptly, and the site reopened, as long as safety and cost thresholds are met and strategic outcomes are supported.

Strategic importance and visitor movement

38. The following conclusions are drawn from an assessment of the cultural, economic and social importance of the site that needs to be factored into the adaptation plan.

Cathedral Cove is a nationally and internationally iconic destination

39. Its location beside the Te Whanganui-O-Hei Marine Reserve and long-standing international marketing success³ have made it one of New Zealand's top visitor attractions, drawing 250-300K visitors annually before COVID-19.

The site holds significant economic and social value for the region

40. Cathedral Cove serves as an economic anchor for the Coromandel Peninsula, generating political, community, and business pressure to maintain access and visitor experiences.

Access to the Cove is the central priority for visitors

41. The archway at Mautohe Cathedral Cove is the primary attraction and maintaining access to this location is the cornerstone of the adaptation plan. All other tracks or destinations are evaluated based on their strategic value in complementing access to the Cove.

Visitor demand remains high regardless of access limitations

42. Even during closures, large numbers of visitors attempted to access the site, indicating strong public interest and a resilient tourism draw. Visitor insights⁴ identified visitors will continue to desire to visit the location due to its attractive landscape and high profile, irrespective of any visitor risks.

There is a strong expectation of repair and reopening after damage

³ Cathedral Cove is the only New Zealand beach to be included on the 2025 list of the 50 best beaches in the world. [NZ's Cathedral Cove named among the World's 50 Best Beaches of 2025 - NZ Herald](#); [Cathedral Cove Beach, Voted One Of The World's Best Beaches](#)

⁴ Short Walk/Day Hike Surveys, Trip Advisor reviews, observed visitor behaviour during closure and reopening of the site – summer rangers and cellphone data.

43. Public sentiment and statutory frameworks support the assumption that infrastructure will be repaired, and access restored, provided it is safe and cost-effective to do so.

Any changes to access must be carefully socialised

44. Given its high profile and importance, any shift away from the current visitor experience—such as retreating from land-based access—must be communicated clearly and proactively to stakeholders.

Grange Road as the preferred access point

45. Grange Road is the preferred main entry point to Cathedral Cove for several reasons:

- a. Statutory access protections and mandate as the only public legal access
- b. Cultural significance that is supported by DOC's statutory protections and mandate
- c. The entrance is important for storytelling and sharing conservation messages.
- d. Connection to Hahei Village

46. For Ngāti Hei, the ability to provide manaaki to visitors is important and this is most appropriately provided for via the public legal access. This is reinforced by legal advice which indicates Grange Road should remain the primary access point due to our statutory obligations and protections via Public Conservation Land.

47. Entering the track from Grange Road is also highly valued by the Hahei business community for the direct connection it provides to the village and the opportunities this provides for local businesses.

48. Consequently, the adaptation plan assumes this access point will remain primary for the foreseeable future. However, if geological instability renders Grange Road unusable, a shift to a secondary access route should be considered to maintain connectivity and the visitor experience but implications for Ngāti Hei must be understood.

Hahei rerouted track is a strategic connector

49. The Hahei rerouted track provides a vital free walking link between Hahei Village and the main public entry point to the Mautohe Cathedral Cove track at Grange Road. Its role in supporting local access, community values, and the visitor experience makes it a strategically important part of the overall access network. It provides a free option for those visitors who chose not to use the shuttle. Maintaining this connection for as long as it remains geotechnically and structurally viable will help preserve the integrity of the overland access pathway to Cathedral Cove.

What success looks like at Mautohe Cathedral Cove

50. From the above assessment, success means maintaining safe, sustainable, and meaningful visitor access to the iconic Mautohe Cathedral Cove archway for as long as it remains viable, while protecting the site's natural, cultural, and recreational values. Infrastructure decisions must be responsive to environmental risks, aligned with statutory obligations, and supported by iwi, community, and stakeholders. The visitor experience should remain consistent with the site's undeveloped coastal character and be adaptable to future changes, including a potential shift to marine-only access.

51. The following objectives synthesize all the above findings into a set of objectives for the adaptation plan:

- a) **Maintain safe overland access to the Cathedral Cove archway for as long as it remains viable while protecting the site's natural, cultural and recreational values.**

This reflects the site's status as the primary visitor destination and the central focus of public interest.

- b) **Prioritise low-cost, low-impact infrastructure solutions that can be quickly reinstated.**

Strongly engineered solutions are impractical in this landscape; simple, replaceable infrastructure is preferred. If replacement costs remain within an acceptable level (benefits higher than costs) and deliver to the strategic outcomes, the site should remain open.

- c) **Retain Grange Road as the primary access point, unless geological conditions require a shift.**

This entry supports iwi values, community connectivity, and economic outcomes and aligns with legal advice.

- d) **Ensure all decisions align with statutory frameworks and Ngāti Hei settlement cultural overlay and protect the site's natural and cultural values.**

Infrastructure must comply with legal obligations and maintain the undeveloped coastal character.

- e) **Prepare for a transition to marine only access in the future if land-based repair options become geotechnically, financially infeasible or impact values significantly.**

This ensures continuity of visitor experience even if retreat from walking access becomes necessary.

Steps 3 and 4: Possible actions and evaluation of actions

Triggers

52. Based on the geotechnical knowledge and landslide predictive modelling further landscape damage is likely to occur and impact on infrastructure and visitor experience.

53. Decisions have already been made to reroute the Hahei Beach Walk away from the highest landslide risk areas, close Stingray Bay from land access to reduce visitor risk and infrastructure damage and rebuild Gemstone Bay stairs in a location less likely to be destroyed by storm surge.

54. Table 1 shows the likely trigger events that could occur on Cathedral Cove Recreation Reserve to landscape and assets.

Table 1: Infrastructure damage trigger events assessment

Trigger Event	Likelihood	Mitigation	Consequence if it can't be mitigated	Adaptation plan pathway recommendation
Landslides on the remaining neck of land to access the Cove	High Geotechnical reports and landslide predictive modelling show a high likelihood.	Stabilise the track approach to the Cove to improve resilience. Ensure the main access route is regularly maintained with a focus on water management. Ensure that the area is planted with appropriate species that will not pose significant risks to infrastructure when they fall. Design a fall route, so water and debris have a designated pathway. Design the track for ease of reinstatement. Rebuild the track as required.	The track approach may slip even with stabilisation measures. The only other access ways into the Cove, if chosen will have high impacts. Economic, social and political impacts. Political direction may determine a rebuild despite cost.	Work with the regional tourism organisation and local council to identify alternative experiences, to reduce future economic, social and political impacts. If no other alignment can be found due to the fall heights, land stability, cultural heritage considerations and cost retreat from walking access and shift to water only access. Consider if a walking track to a platform with a view of the Cove is viable and maintain access from Grange Road primary entry or farm secondary entry.
Storm surge impacting on stair infrastructure to reach the beach	High	Build low-cost stairs and expect to replace. If the access above the stairs is still intact continue to replace.	Structural, risk and geotechnical assessments showed that the existing stair location is the only practical option. Other stair options were too high risk or high impact.	Keep replacing low-cost stair structure to the beach if the benefits outweigh the costs until the land access is no longer viable. If the track above is irreparable or costs higher than benefits do not replace steps.

Significant partial or total collapse of the Cathedral Cove archway	Low However, archways on the coastline have collapsed before (Mares Leg was the key attraction before it collapsed in the 1970's).	Can't be mitigated.	Major consequence – the main attraction would have been destroyed. Access may still be available to the Cove overland.	If archway collapses continue track access to Mare's Leg Cove if viable. If track to Cove also irreparable, retreat from walking access and shift to water only access. Change to a different visitor experience. A platform to view the cove won't be viable at this point as the main attraction was a view of the archway.
Landslides damage the track from Grange Road to the Cove	High	Reroute track around damage If rerouting is impractical, move access to the Cathedral Cove Gateway Trail – which has a more resilient access over private farmland if agreements can be made and Ngāti Hei concerns are able to be addressed. If not, shift to water only access.	Most likely able to be rerouted, stabilised or bridged.	Continue to reroute as required until the access to the Cove is no longer irreparable due to geological, cultural, visual, and structural constraints and costs higher than benefits.
Tauraopaha Grange Road carpark area is damaged by landslides or slumping	Medium	Maintain a park and ride to reduce pressure on the carpark Reduce the area of carpark and non-permeable surfaces Design with drainage as a key focus	Major consequence, local businesses rely on the link to Hahei.	In the event that costs outweigh benefits – shift the main entrance to the Lees Road farm.
Grange Road is damaged by weather events	Medium	Work with TCDC to ensure the road access is reopened.	Walking access only.	Walking access only.

	Grange Road is susceptible to damage.	Ensure only shuttle size traffic or less access carpark, no buses		
Storm surge damaging Waimata Gemstone Bay stairs to reach bay	Medium	Adjust the location of the stairs to a less vulnerable access.	Build low-cost stairs and replace. If the above access is still intact continue to replace.	Keep rebuilding stair structure to Gemstone Bay until costs higher than benefits.
Storm damage to rerouted Hahei Walk to Grange Road carpark	Low	Keep rerouting Hahei Walk as the main walking link from the village to the Cath Cove track entrance until is irreparable due to geological and structural constraints and costs higher than benefits.	Shift to the Grange Road footpath	Keep rerouting Hahei Walk as the main walking link from the village to the Cath Cove track entrance until is irreparable due to geological and structural constraints and costs higher than benefits. Shift to visitors walking up Grange Road.

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Steps 5: Assemble the preferred pathways

55. All the information in the paper above has been used to form the dynamic adaptation pathway for access to Mautohe Cathedral Cove beaches in Figure 1. This also includes criteria considerations for testing if an action should be taken (use these for any of the scenarios and actions for Figure 2 as well).
56. The full adaptation plan of the Recreation Reserve provides the potential scenarios and recommended actions for all tracks and access points in Figure 2.

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Figure 1: Infrastructure dynamic adaptation pathway for Mautohe Cathedral Cove access

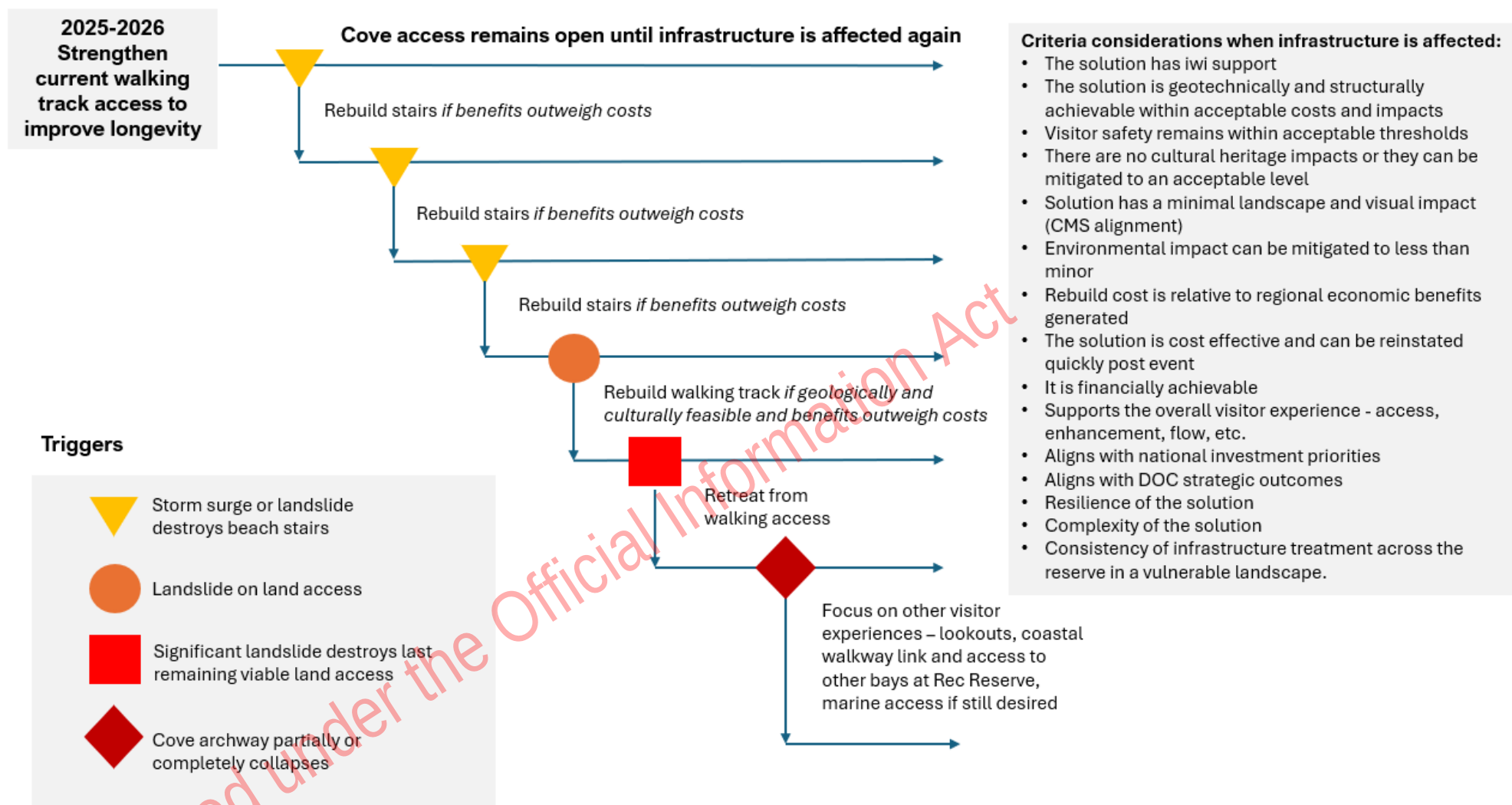


Figure 2: Infrastructure Adaptation Plan for Mautohe Cathedral Cove



Step 6 and 7: Implementation testing when triggers occur and recommendations for immediate actions

Implementation testing

57. When a trigger event occurs that damages infrastructure, access or the landscape in a significant way, we need to assess whether the proposed adaptation plan recommendation should go ahead.

- a. We can keep returning to Mautohe Cathedral Cove overland until:
 - i. the costs of replacing infrastructure are higher than the benefits (running benefit cost analysis)
 - ii. the last remaining land access is no longer viable past Mautohe Cathedral Cove pa
- b. For each piece of infrastructure:
 - i. the costs of replacing infrastructure are higher than the benefits (running cost benefit analysis)

58. Run the following tests:

- a. Constraints analysis
- b. Benefit cost analysis if the costs involved are large enough to warrant it.
- c. Considerations assessment – this take into account all the matters below that cannot be factored into a benefit cost analysis.

59. The following criteria should be considered to ascertain if the infrastructure should and can be rebuilt in that location.

- a. The solution has iwi support
- b. The solution is geotechnically and structurally achievable within acceptable costs and impacts
- c. Visitor safety remains within acceptable thresholds
- d. There are no cultural heritage impacts or they can be mitigated to an acceptable level
- e. Solution has a minimal landscape and visual impact (CMS alignment)
- f. Environmental impact can be mitigated to less than minor
- g. Rebuild cost is relative to regional economic benefits generated
- h. The solution is cost effective and can be reinstated quickly post event
- i. It is financially achievable
- j. Supports the overall visitor experience - access, enhancement, flow, etc.
- k. Aligns with national investment priorities
- l. Aligns with DOC strategic outcomes
- m. Resilience of the solution
- n. Complexity of the solution
- o. Consistency of infrastructure treatment across the reserve in a vulnerable landscape.

Recommendations

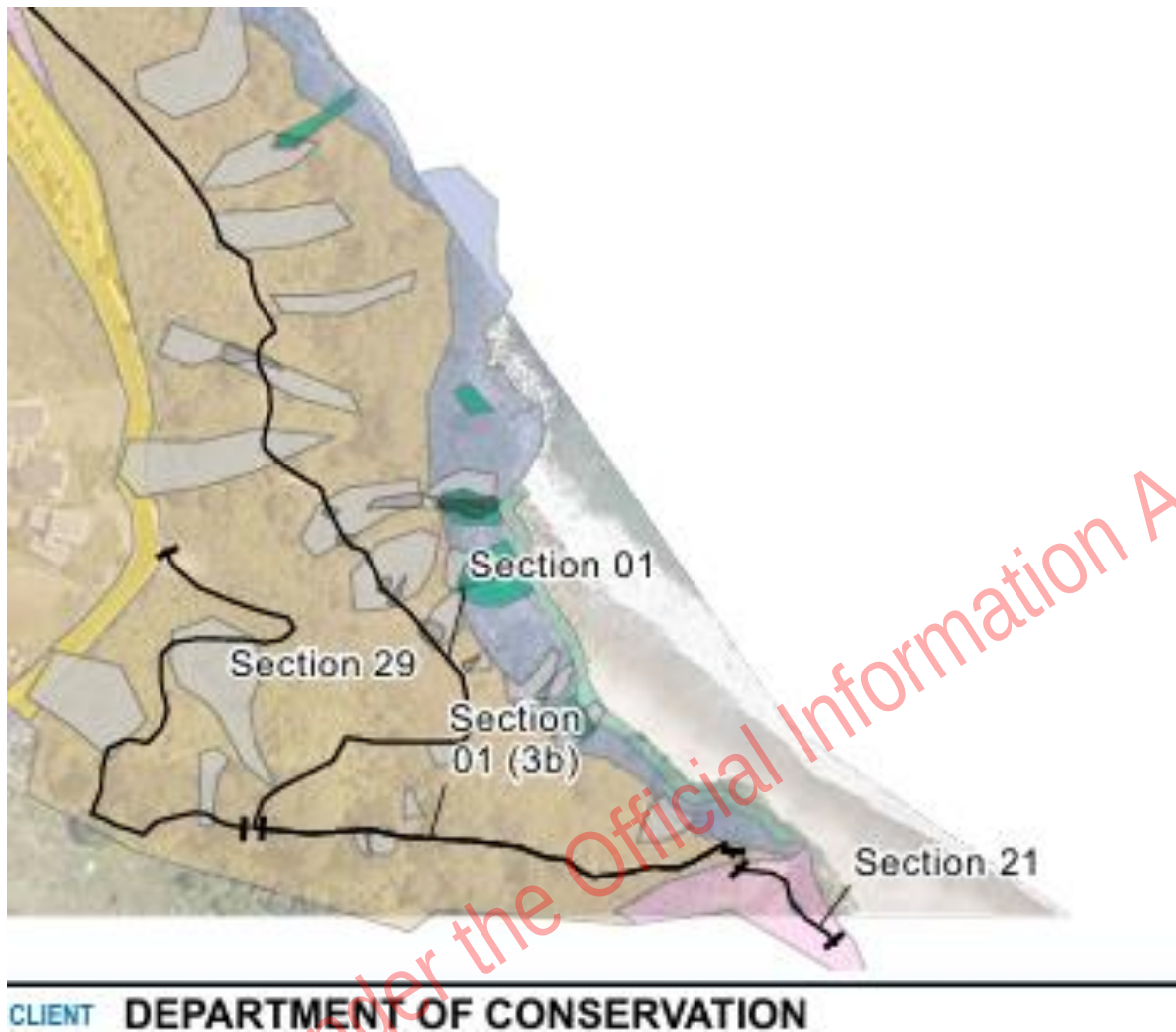
60. The adaptation plan may be looking to events in the future, but the operating model and visitor management plan development needs to be cognisant of the unstable landscape and infrastructure vulnerability to storm damage and factor this into current decision making, particularly about how much to spend on infrastructure now.

61. These recommendations cover the immediate future as well as the more distant.

- a. Approve the draft adaptation plan.
- b. Socialise with the community and refine.
- c. When damage does occur rebuild quickly once the criteria tests have been assessed.
- d. Improve the entrance and visitor experience at Grange Road but don't build heavy infrastructure at this site.
- e. Always look for the most cost effective, lightweight infrastructure solutions with the knowledge that they may not be resilient long term and need replacement.
- f. Don't spend huge amounts of money on a carpark to hold buses at Grange Road. Buses can be directed to the village carpark.
- g. Redevelop the carpark to minimise impermeable surfaces and reduce loading through park and ride, with parking provision for guiding and essential services when facilities are developed.
- h. Invest in drainage and planting schemes designed to protect key access routes and ensure water management is a priority.

Framework approved in principle for use

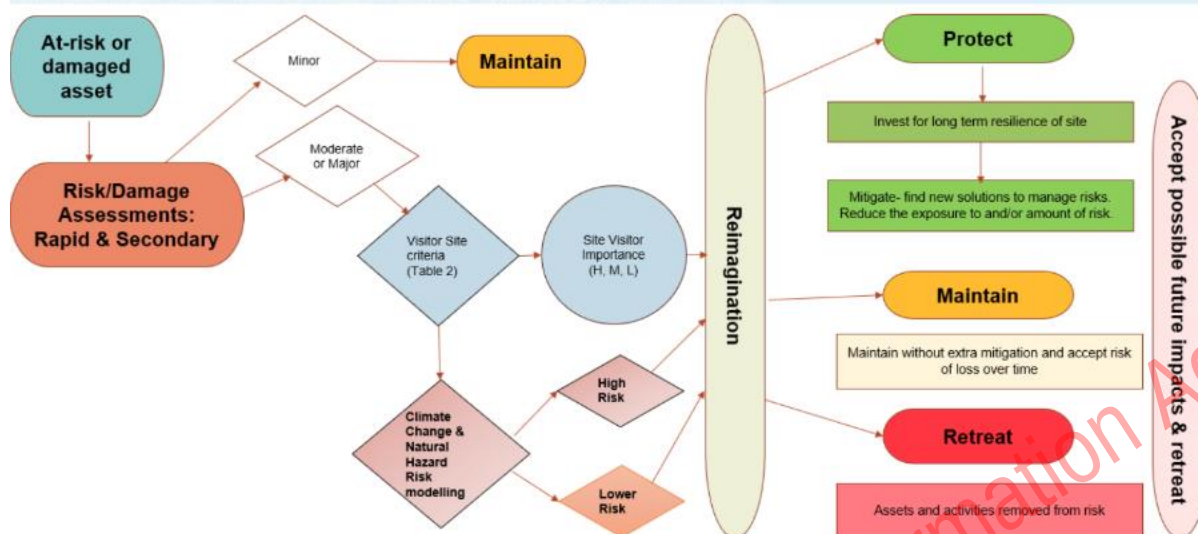
Released under the Official Information Act



From the Adaptation Plan

1. The unstable terrain of the Cathedral Cove Recreation Reserve significantly limits the type and quality of visitor infrastructure that can be provided and must be considered in all investment.
2. The archway at Mautohe Cathedral Cove is the primary visitor attraction and is the main priority for access investment.
3. Track and structure damage will continue due to natural hazards.
4. Low-cost, lightweight infrastructure is preferred, as resilient structures offer little benefit when the surrounding landscape remains unstable.
5. Repairs should be prioritised only if visitor risks can be managed to an appropriate level
6. Cost-effective for the benefits gained.
7. Where necessary the access track to the archway should be reinforced if benefits outweigh costs
8. water should be managed and planting considered.

Table 1: Your step-by-step decision-making tool



ASSESSMENT CRITERIA ¹	DESCRIPTION
What do statutory documents say about the destination?	CMS description - The walking track from Hahei Beach to Cathedral Cove is the only land access to the bays and coves within the reserve, and is an integral part of the visitor experience. Large crowds at Cathedral Cove and Mares Leg Cove during peak periods can at times alter the visitor experience. Gemstone Bay, Stingray Bay and bays northwest of Cathedral Cove (the latter being accessible by water only) have lower visitation and provide a more peaceful setting for visitors. Maintaining this range of visitor experiences is a management priority. The Marine Reserve is accessed from Hahei Beach and Cathedral Cove Recreation Reserve, which provides an opportunity to showcase the marine environment in a location that is popular with domestic and international visitors. In particular, the Gemstone Bay snorkel trail provides a recreation and educational opportunity for visitors to experience and learn about the marine ecosystem.
Is this site material to the visitor experience?	According to the CMS it is an integral part of the visitor experience.
Are environmental & heritage impacts from the visitor experience able to be managed? Is the management consistent with the reasons the site is PCLW? (Incl compliance with statutory)	N/A relevant to the discussion
Have iwi, hapū or whānau raised issues regarding management of the site?	Not relevant to this discussion. 9(2)(g)(i)

Is the site well used, what Tier is it in the FVN? Visitor data? e.g. the Strategic intentions tool tests? <i>OR</i> is it regularly used for educational purposes?	Yes, it used to get 50K visitors prior to Covid at peak. However we put it into FVN at Tier 2 due to its challenges.
Is the site managed more for biodiversity, heritage, infrastructure or agreements with other parties than for its visitor value?	Community traplines only. An adze flake found at the beach below but don't know where it came from.
Does the site have known significant visitor safety risk? (risk that could cause serious harm)	Yes, the previous alignment had higher visitor risk due to being above cliffs and the landslide vulnerability.
Is the site vulnerable to ongoing natural hazards (including climate); technical assessment show natural hazards risks are minor? How often has significant weather damage occurred (40 years?)	Yes, the previous alignment did have elevated landslide vulnerability and cracking and previous landslides below. The new alignment has slips.
Does it provide an experience key to a diverse or unique offering at a regional scale? (uniqueness or representativeness)	Nope, it was just an access track with a new view.
Is there a comparable alternative experience (DOC & non-DOC) within a similar travel distance of key population centres?	Is not necessary
If the site is managed for cost recovery, does it achieve a reasonable level of cost recovery?	N/A
Does the site align with the relationship the community has with its natural and cultural heritage?	The community has expressed that it is very important to them to reopen a track up to Grange Road. However it hasn't stopped people getting to the Cathedral Cove track. Daily walk for locals.
Can the visitor experience be achieved with a lower site service standard?	No, land stability issue and technical feasibility issue so changing standard would not improve the situation. Changing to tramping standard could help but the intended visitor use wouldn't align with the target user.
Can reimagining of the site resolve the problems identified?	Consider if there are potential options below.
Is divestment or managed retreat an option to explore? Is it warranted if for the cost to reinstate and the usage and function the asset performs?	Need to consider.

- a) The solution is geotechnically and structurally achievable within acceptable costs.
- b) The solution has iwi support.
- c) The benefit of replacing infrastructure is higher than the costs of rebuilding.
- d) Environmental impacts can be mitigated to less than minor.
- e) There are no cultural heritage impacts, or they can be mitigated to an acceptable level.
- f) Visitor safety remains within acceptable thresholds.
- g) Solution has a minimal landscape and visual impact (CMS alignment).
- h) The solution is cost-effective and can be reinstated quickly post event.
- i) It is financially achievable for the department

- j) The solution supports the overall visitor experience - access, enhancement, flow, etc.
- k) Aligns with DOC strategic outcomes.
- l) Aligns with national investment priorities.
- m) The solution is consistent with infrastructure treatment across the reserve in a vulnerable landscape.

OPTIONS	ANALYSIS
1) Repair in the same place	We're already in a location chosen to avoid existing issues with the main track, and we haven't been successful in implementing that reroute. A landslide has affected the track.
2) Repair in a better spot	Explored options for the reroute post Gabrielle and this was the only potentially viable option. Now this option is off the table too.
3) Retreat and remove	Only viable option is to retreat and remove existing track alignment and not continue with the proposed reroute. Removing infrastructure, bridges, handrails, steps etc and scour existing track alignment and remove asphalt, replant at top and other locations as can. Removes a porous border of Mautohe Cathedral Cove.

Trading issues with coastal geology for unstable trees.

Financially sustainability – shouldn't invest in places that are very vulnerable to landslide instability.

Sarah: Did a walkthrough of Gemstone with Keir including the Hahei reroute. As we were turning up the reroute, we saw a huge piece of land where the track has been under bitten and a landslide has dropped down. This is in an area that was considered more stable. There are two adult sized trees holding up a portion of the track, once they topple, they will take out another section of track. If we do look to go back in there, it will require a massive retaining wall. I assume the rest will fall out once the trees come down. It is around two to three times the width of the Gemstone landslide. 10-15m wide. Sarah has Photos and a video.

Nick and Sarah both checked that the DOC tape telling visitors the track is closed is in place. It is still being removed by someone.

There are two decent slips, one of the reroute and one on the old track. There were two root balls, an arborist went in and cut them, when Keir and DOC were at site, there was concern for further trunks above the track, there are lots (could be 50) which will cause issues over time. Water is pooling where the track is supposed to go. Concerns on the reroute track, Keir raised concerns, that even if the land was stable and the track was built, the rotting of those tree trunks and moving over time would also be an issue.

Theo: What's the Visitor Risk aspect of this and any considerations we need to pay attention to?

I haven't been to site, I've not seen it in person. Can't comment on the level of risk. Same as for Gemstone. More than being compelled to a decision by a level of risk we see is unacceptable, we're being shown the track itself is not sustainable. It comes down to a range of other factors including financial feasibility. If the site is being managed the same as the rest of the reserve, the risk is being managed. Seems healthier use of DOC resource to focus on the main track. This looks like another distraction. Having these other experiences increases visitor risk by having these things open, how quantifiable this is unknown. Just putting the Hahei Reroute in, was going to halve visitor risk.

May be more helpful to use landslide vulnerabilities rather than visitor risk.

"Key points from adaptation plan shared.

1. The unstable terrain of the Cathedral Cove Recreation Reserve significantly limits the type and quality of visitor infrastructure that can be provided and must be considered in all investment.
2. The archway at Mautohe Cathedral Cove is the primary visitor attraction and is the main priority for access investment.
3. Track and structure damage will continue due to natural hazards.
4. Low-cost, lightweight infrastructure is preferred, as resilient structures offer little benefit when the surrounding landscape remains unstable.

5. Repairs should be prioritised only if visitor risks can be managed to an appropriate level and are cost-effective for the benefits gained.
6. Where necessary the access track to the archway should be reinforced if benefits outweigh costs and water should be managed and planting considered.”

Discussions on Adaptation Plan points:

A need to separate the visitor risk and cost benefits. As they are two separate things.

We’re not buying any resilience from this work, we’ve been attempting to buy it, but we’re not getting that benefit.

The benefit for the community is fairly and squarely Mautohe. We need to refocus effort towards that one goal.

Sarah’s completed a moderate assessment. T+T not needed, we already have enough geotechnical advice from previous work.

Now visitor site criteria:

We have modelling, we know it is higher risk, we’re just going through the list.

1. Stat Docs: CMS description – is an integral part of the visitor experience. Not sure why it is in there. Mentions maintaining this range of visitor experiences is a management priority. We are shifting management priorities from what was written in the CMS. At time of writing there weren’t steps down to Te Karaka Stingray Bay. On Google Maps it shows before the tarseal came in. Doesn’t hold us back from making decisions. CALM will rewrite the area plans within 12 months. Went through cabinet yesterday.
2. Integral according to VX.
3. Heritage/Environmental (not relevant to this discussion)
4. Iwi/Hapu. (not relevant to this discussion).
5. Well used/ it was when it was open. 50K visitors prior to Covid.
6. Community – they have always iterated that this site is important to them. Maintains connection to Hahei Village.
7. This track is a short walk standard. As opposed to a walking track. CC track is a walking track. Not sure why this difference exists, its in our system this way. Does changing it to walking standard change this in any way. Technical feasibility is that we still have issues with the land shifting. The only option is to put in a heavy-duty retaining wall. It will be a very significant amount – hundreds of thousands of dollars. If it was a tramping track, this would make a difference and would be much more manageable for this. However visitor use doesn’t align with this. The type of visitor is not suited to a tramping track.
8. Reimagination:

Repair in the same place – we’re already in a new place designed to avoid existing issues, and we haven’t been successful in achieving the desired outcome.

Trading of issues, moving problems around the board. It's an interconnected network of issues. They're all symptomatic of a problem across the Reserve and everything compounds.

\$110K for just heli work to remove the compacted material. It will be cost prohibitive. For Gemstone. Double that to include Stingray. Usual practice is to scour it. Leave it at the location. Scouring is preferred as it does also allow planting.

Once the first and second stairs have been removed it will be very difficult to get up there.

Two benefits here, because they only wanted one entrance. In terms of future thinking for the site, we've reduced the border to one.

9(2)(a) wanted the Hahei track because it aligned with the wider destination walk that is part of TCDC plans, that is, walking from Whitianga to Hahei.

Struggled to get any storm support this year, indicated that these recoveries need to come from baseline in future. It makes sense to not invest in places that already are falling away before we've even touched them.

We've already got this track that is highly susceptible to land movement, we have to put our attention in the right places.

Community Engagement required as part of the Destination document.

Need to remove the stairs as soon as. It's a visitor safety issue.

Timeframes: How quickly does this need to be completed.

Do we need to get something prepared to get the MOC across this fairly soon. Can't close it until the consultation with the community has occurred. Removing the steps before engagement and MOC is not the right way around.

Status update for MOC etc first.

Destination change Doc is 90% there, already written up. Decision document will need to be written up and endorsed before you go. Key items for conservation package.

Assuring the community in terms of the main track will be critical.

Key Messages document too.

From: 9(2)(a)@tonkintaylor.co.nz>
Sent: Thursday, 21 March 2024 2:45 pm
To: Joshua Angell; Rachael McMillan
Cc: 9(2)(a)
Subject: February 2024 Monitoring update
Attachments: Attachement Feb 2024 Mon Round_Optimized.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Josh and Rachael,

T+T visited the Cathedral Cove and Hahei track and beach areas on 28 and 29 February 2024 (refer the site plan below). The purpose of the visit was to carry out the first of two monitoring rounds, focusing on the condition of landslides and rockfalls at the site as agreed in our variation (VO4) dated 7 February 2024.

Figure 1, site plan.



Site conditions/changes can be summarised as follows:

- 9 of approximately 50 existing landslides within the monitoring area were observed to have had some change since 2023.

tension crack is likely associated with the early 2023 storm event (i.e. not new) and no additional movement is indicated.

- Additional tension cracks observed along the track below the Grange Rd carpark.
- Mitigation route to avoid the steep coastal cliffs:
 - No new landslides were observed.
 - Some additional seepage zones were noted associated within the gully.
 - Some boulders were observed near the top of slope from the Grange Road access, but these appear to be an old feature.

Large pine trees remain, as well as some large fallen pine which were first observed in 2023 and likely fell during the early 2023 storm event.

Kind Regards

9(2)(a)

This email and attachment have been prepared for the exclusive use of our client Department of Conservation, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Ngā Mihi | Kind regards,

9(2)(a) | Senior Engineering Geologist

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Level 5, 711 Victoria Street, Hamilton 3204 | PO Box 9544, Hamilton, New Zealand

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Date: 6 May 2026

To: Nick Kelly, Operations Manager - Whitianga

CC: Tinaka Mearns, Regional Director Hauraki, Waikato, Taranaki.
Cat Wilson, Director Heritage and Visitor

From: Rachael McMillan, Senior Visitor Advisor and Tania Short, Principal
Advisor, Heritage and Visitor Directorate

Subject: Hahei Beach Short Walk Options Paper

Purpose

1. This paper sets out the context and damage to Hahei Beach Short Walk (Hahei Walk), the intended reroute alignment, the assessment methodology used, the options considered, and recommendations for next steps.

Recommendation

2. Note providing access from Hahei Beach to the entrance of the Mautohe Cathedral Cove walk, either via the existing Hahei Beach Short Walk or the realigned Short Walk no longer appears to be viable.
3. Note the evidence indicates removal of the track and not proceeding with the re-route is the preferred option.
4. Agree/not agree – DOC makes a deliberate shift to focus on the core experience by prioritising reliable access to Mautohe Cathedral Cove via the Grange Road carpark and primary track, rather than investing in a secondary connector track where the infrastructure is more vulnerable.
5. Propose consulting with key stakeholders regarding the removal of the track (and not proceed with the re-route) to inform the final decision paper.

Executive Summary

6. The Cathedral Cove Recreation Reserve is a nationally significant visitor destination with persistent infrastructure vulnerability due to unstable coastal terrain and is subject to increasingly frequent extreme weather events. The primary visitor destination is the Mautohe Cathedral Cove archway and beach, accessed by a popular walking track reopened to the public in December 2024.
7. Hahei Beach Short Walk (Hahei Walk) is a track linking from Hahei Beach to the Mautohe Cathedral Cove Track. Visitors who don't wish to walk up the road or pay for the shuttle often use this walk to reach the cove track. A stroll through the trees with beautiful views over Hahei Beach was more pleasant than walking up the steep road in full sun. It is also popular with locals for daily exercise. Prior to COVID-19 and Cyclone Gabrielle this track was very popular, with 20% of visitors arriving at the track start via this route.
8. The track has been closed since early 2023 due to landslide risks and land movement following severe weather events including Cyclone Gabrielle. Geotechnical assessments and landslide predictive modelling indicate the area is susceptible to landslides and rockfalls, especially during and

immediately after high rainfall events. The existing Hahei Walk was assessed as higher visitor risk than other sections of the Cathedral Cove Reserve due to significant fall heights and landslide vulnerability along the cliff edge¹. Consequentially a concept was developed as part of the Cyclone Gabrielle Recovery Options Development Phase (pre-IVL assessments), to shift the second half of the track away from the vulnerable cliff edge with the exit to Grange Road and this option was deemed to halve the visitor risk for that section of track². The delivery of the reroute was then scheduled for delivery in 2026.

9. Previous community consultation during development of post-Cyclone Gabrielle recovery options confirmed the Hahei to Cathedral Cove walking link is important to the community. DOC therefore prioritised restoring this connection once the main Mautohe Cathedral Cove Track reopened.
10. The proposed reroute was designed to avoid the most vulnerable section of the Hahei Walk and to remove the need to use high-risk structures, such as bridges. Although geotechnical advice noted there would still be potential land instability, the proposed reroute was the lesser risk of the two options for visitor risk and infrastructure vulnerability to landslides³. The Hahei Walk reroute proposed alignment branched off midway along the existing Hahei Walk to connect with Grange Road near the start of the Mautohe Cathedral Cove track. The intention was to keep ongoing maintenance to a minimum through targeted tree felling, groundwater management, and the installation of box steps.
11. Construction of the reroute was about to commence when the January 2026 storms impacted the region. Two slips damaged 1) the track from the beach to the beginning of the reroute alignment and 2) the proposed reroute alignment, prompting reconsideration of progressing the reroute and its long-term viability⁴.
12. DOC used decision-making methodology designed following Cyclone Gabrielle, as well as the Mautohe Cathedral Cove Adaptation Plan criteria, to assess the recent storm damage, the previous track access route, the damaged alternative alignment, and previous rebuild options considered following Cyclone Gabrielle.
13. Adaptation planning⁵ for the entire recreation reserve concluded:
 - a. The unstable terrain of the entire Cathedral Cove Recreation Reserve significantly limits the type and quality of visitor infrastructure that can be provided and this must be considered in all investment.
 - b. The rock archway at Mautohe Cathedral Cove is the primary visitor draw and is the main priority for access investment.
 - c. Track and structure damage will continue due to known and publicised natural hazards.

¹ Tonkin & Taylor July 2023 Cathedral Cove Basic Level Landslide Risk Assessment. DOC-7669260
Tonkin & Taylor May 2024 Cathedral Cove Track Feasibility Assessment. DOC-7645108
Tonkin & Taylor April 2025 Gemstone Bay Geotechnical Feasibility Report. DOC-10705786
Wigmore, O. March 2024 Hahei Cathedral Cove Landslide Risk Modelling DOC-7879967

² Tonkin & Taylor May 2024 Cathedral Cove Track Feasibility Assessment. DOC-7645108

³ Tonkin & Taylor May 2024 Cathedral Cove Track Feasibility Assessment p13, 14, 41

⁴ Email from Project Manager for Hahei Beach Short Walk reroute observations of a site visit with Frame Group and rangers, specifying new slips on the Hahei Short Walk and proposed realignment – 20 April 2026. DOC-10705786

⁵ Mautohe Cathedral Cove Adaptation Plan 2025 (SharePoint)

- d. Low-cost, lightweight infrastructure is preferred, as resilient structures offer little benefit when the surrounding landscape remains unstable.
 - e. Repairs should be prioritised only if visitor risks can be managed to an appropriate level and are cost-effective for the benefits gained.
14. Options were assessed against key criteria including the level of infrastructure vulnerability informed by geotechnical investigations, predictive landslide modelling, statutory obligations, iwi and community expectations, cost-effectiveness of continuing to replace infrastructure, environmental impact, cultural values, and visitor safety.
15. As part of this process DOC reconsidered the previous geotechnical advice on options for the Hahei Walk. The previous assessment which provided the initial development of the reroute showed the current alignment of the Hahei Walk was not viable. Therefore, the only option was the rerouted alignment. With further landslides destroying the land the new track would pass over, it is now impractical to continue with the reroute. The infrastructure vulnerability, likelihood of repeated future storm and cyclone events, existing debris, environmental impacts, and infrastructure costs are too high to warrant the benefits.
16. The recent infrastructure and land damage on the Hahei Walk and at Waimata Gemstone Bay confirm a high likelihood of repeated damage, escalating maintenance costs, and a poor return on further investment in these alignments.
17. Given this, we recommend DOC make a deliberate shift in approach. Rather than continuing to spread effort across multiple vulnerable access points, DOC should focus on the core experience and prioritise reliable access to Mautohe Cathedral Cove via the Grange Road carpark (the primary track to Cathedral Cove).
18. Reaching the Cove is the experience which matters most to visitors. DOC should invest resources into strengthening the Mautohe Cathedral Cove track stability and resilience by improving drainage and water management, targeted planting to support land integrity, ongoing monitoring and maintenance in line with our Adaptation Plan, reducing exposure to ongoing risk and cost, instead of diluting the overall budget by focusing on other tracks on the reserve.
19. DOC needs to respond to increasing frequency and intensity of weather events, known geotechnical constraints and the need to operate within fiscal limits for the longer term. Managing within these constraints will support DOC to improve long-term reliability, reduce lifecycle costs, focus staff resources on delivering the primary visitor experience.
20. It is recommended to consult with key stakeholders to inform the final decision paper process to:
- a. permanently remove the existing Hahei Beach Short Walk due to visitor safety risk and landslide vulnerability
 - b. remove the bridges on the existing Short Walk due to visitor safety risk
 - c. remove the steps to access the track from Hahei Beach
 - d. Not proceed with building the proposed Hahei Walk reroute, which was about to get underway due to higher infrastructure vulnerability than previously considered, and a shift of priorities to focus resources on the main Mautohe Cathedral Cove experience.

Assessment

21. Table 1 shows the decision-making process flow chart⁶ used to guide this assessment. The first step was to understand the risk/damage.
22. The Project Manager for the track reroute and construction experts undertook damage assessments in January and February 2026. The assessment undertaken was based on operational and constructability expertise and informed by existing geotechnical reporting for the area as well as direct observation of current site conditions. Damage assessments confirmed two landslides, one on a section of the existing track which needed to be retained for the reroute; and one on a section the new reroute would have crossed, where water is pooling and there is evidence of further instability.
23. Fallen tree trunks have exacerbated the land instability. Figure 1 highlights in yellow the new slip affecting the Hahei Beach Short Walk. This section was to be kept as part of the new track alignment. The slip would prevent end-to-end access, meaning the track would remain closed even if the reroute proceeded. This reinforces the ongoing vulnerability of the track to slip events.
24. The green square marks a section of the proposed reroute where three fallen trees are obstructing the alignment. Their root balls encroach onto the track, and the cut trunk sections remain upslope. Over time, these pose an ongoing risk as they may rot, shift, and potentially slip onto the track. Removal was not feasible within budget and relocating the material downslope risked damage to adjacent private property. There are another 50-plus tree trunks above the track expected to cause further instability over time. No other track alignments were considered practical.

Figure 1: Landslide and track vulnerability on Hahei Beach Short walk section 1 that was to be retained (yellow) and proposed reroute (green)

⁶ Decision making process flow chart developed by the Cyclone Recovery Programme 2023-2024



Figures 2 & 3: Landslide and track damage: Photos DOC





Figure 4: Landslide and track damage:
Photos DOC

25. This site damage was assessed as major, with repair requiring funding beyond the district budget⁷. It was confirmed there is no funding available to undertake the works required to repair this new slip area. This aligns with DOC prioritising limited capital investment toward resilient, high value assets and core visitor experiences, while reducing exposure to assets that are vulnerable, high maintenance, or unlikely to deliver reliable outcomes.
26. The next step of the assessment is to consider visitor site criteria, importance of the site and climate change and natural hazard risk modelling.
27. The Hahei Walk has known geological instability confirmed by geotechnical reports. Previously bridges have been placed to cross historic landslides. These were assessed as needing replacement due to foundation issues.

⁷ Cyclone Recovery Programme categorisation: Minor – Repairs can be completed by District staff with minimal additional resource. Moderate – Repairs require support from outside the District and may need extra resource beyond the current budget, though not higher level project management. Major – Repairs require significant additional resource, specialist expertise, and project management for more than 12 months.

28. The 2023 geotechnical report recorded 180 recent and historic landslides on the whole recreation reserve⁸. By May 2024 monitoring noted a further 11 landslides⁹. The most recent storms in January 2026 have added to that number with significant landslides above the Cathedral Cove access, Gemstone Bay¹⁰ and on the Hahei Beach Short Walk existing track and the Hahei Beach Short Walk proposed reroute¹¹, alongside many other smaller landslides not affecting the track alignments. This confirms the significant instability of this landscape. Any reroute of tracks will also be subject to ongoing landslide vulnerability due to the geology.

29. The geotechnical reports for the options development phase of Cyclone Gabrielle recovery notes the following points.

Figure 5: Map of the Hahei Beach Short Walk Options during the option development phase – Cyclone Gabrielle Recovery



Geotechnical assessment of 3a showed:

- Evidence of historic landslides upslope and downslope of the track and bridges.
- Bridge piles not touching the ground.
- Steep 50-degree slopes highly possible for landslides.
- Potential for further landslides upslope and downslope.
- Unstable and weak ground conditions above high cliffs.

Figure 3: 3a Hahei Beach Short Walk

⁸ Tonkin & Taylor July 2023 Cathedral Cove Basic Level Landslide Risk Assessment DOC-7669260

⁹ Tonkin & Taylor May 2024 Cathedral Cove Track Feasibility Assessment. DOC-7645108

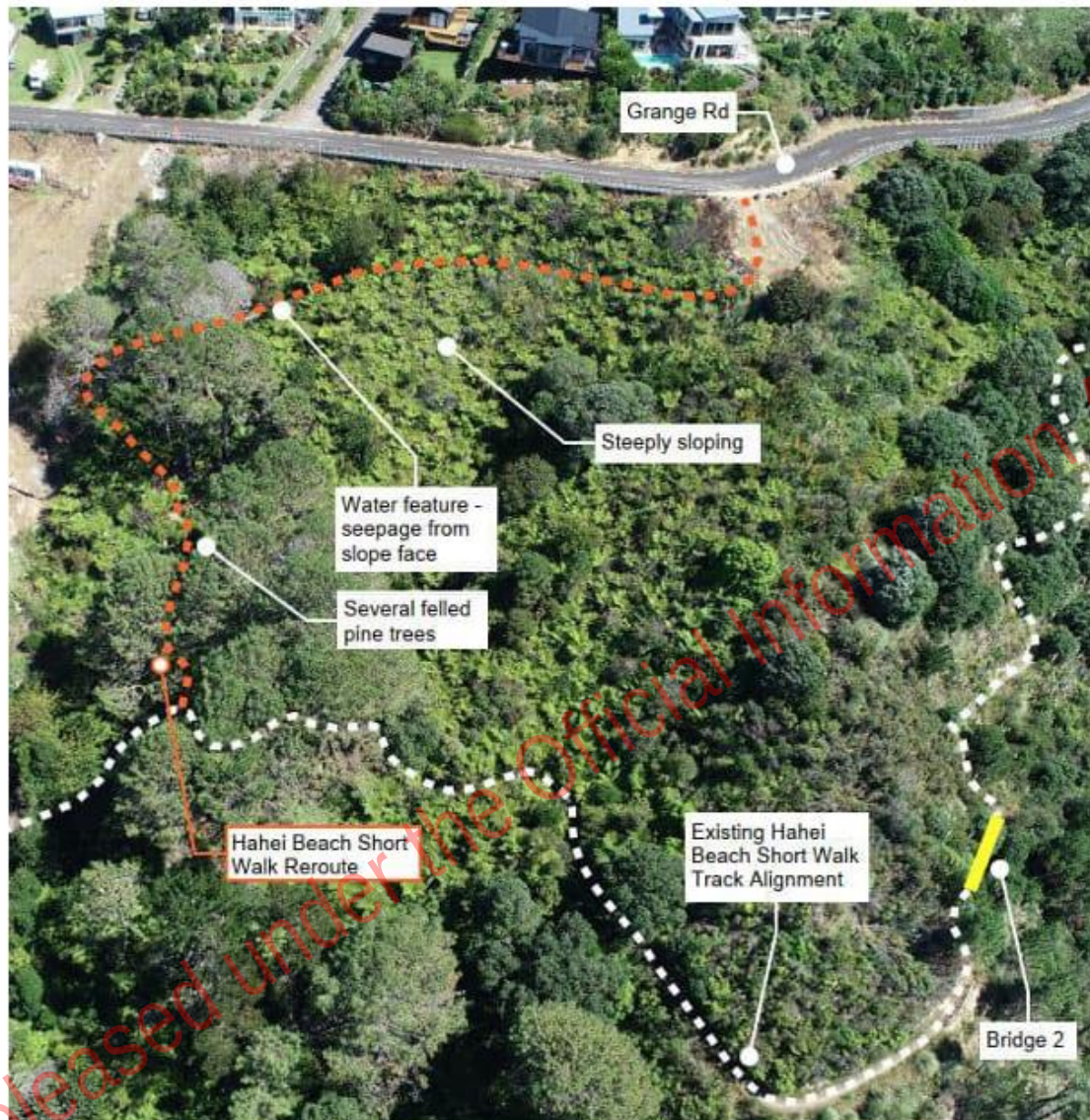
¹⁰ Email from Tonkin & Taylor recording observations of the January storm damage - 17 February 2026 and Gemstone Bay Geotechnical Feasibility Report April 2025 providing the discussion material on lack of options and significant potential instability. DOC-10705786

¹¹ Email from Project Manager for Hahei Beach Short Walk reroute observations of a site visit with Frame Group and rangers, specifying new slips on the Hahei Short Walk and proposed realignment – 20 April 2026. (SharePoint)



Geotechnical assessment of 3b showed:

- Parts of the reroute track alignment are on steeply sloping areas with some potential for future landslides.
- Seepage area observed from the slope face crossing the track alignment.
- Ground uncertainties but proposed track lower risk structures.
- The reroute track alignment is relatively less concerning than the 3a existing alignment but still vulnerable to landslides.
- The proposed reroute does not include any critical structures such as staircases or bridges.
- The land is typical of the steep coastal hills in the area which are prone to landslides.



30. A proposed reroute was designed to avoid the most vulnerable section of the Hahei Walk, avoid the steeper sections and to remove the need to use structures such as bridges. The Hahei Walk Reroute halved the Annual Individual Fatality Risk for the Hahei Walk section.

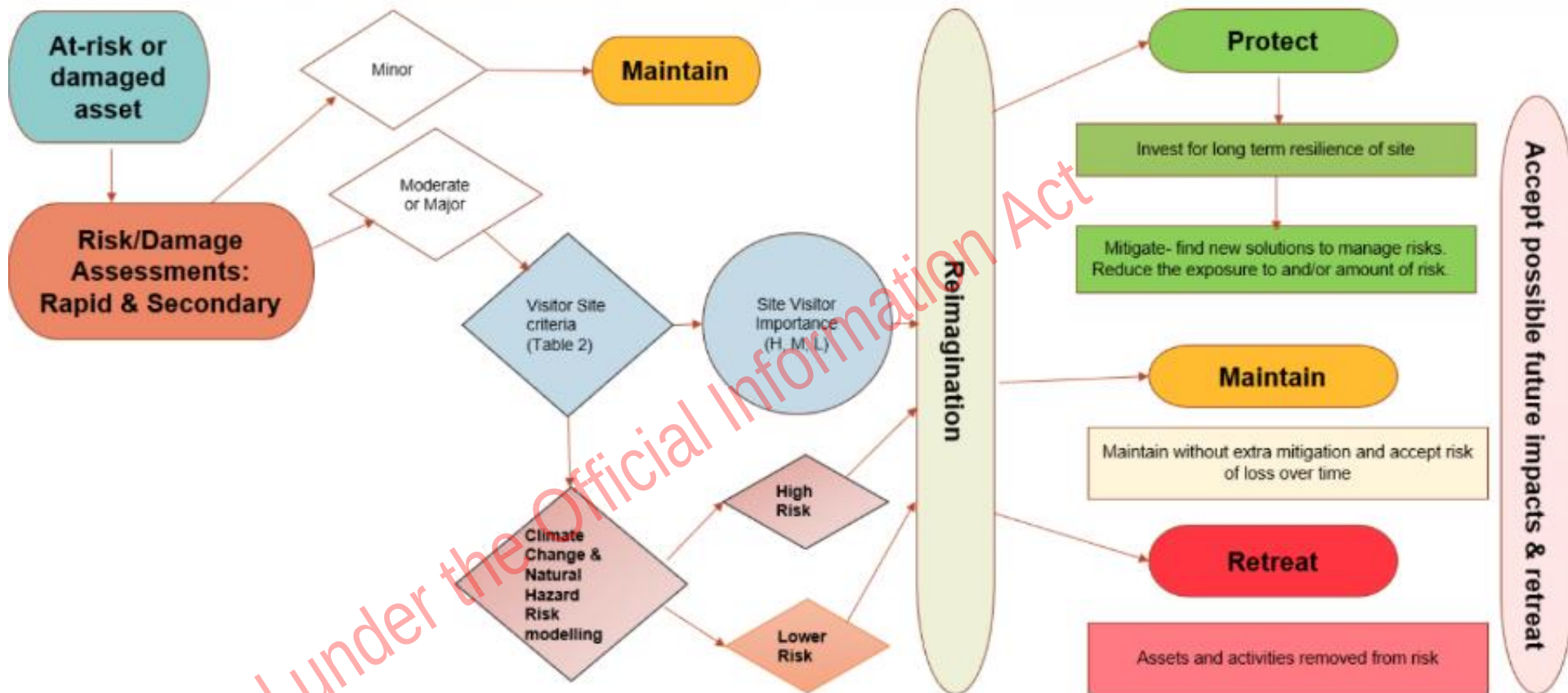
31. The Hahei Walk reroute would have branched off midway along the existing Hahei track and connected with Grange Road near the start of the Mautohe Cathedral Cove track. The intention was to keep ongoing maintenance to a minimum through targeted tree felling, groundwater management, and the installation of box steps. However as noted above geotechnical specialists stated there would still be potential land instability, but it was the less risky of the two options¹² and was intended to find the best option considering the range of factors.

¹² Tonkin & Taylor May 2024 Cathedral Cove Track Feasibility Assessment p13, 14, 41

32. Together, these constraints further indicate the limited resilience and impracticality of maintaining this route. The key change since the previous decision to proceed is not simply that slip events have occurred, but how recent events have validated and reinforced the risks identified in earlier geotechnical assessments.
33. Although instability and slip risk were known, the recent storm damage has demonstrated these risks are more extensive and impactful than previously assumed. Slips outside the reroute footprint continue to prevent end-to-end access, meaning the intended benefits of the reroute would not be realised.
34. When considered alongside existing geotechnical information for the area, these observed conditions indicate a higher level of ongoing instability and a greater likelihood of continued disruption. This shifts the assessment from a risk that could be mitigated through targeted works to a level of vulnerability where achieving a resilient and reliable track is unlikely.

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Table 1: Your step-by-step decision-making tool



Workshop Assessment

35. A workshop was run with Coromandel District staff and key advisors to consider the site and potential options. The site assessment criteria was developed by the Cyclone Recovery Programme and modified to include Future Visitor Network and other considerations.

Table 2: Site assessment criteria

ASSESSMENT CRITERIA ¹³	DESCRIPTION
What do statutory documents say about the destination.	CMS description - The walking track from Hahei Beach to Cathedral Cove is the only land access to the bays and coves within the reserve and is an integral part of the visitor experience.
Is this site material to the visitor experience.	According to the CMS it is an integral part of the visitor experience.
Are environmental and heritage impacts from the visitor experience able to be managed? Is the management consistent with the reasons the site is PCLW? (Incl compliance with statutory).	From an archaeology perspective, some time ago, a worked flake was found in the area, it was recorded near the track, but nothing else has been identified. A consultant did do assessment of the proposed realignment, but we don't know if that was a deep dive or not. Nothing was identified.
Have iwi, hapū or whānau raised issues regarding management of the site.	Ngāti Hei consistent input following Cyclone Gabrielle is for a simple approach to infrastructure rebuilds and they were not supportive of any impactful modifications.
Is the site well used, what Tier is it in the FVN? Visitor data? e.g. the Strategic intentions tool tests? <i>OR</i> is it regularly used for educational purposes.	It was well used prior to COVID-19 with more than 50,000 visitors annually at peak, using the track. It was not used for educational purposes. It is essentially a link track to the significant experiences, which does not require visitors to pay to get to the start of the track.
Is the site managed more for biodiversity, heritage, infrastructure or agreements with other parties than for its visitor value?	The site is primarily managed to support visitor outcomes.
Does the site have known significant visitor safety risk? (risk that could cause serious harm)	Yes, the original alignment has the highest visitor risk due to the landslide vulnerability as well as being built on cliffs. The reroute was planned to lower the risk by avoiding the cliffs. See the geotechnical report
Is the site vulnerable to ongoing natural hazards (including climate); technical assessment show natural hazards risks are minor? How often has significant weather damage occurred (40 years?)	See the geotechnical notes above.
Does it provide an experience key to a diverse or unique offering at a regional scale? (uniqueness or representativeness)	This track does not have a unique experience, except for a beautiful view of the Hahei Beach. This view can also be experienced on the footpath on Grange Road. The track is simply a nature walk link to the Cathedral Cove track.
Is there a comparable alternative experience (DOC & non-DOC) within a similar travel distance of key population centres	Not applicable as this track is just a link track.
If the site is managed for cost recovery, does it achieve a reasonable level of cost recovery	Not managed for cost recovery.

¹³ Modified from the Cyclone Recovery Programme criteria

Does the site align with the relationship the community has with its natural and cultural heritage	The community has expressed that it is very important to them to reopen the track up to Grange Road. It is used as a daily constitutional walk for locals, and it supports businesses in Hahei. However, it hasn't stopped people getting to the Cathedral Cove track, they are still able to walk along a path beside the road.
Can the visitor experience be achieved with a lower site service standard?	No, land stability issue and technical feasibility issue so changing standard would not improve the situation. Changing to tramping standard could help but the intended visitor use wouldn't align with the target user. The challenges cannot be managed via standards.
Can reimagination of the site resolve the problems identified?	Potential options are below.
Is divestment or managed retreat an option to explore? Does it warrant continued investment for the cost to reinstate and the usage and function the asset performs	Potential options are below.

Options analysis

36. Staff explored reimagining the site as per the Table 1 decision flow chart – which focuses on protecting, maintaining or retreating. Table 3 outlines the three options that were considered. These options were weighed against the following criteria from adaptation planning to ascertain if the infrastructure should and can be rebuilt in that location.

- a) The solution is geotechnically and structurally achievable within acceptable costs.
- b) The solution has iwi support.
- c) The benefit of replacing infrastructure is higher than the costs of rebuilding.
- d) Environmental impacts can be mitigated to less than minor.
- e) There are no cultural heritage impacts, or they can be mitigated to an acceptable level.
- f) Visitor safety remains within acceptable thresholds.
- g) Solution has a minimal landscape and visual impact (CMS alignment).
- h) The solution is cost effective and can be reinstated quickly post event.
- i) It is financially achievable for the department.
- j) The solution supports the overall visitor experience - access, enhancement, flow, etc.
- k) Aligns with DOC strategic outcomes.
- l) Aligns with national investment priorities.
- m) The solution is consistent with infrastructure treatment across the reserve in a vulnerable landscape.

Table 3: Options analysis

OPTIONS	ANALYSIS
1) Repair in the same place	This rerouted track alignment was chosen to reduce infrastructure damage due to landslide vulnerability. DOC could use lower risk structures (not bridges) to lower the visitor risk. Out of the two alignments (the existing and the rerouted) this was the best choice in the balance of all factors. Geotechnical specialists made it clear there was still landslide vulnerability in this location. DOC sought to support the community and the visitor flow between Hahei and the Grange

	Road entrance. Unfortunately, the landslide vulnerability has proven to be higher than expected. It is impractical to continue with the reroute and the existing track from the beach to where the reroute would have branched off as it is also damaged. The landslides across the track and reroute alignment, the infrastructure vulnerability, likelihood and frequency of another storm event, existing debris, environmental impacts, and infrastructure costs are too high to warrant the benefits of trying to repair the existing track section and start building the reroute.
2) Repair in a better spot	Options for the reroute following Cyclone Gabrielle were thoroughly explored as discussed above. There is no other alignment that is practical.
3) Retreat and remove - preferred	Only viable option is to retreat and remove existing track alignment and not continue with the proposed reroute. Removing infrastructure, bridges, handrails, steps etc and to scour existing track alignment and remove asphalt, replant at the top and in other locations to formally close the track.

Conclusions

37. The assessment of options found there is no viable alternative to the proposed track alignment. Building across the landslides is not viable with such unstable ground and there is no other practical alignment for the track. The infrastructure vulnerability to landslides, the likelihood of another storm event (including the frequency), the environmental conditions, and infrastructure costs are too high to warrant the benefits of reinstating the access.
38. Given fiscal settings requiring all future recovery costs be managed within operational budgets, investment in an asset with a high probability of repeated failure is not supported.
39. Given this, we recommend DOC make a deliberate shift in approach. Rather than continuing to spread effort across multiple vulnerable access points, DOC should focus on the core experience and prioritise reliable access to Mautohe Cathedral Cove via the Grange Road carpark (the primary track to Mautohe Cathedral Cove). Reaching the cove and beach is the experience which matters most to visitors.
40. DOC should invest resources into strengthening the Mautohe Cathedral Cove track stability and resilience, by improving drainage and water management, through targeted planting to support land integrity, and via ongoing monitoring and maintenance in line with the Adaptation Plan. Reducing exposure to ongoing risk and cost is more prudent than spreading the operational budget across the expanded range of tracks on the reserve.
41. It is recommended to consult with key stakeholders regarding the removal of the track (and not proceed with the re-route) to inform the final decision paper.

From: Sarah Adams
Sent: Wednesday, 6 May 2026 2:29 pm
To: Rachael McMillan; Tania Short
Subject: RE: Permanent track removal decision papers - Cathedral Cove recreation reserve

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Rachael,

The January/February site visit to the Hahei Short Walk was undertaken by myself, in my capacity as project lead with responsibility for track delivery and assessment of operational feasibility, alongside the delivery contractor who has practical experience in track construction and maintenance works. The assessment undertaken was therefore based on operational and constructability expertise, rather than geotechnical certification, and was informed by existing geotechnical reporting for the area as well as direct observation of current site conditions.

No geotechnical specialist attended this visit. Instead, the assessment draws on existing geotechnical reports and previous advice for the area, alongside our direct observations of current site conditions.

As discussed, the image below highlights in yellow a new slip affecting the Hahei Short Walk. This slip sits outside of the current project site and would continue to prevent end-to-end access once the reroute was delivered. As a result, even if the reroute proceeded, it would offer no benefit as the track would remain unusable.

During the meeting with you, Tania, Nick, and myself, we also confirmed that there is no funding available to undertake the works required to repair this new slip area. This aligns with the Department prioritising limited capital investment toward resilient, high value assets and core visitor experiences, while reducing exposure to assets that are vulnerable, high maintenance, or unlikely to deliver reliable outcomes.

The green square marks a section of the proposed reroute where three fallen trees are obstructing the alignment. Since the original project scope was agreed, site conditions have changed, with these trees and their associated root balls now encroaching onto the track and cut trunk sections remaining upslope.

This introduces additional risk and complexity not accounted for in the original scope, as the material may deteriorate, shift, and potentially slip onto the track over time. Addressing this would require works beyond what was planned and funded, and options such as removal or relocation present further constraints, including potential impacts to adjacent private property.

The decision to not proceed with further geotechnical engagement, and to reassess the viability of the track, was made at a district level. This reflects both the existing body of geotechnical evidence already available and current funding constraints, with

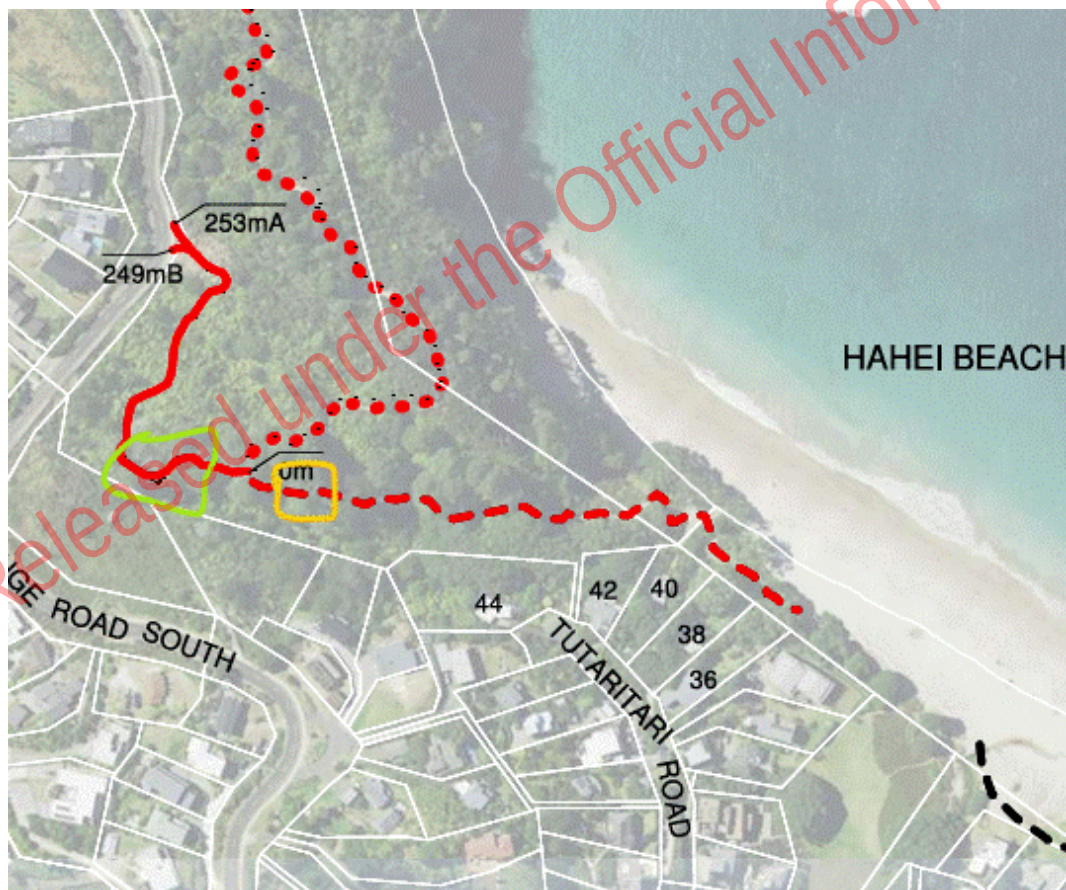
the view that further geotechnical input would be unlikely to materially change the established understanding of ongoing instability and risk.

Based on this, and the recent on-site observations, the district has determined that investing further in remediation or rerouting would be unlikely to achieve a resilient or reliable outcome and would not represent value for money.

In relation to the Gemstone Track, this was previously assessed by Tonkin + Taylor, who identified an active landslide affecting the proposed alignment.

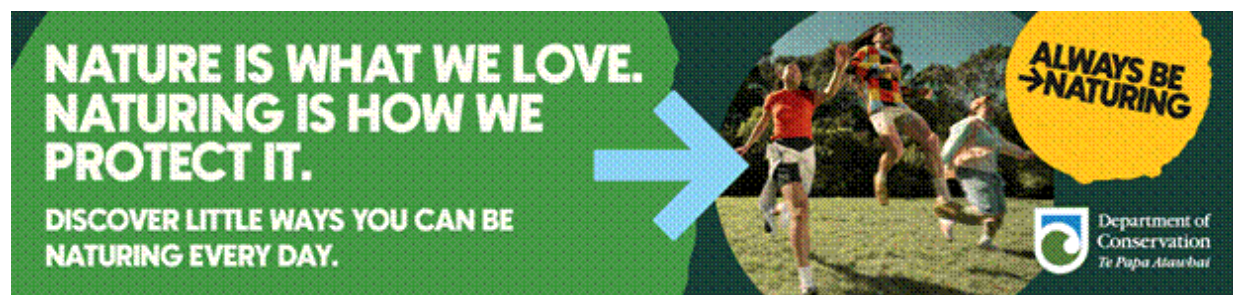
To be clear, an active landslide is not a suitable foundation for track construction. Where ground is currently moving, or has an ongoing failure plane, it cannot provide the stability required to safely support built infrastructure. Any construction in these conditions would be subject to continued ground movement, resulting in ongoing damage, loss of integrity, and eventual failure of the track.

On that basis, the presence of an active landslip makes the alignment not viable for construction of a safe or maintainable track under current conditions.



All the best and look after yourself. Thinking of you

Sarah Adams
Infrastructure Project Manager – Asset Management Unit



Out of Scope

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Functional Loc.	Description	Equipment	Description	Order	Description	Bas. start date	Main WorkCtr	System status	User status	Revision	Created on	Order Type	Priority
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4916263	Short Walk Track Inspection	16/03/2022	P100-I02	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y22_M03	24/04/2020	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4565885	Short Walk Track Inspection	20/04/2016	P100-I02	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE	Y16_M04	07/12/2014	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4741263	Short Walk Track Inspection	18/03/2020	P100-I02	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y20_M03	21/10/2017	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4462030	Short Walk Track Inspection	28/04/2014	P100-I02	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE	Y14_WK18	04/05/2013	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4655775	Short Walk Track Inspection	18/10/2017	P100-I02	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y17_M10	23/04/2016	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4253874	Walking Track Inspection	17/05/2009	632R2	TECO MANC MOBI NMAT PRC SETC	DECL ACMP DECN		27/06/2008	PM02	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4880002	Track Maintenance	01/12/2019	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		21/09/2019	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	5076810	Track Maintenance	01/06/2022	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		19/03/2022	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4821149	Track Maintenance	01/03/2019	S108-R01	CLSD MANC NCMP NMAT PRC	INIT		22/12/2018	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4898490	Track Maintenance	17/06/2020	S108-R01	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y20_M06	21/12/2019	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4916264	Track Maintenance	01/06/2020	S108-R01	CLSD MANC NCMP NMAT PRC	DECL DECC		24/04/2020	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4930418	Track Maintenance	01/09/2020	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		20/06/2020	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4993801	Track Maintenance	17/11/2021	S108-R01	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y21_M11	20/03/2021	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	5013216	Track Maintenance	01/09/2021	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		19/06/2021	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	5034022	Track Maintenance	01/12/2021	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		18/09/2021	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	5056650	Track Maintenance	31/05/2022	S108-R01	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y22_M05	18/12/2021	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4753380	Track Maintenance - Contractor	01/03/2018	S108-C01	CLSD MANC NCMP NMAT PRC	INIT		16/12/2017	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4971820	Track Maintenance	01/03/2021	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		19/12/2020	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4599333	Track Maintenance	22/11/2015	S108-R01	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE		13/06/2015	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4664266	Track Maintenance - Non Seasonal	01/09/2016	S108-R01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		18/06/2016	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4675798	Track Maintenance - Non Seasonal	01/12/2016	S108-R01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		17/09/2016	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4532442	Track Maintenance - Non Seasonal	01/12/2014	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		02/08/2014	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4693315	Track Maintenance - Contractor	01/03/2017	S108-C01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		17/12/2016	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4606876	Track Maintenance - Non Seasonal	01/12/2015	S108-R01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		08/08/2015	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4708223	Track Maintenance	15/08/2019	S108-R01	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE	Y19_M08	18/03/2017	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4650031	Track Maintenance - Non Seasonal	01/06/2016	S108-R01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		19/03/2016	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4632402	Track Maintenance - Non Seasonal	20/04/2016	S108-R01	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE	Y16_M04	19/12/2015	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4574233	Track Maintenance - Non Seasonal	18/03/2015	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE	Y15_M03	31/01/2015	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4950016	Track Maintenance	20/01/2021	S108-R01	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y21_M01	19/09/2020	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4835823	Track Maintenance	01/06/2019	S108-R01	CLSD NMAT PRC SETC	SCHD		23/03/2019	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4781670	Track Maintenance - Contractor	17/04/2019	S108-R01	CLSD MANC NMAT PRC SETC	SCHD	Y19_M04	23/06/2018	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4736145	Track Maintenance - Contractor	21/03/2018	S108-C01	TECO MANC NMAT PRC SETC	DECL DECN	Y18_M03	23/09/2017	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4850124	Track Maintenance	01/09/2019	S108-R01	TECO CNF NMAT PRC SETC	DECL DECF		22/06/2019	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4803523	Track Maintenance	01/12/2018	S108-R01	CLSD MANC NCMP NMAT PRC	INIT		22/09/2018	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4767313	Track Maintenance	15/08/2019	S108-R01	TECO CNF MANC NMAT PRC SETC	SCHD DONE	Y19_M08	17/03/2018	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4722452	Track Maintenance - Contractor	01/09/2017	S108-C01	CLSD MANC NCMP NMAT PRC	INIT		17/06/2017	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4325723	Track Maintenance, deferred see previous	12/06/2010	632R1	CLSD MANC NCMP NMAT PRC	INIT		06/03/2010	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4368189	Track Maintenance	12/06/2011	632R1	TECO NMAT PRC SETC	DECL ACMP DECN		05/03/2011	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4409206	Track Maintenance	12/06/2012	632R1	TECO NMAT PRC SETC	DECL ACMP DECN		03/03/2012	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4267948	Track Maintenance side drains, veg contr	14/12/2009	632R1	TECO MANC MOBI NMAT PRC SETC	DECL DECN	Y09_WK51	22/10/2008	PM03	Planned
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4569676	OGL STEPS_RISER_TREAD:11	20/01/2015	S108-R01	TECO CNF MOBI NMAT PRC SETC	SCHD DONE		20/01/2015	PM04	Low
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4548252	OGL VEG_LESS_TKWIDTH:15.000	18/03/2015	S108-R01	TECO CNF MANC MOBI NMAT PRC SETC	SCHD DONE	Y15_M03	18/11/2014	PM04	Low
DN-14-105-2128	Hahei Beach Short Walk	100044004	HAHEI BEACH SHORT WALK	4538394	track maintenance	28/07/2014	S108-R01	TECO CNF NMAT PRC SETC	SCHD DONE		19/09/2014	PM04	Medium

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Notification	Notification Text	Long Text	Technical Object Description	Superior Floc Description	Priority Text	Notification Type	Notification Type Name	Required Start Date	Main Work Center Text	Notification Status	Created on	Created by	Created by User Name
30041183	Cyclone damage - Geotechnical reported r	08.03.2023 13:46:22 NZST (KDAWICK) Wed 08 Mar 23 13:37 (KDAWICK - BlueWorx) Multiple slips occurred, near upper section of track. Will require Geotechnical advice prior to opening track. Photos and further details (kim Dawick).	Hahei Beach Short Walk	Cathedral Cove	Medium	M1	Maintenance Request	3/8/2023	PR - Whitianga - H&V Matt	Completed	3/8/2023	KDAWICK	Kim Dawick
30064415	Temp fencing, track closed sign		Hahei Beach Short Walk	Cathedral Cove	Medium	M1	Maintenance Request	8/11/2024	PR - Whitianga - H&V Matt	Completed	7/12/2024	IBOOTH	Ian Booth
30076292	SCP-Hahei Beach Track reroute -landslide	27.05.2025 11:21:26 NZST (MCHIKWIRI) Notification - one-off task "Landslide and rockfall hazards Rock arch and overhang hazards" Hahei Beach Track reroute - landslide Realign the Hahei Beach Short Walk to avoid the unstable upper section of track that traverses the top of the cliffs. Visitors are still using the closed track and this behaviour won't stop until the realignment is in place. The Hahei Beach Track realignment needs to be completed to avoid the unstable upper section of track that traverses the top of the cliffs. Visitors are still using the closed track and this behaviour won't stop until the realignment is in place. "Task Duration (Hours)" = 40hrs Number of Resources (Rangers)=2rangers	Hahei Beach Short Walk	Cathedral Cove	High	MH	Safety System	6/26/2025	PR - Whitianga - H&V Matt	Completed	5/27/2025	MCHIKWIRI	Mectildah Chikwiri