Quick Pass Dune Vulnerability Assessment

In association with Christchurch City Council and Environment Canterbury

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Executive Summary

Climate change is predicted to have significant effect on global coastlines, including in the New Brighton/Waimairi Beach area on Christchurch's East Coast. While dunes have natural morphological changes depending on the season, and sediment supply, increasing sea levels and changing storm events are increasing the vulnerability of coastal dune systems to erosion. This presents a significant risk to infrastructure. The New Brighton area houses significant social amenities including surf clubs, housing and roading networks which require protection. Dunes also provide wider services to the environment including biodiversity and recreation.

While local authorities are aware of the risks surrounding climate change, there is limited funding and resources available to assist in coastal hazard management. This provides an issue where only some sites can receive restoration efforts. This knowledge gap formed the basis of the research question; What areas between Southshore Spit and Waimairi Beach should be prioritised for dune restoration to ensure protection of coastal assets?

To determine sites of highest vulnerability and therefore prioritisation for restoration, the beach was split into 250m long segments. In each segment, the vulnerability was assessed according to seven different criteria, as identified in the literature. These criteria were determined to be; (1) dune height and width, (2) lack of vegetation, (3) distance to infrastructure, (4) high shoreline retreat potential (5) being near walkways, and (6) having seen significant areas of erosion over the past 8 years. A multicriteria analysis was used to collate the seven factors into one succinct output. At each site, each factor was assigned a numerical rating depending on its characteristics. A score of 5 indicated the factor was not performing well and increased the vulnerability of the site to coastal hazards. In contrast, a score of 0 indicated it was performing well, and therefore decreasing the vulnerability of the site.

The results of this analysis achieved our aim of identifying the 10 most vulnerable sections of beach and dune. The spatial distribution of these sites is clustered around the North Beach and New Brighton Pier area, with nine vulnerable sections of beach identified in this area. The remaining one (site 36) is located in the Southshore Spit area. The most vulnerable site identified is site 15, located in front of the New Brighton surf club.

The significant factors affecting the vulnerable sites primarily occur in the forms of infrastructure such as buildings located on or closely adjacent to the dune, walkways both designed and formed, and public opinion. Coastal squeeze is fixing the dune in place therefore disrupting the ability of the dune to morph and recede as natural processes dictate. This increases the vulnerability of sites. Another identified issue is the social behaviours. Individuals commonly walk through the dunes, trampling vegetation and publicly opposing the scientific knowledge supplied by the rangers. All these factors have significant potential to affect the long-term functionality of the dunes and the services they provide. Therefore, the underlying issues need to be understood to shape broader decision-making processes. The results and discussion undertaken in this report will allow the targeted management of the identified sites of interest to ensure they can be preserved for future generations.

1.Introduction

Christchurch City Council (CCC) and Environment Canterbury have requested important research be undertaken to identify vulnerable areas between Southshore Spit and Waimairi beach. This will allow these sites to be prioritised for dune restoration, ensuring the protection of coastal assets. The study site consists of a continuous stretch of sand dunes which protect infrastructure such as housing, surf clubs, hot pools, New Brighton Village and this site has cultural, ecological and recreational significance to the local Manu Whenua. These sand dunes play a key role as natural protection for these valuable features of the coast, as they can ease the impacts of coastal erosion, flooding and storms. The three main research aims for this project are:

1. To identify 10 areas of risk along the study site for possible dune restoration,
2. To create GIS maps to aid in visual interpretation of overall findings,
3. To create graphs of site Sea Level Rise and Wave Height data.

Climate change is having significant effect on coastal systems across the globe (Silva et al., 2020)). A 1-degree Celsius increase in global temperature due to anthropogenic induced climate change, has led to a 10mm rise Sea Level Rise (SLR) in Canterbury since 2005 increased storm frequency and intensity (NZ Sea Rise, 2023). These environmental factors increase the likelihood of inundation and erosion, potentially putting the coastal assets between Southshore Spit and Waimairi beach at risk (Lindsey & Dahlman, 2023). As well as protection of coastal assets, dunes provide wider services to the local environment such as biodiversity and recreation.

Whilst the initial effects of this are being seen on the coastline today, there is a significant knowledge gap into where the future risks may be. This research will identify the dune areas with high vulnerability to erosion and inundation between Southshore Spit and Waimairi Beach and contribute to the quick-pass vulnerability assessment undertaken by the Councils. The results from this project will help inform a process of prioritising sites for dune management and climate adaptation planning to ensure the future sustainability of the area.

2.Background Information

Waimairi Beach to Southshore Spit is a sandy beach located at the Southern end of Pegasus Bay (Canterbury, New Zealand), as shown in Figure 1 The beach is 9.5km alongshore and presents a dune system of variable widths behind it. This leeward side of the dune system is characterised by numerous coastal assets including surf clubs, libraries, and protects 14,712 residents from coastal hazards (Stats NZ, 2018).

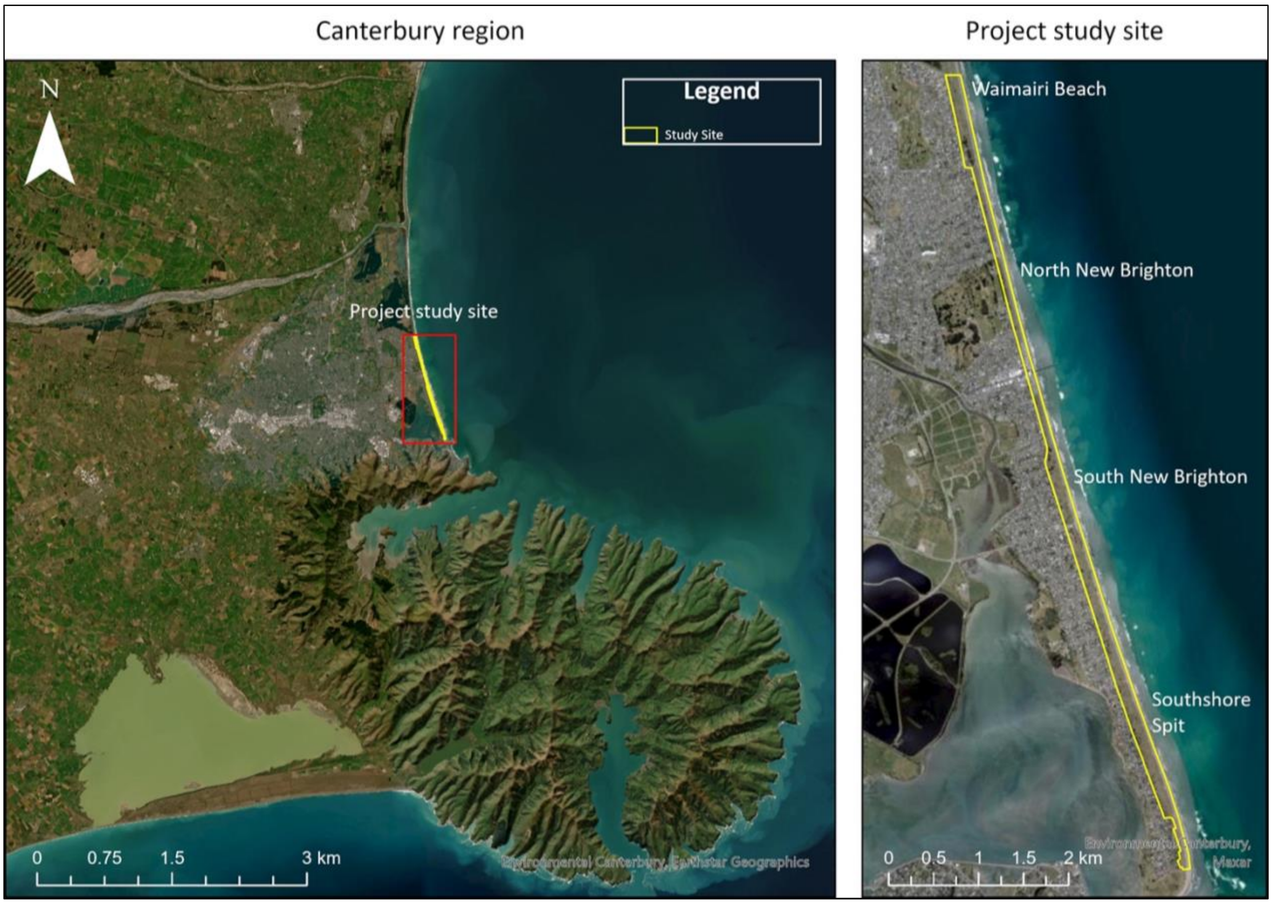

Figure 1

Map of Canterbury New Zealand, in Relation to the Study Site.

Note. The following map shows the study site of Waimairi beach to Southshore Spit, outlined in yellow, in relation to the wider Canterbury region.

3.Context

3.1 Importance of Sand Dunes

It is vital to understand the importance of dunes as environmental and societal assets as this provides justification for completing this project. Identified throughout the literature are four key points which explain the importance of dunes consisting of their capabilities to act as biodiversity sources, archaeological values, societal benefits and protecting coastal assets.

Coastal dunes are areas of high biodiversity. Fixed dunes, like the ones observed in Canterbury have high plant diversity (Druis et al., 2016). Natural dune zonation, as seen in undisturbed dune environments guarantees high dune species diversity, an important aspect of coastal dunes (Druis et al., 2016). Similarly, Johansen et al. (2015) found that coastal sand dunes in New Zealand can provide high fungal diversity through the presence of arbuscular mycorrhizal fungi, highlighting the importance of coastal dunes as sources of ecological diversity, which is essential for their survival.

The protective properties of sand dunes are heavily relied on by coastal communities. Everard et al., (2010), explains how coastal sand dunes have socio-economic, tourism and coastal defence significance. They conclude sand dunes deserve greater recognition and protection for their societal benefits, which directly relates to the purpose of this project.

Hilton et al., (2018) describes how archaeological sites represent a strong maritime focus of Māori and early European economies. They can be perceived as an archaeological landscape with "ideational, ritual, spiritual and economic dimensions" which makes dunes important in terms of their cultural and historical significance (Hilton et al., 2018, p. 608). This project recognises the cultural significance that this stretch of coast has to Māori and protecting the coast means acknowledging Kaitiakitanga and their indigenous history.

3.2 Dune Processes

When left in an undisturbed state, dune systems have their own set of processes which drive their changing morphology. By first understanding these natural processes, it is easier to understand the effect that humans may be having on the system.

3.2.1 Dune Retreat.

Dune retreat refers to the natural process in which sand gradually moves inland due to erosion, forcing the dune to move. This can have a negative effect on coastal landscapes, ecosystems, and communities. A study on Karekare Beach and Piha Beach in New Zealand showed the effects of dune retreat and the rate of which it is occurring (Blue et al., 2016). Figure 2 shows that Piha beach has had a total dune It was found Karekare has retreated at a mean rate of 3.9 m/yr. since 1980. Unlike Karekare and Piha our site holds large amounts of coastal assets behind the dune. These structures will fix the dune in place and therefore hinder its ability to naturally retreat.

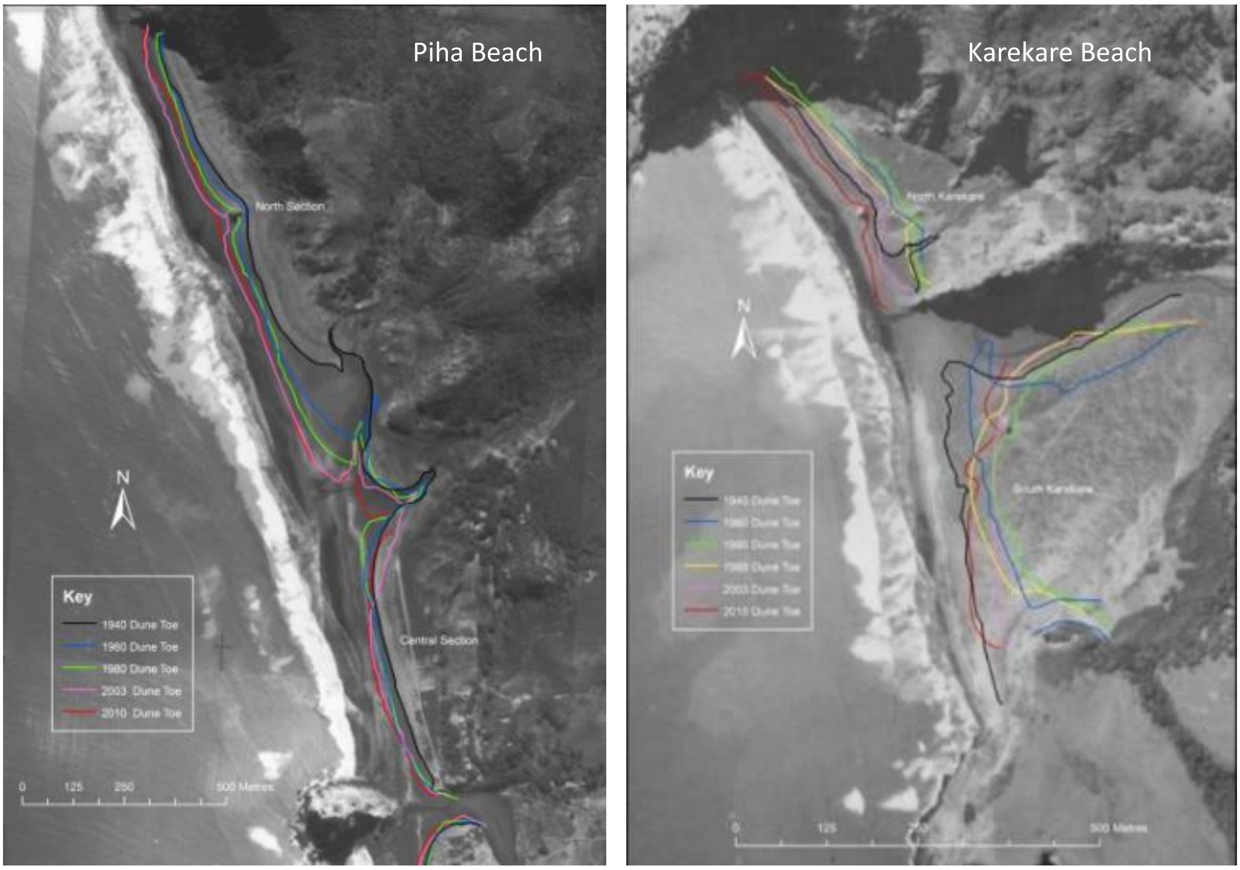

Figure 2

Comparison of Maximum Dune Extent at Piha and Karekare Beach

Note. The image on the left shows the maximum dune extent at Piha Beach. The image on the right shows the maximum dune extent at Karekare beach. The coloured lines indicate change over time. Adapted from Blue, B., & Kench, P. S. (2016). Multi-decadal shoreline change and beach connectivity in a high-energy sand system. *New Zealand Journal of Marine and Freshwater Research, 51*(3), 406-426. https://doi.org/10.1080/00288330.2016.1259643

3.2.2 Dune Erosion.

Dune erosion is another naturally occurring dune process. Dune erosion causes dune retreat and is the main cause of the different dune heights seen in figure 2. Erosion can be caused by hydrodynamic processes, geomorphology, sediment budget, vertical land movement and sea-level rise (Ministry for the Environment., 2017). Main dune erosion causes in the site include storm events, SLR and human activity.

3.2.3 Weather Events.

Severe weather events in coastal areas can lead to rapid dune erosion. Powerful waves, high water levels, and strong winds strip away large amounts of sand from dunes (Vellinga et al., 2016). SLR can accelerate natural sand loss and erosion of dunes. Our site could be experiencing increased sea levels with +2.24 mm/yr increases in Lyttleton [6]. Lyttleton is near our site and would therefore show similar trends in sea levels.

3.2.4 Human Activities.

Human activities have altered natural dune processes. These actions include construction, removal of vegetation and installation of structures such as seawalls. These namely affect the geomorphological elements of the dune as well as vegetation cover, posing increased risk of erosion (Peña-Alonso et al., 2016).

3.3 Dune management techniques/practices

Dune management and stabilization strategies are important in ensuring the future protection of coastal environments. These range from 'hard' methods such as bulldozing and moving sand, to 'soft' measures such as planting and diverting foot traffic (Nordstrom, 2008). Soft engineering structures are considered more beneficial for the protective and habitat enhancing properties they provide, while hard structures significantly change the sediment structure and impact local biodiversity (Hanley et al., 2014, Charbonneau, 2015, and Druis et al. 2016). Planting and sand fences are both commonly used strategies used in New Zealand, however for them to be effective, the sites that are at risk of eroding need to be first be identified (Nordstrom, 2008). As dunes are dynamic environments, different areas often require different techniques, or a combination of techniques (Nordstrom, 2008). Understanding all aspects of dune systems, including biological and human impacts is important for an integrated coastal management approach which is required when undertaking vulnerability analysis. Without identifying these vulnerable areas, we are unable to use this knowledge in site protection, and in the future will have to resort to hard-engineering solutions which have significant effects on the wider physical and social environments of the area.

3.4 Vulnerability and Multicriteria Decision Analysis

Multicriteria decision analysis (MCDA) is a decision-making support system used to facilitate decision making where there are a variety of different contributing factors (Sauvé et al., 2022). It provides a comprehensive analysis of all the different factors, outputting an overall ranking of the different sites (Oropeza-Orozco, 2011). Using a combination of the knowledge around erosional risk factors and a MCDA framework allows for the undertaking of a comprehensive analysis to identify 10 areas of risk along the study site for possible dune restoration.

4.Methods

4.1 Data Collection and Processing

In this study, three Digital Elevation Models (DEM's) were used to calculate the change in dune shape overtime. These DEM's (2015, 1m, 2018, 1m & 2021/22, 1m) were acquired from Land Information New Zealand's (LINZ) data service database. Aerial imagery (2019, 0.075m) sourced from LINZ was also used to analyse vegetation and walkways present.

Both ArcMap and ArcGIS pro were used to process and analyse the data. To build the map, the DEM files were mosaicked to form a new raster layer. This gave a continuous elevation model of the study area. To aid in analysis the area was divided into 37 sections. This was done by creating transects along the beach every 250m. Each variable (dune height, width, erosion potential etc..) was measured at each of the 37 sites.

4.2 Individual Metric Analysis

4.2.1 Dune Height.

Dune height was measured by creating a 3D surface of the DEM and subsequently interpolating the shape of the dune. The obtained beach profiles were used to identify the maximum height of the dune. Profiles were taken along each transect line.

4.2.2 Beach Width.

Beach width was measured from the high tide mark on aerial imagery to the edge of the infrastructure on the leeward side of the dune. The beach width was also measured at the point of the transect to ensure the whole beach was covered.

4.2.3 Erosion Potential.

Geomorphic Change Detection software (GCD) was used to visualize areas of erosion and accretion (Riverscapes Consortium, n.d.). This tool allows for comparison of 2 DEM datasets and highlights changes in elevation between the two years. Figure 3 Shows the visuals produced from this software.

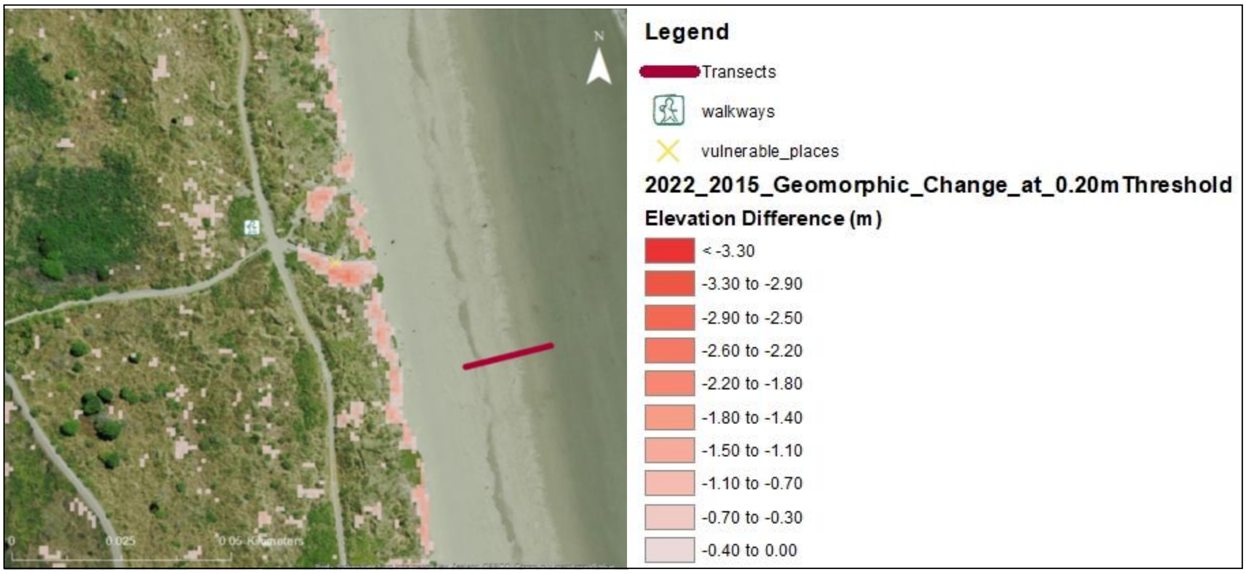

Figure 3

Example Image of the visuals produced by the GCD software.

Note. The areas highlighted in red are areas of change detected by the GCD tool between the years of data from 2015 and 2022. The darker the shade of red, the larger and more severe the erosion is in that area. The GCD software was developed by the company Riverscapes Consortium. (n.d.). *Geomorphic Change Detection*. https://gcd.riverscapes.net/

The 2015 and 2022 DEMs were compared at 0.20m, 0.3m and 0.1m thresholds. Comparing across thresholds removed the potential for registration errors to be interpreted as land-cover and land-use change, which may lead to an over or under estimation of erosion (Stow, 1999). The erosion potential was then visually identified. This was done by locating areas that a) had large pockets of dark red and b) were consistent across the three thresholds. The erosional areas identified were then marked with a yellow cross. The number of yellow crosses within the site gave its erosional potential.

4.2.4 Walkways.

The number of walkways through or along the dunes was identified using 2019, 0.075m aerial imagery. They were simply counted and totaled.

4.2.5 Shoreline Retreat Potential.

The CCC Coastal Hazards portal provides data on the estimated shoreline retreat in the next ~100 years. This portal considers erosion and SLR in the area and maps the estimated shoreline position in 2130 under a 1.3m SLR scenario. This portal has 5 different coastline segments with different projected shoreline positions. The CCC map was aligned with this projects map and the different shoreline positions were taken for each site. A copy of the shoreline projection is attached in Appendix B.

4.3 Multi Criteria Decision Analysis

To accurately identify vulnerable sites, all seven factors need to be considered together and combined into a succinct output. The most appropriate method for this was determined to be a multi criteria analysis (Sauvé et al., 2022). Each vulnerability factor at each site was rated between 1 and 5. High numbers indicate the site is performing badly in a criterion and is therefore vulnerable, and low numbers indicate it is performing well and not deemed a risk. Appendix A shows the final MCDA table output and how each of the variables were assigned values. The total sum of all the different criteria for each site determined its overall vulnerability, with a maximum sum of 35.

5.Results

5.1 Overall Results

The results of the MCDA provided an overall vulnerability rating for each of the 37 sections of beach. This is displayed in Appendix One. A distribution of the scores is shown in Figure 4 below.

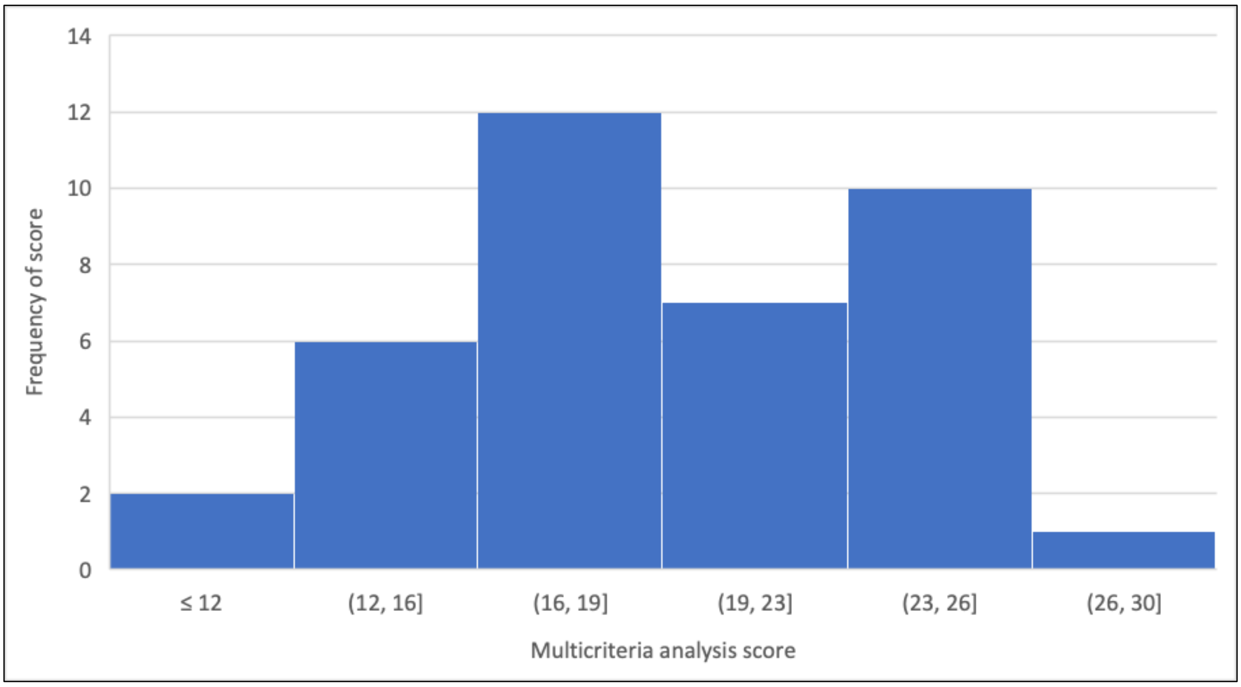

Figure 4

Distribution of Multicriteria Decision Analysis Scores.

When looking at the distribution of results, 8 of the 37 sites were ranked between 12 and 16. This indicates an average of 1.5 across the 7 categories. These can be categorised as having low vulnerability to erosion. The 16 – 23 band contains 19 sites. These can be categorised as moderately vulnerability to erosion, with an average rating of 2.7 across the categories. The 23 – 30 category contains 11 sites. With an average rating of 3.7 across the categories this indicates moderate to high risk in each of them and therefore high vulnerability overall.

5.2 Top 10 Vulnerable Sites

Regarding the aim of this study, the top 10 sites from the MCDA are identified. The numerical values and ranking are in Table 1 below.

Table 1

Top 10 most vulnerable sites score total

Relative vulnerability rank	Site	Total	General Location
1	15	30	New Brighton Pier
2	9	26	North Beach
3	14	26	New Brighton Pier
4	36	26	Southshore spit
5	8	25	North beach
6	12	25	New Brighton Pier
7	7	24	North beach
8	11	24	North Beach
9	18	24	South of pier - Shackleton St
10	10	23	North Beach

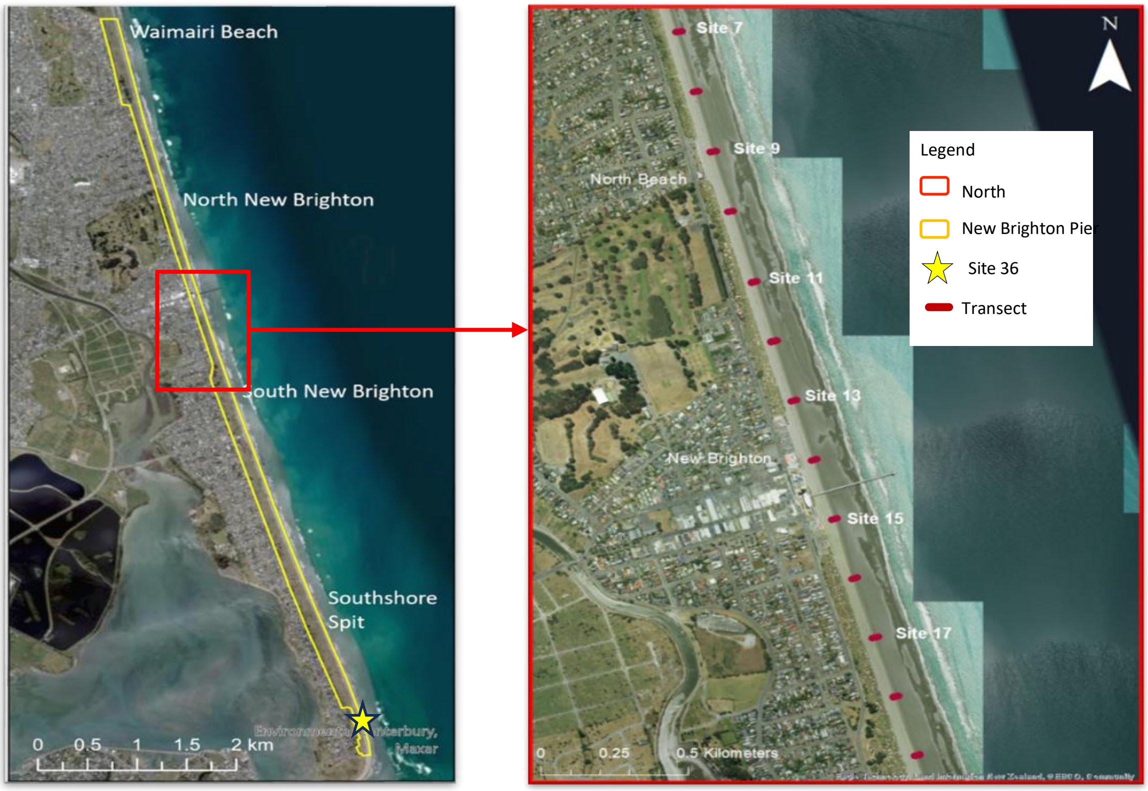

Figure 5

Graphic of vulnerable sites.

5.2.1 North Beach Location.

Four out of the five New Brighton Beach areas ranked in the top 10 for most vulnerable to future coastal erosion. These are sites 7, 8, 9, 10, and 11. The location of the sites as well as beach profiles are displayed in Figures 6 – 9 below.

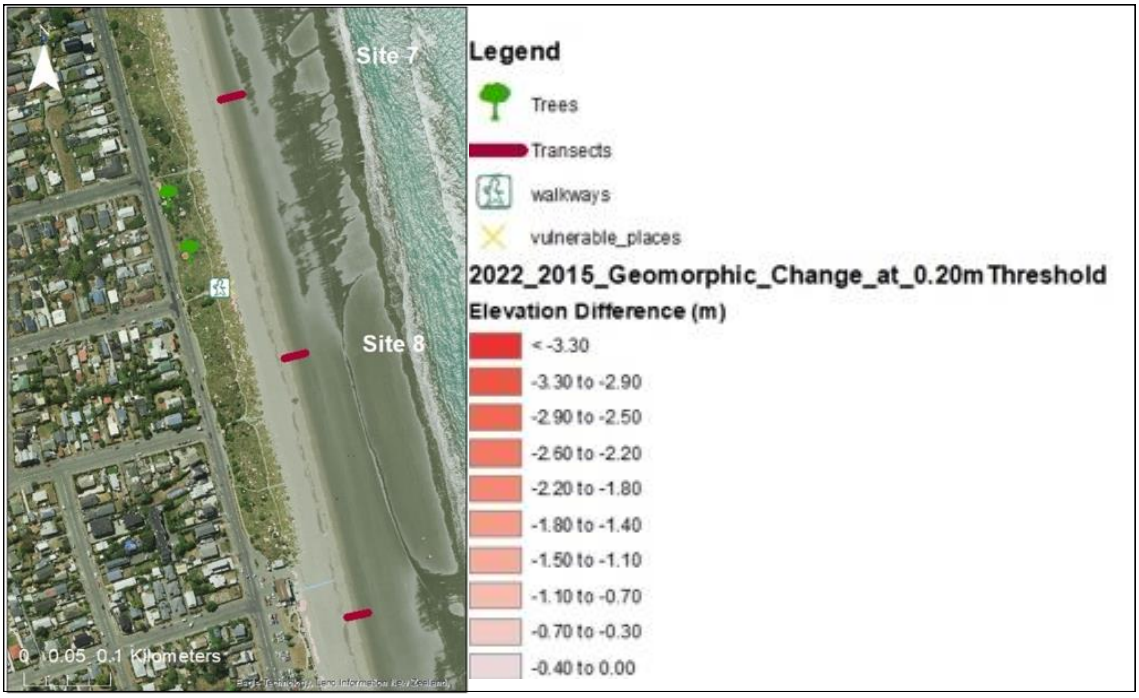

Figure 6

Aerial Imagery of Sites 7 and 8.

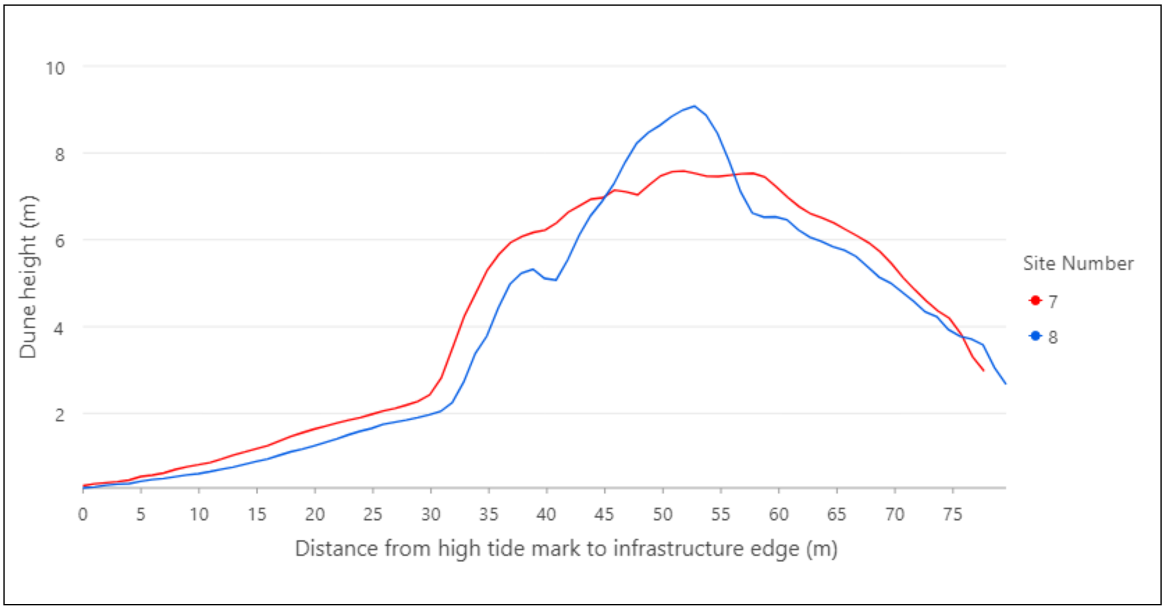

Figure 7

Beach Profile of Sites 7 and 8;; height measured from Vertical datum NZVD2016.

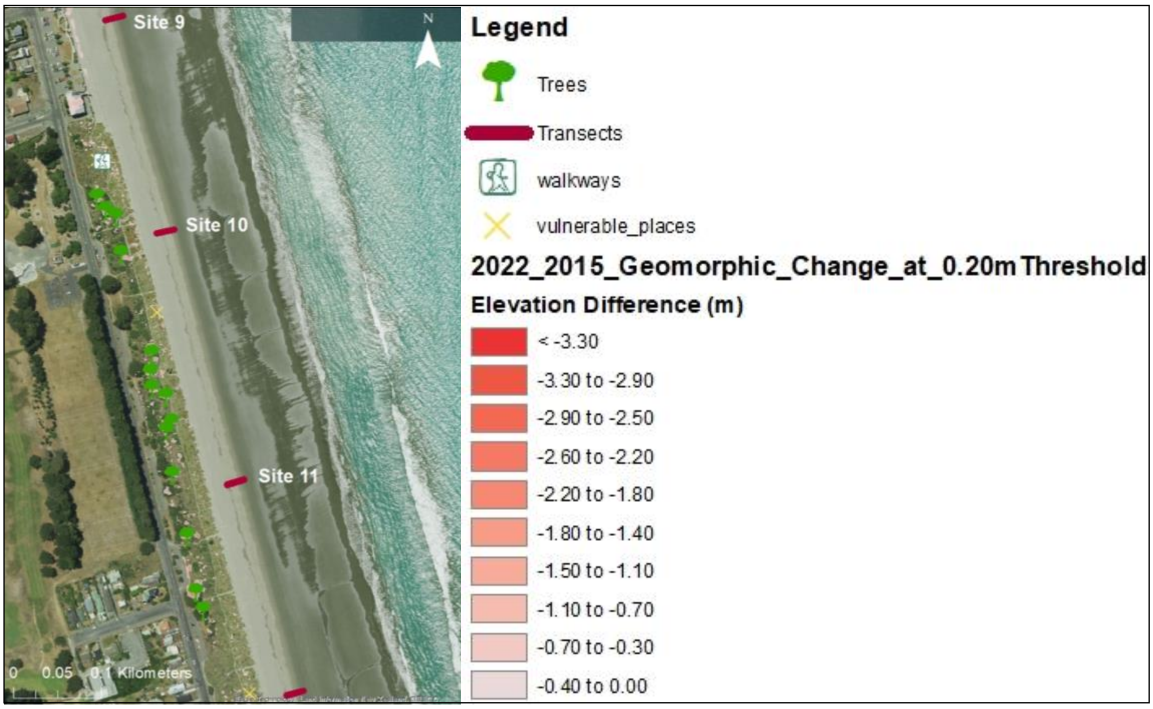

Figure 8

Aerial Imagery of Sites 9, 10 and 11.

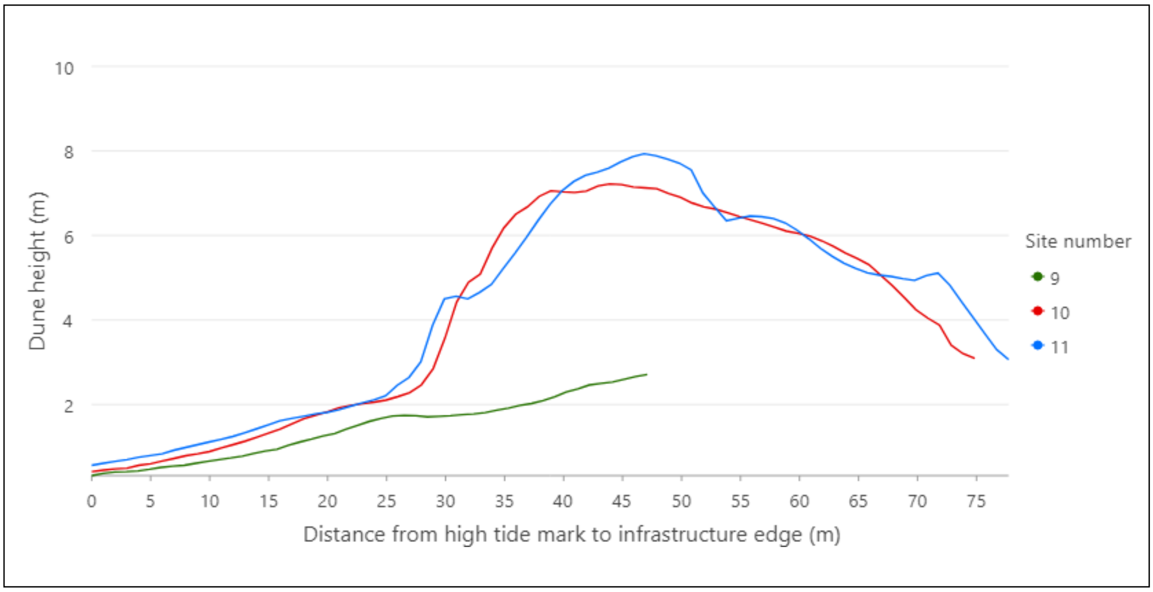

Figure 9

Beach Profiles of Sites 9, 10 and 11; height measured from Vertical datum NZVD2016.

5.2.2 New Brighton Pier Locations.

Sites 12, 14, 15 and 18 are all in the top 10 most vulnerable sections of the beach. This accounts for four of the five total New Brighton sites. A visualisation and general site characteristics are displayed in Figures 10 – 15 below.

Figure 10

Aerial Imagery of Sites 12, 13, and 14

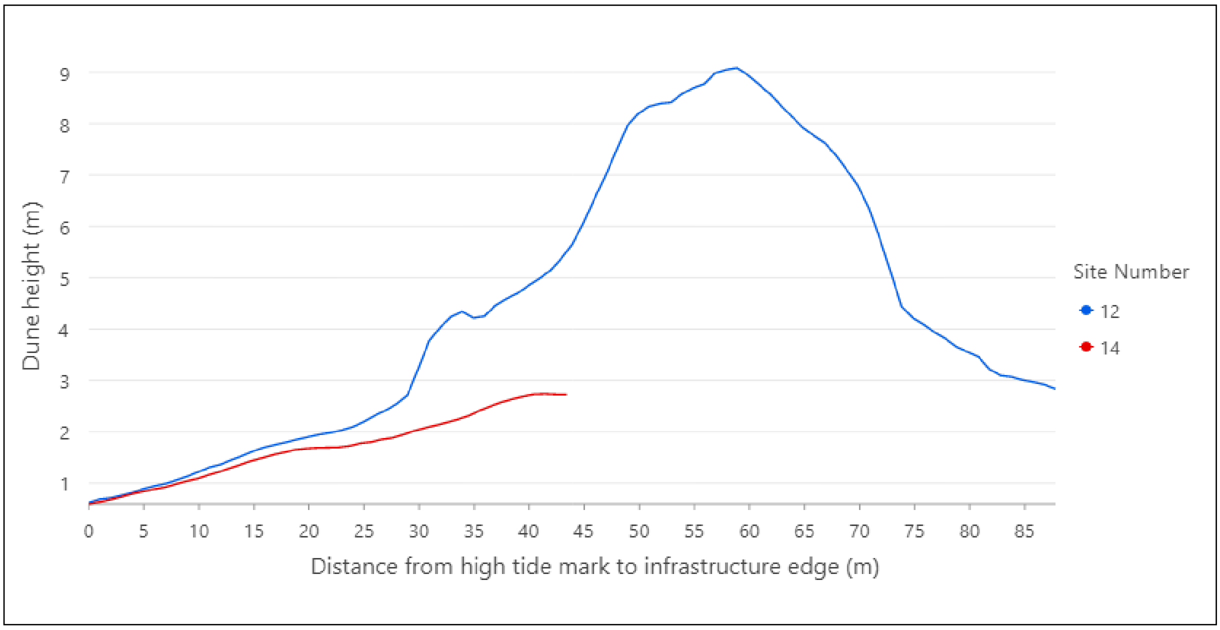

Figure 11

Beach Profiles of Sites 12 and 14; height measured from Vertical datum NZVD2016.

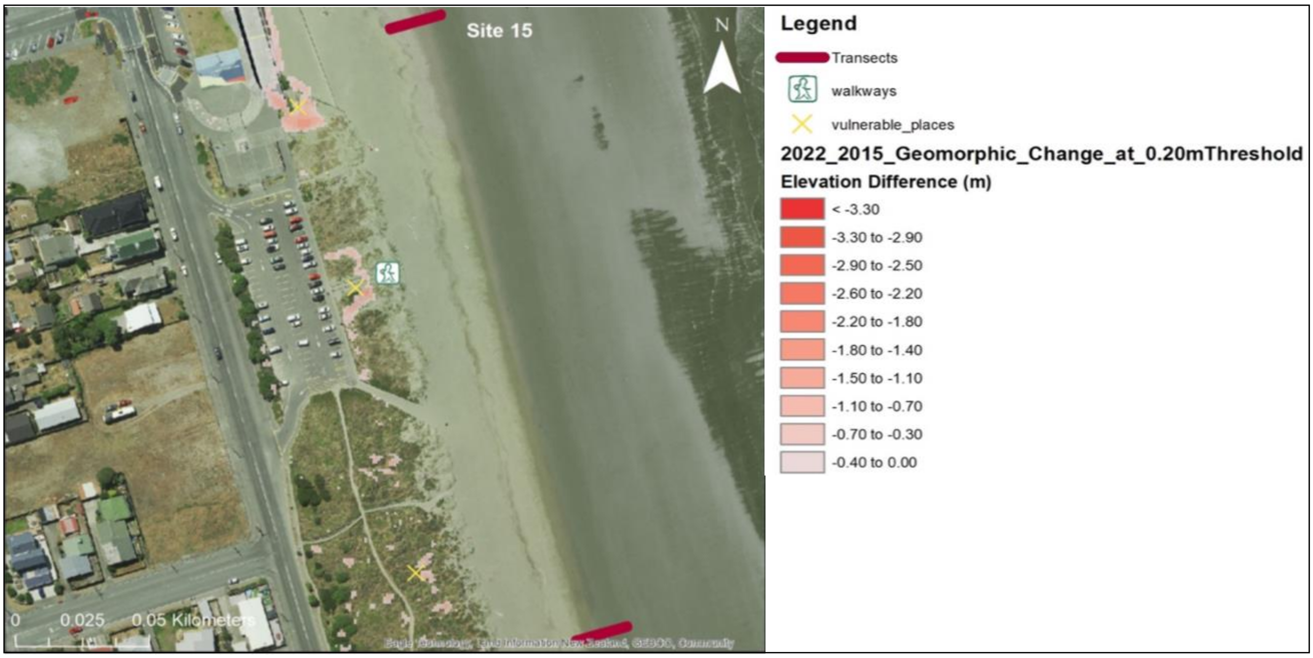

Figure 12

Aerial Imagery of Site 15.

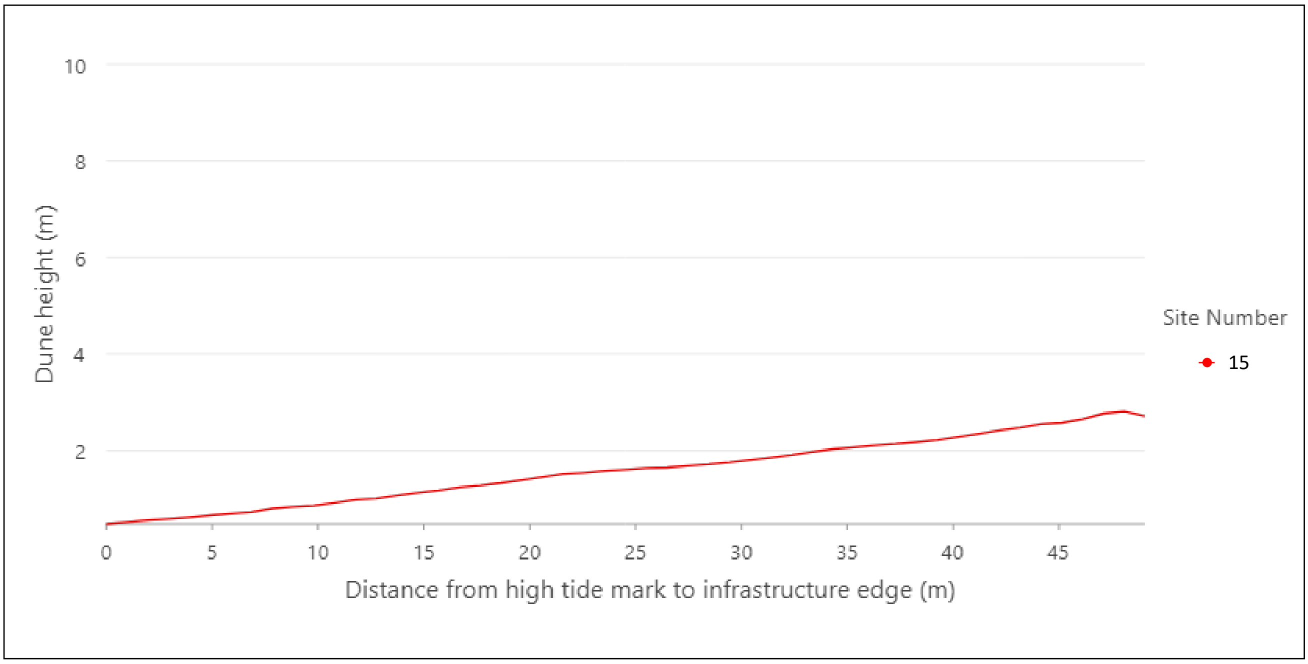

Figure 13

Beach Profile of Site 15; height measured from Vertical datum NZVD2016.

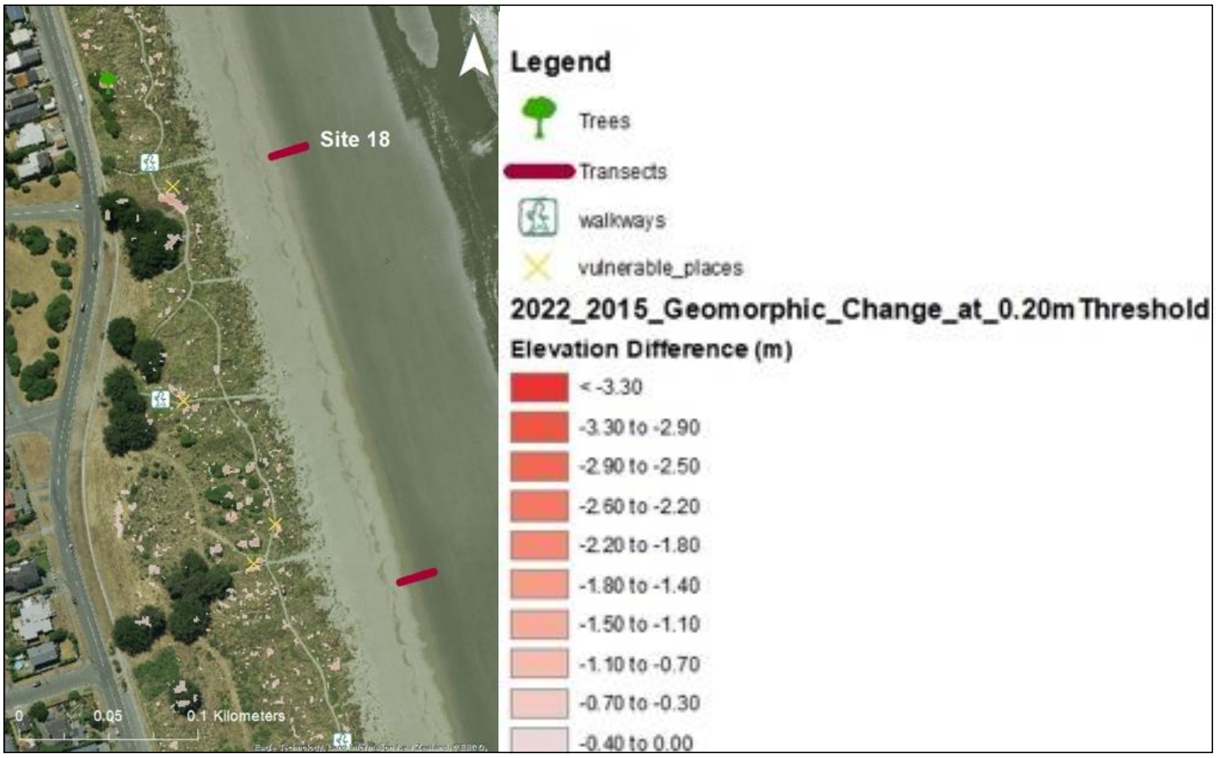

Figure 14

Aerial Imagery of Site 18.

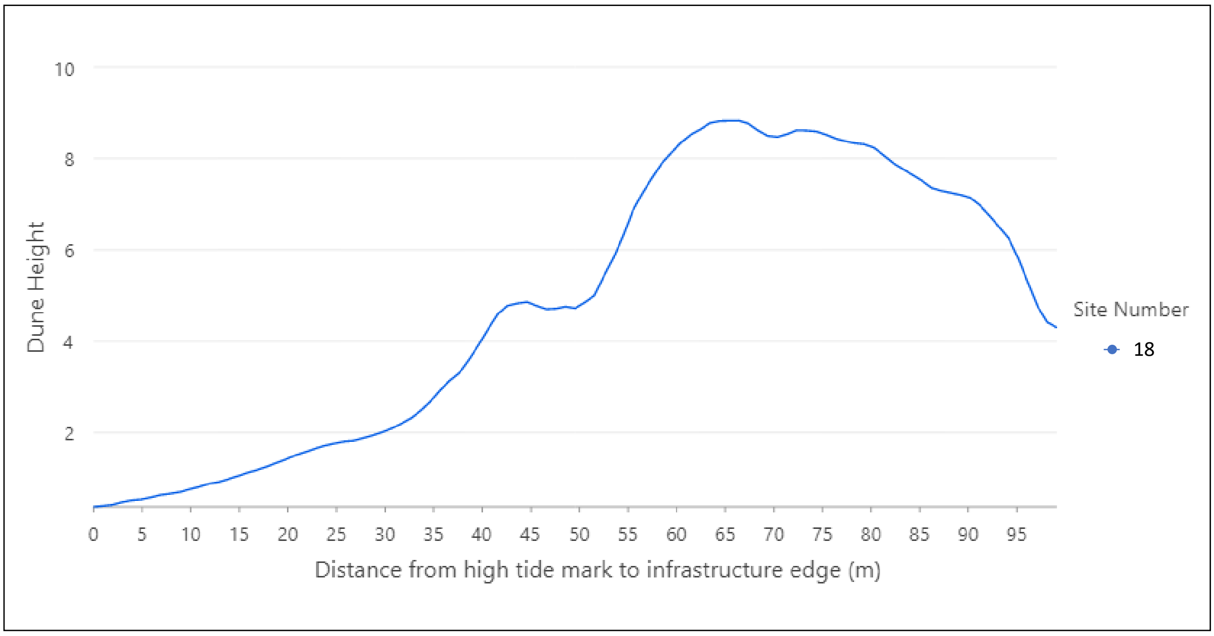

Figure 15

Beach Profile of Site 18; height measured from Vertical datum NZVD2016.

5.2.3 Southshore Spit Location 36.

Of the top 10 most vulnerable locations, site 36 was the only one outside the concentrated urbanised area of New Brighton / North Beach. Figures 16 and 17 show the general characteristics of this location.

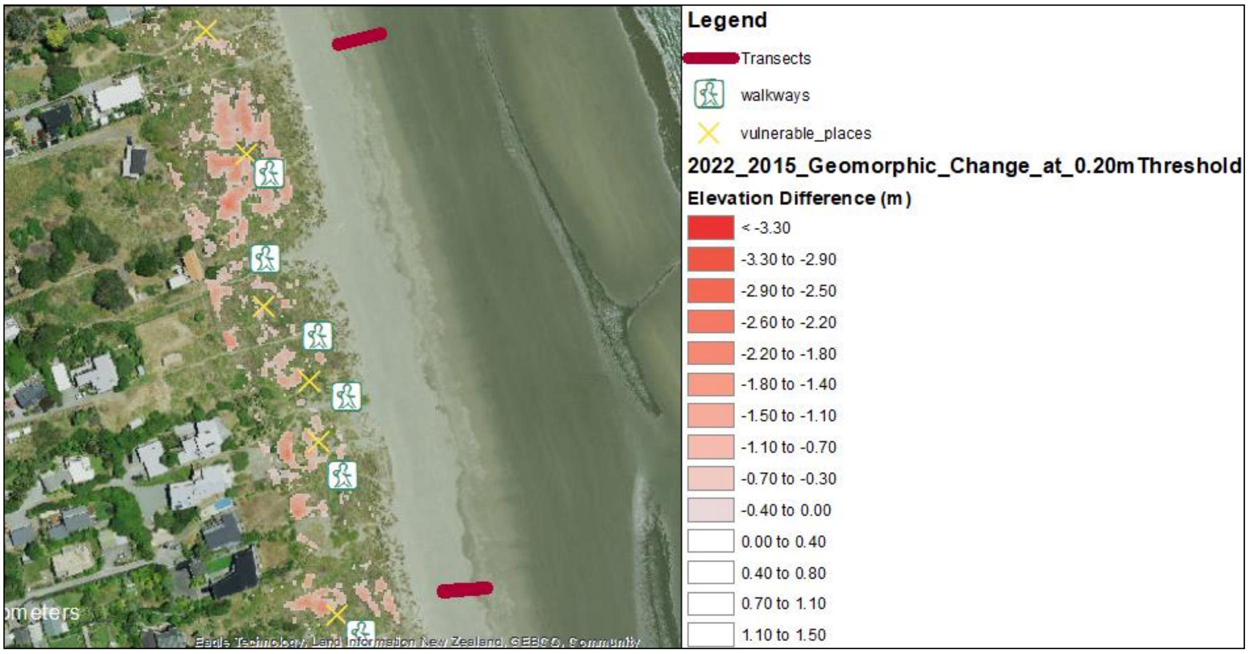

Figure 16

Aerial Imagery of Site 36.

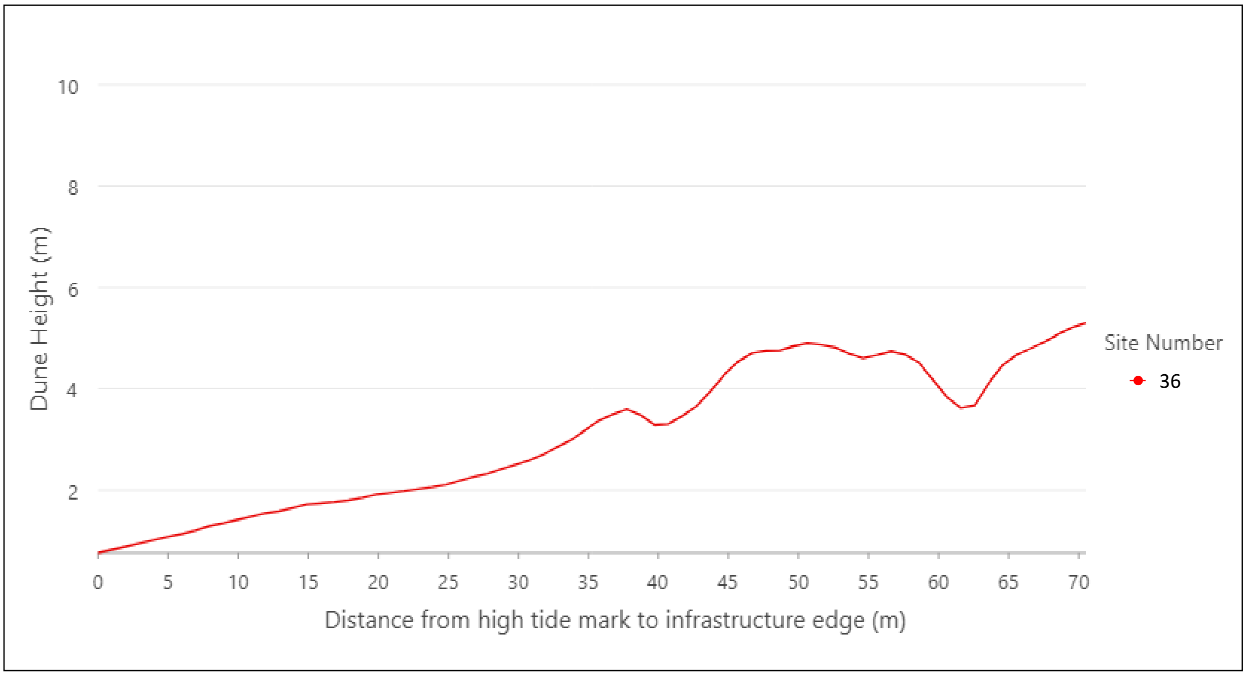

Figure 17

Beach Profile site 36; height measured from Vertical datum NZVD2016.

6. Discussion

6.1 Vulnerable Sites

The results of our analysis identified the top 10 sections of vulnerable beach and dune. These sites and their locations are displayed in Appendix A.

6.1.1 Spatial Distribution of Vulnerable Sites.

The 10 sites identified as most vulnerable are clustered around the North Beach and New Brighton Pier area, with the remaining one (site 36) located in the Southshore Spit area. These sites are shown in Figure 18 below. This is due to this section of the beach being highly urbanised and having lots of built infrastructure.

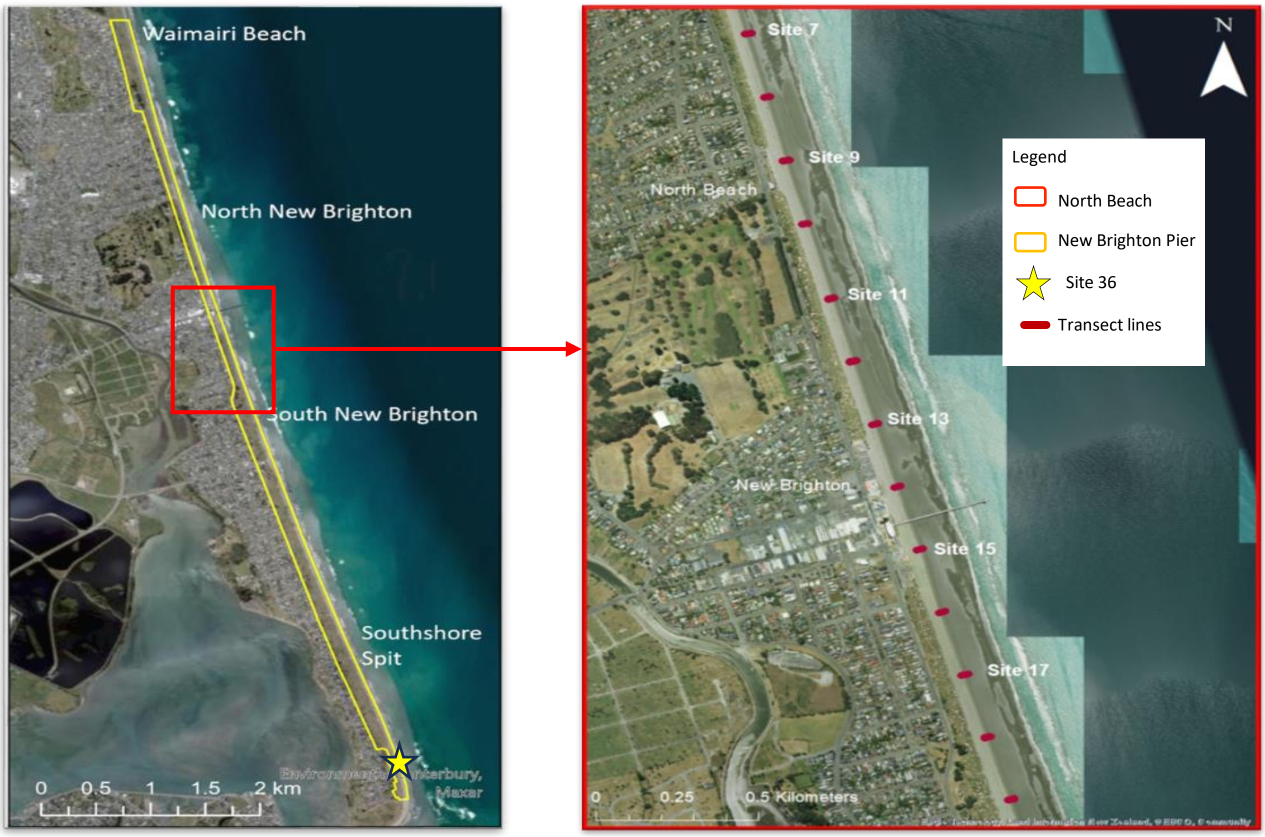

Figure 18

Graphic of Vulnerable Sites

6.1.2 Most Vulnerable Site.

Site 15 (Figure 12) is the most vulnerable site on the beach. This can be attributed to the high human influence and therefore high scoring in many of the factors in the MCDA. Looking at the physical dune profile in Figure 13, the dune rises by 3m, and the beach width is 50m. This is substantially less than the site medians of 8.09m and 151.8m respectively. CCC erosion modelling predicted a moderate amount of shoreline recession over the next 100 years at this site. Of significant concern is the distance to infrastructure at this point. The buildings and infrastructure are located directly on the dune crest, negating the protection services dune systems provide. There are also large areas of erosion seen and not much vegetation present. The combination of all these characteristics means the effects of climate change have the potential to cause damage to both the dune and the infrastructure present at the site.

6.1.3 Outlying Sites.

Site 36 is an outlying site. It is located far away from the other vulnerable sites, near the end of Southshore Spit. This may be an outlier due to the morphology of the spit at this point. The width narrows considerably and starts to curve around. This increases tidal activity in this area. Tidal currents can move up to 1m/s at an estuary mouth, compared to 0.1m/s along beaches (Washington Ocean Acidification Center, 2021). This may account for the narrow beach, high erosion potential and subsequent lack of vegetation at this site. Whilst still valuable knowledge, the possible difference in contributing forces are outside the scope of the study, therefore the vulnerability of this site may not be entirely relevant.

6.2 Underlying Drivers of Vulnerability

6.2.2 Infrastructure and Coastal Processes.

Infrastructure is a major driver of erosion vulnerability at this site. Whilst the entire dune system is backed by infrastructure, highly vulnerable areas are characterized by infrastructure on top of the dune itself. Site 14 (Figure 19) is an excellent example of this, where the car park and surf lifesaving clubrooms are located directly on the dune crest. Infrastructure fixes the dune in position making it highly vulnerable to storm surge events through the process of coastal squeeze. Coastal squeeze is the loss of beach width, resulting from increasing sea levels and fixed infrastructure on the lee side of dunes (Mills et al., 2015). This process causes a loss of space both in front and behind sand dunes (Silva et al., 2020). When big swells occur, dunes naturally migrate landward to accommodate this change, however when infrastructure is there, their morphology and function is interrupted (Silva et al., 2020). The analysis of shoreline position and SLR in the study area adds to the coastal squeeze concern. Shoreline position and SLR are projected to move landward significantly within the next 100 years. This will further limit the beach width, changing beach profiles and dune form. Consequently, the morphology and function of the dunes is limiting its capability for response to abnormal conditions therefore making it extremely prone to coastal erosion (Martínez et al., 2014). A coastal squeeze study of the Boca del Río coast highlighted similar squeeze and vulnerability characteristics as this study site. This study classified a highly urbanised eroding stetch of coastline to be vulnerable and suggested risk mitigation is highly important.

6.2.3 Vegetation Cover.

As a result of high-density infrastructure, SLR and frequent storm events, a lack of vegetation has been seen across segments of the study area (figure 19). Plants are essential to coastal ecosystems as they trap dune sediment in their roots which reduces erosion, weakens wave energy, and helps to trap sediment blown by wind. All of these factors contribute to dune growth (Sigren et al., 2014). The limited available space for dune growth and high wave energy in this site has made it difficult for dune plants to establish in these vulnerable areas and as a result the dunes have been unable to build up. Areas along the dune with increased rates of erosion also show little vegetation cover.

Figure 19

Sites Showing a Lack of Vegetation in Front of Heavy Foot Traffic Areas.

Note. Sites 9 and 10 have a lack of vegetation coverage due to the amenities behind the beach. This leads to the public frequently accessing the beach through these areas, hindering vegetation growth. These public amenities are essentially located on top of the sand dunes and reside within the red ovals present in the image.

6.2.4 Beach Access and Social Aspect.

The results showed a significant effect of beach access paths on areas of erosion, with the GCD tool significantly highlighting areas like seen In Figure 20 below. Beaches like New Brighton and North Beach are popular for recreational activities such as swimming, surfing, the hot pools and fishing. Recreational beach use can lead to trampling of dune vegetation by humans, which decreases vegetation and increases erosion (Purvis et al., 2015). There are many established walkways along the beach to limit the areas of erosion, with them being constructed from bare sand or wood steps, with some paths having rails. The paths vary in distance from each other and width, influencing the degree of erosion on each path. Purvis et al. (2015) revealed that vegetation is typically reduced around pathways and species richness is reduced in areas where pathways are near each other. Erosion on these paths is an issue however individuals often make their own paths through establishing sand dunes, which poses more of a risk. This reduces dune height which hinders dune stabilisation/accretion, causing dune habitats to shrink and become fragmented (Purvis et al., 2015). Patches of natural habitat within urban areas is important for global diversity. The biodiversity provided by these dune ecosystems provides important ecosystem services such as ecological corridors and protection of natural and built environments from coastal hazards (Purvis et al., 2015).

Figure 20

Points of Erosion Caused by Human Activity Around Walkways in Sites 1 and 32

Human activity massively disrupts dune processes as people trample through the dunes off the walkways (Steven-Newman, n.d.). Getting people to acknowledge issues and understand that they need to make changes is also an issue. CCC rangers alerted us to this as they have struggled with this issue for years. Humans as species are resistant to change (Jost, 2015). The management of the dunes in the New Brighton and North Beach area will cause changes in people's day-to-day lives resulting in resistance to dune management practices. There has been minimal change in the dune systems in these areas, hence the public's strong backlash. Resistance to change has been occurring the most from the residents as they bought their homes in these areas because of the recreational activities and views the beach provides. However, dune management practices are needed to ensure future use of the beach can continue.

6.3 Wider Physical Environmental Processes

6.3.1 Sea Level Rise.

Climate change is having a major effect on global marine systems through the melting of ice sheets and other natural processes. Globally, sea level has risen 15cm since 1923 and is accelerating in its rate overtime due to positive climatic feedback loops (Dangendorf et al., 2019). Along the New Brighton coast, there has been a steady rate of SLR of approximately 10mm every 10 years. Extrapolating these results suggests 1 metre SLR increase by 2100, however this potentially underestimates the accelerating rate occurring (NZ SeaRise, 2023). This has a direct effect on coastal erosion as SLR increases the plane at which wave processes act, increasing the potential risk of wave-driven erosion in storm events.

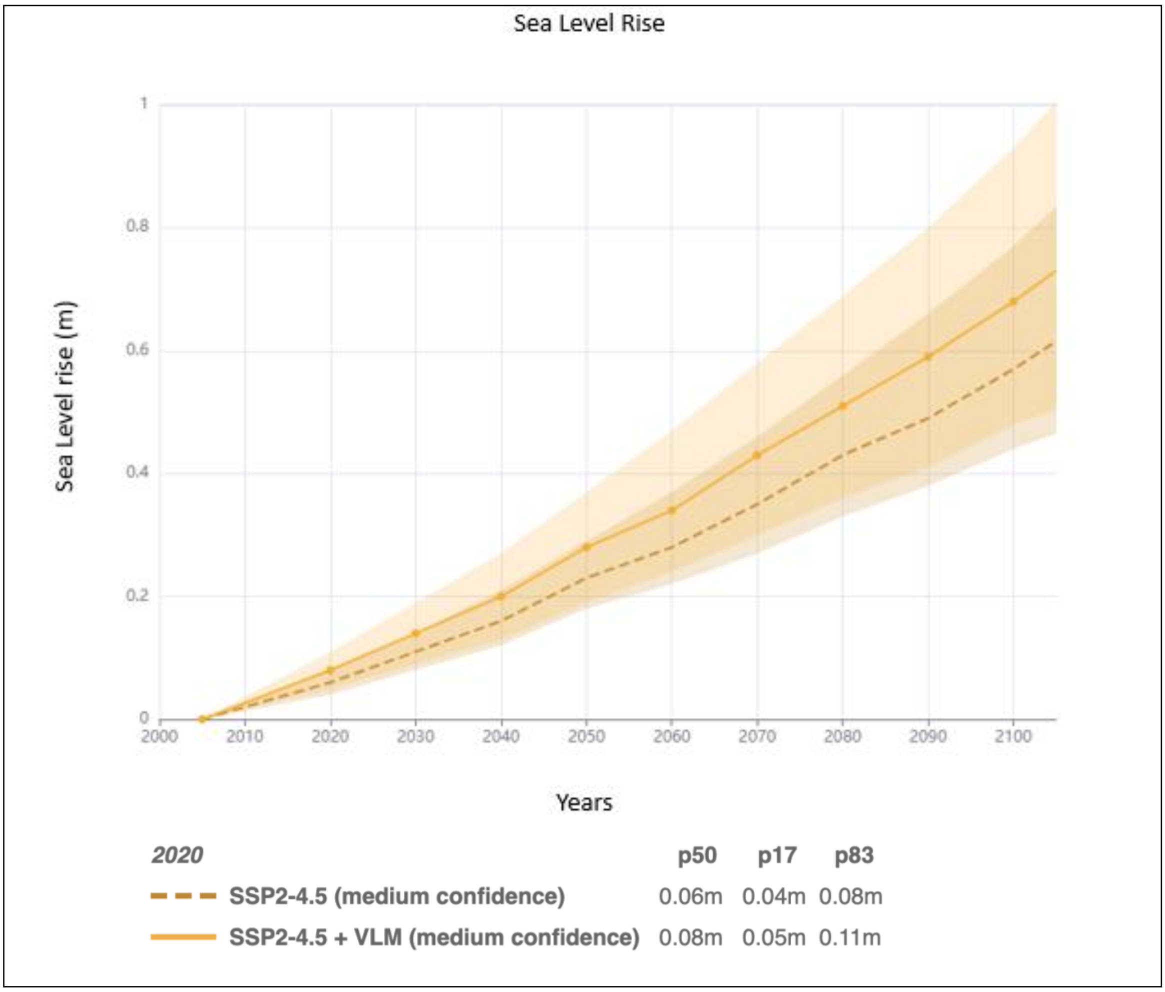

Figure 21

Sea level Rise Graph showing possible future scenarios

Note. The data for this graph was obtained from NZ SeaRise. (2023). Sea-level Rise. Retrieved from https://searise.takiwa.co/map/6233f47872b8190018373db9/embed

6.3.2 Wave Height.

Changing climatic patterns and characteristics are other physical processes that pose a risk to New Brighton. Increasing storm frequency and intensity bring bigger waves onshore, thereby increasing rates of dune erosion and destabilisation. Wave data collected from the New Brighton Area have recorded heights over six meters (Figure 22). Contextualising these results, if these wave heights occur at any of the vulnerable sites but more specifically sites with low lying dune (site 9, 15) or sites which have a narrow dune (Site 28, 29). This will negatively affect coastal assets along our site. If this situation occurred in conjunction with a king tide event, the consequences could result in significant dune loss, and damage to houses and other social assets. It is important to identify risk sites to implement management strategies to withstand possible wave damage in the identified vulnerable sites before extreme events reoccur.

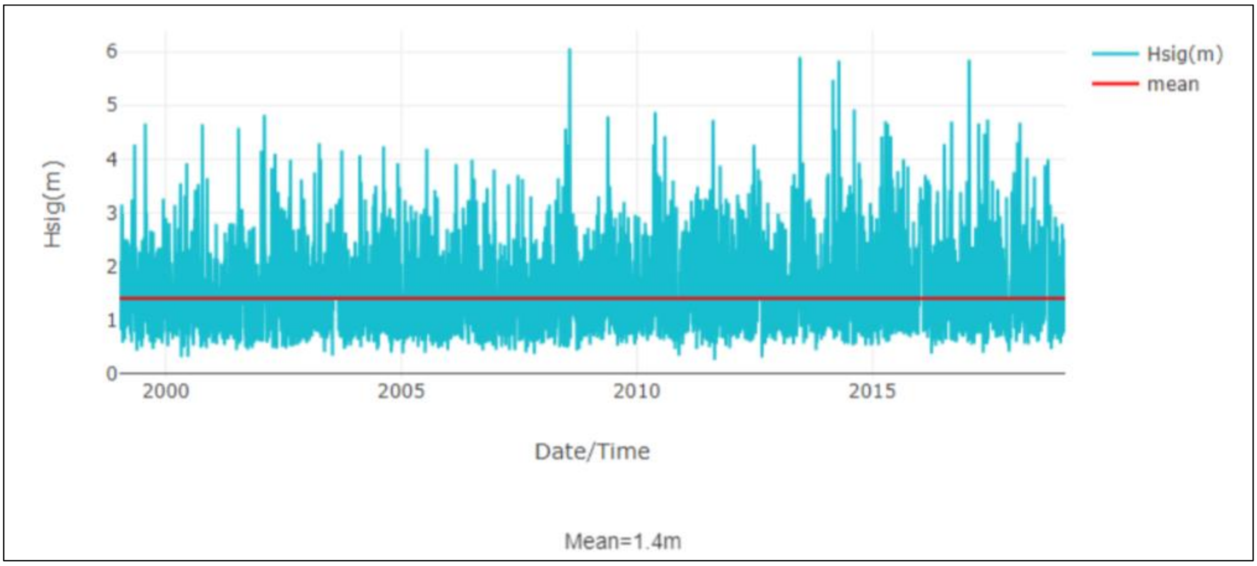

Figure 22

Wave height data collected between 2000 and 2020 collected off New Brighton coast

Note: Data collected from NZ wave data tool showing the total wave heights across the country. This figure shows the wave heights specific for the study site over a 20-year period with the max wave heights which can be clearly seen approaching 6 meters. Adapted from *NZ wave data tool: Hindcast 1993-2019*. (n.d.). GitHub Pages. https://uoa-eresearch.github.io/waves/hindcast.html#NZ-HIST-000-HSIGN-Hsig@2019-01-02%2000:00

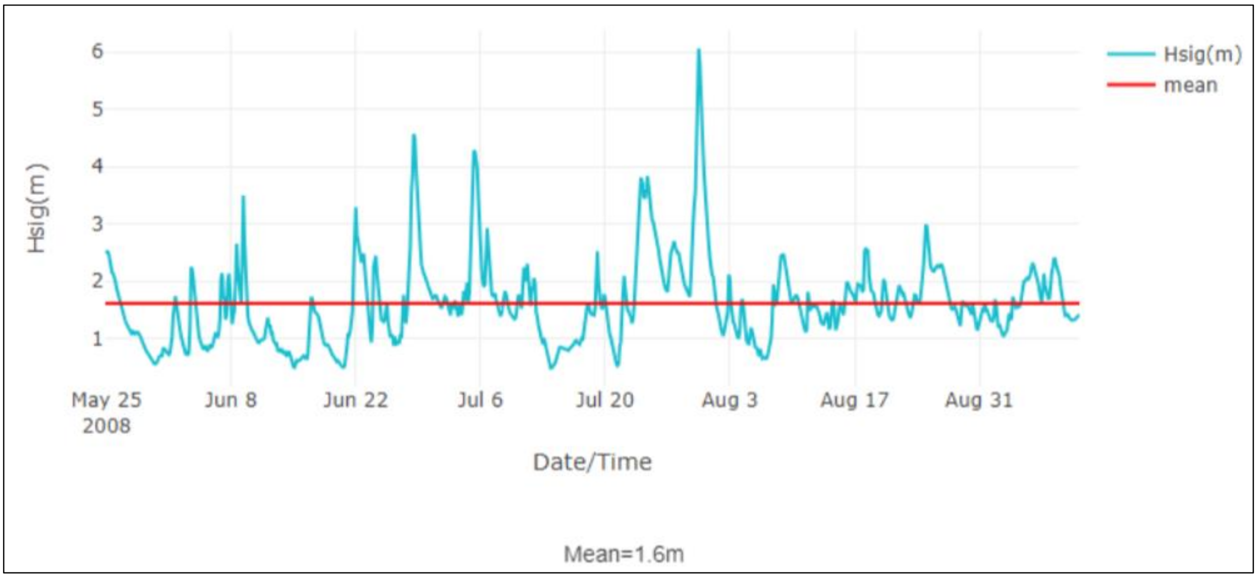

Figure 23

Wave heights going into the area between Waimairi Beach and Southshore Spit in 2008 between May 25th and September 15th.

Note: Data collected from NZ wave data tool showing the total wave heights across the country. This figure shows the wave heights specific for the study site. This shows the wave heights over a three-month period. Adapted from *NZ wave data tool: Hindcast 1993-2019*. (n.d.). GitHub Pages. https://uoa-eresearch.github.io/waves/hindcast.html#NZ-HIST-000-HSIGN-Hsig@2019-01-02%2000:00

6.4 Wider Implications

With the most vulnerable sites identified from Waimairi Beach to Southshore Spit, the CCC can prioritise these areas for dune restoration and coastal management. Using these targeted sites, a focused approach of management strategies can be applied, tailored to the specific areas. Since majority of the vulnerable sites are located together, resources can be applied directly to these areas, saving time and effort for the CCC. This should ensure a more effective management approach to be undertaken by the CCC to protect coastal assets.

6.4.1 Similar Studies and Potential Management Options

Coastal erosion is a pressing issue which is affecting coastlines worldwide (Mentaschi et al., 2018). Narrabeen - Collaroy Beach (NSW, Australia) has many parallels with Waimairi Beach and Southshore Spit. The two sites both include significant coastal infrastructure development and have undergone significant erosional damage due to climate change and SLR. The effects of not having sufficient coastal management plans are more apparent at Narrabeen Beach where 25m of beach width has been lost due to a seawall constructed to protect coastal properties (Siddeek, 2020). This provides an excellent case study on how not to undergo coastal management.

An alternative management approach has been undertaken on the North Sea coastline of the Netherlands. Due to the threat caused by climate change, a coastal flood defence system consisting of dunes, dams, and storm-surge barriers has been implemented (Borsje et al., 2011). These barriers have been designed and maintained to be high and strong enough to withstand storm surge levels that may occur with a probability of 1/10,000 per year (de Ruig, 1998). The approach that the Dutch are taking is to add the same volume of sand to the profile of the near coastal zone as the water volume increases because of SLR (Climate Change Post, n.d.). Sand build ups to match SLR becomes a difficult operation as the amount of sand needed is monumental as well as the resources needed (Climate Change Post, n.d.).

6.5 Limitations

6.5.1 GIS Analysis.

Beach profiles have different seasonal shapes, and the obtained LINZ DEM's were collected at different times of the year, affecting the conclusions that can be drawn. 2015 data was obtained during November where beaches are transitioning to their summer state, while the 2022 data was obtained during May where transition to winter state was occurring. Winter storms erode beaches whilst summer swells build them up, therefore, we expect to see more erosion in 2022 and less in 2015 (Dubois et al., 2008). The 2022 data therefore shows the erosion "worst-case scenario". When consistent erosion was seen across the different years assumption where able to be made.

The GCD tool did not identify erosional areas where there was little dune to begin with. The area in front of the New Brighton surf club is well documented dune erosion area. As there is almost no dune here, the GCD tool does not highlight it as a vulnerable area of erosion, as shown in Figure 10.

6.5.2 Multicriteria Decision Analysis.

MCDA is a subjective measure of analysis. This was an issue with the assessment of significant areas of erosion and vegetation. Interpretation of data can never be completely objective and consequently is subject to personal beliefs and experiences (Jarvinen et al., 2014). The primary purpose of the system is to identify risk areas for future management. Therefore, although individual scores may be subject to change, the overall identification may not be impacted. The spatial distribution of the transects used to measure dune height and beach width has the potential to neglect actual low-lying dunes between transects which could alter the results of the analysis. With a larger timeframe, a different analysis could have been undertaken to create averages or median values for more accurate results.

6.6 Future Research

This study sought to identify the most vulnerable areas in the study region which has been achieved. The next progression is to understand the best management techniques for these areas to ensure the functioning of the ecosystem and the protection of coastal assets. With the social issues present in the study area, hard engineering structures may not be appropriate and therefore soft solutions are more desirable. Previous research on dune management has investigated the impact of vegetation on sand transport and the patterns of deposition over the sand dunes to assess a gap in the current coastal dune restoration efforts (Hilgendorf et al., 2022). Therefore, understanding these concerns will shape the broader decision-making process and overall impact the successfulness of potential management strategies between Waimairi Beach and Southshore Spit.

An investigation into effective engagement with the community is important to ease the difficulty of implementing management techniques and restoration strategies in our study region by the park Rangers. Building community support for coastal management is crucial in this context due to the large social issues present. Research suggests that supplying information about coastal management can increase support for related initiatives and is important for behavior change strategies (Dean et al., 2019). It may be beneficial to focus on educating the residents to increase support for coastal management in the study region. Research also suggests that it is important to consider the way information is framed as this changes how people process the information and its influence on their attitudes or behaviors (Dean et al., 2019). Further research flowing on from this project could involve understanding the public perceptions to tailor how specific information is conveyed to them. Information given to the highly opposed should be conveyed differently to those who are dismissive of the ideas. In turn, this would increase coastal management support and make the job easier for the council.

7.Conclusion

Natural dune processes, climate change and sea level rise all present significant challenges to coastal communities over the coming century. This report demonstrates how MCDA can be used effectively to integrate both physical and social criteria to identify vulnerable sections of beach and dune. The vulnerable sites between Waimairi Beach to Southshore Spit are mainly characterised by human influence. This primarily occurs in the forms of infrastructure such as buildings on or closely adjacent to the dune, walkways both designed and formed, and public opinion. This has significant potential to affect the long-term viability of the dunes and also the functions and services they provide. This report will allow the targeted management of the identified sites of interest to ensure they can be preserved for future generations.

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Appendix A

Site Number	Height	Width	Erosion potential	Distance to Infrastructure	Number of walkways present	Vegetation present	Shoreline retreat potential	Totals
Site 1	2	1	4	1	4	3	5	20
Site 2	2	1	1	1	4	3	5	17
Site 3	2	1	2	1	3	3	5	17
Site 4	2	1	3	1	3	2	5	17
Site 5	2	1	-	1	3	3	5	15
Site 6	2	4	-	5	3	3	5	22
Site 7	3	4	1	5	3	3	5	24
Site 8	4	4	-	5	3	4	5	25
Site 9	5	5	1	5	2	4	4	26
Site 10	3	4	1	5	4	2	4	23
Site 11	3	4	1	5	4	3	4	24
Site 12	1	3	3	5	6	3	4	25
Site 13	2	3	-	5	1	5	3	19
Site 14	5	5	-	5	3	5	3	26
Site 15	5	5	3	5	5	4	3	30
Site 16	2	3	3	5	4	3	3	23
Site 17	1	3	2	5	4	3	3	21
Site 18	2	3	4	3	6	3	3	24
Site 19	1	1	3	2	5	2	3	17
Site 20	2	1	2	2	5	5	3	20
Site 21	2	1	2	2	5	2	3	17
Site 22	1	1	3	3	4	2	2	16
Site 23	3	2	1	2	3	2	2	15
Site 24	2	1	1	3	4	2	2	15
Site 25	3	1	5	3	4	1	2	19
Site 26	3	1	2	2	3	1	2	14
Site 27	2	1	3	2	2	1	2	13
Site 28	3	1	2	1	4	1	1	13
Site 29	3	1	2	1	3	1	1	12
Site 30	1	1	5	2	5	1	1	16
Site 31	3	1	5	2	5	2	1	19
Site 32	2	1	5	1	5	2	1	17
Site 33	3	1	5	2	7	2	1	21
Site 34	3	1	2	2	7	4	-	19
Site 35	3	1	3	5	5	4	-	21
Site 36	5	5	5	2	5	4	-	26
Site 37	5	3	5	2	3	4	-	22

Appendix B – Christchurch City Council Coastal Hazards Portal coastal erosion prediction (Christchurch City Council, 2021)