Estimating the economic impacts of Cyclone Gabrielle

Insights on the quantitative economic impacts of Cyclone Gabrielle on DOC and affected regions

12 April 2023

Department of Conservation
Te Papa Atawhai

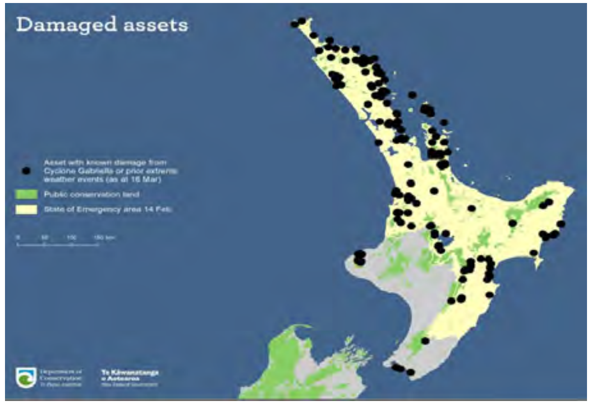
New Zealand Government

Executive summary

High-level findings of the economic impacts of the cyclone on DOC across affected regions

Main findings

- **Regional tourism expenditure lost** due to fewer visitors at DOC sites is estimated at **$2.7 million** and **tourism GDP lost is estimated at $1.5 million** due to accommodation bookings cancelled during the state of emergency period.
- **DOC's concessionaires** in the affected districts are estimated to have lost between **$28 million to $69 million in business revenue.**
- Five popular DOC sites (**Mt. Manaia, Morere Hot Springs, Cathedral Cove, Te Henga Walkway and Karangahake Gorge**) suffered significant damages. Decline in visitors to some of these sites are estimated to **negatively impact tourism GDP by $4 million to $10 million in their respective regions,** thereby suggesting that these sites significantly support their regional economies.
- **Total recovery costs is estimated at** 9(2)(f)(iv) [redacted] **until 2027/28** (9(2)(f)(iv) [redacted] 9(2)(f)(iv) for capital expenditure). The rebuild will have a **positive GDP impact** in the long-term. Elevated inflation would add to the costs.



Known DOC asset damages as of 16th March 2023. Source: DOC GIS Mapping.

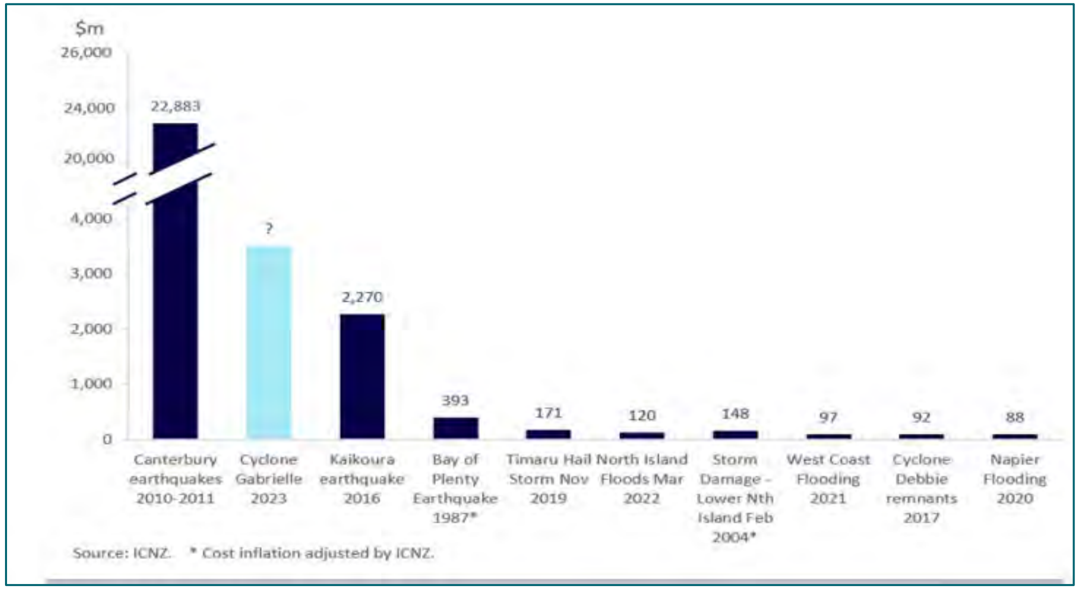
Introduction

Cyclone Gabrielle caused unprecedented loss across the North Island. Official economic loss estimates of Cyclone Gabrielle not yet quantified.

Cyclone Gabrielle and other natural disasters

- Natural disasters cause damages that often entail a long recovery period ahead (BERL).
- Cyclone Gabrielle is New Zealand's costliest non-earthquake natural disaster (MFAT).
- Total economic losses of the Cyclone to New Zealand has not yet been quantified.

Ten costliest natural disasters faced by insurers



Source: Cyclone Gabrielle's impact on New Zealand, MFAT, March 2023

Insights from economic agencies and other studies

- NZ Treasury expects the economic losses to exceed the 2016 Kaikōura earthquake ($2-4bn) but dwarfed by $40bn losses from 2010/11 Canterbury earthquakes.
- Long-term economic impacts and flow-on effects are complex to estimate due to the extent of damage.
- Economic insights from BERL noted that there could be short-term boost in economic activity for the construction industry.
- Adverse effects are likely to be seen in other industries such as horticulture.
- RBNZ indicated that the severe weather events are driving up prices and inflation expectations.

Key measures of estimated Economic Impacts

Lost capital value from DOC facilities and estimated recovery costs

GDP lost from visitor spending due to cancelled bookings in DOC facilities

Concessionaires' business revenue loss

Regional case studies of damaged DOC sites

Lost capital and needed repair costs on DOC assets

Lost capital value from DOC facilities and estimated recovery costs

Key findings

$5 million[1] estimated value loss of destroyed facilities

[redacted] 9(2)(f)(iv) estimated total recovery costs of damaged facilities (including [redacted] 9(2)(f)(iv) for capital expenditure)

42% of sites will require repairs and/or full asset replacements

18,000 assets affected

Damaged properties include buildings, signages, tracks, carparks and boardwalks.

Impacts on DOC assets vary widely from needing minor repairs to complete replacements. Heavily impacted assets are in the northern areas and eastern coasts of the North Island. Key considerations are:

- Damage assessments are still on-going across districts and regions.
- Estimated value of damaged DOC facilities and repair costs are based on Treasury bid lodged in March 2023.
- Total recovery costs is estimated at [redacted] 9(2)(f)(iv) until 2027/28. The rebuilding activities will positively impact GDP.

Slips beside Boundary Stream Track, Hawkes Bay. Source: DOC LNI damage assessments

Glenfalls Campsite sign beside Mohaka river. Source: Shellie Evans Photography

[1]*Asset value losses are write-offs from the net book value (NBV). As many damaged assets are old these losses understate the support they have been providing to the regional economies.*

Economic activity from DOC visitors

Key findings

$2.7 million estimated expenditure loss from visitor spending during the state of emergency

$1.5 million estimated GDP loss from 7,000 cancelled bookings

Around 41% of total DOC accommodation bookings cancelled (**recreation revenues loss** estimated at **$68,000)** during this period[1]

Bookings cancelled mostly in **Northland and Coromandel**

GDP lost from visitor spending due to cancelled bookings in DOC facilities

Cancelled bookings in DOC recreation facilities have flow-on effects through the local district's economies. Figures above are based on immediate and short-term economic effects, when most DOC facilities in the impacted districts are closed.[1]

- DOC visitor cancellations in impacted areas estimated at 7,000 visitors within the one-month state of emergency period
- This includes visitors staying in huts, campsites, and sole occupancy lodges and cabins.
- Visitor expenditure losses were based on MBIE's average tourism expenditure estimates per district and cancelled DOC bookings.
- Regional tourism GDP/expenditure ratios were used based on Infometrics and MBIE data.

No access from North Block road to Sunrise Hut (photo). Image by Jack Mace.

Glenfalls Campsite. Source: DOC LNI damage assessments

[1] Time period analysed from 10th February (weekend before the Cyclone hit) to 14th March when State of Emergency was lifted in most areas

Business activity from DOC Concessionaires

Key findings

$28 million to $69 million[1] estimated business revenue lost of the impacted concessionaires.

Estimated concession fees lost to DOC is **at $1.4 million** in the affected regions

Around 800 DOC concessionaires affected from the Cyclone covering recreation and other sectors

Top 3 impacted services and activities are **accommodation, grazing and attractions/tours.**

Concessionaires' business revenue loss

DOC concessionaires cover a wide range of industries across regions. Estimated revenue impacts to these businesses provide a snapshot of how much some industries have been impacted by the cyclone.

- Estimated business revenues impacted are short-term.
- Inflation and continued business uncertainty in heavily affected districts could contribute to higher business losses.
- Figures mentioned focus on businesses located in impacted regions and districts, this excludes national concessionaires with a presence in multiple areas across New Zealand.[2]
- For businesses with presence across multiple districts (not just impacted areas), estimated concession fees lost is around $1.3 million.
- Concession fee rates scenarios and losses in business revenues:
  - 2% - $28 million
  - 3.5% - $40 million
  - 5% - $69 million.

Beekeeping, Christchurch. Source: Revolt.

Guided hiking tour in Fiordland. Image by M. Strawsine.

[1] *The wide range of business revenue lost reflects a wide range of average concession fee rate scenarios.*

[2] *Due to the difficulty of breaking down business revenues coming from specific districts, national concessions are excluded.*

Impacts in popular DOC sites

Key findings

Regional case studies on **Mt. Manaia, Mōrere Hot Springs, Cathedral Cove, Te Henga Walkway and Karangahake Gorge** highlight impacts on these popular sites.

Total visitors are **around 400,000** when all five sites are in operation

Estimated negative tourism GDP impact from lost visitors in some of these sites due to closures range from **$4 million to $10 million in their respective regions.**

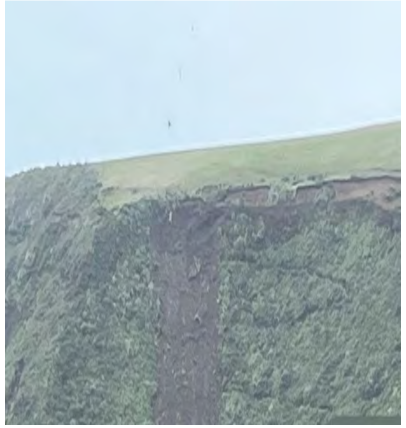
Capex funding plans in these sites range from **$100,000 to $1.2 million**

Cyclone damages include tracks, boardwalks, water systems, bridges and road networks.

DOC identified these popular sites based on their significant damages and are located within the impacted regions.

- Impact on assets are provided in terms of pictures, descriptions and percentage damages to the assets.
- Short-term negative impacts on tourism GDP in regions are estimated by assuming that there is a 50% decline in annual visitor numbers to the site and these visitors would not visit the region due to cyclone damages.
- Over the long-term, the rebuild work is likely to have positive impacts to GDP but this work would be a part of DOC's future visitor network planning – so at this stage, their impacts on GDP are uncertain.

Mt. Manaia Walkway, Northland. Source: DOC damage inspections



Te Henga Walkway, Auckland. Source: DOC damage inspections

Regional case studies of damaged DOC sites

Appendix:

Case studies*

- Mt. Manaia track and associated facilities (Whangarei, Northland)
- Te Henga / Bethels beach and associated facilities (Muriwai, Auckland Mainland)
- Cathedral Cove walk (Hahei, Coromandel)
- Mōrere tracks, hot pools and facilities (Wairoa District, East Coast)
- Karangahake Gorge (Kaimai Mamaku Conservation Park, Bay of Plenty)

**Based on information provided by Senior Visitor Advisors*

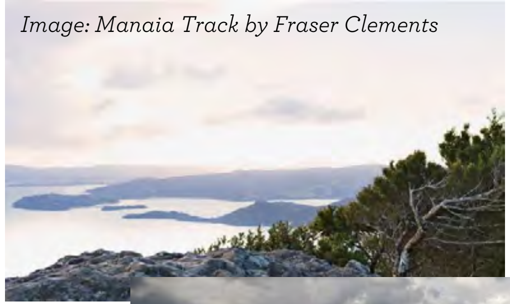


Image: Manaia Track by Fraser Clements

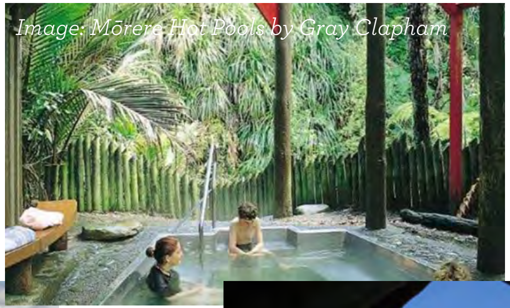


Image: Mōrere Hot Pools by Gray Clapham

Image: Karangahake Gorge by Stefan Marks

Image: Te Henga Walkway by Martin Sercombe

Image: Cathedral Cove by Tahu Taylor-Koolen

Mount Manaia, Northland

Product: *Short Walk* (up to Mount Manaia Summit) (*Local treasure*)

Assets: track, boardwalk, steps and bridge

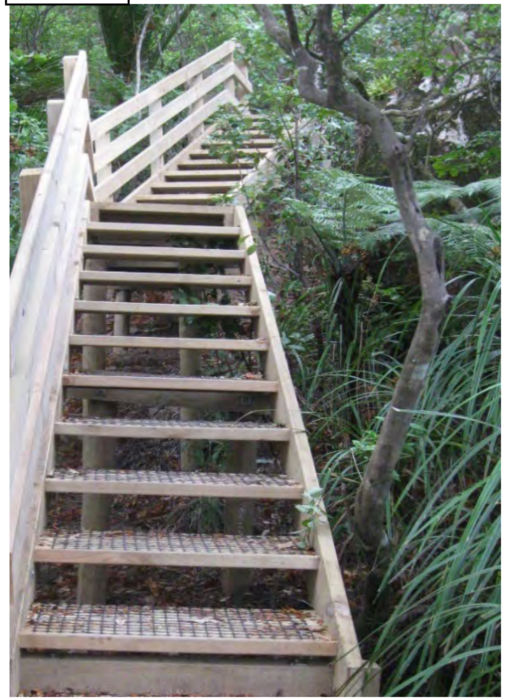
Capex: $400k in 2016 (84% of boardwalks and steps built)

Visitor numbers: 42k in 2021/22

Cyclone damage: track (40%), Board walk (20%) and Steps (5%)

A 50% decline in visitor level from 42k could negatively impact the region's tourism GDP by 1 % (– $4.8 million).

Before



After

Te Henga Walkway, Auckland

Product: A *walkway* connecting to other Auckland Council tracks. It is DOC's only open track across Waitakere ranges.

Investment: $335k over 2020-22 on bridges and aligning tracks since 2020, planned investment:$740k

Visitor numbers: 34.5k in 2021/22

Cyclone damage: two bridges washed away, multiple slips present and about 40% of track is affected.

A 50% drop in visitor level from 34.5k could negatively impact the region's tourism GDP by 0.4 % (– $10 million).

Before

After

Cathedral Cove, Coromandel

Product: Short Walk

Local iwi: Strong interest of Ngāti Hei

Capex plans: $97.4k (current), $682k (forward 4-year plan)

Visitor numbers: 250k in 2019/20

Cyclone damage: Cove track (<5%), Hahei walk (<10%), others (100%) with repair costs estimated at $1.4m and $180k respectively; road closures.

Site closed: A drop in visitor level by 50% from 250k could negatively impact the region's tourism GDP by 3% (– $4 million).

Before

After

Morere Hot Springs, East Coast

Product: Hot pools administered by DOC (*Gateway site*)

Deed of settlement (2016): Strong interest of Tātau Tātau o Te Wairoa

Assets: Ageing assets, no new investment done, upgrade cost estimated ($583k plus costs for strengthening against earthquakes)

Visitor numbers: 30k, fell in recent years, site closed prior to Cyclone, **hence GDP impact from lost visitors is not estimated**

Cyclone damage: Nearby track eroded, water reticulation system destroyed (old with nil current value) with replacement value $200-300k.

Before

After

Karangahake Gorge, Bay of Plenty

Product: Karangahake Gorge Historic Walkway and other walks (Icon)

Heritage site and biodiversity values (Hochsetters Frog, kauri dieback)

Investment: $500k (2019-22), Planned investment:$1.2m

Visitor numbers: 84k (2018/19), 40 k (2020/21)

Cyclone damage: Flooding of Karangahake Gorge River, multiple slips, barrier damages and tracks buried under overburden debris.

Visitor impact: Uncertain – Some visitors may come and walk as far as they can, while others may not due to natural hazard risks. Hence GDP impact is not estimated.

Before

After

Drought exposure and climate change

A nationwide assessment for DOC's Climate Change Adaptation Action Plan

Prepared for Department of Conservation

June 2023

Prepared by:
Gregor Macara
Ashley Broadbent

For any information regarding this report please contact:

Gregor Macara
Climate Scientist
Climate Data and Applications
9(2)(a) [redacted]
gregor.macara@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone 9(2)(a) [redacted]

NIWA CLIENT REPORT No:	2023113WN
Report date:	June 2023
NIWA Project:	DOC23301

Quality Assurance Statement		
9(2)(a) [redacted]	Reviewed by:	Andrew Tait, Chief Scientist – Climate, Atmosphere and Hazards
9(2)(a) [redacted]	Formatting checked by:	Alex Quigley
9(2)(a) [redacted]	Approved for release by:	Alison MacDiarmid

Contents

Tables

Figures

Executive summary

This report identifies where, and to what extent, Department of Conservation (DOC) assets and management areas will be exposed to increased drought risk caused by climate change. The report provides a national-scale drought exposure screening assessment to guide DOC priorities in light of climate change, and the necessity for adaptation.

The Standardised Precipitation Index (SPI) is used as an indicator of drought in this study, from which we have classified drought severity into three categories: moderate, severe and extreme. Downscaled results of selected global climate models based on two representative concentration pathway (RCP) scenarios (RCP4.5 and RCP8.5) are presented, with changes in drought occurrence for two future periods (2040 and 2090) presented relative to the historic period (1995).

This report focusses on the drought exposure of several DOC responsibilities and assets, including ecosystem and species management units, non-migratory freshwater fish, huts and campsites, and flushable toilets. Most DOC responsibilities and assets are expected to see a change in exposure to severe drought in future, however the projected increase in severe drought occurrence is relatively small (i.e. no more than 1 more severe drought per 20 year period). The largest increases in drought exposure occur in summer by 2090, notably under both RCP4.5 and RCP8.5.

More detailed risk assessments of specific locations and responsibilities using these drought projections should follow this national-level study – particularly areas, assets, and responsibilities where water availability is a key consideration. It is further recommended that a communication and engagement plan is developed to ensure the findings presented in this report are shared with relevant DOC staff, with particular focus on those staff involved in planning. It is anticipated this report, and subsequent detailed assessments, will help inform climate change adaptation activities within DOC.

1 Introduction

1.1 Purpose of this report

This report (and the associated GIS datasets) identifies where, and to what extent, Department of Conservation (DOC) assets and management areas will be exposed to increased drought risk caused by climate change, to enable forecasting and planning of future management requirements.

The information in this report should be used as a national-scale drought exposure screening assessment to guide DOC priorities – noting that the Standardised Precipitation Index (SPI) is used as an indicator of drought in this application. More detailed risk assessments of specific locations and responsibilities using these drought projections should follow this national-level study – particularly areas, assets, and responsibilities where water availability is a key consideration.

1.2 Context

Aotearoa New Zealand's changing climate is affecting nearly every aspect of DOC's responsibilities. The Department's Statement of Intent 2022-2026[1] says:

Our (DOC's) roles are to:

1. *protect the land, species, ecosystems, and cultural heritage for conservation purposes*
2. *manage threats and adverse impacts*
3. *be a voice for conservation*
4. *connect people to nature.*

To achieve these roles, particularly 1. and 2., requires an understanding of the impacts of climate change, and how DOC's responsibilities are exposed to these impacts. In response to the challenge of climate change, DOC have developed the Climate Change Adaptation Action Plan 2020-2025 (CCAAP). The plan sets out actions to inform, prepare and guide DOC's response to climate change impacts, with a focus on New Zealand's biodiversity and DOC-managed infrastructure.

There are significant knowledge gaps that limit DOC's ability to both adapt their management, and understand how climate change will affect the assets they manage. The CCAAP seeks to address this through targeted research - to identify the exposure and vulnerability of DOC's areas of management to climate change impacts and inform the development of adaptation management plans.

Research into the impacts of climate change is ongoing at DOC, which is helping to fill the knowledge gaps. A recent study by Tait (2019) involved a risk-exposure assessment of DOC coastal locations to flooding from the sea. This work provided a general template of processes required for the assessment of exposure to drought which is presented in this report.

1.3 Background on drought

Drought is a prolonged dry period in the climate cycle that can occur anywhere in the world. It is a slow onset phenomenon caused by a lack of rainfall (WMO, 2023). Like other hazards, droughts can be characterized in terms of their severity, location, duration and timing (WMO & GWP, 2016).

[1] https://www.doc.govt.nz/globalassets/documents/about-doc/role/publications/statement-of-intent-2022-2026.pdf

Droughts can arise from a range of hydrometeorological processes that supress precipitation and/or limit surface water or groundwater availability, creating conditions that are significantly drier than normal or otherwise limiting moisture availability to a potentially damaging extent (WMO & GWP, 2016).

Drought is a common feature of New Zealand's climate. On average, every year or two somewhere in New Zealand experiences a drought (NIWA, 2023). In a study of 30 New Zealand locations between the period 1972-2019, drought frequency (based on the Standardised Precipitation Evapotranspiration Index; SPEI) increased at 13 locations, decreased at nine locations, and 8 locations had indeterminate trends (MfE and Stats NZ, 2020). New Zealand will continue to experience droughts, and it is anticipated that climate change will slowly increase the frequency and length of droughts this century and beyond (NIWA, 2023). Good preparation, early warning and close monitoring of drought are three key factors for minimising the impact of drought (NIWA, 2023).

2 Data used for this study

2.1 Climate modelling and climate change scenarios

In this report, the downscaled results of selected global climate models based on two representative concentration pathway (RCP) scenarios (RCP4.5 and RCP8.5) are presented. The RCPs are scenarios of how greenhouse gas concentrations and other atmosphere pollutants might change during the 21st century. The RCPs chosen represent a range from a 'high end' scenario if atmospheric greenhouse gas concentrations continue to rise at high rates (RCP8.5), to a 'mid-range' scenario (RCP4.5) that could be realistic if moderate global action is taken soon towards mitigating greenhouse gas emissions.

RCP8.5 is described as a high emissions scenario, with greenhouse gas concentrations continuing to increase at the current or an accelerated rate. Whilst global emissions are unlikely to continue increasing at current rates to the end of the 21st century (Hausfather & Peters, 2020), the RCP8.5 projections serve the purpose of defining the upper envelope of futures required for high risk impacts. Additional unaccounted risks resulting from other mechanisms (e.g. positive feedback loops) may result in impacts similar to those projected in the RCP8.5 scenario, even if the emissions scenario doesn't play out as projected. Examples of positive feedback loops include the melting of permafrost in Arctic regions, melting ice (e.g. Arctic sea ice) and clouds. Notably, RCP8.5 most closely resembles the total cumulative carbon dioxide emissions from 2005-2020, thus remaining RCPs assume a level of mitigation during the 2005-2020 period that did not occur (Schwalm et al., 2020).

The RCPs inform projections which provide plausible futures under climate change. However, climate change over the remainder of the 21st century and beyond is uncertain. This is due to:

- It is unknown how greenhouse gas concentrations will actually change over this period. Emissions may be significantly reduced, or they may continue to increase, or they may plateau. The two RCPs represent two representative choices among a wide range of possible options.
- Limitations in understanding of climate processes and how they are represented in the climate models used to predict how the climate will change. There is considerable complexity and inherent uncertainty in climate modelling (e.g. the response of the Antarctic ice sheet to increasing temperatures resulting in increased sea level rise).
- Uncertainty in natural climate variability.

This inherent uncertainty is the basis for why projected climate changes (for the globe and for New Zealand) are modelled based on a suite of RCPs. For risk assessments, it is best practice (e.g. as was done for the National Climate Change Risk Assessment; Ministry for the Environment, 2020) to consider climate change projections based on a range of RCPs, including a high concentration pathway.

2.1.1 Time periods selected

In this report, data were calculated for three time periods:

- 1995 (calculated as the average over the period 1986-2005)
- 2040 (calculated as the average over the period 2031-2050)

- 2090 (calculated as the average over the period 2081-2100)

The time periods chosen for historic and future projection span 20-year periods. This is seen as a relatively short timeframe to understand average conditions in the historic period and in the future, as there is likely an influence of underlying low frequency climate variability (e.g. decadal signals from climate drivers like the Interdecadal Pacific Oscillation etc.). However, as climate data is subject to significant trends, a short period is more homogenous and representative. Moreover, the Intergovernmental Panel on Climate Change (IPCC) uses 20-year periods, so we have followed that approach for consistency.

2.2 Standardised Precipitation Index

The Standardised Precipitation Index (SPI) can be used as an indicator of drought, and is described by WMO (2012) as follows:

> *"The SPI was designed to quantify the precipitation deficit for multiple timescales. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalised, wetter and drier climates can be represented in the same way."*

The final sentence is emphasised because this was a key reason for choosing SPI for this report. There is considerable spatial variability of monthly, seasonal, and annual rainfall over New Zealand (Macara, 2018), which needed to be accounted for by the drought index chosen.

As with any measure of drought, SPI has strengths and weaknesses. The key strengths of the SPI include i) only precipitation data is required, ii) it is applicable in all climate regimes, iii) by being normalised, values for very different climates can be compared, and iv) SPI has a wide breadth of application SPI can be calculated over multiple timescales. In this report the 3-month timescale of SPI was chosen, which is useful for basic drought monitoring (WMO & GWP, 2016).

A primary weakness of SPI is that with precipitation as the only input, it is deficient when considering the temperature component, which is important to the overall water balance of a region (WMO and GWP, 2016). For example, higher temperatures can exacerbate evapotranspiration and intensify water deficiencies associated with drought. This is relevant considering temperature increases projected for New Zealand due to climate change (MfE, 2018). Other variables that can influence drought occurrence include soil type and land cover (including forest), and these aren't accounted for in a simple index such as SPI. Other drought indicators such as SPEI, Soil Moisture Deficit, or Potential Evapotranspiration Deficit were considered, but these are primarily used for grassland environments. For the purposes of this report – a national-scale drought exposure screening assessment – SPI was deemed appropriate.

Drought intensities resulting from the SPI are defined using the classification system developed by McKee et al. (1993), which are shown in Table 2-1.

Table 2-1: SPI values and their associated drought intensity classification. Adapted from WMO (2012). Severe drought is emphasised with bold text, as this classification was selected for use in this report.

SPI Index Values	Classification
-2 and less	Extreme drought
-1.5 to -1.99	**Severe drought**
-1.0 to -1.49	Moderate drought
-0.99 to 0.99	Near normal
1.0 to 1.49	Moderately wet
1.5 to 1.99	Very wet
2.0 or more	Extremely wet

2.2.1 Calculation of SPI

SPI was calculated for this report in Python, using the package developed by Adams (2017) that was originally developed by the National Oceanic and Atmospheric Administration (NOAA) for drought monitoring purposes. Input rainfall data required for generating SPI were sourced from NIWA via six regional climate models (RCMs), which apply downscaling and bias-correction to global climate models (GCMs) from the Fifth Coupled Model Intercomparison Project (CMIP5), as described in MfE (2018). Further details of the steps involved in calculating SPI are outlined below:

1. Calculated 3-month seasonal SPI for historic (1995; 1986-2005) and future (2040; 2031-2050, and 2090; 2081-2100) time periods, for all six RCMS, under RCP4.5 and RCP8.5.

2. Tally occurrences of each classification of SPI by season for all six RCMs – for a given RCM, time period, and RCP there are 20 data points per season. For example, summer (December, January and February) in the historical period (1986-2005) experienced *x*/20 severe droughts.

3. Take the seasonal means of all SPI classification occurrences across all six RCMs. This gives the model mean of the number of, for example, "severe drought" occurrences per 20 year period for all time periods under each RCP scenario.

4. Calculate the probability of occurrence for each drought intensity classification, which is simply the seasonal means of SPI classification occurrences (i.e., step 3) divided by 20.

5. Historic data were left as the absolute probability of occurrence, whereas the 2040 and 2090 time periods were calculated as the change in probability of occurrence (i.e. future probability minus historic probability).

6. GIS layers of the probability of occurrence (i.e., step 5) were generated and provided to DOC.

7. Note, steps 2-6 above were repeated for all time periods, and both RCPs.

2.3 Drought data selected

As described in Section 2.2, there are different classifications of drought intensity. Carrying out an assessment for all three categories of drought was deemed too cumbersome for this report, so a single classification of drought (severe drought; Table 2-1) was chosen. These data have a gridded spatial resolution of 5 x 5 km, and are only available for areas where the centre of the grid are based over New Zealand's mainland. This means some coastal and island locations are not covered by the modelled drought data.

Drought data were available for all seasons, however only data for summer and autumn were selected for this report. This was recommended by DOC experts because they are the primary seasons when people are out recreating in the conservation estate, and also because demand for water (and therefore susceptibility to drought) is higher during warmer times of year.

2.3.1 Caveats associated with drought data

As with any modelling exercise, there are limitations on the results and use of the data. This section outlines some of these limitations and caveats that should be considered when using this report.

- The average of six models is used in this report, however data from individual models is available for further assessment if required in the future. The six models chosen represented historic climate conditions in New Zealand well, and span a range of future outcomes (MfE, 2018). The climate signal is better represented by ensemble averages since the uncertainty due to climate models and internal variability is much reduced.
- Though only a small number of model simulations (six) were possible due to the large computing resources required for running climate model simulations, they were very carefully selected to cover a wide range of climate model projections.
- Care needs to be taken when interpreting grid-point-scale projections such as those available in the GIS layers provided to DOC. The underlying rainfall data used to derive SPI have been bias-corrected, downscaled and interpolated from the 30 km regional climate model grid to the 5 km grid across New Zealand using physically based models and interpolation. The regional climate model and bias correction may not accurately reproduce the role of mountain ranges in blocking rainfall, for example. Therefore, the data from these grid points does not correspond to on-the-ground observations. It is more appropriate to consider relative patterns rather than absolute values, e.g. the magnitude of change at different time periods and scenarios.

Although there are some limitations and caveats in the approach used here, considerable effort has been made to generate physically consistent climate change projections at useful temporal and spatial resolutions.

2.4 DOC responsibilities and assets

The following DOC GIS datasets were utilised in this study:

- NATIS1.NATISADM.OPERATIONAL_DOC_PrescriptionManagementUnits

This dataset comprises Management Units that fall under the Natural Heritage Intermediate Outcome Objectives (IOO) framework. This data is used within DOC for systematic conservation prioritisation to support the cost-effective management of a full range of New Zealand's ecosystems and species.

The analysis carried out for this report used the subset of this dataset which comprised:

- All ecosystem management units (EMUs) that contain wetland ecosystem types, because wetland biota are particularly vulnerable to changes in hydrology;
- All species management units (SMUs); and
- All ecosystem or species Management Units that support category 'A' populations of threatened species (CatA MUs).

EMUs are based around sites identified for DOC by panels of experts as being best examples of each ecosystem type. They were designed to be large enough to provide a functioning example of one or more ecosystems and of an appropriate size for management. Many EMUs also support potentially viable populations of threatened species. EMUs were created to support IOO 1.1: A full range of New Zealand's ecosystems is conserved to a healthy functioning state.

SMUs are sites identified for DOC by panels of experts as being critical for the long-term security of each species. They were designed to be large enough to provide for a viable population of one or more species. SMUs were created to support IOO 1.2: Nationally threatened species are conserved to ensure persistence.

CatA MUs are ecosystem or species management units where management of a threatened species' population was deemed essential to prevent the species' extinction.

- Non-migratory Freshwater Fish Distribution[2]
- NATIS1.NATISADM.INFRASTRUCTURE_EAM_AssetPts

  The analysis carried out for this report used a subset of this dataset which comprised:

  - Huts and Campsites;
  - Flushable Toilets.

Several DOC staff were involved in choosing the DOC GIS datasets to be used in this study. These datasets were chosen due to their i) perceived reliance on rainfall, ii) their vulnerability to impacts associated with periods of drought, and iii) availability and completeness at a national scale.

[2] https://services1.arcgis.com/3JjYDyG3oajxU6HO/ArcGIS/rest/services/NonMigratoryFreshwaterFishDistribution/FeatureServer

3 Methodology

As described in Section 2.2, there are seven different classifications of SPI, including three for drought. Carrying out an assessment for all drought categories was deemed too cumbersome for this report, as it would be difficult to distil the analyses into meaningful results that could be readily interpreted. Therefore, a single classification of drought (severe drought) was chosen. GIS layers for all drought categories were provided to DOC for use in more detailed follow-on studies.

The severe drought GIS layers were loaded in R 4.2.2 using the *terra 1.7-3* package, and GIS layers of DOC responsibilities and assets were added to this assessment. The terra function 'extract' was used to identify the probability of severe drought occurrence corresponding to the location of DOC features responsibilities and assets, for all time periods and both RCPs. The probability of occurrence data (i.e. the data are numbers between 0-1) were converted back to seasonal totals (i.e. average number of severe droughts per 20-year period) – as absolute totals for the historic time period, and relative totals (difference from historic) for future time periods – to aid the interpretation of results.

Some of the DOC GIS datasets cover areas of varying extents (i.e. lines and polygons), as opposed to being point-based data. This creates a challenge when seeking to determine the historic or projected drought occurrence, as the drought data are spatially variable. Each DOC responsibility or asset was assigned to a drought occurrence category that represented the level of drought occurrence across the most-affected 25% of the area, using the function 'exact extract', from the R package *exactextractr 0.9.1*. For the assessment of non-migratory freshwater fish, the 3-monthly seasonal SPI was still used to classify severe drought, i.e. an alternative hydrological drought indicator was not used.

As described in Section 2.3, some coastal and island locations are not covered by the modelled drought data. This resulted in portions of each DOC responsibility and asset having no corresponding drought occurrence data. These cases were treated as "NA's", and NA's are included in the results.

4 Results

4.1 Historic occurrence of severe drought

The historic (i.e. 1986-2005) occurrence of severe drought in summer and autumn is illustrated in Figure 4-1. These data provide the baseline from which projected changes in severe drought frequency were calculated (Section 4.2).

As noted in Section 2.2, SPI is normalised, meaning wetter and drier climates can be represented in the same way. This is relevant because DOC's responsibilities and assets are affected explicitly by the rainfall characteristics of the area in which they are located. Therefore, it is the relative changes to that rainfall which enable a national-scale drought exposure screening assessment to be performed.

Note, a severe drought (as defined by SPI) in a relatively wet area (such as the West Coast) will have different characteristics to that observed in a relatively dry area (such as Central Otago), because of the significant difference in rainfall totals observed at each location. It is important to consider this context when interpreting the historic (Figure 4-1) and projected future (Section 4.2) drought occurrence across New Zealand.

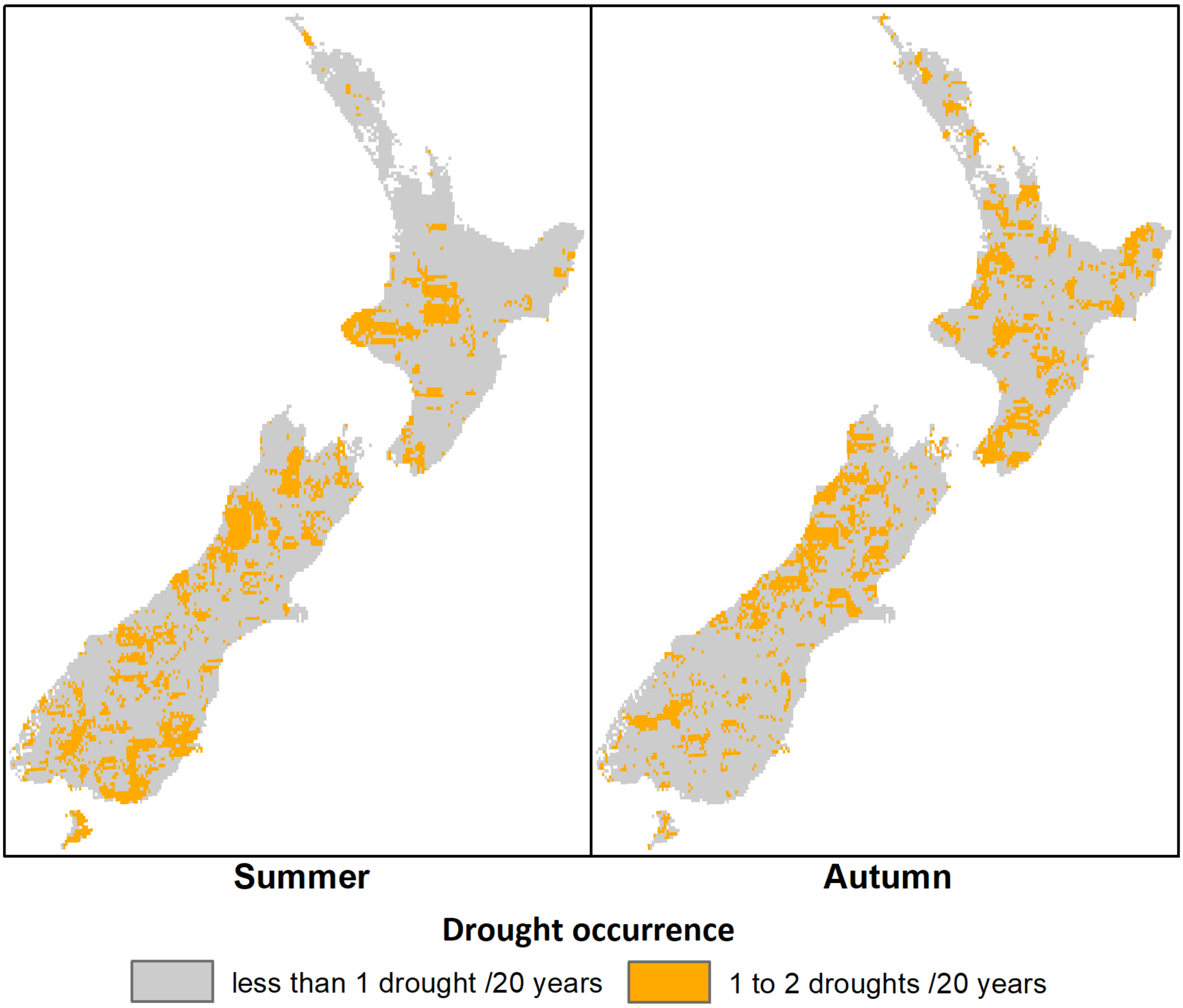


Figure 4-1: Historic occurrence of severe drought in summer (left) and autumn (right).

4.2 Projected increases in severe drought

Projected increases in severe drought occurrence are illustrated for summer (Figure 4-2) and autumn (Figure 4-3). These are presented as standalone figures (i.e. without the DOC GIS layers overlaid) to highlight the underlying drought data used for further assessment with the selected DOC GIS layers. Increases in severe drought are larger and more widespread in summer compared to autumn.

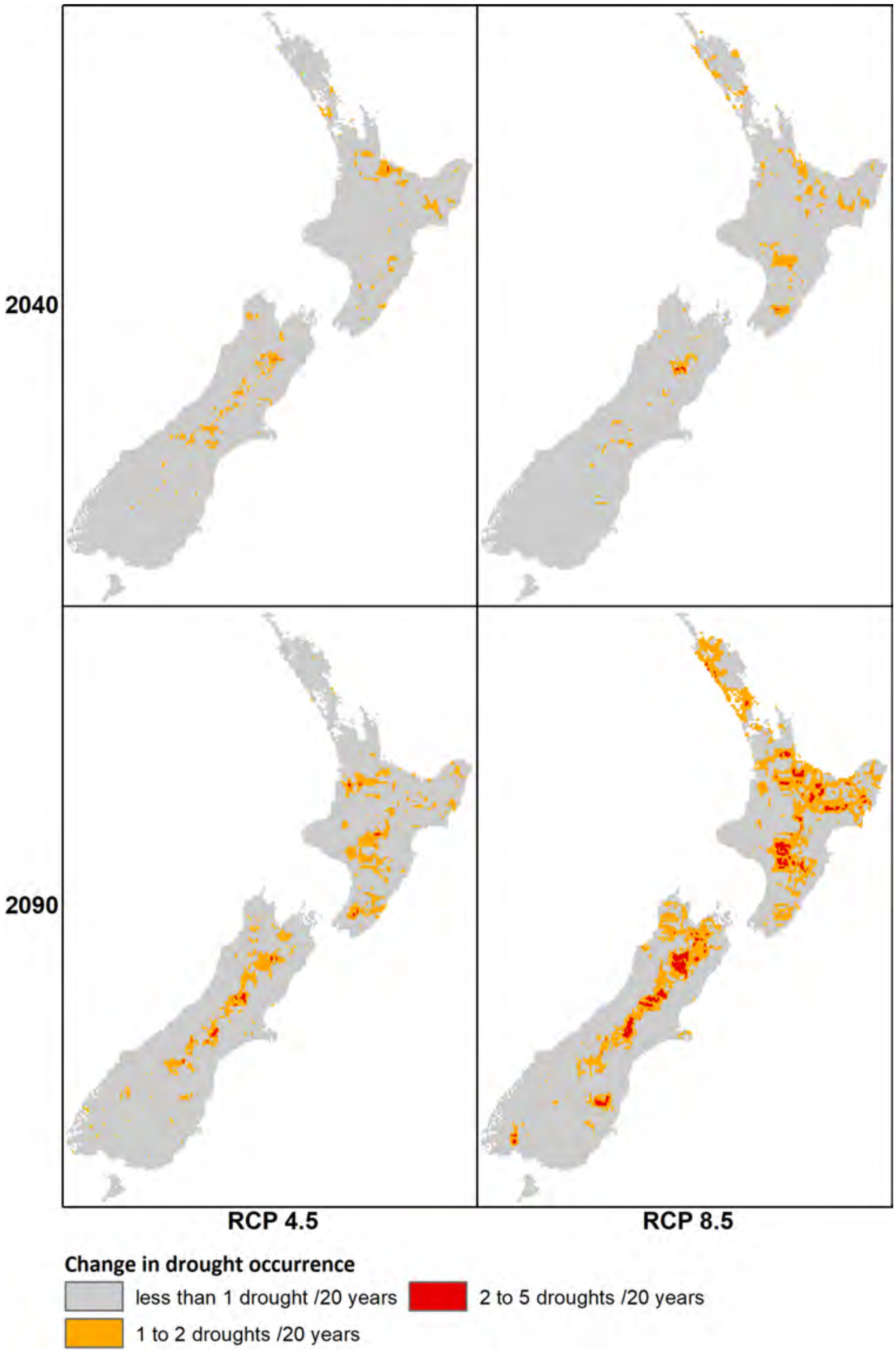


Figure 4-2: Projected increase in summer severe drought occurrence. The category "less than 1 drought /20 years" includes decreases in severe drought frequency, i.e. there may be fewer severe droughts compared to the historic period.

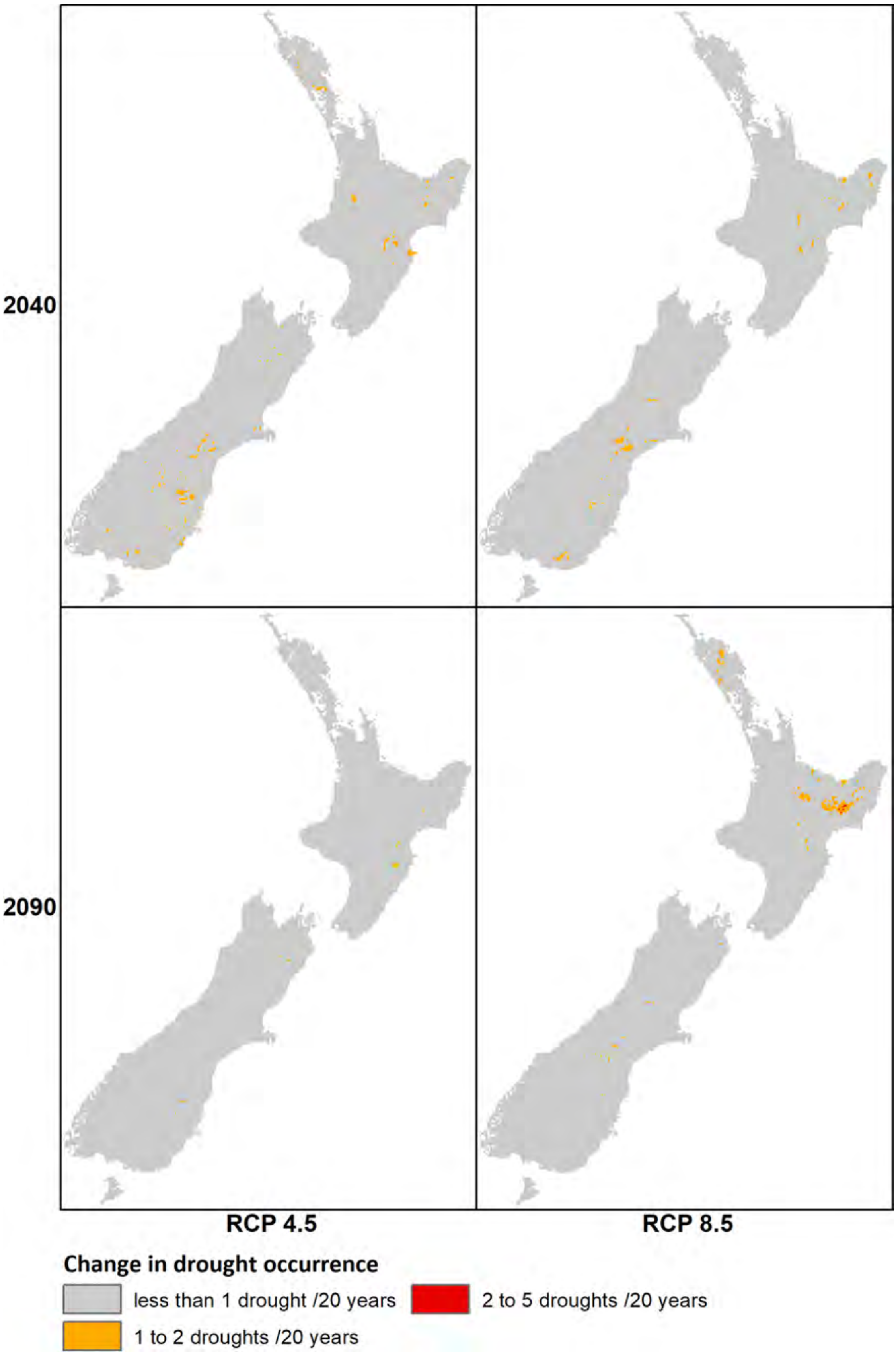


Figure 4-3: Projected increase in autumn severe drought occurrence. The category "less than 1 drought /20 years" includes decreases in severe drought frequency, i.e. there may be fewer severe droughts compared to the historic period.

4.3 Assessment of DOC biodiversity management units

4.3.1 Ecosystem Management Units (EMUs)

Drought exposure results were calculated for a total of 934 EMUs, noting there were 112 NA's (12%). Table 4-1 shows the historic exposure of EMUs to severe drought, while Table 4-2, Figure 4-4 and Figure 4-5 show the projected change in exposure to severe drought.

Table 4-1: Number of Department of Conservation (DOC) Ecosystem Management Units (EMUs) exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of EMUs (proportion of total EMUs, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	517 (55%)	305 (33%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	478 (51%)	344 (37%)	0 (0%)

Table 4-2: Change in exposure to severe drought for Department of Conservation (DOC) Ecosystem Management Units (EMUs). Changes are relative to the historic period, and numbers of DOC EMUs are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of EMUs (proportion of total EMUs, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	775 (83%)	47 (5%)	0 (0%)
		RCP8.5	756 (81%)	66 (7%)	0 (0%)
	2090 (2081-2100)	RCP4.5	718 (77%)	102 (11%)	2 (0%)
		RCP8.5	581 (62%)	213 (23%)	28 (3%)
Autumn	2040 (2031-2050)	RCP4.5	809 (87%)	13 (1%)	0 (0%)
		RCP8.5	813 (87%)	9 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	822 (88%)	0 (0%)	0 (0%)
		RCP8.5	815 (87%)	7% (1%)	0 (0%)

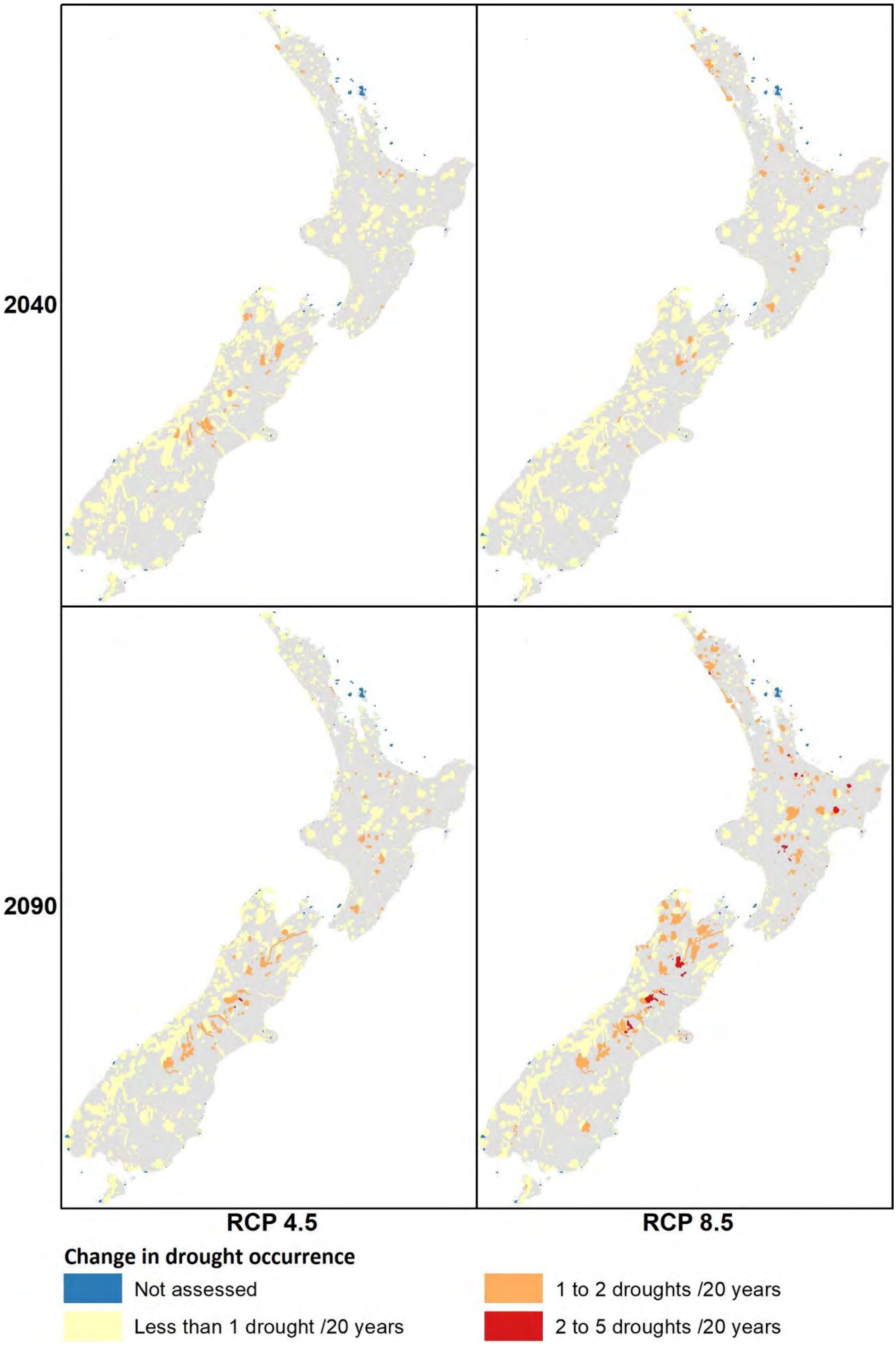


Figure 4-4: Change in summer exposure to severe drought for Department of Conservation (DOC) Ecosystem Management Units (EMUs). EMUs are coloured according to their projected change in drought occurrence. Blue colour represents EMUs where projections of severe drought were unavailable.

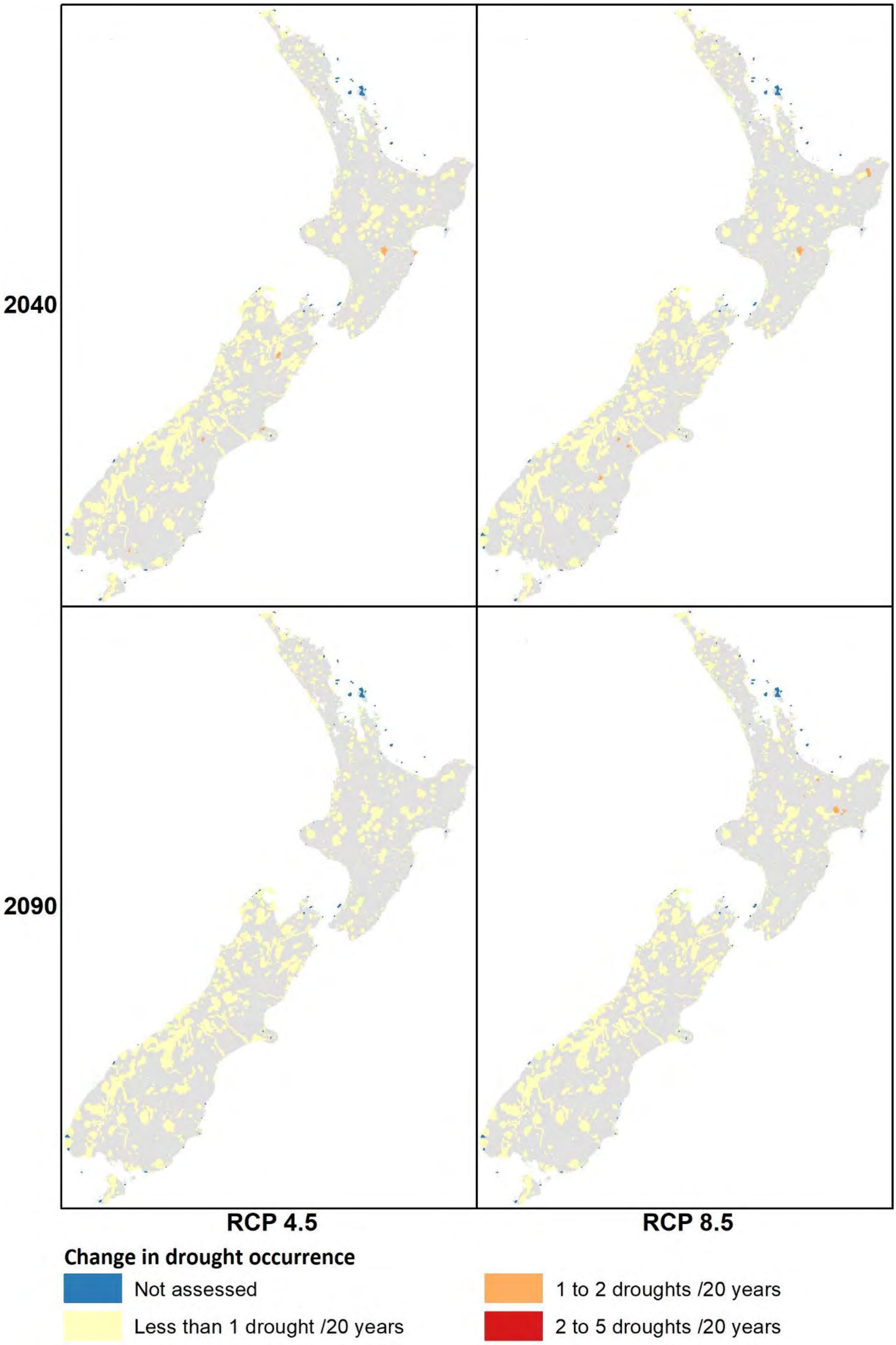


Figure 4-5: Change in autumn exposure to severe drought for Department of Conservation (DOC) Ecosystem Management Units (EMUs). EMUs are coloured according to their projected change in drought occurrence. Blue colour represents EMUs where projections of severe drought were unavailable.

4.3.2 Wetland EMUs

Drought exposure results were calculated for a total of 326 Wetland EMUs, noting there were 29 NA's (9%). Table 4-3 shows the historic exposure of Wetland EMUs to severe drought, while Table 4-4 shows the projected change in exposure to severe drought.

Table 4-3: Number of Department of Conservation (DOC) Wetland Ecosystem Management Units (EMUs) exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of Wetland EMUs (proportion of total Wetland EMUs, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	160 (49%)	137 (42%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	161 (49%)	136 (42%)	0 (0%)

Table 4-4: Change in exposure to severe drought for Department of Conservation (DOC) Wetland Ecosystem Management Units (EMUs). Changes are relative to the historic period, and numbers of DOC Wetland EMUs are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of Wetland EMUs (proportion of total Wetland EMUs, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	280 (86%)	17 (5%)	0 (0%)
		RCP8.5	280 (86%)	17 (5%)	0 (0%)
	2090 (2081-2100)	RCP4.5	260 (80%)	35 (11%)	2 (1%)
		RCP8.5	221 (68%)	65 (20%)	11 (3%)
Autumn	2040 (2031-2050)	RCP4.5	294 (90%)	3 (1%)	0 (0%)
		RCP8.5	294 (90%)	3 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	297 (91%)	0 (0%)	0 (0%)
		RCP8.5	295 (91%)	2 (1%)	0 (0%)

4.3.3 Species Management Units (SMUs)

Drought exposure results were calculated for a total of 567 SSUs, noting there were 98 NA's (17%). Table 4-5 shows the historic exposure of SMUs to severe drought, while Table 4-6, Figure 4-6 and Figure 4-7 show the projected change in exposure to severe drought.

Table 4-5: Number of Department of Conservation (DOC) Species Management Units (SMUs) exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of SMUs (proportion of total SMUs, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	262 (46%)	207 (37%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	274 (48%)	195 (34%)	0 (0%)

Table 4-6: Change in exposure to severe drought for Department of Conservation (DOC) Species Management Units (SMUs). Changes are relative to the historic period, and numbers of DOC SMUs are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of SMUs (proportion of total SMUs, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	453 (80%)	16 (3%)	0 (0%)
		RCP8.5	447 (79%)	22 (4%)	0 (0%)
	2090 (2081-2100)	RCP4.5	411 (73%)	55 (10%)	3 (1%)
		RCP8.5	344 (61%)	113 (20%)	12 (2%)
Autumn	2040 (2031-2050)	RCP4.5	459 (81%)	10 (2%)	0 (0%)
		RCP8.5	463 (82%)	6 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	468 (83%)	1 (0%)	0 (0%)
		RCP8.5	465 (82%)	4 (1%)	0 (0%)

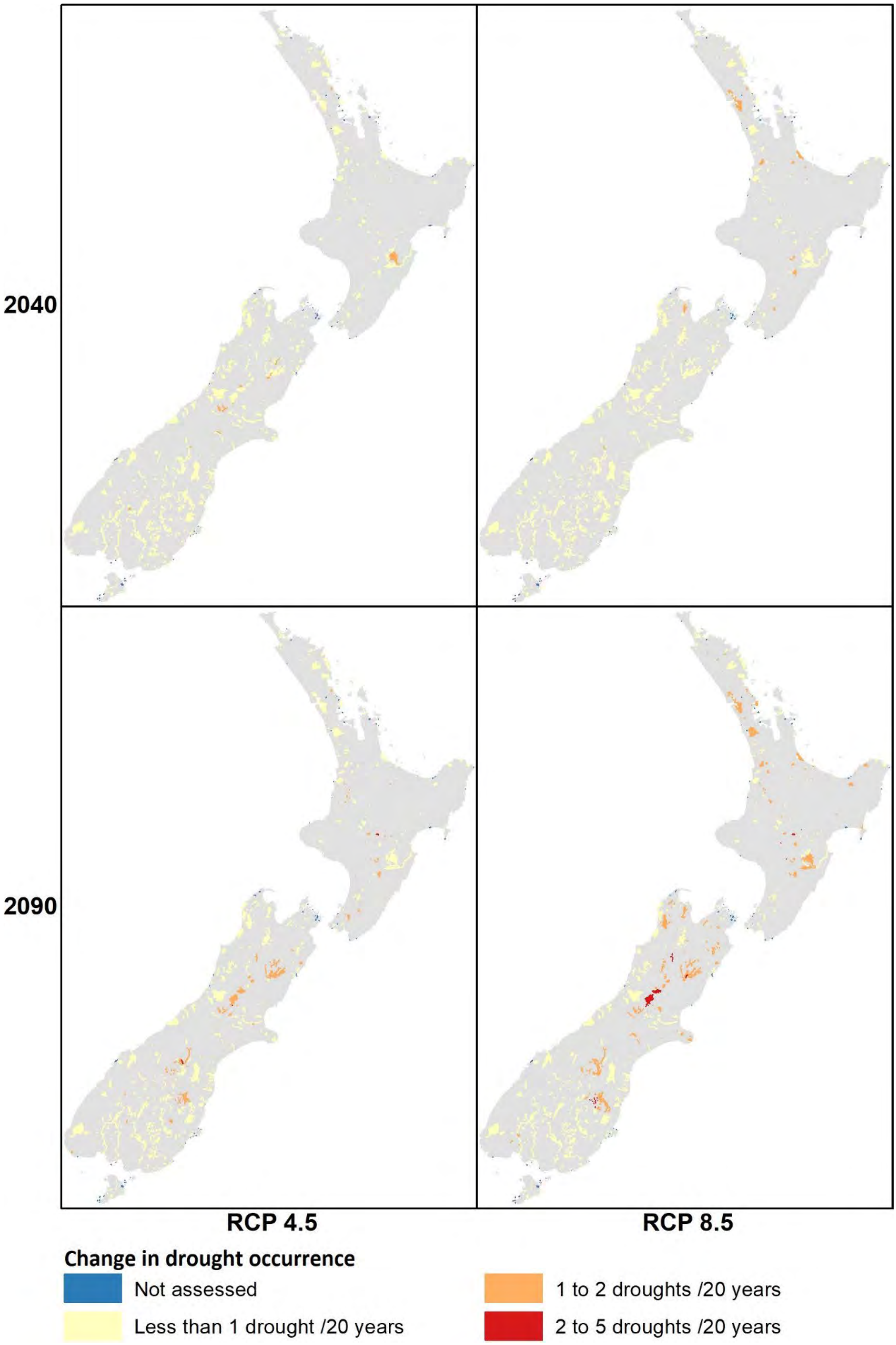


Figure 4-6: Change in summer exposure to severe drought for Department of Conservation (DOC) Species Management Units (SMUs). SMUs are coloured according to their projected change in drought occurrence. Blue colour represents SMUs where projections of severe drought were unavailable.

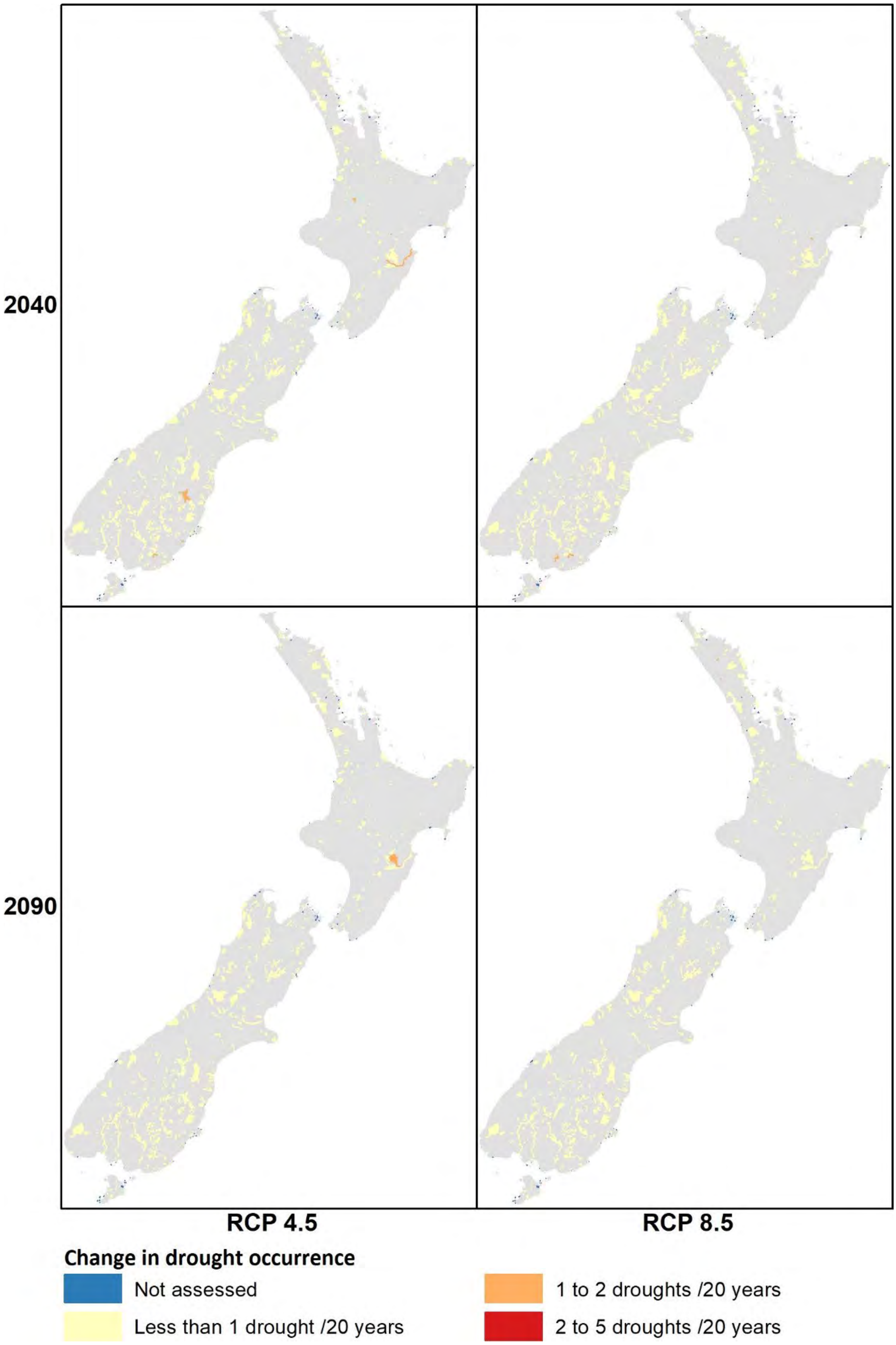


Figure 4-7: Change in autumn exposure to severe drought for Department of Conservation (DOC) Species Management Units (SMUs). SMUs are coloured according to their projected change in drought occurrence. Blue colour represents SMUs where projections of severe drought were unavailable.

4.3.4 Assessment of CatA MUs

Drought exposure results were calculated for a total of 911 Catergory A Management Units (CatA MUs), noting there were 150 NA's (16%). Table 4-7 shows the historic exposure of CatA MUs to severe drought, while Table 4-8 shows the projected change in exposure to severe drought.

Table 4-7: Number of Department of Conservation (DOC) Category A Management Units (CatA MUs) exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of CatA MUs (proportion of total CatA MUs, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	441 (48%)	320 (35%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	433 (48%)	328 (36%)	0 (0%)

Table 4-8: Change in exposure to severe drought for Department of Conservation (DOC) Category A Management Units (CatA MUs). Changes are relative to the historic period, and numbers of DOC Category A MUs are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of CatA MUs (proportion of total CatA MUs, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	726 (80%)	35 (4%)	0 (0%)
		RCP8.5	712 (78%)	49 (5%)	0 (0%)
	2090 (2081-2100)	RCP4.5	668 (73%)	91 (10%)	2 (0%)
		RCP8.5	537 (59%)	202 (22%)	22 (2%)
Autumn	2040 (2031-2050)	RCP4.5	745 (82%)	16 (2%)	0 (0%)
		RCP8.5	750 (82%)	11 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	760 (83%)	1 (0%)	0 (0%)
		RCP8.5	753 (83%)	8 (1%)	0 (0%)

4.4 Assessment of non-migratory freshwater fish

Drought exposure results were calculated for a total of 2321 non-migratory freshwater fish units, noting there were 72 NA's (3%). Table 4-9 shows the historic exposure of non-migratory freshwater fish units to severe drought, while Table 4-10, Figure 4-8 and Figure 4-9 show the projected change in exposure to severe drought.

Table 4-9: Number of non-migratory freshwater fish units exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of non-migratory FW Fish (proportion of total non-migratory FW Fish, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	1114 (48%)	1135 (49%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	1397 (60%)	852 (37%)	0 (0%)

Table 4-10: Change in exposure to severe drought for non-migratory freshwater fish. Changes are relative to the historic period, and numbers of non-migratory freshwater fish are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of non-migratory FW Fish (proportion of total non-migratory FW Fish, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	2010 (87%)	238 (10%)	1 (0%)
		RCP8.5	2106 (91%)	135 (6%)	8 (0%)
	2090 (2081-2100)	RCP4.5	1861 (80%)	350 (15%)	38 (2%)
		RCP8.5	1619 (70%)	506 (22%)	124 (5%)
Autumn	2040 (2031-2050)	RCP4.5	2184 (94%)	65 (3%)	0 (0%)
		RCP8.5	2207 (95%)	42 (2%)	0 (0%)
	2090 (2081-2100)	RCP4.5	2236 (96%)	13 (1%)	0 (0%)
		RCP8.5	2231 (96%)	18 (1%)	0 (0%)

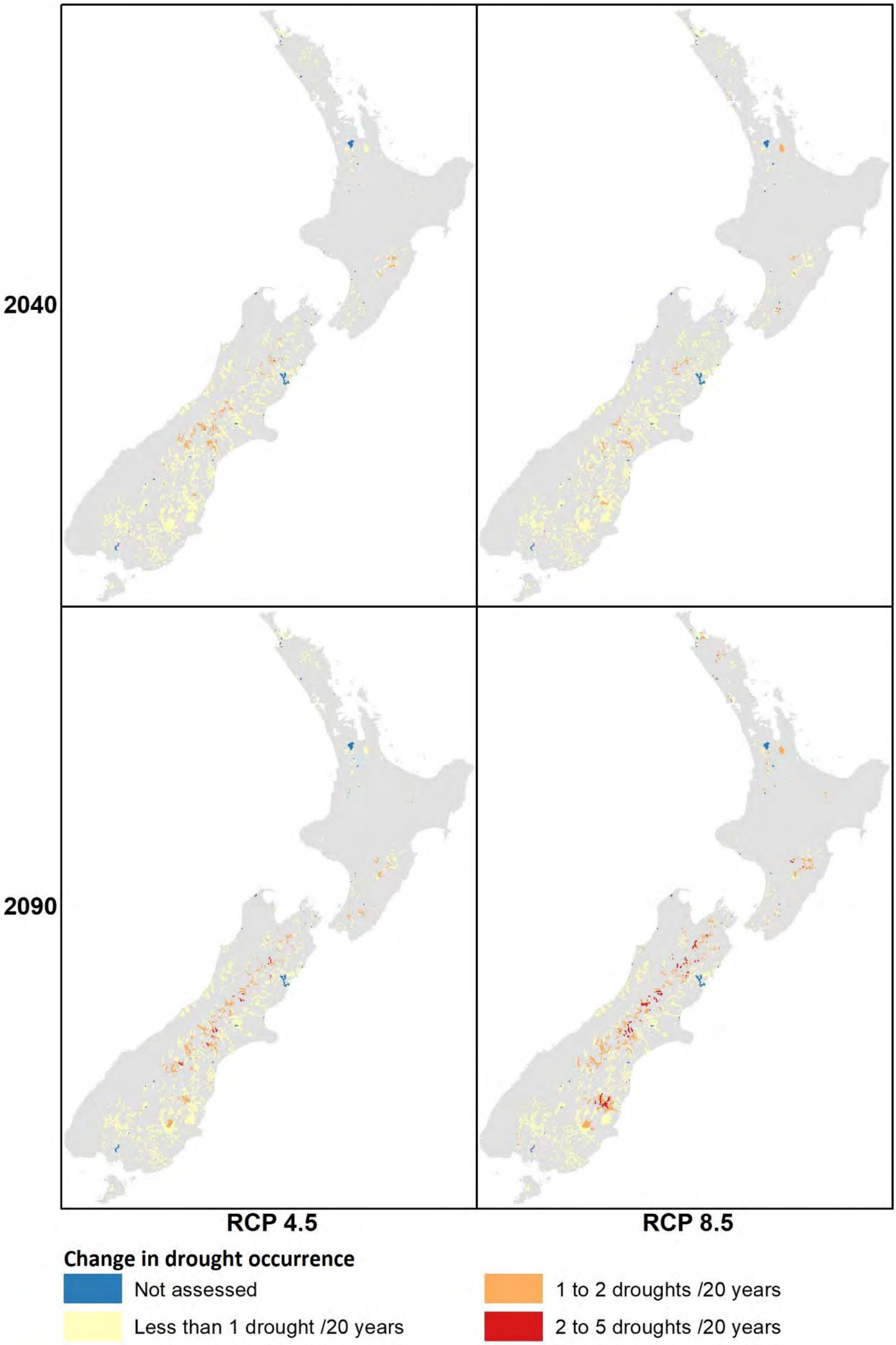


Figure 4-8: Change in summer exposure to severe drought for non-migratory freshwater fish. Non-migratory freshwater fish units are coloured according to their projected change in drought occurrence.

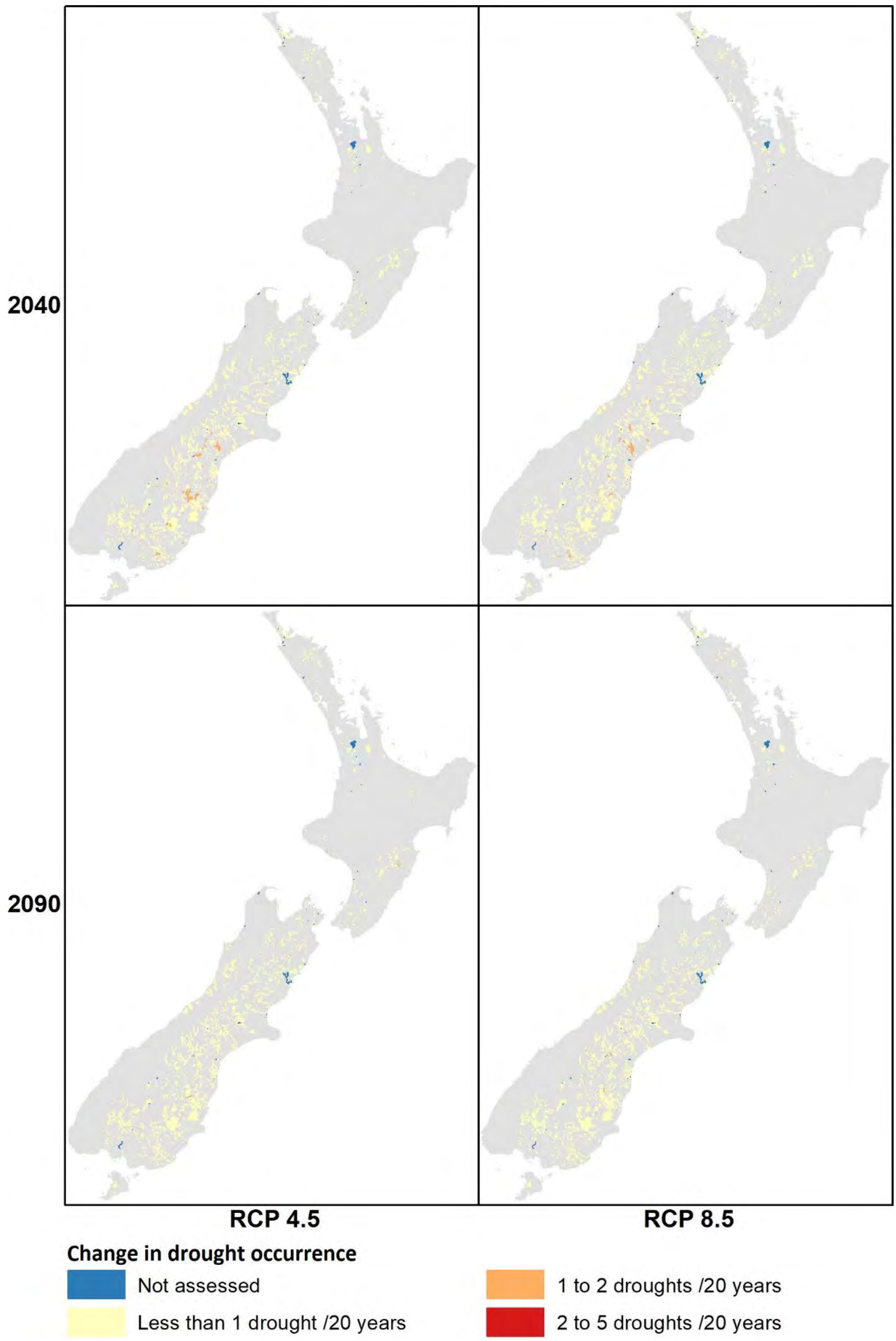


Figure 4-9: Change in autumn exposure to severe drought for non-migratory freshwater fish. Non-migratory freshwater fish units are coloured according to their projected change in drought occurrence.

4.5 Assessment of DOC Huts and Campsites

Drought exposure results were calculated for a total of 1836 DOC huts and campsites, noting there were 209 NA's (11%). Table 4-11 shows the historic exposure of DOC huts and campsites to severe drought, while Table 4-12, Figure 4-10 and Figure 4-11 show the projected change in exposure to severe drought.

Table 4-11: Number of Department of Conservation (DOC) huts and campsites exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of huts and campsites (proportion of total huts and campsites, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	933 (51%)	693 (38%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	827 (45%)	800 (44%)	0 (0%)

Table 4-12: Change in exposure to severe drought for Department of Conservation (DOC) huts and campsites. Changes are relative to the historic period, and numbers of DOC huts and campsites are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of huts and campsites (proportion of total huts and campsites, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	1520 (83%)	106 (6%)	0 (0%)
		RCP8.5	1503 (82%)	122 (7%)	1 (0%)
	2090 (2081-2100)	RCP4.5	1342 (73%)	269 (15%)	15 (1%)
		RCP8.5	1115 (61%)	434 (24%)	77 (4%)
Autumn	2040 (2031-2050)	RCP4.5	1600 (87%)	27 (2%)	0 (0%)
		RCP8.5	1609 (88%)	18 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	1625 (89%)	2 (0%)	0 (0%)
		RCP8.5	1595 (87%)	32 (2%)	0 (0%)

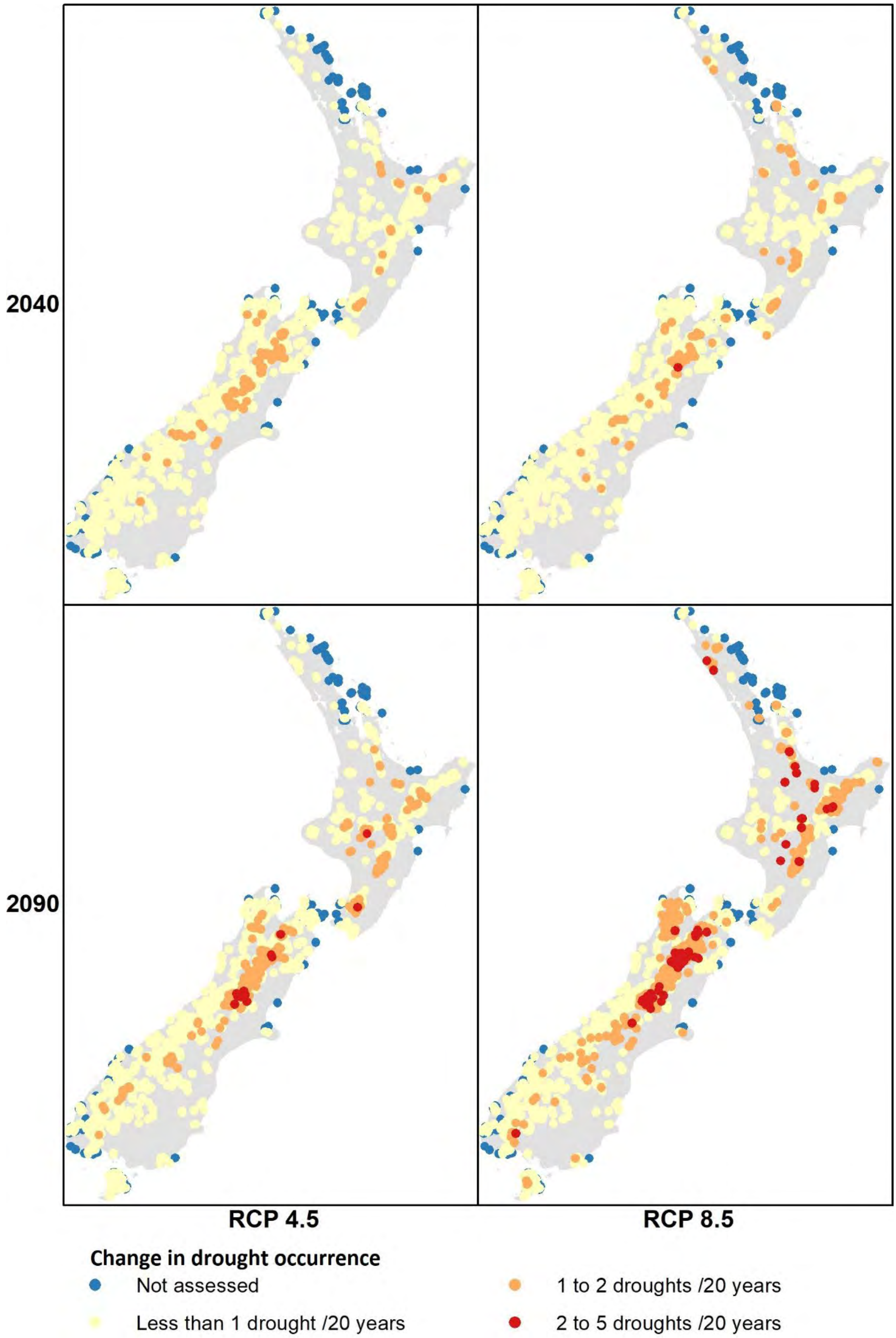


Figure 4-10: Change in summer exposure to severe drought for Department of Conservation (DOC) huts and campsites. Hut and campsite locations are depicted with dots that are coloured according to the projected increase in drought occurrence. Blue dots represent huts and campsites where projections of severe drought were unavailable.

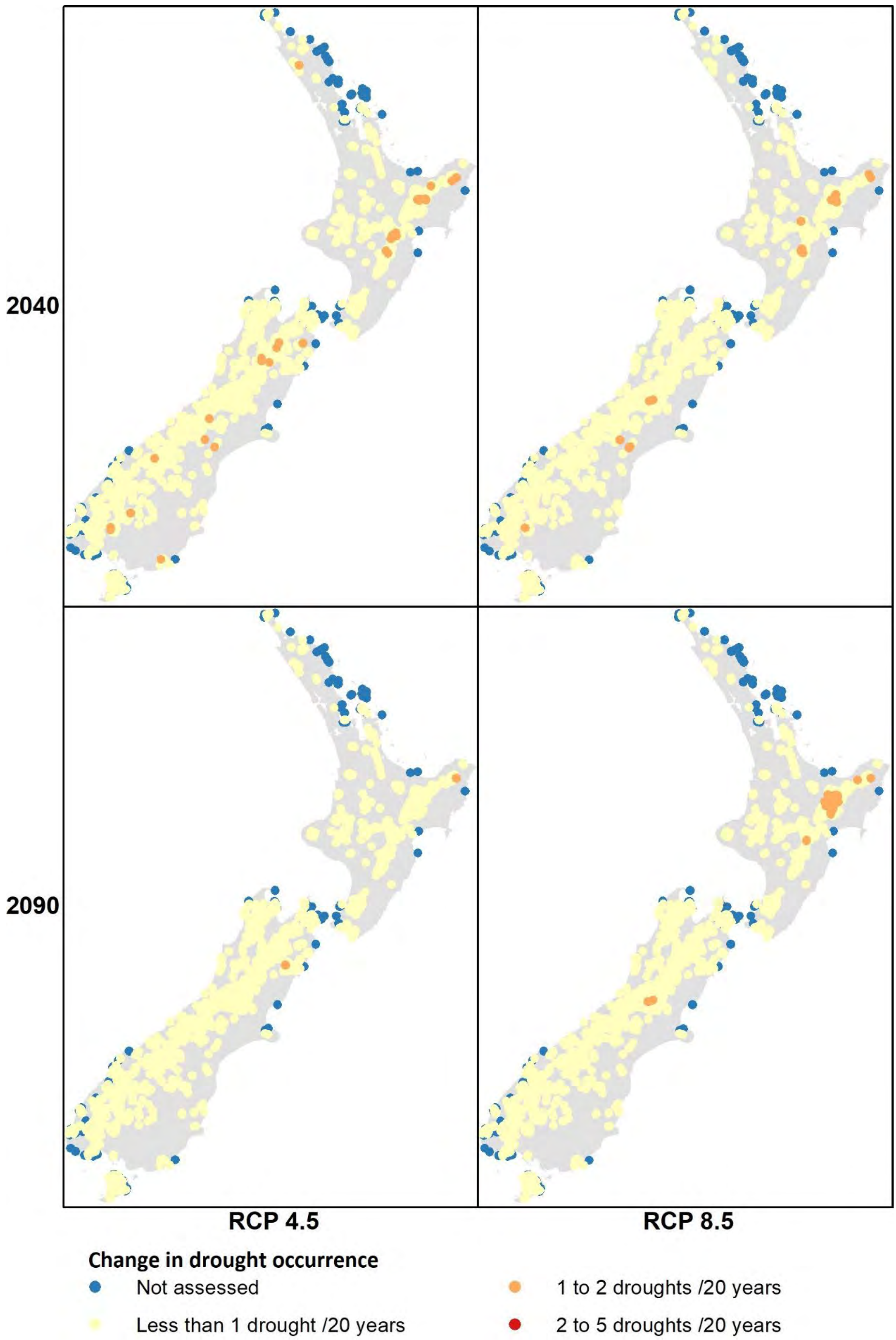


Figure 4-11: Change in autumn exposure to severe drought for Department of Conservation (DOC) huts and campsites. Hut and campsite locations are depicted with dots that are coloured according to the projected increase in drought occurrence. Blue dots represent huts and campsites where projections of severe drought were unavailable.

4.6 Assessment of DOC flushable toilets

Drought exposure results were calculated for a total of 226 DOC flushable toilets, noting there were 37 NA's (16%). Table 4-13 shows the historic exposure of DOC flushable toilets to severe drought, while Table 4-14, Figure 4-12 and Figure 4-13 show the projected change in exposure to severe drought.

Table 4-13: Number of Department of Conservation (DOC) flushable toilets exposed to varying frequencies of severe drought. Valid for the historic 1986-2005 (1995) period.

Season	Time period	Scenario	Number of toilets (proportion of total toilets, %)		
			Less than 1 drought	1-2 droughts	2-5 droughts
Summer	1995 (1986-2005)	N/A	105 (47%)	84 (37%)	0 (0%)
Autumn	1995 (1986-2005)	N/A	91 (40%)	98 (43%)	0 (0%)

Table 4-14: Change in exposure to severe drought for Department of Conservation (DOC) flushable toilets. Changes are relative to the historic period, and numbers of DOC flushable toilets are categorised by varying changes in severe drought frequencies (note, the "Less than 1 more drought" category includes decreases in severe drought frequency). Projections are presented for 2031-2050 (2040) and 2081-2100 (2090) under RCP4.5 and RCP8.5.

Season	Time period	Scenario	Number of toilets (proportion of total toilets, %)		
			Less than 1 more drought	1-2 more droughts	2-5 more droughts
Summer	2040 (2031-2050)	RCP4.5	180 (80%)	9 (4%)	0 (0%)
		RCP8.5	178 (79%)	11 (5%)	1 (0%)
	2090 (2081-2100)	RCP4.5	169 (75%)	20 (9%)	0 (0%)
		RCP8.5	144 (64%)	42 (19%)	3 (1%)
Autumn	2040 (2031-2050)	RCP4.5	186 (82%)	3 (1%)	0 (0%)
		RCP8.5	187 (83%)	2 (1%)	0 (0%)
	2090 (2081-2100)	RCP4.5	189 (84%)	0 (0%)	0 (0%)
		RCP8.5	188 (83%)	1 (0%)	0 (0%)

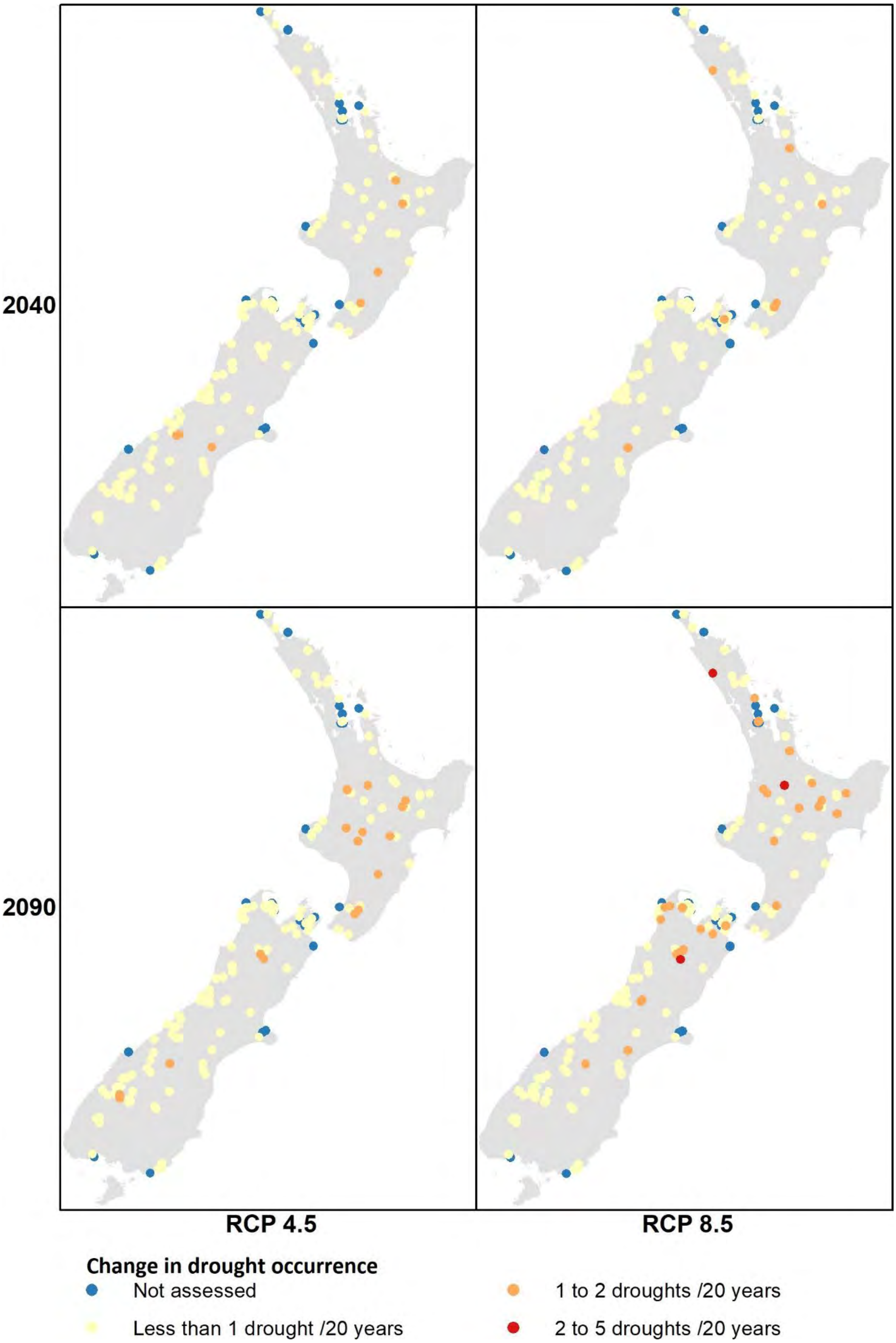


Figure 4-12: Change in summer exposure to severe drought for Department of Conservation (DOC) flushable toilets. Flushable toilet locations are depicted with dots that are coloured according to the projected increase in drought occurrence. Blue dots represent flushable toilets where projections of severe drought were unavailable.

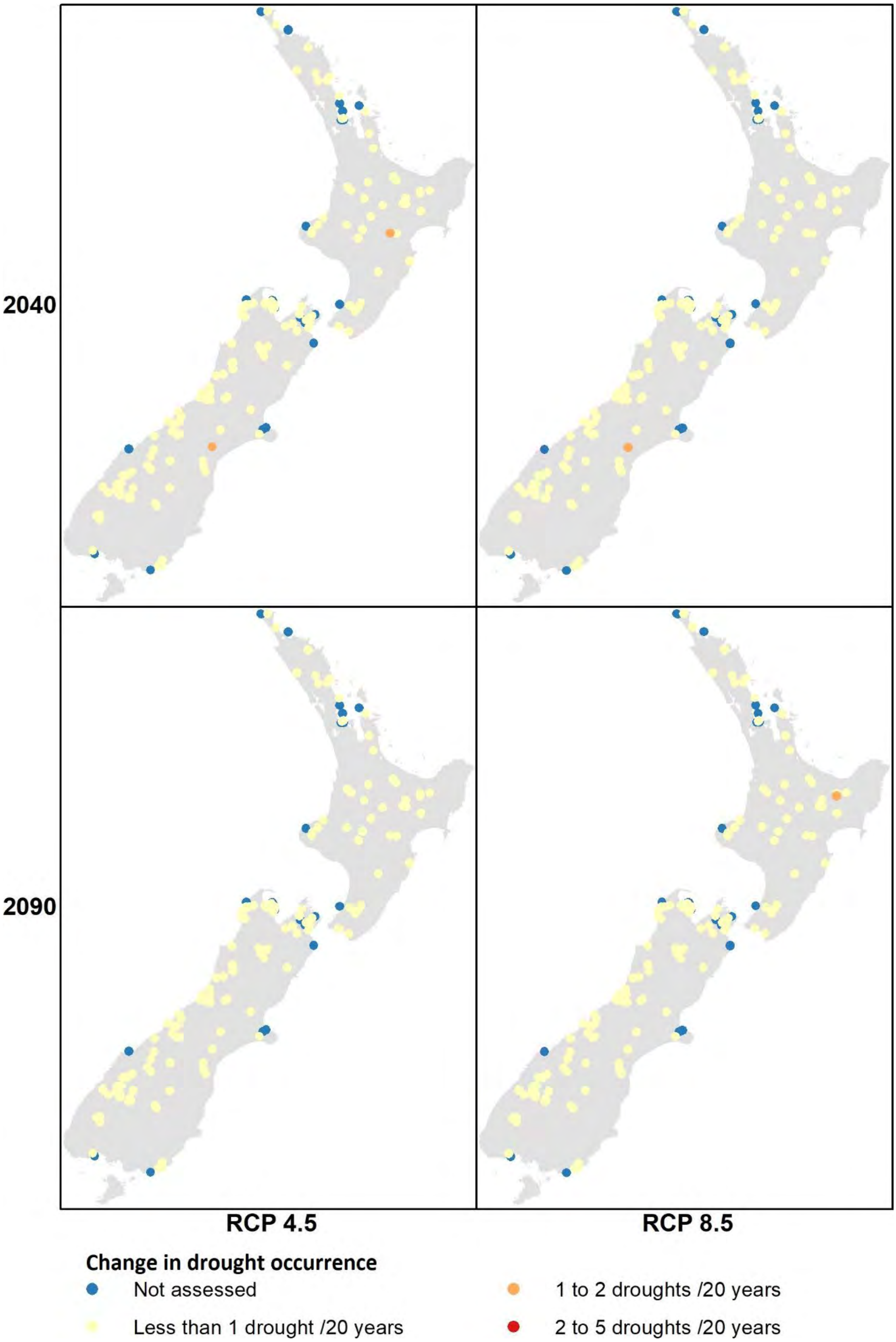


Figure 4-13: Change in autumn exposure to severe drought for Department of Conservation (DOC) flushable toilets. Flushable toilet locations are depicted with dots that are coloured according to the projected increase in drought occurrence. Blue dots represent flushable toilets where projections of severe drought were unavailable.

5 Conclusions

This report (and the associated GIS datasets) identifies the changing exposure to severe drought for selected DOC responsibilities and assets (DOC R&As). The assessment is based on SPI, a relatively simple measure of drought. SPI is appropriate for this study because it is normalised, meaning values for very different climates (as is the case in New Zealand) can be compared. The information in this report should be used as a national-scale drought exposure screening assessment to guide DOC priorities, and help identify where more detailed assessments of specific locations could take place.

Most DOC R&As are expected to see a change in exposure to severe drought in future, however the projected increase in severe drought occurrence is relatively small (i.e. no more than 1 more severe drought per 20 year period). In some cases, exposure to drought is projected to reduce (i.e. fewer droughts are projected in future compared to the historic period), although those results are not presented specifically here.

In order to highlight the most notable projected changes, Table 5-1 presents the outcome of a subjective criterion, where at least 10% of the respective DOC R&As are projected to observe 1-2 more severe droughts in future, and/or at least 1 of the respective DOC R&As is projected to observe 2-5 more severe droughts in future. All such instances occur in summer, with none in autumn. The majority occur by 2090, but notably under both a mid-range (RCP4.5) and high end (RCP8.5) scenario.

Three instances occur by 2040:

- Non-migratory freshwater fish
  - Under RCP4.5, 238 non-migratory freshwater fish units (10%) are projected to observe 1-2 more severe droughts per 20-year period.
  - Under RCP4.5, 1 non-migratory freshwater fish unit (the Northern flathead galaxias, Clarence River, south Marlborough) is projected to observe 2-5 more severe droughts per 20-year period.
- DOC huts and campsites
  - Under RCP8.5, 1 DOC hut/campsite (Lake Guyon Hut, St James Conservation Area, Canterbury) is projected to observe 2-5 more severe droughts per 20-year period.

Table 5-1: Most notable increases in summer severe drought occurrence projected for DOC's responsibilities and assets (R&As). Subjective criteria were applied, where at least 10% of the respective DOC R&As are projected to observe 1-2 more severe droughts in future, and/or at least 1 of the respective DOC R&As is projected to observe 2-5 more severe droughts in future.

DOC R&As	Period	RCP	Number (%) of DOC R&As	
			1-2 more droughts	2-5 more droughts
EMUs	2090	RCP4.5	102 (11%)	2 (0%)
	2090	RCP8.5	213 (23%)	28 (3%)
Wetland EMUs	2090	RCP4.5	35 (11%)	2 (1%)
	2090	RCP8.5	65 (20%)	11 (3%)

DOC R&As	Period	RCP	Number (%) of DOC R&As	
			1-2 more droughts	2-5 more droughts
SMUs	2090	RCP4.5	55 (10%)	3 (1%)
	2090	RCP8.5	113 (20%)	12 (2%)
CatA MUs	2090	RCP4.5	91 (10%)	2 (0%)
	2090	RCP8.5	202 (22%)	22 (2%)
Non-migratory freshwater fish	2040	RCP4.5	238 (10%)	1 (0%)
	2090	RCP4.5	350 (15%)	38 (2%)
	2090	RCP8.5	506 (22%)	124 (5%)
Huts and Campsites	2040	RCP8.5	NA	1 (0%)
	2090	RCP4.5	268 (15%)	15 (1%)
	2090	RCP8.5	433 (24%)	77 (4%)
Flushable Toilets	2090	RCP8.5	42 (19%)	3 (1%)

5.1 Recommendations

- The GIS layers showing the historic occurrence and projected changes to drought (moderate, severe, and extreme) should be included in DOC's database, and depicted in the 'DOC GIS' interface system.
  - The availability of these data should be publicised via DOC's intranet (e.g. Climate Change Adaptation intranet pages).
- The results should be assessed to identify which DOC R&As are prioritised for further detailed assessment. While an attempt has been made to highlight the most notable projected changes identified in this report (Table 5-1), this is not to say that smaller proportional changes are insignificant. Focus for this process should be placed on changes projected to occur by 2040 (under either RCP4.5 or RCP8.5), given these pose a more imminent risk for DOC R&As compared to the 2090 time period.
  - Detailed assessments should begin with a screening exercise to identify whether the DOC R&As are likely to be meaningfully impacted by increasing drought occurrence. If not, then the assessment may not need to proceed.
  - It is noted that at the time of writing, the projections of drought described in this report are already being used by Manaaki Whenua and DOC for an assessment on the exposure of kiwi to drought (M. Barron, personal communication, 30 January 2023). This investigation should be leveraged to understand key methods, and challenges encountered, to help improve future detailed assessments.

    - When scoping a detailed assessment, it is important to be aware there are other indices of drought, and these may be appropriate to use in addition to or instead of SPI.

- A communication and engagement plan should be developed to ensure the findings presented in this report are shared with relevant DOC staff, with particular focus on those involved in planning (e.g. regional operations staff). It is anticipated this report, and subsequent detailed assessments, will help inform climate change adaptation activities within DOC.

- As noted in Section 2.4, DOC GIS datasets were chosen based on their availability and completeness at a national scale. Time and resources did not allow for collating locally held data for creating new datasets (e.g. predictive models of species distribution), although this would be a useful future piece of work.

6 Acknowledgements

David Burlace, Amy Hawcroft, Jenny Christie, and Terry Greene (all Department of Conservation staff at the time of this project) are each thanked for their significant contributions of time and expertise to this project.

Amy Hawcroft and David Burlace are additionally thanked for their review of the draft version of this report, which contributed to an improved final version.

7 Glossary of abbreviations and terms

CatA MUs	Category A Management Units
CCAAP	Climate Change Adaptation Action Plan
CMIP5	Fifth Coupled Model Intercomparison Project
DOC	Department of Conservation
DOC R&As	DOC responsibilities and assets
EMUs	Ecosystem management units
GCMs	Global climate models
GIS	Geographic Information System
IOO	(Natural Heritage) Intermediate Outcome Objectives
IPCC	Intergovernmental Panel on Climate Change
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
RCMs	Regional climate models
RCP	Representative concentration pathway
SMUs	Species management units
SPEI	Standardised Precipitation Evapotranspiration Index
SPI	Standardised Precipitation Index
WMO	World Meteorological Organization

8 References

Adams, J. (2017) Climate_indices, an open source Python library providing reference implementations of commonly used climate indices. Available at https://github.com/monocongo/climate_indices

Edwards, D.C., McKee, T.B. (1997) Characteristics of 20th Century Drought in the United States at Multiple Time Scales. *Climatology Report Number 97-2*. Colorado State University, Fort Collins.

Hausfather, Z., Peters, G.P. (2020) Emissions – the 'business as usual' story is misleading. *Nature*, 577: 618-620.

Macara, G.R. (2018) The climate and weather of New Zealand. *NIWA Science and Technology Series*, 74: 50.

Ministry for the Environment (2018) *Climate change projections for New Zealand: atmospheric projections based on simulations undertaken for the IPCC 5th Assessment, 2nd edition.* Ministry for the Environment, Wellington.

Ministry for the Environment (2020) *National Climate Change Risk Assessment for New Zealand – Arotakenga Tūraru mō te Huringa Āhuarangi o Āotearoa: Technical report – Pūrongo whaihanga*. Ministry for the Environment, Wellington.

Ministry for the Environment and Stats NZ (2020) *New Zealand's Environmental Reporting Series: Our atmosphere and climate 2020.* Available from www.mfe.govt.nz and www.stats.govt.nz

NIWA (2023) NZ Drought indicator products and information. Accessed at https://niwa.co.nz/climate/information-and-resources/drought-monitor/drought-indicator Date accessed: March 2023.

Schwalm, C.R., Glendon, S., Duffy, P.B. (2020) RCP8.5 tracks cumulative CO_2 emissions. *Proceedings of the National Academy of Sciences of the United States of America*, 117: 19656-19657.

Tait, A. (2019) Risk-exposure assessment of Department of Conservation (DOC) coastal locations to flooding from the sea: A national risk assessment of DOC assets, archaeological sites, recreation functional locations, destination and ecosystem and species management units vulnerable to coastal inundation and sea-level rise. *Science for Conservation*, 332: 40.

World Meteorological Organization (2012) Standardized Precipitation Index: User Guide. WMO-No. 1090. Geneva.

World Meteorological Organization (WMO) (2023) Drought. Accessed at https://public.wmo.int/en/our-mandate/water/drought Date accessed: March 2023.

World Meteorological Organization (WMO) and Global Water Partnership (GWP) (2016): *Handbook of Drought Indicators and Indices* (M. Svoboda and B. A. Fuchs). Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva.

Cultural Impact Assessment By Ngāti Koata on Te Papa Atawhai (Department of Conservation) Dynamic Adaptative Pathway Plans for Takapourewa Frogs in Response To Climate Change

29 June 2023

Authors: Laken Gieger, Pene Gieger,

Louisa Paul, Melanie Nelson

Ngā Mihimihi | Acknowledgements

He Mihi

E rau rangatira mā, e te tini, e te mano, tēnei te tuku mihi ki a koutou katoa i raro i ngā tini āhuatanga o te wā.

Ki ngā tini mate o ia marae, o ia maunga, haere, haere, whakangaro atu rā.

Ko te akaaka o te rangi ki a rātou mā, kei a tātou ngā purapura ora, ko te akaaka o te whenua.

Tihei Mauriora!

Ngā mihi nui ki te whānau, to all whānau members who took the time to speak with us or filled out our survey and to the Kaunihera Kaumātua o Ngāti Koata for their time and feedback on this report.

Ngā Kai o Roto | Table of Contents

Front Cover Photo Source: https://www.ngatikoata.com/wp-content/uploads/2023/05/20230412_201416-300x225.jpg

Other photo credits: Jen Germano, DOC.

1. Whakarāpopoto | Executive Summary

Takapourewa frogs are a highly significant taonga species of Ngāti Koata. They are an extremely rare species and there is a strong desire for the iwi as kaitiaki to ensure that they are protected and thrive into the future.

Climate change will have a significant impact on the frogs, and it is important that ways to protect them and enable them to continue to thrive are found. The Department of Conservation (DOC) has developed a Dynamic Adaptive Pathway Plan (DAPP) for the Takapourewa frogs, in considering possible pathways forward to ensure the survival of the frogs in the face of climate change.

Ngāti Koata, their relationship to Takapourewa, including the historical disconnection and reconnection are introduced and described. The context of the proposal and the legislative context is outlined and assessed in relation to the proposal.

Key values of Ngāti Koata are described and applied to the proposal, highlighting key areas of priority and of concern for the iwi. These include:

- Ensuring intergenerational relationships with Takapourewa and the frogs are enabled
- Maintaining the integrity of the whakapapa of the frogs, both as a distinct population, and to ensure it continues into the future
- Active protection of the kaitiaki relationship of Ngāti Koata to the Takapourewa frogs, and that this is a key driver of decisions and approaches
- Supporting the re-development of Ngāti Koata's mātauranga ā-iwi in relation to the frogs in their natural habitat, and the application of a mātauranga ā-iwi and maramataka approach to frog research, planning and management, in particular of any future translocations
- The Treaty of Waitangi partnership is of key importance, and must be given more prominence and strengthened going forwards, in relation to future management options for the Takapourewa frogs and any thinking and decisions around this.
- Ultimately the mauri of the Takapourewa frogs must be protected and enhanced, and Ngāti Koata support initiatives to do this, firstly in situ, secondly by translocating to another site within their rohe. Translocation to a site outside their rohe is not a preferred option, and significant work would be need to done to properly consider this option if it is deemed to be necessary.

Section 4 of the Conservation Act and the Wai 262 claim report by the Waitangi Tribunal, of which Ngāti Koata was a claimant, provide key guidance to the future of the partnership between DOC and Ngāti Koata. Ngāti Koata look forward to continuing to strengthen their Treaty Partnership with DOC as they work collaboratively to ensure that the Takapourewa frogs survive and thrive through the pending threats of climate change.

2. Kupu Whakataki | Introduction

The Takapourewa are a highly significant taonga species of Ngāti Koata, located on Takapourewa in the Marlborough Sounds. They are an extremely rare species and there is a strong desire for the iwi as kaitiaki to ensure that they are protected and thrive into the future.

The Department of Conservation (DOC) has developed a Dynamic Adaptive Pathway Plan (DAPP) for the Takapourewa frogs, in considering possible pathways forward to ensure the survival of the frogs in the face of climate change.

Climate change will have a significant impact on the frogs, and it is important that ways to protect them and enable them to continue to thrive are found. DOC has commissioned Ngāti Koata to complete a Cultural Impact Assessment on the proposed DAPP.

While Ngāti Koata, as a partner, would have expected to be at the table from the start in developing the DAPP, they have completed this CIA to help DOC understand the cultural impacts of the proposed DAPP on their iwi and the frogs.

3. Ngāti Koata

Ngāti Koata hekenga

Ngāti Koata are a small but mighty iwi of approximately 3000 people, situated in Te Tauihu o te Waka a Māui. Ngāti Koata originally comes from Kāwhia which is located on the western side of the North Island, about 50km southwest of Hamilton. In Kāwhia, population growth was on the rise, which combined with conflict and pressures of war between colonists and Māori, initiated the Ngāti Koata hekenga (migration). This led Ngāti Koata in their migration south alongside other iwi from the waka Tainui, Ngāti Rarua and Ngāti Toa. This journey is known as Te Heke Whirinui. Ngāti Koata started their heke from Kāwhia down the western side of the North Island. Ngāti Awa [1]helped Ngāti Koata pass through Taranaki and into Te Waewae Kāpiti o Tara rāua ko Rangitāne, otherwise known as Kāpiti Island. Here they settled at Te Waiorua.

Not long after they settled, Kurahaupō tribes led an assault on them. During this assault Ngāti Koata captured Tūtepourangi, a leader of the Kurahaupō waka people. While Ngāti Koata captured their leader, they captured Tāwhi, the son of the Ngāti Koata chief. Ngāti Koata began pursuing the waka that held Tāwhi, as it was fleeing. Fortunately Tāwhi was found. For the safety of his people and the safe return of Tāwhi, Tūtepourangi gave a tuku (conditional gift) to Ngāti Koata. The tuku boundary ranges from Clay Point to the Trios, from the Trios, to the Jags, from the Jags, to Takapourewa and all the way out to Farewell Spit. Te Putu, on behalf of Ngāti Koata accepted this tuku. This is how Ngāti Koata came to be in the top of the South Island and inherited their connection with Takapourewa.

Figure 1. Map of Ngāti Koata's rohe (tribal area) [2]

[1] Ngāti Koata Trust. Our History. Retrieved June, 2023, from https://www.ngatikoata.com/our-history/
[2] Ngāti Koata Trust. Our History. Retrieved June, 2023, from https://www.ngatikoata.com/our-history/

4. He Whakamāramatanga o te Marohi | Outline of Proposed Dynamic Adaptive Pathway Plan (DAPP) for Takapourewa Frogs

In 2022, DOC convened a group of species and climate change experts in Hamilton to develop a Dynamic Adaptive Pathway Plan (DAPP) for native frogs to help advise the Department on how to adapt frog management to the impacts of climate change. Unfortunately Ngāti Koata were not included in the meeting, but the resulting document was shared with them. The DAPP split proposed management into two sections – in situ (in place) and ex situ (off site) management.

Proposed in situ (on island) adaptive frog management activity

In situ management involves managing a species where they are naturally found. For example, managing Takapourewa frogs on Takapourewa is in situ management. The management actions that were proposed to occur on Takapourewa are:

1. Increase the number of Takapourewa frogs by constructing new areas of rocky habitat.

Currently the frogs on Takapourewa are at carrying capacity, meaning that the population has filled the available tuatara-free suitable habitat and can't grow any further. Constructing new areas of rocky habitat will allow the Takapourewa frogs to populate a larger area of the island and grow their numbers. The new area of habitat will provide more room for the younger frogs to grow and reproduce without competition with the older adult frogs or feeling pressured to leave their safe enclosure to look for more room to grow, therefore allowing the increasing of the numbers of the population.

2. Protect frogs from prolonged dry periods by creating a variety of non-invasive, artificially manipulated habitat and micro-climates inside the existing enclosure (e.g., water storage, irrigation, more shade, other rock piles or more frog accommodation/habitat).

Some artificial environment manipulation will allow us to monitor over time the habitat to gain an understanding of what is or is not working. Ngāti Koata are keen to see how we can collect and retain moisture even through the dry seasons. This may not be a permanent long-term solution but it can help us to monitor the situation and to minimise some of the impacts of droughts and drying conditions.

3. Protect frog sites prone to rainfall-induced landslips by stabilizing slopes.

Currently there are no frog sites that are prone to rainfall-induced slips on Takapourewa. The only potential for slips is on the tracks that lead to the frog bank.

4. Protect frogs from increased predator incursion risk by heightening island biosecurity measures.

Takapourewa has strict biosecurity protocols. This requires a thorough and comprehensive quarantine or bio security check through the protocols and procedures that have been established to protect the island. The pre-quarantine requirement for any person planning to go onto the island is to do the first stage of it on their own. Instructions of how to do so are provided by DOC. All gear traveling there are to be checked and all clothes are to be washed in Sterigene prior to arriving to the mid quarantine processes before departure to the island. Sterigene is also provided by DOC). Certain items are banned (e.g. personal bags, food items that could carry diseases/pests). All gear must be free of dirt and seeds, then washed in Sterigene which destroys bacteria, fungi, spores and viruses. Final and the last quarantine check once you are on the island. No bags or buckets opened before the final check is complete.

5. Protect frog sites on existing islands by heightening fire protection measures.

Since Takapourewa is a dry and remote island with little ability to fight fires, strict safety guidelines are already in place and adhered to.

Proposed ex situ (off island) adaptive frog management

Ex situ management involves managing a species outside of where they are naturally found. The management actions that were proposed to occur off of Takapourewa are:

1. *Create new frog sites on other predator free and local islands by translocating frogs to wetter, cooler areas not prone to landslips.*
2. *Translocate frogs to wetter cooler islands in the Marlborough Sounds.*
3. *Translocate frogs south to a mainland South Island predator free sanctuary.*

Translocation could be used to create a backup population, increase population numbers and improve genetics. This being said, any translocations should be carefully considered if the current frog area is no longer suitable for the Takapourewa frogs' needs. Unfortunately, when a Takapourewa frog or tuatara are taken off the island they can never return. The risks would be too great in the event that a returning taonga had disease that transfers to the main population upon a return. Ngāti Koata do not make these kinds of decisions without careful consideration of the facts. All avenues to keep them on the island are exhausted before a decision to move them off is ever made.

One iwi member had shared, that due to the cost and limitations of access onto the Island and also to the frogs because of their small numbers and security around them that a translocation onto the mainland within their rohe could support Ngāti Koata connection and mātauranga in the future. Translocating a population onto the mainland or closer to most iwi members would allow for real tangible application of kaitiaki roles and responsibilities.

5. Te Horopaki ā-Ture | Legislative Context

Te Tiriti o Waitangi 1840

Ngāti Koata signed te Tiriti o Waitangi at Te Hoera Pā at Te Marua on Rangitoto ki te Tonga on 11th May 1840.[3] The indigenous language version of the Treaty of Waitangi, te Tiriti o Waitangi, is the version which according to international law should be given precedence when interpretations vary.

Although neither te Tiriti o Waitangi or the Treaty of Waitangi have become law in Aotearoa, it is the founding constitutional document of this country. The Treaty **established a constitutional relationship between Māori and the Crown**. While Te Puni Kōkiri administers the Treaty of Waitangi Act 1975, the Ministry of Justice is responsible for the place of the Treaty in our constitutional arrangements.[4]

Legislation and policies have incorporated aspects of te Tiriti/the Treaty through reference to the Principles of the Treaty of Waitangi. Although the principles are hugely important, and more often than not are fallen short of in government practice and Crown-Iwi relationships, iwi have not lost sight of the importance of the actual Tiriti/Treaty itself and its provisions.

In Article 1 of te Tiriti, Māori gave the British 'kāwanatanga', the right of governance. In Article 2 te Tiriti promises to uphold the rangatiratanga (authority) that tribes had always had over their lands and taonga. In Article 3, the Crown promised to Māori the benefits of royal protection and full citizenship. [5]

In the context of this proposal, the Takapourewa frogs are clearly a taonga, and Ngāti Koata retain rangatiratanga over the frogs and Takapourewa as a whole. The Crown has the right of governance, and the government agency with this responsibility is Te Papa Atawhai/Department of Conservation. The right of governance does not come at the expense of, or detriment to, the rangatiratanga of Ngāti Koata.

---

[3] Ngati Koata No Rangitoto Ki Te Tonga Trust. 10 June, 2002. Iwi Management Plan.
[4] Ministry of Justice. Regulatory Stewardship. June, 2023. Retrieved from https://www.justice.govt.nz/justice-sector-policy/regulatory-stewardship/regulatory-systems/constitutional/
[5] Waitangi Tribunal. Meaning of the Treaty. June, 2023. Retrieved from https://www.waitangitribunal.govt.nz/treaty-of-waitangi/meaning-of-the-treaty/

5.2 Ngāti Kōata, Ngāti Rārua, Ngāti Tama ki Te Tau Ihu and Te Ātiawa o Te Waka-a-Māui Claims Settlement Act 2014

The Treaty Settlement Act which includes Ngāti Koata acknowledges that since 1856 much of Ngāti Koata reserve land have been alienated from Ngāti Koata ownership. This included the Crown's acquisition of Takapourewa Island for public works purposes and purchase of part of Whangarae reserve for scenery preservation purposes. The Crown also acknowledged that through the alienation of land, Ngāti Koata lost control over many of their significant sites and resources, which had an ongoing impact on their ability to maintain spiritual connections to their ancestral lands.[6]

Key points of the redress through the Treaty Settlement relevant to this proposal include:

5.1.1 Appointment of statutory advisers to the Minister of Conservation and the Director-General

The Trustees of Te Pātaka a Ngāti Koata are appointed as statutory advisers to the Minister of Conservation and the Director-General in relation to Takapourewa. They may provide written advice to the Minister and Director-General about the restoration of native plants and the management of species of native animals at, or proposed to be relocated to, Takapourewa. The Minister of Conservation or Director-General must have regard to written advice received from the trustees when making a decision on the matter.[7]

5.1.2 DOC protocol

The Settlement provided for the development of a protocol between DOC and Ngāti Koata, to guide interactions.

5.1.3 Takapourewa Operational Plan

In the Settlement, DOC and Ngati Koata agreed to jointly prepare and approve an operational plan Takapourewa no later than two years after the settlement date (Takapourewa Operational Plan or 'the Plan'). The first Plan was drafted in 2015 and signed in 2019, and the most recent Plan is currently under development. The Plan will be reviewed every 5 years from the date of signing, and it may be reviewed and amended by Te Papa Atawhai and Ngāti Koata agreement at any point in time.[8]

---

[6] Ngāti Kōata, Ngāti Rārua, Ngāti Tama ki Te Tau Ihu, and Te Ātiawa o Te Waka-a-Māui Claims Settlement Act, No 20, 2014.
[7]Ngāti Kōata, Ngāti Rārua, Ngāti Tama ki Te Tau Ihu, and Te Ātiawa o Te Waka-a-Māui Claims Settlement Act, No 20, 2014.
[8] Ngāti Koata Trust and Department of Conservation. March 2019. Takapourewa Operational Plan, p8.

The Takapourewa Operational Plan 2019[9] contains the following objectives and context:

1. **To maintain a strong, thriving partnership, working to achieve shared aspirations.** *Kaitiakitanga and kāwanatanga roles and responsibilities providing the framework for this objective.*
2. **Ngāti Koata and Te Papa Atawhai nurture their relationship with Takapourewa by encouraging indigenous ecosystems and taonga species to thrive.** *As the mauri is restored the relationship between people and the natural world is restored. Restoration enables the expression of kaitiakitanga and associated customary practices.*
3. **The mana of Takapourewa and associated relationships are protected through managed access.** *The transfer of knowledge across Ngāti Koata generations strengthens whānau connections with Takapourewa and supports evolving mātauranga. Established protocols around communication and sharing knowledge guide initiatives on and off Takapourewa.*
4. **To sustain flourishing ecosystems and support strong thriving taonga through restoration and enhancement of biodiversity.** *Takapourewa remains pest-free to ensure taonga species are healthy and safe.*
5. **The whakapapa of the unique biodiversity of Takapourewa is honoured.**
6. **The hauora of Takapourewa is monitored continuously.** *The hauora of Takapourewa ecosystems, species and relationships is honoured.*

In the context of this proposal, the Takapourewa Operational Plan codifies the joint approach to management as being one of partnership, with both kaitiakitanga and kāwanatanga roles and responsibilities being upheld to provide a framework for this partnership. In this situation Ngāti Koata are saddened that DOC has significantly progressed their thinking on possible approaches to managing the Takapourewa frogs in the face of climate change without including Ngāti Koata at the table from the earliest point, in what would be a true manifestation of partnership and inclusive of kaitiakitanga. Consultation at an advanced stage of planning of options does not constitute partnership in the way the operational plan envisages.

The restoration of the mauri of the taonga species and ecosystem, and the mana of Takapourewa and its relationships are aspects which only Ngāti Koata can fully understand and implement, and it expects DOC to support and enable them to do this in relation to the frogs, now and ongoingly. This is a key opportunity to honour the whakapapa of the frogs, and to develop mātauranga of Ngāti Koata from their own perspectives to support and lead the protection and survival of the frogs through the pending climate crisis.

The ex situ management options raise concerns for Ngāti Koata about their kaitiaki responsibilities and relationships, should the frogs be translocated to a site outside of their rohe. These issues need to be fully explored and understood at the earliest stage possible.

[9] Ngāti Koata Trust and Department of Conservation. March 2019. Takapourewa Operational Plan, p8.

5.3 Conservation Act and the Principles of the Treaty of Waitangi

This Conservation Act requires anyone working under the Act (including Conservation Boards, DOC, and the NZCA) to give effect to the principles of the Treaty of Waitangi when interpreting or administering the act.[10] This is the strongest Treaty clause existing in legislation, which recognises the significance of the conservation estate to iwi. This also means that all Acts listed on Schedule 1 of the Conservation Act (including the Reserves Act and the Wildlife Act) must also be read through the lens of the Treaty Principles and implemented in a way that gives effect to the Treaty Principles.

DOC's Conservation General Policy significantly narrows the interpretation of Section 4, including limiting the principles which are to be considered and downplaying the way they are to be applied to processes, plans and operational work by the Department. This was confirmed by the Supreme Court in a landmark decision on the case of Ngāi Tai ki Tāmaki Tribal Trust and the Minister of Conservation in 2018.[11]

Since then DOC has commenced a partial review of their Conservation General Policy and the General Policy for National Parks to ensure they are well placed to give effect to the principles of the Treaty, and help them meet their responsibilities as a Treaty partner.[12]

The General Policies outline what DOC needs to consider when making decisions, such as how they:

- Work with whānau, hapū and iwi and Māori and the wider community on particular issues,
- Set conservation objectives or outcomes for specific areas,
- Prioritise conservation work within a region,
- Consider applications for concessions and similar decisions (which includes wildlife permits and translocations).[13]

The General Policies therefore are of great importance to the management of Takapourewa frogs and the processes by which pathways for climate adaptation are identified, decided, implemented and managed. Given that the Partial Review of the General Policies is not yet complete, it is of critical important to Ngāti Koata that DOC does not limit itself to working within its existing General Policy, and that the full range of Treaty principles, as outlined by the Courts and the

[10] Department of Conservation. Conservation management framework: how conservation work is planned. Retrieved June 2023, from https://www.doc.govt.nz/about-us/statutory-and-advisory-bodies/conservation-boards/conservation-board-manual/conservation-management-framework-how-conservation-work-is-planned/#:~:text=Section%204%20of%20the%20Conservation,administering%20anything%20under%20the%20Act.
[11] Courts of New Zealand. 14 December, 2018. Ngāi Tai Ki Tāmaki Tribal Trust v Minister of Conservation – [2018] NZCS 122. Retrieved June, 2023, from https://www.courtsofnz.govt.nz/cases/ngai-tai-ki-tamaki-tribal-trust-v-minister-of-conservation-1/?searchterm=NG%C4%80%20I%20TAI%20KI%20T%C4%80MAKI.
[12] Department of Conservation. Partial reviews of Conservation General Policy and General Policy for National Parks. Retrieved June, 2023, from https://www.doc.govt.nz/our-work/partial-reviews-of-conservation-general-policy-and-general-policy-for-national-parks/
[13] Department of Conservation. Partial reviews of Conservation General Policy and General Policy for National Parks. Retrieved June, 2023, from https://www.doc.govt.nz/our-work/partial-reviews-of-conservation-general-policy-and-general-policy-for-national-parks/

Waitangi Tribunal, are given effect to in all aspects of DOC's work regarding the Takapourewa frogs.

The Treaty Principles which must be given effect to are outlined below:

Principles of the Treaty of Waitangi include, but are not limited to:

Partnership	Reciprocity	Active protection
Good faith	Reasonableness	Informed decision making
Mutual benefit	Equity	Options

These principles are all relevant to the Takapourewa frogs and climate change, and some are further explored and applied in the analysis of Ngāti Koata values below.

5.4 Reserves Act 1977

The Reserves Act 1977 was established to acquire, preserve and manage areas for their conservation values or public recreational and educational values.

The Reserves Act has three main functions. These are:

- To provide for the preservation and management, for the benefit and enjoyment of the public, areas possessing some special feature or values such as recreational use, wildlife, landscape amenity or scenic value. For example, the reserve may have value for recreation, education, as wildlife habitat or as an interesting landscape.
- To ensure, as far as practicable, the preservation of representative natural ecosystems or landscapes and the survival of indigenous species of flora and fauna, both rare and commonplace.
- To ensure, as far as practicable, the preservation of access for the public to the coastline, islands, lakeshore and riverbanks and to encourage the protection and preservation of the natural character of these areas.[14]

While the Reserves Act itself does not make reference to the Treaty of Waitangi, rangatiratanga or kaitiaki relationships and responsibilities, it must be read to give effect to the Treaty Principles, in accordance with Section 4 of the Conservation Act.

Regarding the Takapourewa frogs, the purposes of the island reserve cannot be read exclusively as per the text in the Reserves Act, but it must be considered through the lens of the Treaty Principles what the text would mean in the context of a Treaty partnership, both actively

[14] Department of Conservation. Reserves Act 977. Retrieved June, 2023, from https://www.doc.govt.nz/about-us/our-role/legislation/reserves-act/

protecting taonga species and actively protecting the relationship of Ngāti Koata with all taonga species on the island, and for this report, the frogs in particular, as their kaitiaki.

5.5 Wildlife Act 1953

The Wildlife Act is the principal means for protecting wildlife, including some of New Zealand's most endangered species. It regulates human interactions with protected wildlife. DOC is currently undertaking a first principles review of the Wildlife Act and says that,

"The current act is not fit for modern conservation management. It lacks the tools we need to protect threatened species. It also prevents fulfilment of some obligations under Te Tiriti o Waitangi. Engaging with tangata whenua and stakeholders is an important part of reviewing the Wildlife Act. Together, we will examine the key issues and identify aspirations. We can then explore options for a modern, purpose-built species management system that is based on the values and outcomes important to New Zealanders."[15]

Ngāti Koata agrees that the current act is not fit for modern conservation management, and processes and management led by the Wildlife Act are frequently at odds with legislative requirements to honour the Treaty partnership and the principles of the Treaty of Waitangi. Wildlife Act authorisation would be required for translocations of Takapourewa frogs from the wild to captivity, from captivity to the wild, and between wild locations. It must be noted that the current formal requirements of the translocation process which allow for 20 days consultation with iwi are insufficient to meet the requirements of Section 4.

As a Treaty partner, Ngāti Koata expects to co-lead any translocation planning from the earliest stage, and to have sufficient time to build relationships with other iwi involved in frog translocations, if needed, rather than be consulted at a later stage in the process. It is important that these processes are worked out now so that Ngāti Koata are ready to make decisions as the urgency of the climate crisis approaches.[16]

5.6 Wai 262

Ngāti Koata was one of six claimants in the Wai 262 claim, which is about the place of Māori culture, identity and traditional knowledge in New Zealand's laws and in government policies and practices. It concerns who controls Māori traditional knowledge, who controls artistic and cultural works such as haka, waiata and who controls the environment that created Māori culture. It also concerns the

[15] Department of Conservation. Modernising conservation legislation. Retrieved June, 2023, from https://www.doc.govt.nz/about-us/our-role/legislation/conservation-law-reform/
[16] Department of Conservation. Translocation Proposals. Retrieved June, 2023, from https://www.doc.govt.nz/get-involved/run-a-project/translocation/proposals/

place in contemporary New Zealand life of core Māori cultural values, which includes the obligation of iwi and hapū to act as kaitiaki towards taonga such as traditional knowledge, artistic and cultural works, significant places and all flora and fauna that are significant to iwi or hapū identity.

The Waitangi Tribunal report on Wai 262, Ko Aotearoa Tēnei, found that the government had failed to comply with its obligations, under the Treaty of Waitangi, to ensure that kaitiaki relationships between Māori and their taonga (their traditional knowledge and artistic works, and their culturally significant species of flora and fauna) were acknowledged and protected, and recommends that future laws, policies and practices do acknowledge and respect those relationships.

The Tribunal found that the government has an obligation to actively protect Māori interests in taonga, and that it had not satisfied that obligation. The report discusses the gap between the protections provided by intellectual property laws and those sought by kaitiaki. The Tribunal acknowledged there was a need to balance Māori interests with those of other participants in the cultural and commercial life of New Zealand. It considered there was a need for a transparent and principled balancing mechanism.

The government has not yet implemented the recommendations of the Waitangi Tribunal in response to the Wai 262 claim, however claimants continue to keep the claim and its recommendations alive.

Wai 262 recommended an overhaul of conservation legislation to incorporate kaitiaki conservation, genuinely enabling a double hulled waka approach to conservation in Aotearoa, incorporating mātauranga Māori alongside equally valuing Western approaches. While this overhaul of conservation legislation has not yet happened, the framework to enable this approach already exists within the Section 4 requirement. Indeed this is clearly a necessary process to give effect to Section 4 and therefore the legislation DOC operates under. To not do this would be a breach of the Principles of the Treaty of Waitangi, and therefore of DOC's own legislation.

Wai 262 is particularly relevant to the proposal for the Takapourewa frogs, partly due to Ngāti Koata being one of the six claimants, and also because it directly pertains to mātauranga Māori, the protection of taonga (frogs) and of the kaitiaki relationship.

Ko Aotearoa Tēnei provides invaluable insights and guidance to DOC and Ngāti Koata for navigating the future pathways for Takapourewa frogs in response to climate change. Its recommendations are pertinent and nimble, and able to be applied adaptively to the changing times and environment we find ourselves in. They specifically hold important guidance in relation to the role given to mātauranga Māori, working in partnership with Ngāti Koata to protect the frogs as a taonga and the importance of also actively protecting their relationship with the frogs as kaitiaki.

These issues cannot be progressed without drawing on the wisdom of the Wai 262 report, which can be a friend on the path. The findings in Ko Aotearoa Tēnei are explored further later in this report.

5.7 International conventions

5.7.1 The Convention on Biodiversity 2010

The United Nations Convention on Biodiversity contains the goal that 'by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people'.

5.7.2 The Hawai'i Commitments 2016

The Hawai'i Commitments of the IUCN in 2016, along with previous global initiatives such as the UN Sustainable Development Goals and the Paris Agreement, stress that climate change is a particular threat for indigenous peoples, in part because indigenous needs and rights are often marginalised.[17]

These international agreements are relevant to this proposal in their emphasis on the relationships of people with biodiversity, and in particular indigenous people. Ngāti Koata are also wary that as the urgency of taking action towards climate adaptation hastens with the progression towards the climate crisis, that their needs and rights as mana whenua and kaitiaki are at risk of being marginalised. Ngāti Koata wishes to be at the table as a partner in the early stages to mitigate this risk.

6. Te Horopaki o te Marohi | Context for Proposal

Description of Takapourewa

Takapourewa is at the northern most tip of the Marlborough Sounds and lies two kilometres to the north east of Cape Stephens, the northern most point of Rangitoto. The island is 2.6 kilometres in size but rises up to 305 metres from the sea; the largest island off the coast of Rangitoto. Takapourewa is utilized both as an important seamark and navigation aide, along with being a major tribal boundary marker.[18]

The island is a nature reserve, which is co-managed by Ngāti Koata Trust and DOC. It is a special refuge, free from introduced predators, which is home to many threatened and endemic taonga

[17] Bond, M., Anderson, B., Henare, TH. and Wehi, P. 2019. Effects of climatically shifting species distributions on biocultural relationships. *People and Nature, 1,* 87-102. Doi: DOI: 10.1002/pan3.15.

[18] Ngāti Koata Trust and Department of Conservation. March 2019. Takapourewa Operational Plan.

species. It hosts an extraordinary array of endemic flora and fauna with high genetic integrity. Many of these species, particularly frogs and invertebrates, are limited in number and available habitat. It is a unique place in terms of its flourishing ecosystems and species, which have been able to survive, revive and thrive with the exclusion of predators.

"The island is so special – it comes alive at night time. It's pretty docile in the day with the odd bird or two, and lots of scuttle sounds through the grass as you walk that turns your attention with every step. But at night it's so alive. I love how you stand on it and as soon as you land on it you feel like you're back in time. Takapourewa is a place of such significance, taonga species have thrived and survived.

To see the Island biodiversity thriving is heartwarming, and to know that the Island is returning back to what it was in front of our eyes is a true blessing. We hope our old people who had seen it when it was still farmland would be proud of the combined efforts of all involved. ".[19]

Takapourewa has been described thus:

> *"Takapourewa is the jewel in Ngāti Koata's crown, and is of great significance to the natural heritage of New Zealand. Takapourewa is home to more than half of the world's existing tuatara population. It is a 'Galapagos of the South' in that the gene pool on Takapourewa is diverse, distinct and unique and forms a critical foundation stone for the restoration and expansion of indigenous biota gene pools nationally."*[20]

Flora on the islands once included low forest species such as ngaio, taupata and mahoe. Protection of the existing environment, including the flora, is necessary to ensure the survival of the many endangered species living on the islands.[21]

Cultural importance of Takapourewa to Ngāti Koata

Takapourewa is spiritually, culturally and historically significant to Ngāti Koata, who are recognised and acknowledged as kaitiaki and mana whenua of Takapourewa in their Treaty Settlement and the Wai 262 claim. The island is of huge cultural importance to Ngāti Koata, as a wāhi tapu, as a

---

[19] Ngāti Koata iwi member (personal communication, June, 2023).

[20] Ngāti Koata Trust and Department of Conservation. March, 2015. Draft Operations Plan for Takapourewa (Stephens Island), p4.

[21] Ngāti Koata Trust and Department of Conservation. March 2015. Draft Operations Plan for Takapourewa (Stephens Island). p11.

landscape, for its location, for ancestral connections, for its rare taonga species such as tuatara and frogs, for the connections within te ao tūroa between the land and sea, and on the island, and for the interconnections with people, as a principal boundary marker and an important seamark and navigational aid. Ngāti Koata used to go there for mahinga kai (food gathering), from land and sea.

Takapourewa was a training ground for tohunga (skilled repositories of knowledge, specialists and experts), and for the iwi the island was the place where tohunga used to go and just be tohunga.[22] Ngati Koata is able to restrict access under its tikanga for cultural purposes on Takapourewa as kaitiaki of the island.[23]

The Wai 262 report by the Waitangi Tribunal, Ko Aotearoa Tēnei,[24] described the island and tuatara as remaining of immense importance to Ngāti Koata, and quoted kaumatua Benjamin Hippolite:

"Takapourewa is the outermost boundary of our rohe meaning it was very sacred to us. We went there and used it as a place of wānanga such as taiaha wānanga, wānanga for spiritual things and things like that. We learnt things from our old people that were never taught elsewhere, such as things about the endangered species there. That island had a spirit of its own, had a wairua of its own, and that is one of the reasons why we used to go there. We had marvellous times growing up there. We were told many stories on that island."

Ngāti Koata worldview

For many centuries, Ngāti Koata lived entirely within te ao tūroa, the natural world, of Aotearoa and Te Waipounamu. Their worldview and values have evolved intricately interwoven with the indigenous environment, and despite the separation forced by colonisation, they have done their utmost to retain and promote their values, and to find ways to implement and embody them in the rapidly changing world. As descendants of Ranginui and Papatūānuku, they are related to the trees, the birds, and all other beings on the land. Inherent in this relationship is a reciprocal duty to care for the natural world, as it also cares for people. All flora and fauna on Takapourewa are considered taonga tuku iho, and Ngāti Koata have a responsibility and obligation to protect them for current and future generations.

Ngāti Koata describe their descent from the primeval parents:

> *"Life stemmed after the void, from Io Matua Kore, the parentless one, who created the primeval parents, Ranginui and Papatūānuku and from their union sprang Atua or Gods. The departmental Atua became the first Kaitiaki of the*

[22] Ngāti Koata iwi member. (Personal communication, June, 2023).
[23] Ngāti Koata Trust and Department of Conservation. March 2015. Draft Operations Plan for Takapourewa (Stephens Island). P9.
[24] Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuarua (Volume 1). Wellington, New Zealand: Legislation Direct. p303.

domains world of light, Te Ao Marama, and presided over the domains of the natural world.

Principle among them were:

Tāne Mahuta	*Atua of forests and all living things within them.*
Tangaroa	*Atua of the fish and sea life.*
Tūmatauenga	*Atua of war and guardian of the Marae Ātea and people.*
Tāwhirimātea	*Atua of the winds, storms and air.*
Rūaumoko	*Atua of earthquakes and volcanoes.*
Haumiatiketike	*Atua of fern roots and other wild foods.*
Rongomātāne	*Atua of the Kūmara and of cultivated foods.*
Tūtewehiwehi	*The grandson of Tangaroa and Atua of amphibians and the inland water creatures.*

The domains of Atua provide integration across resources giving a more holistic approach to environmental management."[25]

The Ngāti Koata perspective is intergenerational, looking towards the past to move into the future. The presence of the ancestors is regularly felt, and they are a reference point to guide current behaviours and decisions. The responsibility to future generations is also keenly felt, and decisions are based on expansive consideration of the past and future generations.

Ngāti Koata strategic plan

The Ngāti Koata Trust Strategic Plan[26] is depicted in the form of a waka that embodies the Vision, Purpose, Values and Goals that will progress the iwi into the future with purpose and unity. Its vision is that Ngāti Koata are flourishing, and its purpose is Tiaki Tangata, Tiaki Taiao, Tiaki Taonga | Caring for our People, Places and Treasures. The most relevant Ngāti Koata value and goals will be explored later in the context of this proposal.

Key values are:

- Kaitiakitanga
- Whanaungatanga
- Rangatiratanga
- Kotahitanga

[25] Ngati Koata No Rangitoto Ki Te Tonga Trust. 10 June, 2002. Iwi Management Plan.
[26] Ngāti Koata Trust. ND. Ngāti Koata Trust Strategic Plan.

- Whakatupuranga
- Auahatanga
- Mātauranga
- Manaakitanga
- Wairuatanga

The base of the waka, and associated goals are:

Ngāti Koatatanga | Cultural Revitalisation	*To promote, enhance, celebrate and protect our whakapapa, our kawa, our reo and our mātauranga*
Tiaki Tangata | Wellbeing	*To provide opportunities for our people to succeed*
Tiaki Taiao | Environmental Management	*To maintain, strengthen and develop our kaitiakitanga and relationship with our environment*
Tiaki Taonga | Cultural Wealth	*To assist Ngāti Koata whānau to maintain, protect and strengthen their kaitiaki role with our taonga*
Mana Motuhake | Iwi Development	*To foster the growth of te mana Motuhake o Ngāti Koata*
Te Hāpai Ō | Organisational Development	*To provide an organizational, sustainable, informative, representative, transparent structure for Ngāti Koata*

Ngāti Koata environmental plan

The Ngāti Koata vision statement in their environmental plan, Ngāti Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan (IMP),[27] is:

“Ngāti Koata seek to ensure that the environment and human activities are culturally managed in harmony with the appreciation that the natural world is dynamic, fragile and finite.”

The IMP describes Ngāti Koata as having a complex set of customs and lore to conserve, manage and protect their water, land, air, forests, flora and fauna. The iwi considers all living things as having a mauri or life force. Ngāti Koata kawa such as tapu, rāhui, mana, kaitiakitanga and mauri were utilised to ensure the resources were managed sustainably and the mauri protected. This system of laws holds the same validity today. The Ngāti Koata approach to environmental management incorporates the needs and values of people, and recognises the interrelated nature of the natural

[27] Ngati Koata No Rangitoto Ki Te Tonga Trust. 10 June, 2002. Iwi Management Plan.

world. They stress that if true partnership is to flourish then iwi need to be involved at the decision making level.

The IMP assists Ngāti Koata to openly declare their exercise of tino rangatiratanga and kaitiakitanga over resources, and supports them to move toward a proactive rather than reactive involvement in decision-making.

6.6 Takapourewa frog biology

The Takapourewa frogs (Leiopelma hamiltoni – Hamilton's frog) is endemic to both New Zealand and the island. They are located in a remote and protected location on Takapourewa. From a Western science point of view the Takapourewa and the Te Pākeka frogs are the same species, but with deep genetic differences due to their isolation on islands. It is important that both species are retained. Native frogs disappeared from Te Waka a Māui (South Island) with the arrival of humans and predators. Even on Takapourewa, due to deforestation on the island, the numbers were down to 100 frogs when they were discovered in the early 1900s.

Takapourewa frogs live for over 40 years. They have extremely low reproductive rates with females the breeding only every few years with clutches of only 10-20 eggs. Additionally, the male frogs show parental care by protecting eggs in the nest and carrying newly hatched metamorphs on their back for the first few weeks of their life. Unlike frogs overseas, the Takapourewa frogs have no external eardrums and do not communicate vocally but instead use chemosignals and pheromones.

6.7 Threats to frogs

The main threats that the Takapourewa frogs face are fire, disease, predation and climate change. Takapourewa is a dry island and as climate change worsens, the island will only continue to grow hotter and dryer, increasing the risk for fire. If fire were to spread across the island it would be devastating to all Takapourewa taonga and Ngāti Koata, as the various taonga species rely on the island for the sole survival of their species. Since this island is isolated, there is nowhere for the species to go if a fire were to take effect and spread. The same can be said for disease. Since our frogs live relatively close together, the rate at which any disease will spread will increase. There will also be nowhere to go, to get away from the disease on the island.

Predation is another threat to the Takapourewa frogs. Fortunately, Takapourewa is a predator free island, so no mammalian predators reside there. Tuatara are a native predator to the Takapourewa frogs, and are at high densities on Takapourewa. The frog population tripled over a 10-year period in the 1990s when a fence was build to keep tuatara out, but the available rocky habitat inside the fence has been at carrying capacity for the last 15 years.

6.8 Climate change

The key focus of the proposed Hamilton's frog DAPP is climate change, which poses a significant threat to Takapourewa frogs. Climate change is causing the environment to get warmer. There is no natural source of water on the motu (island). As the environment heats up, the rate at which water is evaporated increases. There will also be more droughts and extreme rain events. Even without predictions, the climate data collected on Takapourewa for the past 50 years has shown a warming and drying climate (see Figure 2 below). Not only does this increase the risk for fire but this also makes Takapourewa less suitable for the Takapourewa frogs who rely on moisture to survive. All amphibians require moisture for respiration and in a sense, they "breathe through their skin". A drying climate and increased drought conditions could cause death for numerous Takapourewa frogs.

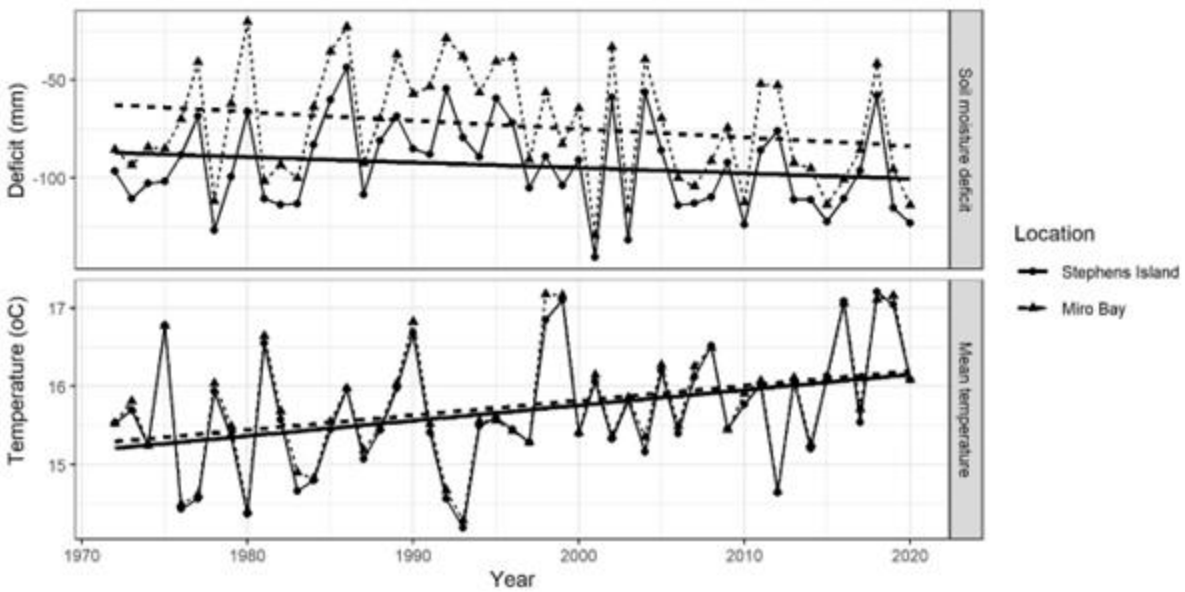


Figure 2. This graph from a climate change paper by DOC and NIWA scientists (Germano et al 2023) shows how over a 50-year period from 1972-2020, mean monthly temperatures increased and soil moisture deficits decreased (i.e. the soil dried).

It is likely that these trends will continue due to climate change in the coming years. The probability of fire, predator incursions and extreme storm events is also predicted to rise as climate change progresses, all of which provide threats to Takapourewa frogs.

Because mātauranga ā-iwi is linked to the diversity and conservation of local ecosystems, the loss of biological diversity is strongly correlated with loss of indigenous culture and language. Therefore, local extinctions and ecological changes occurring because of climate change are also impacting indigenous knowledge and social systems. Planning for climate change adaptation does not yet deeply consider how climate change might impact those interactions. Additionally, the spatial concepts and relationships that iwi have to species and places differ from government or ecosystem boundaries, therefore integrating Ngāti Koata boundaries in conservation prioritisation and future planning is a critical step towards ensuring that biocultural perspectives and tikanga are included.[28]

[28] Bond, M., Anderson, B., Henare, TH. and Wehi, P. 2019. Effects of climatically shifting species distributions on biocultural relationships. *People and Nature, 1,* 87-102. Doi: DOI: 10.1002/pan3.15.

6.9 Separation of Koata from Takapourewa and Takapourewa frogs

Ngāti Koata has lost a lot of their knowledge about Takapourewa through the years as they have been separated from the island due to numerous Acts and actions of the Crown. Despite this, Ngāti Koata has been working hard to reconnect with Takapourewa over the last few decades through restoration plantings (after farming), species monitoring, translocations, permitting, decision making, infrastructure upgrades, documentaries, replacement Ranger interviews, co-management planning of the motu (island) with Te Papa Atawhai/Department of Conservation (DOC).

An iwi member described the disconnection and alienation from the island:

> *"I think about my aunties and uncles who have been cut from here prior to me – iwi were utilised as service people – mail deliverers was the only way to get access on, or food parcel deliveries for people and animals, or visiting the farm and having relationships there. If you didn't have that relationship you didn't get on. We did have a lighthouse keeper – one uncle who was on there. There is a visitor's book on the island, we went on for filming, and were looking through the visitor's book – all the names who had accessed the island and reasons why – there were parties, dress ups etc. And we thought, where the hell are our people's names. We felt eliminated, we felt disconnected. However if we were to look at the visitor's book now, there's a clear balance of Koata and other visitors there."*[29]

6.9.1 Public Works Act 1864

The Public Works Act allows the crown to confiscate any piece of land that belongs to private landowners, Māori and European, for the use of public works. This Act, amongst others, separated us from our motu. Not long after this legislation passed, Takapourewa was confiscated, and a 15m high cast iron lighthouse was built. It was first lit in 1894 and de-manned in 1990. Today the lighthouse is fully automated and is still in operation. The island was also used for military purposes in World War II in the form of a radar station, the remnants of which are still visible today. This Act also stopped any rights Ngāti Koata had over Takapourewa.

6.9.2 Tohunga Suppression Act 1907

Tohunga held an exceptional amount of knowledge in their profession and would pass their knowledge down to the next generation. The Tohunga Suppression Act 1907 states, "Every person who gathers Maori around him by practising on their superstition or credulity, or who misleads or attempts to mislead any Maori by professing or pretending to possess supernatural powers in the treatment or cure of any disease; or in the foretelling of future events, or otherwise, is liable on summary conviction".

The Tohunga Suppression Act therefore prevented tohunga from using traditional methods because they were considered spiritual or supernatural. This meant they could be convicted if they were caught practicing any of their methods. This prevented tohunga from teaching this knowledge of

[29] Ngāti Koata iwi member. (Personal communication, June, 2023).

Takapourewa and their beliefs around the tuatara and their third eye, which Ngāti Koata believe is a portal to seeing into the future and back into the past.

This Act breached Ngāti Koata practices and created a separation of multiple cultural and intergenerational taonga to Ngāti Koata iwi through loss of purākau (traditional narratives), mātauranga (knowledge), tikanga (customs), kaitiakitanga of their motu and the taonga species of flora and fauna on the island that should have been passed down through the generations. This is one of many factors that helped to create the issues of separation and knowledge loss faced today.

6.9.3 Wildlife Act 1953

The Wildlife Act 1953 asserts that the crown owns all wildlife, except unprotected species. This Act also created another avenue of separation for the iwi from their taonga species, kai resources and motu. The iwi were unable to assert their kaitiaki roles and responsibilities as the taonga were no longer considered to be a part of them.

6.9.4 Conservation Act 1987

The Conservation Act of 1987 designated Takapourewa as a Nature Reserve. Takapourewa had already been listed as a Wildlife Sanctuary in 1966 and this was changed to a nature reserve in 1997. Designation as a sanctuary or nature reserve means that entry is by permit only and is restricted and controlled by DOC. It also limits commercial activities. This in turn meant that Ngāti Koata, to whom the island is a place of extreme significance, were expected to jump through the same hoops as all others who wished to go onto the island.

6.9.5 Pepper potting and assimilationist housing policies

Assimilationist and integrationist policies were pushed by Crown entities such as the Department of Māori Affairs, the State Advances Corporation, the Housing Division and others over decades and generations in New Zealand. Locally for Ngāti Koata that meant that whānau who were living on islands in the Marlborough Sounds were forced to send their children to public schools on the mainland. This “pepper-potting” was used as a mechanism to encourage Māori to adopt a Pākehā way of life. For Rangitoto (D’Urville Island) in particular, this meant that generations were pulled away from the island and was a conduit or another avenue that contributed to the loss of land for Ngāti Koata. Rangitoto is the gateway to Takapourewa, therefore, these housing and school policies caused yet another avenue of separation.

6.10 Reconnection with Takapourewa and taonga species

The reconnection to the island has been thwarted with many barriers outside of the Acts of Parliament which are discussed in this section. But more so due to the isolation and difficult terrain which incurs exorbitant costs for Ngāti Koata especially those who are inhibited by age concerns or physical incapabilities. Ngāti Koata has an obligation to the island and requirement of Koata participation, to date the iwi has had to leverage their trips from those who wish to visit the island for scientific, filming and other such approved matters. This will also be discussed in this section. Without proper sustainable funding to address these access concerns onto the island reconnection will always be limited and so will the ability to ensure the Ngāti Koata ongoing commitment to their kaitiaki roles and responsibilities. Furthermore, access continues to be of the upmost importance.

In 1994 a deed signed between Crown and Ngāti Koata agreed that the island would be made a reserve under the Reserves Act 1977 to be administered by the Department of Conservation. The Deed required the Crown to consult with Ngāti Koata on planning and management matters concerning the island. Through that the island of Takapourewa was returned to the iwi then handed back to the Crown as what the then conservation minister called "a gift to the people of New Zealand". According to Louisa Paul, who is knowledgeable in the affairs of Ngāti Koata, “this changed the relationship as Ngāti Koata was now recognised as equal partners in all matters pertaining to the island and all taonga species on it moving forward”. Although recognition was established Ngāti Koata still had a lot of negotiating to do in terms of what that relationship looked like moving forward as agreement often could not be made. It was almost like being back at step one again.

6.10.1 Filming on Takapourewa

Filming on Takapourewa has provided the opportunity for Ngāti Koata to reconnect with the island. When filming was in process on the island, Ngāti Koata would go out and share their knowledge and stories with the film crew. From this Takapourewa has intrigued many filmmakers due to its limited access and the rare species that reside there.

6.10.2 Tuatara partnerships

Tuatara research has been happening on Takapourewa since the late 1980s. This has been led mainly by universities but also by DOC and various zoos. It has opened numerous opportunities for Ngāti Koata whānau to both connect with Takapourewa and their taonga, while also allowing the ability to gain skill sets and knowledge in handling, sample collection, biology and conservation management. Ngāti Koata has been assisting with various research for the past 30 to 40 years. Furthermore, tuatara from Takapourewa were translocated off the island and onto the mainland as a way to ensure their survival by not keeping all of them on the island in case something negative happened to the island, i.e. fire etc.

Through this work, some of the Ngāti Koata members have become leaders in the tuatara and conservation spaces. They have led and helped to facilitate translocations to other rohe and have worked with iwi, hapū, and conservation organisations throughout Aotearoa.

6.10.3 Restoration planting

A revegetation programme was launched in 1953 on Takapourewa. Resident Rangers/lighthouse keepers would go out, collect seeds and propagate the vegetation. In 2009 Pene Gieger, Trainee Ranger and a Koata wahine, was employed by DOC to lead the last nine years of the restoration planting. As both Koata and an employee of DOC she was able to combine both roles in order to progress the work and reconnect Ngāti Koata iwi members back to the island. With boots on the ground, she played a huge role in the reconnection of Koata to the island, through volunteer tree planting trips. Approximately 100,000 native plants under her watchful eye. Through these tree planting trips, Ngāti Koata gained the ability for Koata people to lead in these spaces and on an isolated island. This led to a hands-on connection for the iwi's kaitiaki and experiences, and participation began to flourish.

6.10.5 Treaty Settlement 2012

In 2005 Ngāti Koata lodged a Treaty Claim with the Crown. This Claim set out an account of the acts and omissions of the Crown before the 21st of September 1992 that affected Ngāti Koata and breached the Treaty of Waitangi and its principles. After intensive negotiations Ngāti Koata and the crown signed their Treaty Deed of Settlement on the 21st of December 2012 at Whakatū Marae.

This further acknowledged Ngāti Koata and its role and their connection to Takapourewa and created opportunities for formally cementing this, such as through the DOC-Ngāti Koata Protocol and a co-management plan for Takapourewa.

6.10.4 Co-management with DOC

In 2019 Ngāti Koata and DOC signed the joint Takapourewa Operational Plan.[30] The objective of this plan is to create:

- Flourishing ecosystems
- Strong thriving taonga
- Koatatanga and kāwanatanga
- Guide decision-making.

The Takapourewa Operational Plan highlights the shared interest between DOC and Ngāti Koata to restore and protect Takapourewa as well as rebuilding and maintaining a strong connection to island and taonga. Through this plan Ngāti Koata and DOC have co-manged many trips to Takapourewa for tree planting, improving infrastructure and taonga research and management. These trips have given and continue to give Ngāti Koata opportunities to go out to Takapourewa, learn new skills and reconnect with the motu and their taonga. Because of these opportunities, the relationship between Ngāti Koata and DOC continues to improve.

DOC and Ngati Koata share a vision of the island restored to a condition very similar to that prior to European contact. As the mauri, including the biodiversity, of the island is restored, 'right relationship' with humans and the natural world is restored. Because Takapourewa is now wholly free of introduced pest and grazing animals, this vision is achievable. The long-term restoration of Takapourewa may result in an increased ability for Ngāti Koata to transfer knowledge to future generations relating to their cultural practices in relation to these species and this place.

The detail of the Takapourewa Operational Plan was outlined in more detail above.

[30] Ngāti Koata Trust and Department of Conservation. March, 2019. Takapourewa Operational Plan.

7. Ngā Uara o Ngāti Koata | Ngāti Koata Values and Analysis

Intergenerational relationships with Takapourewa and the frogs

It is important to Ngāti Koata that people from all generations of the iwi can be taken out to the island, not just the worker's generation. This is critical for intergenerational relationships with each other, the island and the frogs, and for the transfer and regeneration of mātauranga.

An iwi member described that:

> *"When mahi is finished there is an opportunity to breathe and appreciate, rather than being tired and sore, to feel and see everything, walk where you want to walk, feel what you want to feel, to experience the wairua connection – it's the wairua of that place, it comes to life, breathes life back into you when you have that moment to breathe and pause."*

This is currently only able to be experienced around the edges of scientific project work, due to the prohibitive cost of getting to the island independently. However, it is important to Ngāti Koata to be able to increase this kind of experience, on their own terms, and with groups which span several generations.[31]

A young iwi member describes how their relationship with the tūpuna and future generations helps guide their work:

> *"I like to imagine seeing my tūpuna out there and seeing what they would have seen back then, putting myself in their shoes and seeing what they would have wanted done. I ask myself, would they be proud of what I'm doing now and how we're restoring the island. I think they would be proud of how we're coming along with it and how we're getting to the original state. There is still lots to do with it, but it's coming along pretty well. I wonder if they knew about the frogs and what they thought about them, knew about them – their stories with them. I just wish we know that."*[32]

An intergenerational approach seeks to ensure that the adaptation and survival of Ngāti Koata people, tikanga and taonga species in a world where they can thrive. The iwi has the great privilege of whakapapa, learning from the generations of tūpuna before them. They also ask themselves what their mokopuna will say about their actions, and what their legacy will be to those in 200 or 1000 years time.

[31] Ngāti Koata iwi member. (Personal communication, June, 2023).
[32] Ngāti Koata iwi member. (Personal communication, June, 2023).

Whakapapa

Protection of the whakapapa of the frogs is paramount. The iwi, as kaitiaki, take the perspective of translocation being about the survival of the species from a perspective of the island being decimated – that there needs to be whakapapa off the island to continue that line. Ngāti Koata and DOC therefore have the same outcomes in mind, but from a different perspective, and possibly via a different method.

Iwi are constantly thinking about whether something was to happen in a space or to a line, whether they have the populations elsewhere to be able to continue their whakapapa – it can be likened to their tikanga of not letting the whole family travel long distances together in a car, so that if something was to happen, that line can continue. A translocation of the frogs will give the opportunity to capture their whakapapa moving forward, however Ngāti Koata are not happy with the idea of sending their species anywhere and everywhere. Koata needs to be there for discussions at the beginning, not just consulted later.

It is important to note that the approach of Ngāti Koata science and mātauranga to the definition of a species differs to the Western approach, and is distinctly rohe based. Therefore for Ngāti Koata the Hamilton's frog on Takapourewa is a different species to the frog on Te Pākeka (Maud Island). Therefore it is of critical importance to Ngāti Koata that the whakapapa of the Takapourewa frogs are saved separately to the Te Pākeka population.

For Ngāti Koata, each species that leaves the island is a piece of home being gifted – Ngāti Koata's relationship continues forever. It is critically important that the whakapapa of taonga from Takapourewa are tracked and honoured, and that Ngāti Koata give express approval of any translocations away from the island, and are involved from the earliest point in considering recipient site options. The iwi would not approve of them being taken from their home unless necessary – all the facts need to be well understood and considered.

Upholding kaitiaki responsibilities

Ngāti Koata hold kaitiaki relationships and responsibilities for the Takapourewa frogs. As described in the iwi environmental plan, the term kaitiaki includes the ideas and principles of guardianship, care, wise management and resource indicators of the state of their own mauri. Kaitiaki are person(s) and other agents who perform the tasks of kaitiakitanga (guardianship) over a particular resource or area. Kaitiaki derive their role and function from their own relationship with a resource, not through appointment by another agency.[33] The terms kaitiaki and kaitiakitanga have specific meanings as defined by Ngāti Koata, and must be interpreted according to its intents, origins and

[33] Ngati Koata No Rangitoto Ki Te Tonga Trust. 10 June, 2002. Iwi Management Plan, p 60.

purposes of the people who the terms belong to. Under Section 4 of the Conservation Act, DOC is required to actively protect the kaitiaki relationship with taonga.

The threat of climate change to kaitiaki responsibilities and relationships is real and significant, and a key layer of climate adaptation planning for species is described:

> *"Including socioecological context is the first step towards advancing climate change spatial conservation prioritization beyond mapping ecological and evolutionary processes to mapping important human–ecological processes... climate change will affect access to these culturally valued plant [substitute fauna] species with the potential to place biocultural connections at risk where human access to resources does not shift with species shifts. Mapping future suitability for currently accessible and culturally significant populations of useful [substitute taonga] species exposes risks to biocultural connections and reveals where and how adaptations should be targeted to support biocultural resilience."*[34]

The preservation of their kaitiaki role, as adaptive pathways for the preservation of the Takapourewa frogs are explored and implemented, is of paramount concern to Ngāti Koata. This is lacking in DOC's current approach and must be rectified with urgency and in genuine partnership, to ensure that DOC gives active protection to the kaitiaki role through all their work and planning for the Takapourewa frogs, as required by Section 4.

In some ways, the translocation of the Takapourewa frogs to a more accessible environment would further support the kaitiaki role, as there would be easier access for the iwi to the frogs.

The Waitangi Tribunal found that, "Māori, kaitiaki unquestionably have a right to protect their relationships with taonga species and a right to a reasonable level of control over their mātauranga Māori. We say that these are legitimate interests entitled to a reasonable degree of protection." [35]

They go on to explain:

> *"This plurality has important implications for the protection of kaitiaki relationships with taonga species. It means the needs of the relationship must be defined case by case. Each species is different, and particular contexts and kaitiaki will determine priorities. Different uses may also have different effects. Generally, the greater the effects of the proposed research or use upon the kaitiaki relationship, the greater the right of involvement. Indeed, where the proposed use is so invasive it threatens to undermine the relationship completely, kaitiaki consent will invariably be necessary. The important point is that the trigger for a substantive Māori role in decision-making is the need to protect the relationship*

---

[34] Bond, M., Anderson, B., Henare, TH. and Wehi, P. 2019. Effects of climatically shifting species distributions on biocultural relationships. *People and Nature, 1,* 87-102. Doi: DOI: 10.1002/pan3.15.

[35] Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct, p85.

between kaitiaki and taonga species wherever proposals to exploit those species might affect it. It is the relationship that is entitled to protection, not any property right in genetic and biological resources per se."[36]

Mātauranga ā-iwi

Mātauranga Māori is described by D. Hikuroa as:

> *"The pursuit and application of knowledge and understanding of Te Taiao, following a systematic methodology based on evidence, incorporating culture, values and world view. Pūrakau [traditional narratives] and maramataka [Māori lunar calendar] comprise codified knowledge and include a suite of techniques empirical in nature for investigating phenomena, acquiring new knowledge, and updating and integrating previous knowledge. Pūrākau and maramataka can be both accurate and precise, as they incorporate critically verified knowledge, continually tested and updated through time.*
>
> *Mātauranga Māori is the term most commonly used to describe Māori knowledge incorporating 'the body of knowledge originating from Māori ancestors, including Māori world view and perspectives, Māori creativity and cultural practices', the knowledge, comprehension, or understanding of everything visible and invisible existing in the universe, including present-day, historic, local and traditional knowledge; systems of knowledge transfer and storage; and Māori goals, aspirations and issues and 'the unique Māori way of viewing the world, encompassing both traditional knowledge and culture'."*

He goes on to conclude that, "mātauranga Māori is therefore a method for generating knowledge, and all of the knowledge generated according to that method".[37]

Accordingly mātauranga ā-iwi is iwi-specific mātauranga Māori, generated in the locally unique adaptation of the processes described above, and including all of the iwi knowledge generated according to that method. Some scholars consider mātauranga Māori or mātauranga ā-iwi to be incompatible with science, however it is knowledge generated using the scientific method, explained

---

[36] Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct, p87.

[37] Hikuroa, D. 2017. Mātauranga Māori – The ūkaipō of knowledge in New Zealand. Journal of the Royal Society of New Zealand, 47:1, 5-10, p3. doi: DOI 10.1080/03036758.2016.1252407.

according to a Māori world view.[38] Ngāti Koata hold mātauranga ā-iwi about Takapourewa, the ecosystems there and tuatara. Colonisation and its impacts have severely impacted the continuity of mātauranga ā-iwi, as peoples connections to places and to taonga have been severed, and intergenerational relationships have been thwarted. Tohunga had to go into hiding, and so weren't able to carry out that transmission. Some of that mātauranga has been handed down through the generations, while other mātauranga has been rebuilt as they have regained access and experience of the island's unique environment and taonga species.

Much of the Ngāti Koata opportunity to rebuild their mātauranga has been due to the channelling of funding into the tuatara, and the opportunities offered through their kaitiaki role with tuatara to travel to the island and spend time with them, observing in traditional ways alongside learning about Western scientific approaches. Ngāti Koata wish for their existing mātauranga about the motu to be protected, and further enhanced, through any climate change adaptation plans.

Ngāti Koata are currently transforming their approach to kaupapa (initiatives) they are involved with to be guided by the maramataka. They have not yet been able to undertake their own research and mātauranga trips to Takapourewa around the maramataka, because they are not the ones on the island, so can only live and breathe it through those who are going there for other purposes.

"The maramataka is a calendar that divides the Māori year into lunar months, and is structured to respond to the natural rhythms and variations of the lunar cycle. Centuries of detailed observations built up evidence, and hypotheses and predictions were made, tested and critically analysed. Inductive reasoning was employed with results and conclusions subjected to verification and testing. Different hapū and iwi developed their own respective rohe-specific maramataka. The key role of the maramataka is as a predictive tool for scheduling activities critical to the continued success of hapū and iwi."[39]

The iwi is also passionate about restoring the mātauranga they have lost pertaining to the Takapourewa frogs. An iwi member described the embarrassment and sadness that they feel when they have to meet with captive institutions or DOC scientists who inform them about the taonga species they are kaitiaki of, and are unable to contribute their own perspectives and mātauranga from their own world-view.

"It's belittling because they [captive managers and scientists from other organisations] have the experience of living with them, holding them, caring for them, feeding them – and we don't."

The mātauranga ā-iwi that Ngāti Koata has been able to rebuild around the tuatara, is due to the opportunities to accompany DOC and scientists to the island on their work. They have not yet had

[38] Hikuroa, D. 2017. Mātauranga Māori – The ūkaipō of knowledge in New Zealand. Journal of the Royal Society of New Zealand, 47:1, 5-10, p3. doi: DOI 10.1080/03036758.2016.1252407.
[39] Hikuroa, D. 2017. Mātauranga Māori – The ūkaipō of knowledge in New Zealand. Journal of the Royal Society of New Zealand, 47:1, 5-10, p4. doi: DOI 10.1080/03036758.2016.1252407.

that opportunity with the frogs, and describe the frogs as being of equal significance to them as the tuatara, and deeply wanting to guide their future options and management from the perspective of their own mātauranga. The iwi's lens on what is best practice for a species, for example tuatara, in captive management is based on their observations on the island, and differs from what captive managers perceive to be best practice. The iwi desires to be able to inform translocations and captive management possibilities based on what the frogs do on the island at home in their natural environment.[40]

Ngāti Koata desire to reclaim their stories and to re-indigenise the understanding of the Takapourewa frogs, from a mātauranga ā-iwi perspective. It is incredibly hard for them to get to Takapourewa as the cost is prohibitive of transporting themselves out there, so their trips are tagged to other organisations and their initiatives and timing, rather than those of Ngāti Koata. It is the only way to truly fund access onto the island, therefore scientific research projects are hugely important to help the iwi reconnect with their taonga. However, it is not sustainable, as when the funding ends the iwi can't afford to get their people back on. Ngāti Koata also wishes to do it on their own terms, not just because others wish to go. Ngāti Koata want DOC to support and enable the iwi doing what they wish to themselves, with the space, time and resource for the iwi to figure out what they want to do. Without access to their taonga, mātauranga simply cannot survive.[41]

Ngāti Koata desire to develop their understanding of the maramataka data in relation to Takapourewa frogs, and for their maramataka to drive timing and approach to research and management, alongside of Western science understandings. The changes to the maramataka driven by climate change are also critically important to understand and monitor, and this should be integrated as a core part of long-term research on the island. Better understanding of this will further enhance our collective ability to protect and manage the frogs into the future.

7.5 Rangatiratanga

Ngāti Koata wish to see their own mātauranga ā-iwi, tikanga, kawa and values as the foundation of the approach to responding to the risk posed by climate throughout their rohe, in particular on Takapourewa and in relation to the Hamilton frogs. From this foundation Ngāti Koata also recognise the importance of Western science and the role of kāwanatanga, alongside rangatiratanga, with its processes and tools to weave in to exploring and deciding possible approaches to safeguard their taonga. Ngāti Koata want their iwi and their taonga to thrive, even amidst the most extreme challenges.

---

[40] Ngāti Koata iwi member. (Personal communication, June, 2023).
[41] Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct. p127.

The Waitangi Tribunal found that:

> *"The Treaty obliges the Crown to actively protect the continuing obligations of kaitiaki towards taonga, as one of the key components of te ao Māori, and also obliges the Crown to conduct its conservation activities in a manner that is consistent with the tino rangatiratanga of iwi and hapū to the greatest extent practicable."*[42]

7.6 Te Tiriti o Waitangi partnership

The Waitangi Tribunal described the importance of the conservation estate and of the Treaty partnership:

> *"Given the importance of the environment under DOC control to the survival of the Māori culture, Treaty principle requires that partnership and shared decision-making between the department and kaitiaki must be the default approach to conservation management. Within that overall partnership framework, decisions can be made case-by-case about management of individual taonga, taking into account the interests of kaitiaki, the interests of the taonga themselves, and other interests."*[43]

Wai 262 described the co-management of taonga, based on Treaty principles:

> *"Those changes and the partnership approach they encompass have potential to provide a basis for a new approach to conservation management, one that acknowledges the commonality between kaitiaki and conservation interests, and reconciles the differences; one that protects and*
>
> *supports mātauranga Māori while also preserving and protecting the environment. This synthesised 'kaitiaki conservation' approach would of course have the survival and regeneration of the environment as its primary concern, and it would harness both mātauranga Māori and te ao Pākehā's conservation expertise to that end. In bringing mātauranga Māori into a genuine partnership, it would acknowledge the importance of human-environment relationships. The environment needs active protection; damaged ecosystems and vulnerable species will not recover and flourish without human intervention.*

---

[42]Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct. p145.

[43] Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct. p146.

For the Crown, the joint endeavour in this instance is the mutual survival of mātauranga Māori, and land and species. For the department, stewardship of the DOC estate and protected species is about respecting the intrinsic value of that which remains to us, and offering New Zealanders – indeed the world – the opportunity to feel their wonder. For Māori, it is about those things and the survival of their own identity. Without the mātauranga Māori that lives in the DOC estate, kaitiakitanga is lost. Without kaitiakitanga, Māori are themselves lost. There may not be equal power, but there is certainly equal investment in the outcome. That is why in our view ultimately the partnership between DOC and Māori will prevail."[44]

The Treaty partnership, under Section 4 of the Conservation Act, is of paramount importance to Ngāti Koata and their kaitiaki relationship with the Takapourewa frogs, and must be given high priority by DOC in all consideration, planning and decision making about the frogs in response to climate change. This requires Ngāti Koata being at the table at the earliest time possible, and their mātauranga ā-iwi being actively protected by DOC, and jointly guiding informed decision making by both parties.

7.7 Protecting and enhancing the mauri of the Takapourewa frogs

The Takapourewa frogs are a highly valued taonga species of Ngāti Koata, as are all the taonga species on the island. The Takapourewa frogs are of a similar degree of significance to Ngāti Koata as are the tuatara, and it is of paramount importance to Ngāti Koata that they survive and thrive into the future. Ngāti Koata support active partnership in conservation management and kaitiakitanga of the frogs to ensure their mauri is protected and enhanced into the future.

Climate change is clearly a significant threat to the Takapourewa frogs, and ensuring their survival in perpetuity is a high priority for Ngāti Koata, and indeed a serious responsibility.

As explored later, Ngāti Koata has undertaken qualitative research with iwi members on the management options for the frogs proposed by DOC in the DAPP. In situ management and understanding the frogs fully in their natural environment is a high priority. As above, developing this mātauranga of them in their natural environment with their complex ecological relationships prior to moving a safety population is extremely important and should be fast-tracked and supported by DOC.

---

[44]Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct. p146.

Ex situ management through moving the frogs to a site within the Ngāti Koata rohe is also supported, if needed, and has a benefit to Ngāti Koata of them being more accessible to Ngāti Koata for the direct relationship to be further developed. Easeful access is a key consideration here in such instance to ensure the mātauranga can continue to be developed and kaitiaki responsibilities can be carried out in a meaningful and practical way.

If sites outside the rohe are necessary, this needs to be done entirely in partnership with Ngāti Koata, and put access and relationships first and foremost, alongside the wellbeing of the frogs.

Ngāti Koata have experience with translocations of tuatara, and much of the earlier translocations happened without their involvement. The learning from experience with this species is valuable to draw on and inform collaborative approaches and management approaches to tuatara.

8. Te Rangahau | Qualitative Research

Methods – interviews, wānanga, surveys

Ngāti Koata is a small but mighty iwi with approximately 3000 members. Online surveys were sent out to all registered iwi members. Forty-six online surveys were completed. 1.3% of the iwi completed the survey, so the results are based off a small portion of Ngāti Koata iwi feedback. Additionally, an in-person hui was held with kaumātua at the Kaumātua Flats on Whakatū Marae in Whakatū. Five kaumātua attended this hui to talk through the survey questions kanohi ki te kanohi. Finally, this report was reviewed by the Ngāti Koata Kaumatua Council, a group of 20 kaumātua who endorsed this report.

Qualitative research results

DOC's DAPP for managing native frogs in the face of climate change can be split into two categories – management that occurs on site (in situ) and off site (ex situ). The responses of iwi members to the proposed management actions are summarised below.

General knowledge of iwi members about frogs, Takapourewa and climate change

Due to being separated from Takapourewa and its remote location its estimated that less than 20% of Ngāti Koata members have been to Takapourewa. Because of this even fewer know about the endemic Takapourewa frogs.

Gathered from the survey that was sent out, 93% of the respondents stated they know of climate change. However, many are unsure how it affects the Takapourewa frogs. One respondent stated: "I know it impacts them. Can't say how, though."

Other respondents commented on ideas of how they think the Takapourewa frogs may be impacted based on other knowledge they have gathered: "It may mean that other species invade their territory because climate change has caused a need to leave their normal habitat. Maybe. Don't really know".

DOC's Proposed in situ (on island) adaptive frog management for climate change

There was overwhelming support, nearly 100%, from Ngāti Koata members for in situ management of frogs on Takapourewa. These management options included:

- Increase the number of Takapourewa frogs by constructing new areas of rocky habitat with 97.7% agreement (Figure 3)

• Protect frogs from prolonged dry periods by artificially manipulating habitat and micro-climate (e.g. water storage, irrigation, more shade.) with 97.1% agreement (Figure 4)

• Protect frog sites prone to rainfall-induced landslips by stabilizing slopes – not applicable on Takapourewa. With 91.1% agreement. (Figure 5)

Figure 3

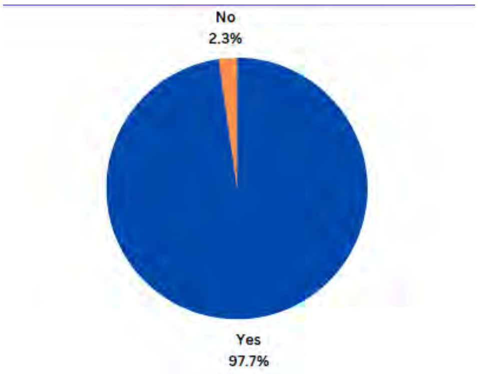
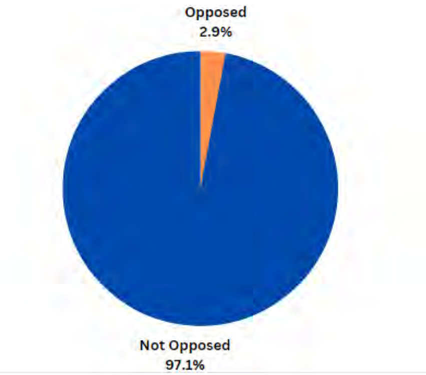


Figure 4



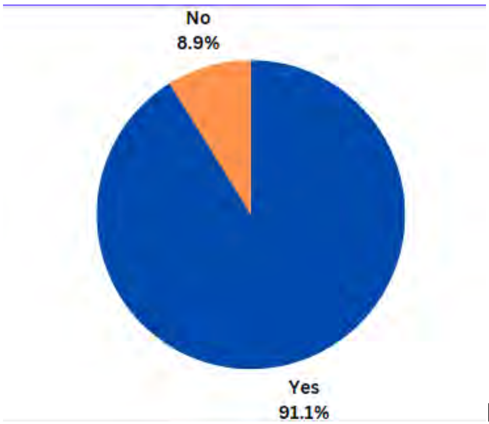


Figure 5

Proposed ex situ (off island) adaptative frog management

Though Ngāti Koata are wary of ex situ management, the majority agreed to the proposed activities. These management options include:

• Translocate frogs to wetter cooler islands in Marlborough Sounds. 91.1% agreement (Figure 6)

• Translocate frogs south to protected sites in Te Wai Pounamu 95.6% agreement (Figure 7)

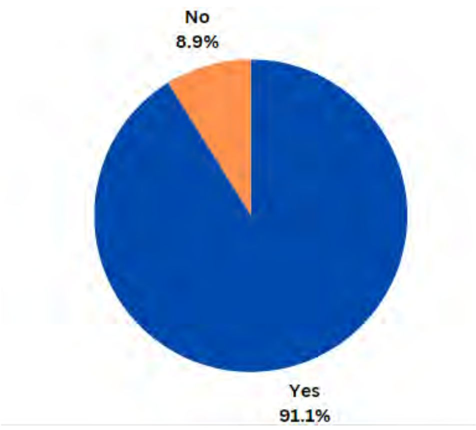


Figure 6

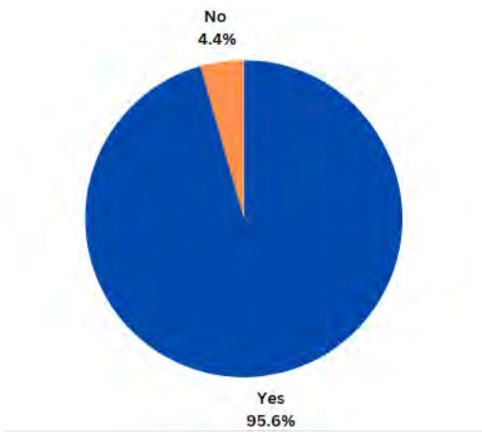


Figure 7

Discussion of qualitative research results

8.6.1 Ngāti Koata general knowledge on Takapourewa frogs

Ngāti Koata are re-establishing their knowledge of the Takapourewa frogs due to their forced separation from the island. Rather the relationship derives from the key Treaty of Waitangi principle, which was further embedded by the Waitangi Tribunal's landmark report on the claim Wai 262, of which John Hippolite of Ngāti Koata was one of six claimants. In that claim, it asserts tino rangatiratanga over all native species in their rohe. The Waitangi Tribunal responded by reconfirming Ngāti Koata and other claimant iwi's special status as kaitiaki of the native species in their rohe, and it is this which defines and seals the tribe's relationship with the frogs and other taonga species.

The situation which has been forced by history, of the lack of specific knowledge of Ngāti Koata regarding the frogs, is a sad reality and situation for the iwi, who have a strong desire to resurrect and redevelop their mātauranga as part of fulfilling their kaitiaki responsibilities.

8.6.2 Ngāti Koata general knowledge on climate change

Most of Ngāti Koata have a general understanding of climate change due to the tuatara research that was done on Takapourewa, however many are unsure how climate change affects the Takapourewa frogs. This being said Ngāti Koata members would like to gain a better understanding how the Takapourewa frogs are affected by climate change.

Ngāti Koata would also like to offer any knowledge or skills they have that may be useful in the future management and protection of this taonga species. This includes resurrecting and redeveloping their mātauranga and an approach to management of the frogs through climate change which is based on their worldview and a mātauranga Māori approach.

8.6.3 Ngāti Koata perspectives on in situ management

Overall Ngāti Koata are supportive of DOC's proposed climate change adaptation management activities. Takapourewa and its species are of huge significance to Ngāti Koata, therefore the iwi is supportive of the in-situ management proposed. This being said Ngāti Koata must be involved in all kōrero involving management decisions for the Takapourewa frogs.

8.6.4 Ngāti Koata perspective on ex situ management

While Ngāti Koata are supportive of ex situ management, there are numerous concerns that would need to be addressed and discussed before it is further progressed. Their strong preference as an iwi is to manage their taonga species within their rohe. As an iwi with experience in sharing one of our most treasured taonga (i.e. tuatara), they are very wary of losing access to this species and sharing kaitiaki roles and decision making with another iwi.

Therefore, any ex-situ management must prioritise the Ngāti Koata rohe first and efforts must be made, where practicable, to keep these taonga species where they can continue to exercise their responsibilities as kaitiaki. These discussions and decisions must be carried out jointly with Ngāti Koata representatives. It is only if these options are exhausted and if Ngāti Koata is a part of the decision-making process that other options might be considered. Decisions to move the frogs to locations outside the rohe which are not expressly approved by Ngāti Koata must not be undertaken.

9. Ngā Tūtohu | Recommendations

1. Climate change is clearly a significant threat to the Takapourewa frogs, and ensuring they survive and thrive in perpetuity is a high priority for Ngāti Koata, and indeed a serious responsibility. It is recommended that a clear partnership approach to the frogs' future is established and implemented. Further research in situ and protecting the population in situ as much as possible is supported. Translocating a safety population to another site within the Ngāti Koata rohe is also supported (with caveats of the other recommendations of this report). Translocating to another site outside the Ngāti Koata rohe is not supported, unless it is deemed absolutely necessary, and must only be done with the express agreement of Ngāti Koata and with strong conditions around their ongoing relationship with the frogs, agreed to by Ngāti Koata.

2. Ngāti Koata appreciates DOC coming to them to write this cultural impact assessment on their proposed climate change adaptation plans for Takapourewa frogs. However, as kaitiaki and co-management partners, Ngāti Koata must be given the option to be included at the table at the very beginning rather than being given the results of DOC's climate change adaptation plans to consult on after they are written. To not do so, is a breach of Section 4, the recommendations of the Waitangi Tribunal in Wai 262, and the Operational Management Plan for Takapourewa. In the future, an invitation to participate in discussions around key frog management should involve iwi representatives alongside scientists. This will ensure that a te ao Māori view is fully incorporated into plans and that Ngāti Koata's priorities and aspirations are included, as well as their mātauranga assisting and informing from different perspectives, all of which are critical to draw on with the complexity of climate change issues ahead.

3. Ngāti Koata must be involved at the earliest stage in all kōrero involving management decisions for the Takapourewa frogs, and liken the significance of the frogs to that of the tuatara for them.

4. Ngāti Koata should be supported to resurrect and redevelop their mātauranga and an approach to management of the frogs through climate change which is based on their worldview and a mātauranga Māori approach. An initiative should be developed to fund this being progressed urgently, so that their kaitiaki relationship and their mātauranga can be actively protected as required by Section 4, and that the mātauranga can be applied in a timely manner to guide decision making for approaches to climate change adaptation pathways for the frogs.

5. The initiative to resurrect and redevelop the Ngāti Koata mātauranga of the Takapourewa frogs should cater for intergenerational observation and learning, and transfer of observation methods from elders to the younger generation. This requires that this initiative is not just tagged on to physical work programmes, but specifically caters for and gives sufficient time to a multi-generational and maramataka based approach to mātauranga

development for the future management of Takapourewa frogs in the face of climate change.

6. Ngāti Koata should be supported to develop their understanding of the maramataka data in relation to Takapourewa frogs, and for their maramataka to drive timing and approach to research and management, alongside of Western science understandings. The changes to the maramataka driven by climate change are also critically important to understand and monitor, and this should be integrated as a core part of long-term research on the island. Better understanding of this will further enhance our collective ability to protect and manage the frogs into the future. Ngāti Koata should be supported to fast-track re-development of their mātauranga ā-iwi of their maramataka and utilise this approach to research the frogs according to their traditional approaches to inform.

7. Any ex-situ management must prioritise the Ngāti Koata rohe first and efforts must be made, where practicable, to keep these taonga species where they can continue to exercise their responsibilities as kaitiaki. These discussions and decisions must be carried out jointly with Ngāti Koata representatives. It is only if these options are exhausted and if Ngāti Koata is a part of the decision-making process that other options might be considered.

8. Decisions to move the frogs to locations outside the rohe which are not expressly approved by Ngāti Koata must not be undertaken.

9. The next iteration of the dynamic adaptive pathway for Takapourewa frogs should be led by mātauranga Māori and mātauranga ā-iwi with equal weight alongside Western science – a double hulled waka approach in line with the principle of partnership under Section 4.

10. Planning for climate change adaptation must include the Ngāti Koata spatial layer and relationships, and integrate their boundaries into conservation prioritisation and future planning, to ensure that their biocultural conservation perspectives and tikanga are adequately included, and that the threats climate change poses to their mātauranga and kaitiaki relationships are mitigated.

11. The whakapapa of the Takapourewa frogs from a Ngāti Koata perspective should be a priority layer to considering the future options for the frogs.

12. Ngāti Koata has a strong relationship with the current DOC manager of the frogs. Ngāti Koata and DOC both have high turnover of staff and the iwi have the experience of having to re-educate staff in DOC about the relationship and history. Recommend that the DOC – Ngāti Koata protocol required by the Treaty Settlement is developed and maintained, and that a process for ensuring continuity of relationships and knowledge of each other over time is maintained. A team of key people within different parts of DOC being responsible as a committee for the relationship is an approach to explore.

10. Kupu Whakatepe | Conclusion

Ngāti Koata strongly support the joint development with Te Papa Atawhai of an adaptive pathway for the Takapourewa frogs to ensure that they survive and thrive through the impacts of climate change. The pathway should be informed by Western science and the mātauranga ā-iwi of Ngāti Koata.

DOC should support Ngāti Koata to actively fast-track the re-development of their mātauranga through an iwi and maramataka lens, of the frogs in their natural habitat, so that the best of both Western and Māori science can work together creatively to find unique solutions for the pending crisis.

The kaitiaki relationship that Ngāti Koata holds with the frogs is a key principle to uphold, and DOC must actively support this at all levels, and in all aspects of Takapourewa frog management and recovery, to ensure that the requirements of Section 4 of the Conservation Act are met, and the recommendations of Wai 262 are followed.

Ngāti Koata appreciate and value their active and strengthening relationship with DOC and look forward to continuing to grow and deepen the relationship into the future, for the benefit of both parties and ultimately the Takapourewa frogs.

11. Ngā Tohutoro | References

Anderson, C. 17 June, 2010. Land of the dinosaurs. Retrieved June, 2023 from https://www.stuff.co.nz/nelson-mail/lifestyle-entertainment/weekend/781969/Land-of-the-dinosaurs.

Bond, M., Anderson, B., Henare, TH. and Wehi, P. 2019. Effects of climatically shifting species distributions on biocultural relationships. *People and Nature, 1,* 87-102. Doi: DOI: 10.1002/pan3.15.

Courts of New Zealand. 14 December, 2018. Ngāi Tai Ki Tāmaki Tribal Trust v Minister of Conservation – [2018] NZCS 122. Retrieved June, 2023, from https://www.courtsofnz.govt.nz/cases/ngai-tai-ki-tamaki-tribal-trust-v-minister-of-conservation-1/?searchterm=NG%C4%80%20I%20TAI%20KI%20T%C4%80MAKI.

Department of Conservation. Conservation management framework: how conservation work is planned. Retrieved June 2023, from https://www.doc.govt.nz/about-us/statutory-and-advisory-bodies/conservation-boards/conservation-board-manual/conservation-management-framework-how-conservation-work-is-planned/#:~:text=Section%204%20of%20the%20Conservation,administering%20anything%20under%20the%20Act.

Department of Conservation. Partial reviews of Conservation General Policy and General Policy for National Parks. Retrieved June, 2023, from https://www.doc.govt.nz/our-work/partial-reviews-of-conservation-general-policy-and-general-policy-for-national-parks/

Department of Conservation. Translocation Proposals. Retrieved June, 2023, from https://www.doc.govt.nz/get-involved/run-a-project/translocation/proposals/

Department of Conservation. Reserves Act 977. Retrieved June, 2023, from https://www.doc.govt.nz/about-us/our-role/legislation/reserves-act/

Department of Conservation. Modernising conservation legislation. Retrieved June, 2023, from https://www.doc.govt.nz/about-us/our-role/legislation/conservation-law-reform/

Hikuroa, D. 2017. Mātauranga Māori – The ūkaipō of knowledge in New Zealand. Journal of the Royal Society of New Zealand, 47:1, 5-10, doi: DOI 10.1080/03036758.2016.1252407.

Ministry of Justice. Regulatory Stewardship. June, 2023. Retrieved from https://www.justice.govt.nz/justice-sector-policy/regulatory-stewardship/regulatory-systems/constitutional/

New Zealand History. The Treaty in practice. Page 3 – Obtaining land. Retrieved June, 2023, from https://nzhistory.govt.nz/politics/treaty/the-treaty-in-practice/obtaining-land.

Ngati Koata No Rangitoto Ki Te Tonga Trust. 10 June, 2002. Iwi Management Plan.

Ngāti Koata Trust. ND. Ngāti Koata Trust Strategic Plan.

Ngāti Koata Trust. Te Tiriti | The Treaty. Retrieved June, 2023, from https://www.ngatikoata.com/te-tiriti/.

Ngāti Koata Trust. Tiaki Taiao. Retrieved June, 2023, from https://www.ngatikoata.com/tiaki-taiao/.

Ngāti Koata Trust and Department of Conservation. March, 2015. Draft Operations Plan for Takapourewa (Stephens Island).

Ngāti Koata Trust and Department of Conservation. March, 2019. Takapourewa Operational Plan.

Ngāti Kōata, Ngāti Rārua, Ngāti Tama ki Te Tau Ihu, and Te Ātiawa o Te Waka-a-Māui Claims Settlement Act, No 20, 2014.

Ngāti Koata Trust. Our History. Retrieved June, 2023, from https://www.ngatikoata.com/our-history/

Waitangi Tribunal. Meaning of the Treaty. June, 2023. Retrieved from https://www.waitangitribunal.govt.nz/treaty-of-waitangi/meaning-of-the-treaty/

Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuatahi. Wellington, New Zealand: Legislation Direct.

Waitangi Tribunal. Waitangi Tribunal Report, 2011. Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Te Taumata Tuarua (Volume 1). Wellington, New Zealand: Legislation Direct.

12. Ngā Āpitihanga | Appendices

Some of the most significant taonga species from Takapourewa

Compiled by Oliver Sutherland, June, 2023

The report of the landmark 1991 Fauna and Flora claim to the Waitangi Tribunal (WAI 262) affirms Ngāti Koata's status as kaitiaki of Takapourewa and all the species present on the island. But, what are the species that make up the rare assemblage of animals that populate the island? These are some of the most special animal wildlife:

Vertebrates

<u>Mammals</u>

Fur seal

Number: a rookery has recently become established which produces perhaps 200 pups per year

<u>Birds</u>

Fairy prion

Number: 1,000,000+ present. This huge population of seabirds adds immense fertility to the island and is the key to the abundance of wildlife on Takapourewa

Habits: nest in burrows, which they can share with tuatara, under forest canopy; spend most of the time foraging in nearby coastal seas

Sooty shearwater – tītī

Number: several thousand

Habits: nest in burrows in discrete cliff-edge colonies; long distance ocean travellers; after completion of breeding undertake extensive circuit of the Pacific, then return to breed again

Diving petrels and fluttering shearwaters

Number: present in large numbers

Habits: nest in burrows wherever they can find the space – shearwaters on steeper cliffs; diving petrels under vines or on cliff edges

Kororā – little blue penguin

Number: hundreds

Habits: nest all over the island including under buildings

Kārearea - falcon

Number: several pairs are now resident on the island

Habits: range far and wide

<u>Reptiles</u>

Tuatara

Number: about 50,000; density can be up to 2000 per hectare

Habits: live in burrows under the forest canopy, sometimes shared with fairy prions (unless the birds get their head bitten off!); top predator on the island, preying on just about anything that moves – wētā and other insects, other reptiles, young tuatara, Hamilton's frog, baby fairy prions etc; live for 130+ years; have existed in Aotearoa for 65 million years (since Aotearoa was a part of Gondwanaland)

Southern striped gecko

Number: rare but perhaps increasing – not often encountered - endangered

Habits: on forest margins; the re-plantings carried out by Ngāti Koata and DOC have dramatically increased the population f this species

Raukawa (common) gecko

Number: many thousands – very common

Habits: everywhere on the island – under every piece of wood – inside houses and other buildings

Marlborough green gecko

Number: uncommon; sunbathe in the daytime, almost invisible to see until they move

Habits: live among bright green spinach vine

Northern spotted skink

Number: very common – estimated to be more than a million

Habits: generalists which live in a range of habitats on the island

Speckled skink

Number: quite common – grow to 25-cm length

Habits: same as for tuatara – lightening quick reflexes keep it out of harm's way

Glossy brown skink

Number: not so common

Habits: most often found in modified grassland

Northern grass skink

Number: quite common

Habits: most often in modified grassland or vineland

Amphibia

Hamilton's frog

Size: very small – 8 to 13 grams

Number: one of the world's rarest and most vulnerable species and as ancient as the tuatara – about 300 remain on the island

Habits: live in damp conditions in the rock-boulder 'frog bank', protected from predation by tuatara by a tuatara-proof fence. May live for 30+ years. No free-swimming tadpole stage – young frog develops within the egg; male carries tiny froglets around on his back. Strictly nocturnal

Invertebrates

Snail

Rhytida stephenensis

Number: uncommon and found in patches

Habits: a carnivorous snail found in moist areas

Insects

Giant wētā

Size: up to 15 grams

Number: common

Habits: live mainly in grassland – preyed on by tuatara

Wellington tree wētā

Size: very large – up to 15 grams, males with an enormous head

Number: very common – up to 5,300 per hectare

Habits: live in forest trees

Ngaio weevil

Size: very large – up to 30 mm long; flightless

Number: Uncommon – highly endangered - only population in the world and numbering several hundred individuals

Habits: live and feed only on the Ngaio tree; strictly nocturnal. The re-plantings carried out by Ngāti Koata and Doc have dramatically increased the population of this species

Flax weevil

Size: as big as Ngaio weevil; flightless

Number Uncommon – at risk

Habits: live and feed exclusively on flax

Large black carabid beetle – Stephens Island ground beetle

Size: large - up to 38 mm

Number: rare – only population in the world

Habits: live on forest floor; shelter under fallen logs and wood especially in Keeper's bush and frog bank area; the tuatara-proof fence around the frog bank helps not only the frogs but also this beetle and other invertebrates

***Zeopoecillus* - ground beetle**

Number: rare; as yet an undescribed species. Only population in the world

Habits: live under wood particularly in the frog bank area where they are protected from tuatara predation by the fence

Cook Strait click beetle

Size: 18 – 23 mm long; a primitive species which is rarely able to 'click'; flightless

Number: rare – perhaps a few hundred and only found on a handful of islands in the Sounds. Takapourewa is probably the second largest population of this species

Habits: live in knot holes in trees, and under rocks and logs

Acknowledgements

E rere ana ngā tai ō mihi ki ngā ringa rehe i whakapau kaha, āwhina hoki kia tutuki pai i tēnei tuhinga hei whai hua te iwi.

Ka hoki ngā whakaaro ki ngā kaiurungi ō mua i whakarewa i tō tātou waka whakarauora taiao kia hoki mai te manu hākapakapa!

We greatly appreciate the support from: Jen Germano, Derek Brown, Graeme Elliott, Peter Gaze, and Mark Anderson for their expert advice.

We would like to express our deepest appreciation to:

- Te Kaunihera Kaumātua o Ngāti Koata
- Whakatū Marae Kaumātua
- Melanie McGregor
- Kimiora McGregor
- Oliver Sutherland
- Ngāti Koata Iwi
- Larry
- Takapourewa Frog Survey Participants (Climate Change Adaption and Cultural Impact Assessment)

E kore e ārikarika ngā mihi ki a koutou.

ENGLAND AND CO.

Department of Conservation
Te Papa Atawhai

Landslides and predicted climate change effects on the Abel Tasman Coastal Track

9(2)(a) [redacted] 04/09/2023 9(2)(a) [redacted]	9(2)(a) [redacted] 9(2)(a) [redacted] 05/09/2023

Table of contents

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

1. Introduction

The 60-km Abel Tasman Coastal Track (ATCT) is a 'Great Walk' that follows the coastline of the Abel Tasman National Park. As a Great Walk, it is popular for multi-day tramping, typically walked in 3-5 days, with four huts, and several campsites and shelters along the way. However, the predominant users are day visitors who utilise the water taxi operators to access the track at several beach access points.

The Department of Conservation has become aware that landslides are increasingly causing track closures and damage to track infrastructure on the ATCT. In August 2020 a storm event triggered multiple landslides resulting in the closure of significant sections of the track. In September 2022 another significant storm event forced the closure of the track in the Medlands Bay to Bark Bay Area. The observed landslide damage is likely to be exacerbated by the effects of ongoing climate change.

This project provides an evaluation of landslide hazards along the ATCT and estimates the ongoing maintenance and projected trouble areas that are likely to cause track closures as a result of rainfall triggered landslides. Rainfall-triggered landsliding under current and future climate scenarios is evaluated. This report addresses slope instability hazards related to slippage and debris inundation associated with rapid landslides (debris flows, rock fall, and rock/debris avalanche, etc), triggered by intense rainfall. It does not evaluate slow moving, or creeping landslides, or other natural hazards that could affect track users such as subsidence, outburst floods or flooding. It focusses on damage to the track and structures by assessing the potential of landslide slippage hazards and landslide debris inundation hazards. To quantify the risk of these impacts, the project has assessed:

i) The likely locations of landslide source areas (slippage hazards),
ii) The likelihood of rapid landslides of different sizes occurring with the potential to reach the tracks, campsites or huts (debris inundation hazards), and
iii) The likely extent of damage caused by these landslides.

The objective of this project is to provide the decision maker with an enhanced means of strategically managing the landslide risk in respect to climate change on the ATCT.

2. Context

The Abel Tasman coastline is a dynamic environment where the mountains meet the sea, and over the past few years there have been a number of geological hazard incidents, which have caused damage to the track. These incidents have led to temporary track closures, increased maintenance costs and in some cases an elevated level of safety risk for visitors and staff.

Over the past few years there has been a noticeable increase in the frequency and magnitude of heavy rainfall events in the region, causing more frequent and larger landslides. The New Zealand Climate Change Centre published a report titled Climate Change IPCC Fifth Assessment Report New Zealand Findings[1], which explains the findings from the most recent Intergovernmental Panel on Climate Change (IPCC) report. It notes:

- New Zealand's temperature is expected to keep on rising throughout this century – by about 3.5°C above the 1986-2005 average
- Expected rise in extreme rainfalls (up to 8% more intense rain for every 1°C of warming, but with significant regional variations)
- Global sea level rise by 2100 of about 0.5–1 metre above the 1986–2005 average. Even if temperatures peak and decline, sea level is projected to continue to rise for many centuries at a rate

[1] Available from:
https://niwa.co.nz/sites/niwa.co.nz/files/NZCCC%20Summary_IPCC%20AR5%20NZ%20Findings_April%202014%20WEB.pdf

dependent on future emissions. Sea level rise around New Zealand may be up to 10% higher than the global average
- Rising sea levels and increasing heavy rainfall are projected to increase flooding and erosion in many coastal areas and particularly near river mouths, with escalating risks to many low-lying ecosystems, infrastructure and housing.

The National Institute of Water and Atmospheric Research (NIWA) has developed and maintain a modelling tool called the High Intensity Rainfall Design System[2] (HIRDS), which can estimate expected rainfall depths (annual) and intensity (mm/hour) for future design storm events based on the IPCC climate change projections, taking into account local topographic effects and other factors. It shows that the current average rainfall intensity of a ten year storm event for the Abel Tasman coastline is in the order of 40 mm/hour (181 mm in 24 hours), but that this is predicted to increase to approximately 45 mm/hour by 2031[3] (193 mm in 24 hours). Similarly, the current average rainfall intensity of a one hundred year storm event is in the order of 62 mm/hour (274 mm in 24 hours), but this is predicted to increase to approximately 69 mm/hour (294 mm in 24 hours) by 2031.

The specific *local* effects of climate change are difficult to accurately predict, but it can be expected that landslides will have severe effects on the ATCT in the future. It should also be noted that other effects of climate change may impact the use and maintenance of the ATCT. These include drought related forest fires and high wind events causing large scale tree fall as well as other, unprecedented events, which are not presented in this report. This report focuses solely on the landslide hazards present on the ATCT.

3. Methodology

Fieldwork observations combined with GIS interrogation of remote data[4] has allowed for estimations of the various effects described below. The remote datasets[5] comprise:

- Aerial photography collected in 2001-2002 (not a complete dataset for the entire study area)
- Aerial photography collected in 2004-2005 (not a complete dataset for the entire study area)
- Aerial photography collected in 2022 (a complete dataset for the entire study area)
- 1 m LiDAR based digital elevation model (DEM) supplied by Tasman District Council, collected in 2016 (a complete dataset for the entire study area). The LiDAR DEM has been used to generate two maps:
    - A slope angle map, which divides the land area into categories based on slope angle categories and is useful in highlighting where the steeper (and less steep) terrain lies
    - A shaded relief map (sometimes called a hillshade map) which is a cartographic technique where a lighting effect is added to a map based on elevation variations within the landscape. It provides a clearer picture of the topography by mimicking the sun's effects (illumination, shading and shadows) on hills and valleys. This is sometimes useful in identifying landslides that are not visible in aerial photos

A landslide inventory containing 85 landslides has been created based on observations of these datasets and fieldwork observations (38 landslides mapped from remote sources and 47 mapped in the field). For the purpose of GIS interrogation, only slopes that are directly above or below the track have been mapped. The relative spatial distribution of these landslides has allowed for the identification of areas that are more (or less) likely to experience landslides in the future, based on the assumption that the physical conditions (i.e. geology, slope angle, rainfall amounts and ground cover) that led to the current landslide distribution are likely to lead to future landslides in other areas that share similar ground and atmospheric conditions. Where landslides occur in spatial clusters or where similar ground conditions exist in the vicinity of an identified

[2] https://hirds.niwa.co.nz/
[3] Assuming the Relative Concentration Pathway (RCP) 8.5
[4] All remote data for landslide mapping was accessed via the LINZ Data Service available at https://data.linz.govt.nz/data
[5] For examples see Appendix A

landslide cluster, these areas are classed as being highly susceptible to landslides. The highly susceptible areas are then described in terms of:

- Current situation (a description of the recent observations)
- Likely situation by 2033 (ten years from now)
- Likely situation by 2043 (twenty years from now)

The remaining track areas, that are not highly susceptible to landslides, should be treated as being at "moderate" susceptibility unless the ground is inclined at less than 10°, where the landslide susceptibility would be "low". Comment is made below on the likely future landslide risks in the highly susceptible and moderately susceptible areas only. Low susceptibility areas are not discussed further in this report.

Point locations that are at risk of damage due to debris flows have been identified based on the upslope catchment area size and the susceptibility of that ground to landslides. Additionally, bridges with less than 1m clearance (creek bed level to base of deck bearers) that cross waterways that have been identified as being at risk of debris flow have been flagged as being at risk of damage from those debris flows.

The actual effects of increased rainfall amounts and intensities (as shown by the HIRDS model) on landscape stability are not known and to a large degree, experience-based geological and engineering judgement has been used to make the predictions contained within this report. For that reason (and the uncertainty inherent to any climate change predictions) the results of this study are presented with the caveat that this is a "best estimation" of future effects, not an accurate empirical prediction. As such, these effects may be more or less severe than described below. In general the future effects have been estimated based on the Relative Concentration Pathway (RCP) 8.5 scenario, which is widely regarded as the most appropriate scenario for near-term climate change effects studies[6].

Note: due to the low number of data points, lack of any historical landslide catalogue[7] information and incomplete historical aerial photography data, it is not possible to generate a mathematical probability of future landslide occurrence. As such, this report presents the qualitative landslide susceptibility[8] and estimates the likely levels of risk to the track, infrastructure and visitors in the areas that have been identified as being highly susceptible to landslides.

4. Local geology

The published geology[9] shows that the Abel Tasman National Park is underlain almost exclusively by equigranular biotite granite of the Separation Point Suite. The "Separation Point Granite" (SPG) is typically highly weathered with most of the original rock mass strength being lost to chemical decomposition. Much of the rock mass is changed to a residual soil, composed of soft clay and coarse quartz sand. It is this sand that forms the golden beaches that the Abel Tasman National Park is famous for. The weathering persists deeply into the rock mass primarily along tectonically induced fractures and quartz veins, with corestones[10] often suspended within the residual soil. The residual soil is not conducive to plant root growth and the often-dense vegetation cover is formed on a shallow (usually less than 0.5 m thick) veneer of organic soil, with little or no root penetration into the underlying residual soils. The residual sandy soil has low cohesion and is prone to rainfall (and coastal/fluvial) induced erosion and landslides.

In contrast to the deeply weathered granite, there are also local areas within the park where the weathering is very shallow or effectively non-existent and strong to very strong granitic bedrock is exposed at the surface.

[6] https://www.sciencedaily.com/releases/2020/08/200804085912.htm
[7] A landslide catalogue is a database of historical landslides that have occurred in a given study area. It can be a useful tool in identifying landslide frequency over time and is usually collected over a period of years as landslides occur. The longer a landslide catalogue is maintained, the more useful the data becomes for predictive and general landslide management applications.
[8] Landslide susceptibility mapping is a hazard zonation technique that classifies mapped areas as low to high likelihood of landslides occurring. It does not present risk or vulnerability information.
[9] GNS Science. (2012). Geological Map of New Zealand [Data set]. GNS Science. https://doi.org/10.21420/QF82-7D42
[10] Corestones are suspended granite boulders that form as a result of spheroidal weathering

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

The change of weathering grade does not appear to follow a pattern and the ATCT passes through areas where deeply weathered, fully decomposed rock changes to very strong, fresh exposure over a distance of only a few hundred millimetres.

The SPG is locally well known for its easily erodible and unstable form. The Nelson Tasman Erosion and Sediment Control Guidelines[11] classify this rock and soil type (along with the Moutere gravels and Karst areas) as a "vulnerable" geology and they have attributed a set of specific rules for any land development/disturbance being undertaken on SPG sites, designed to limit the effects of uncontrolled erosion. On 15 December 2011 more than 200 landslides and debris flows were recorded around the region causing numerous road closures and 190 evacuations. The landslides and debris flows generally originated in steep hills underlain by SPG geology. In 2018, ex-tropical Cyclone Gita caused widespread landsliding across the SPG geology areas.

5. General descriptions of landslide types affecting the Abel Tasman Coastal Track

There are three principal landslide types that affect the Abel Tasman Coastal Track and all of these are intrinsically related to the SPG geology. It is important to understand that whilst these three landslide types have different characteristics and ground failure modes, there is a continuum of form between all three and some complex (usually larger) landslides will exhibit characteristics oftwo or three of the observed landslide types. These are described in detail below:

5.1 Translational/rotational soil slides

Translational/rotational soil slides are the most commonly observed landslides along the ATCT, occurring within the soft residual soil layer. Where deep soil is positioned on steep slopes (typically over 30°) soil slides can occur due to excess weight of water, increased pore fluid pressure and loss of cohesion during heavy rainfall events. Translational slides will have a planar slide (rupture) surface, which is often associated with the soil/bedrock interface. Whereas a rotational slide will have an arcuate slide surface and the movement is within the residual soil layer. Generally, soil slides are relatively slow moving (1-2 m per minute or less) and often the displacement distance of the slipped material is limited to a few millimetres to a few metres. However, much larger displacements can also occur. Because of the slow moving nature of these types of landslides they typically do not present a high risk of harm to visitors. However, the damage caused to the track can be significant and difficult to effectively remediate, particularly where the movement is ongoing and the track formation itself is removed (an underslip). The displaced soil (landslide debris) is usually composed of sand and clay with a small volume of organic soil and vegetation, but can also contain granite boulders (corestones or fractured bedrock pieces). Soil slides may continue to move (creep) downslope for weeks or months after the initial movement until they either stop moving or a more catastrophic failure occurs. Figures 1 to 6 below show some of the features of soil slides along the ATCT.

[11] Available from: https://www.nelson.govt.nz/assets/Environment/Healthy-Streams/erosion/Chapter-3-Land-Disturbance-Issues.pdf

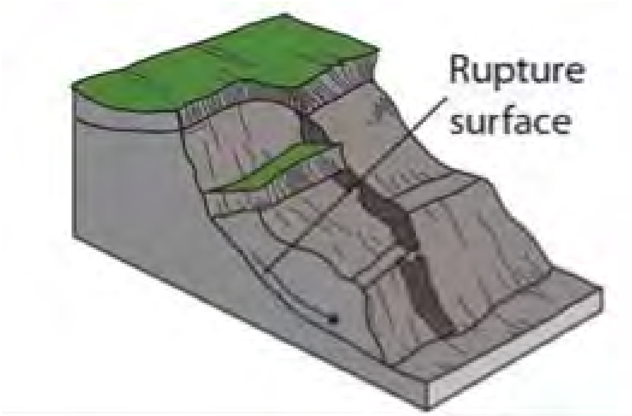


Figure 1. Schematic representation of a translational/rotational soil slide[12].

Figure 2. Typical translational slide below the track close to Anapai Bay.

Figure 3. Translational slide with ~0.5 m displacement south of Tonga Quarry. It is likely that this landslide will continue to be active for some time.

Figure 4. Shallow translational slide with large displacement distance of soil close to Waiharakeke Bay. This landslide likely occurred 3-5 years ago and has begun to revegetate and naturally stabilise.

Figure 5. Large translational slide with complete soil displacement at the Torrent River swing bridge (Cleopatra's Pool). Corestones are visible in the

Figure 6. Translational slide with 0.5 m displacement along the bedrock/soil interface to the north of Tonga Quarry (Onetahuti Beach).

[12] From Varnes' 1978 Landslide Classification System.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

upper part of the landslide scar close to the headscarp[13].	

Soil slides can occur in any steeply sloping area, particularly in bowl-shaped gullies where deep accumulations of soil combined with stormwater and groundwater loading can lead to excessively wet and soft ground conditions. However, these landslides are often associated with the track bench and cut batter. Any natural slope exists in a state of slope equilibrium; i.e. the process of erosion matches the rate of tectonic uplift and the slope angle is defined by the interaction of soil properties, vegetation cover, underlying geology and rainfall amounts. Any change to those defining properties can lead to instability issues. This is particularly the case with track building and maintenance in any mountainous or hilly country. When a track bench is built, the slope is inevitably over-steepened on the upslope side of the track (the cut batter) and on the downslope side of the track (the fill slope). The natural landscape response is for small landslides to occur on the cut batter and fill slope, until the slope equilibrium is re-established. This is particularly common where fill material has been placed on a natural slope without proper stripping and benching of the receiving area. Larger soil slides, which affect a wider area are also commonly caused (or partly caused) by the track construction[14]. This can happen in any of the following ways:

- Direct water ingress through the flat track surface causing saturation of soils under the track and in the fill slope. This can be exacerbated by poor drainage provision and maintenance.
- Uncontrolled stormwater runoff due to culvert blockages, or poor culvert placement. When a culvert becomes blocked, stormwater flows over the track surface and rapidly erodes a channel into the bench that can quickly develop into a soil slide.
- Point loading of stormwater discharge onto a fill slope due to poor culvert design and placement
- Intense or prolonged rainfall causing general saturation of cut or fill slopes

Typically, these effects are minimised by installation and ongoing maintenance of drainage infrastructure and general track maintenance. Changes to rainfall amounts (due to climate change) can also lead to a shift from the state of slope equilibrium and triggering of landslides.

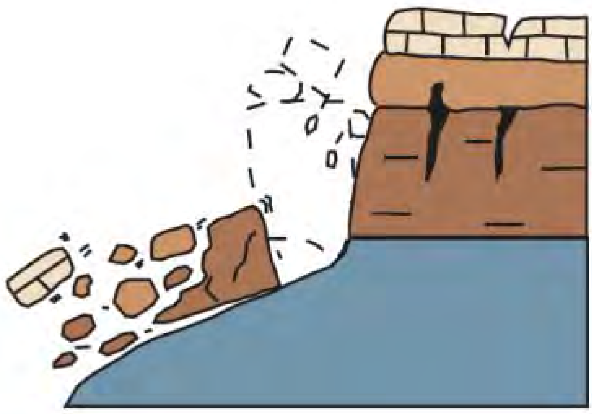
When a landslide originates from above the track inundation on the track bench can result. In these cases, it is usually possible to easily reinstate the track by either removing the debris, or constructing the track over the debris. Due to the slow moving nature of soil slides, the runout[15] distances are usually short (unless the slide transforms into debris flow as described below), meaning that the huts and campsites are generally not affected by these types of landslides. Prevention of these landslides (originating above the track) is usually not possible.

When a landslide originates on or below the track bench and causes slippage of the bench, reinstatement can be much more difficult and often requires re-routing the track. However, in contrast to landslides above the track, it is often possible to limit the likelihood of these events occurring by simply ensuring that effective stormwater drainage is installed and maintained on the track bench. It is much more difficult to retrospectively improve the stability of existing fill that may have been pushed out over an unstripped natural slope.

[13] The headscarp is the upper part of the landslide where the soil layer has torn from its original position.
[14] During fieldwork I observed 33 individual landslides that were at least partly caused by track construction/maintenance
[15] The runout is the distance that the debris travels from the landslide's original position.

5.2 Rock falls

Where rock outcrops are present on steep slopes (often referred to as rock bluffs or cliffs) rock fall (or rock topples) can occur. Due to preferential weathering along fracture surfaces (and sometimes un-weathered fractures) and the inherently weak nature of the SPG, rockfall is common. Additionally, where soil slides have exposed corestones and fractured bedrock (as described above), there is likely to be a risk of rockfall from within that area. Rock fall typically involves a quantity of rock releasing from a rock bluff and free falling, rolling, bouncing or sliding down a slope. if the rock is less-weathered it is likely to remain intact as boulders rather than breaking up as sand. This rock movement is rapid and the rock debris runout zones usually reach the base of the slope, or shallowly inclined ground. The rock debris from a large scale rockfall event can move as dry, fluidised mass and behaves as a rock avalanche type movement. Rockfalls are usually triggered by heavy rainfall events but can also occur due to high wind (usually triggered by a wind thrown tree fall), prolonged periods of drought, erosion at the toe of a slope (sea cliffs or river bank erosion) or randomly. Due to the rapid, high-energy nature of rock fall events, this landslide type presents a high risk of harm to track users if people are present at the time. Figures 7 to 12 below show some of the features of rockfalls along the ATCT.

 Figure 7. Schematic representation of a rockfall / topple[16].	 Figure 8. Large scale rockfall at Bark Bay.
 Figure 9. Granite corestones exposed in the upper part of the Torrent River landslide.	 Figure 10. Residual rockfall risk in a translational soil slide scar at Medlands Bay.

[16] From Varnes' 1978 Landslide Classification System.

	
Figure 11. Small scale rockfall on the track at Ratakura Point.	Figure 12. Rockfall at the Anchorage hut and campsite.

Prevention of rockfall along the ATCT is not possible. Rockfall risk reduction usually involves avoidance of the hazard, because treating the hazard by installation of engineered structures is usually cost prohibitive and, in many cases, not highly effective.

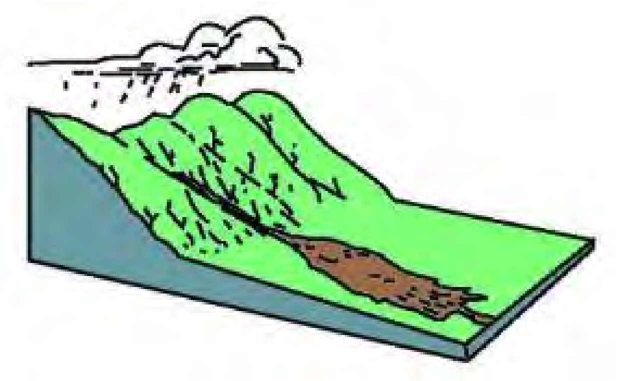
5.3 Debris flows

When a steep river or stream becomes swollen, the stream bed and banks can erode and the eroded material is carried downstream by the high energy water flow. This is normal in any stream or river channel. When stream bank erosion becomes excessive, or if large volumes of debris derived from other landslides are added to the stream water flow, the volume of debris can exceed the volume of water. In these cases, the stream flow is then termed a debris flow. Additionally, landslide debris from a soil slide or rockfall (as described above) can fluidise and form a debris flow if enough water is present within the debris. Debris flows move at high speed with high energy and can entrain additional soil/rock/vegetation material as the debris flow moves downslope gaining in volume and energy as it moves. Typically, debris flows (including along the ATCT) have long runout distances and usually come to rest at the base of the slope (i.e. the valley floor or beach). However, these areas can remain active for a number of weeks/months after the initial event. Repeated instances of debris flow deposition (and normal stream flow deposition) where a creek emerges from a steep slope lead to the build up of an alluvial fan (sometimes called a debris fan). An alluvial fan is a conical shaped sedimentary (sand, gravel and rock) deposit that forms by sporadic, flood related and debris flow related deposition of material over time. Typically, a stream will migrate from side to side over the alluvial fan, depositing debris material more or less uniformly to create the conical shaped landform; i.e. on an alluvial fan where the stream bed is positioned towards the north of the fan, the stream bed will migrate back towards the south as material is deposited in the existing stream bed area. Because of the high speed and high energy movement of debris flows, they present a high risk of harm to track users if people are present at the time. Additionally, debris flows can deposit large volumes of debris on the track surface and/or cause slippage to the track bench, which may be difficult to remediate.

Currently, the occurrence of debris flows along the ATCT is much less frequent than soil slides and this type of landslide appears to be triggered by rainfall amounts in excess of 220 mm in 24 hours. However, it is expected that with increased frequency of high intensity rainfall events, debris flows will become more common.

Figures 13 to 16 below show the typical features of debris flows on the ATCT.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

 Figure 13. Schematic representation of a debris flow[17].	 Figure 14. This debris flow at Bark Bay originated as a rockfall event (Figure 8) and travelled over 180 m, across the track and onto the beach.
 Figure 15. Debris flow gully at Torrent Bay, 300 m south of the campsite.	 Figure 16. Track inundation damage caused by the debris flow shown in Figure 15 (Torrent Bay)
 Figure 17. Debris flow at Bark Bay close to the hut, campsite and warden's hut.	 Figure 18. Track inundation damage caused by the debris flow shown in Figure 17 (Bark Bay).

[17] From Varnes' 1978 Landslide Classification System.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

Prevention of debris flows is not possible, so avoidance is the most effective risk reduction strategy. Many debris flows occur as a result of saturation of landslide debris derived from other landslides (soil slides/rockfall) combined with surface water runoff and in these cases the only sensible way to plan or prepare for the event is avoidance of the hazard (either by utilising different areas of land that are less prone to the hazard, or by temporarily closing debris flow prone areas during heavy rainfall events). However, where specific natural drainage gullies or creeks can be identified to be at risk of debris flows, installation of larger culverts (designed to accommodate the additional volume of debris in the creek bed) may help to reduce the risk of track damage and closures.

6. High landslide susceptibility areas of the ATCT

Ten track sections have been identified as being highly susceptible to landslides. Figure 19 below shows the locations of those track sections and in the following pages each of those sections is described in detail. In each of the tables below, the likelihood of a debris flow causing damage to the track and bridges has been summarised by highlighting point locations where debris flows are likely to occur. For each predicted debris flow point location, it is estimated that a debris flow will affect that point once every 20 years, increasing to once every 10 years by 2033 and increasing again to once every 5 years by 2043. The likely damage to the track caused by a debris flow is of complete bench collapse up to 5 m wide and/or debris inundation up to 1m deep x 10-15 m wide. Additional point locations that are susceptible to debris flow damage (and are not within the ten highly susceptible track sections) are shown in Section 6.11 below.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

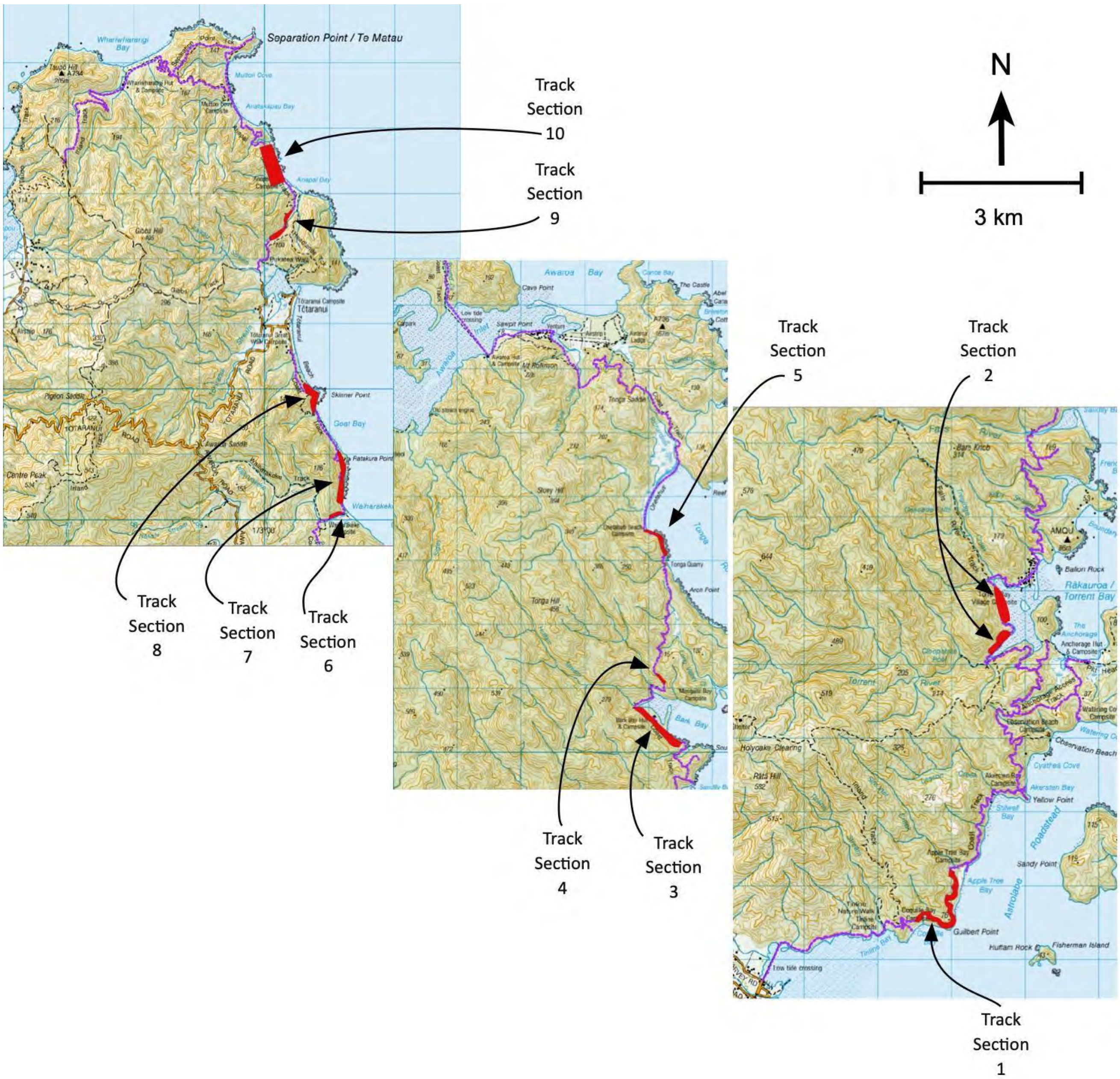


Figure 19. The locations of the ten track sections that have been identified as being highly susceptible to landslides.

6.1 Track Section 1. Coquille Bay to Apple Tree Bay

On this 1709 m long section, the track follows the coast around Guilbert Point, traversing 20-35° ground above steeper (>50°) 20-30 m high coastal slopes and cliffs. Table 1 and Figure 20 below summarise the features and predicted future landslide activity in Track Section 1.

Landslide density (landslides /km)	Debris flow risk to bridge (sites)	Debris flow risk to track (sites)	Current situation	Situation by 2033	Situation by 2043	Comments
4	1	4	Moderately to steeply sloping coastal soil slopes with numerous shallow translational	Landslide frequency increases to 1 every year and the expected increase in size makes remediation more	Landslide frequency increases to 2-3 every year and the expected size makes remediation even more challenging.	All of the identified landslides have originated on the track bench, indicating that improved

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

			soil slides. Low safety risk to track users. Due to the moderate slope, remediation is usually easy and involves cutting a bench back into the weathered bedrock with an excavator. Landslide frequency: 1 every 2 years.	challenging. i.e. larger cut batters and fill slopes. Increased maintenance (clearing small cut batter collapses) due to larger cut batters.	Cut faces begin to require mechanical stabilisation. Still feasible to maintain a track through the area. Erosion at toe of slope due to storm surge and wave action may exacerbate the slope instability issues.	maintenance/track design could help to reduce the likelihood of future landslides occurring.

Table 1. Summary of current and predicted landslide activity in Track Section 1.

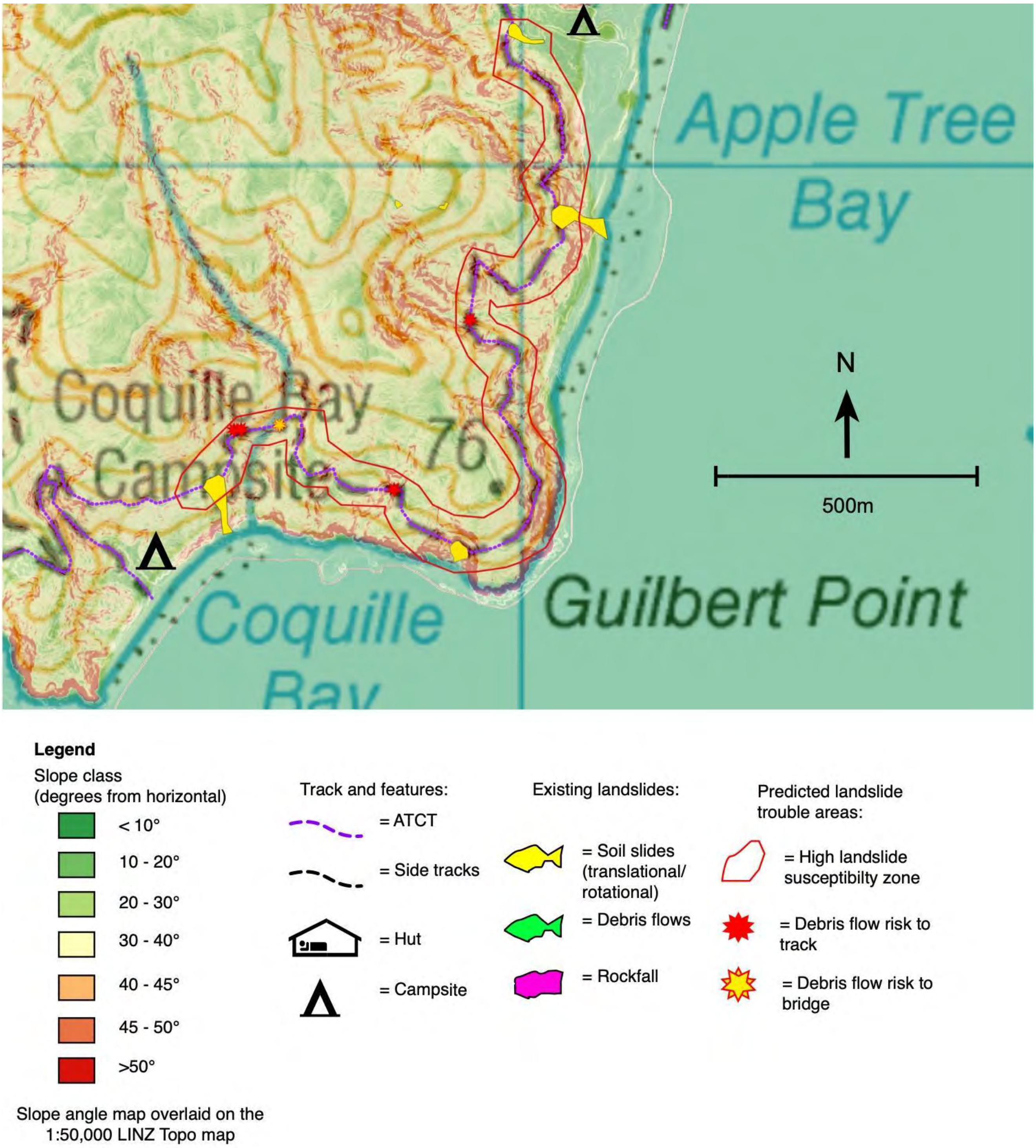


Figure 20. Map of features in Track Section 1.

6.2 Track Section 2. Torrent River to Torrent Bay Campsite

On this 935 m long section, the track follows the coast around the eastern side of the Torrent Bay estuary, traversing 15-35° ground close to the estuary edge. Above the track is a uniformly steep (30-50°+) easterly and south easterly slope that extends 200 m (elevation) above the track. The slope has a shallow soil layer and is prone to shallow translational soil slip type landslides that often transform into debris flows. There is evidence of debris flow deposition on the estuary edge in a number of locations. However, given the shallow depth of soil, the volume of debris is typically low and the debris flow chutes are less than 1 m deep incisions in the ground. Revegetation occurs quickly and the observed debris flows and historic debris flow channels remediate naturally within a few years of occurrence. Figures 15 and 16 (above) show a typical debris flow located within this track section and usually involves deposition of debris material on the track surface (not track slippage).

Table 2 and Figure 21 below summarise the features and predicted future landslide activity in Track Section 2.

Landslide density (landslides /km)	Debris flow risk to bridge (sites)	Debris flow risk to track (sites)	Current situation	Situation by 2033	Situation by 2043	Comments
2 (there are 2 current debris flow chutes that occurred in the past 2-3 years. However, there are at least 4 areas on the estuary edge that show evidence of past debris flows)	1	Entire section	Highly susceptible to low volume, high frequency debris flow events. Low safety risk to track users (assuming that the track is temporarily closed during forecasted heavy rainfall events). Remediation involves building a track over the debris pile and reactive drainage management. Landslide frequency: 1 every 2 years.	Landslide frequency increases to 1 every year. Magnitude of debris flow volumes increases causing larger debris piles on the track bench, and occasionally, this will lead to track bench collapse (slippage), which would be much more difficult to reinstate quickly.	Landslide frequency increases to 2-3 every year and the expected size makes remediation even more challenging. Larger landslides including bedrock failure (rockfall/rock avalanche) may occur. Erosion at toe of slope due to storm surge and wave action may exacerbate the slope instability issues (causing track slippage).	All of the identified landslides have originated above the track bench, meaning that there is no feasible way to reduce the likelihood of future landslides occurring, i.e. track maintenance will have little effect on the risk of damage due to landslides in this track section.

Table 2. Summary of current and predicted landslide activity in Track Section 2.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

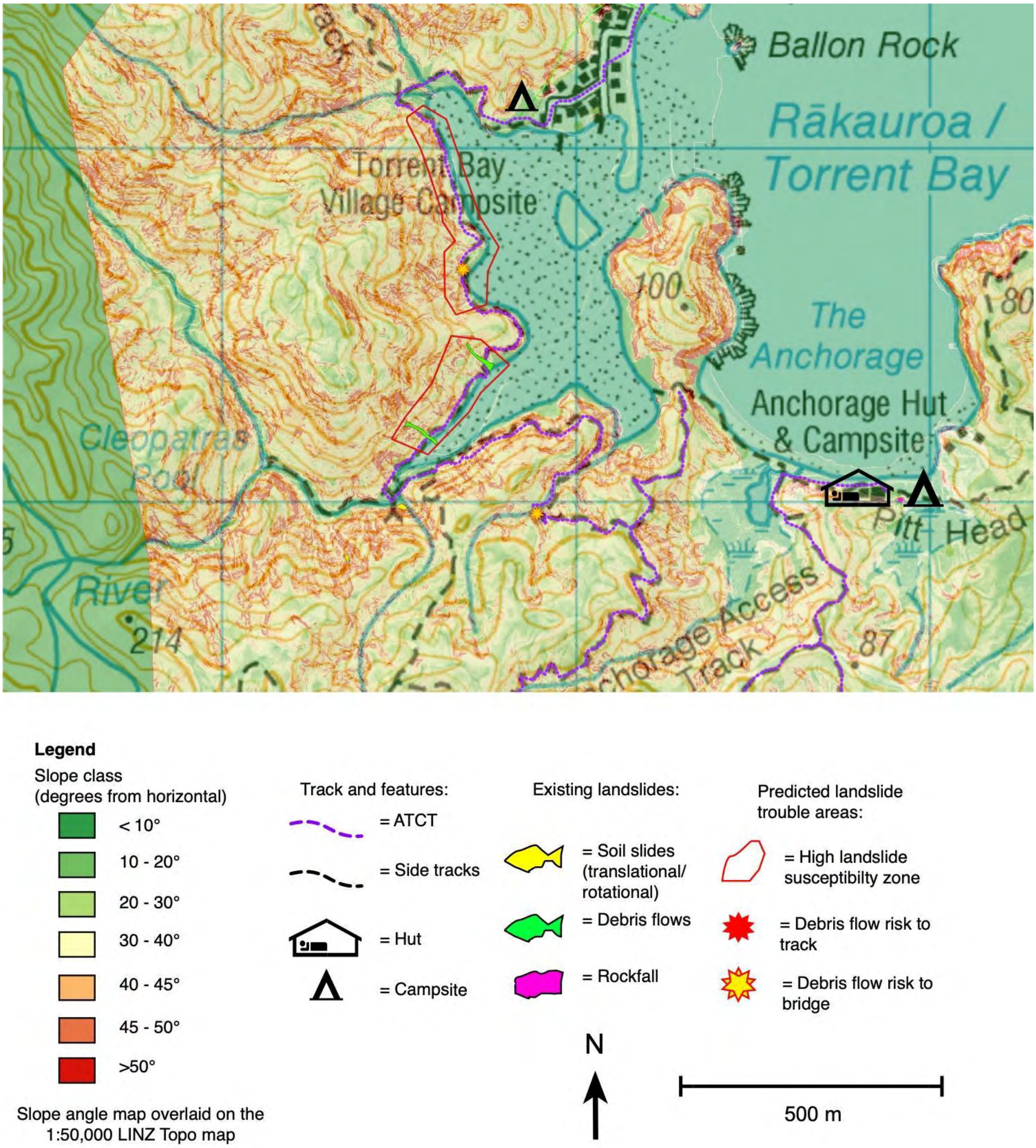


Figure 21. Map of features in Track Section 2.

6.3 Track Section 3. Medlands Bay to Bark Bay (including the Bark Bay Hut and Campsite)

On this 950 m long section, the track follows the coast around the southern side of Bark Bay and through forested flood plain/alluvial fans along the south side of the Huffman Stream estuary. It also includes the Bark Bay Hut and Warden's quarters as well as the iconic Bark Bay sandspit campsite. The coastal section of the track (to the south east of the sandspit campsite) follows the coastline above 15-25 m high coastal cliffs. Recent landslide damage (2022) in this area caused the closure of the track for a number of weeks and the track has been temporarily reinstated over three large landslides (two of these are debris flows with the temporary track crossing the debris, and the third is a translational soil slide with the temporary track benched

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

into the landslide scar utilising temporary timber steps. Planning work is underway to relocate the track to a more permanent location located further up the slope in an area that is less prone to landslide damage.

Table 3 and Figure 22 below summarise the features and predicted future landslide activity in Track Section 3.

Landslide density (landslides /km)	**Debris flow risk to bridge (sites)**	**Debris flow risk to track (sites)**	**Current situation**	**Situation by 2033**	**Situation by 2043**	**Comments**
3 (there are 3 current debris flows chutes and one translational soil slide that all occurred in 2022. However, there is evidence in the estuary edge of repeated past debris flows)	0	Entire current section, but the newly planned section is located above the risk area, so is not prone to debris flows (or soil slides)	Very steep (>50°) rock outcrop positioned at about 120 -160 m (elevation) is prone to large scale rockfall /block topple type landslides. Rock debris can fluidise, and form debris flows which typically reach the base of the slope (beach or forested flood plain / alluvial fans). Planning work is underway to realign the track in the coastal section to a lower risk area. Estuary section (including ground close to the hut site*) is in the potential landslide runout zone area. Inundation is typically low energy and the track can easily be reinstated on top of the debris. Landslide frequency: 1 per year.	Assuming the planned re-route is constructed, the risk of landslide damage on that section will be low. Floodplain section-landslide frequency increases to 2 every year. Magnitude of debris flow volumes increases causing deeper debris piles on the track, but reinstatement will still be straightforward. Risk to hut may increase and should be monitored.	Landslide frequency increases to 3 every year and the expected size makes remediation more challenging. Higher energy debris deposition may cause tree fall close to the base of the slope and this would further complicate the track reinstatement after a debris flow event. If rockfall sourced from the steep rock outcrop band becomes significantly larger, the risk of harm to the hut may also become significant.	All of the identified landslides have originated above the track bench (the soil slide in the south eastern end of the section *may* have originated on the track bench), meaning that there is no feasible way to reduce the likelihood of future landslides occurring; i.e. track maintenance will have little effect on the risk of damage due to landslides in this track section. Due to the potential vulnerability of visitors at the hut site, specific ongoing hazard monitoring should be undertaken, and detailed risk modelling may help to support decision-making about hut site suitability in the future.

Table 3. Summary of current and predicted landslide activity in Track Section 3.

* Note on landslide risk at the hut and campsite:

There is a debris flow runout area that has caused inundation on the track located to the south of the Bark Bay Hut. The inundation comprises up to 0.5 m depth of sand/silt debris and was deposited in a low energy state at the base of the slope (the sand is inclinedat 5-10°, being deposited on relatively flat ground as the sediment being carried by the stormwater dropped out of suspensionas the flow lost its energy on the flatter ground. Trees and other vegetation in the inundated area have not been damaged (other than minor inundation at the base of the trunks), further illustrating the low energy state of the debris inundation. The inundation area extends up to 40 m from the base of the steep slope and has affected a 70 m long section of the track. The hut is located on flat (slightly elevated) ground 50 m from the base of the slope, so is not currently considered to be at risk from debris flow inundation. The hut is located outside of, but within 10 m of the potential inundation zone and the current landslide hazard would likely only cause low energy debris inundation in this area which is not likely to cause structural damage to the hut or present a risk of harm to visitors staying in the hut. However, there is potential for much larger scale rockfall events (due to climate change), which may cause the magnitude of the resultant debris flows to also increase and extend the hazard footprint to *include* the hut

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

site. Currently, the hut is at low risk of harm due to landslide debris impact damage, but larger events may cause damage to the hut site in the future.

The campsite is located on the sand spit, so is not prone to landslide damage (although it is at severe risk of coastal erosion damage, whichis excluded from this report).

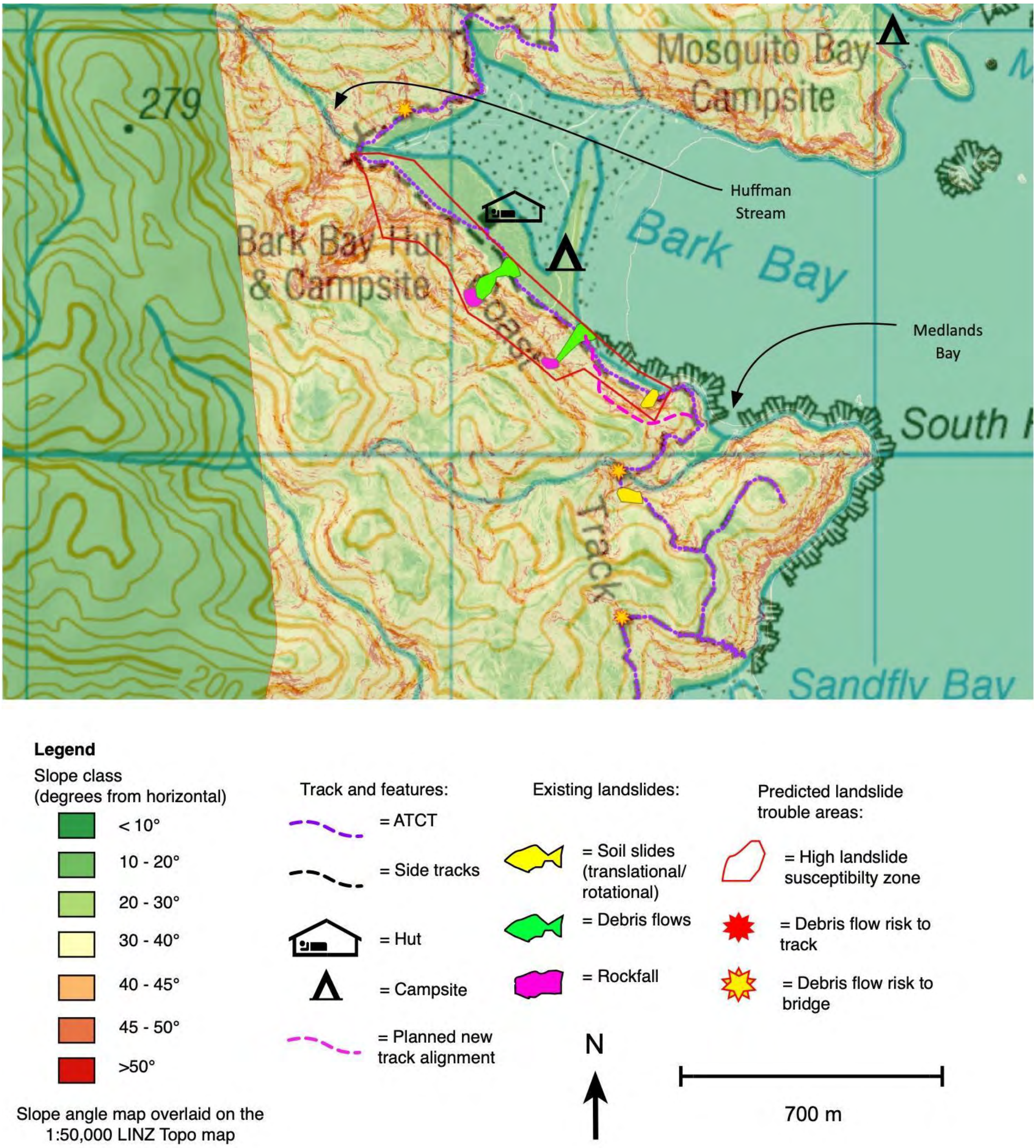


Figure 22. Map of features in Track Section 3.

6.4 Track Section 4. Climb out of Bark Bay

On this 200 m long section, the track climbs (or descends if travelling from north to south) up a 20-40° southerly aspect slope. The track has been cut into the slope and in two areas the cut slope has collapsed, causing minor inundation on the track surface.Ongoing frittering[18] of these unstable cut slope areas causes frequent drain blockages and an elevated likelihood of more severe track damage (i.e. translational soil slide due to bench saturation). The general slope characteristics show deep soil cover with dense vegetation. There is evidence of ongoing slope creep (uniformly bent tree trunks, and exposed tree roots) and minor soil frittering particularly in the steeper areas of the slope. This slope is very fragile and may be highly susceptible to the effects of climate change.

Table 4 and Figure 23 below summarise the features and predicted future landslide activity in Track Section 4.

Landslide density (landslides /km)	**Debris flow risk to bridge (sites)**	**Debris flow risk to track (sites)**	**Current situation**	**Situation by 2033**	**Situation by 2043**	**Comments**
2 (these are minor cut slope collapses that are confined to the area that was excavated as part of the track construction works)	0	0	Minor cut slope collapses causing an elevated risk of drainage related bench slippage. Slope creep in surrounding slope (above and below the track) indicate the fragility of the slope and highlight the requirement for diligent maintenance.	Increased rainfall amounts are likely to cause additional minor cut face collapses and further increase the risk of drainage related issues. Also may cause an overall increased susceptibility to larger soil slides that are not associated with the track bench, but would cause severe inundation or slippage damage to the track. Landslide frequency: 1 every two years	Landslide frequency increases to 1 every year and the likelihood of larger soil slides increases. Entire slope above and below the track becomes unstable and slope creep accelerates.	All of the identified landslides have originated on the cut slope above the track and the debris has the potential to cause drain blockages that are likely to lead to larger scale track bench slippage if not cleared quickly. Future large landslide events on this slope may occur as a result of crossing a climate threshold on this very fragile slope.

Table 4. Summary of current and predicted landslide activity in Track Section 4.

[18] *Fritter* is a term used to describe small scale erosion-related movements of soil and rock

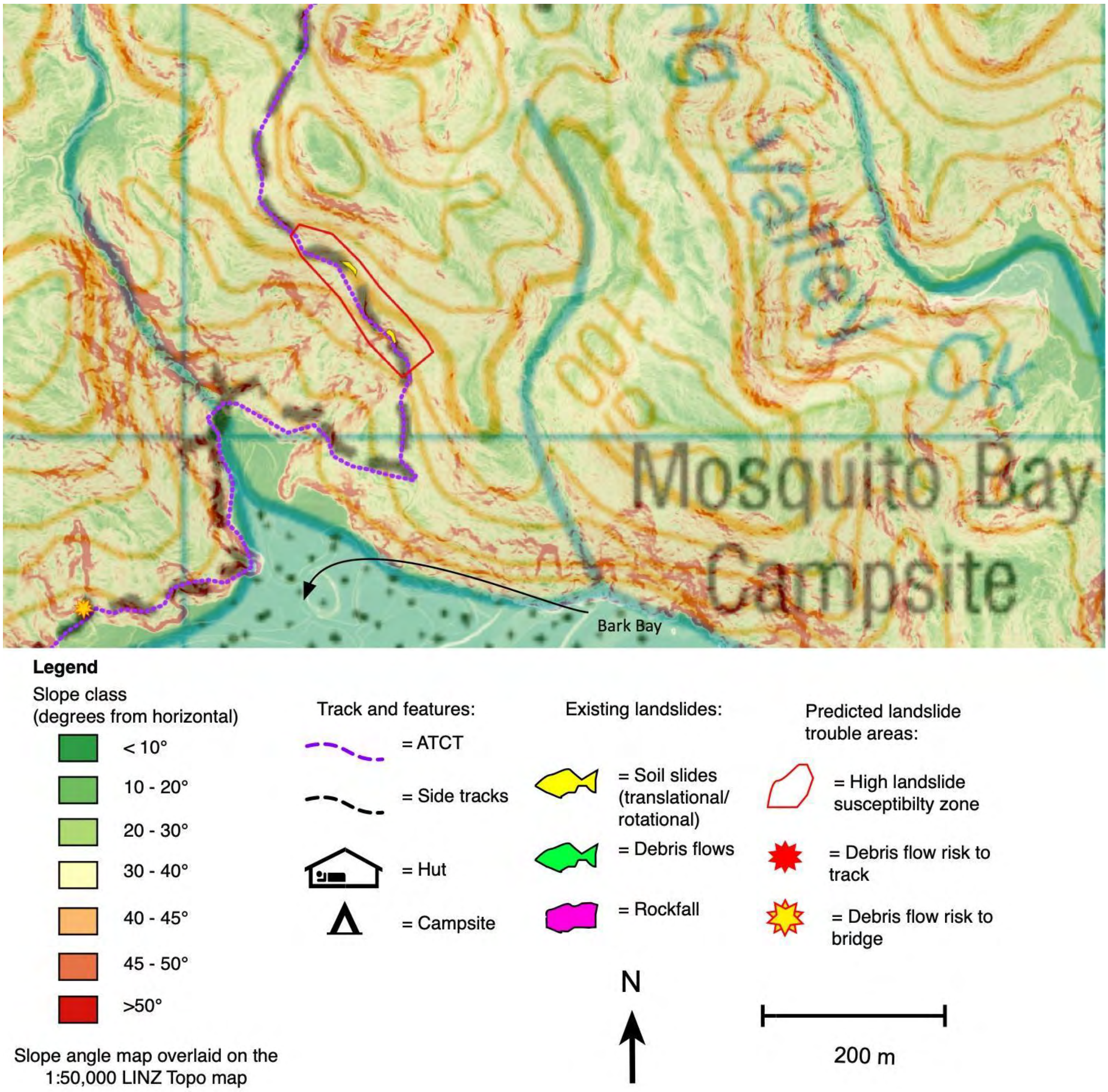


Figure 23. Map of features in Track Section 4.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

6.5 Track Section 5. Tonga Quarry to Onetahuti Beach

On this 570 m long section, the track traverses around steep (often over 50°) coastal cliffs from Tonga Quarry to Onetahuti Beach. The exposed granite in this area is less heavily weathered than in other areas of the ATCT and is stronger[19], being able to form steep, high coastal cliffs. In this area there is an abrupt material type transition at the rock/soil interface with little to no residual soil layer present. The bedrock is strong and has a thin (<1 m thick) veneer of organic soil only, which supports a dense cover of trees and other vegetation. A large translational soil slide (affecting 60-80 m of track) located on the track bench has caused part of the track bench to be displaced downslope by up to 0.7 m vertically and 0.5 m horizontally. In this area the track is positioned close to the top of the coastal cliff and any further movement of the soil slide is likely to result in complete loss of the track bench and collapse onto the beach, 60 m vertically below the site. The affected track section has been closed and an alternative (255 m long) track has been constructed to avoid the problem area. The newly constructed track re-joins the existing track in an area of the coast that shares very similar geology and slope characteristics to the area that has slipped. Due to the steepness of the slope and proximity to steeper ground below the track, any slippage of the track is likely to be rapid and would present a high risk of harm to visitors using that part of the track if they were present at the time.

Table 5 and Figure 24 below summarise the features and predicted future landslide activity in Track Section 5.

Landslide density (landslides /km)	**Debris flow risk to bridge (sites)**	**Debris flow risk to track (sites)**	**Current situation**	**Situation by 2033**	**Situation by 2043**	**Comments**
1	0	0	Very steep side slope with soil slip plane on the well-defined soil/bedrock interface. Newly constructed track avoids the currently damaged area but re-joins the track in an area that is susceptible to the same type of damage. Landslide frequency: 1 every 10 years.	Landslide frequency increases to 1 every 5 years. Reinstatement of the track in its current position will not be possible without building half bridge or other rock bolted structures, so track diversion likely to be required.	Almost certain that multiple areas of the track bench in this section will be lost and track diversion around the entire section will be required.	There is a high safety risk to visitors who choose to use the closed section of track. There is evidence that a number of people do choose this (high risk) option and avoid the re-route.

Table 5. Summary of current and predicted landslide activity in Track Section 5.

[19] Granite from the Tonga Quarry has been used in building construction around the country including the steps of the Wellington Catehederal.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

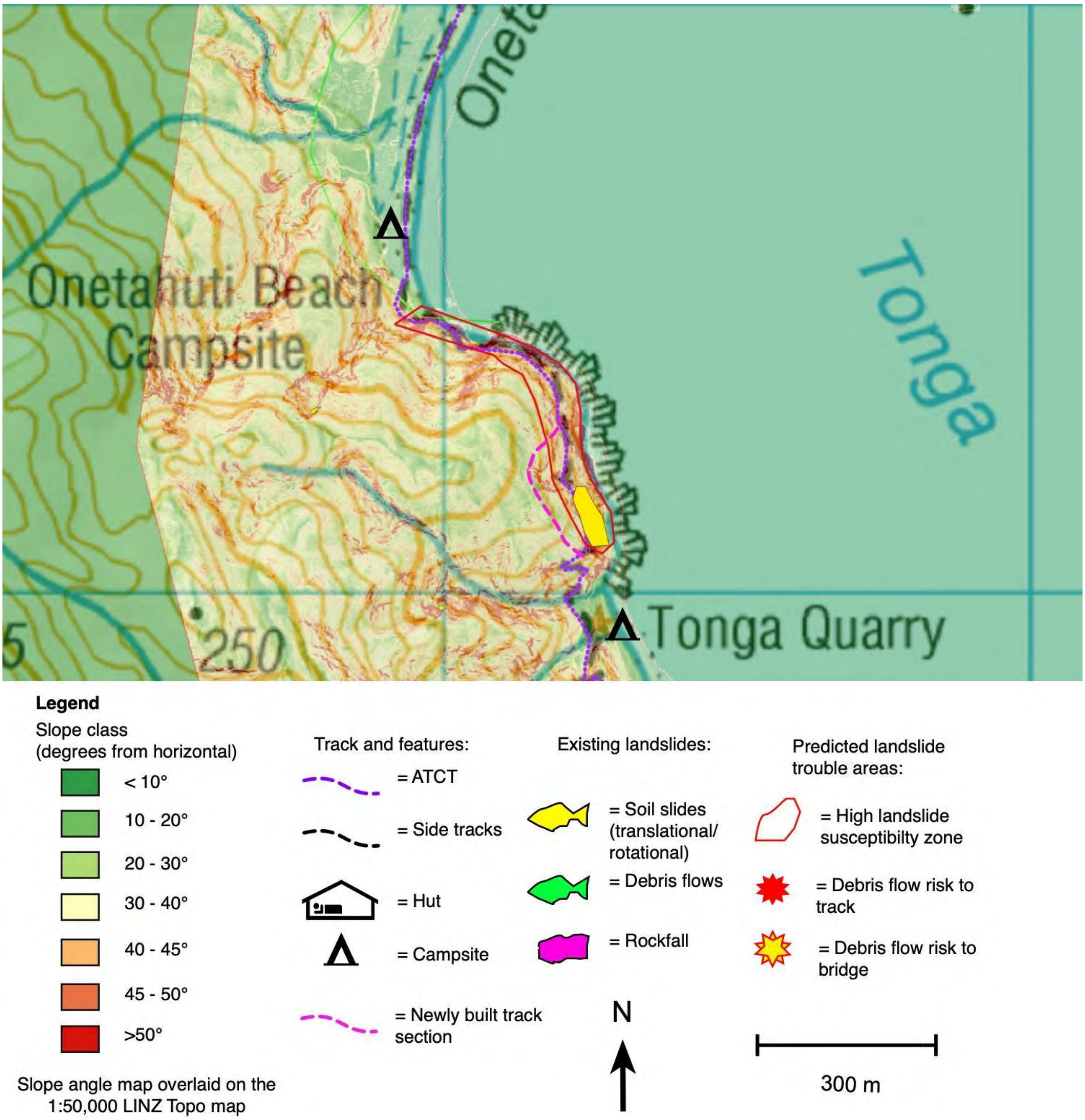


Figure 24. Map of features in Track Section 5.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

6.6 Track Section 6. Lower Waiharakeke Stream

On this 220 m long section, the track traverses along the true left (north) side of the lower reaches of Waiharakeke Stream. The track bench has been cut into a steep (30-55°) southerly aspect slope. The Waiharakeke Stream makes three meanders and on the outside edge of these meanders the toe of the slope beneath the track is being actively eroded by the stream flow. On the easternmost (upstream) meander the river bank erosion has progressed to the point where the slope became unstable and triggered a 12 m wide x 25 m high translational soil slide. The landslide debris has been mostly removed by the stream water flow and the track was able to be easily reinstated by cutting a new bench into the bedrock exposed in the landslide scar. Similar conditions exist on the next two downstream meanders, with active erosion causing oversteepening of the slope below the track and it is likely that similar landslides will occur on these next two meanders in the near future (~5 years).

Table 6 and Figure 25 below summarise the features and predicted future landslide activity in Track Section 6.

Landslide density (landslides /km)	Debris flow risk to bridge (sites)	Debris flow risk to track (sites)	Current situation	Situation by 2033	Situation by 2043	Comments
5	0	0	Steep slope with active erosion at the toe, causing undermining of the track bench, leading to slippage. Landslide frequency 1 every 5 years. Track reinstatement reasonably easy.	Landslide frequency increases to 1 every 3 years. Reinstatement of the track in its current position becomes more difficult as repeated erosion causes more instability on the slopes above and below the track.	Landslide frequency increases to 1 every year. Reinstatement of the track becomes even more difficult as repeated erosion causes more instability on the slopes above and below the track.	It is possible that repeated landslides on the northern side of the stream will add enough sediment to the valley floor that the stream naturally migrates to the south and the erosion issues are alleviated. Erosion protection works or engineered stream diversions to the south could be considered if track reinstatement becomes problematic.

Table 6. Summary of current and predicted landslide activity in Track Section 6.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

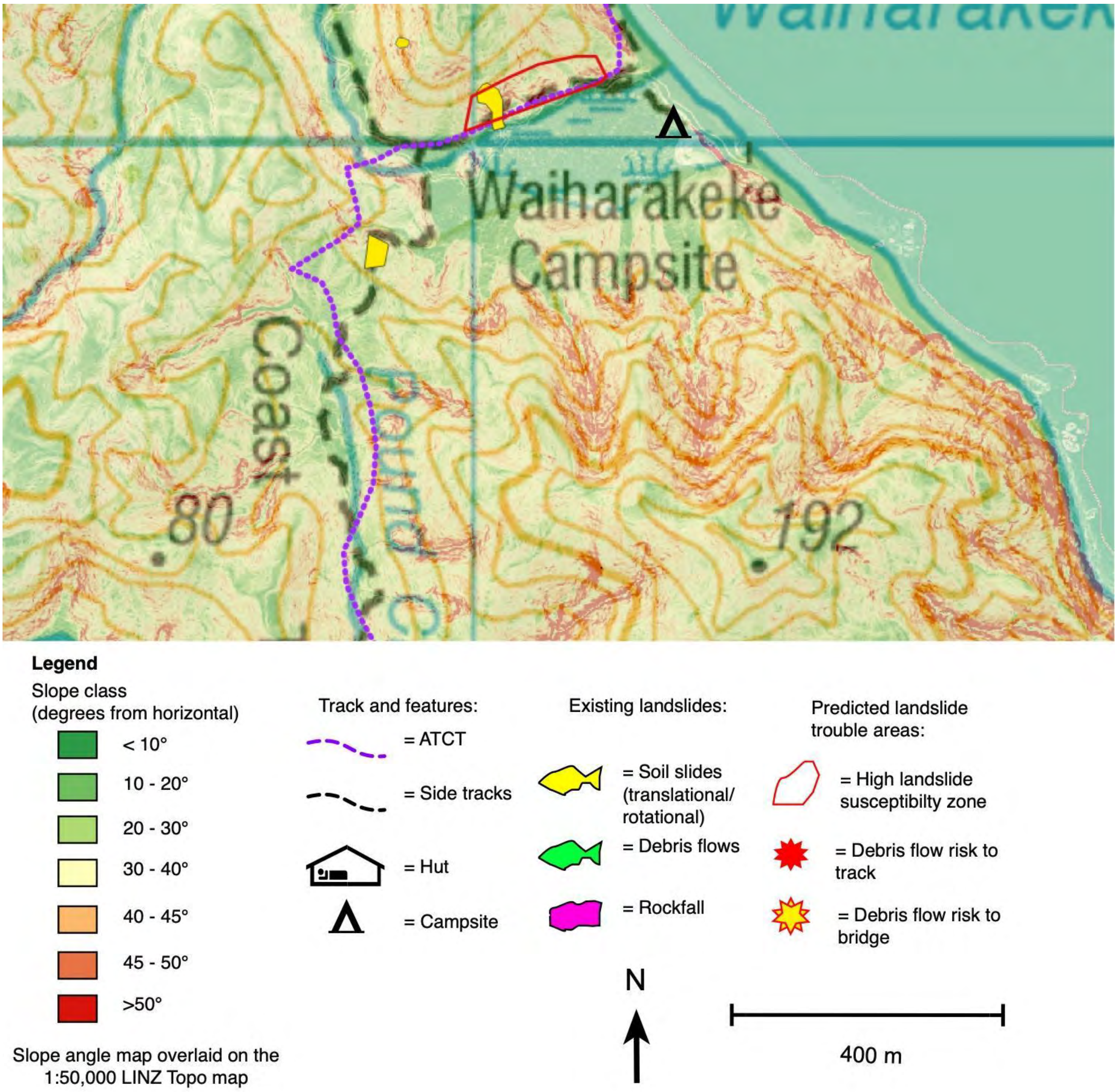


Figure 25. Map of features in Track Section 6.

6.7 Track Section 7. Ratakura Point

On this 850 m long section, the track traverses a steep (30-55°) easterly aspect coastal slope above a rocky headland at Ratakura Point. The exposed rock is heavily fractured and deeply weathered with a thin veneer of residual soil and organic matter supporting a dense covering of vegetation. The track is benched into the slope using minimal track width (presumably to help increase the bench stability) and there are two drainage points where culvert socks have been used to reduce the likelihood of erosional damage and associated bench instability. Nevertheless, there are two large translational soil slides that have affected the track in this section; the southernmost slide has been crossed using a temporary bench that has been cut into the debris and the northernmost slide has forced a reroute to be built utilising a series of switchbacks to gain/lose elevation around Ratakura Point. In both locations, the soil slide has caused some degree of disturbance to the underlying rock, meaning that the debris contains rock as well as soil. Consequently, the debris runout chutes experience high energy rockfall as well as more constant slower soil creep and slide movements. Where the switchback section of the reroute re-joins the original track to the north the slope is steep (~45-50°) and the track bench is showing evidence of small scale fritter and rock movements that are likely to cause damage to the track in the near future. The entire 850 m track section is susceptible to similar landslides.

Table 7 and Figure 26 below summarise the features and predicted future landslide activity in Track Section 7.

Landslide density (landslides /km)	Debris flow risk to bridge (sites)	Debris flow risk to track (sites)	Current situation	Situation by 2033	Situation by 2043	Comments
2	0	0	Steep slope with known previous landslide activity. Fractured, weathered bedrock with shallow soil and dense vegetation is highly susceptible to soil slides and rockfall. Temporary landslide crossings, reroutes and drainage improvements are already being utilised in this area. Landslide frequency: 1 every 3 years.	Landslide frequency increases to 1 every year. Reinstatement of the track in its current position becomes more difficult and the newly built reroute (to the north) is hard to maintain. Track closures due to large landslides are likely.	Landslide frequency increases to 2 every year. Reinstatement of the track becomes even more difficult and reroutes become the obvious choice.	This track section is already built to a minimal track width (<0.5 m singletrack in places) and may be out of specification for a Great Walk. Current efforts to improve bench stability are good (culvert socks and diligent drainage maintenance) but are likely to be insufficient to prevent future large landslides in this area.

Table 7. Summary of current and predicted landslide activity in Track Section 7.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

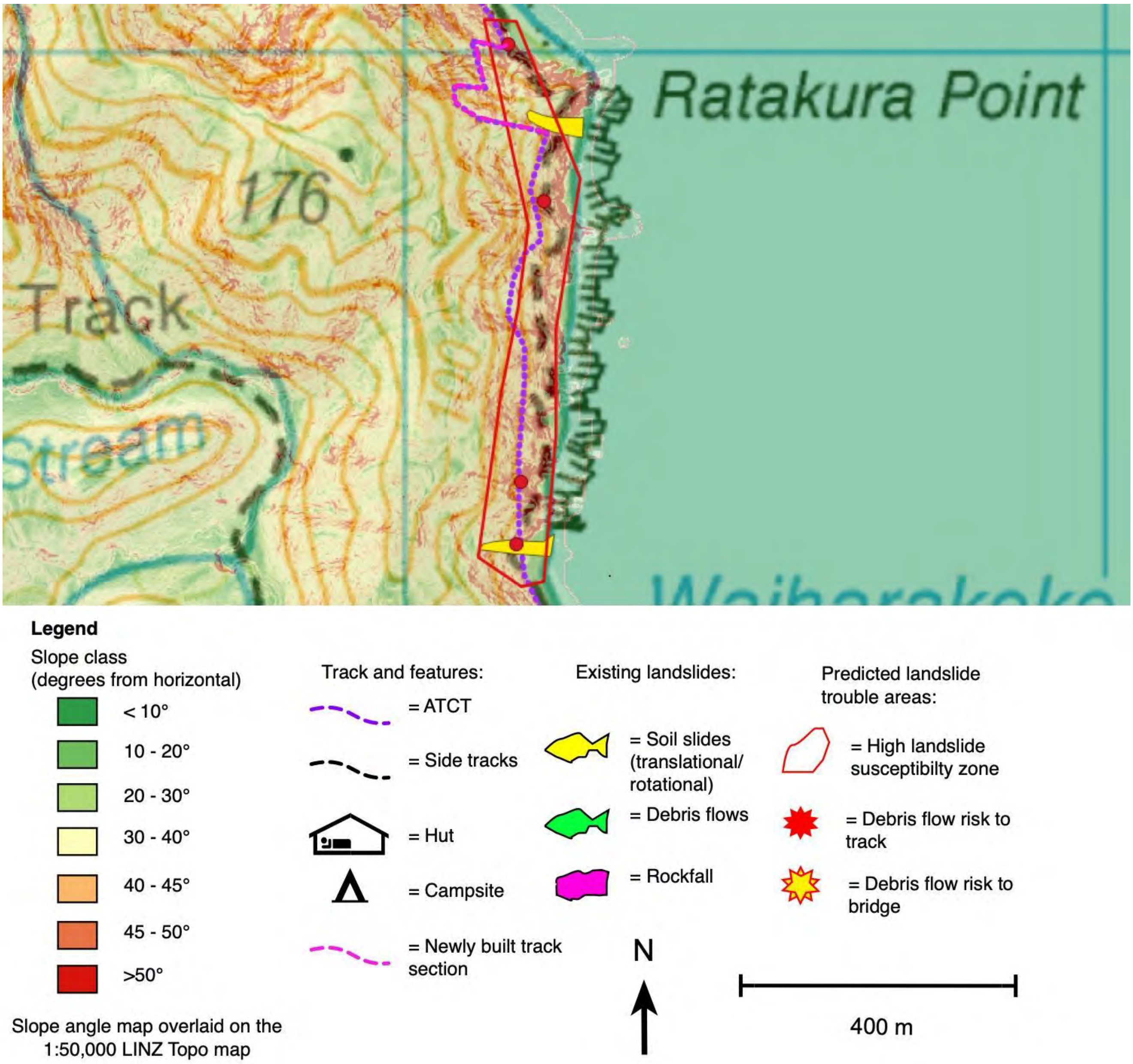


Figure 26. Map of features in Track Section 7.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

6.8 Track Section 8. Skinner Point

On this 530 m long section, the track crosses steep cliff tops above Skinner Point (south end of Tōtaranui Beach) and a series of coastal cliff collapses (soil and rock slides) on the southern side of Skinner Point caused the closure of this section of track in 2020 and 2022. Ground conditions are very similar to the slopes described at Ratakura Point (Track Section 7). As a result of those landslides a 930 m long reroute was built that uses a series of switchbacks to gain/lose elevation around the area affected by the landslides. Where the reroute re-joins the existing track (to the north) there is a 120 m long section of (old) track that is similarly prone to landslides and is likely to experience similar landslides in the near future and these are likely to cause track closures.

Table 8 and Figure 27 below summarise the features and predicted future landslide activity in Track Section 8.

Landslide density (landslides /km)	**Debris flow risk to bridge (sites)**	**Debris flow risk to track (sites)**	**Current situation**	**Situation by 2033**	**Situation by 2043**	**Comments**
2	0	0	Steep slope with known previous landslide activity. Fractured, weathered bedrock with shallow soil and dense vegetation is highly susceptible to soil slides and rockfall. Reroute and drainage improvements are already being utilised in this area. However, the northern 120 m section of track is highly prone to track damage due to similar landslides. Landslide frequency: 1 every 3 years.	Landslide frequency increases to 1 every year. Landslides on the northern part of this section may cause track closures. Existing re-route experiences numerous small slope failures that make maintenance difficult.	Landslide frequency increases to 2 every year. Reinstatement of the track becomes even more difficult and a larger, more permanent reroute becomes the obvious choice.	The existing re-route appears to be a temporary measure that is likely to be damaged by landslides in the future and does not fully avoid the highly susceptible area. Current efforts to improve bench stability are good (culvert socks and diligent drainage maintenance) but are likely to be insufficient to prevent future large landslides in this area.

Table 8. Summary of current and predicted landslide activity in Track Section 8.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

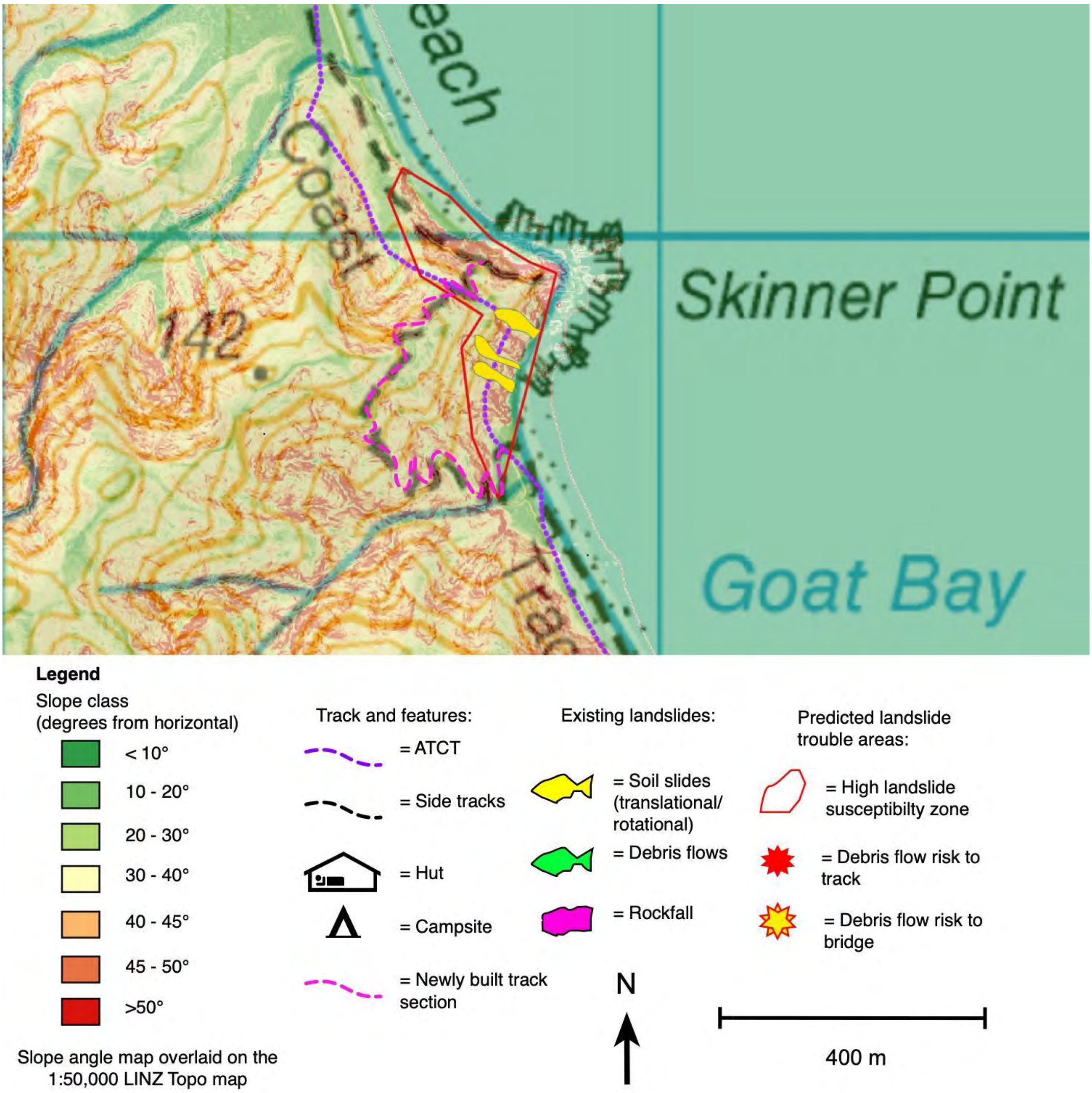


Figure 27. Map of features in Track Section 8.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

6.9 Track Section 9. Stream valley north of Tōtaranui

On this 600 m long section, the track follows the valley floor of a small stream towards Anapai Bay. The ground is generally moderately sloping (30-35°) and the soil layer is thin (<1 m) with deeply weathered bedrock underlying the soil layer. Four small landslides are visible in this area and all of these are likely to have been triggered (or influenced by) by uncontrolled stormwater drainage on the track. Stream bank erosion is also likely to affect the track in several areas and contributes to the general susceptibility of the track to damage caused by small soil slides.

Table 9 and Figure 28 below summarise the features and predicted future landslide activity in Track Section 9.

Landslide density (landslides /km)	**Debris flow risk to bridge (sites)**	**Debris flow risk to track (sites)**	**Current situation**	**Situation by 2033**	**Situation by 2043**	**Comments**
4	0	0	Moderately steep valley with easily erodible bedrock underlying the shallow soil layer. Stream bank erosion combined with inadequate track drainage causes frequent minor damage due to erosion related landslides. Remediation is typically easy and involved cutting a new bench in the same location. Landslide frequency: 1 every year.	Landslide frequency increases to 2 every year. Erosion protection works may be necessary to prevent repeated erosion related landslide occurrence.	Landslide frequency increases to 4 every year assuming no erosion protection works are installed.	General track maintenance and provision of well-designed drainage is likely to have a big influence on track stability in this area. Erosion protection works are likely to be required, if stream flows increase.

Table 9. Summary of current and predicted landslide activity in Track Section 9.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

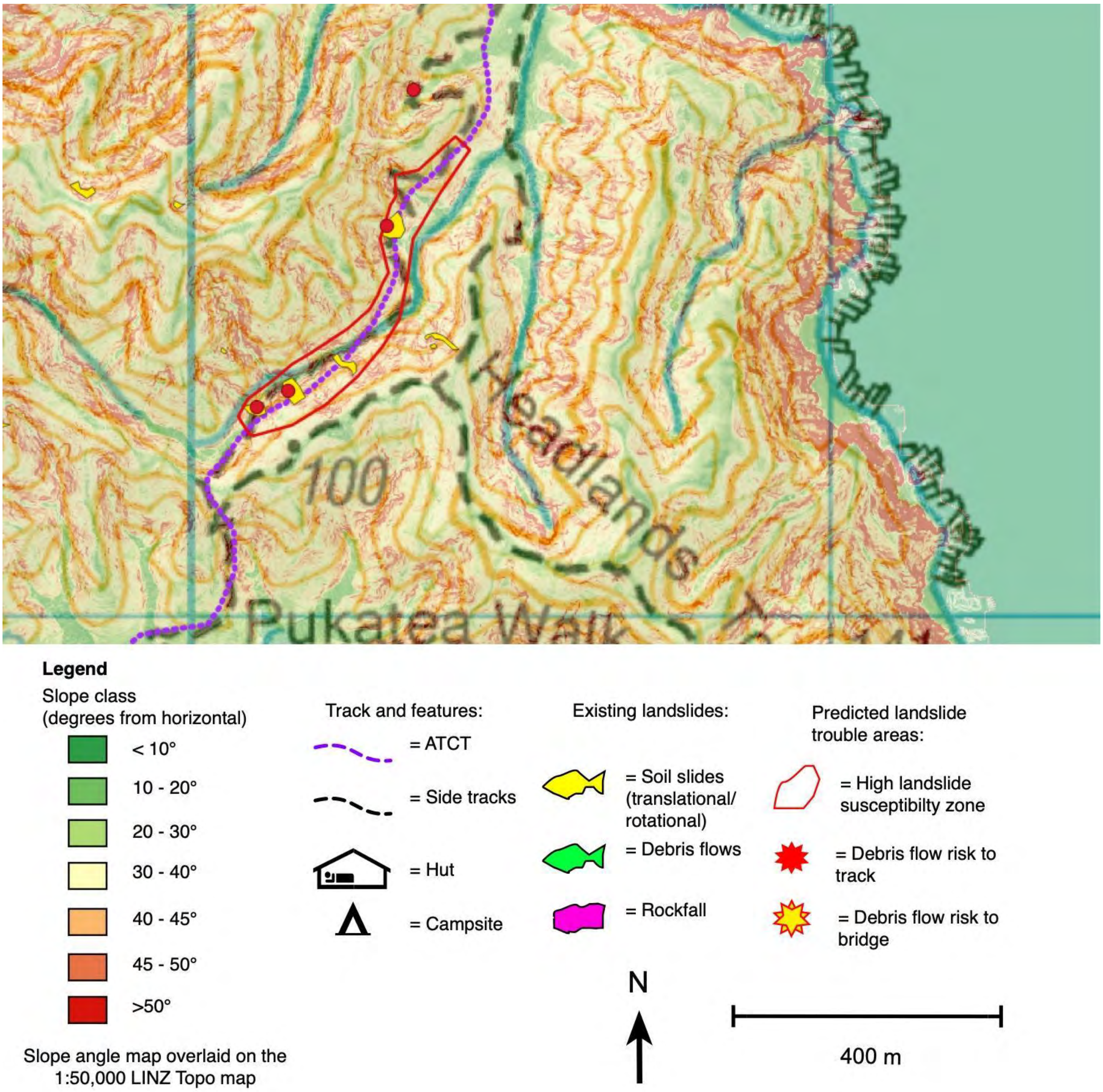


Figure 28. Map of features in Track Section 9.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

6.10 Track Section 10. Anapai Bay

On this 490 m long section, the track originally followed the beach edge to the north end of Anapai Bay, then made a rising traverse up steep coastal slopes to gain flatter ground at the headland between Anapai Bay and Anatakapau Bay. In 2020 a large (50-60 m wide) translational soil slide damaged the section of track where the rising traverse crossed the steep slope and caused a track closure whilst a reroute was constructed[20]. The reroute traverses the slope immediately above the landslide headscarp and crosses moderately steep (30-35°) ground above the coastal cliffs. The landslide that caused the track closure remains active and the headscarp is regressing upslope, with evidence of ongoing extensional cracking in the soil directly supporting the newly constructed track bench. It is likely that this headscarp regression will continue and cause damage to the newly constructed track bench in the near future (within one year). Additionally, there is a smaller translational soil slide that has affected the newly constructed track bench approximately 300 m to the south of the main landslide area. That landslide has caused the loss of the track bench over a 20 m long section and the track has been reinstated by cutting back into the bedrock. A damaged 300 mm plastic culvert is visible in the landslide scar and this is likely to have contributed to the landslide occurrence.

The entire slope is susceptible to large translational soil slides and the newly constructed track is at risk of damage due to slippage (landslides from below progressing back up the slope). This may be exacerbated by coastal erosion at the toe of the coastal slope in some areas in the future. Figure 29 and 30 below show the conditions at the main landslide in Track Section 10.

Figure 29. Newly constructed track (pink dashed line) located immediately upslope of the large landslide. Blue dashed line shows the approximate original track alignment.

Figure 30. Newly constructed track with the headscarp of the large landslide immediately to the left, showing that the track is highly likely to be damaged in the near future. Headscarp indicated with a red dashed line.

Table 10 and Figure 31 below summarise the features and predicted future landslide activity in Track Section 10.

Landslide density (landslides /km)	Debris flow risk to bridge (sites)	Debris flow risk to track (sites)	Current situation	Situation by 2033	Situation by 2043	Comments
2	0	0	Steep coastal slope that is highly susceptible to landslides with the newly built track	Landslide frequency increases to 1 every two years.	Landslide frequency increases to 1 every year.	Reactive track building should be undertaken with a view to future-proofing the

[20] *Pers comms* Simon Bayly.

			located very close to the top of the slope. High risk of additional damage due to ongoing landslide movement (existing landslides) and from new landslides. Landslide frequency: 1 every 5 years.	Track realignment necessary.	Track realignment necessary.	track, not reopening quickly. In this area, the majority of the newly constructed track is still at high risk of damage from existing and future landslides.

Table 10. Summary of current and predicted landslide activity in Track Section 10.

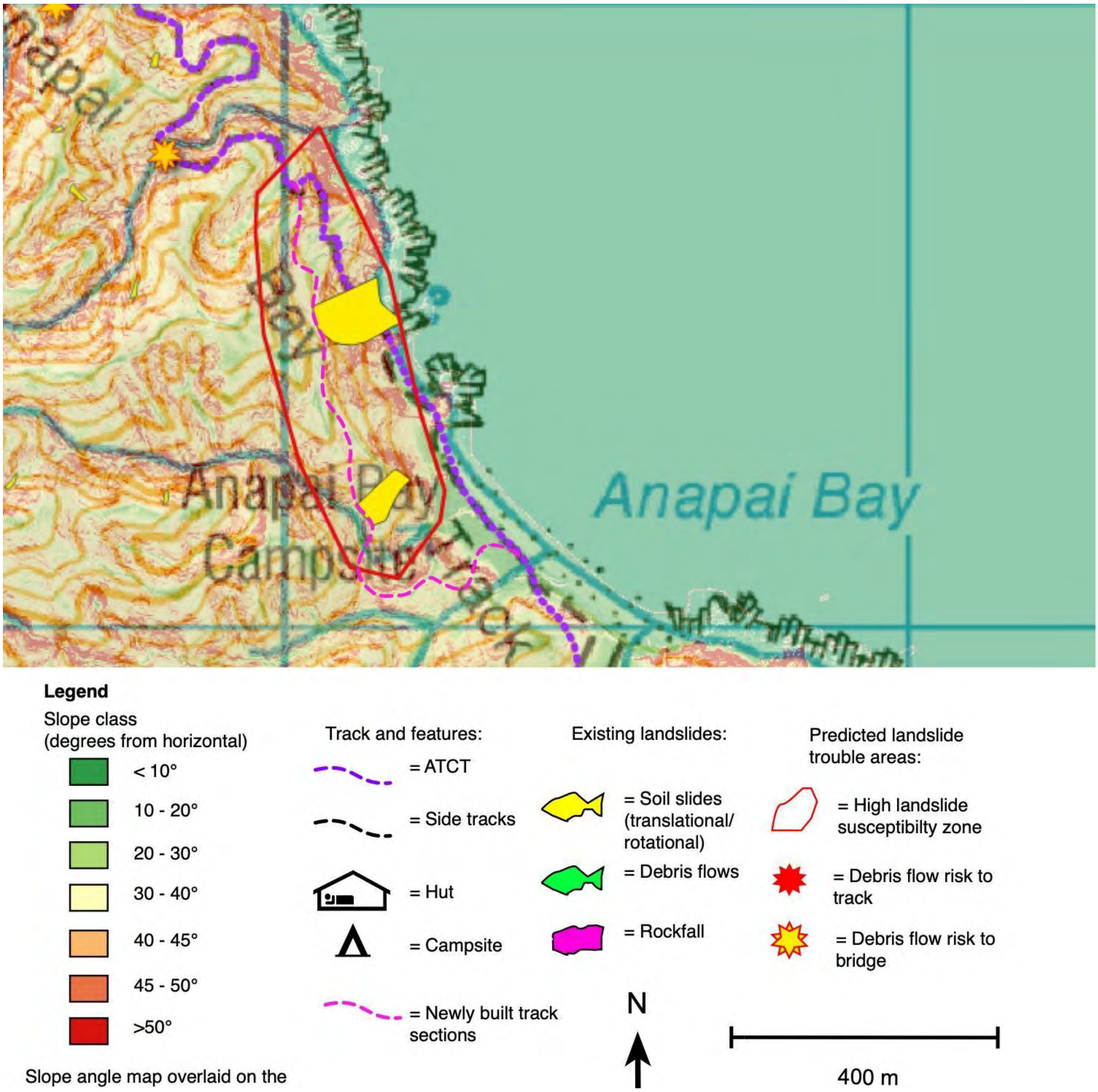


Figure 31. Map of features in Track Section 10.

6.11 Debris flow risk to track and bridges

Point locations that are prone to debris flow damage have been identified based on the catchment size, geometry and upslope catchment susceptibility to soil slides and rockfalls (catchments over 2 km^2 with over 30% of that catchment area being over 50° slope angle). For each predicted debris flow point location, it is

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

estimated that a debris flow will affect that point once every 20 years (under current atmospheric conditions), increasing to once every 10 years by 2033 and increasing again to once every 5 years by 2034. The likely damage to the track caused by a debris flow is of complete bench collapse up to 5 m wide and/or debris inundation up to 1 m deep x 10-15 m wide. Where a bridge is positioned over a drainage channel with less than 1 m clearance to the bridge deck bearers, that bridge has been identified as being at risk from damage caused by debris flows. Where a debris flow point location flows through a culvert (or directly over the track) that track point location has also been identified as being at risk from damage caused by debris flows.

In total there are eight point locations on the track and fourteen bridges that have been identified as being at risk of damage due to debris flows, as shown in Figure 32 below. The coordinates are shown in Appendix B and are available as a GIS (.shp) file.

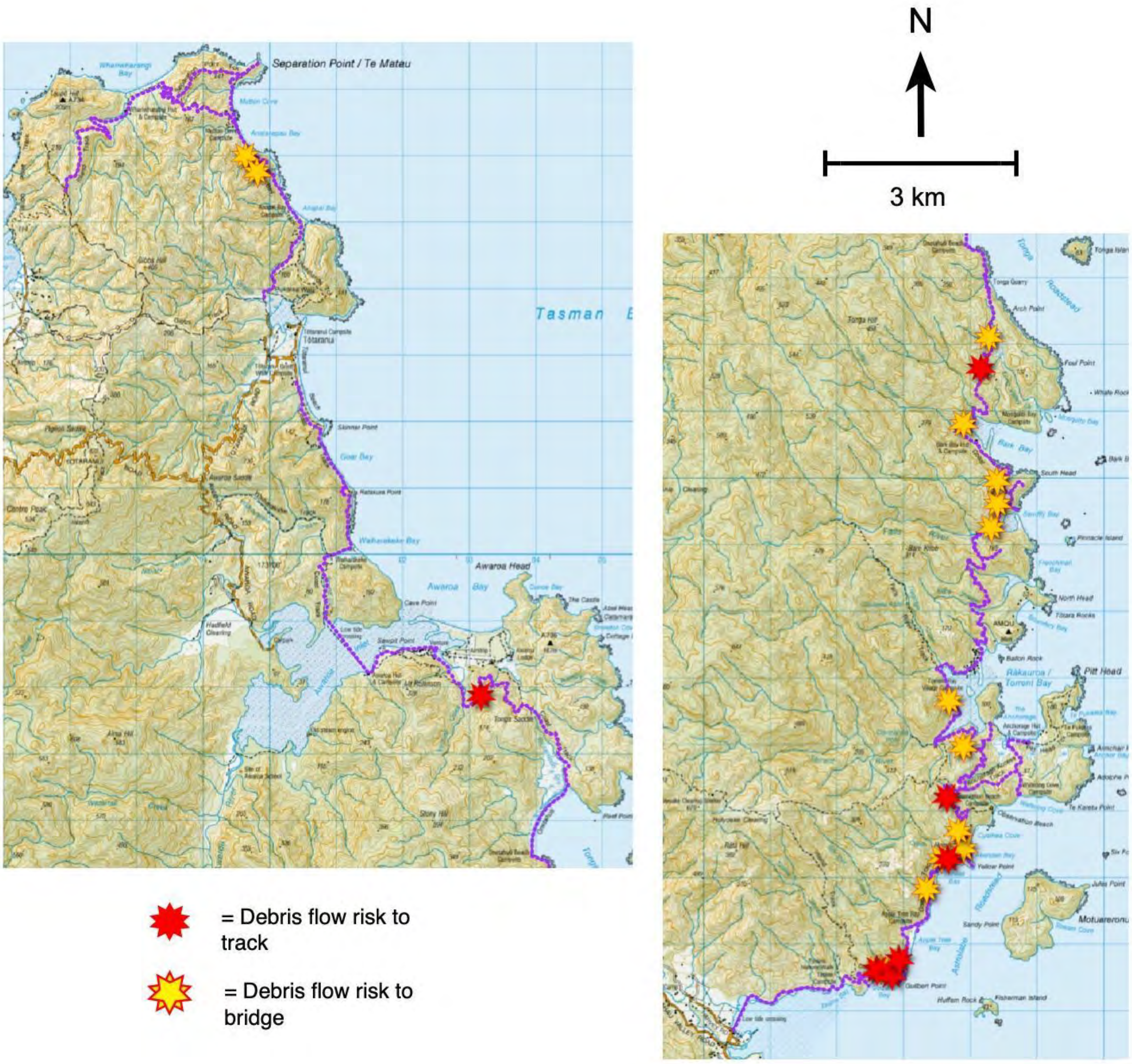


Figure 32. Debris flow risk to track and bridges.

7. Huts and Campsites

In general, the huts and campsites are located in beach and estuary areas that are not close to slopes that are susceptible to landslides (although many of these are exposed to erosion and flood risks). There are two notable exceptions to this: Anchorage hut & campsite and Bark Bay hut.

7.1 Anchorage hut and campsite

The Anchorage hut and campsite is located on flat ground at the base of a 20-40 m high coastal cliff slope. Approximately 50 m to the east of the hut site part of the coastal cliff has collapsed in a block topple/rockfall type landslide. The rock debris is composed of boulders up to 2 m in diameter and has rolled down the slope inundating land up to 15 m from the base of the slope. The inundated land was not in use as part of the camping or hut facilities areas at the time of the rockfall event, but it is in very close proximity to the hut and established tent campsites. Very similar geological conditions exist to the south (directly upslope) of the hut and there is a risk of that part of the slope experiencing similar rockfall events. A rockfall sourced from that area is likely to impact the hut. Given the limited height of the slope (approximately 30 m in the vicinity of the hut), and the dense tree cover, the rockfall is expected to impact the hut with low energy. However, this may still cause damage to the building and severe harm to any people who may be present at the time. It is expected that the likelihood of this event occurring will increase with time as the effects of climate change progress.

Figure 33 below shows the Anchorage hut and campsite and the rockfall source and inundation areas.

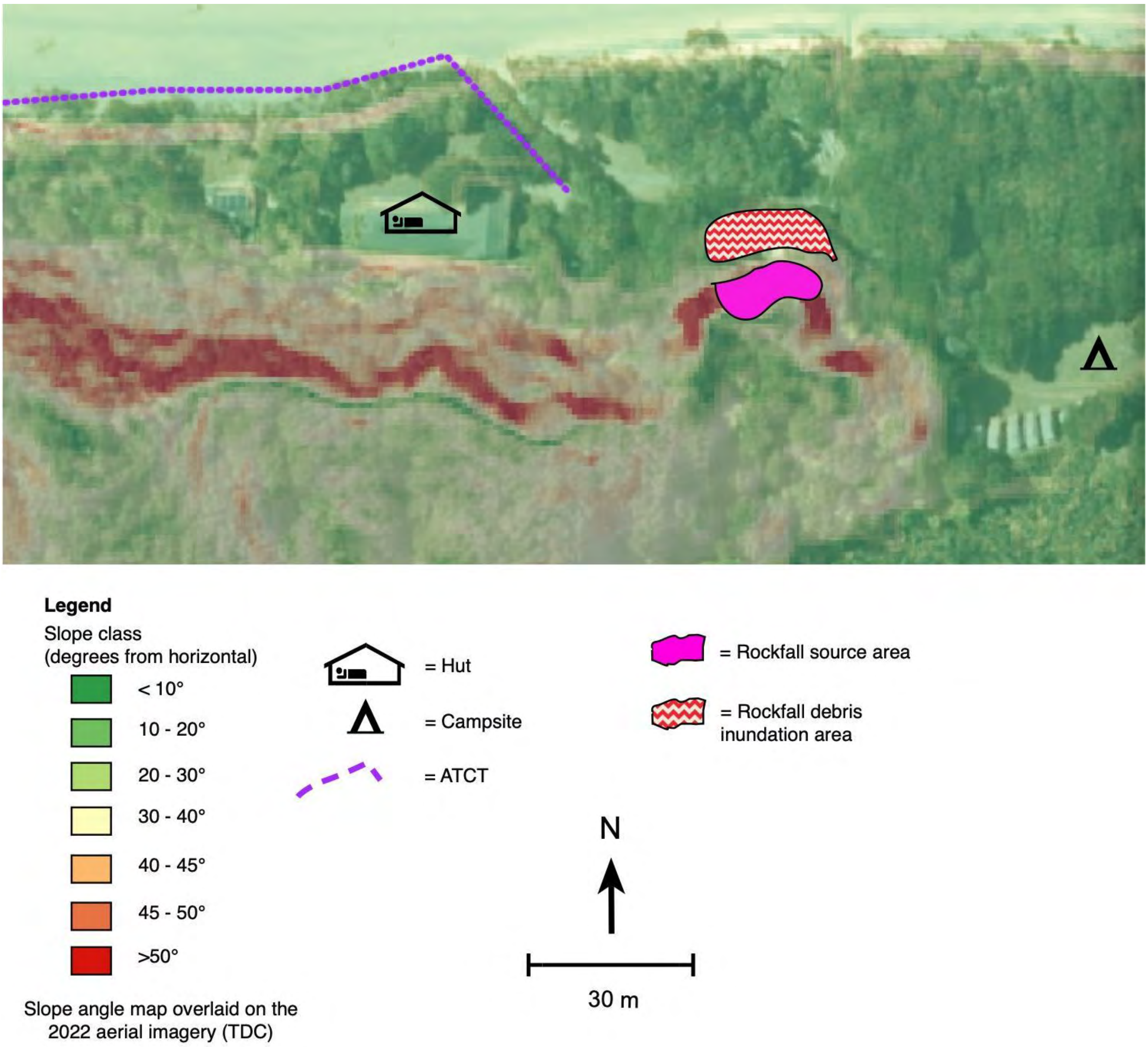


Figure 33. Anchorage hut and campsite

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

7.2 Bark Bay hut

The Bark Bay hut is located within the previously described Track Section 3. A description of the risk to the hut is explained in Section 6.3 above.

8. Recommendations

The following recommendations *may* help to reduce track closures and provide an enhanced means of cost effectively managing/maintaining the ATCT.

1. Develop and maintain a landslide catalogue. This would be a simple database of landslides that affect the ATCT and over time this data would help to support decision making about maintenance, temporary closures, prioritisation of resources, etc. Over time and with enough data, a rainfall amount landslide trigger threshold may become clear, and this would be useful in issuing warnings and track closures for safety reasons. Essential data to collect for each landslide is: Location, type, size, date of occurrence (and time if known), cause (if known), rainfall trigger amount (if the date is known the rainfall data can be found at Tasman District Council's Tākaka/Mārahau rain gauge[21]), and any other pertinent information such as whether the track was closed, cost to remediate etc. It should be a live document that is contributed to by hut wardens, maintenance staff and rangers, but "owned" by a single person, who would be responsible for maintenance, backups and encouraging others to contribute.
2. Monitor and maintain existing drainage structures more effectively:
    a. Staff should regularly walk the entire track and observe all drainage infrastructure items (primarily swale drains and culverts) and check for any blockages or partial blockages.
    b. Blocked or partially blocked culverts or drainage swales should be cleared as soon they are noticed.
    c. Minor cut batter collapses (I observed 32 instances of this that are not included in the landslide inventory) often lead to blockages of the swale drain and uncontrolled stormwater flowing over the track surface. This can rapidly lead to track bench slippage, if not dealt with swiftly. Any minor cut batter collapses should be removed as soon as possible (usually possible with a shovel).
3. Improve drainage infrastructure on the track. 33 of the observed 85 landslides in the landslide inventory used in this study originated on the track bench. In many of those cases, it is likely that improved drainage infrastructure may have prevented those landslides from occurring. Whilst planning for improved drainage infrastructure the following points should be noted:
    a. Culvert size should be calculated based on catchment size, but with the knowledge that *all* water drainages will carry leaf/vegetation/soil debris and the culverts should be (over-) sized appropriately. The "appropriate" size, in this instance should also take into consideration that the ATCT is likely to experience unprecedented rainfall intensities in the coming years.
    b. I estimate that a sensible minimum culvert size should be 375 mm diameter. This will allow for increased water flow and decreased likelihood of blockage due to leaves/branches/other debris. However, more detailed hydrological modelling and discussion would be required to better define the actual culvert sizes.
    c. Where water pools on the track surface, this should be addressed as soon as possible after it is identified.
    d. Where culverts place water on steep soil slopes, culvert socks should be used to avoid downslope erosion of the ground supporting the track bench.

[21] https://www.tasman.govt.nz/my-region/environment/environmental-data/rainfall/takaka-at-canaan/

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

   e. Where retaining walls are used to support the track bench, these should be constructed with effective drainage
4. It may be appropriate to reinforce the track surface with geotextiles in areas where culverts are placed, or where water is known to flow over the track surface. Even with well maintained, oversized culverts, there will always be a residual risk of blockage due to water-borne debris or debris flows during large storm events. In the case of culvert blockage, the water flows over the track bench and can rapidly lead to damaging erosion and track bench slippage. If the track surface weredesigned to accommodate that water flow the risk of slippage could be reduced. Sensibly, this could be installed in any area where a new culvert is being placed and may involve placement of a 4-6 m strip (full track width, plus the affected part of the fill slope) of erosion protection geofabric such as Enkamat[22] (or similar), centred on the culvert location.
5. Where bench slippage is identified due to slow-moving soil slides, or soft soils, it may be appropriate to utilise soil reinforcing geotextiles such as TensarTriax[23] (or similar), to help improve the track longevity.
6. Where bridges are susceptible to damage from debris flows (or floods) the bridge deck height could be increased to allow a (design size) debris flow to pass underneath. This may involve placing a single 1 m^3 rock-filled gabion basket at each end of an existing bridge deck to act as a raised bridge abutment (or similar design). A more detailed catchment level analysis could be used to support individual bridge designs and ensure that debris flows of a certain size will not damage the designed structure. However, given the inherently unpredictable nature of debris flows, it may be appropriate to simply raise all susceptible bridges by 1 m.
7. Where track sections are identified as being highly susceptible to landslides and the repair options are very limited, reroutes could be planned and constructed before the damage occurs. This is particularly relevant to Track Section 5 - Tonga Quarry to Onetahuti Beach and Track Section 7 - Ratakura Point
8. Where large landslides force the closure of the track, a detailed geotechnical investigation of the site should be undertaken. This will allow for well-planned remediation, or long-term robust reroutes to be chosen. This will help to avoid situations like the Anapai Bay re-route, where the newly built track is at high risk of slippage due to the landslide that the re-route was designed to bypass.
9. A detailed assessment of the rockfall risk (including rockfall modelling, vulnerability and risk to life calculations) should be undertaken at the Anchorage hut and campsite. The observations and analysis presented in this report are not sufficiently in-depth to support decision-making regarding the safety risks at the Anchorage hut and campsite. Rather, this report raises a flag to suggest that more work is required to better define that risk, particularly regarding the predicted increased magnitude of rain events, and associated increase in rockfall magnitude/frequency.
10. Specific monitoring of landslide activity on the slope to the south (upslope) of Bark Bay hut should be undertaken. If landslides become significantly larger than the currently observed landslides in that area, the safety risk at the hut site should be re-assessed.

9. Limitations

This report has been produced using the best currently available data and site observations. However, there are various limitations that could affect the accuracy of the results presented:

1. The landslide inventory used for this study is primarily based on three aerial photo datasets, two of which do not cover the entire study area. This limited data is likely mean that some landslides were not captured within the remote data mapping exercise.

[22] Available from Geofabrics.co.nz
[23] Available from Geofabrics.co.nz

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

2. Aerial photography does not allow for observations of ground conditions (i.e. landslide occurrence) under dense vegetation cover, in shadows, or in other areas where imagery is compromised. For this reason, the remote landslide inventory will be incomplete

3. Estimates of the likelihood of occurrence of the various geological hazard events have been based on field observations and recognised triggering thresholds. Where detailed time-based historical observations are not available the prediction of future events is subjective and will include a high degree of uncertainty.

4. The fieldwork component of this study encompasses the main ATCT only and *excludes* the many side tracks. Excluded side tracks are: Tinline Nature Walk, Inland Track, Yellow Point, Observation Beach, Watering Cove, Pitt Head, Sandfly Bay, Pukatea Walk, Headlands Track, Separation Point Tack and Taupo Point Track.

5. Climate change is inherently unpredictable and it is likely that unprecedented atmospheric events will occur in the coming years. Accurate prediction of the effects of unprecedented events is not possible.

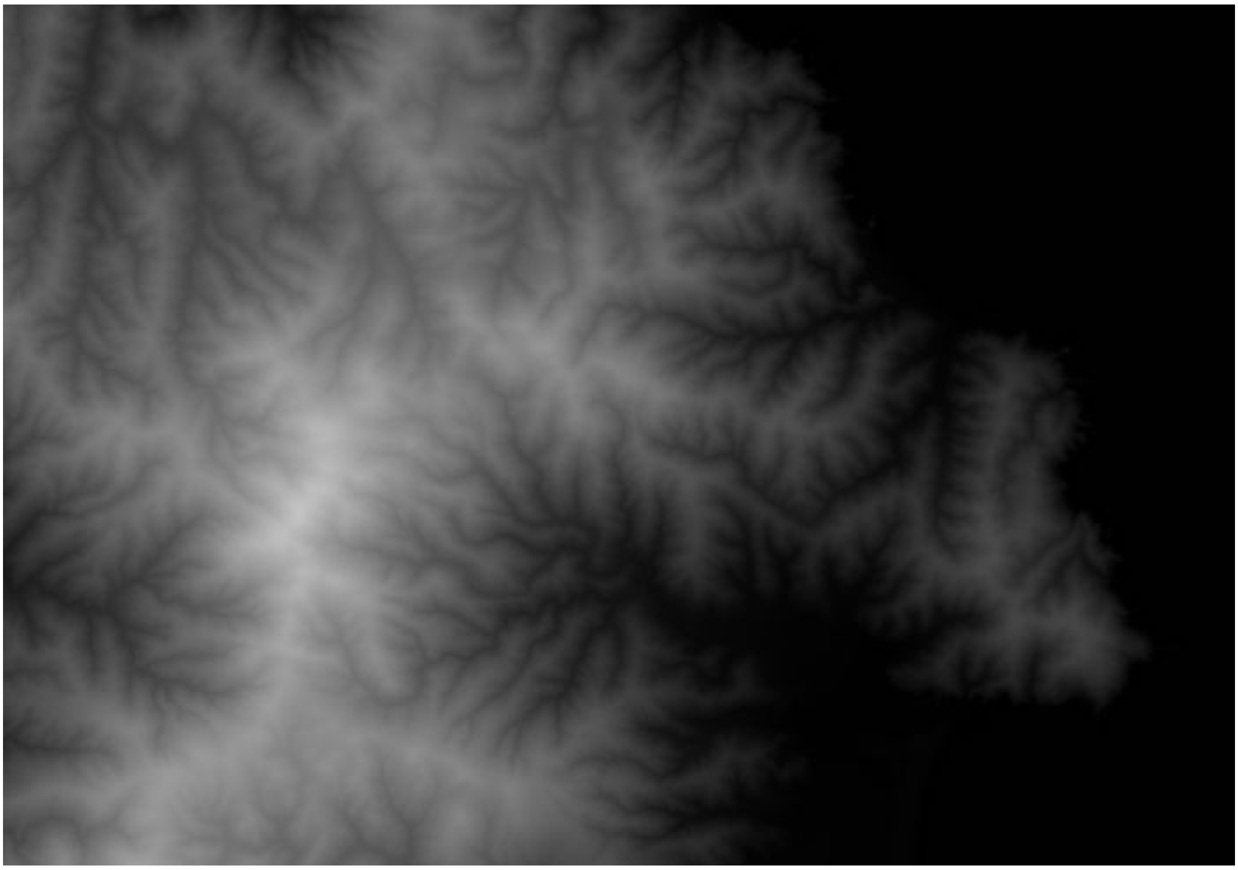
England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

Appendix A

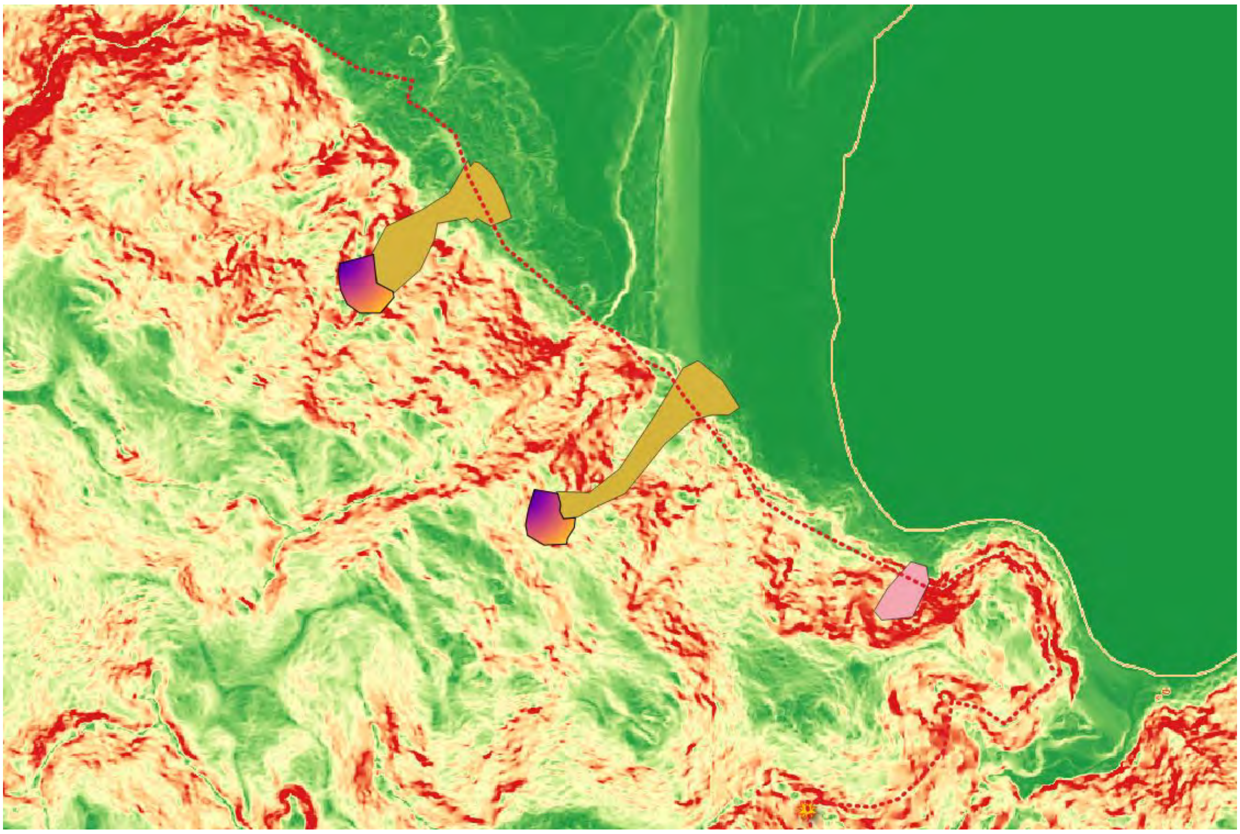
Remote data examples.

Item A1. Landslides visible in the 2022 aerial photo dataset at Skinner Point. The red dashed line shows the location of the track at the time of the event (the track has now been re-routed above the landslides).

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

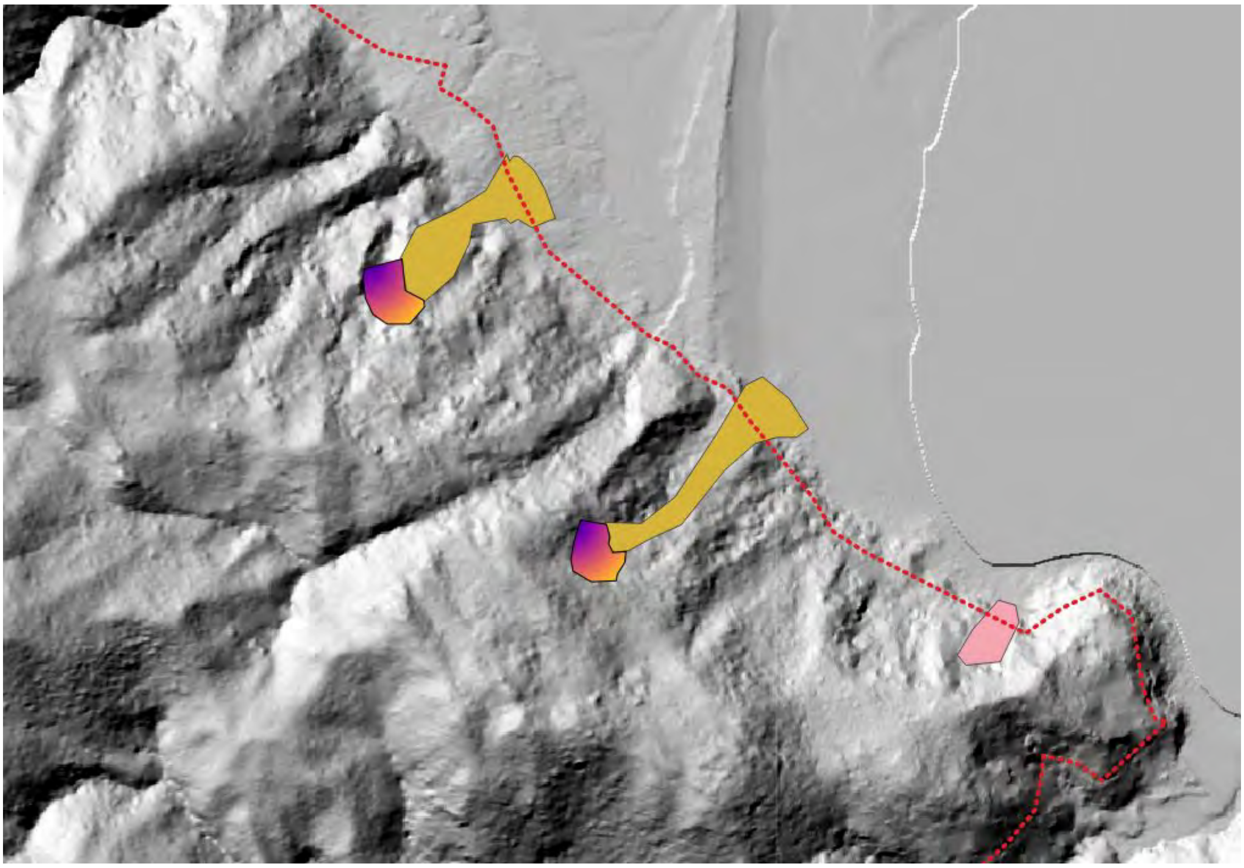


Item A2. Digital elevation model (raw data) of part of the study area (Anapai Bay)



Item A3. Slope angle map (red is over 50° and green is less than 10° with a 7-category colour gradient) showing the mapped landslides at Bark Bay.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669



Item A4. Shaded relief map (hillshade map) of the same area at Bark Bay.

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669

Appendix B

Item B1. Debris flow risk to track point locations.

1	1602587	5462623
2	1602596	5462624
3	1602816	5462537
4	1602924	5462780
5	1603660	5464285
6	1603642	5465209
7	1604149	5471648
8	1603163	5475879

Item B2. Debris flow risk to bridges point locations.

1	1602651.494	5462630.575
2	1603338.004	5463831.98
3	1603560.547	5464293.463
4	1603892.455	5464443.314
5	1603810.837	5464700.724
6	1603886.534	5465967.932
7	1603677.676	5466656.125
8	1604309.052	5469260.052
9	1604401.078	5469616.152
10	1604393.51	5469961.752
11	1603890.276	5470813.867
12	1604269.109	5472110.917
13	1599631.776	5483999.152
14	1599806.066	5483758.052

England and Company Ltd.
info@englandandco.com / +64 (0) 29 771 7669