Coastal Erosion in the Tūhaitara Coastal Park

A study of sea level rise impacts on landscape and community

UNIVERSITY OF CANTERBURY
GEOG309 Project Report

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Executive Summary

- From Pines Beach in the south to Waikuku Beach in the north lies a 10.5 km stretch of coast managed by Te Kōhaka o Tūhaitara Trust. With climate change and sea level rise threatening, the ecological and social communities of the Park are susceptible to coastal erosion.
- This project examines:
    - how sea level rise could impact erosion throughout the area.
    - how current erosion is perceived by the local community.
    - what impacts erosion may have on human activities in the Park.
- Relying on academic literature for information on analysis techniques and erosion management strategies, we created a GIS flood model to assess threat of sea level rise and thus, where erosion could occur. A survey was used to assess local opinions on erosion and understand why residents value the area.
- Key Findings:
    - Estimated inundation areas for three sea level rise scenarios; a low rise of 0.25m yields 730 m^2, a moderate rise of 0.80 m yields 1330 m^2, and an extreme rise of 1.20 m yields 2850 m^2.
    - Greater awareness of current erosion traveling north up the coast from Kairaki, to Woodend Beach, up to Waikuku Beach.
    - Time of residence has an inverse relationship with perceived erosion risk.
    - Neither erosion observations nor knowledge of erosion risk appears to influence the decision to live in these coastal areas.
- Shortcomings and Limitations:
    - Flood analysis does not assess erosion directly. It identifies low-lying areas of risk from sea level rise and does not take beach system dynamics into account.
    - Sea level rise is the only mechanism of erosion considered in physical analyses and only absolute values are used.
    - Insufficient time to collect primary data on long-term erosion, given that trends are observed on a multi-decadal timescale.
    - Limited secondary data available for the Tūhaitara Coastal Park study area.
- Research into the future…
    - How other erosional factors e.g. sediment supply and climate changes e.g. storminess will change in the future and impact future erosion in the Park.
    - To establish a database of land information e.g. elevation and maps to allow better analysis of coastal changes.

Introduction

Te Kōhaka o Tūhaitara Trust expressed interest in learning more about the timeframe of erosional impacts within the Tūhaitara Coastal Park (TCP). The questions we focus on are: *Will sea level rise (SLR) change current erosion trends at the TCP? What impacts will erosion have on activities of the Trust and the community?* This question framework gives the scope to address both physical-risk of climate change to the environment and the role of human-activity within the Park. GIS analysis of future SLR scenarios and a resident survey were used to address these questions.

The Park is an important landmark for many reasons; most significantly the many natural and ecological resources, projects and the people involved and supported by the Trust. Habitats for the endangered Canterbury Mudfish (kowaro), such as Tutaetapu Lagoon and biota nodes (community-cultivated areas of native flora and fauna) are just some of numerous treasures throughout the Park. It is also a place of cultural significance (Maori heritage and mahinga kai) and recreational amenities (beaches, walking and biking trails, to name a few). Much investment from Te Kōhaka o Tūhaitara Trust goes into conserving New Zealand's unique biology and creating an environment enjoyed by residents and visitors alike. A better understanding of the coast's future, especially with the increasing threat of urbanisation and climate change, is needed to inform ongoing activities at the Park.

Along with human activities and conservation efforts, dunes and vegetation in the TCP play a role in protecting the backshore. This is especially important as climate change brings morphological changes to coastlines, as well as unpredictable storm frequencies and sea levels which are important influences on coastal erosion (IPCC, 2013). Dunes act as a barrier between land and sea, absorbing erosional processes. In addition, increasing urban development - seen with the birth of Pegasus town near the northern TCP - places more homes at risk to erosion. The area has not been well-studied in past scientific research and many common data-types used in mapping climatic changes do not cover the TCP. This both provides a reason to conduct further study addressing erosion at the coast, and hinders current ability to model erosion potential with the limited data at hand. For this report, inundation maps tailored to predicted SLR scenarios were produced as an indicator for areas susceptible to erosion.

Literature Review

Whitelaw's graduate diploma (2011) is the most substantial existing research inquiry into climatic change within the study area. In this thesis, the Park is defined as a sandy coastal barrier at the centre of Pegasus Bay, formed from progradation of the Waimakariri delta and moderate-high wave-action over the past 2000 years. Recreational, agricultural and pine plantation sites now occupy a large proportion of the backshore that was once wetland and sand dunes. These changes have altered sediment composition, increased competition for native plants and reduced flood-resistance in the Park. Data on drivers of erosion in the Tūhaitara Coastal Park is collated and placed in context of climate change related SLR to inform future restoration plans.

Whether progradation continues or erosion begins with changes in sea level depends on dune-stability and sediment supply. Results in Whitelaw (2011) suggest "no progradation" has occurred since 1991, despite beachfront accretion of sediment (implies SLR rate matches accretion rate). Tūhaitara Park is argued to be vulnerable to relative rise in sea level under the influence of the following drivers (p. 30):

A. Insufficient sediment supply from the Waimakariri River (fluvial dynamics are affected by increased irrigation-demand with drier El Niño climates, which are increasing frequency with global temperature rise, and precipitation rates).
B. Declining dune-system 'barrier' resilience as a defence against SLR (erosion from predominant and uninhibited E/NE wind and wave action exacerbated by tall, narrow dunes associated with marram grass).
C. Southern inundation due to dune degradation (susceptible to storm surge <1m rise as dunes are adapted to a lower-energy climate).
D. Western inundation due to subsidence in wetlands and river channels (liquefaction due to tectonic movement caused ~1.5m drop in some areas following the earthquakes of 2010/2011).
E. SLR response of coastal features such as Brooklands Lagoon spit and the Waimakariri River mouth (which if inundated will expose the Park to strong south-easterly swells).

Bryan et al. (2009) noted that, specifically for New Zealand, coastal change occurs at multi-decadal scales and is a part of even larger trends. Recognising this, we chose to use existing secondary data to address the breadth of the research question. Measuring and interpreting primary 'erosional' data from the TCP over a 12-week project may have appeared to use more initiative, yet it would not adequately address the problem or be a practical representation for the size of the area and timescale.

Though Holgate and Woodworth (2004) have stated that using local sea level data is important when analysing local SLR impacts, Hannah and Bell (2011) note that recent New Zealand sea level changes have correlated well to global averages. It is also stated that Lyttleton (closest sea level gauge to the TCP) has had the highest rate of SLR in the 20th Century for New Zealand (~0.5mm/yr more than national average). Global average sea level rise predictions have been used in this report, though there are to be unforeseen discrepancies in local change.

Predictions of global SLR vary from 0.18m (IPCC, 2013) to 1.6m (Jevrejeva et al., 2010) between 2000-2100. Variations result from analysing different determinants of sea levels and degree of influence each parameter is allocated. In this report absolute figures have been used due to limited long-term information on local land movements, one factor that influences relative sea level. The IPCC's Fifth Assessment of climate change stated global-average absolute SLR between 2000-2100 as 0.26-0.98m (IPCC, 2013). Note that this depends on anthropogenic greenhouse gas release, hard to predict itself.

Ramsey et al. (2012) identifies three methodologies for physical erosion assessment: Behavioural; reproduces past changes to a feature such as shoreline position, Process-based; relies on computer resources and engineering knowledge to simulate cross-section profile, and Change of state models; considers the effect of one significant physical change (e.g. flood-bank breach). Behavioural models are most common, sometimes combined with process-based to assess factors such as storms (keeping in mind that not all physics of morphological change related to beach response is considered). These methods also do not recognise shoreline changes due to episodic events like earthquakes. It is suggested that hybrid methods are most accurate in developing a full-picture of drivers and coastal response. For anything reaching macro- temporal and spatial scales (1-10km and month-year) some form of extrapolation is necessary (Ramsey et al., 2012). Data requirements for this type of analysis are described in table 1 below. An assessment of long-term erosion requires shoreline-change assessment over a planning horizon of over 100 years (DoC, 2010).

Typical data requirements	Indicative positional error for shoreline features (± m)
Geo-rectified and ortho-rectified aerial photographs	Metres to 10s of metres
Geo-rectified and ortho-rectified high resolution satellite imagery.	Metres
Geo-rectified historic cadastral maps and surveys	10s of metres
Geo-rectified LiDAR data	Metres
Survey-grade Global Positioning System (GPS) equipment	Metres
Beach profile datasets	Metres

Table 1. Long-term erosion assessment data components and associated error margins (sourced from Ramsey et al., 2012).

GIS Methods, Results and Analysis

Methodology

Modelling erosion proves to be a complex problem, even if only the SLR factor is considered and other climatic factors such as wind and storm events disregarded. To reasonably assess erosion requires analysis of beach system-dynamics: this involves sediment budget and type throughout the coast, wave climate and tidal-variation over time. A common method is to combine current beach profile with a predicted shoreline setback factor, then extrapolate from this from long-term erosion observation (Ramsey et al, 2012). The major barrier to executing this task was the lack of data available for such modelling. Much existing data does not cover the TCP study area, and it is impossible to collect sufficient primary data in the project timeframe. We decided to settle for a 'bathtub' methodology, predicting SLR flood areas as though the coast were a static surface. This does not assess erosion directly, nor take sediment budget, beach dynamics, wind conditions, or vegetation-soil dynamics into account. It is the best indicator with the data available.

Methods

To build this model, the area of each flood-level was calculated based on the elevation model - a LiDAR dataset from LAND LINK NZ (Rangiora region LiDAR index times from 2014). This was downloaded, cropped appropriately and composed as a raster file in ENVI Mosaic, producing an elevation-surface for analysis in ArcMap. For each SLR prediction (0.25m, 0.8m, 1.2m), the Spatial Analyst Tools were used to calculate flood areas, which were converted into polygons and superimposed over the LiDAR elevation. A geometry attribute was added to all three polygons to obtain mean area values for each using the statistic function.

GIS Results

Our final output is an inundation map (figures 1 and 2) depicting the Park's susceptibility to three SLR scenarios: a low prediction of 0.25m, a moderate prediction of 0.8m, and an extreme of 1.2m rise. To put this into context, the extent of erosion per se is likely to be greatest in areas with more extreme coastal features, as more surface is exposed to the elements. However, the danger of SLR erosion is of greater concern in low-lying areas where small erosion effects can cause severe flooding. Environments such as the TCP can identify areas where erosion would be a devastating problem by looking at inundation.

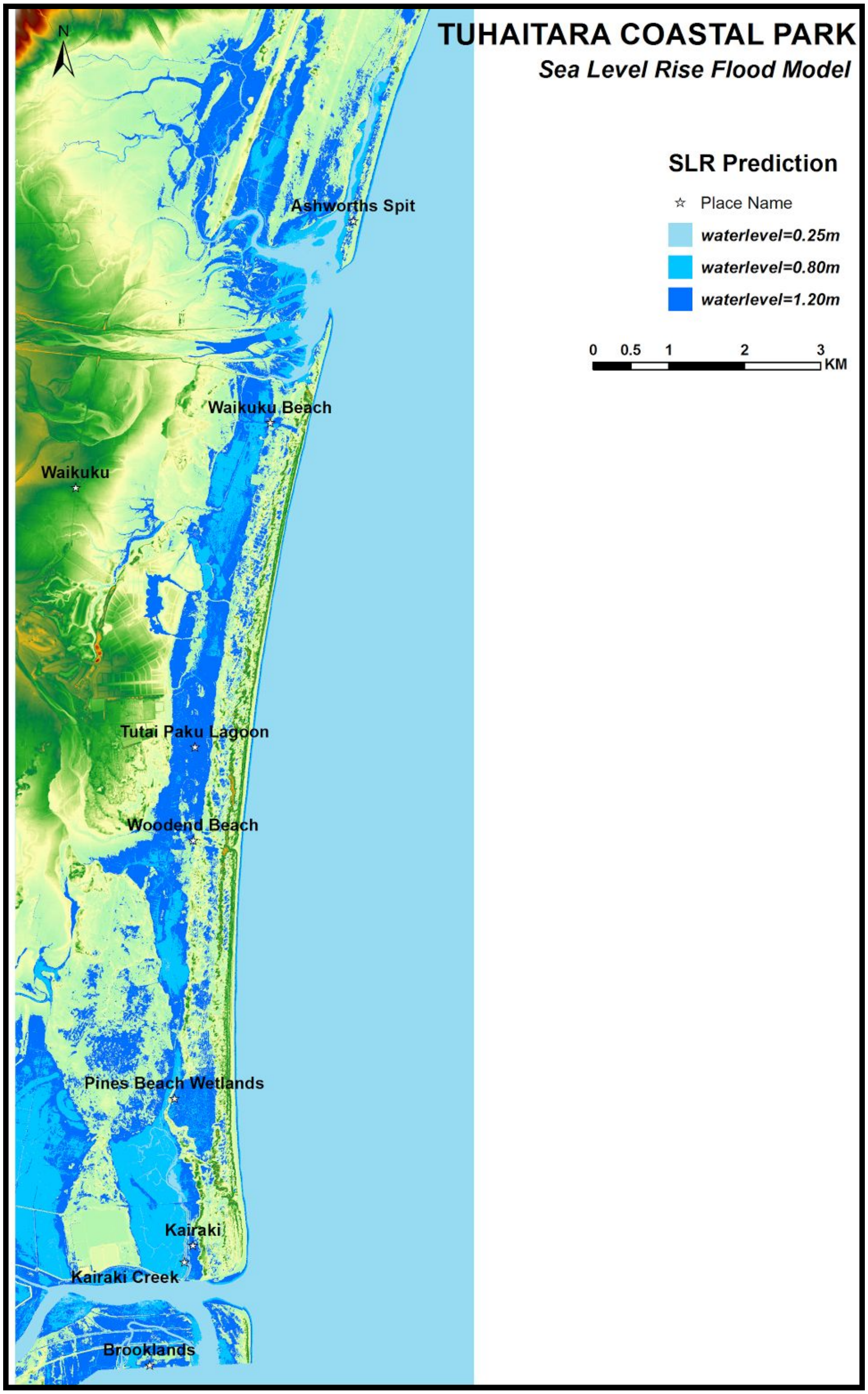

Figure 1. Inundation map depicting three sea level rise scenarios at the Park using a LiDAR (Canterbury-Rangiora LiDAR Tiles, 2014).

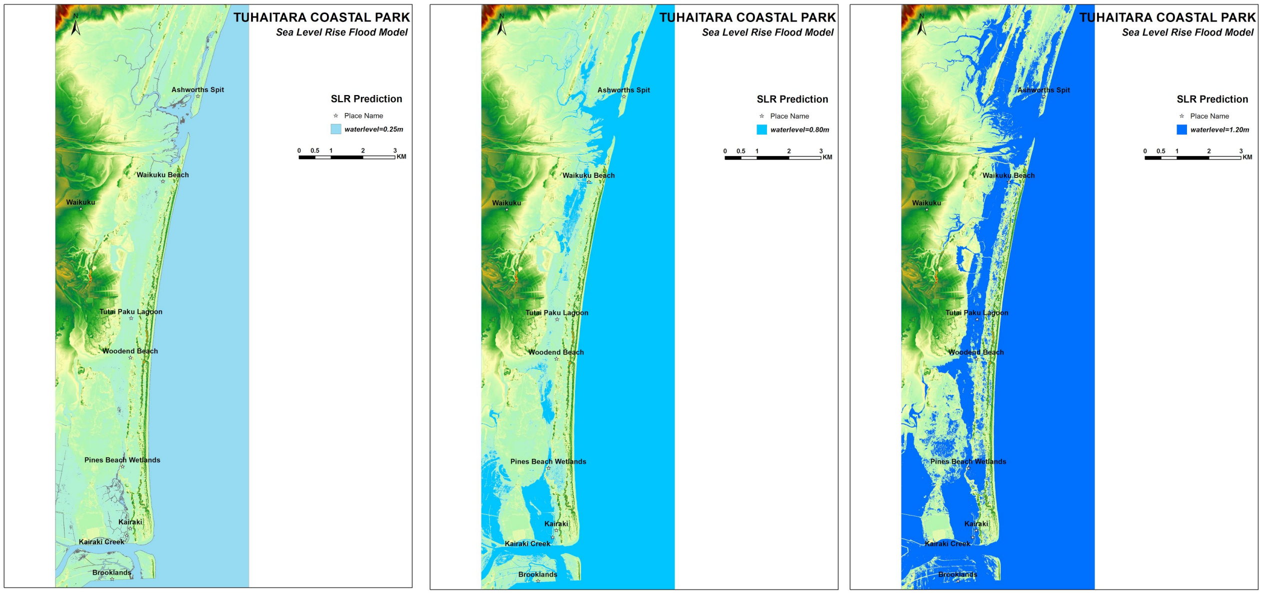

Figure 2. Sea level rise scenario inundation maps separated into a) low (0.25m), area of 730 m^2 b) moderate 0.80m, 1330 m^2 and c) extreme-high 1.20m, 2850 m^2.

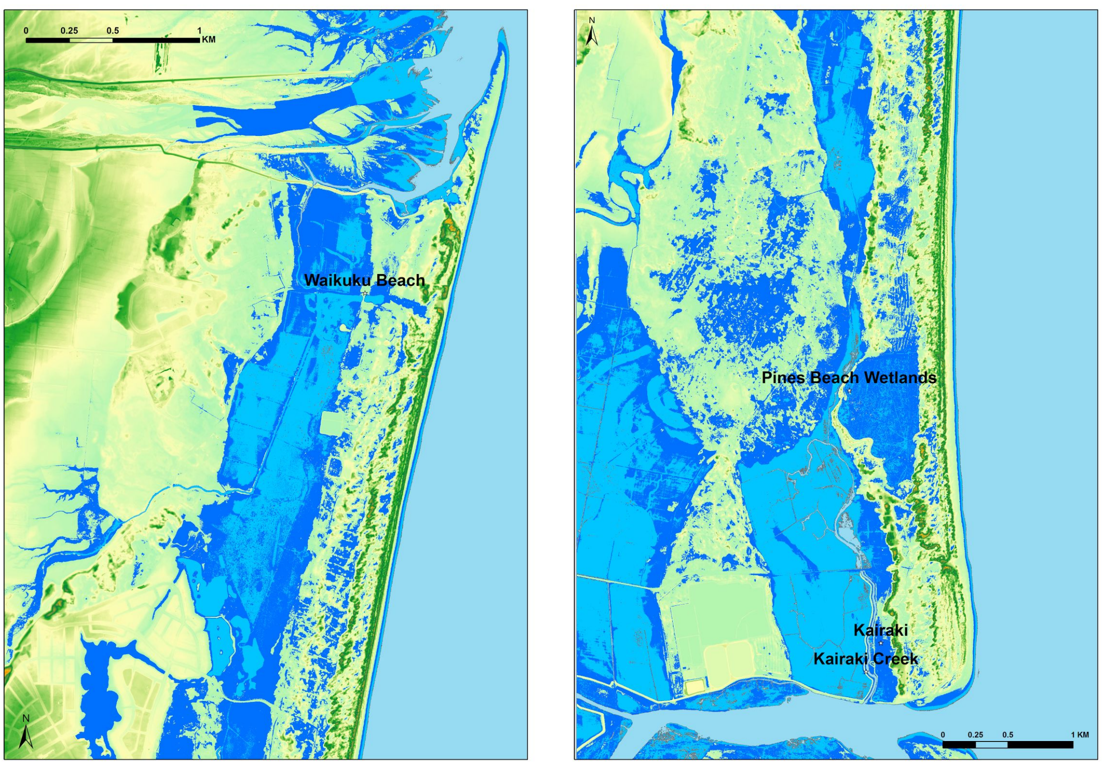

Figure 3. Close-up of the proximity of flood potential to the coast in a) the north and b) the south of the Park.

Discussion of GIS

Considering the GIS model and results from the survey, how might Park communities and the Trust respond to erosion risk? It is apparent from conversations with locals that there is a deep love for the area, and that desertion of the coast in 50-100 years-time, although perhaps the most pragmatic solution, is **not** a probable response. Yet flood areas found in this GIS model indicate erosion poses a substantial threat. Sharing this information about flood-risk and the uncertainty of climate change may prompt the public to reflect on effects of SLR. Acknowledge that accuracy of these outputs is uncertain (see limitations section), but that a general indication of flood-risk accompanies climate change. With a moderate SLR, both North and South TCP will likely experience great erosion and flooding as sea encroaches on the river mouths (figures 2 and 3). Greater support for activities like replacing marram grasses on the dunes with spinifex could accelerate restoration of natural protections. Many of the public expressed awareness of Trust activities, but few understood the progressive stages of replanting, or long-term plan. Publically discussing conservation plans in detail might assist to improve coastal resilience.

Survey Methods, Results and Analysis

Method

Due to limitations with the models produced from Whitelaw's 2011 thesis we decided to survey residents living near the TCP to gain local insight and understanding of the area. We took our interests and formed them into possible questions, which were sent to the Trust for their opinion on changes or improvements. Their suggestion was to specify that the questions were related to flooding from the ocean, not freshwater sources.

Incorporating this feedback, we changed the flooding questions to be more specific to SLR flooding and submitted the survey for ethical approval. The final copy comprised eight survey questions. These questions were mainly quantitative to allow easier analysis and to minimise time spent conducting each survey, increasing response rates. Two qualitative questions were included to give more detailed observations. It was designed to take 3 minutes to fill out, although some residents took longer, slowed by discussions of the definition and effects of climate change over the next 100 years. Surveying was undertaken late-mornings, afternoons and evenings on both weekdays and weekends.

Over two weeks the door-to-door surveying (to maximise responses) was completed. Generally, people willingly completed the survey and were interested in the survey results. Due to factors such as the weather, fewer survey than expected were collected on some days. Scheduling times to go out and survey as a group (for safety reasons) proved to be difficult at times, with conflicting timetables and commitments. A total of 51 survey responses were recorded and processed in Excel, which we felt was reasonable sample size. The results are discussed below.

Results and Discussion

51 surveys were collected from the three locations (Waikuku Beach, Woodend Beach and Pines Beach/Kairaki). Most respondents were from Waikuku (17) and Woodend (25) beaches, this is partly due to the relative population-size at each location and partly that one collection day was rainy for Pines Beach/Kairaki (9). 42% of respondents had lived at their current location for 10 years or more, while only 12% had lived near the TCP for less than 2 years. In all three areas people indicated that they use the beach frequently with no significant difference in use between locations.

Erosion in each location:

Residents were split into groups noticing erosion (25 observing, 24 not) and perceiving an erosion risk (25 no, 24 yes). Moving northwards, people seemed to be more aware of erosion; 59% in Waikuku Beach observing erosion, 52% in Woodend Beach and 33% in Pines/Kairaki. This backs up previous research (e.g. Whitelaw, 2011) and our own observations that the north of the TCP is more susceptible to erosion. Though changes to dunes morphology were noted at all locations (see Figure 4, erosion at each location).

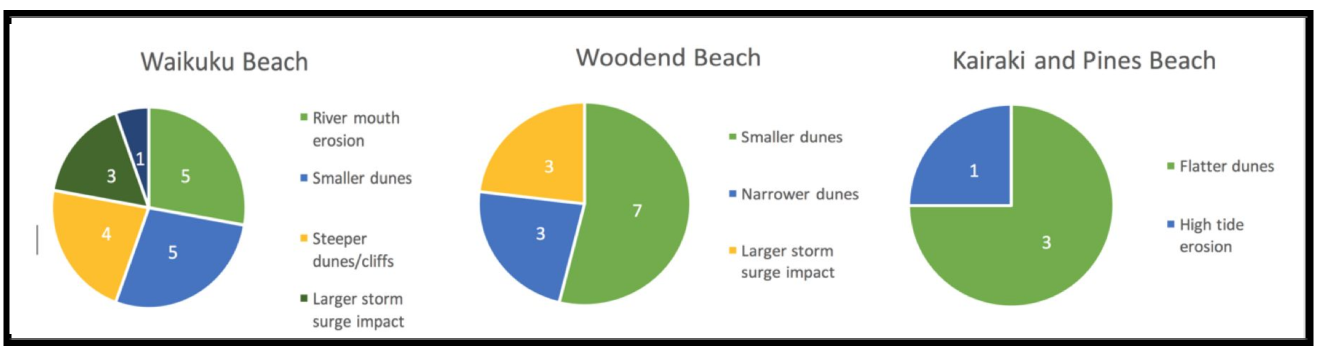

Figure 4. The most common observations of erosion and how these differed by location.

Residents from all locations noted increasing erosion and/or run-up from high tides and storm surges. SLR will drive effects of these localised high water-level events (and erosion) further inland. The most common erosion type noticed at Waikuku Beach was from the Ashley River. Whitelaw (2011) notes that this is a flow-on effect from SLR causing more erosion in the river's estuary and will increase with future SLR.

Does time of residence or beach-use influence residents' awareness of erosion?

A definite relationship was found in that those who use the beach are more likely to observe erosion (54%) than those who do not (20%) (Figure 5). This is likely due to experience of the environment increasing likelihood of noticing changes, though one could argue that it is easier to notice changes in an environment with time spent not experiencing it - a point made speaking to some participants.

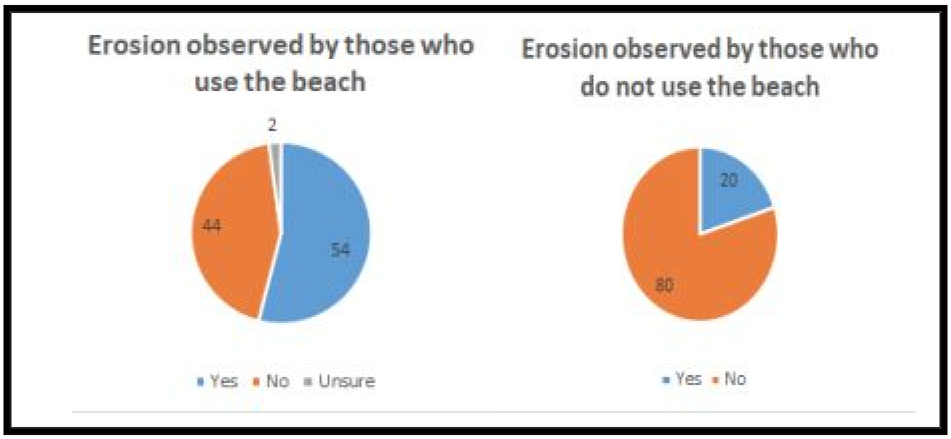

Figure 5. The percentage of residents who observe erosion depending on beach use.

People who had lived in their current location for less than 5 years noticed erosion less (30%) than those who had lived over 5 years near the park (61%). This may be due to a longer time period to observing erosion. Those whose residence was over 10 years were well divided in observing erosion, but this may due to age-related accessibility issues limiting use of the beach and consequent inability to see erosion.

How time of residence relates to the perception of flood risk and the decision to move if property was at risk of flooding.

Those who lived longer at their current location were less likely to believe they lived in an area at risk of flooding, and were less likely to move if they knew their house would be under threat of SLR flooding (Figure 6). More time developing stronger connections to the area could be a reason for this, and those who had lived longer near the park tended to be older and therefore less concerned with the flooding risk in their lifetime.

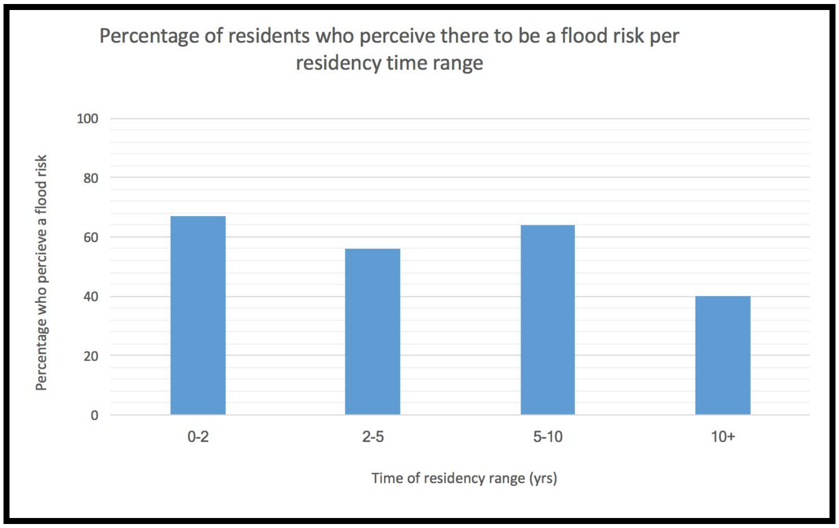

Figure 6a. The percentage of residents who state that flood risk impacts their decision to live near the TCP depending on the amount of time lived at their current location.

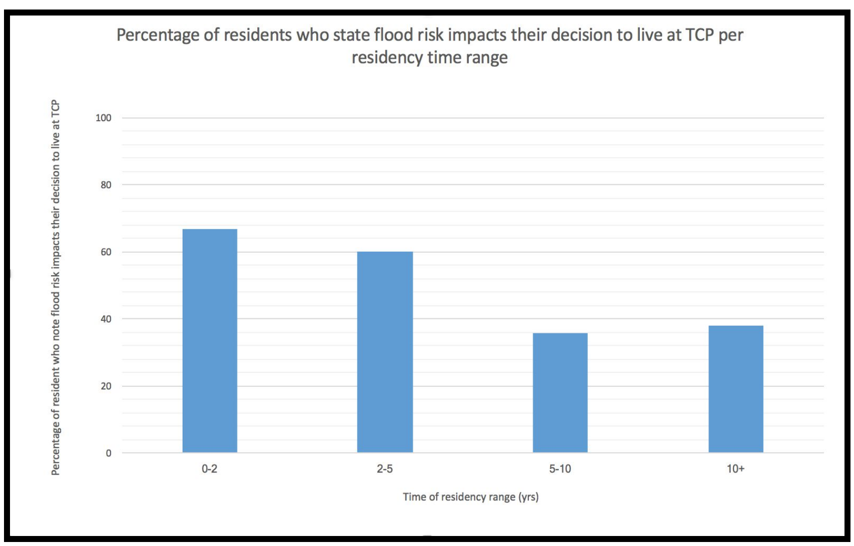

Figure 6b. The percentage of residents living near the TCP who perceive there to be a flood risk for the area depending on the amount of time lived at their current location.

Are residents who observe erosion more likely to move if SLR flooding is known to be a risk?

There appeared to be no relationship for those who had observed erosion with the stated decision to move, knowing that their property was at risk of flooding. This may be due to noticing erosion largely unrelated to flooding, and that if a resident knew their property was at risk they would move irrespective of if they knew about erosion in the area.

Are residents who perceive there to be a flood risk more likely to move if SLR flooding is known to be a risk?

Again, no relationship was found with those noting a flood risk in the area being no more or less likely to live in that area than those who did not perceive a flood threat. It appears if residents' properties were at risk, decision to move may determined by damage extent and inconvenience e.g. permanent risk, family situation, viable accommodation alternatives. Apparently awareness of an existing flood risk does dictate housing choice.

Conclusions

Limitations

Sea level projections - as SLR estimates are based on predictions of greenhouse gas emissions there are uncertainties (IPCC, 2013). Absolute SLR numbers are used in this report with no account for relative land movements, which can offset/enhance absolute changes. This is particularly important for a tectonically active area like TCP, as the south subsided by 1.5m in the 2010-2011 Canterbury Earthquake Sequence (Tonkin and Taylor, 2011).

GIS model - the 'bathtub model' maps SLR but not how sediment will adapt to this change e.g. via the Bruun Rule, which alters coastal response to erosion. With the dynamic nature of the coast, dune elevation is guaranteed to change even without SLR. The model maps SLR inundation and not erosion; flooded areas have the *potential* to be eroded via wave/water action. Another limitation is the accuracy of calculated flood area, which depends solely on the elevation model resolution. The LiDAR dataset has 0.5m pixel resolution, a large error range when examining water levels at a difference of 0.25m.

Survey - it was apparent speaking to residents that there was a lack of understanding of climate change and erosion effects which influenced survey answers. The question "*Do you use the beach near your house*?" was a yes/no answer which was not well defined in terms of frequency of use. Answer options such as daily, weekly and never, would have allowed better understanding.

Erosion - many factors influence erosion other than SLR, including sediment supply, wave climate and storminess to name a few (Bryan et al., 2008; Whitelaw, 2011). Such factors are also subject to change with the climate.

Mitigation

There are a few things that can be done to reduce the effects of erosion in the TCP, including adding coarser sediment for the beach to recycle and move. Erosion is reduced as coarser sediment requires more energy to be transported. This technique has been used and observed in the *Coastal Engineering* article by Kirk (1992). Kirk (1992) discusses how coarser sediment put into the Washdyke Lagoon system increased the fill life by an estimated 53.6 years and reduced the overall erosion rates by 55% over 5 years, with zero crest retreat.

Planting vegetation, as the Trust is already involved with, will help reduce erosion of the beach. Weaker plants, though may not survive large waves, so this impact may be minimal depending on what plants are used and where. As discussed by Lacambra, Spencer and Moeller (2008), mangroves have been observed to provide a natural defense system in freshwater sources. So, with this role, they could possibly be implemented into a salt water system gradually, as mangroves are mainly used in freshwater systems and would take time to get accustomed to the change in salinity.

Reducing the amount of low topography areas along the TCP would reduce risk. Low areas e.g. Waikuku Surf Lifesaving Club can become conduits for flooding and erosion into the backshore as sea levels rise as noted by Whitelaw (2011). This risk can be reduced by minimising the large steep slopes and large basins within the dunes, but still maintaining their height, possibly via vegetation as mentioned. Yet, due to the fine sand and large scale, these actions may not be practical logistically or financially .

GIS could be used to model erosion susceptibility in the TCP. Eikaas and Hemmingsens (2006) reviewed the idea of using GIS to visually understand the dynamics of individual sand and gravel beaches, for future use of reducing erosion susceptibility. For TCP, this could be used in conjunction with physically moving different sediment into the area and data be collected over a period of years. Years of collecting data and representing this in a visual format with the use of GIS, would allow for a visual database to analyse the gradual or sudden change in response to the different sediment implementation.

Analysing sediment cores along the TCP would allow a view into past coastal activity, with respect to climate change and the associated environmental response. Sediment cores would have to be taken in different locations of the beach and it would depend on how far the cores would be taken as well.

These solutions could prove to be financially difficult to achieve, though may be worth it in the long-term, to create a more complete historical record. Overall, there are solutions to the erosional challenges that the TCP faces, yet these would need to be implemented with a view to the next 100 years and more.

Future Research and Ideas

- How alluvial flooding (Waimakariri and Ashley Rivers) could change with climate change and how this will impact the TCP e.g. erosion etc.
- Begin data collection to establish an historical database of land elevation for TCP, preparing for more comprehensive analysis of coastal erosion and beach responses to climate change.
- How climate change will alter other erosional processes e.g. storms, sediment supply and the impact on the TCP.
- Increase awareness of the Trust's actions, most residents knew general going-ons but some misunderstandings.

Summary

The aim of this project has been primarily to give an overview of the risk erosion may pose to the Tuhaitara Coastal Park. However, the real question of interest to the Trust seems to be 'Are we wasting our time?'. By way of response, goals for the preservation of the Park are not a time waste, but rather time limited. Expecting to prevent SLR flooding in any area for an extended period of time (without causing major destructive effects for surrounding coast) is unrealistic. Climate change is a formidable force; working to bolster the natural environment to support itself is more foresighted than attacking the threat head-on. Beyond 200 years, the coast may not look as it does now, but work carried out by the Trust in the present will still be of benefit.

Any conservation success, regardless of temporal and spatial extent, should be viewed as worthwhile. It is key to remember that predictions are just that - predictions. Not realities. Therefore, it does not matter whether the Trust's efforts at the TCP are 'around' for 1 day or the next 1000 years, as long as management of the environment encourages conservation e.g. involving local school children. Awareness and support for nature will follow, building on the Trust's purpose. The Park is an opportunity to support nature and reduce environmental destruction at the hands of anthropogenic activities. It is hoped that this report can be used as a springboard for future planning, outlining requirements for an erosion stocktake and testifying to the value of such research. Truly, a sequential plan to strengthen the coast as a natural buffer according to climatic changes will be an invaluable tool for generations to come.

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