Castlecliff Coastal Management Options

Report prepared for

WHANGANUI DISTRICT COUNCIL
Te Kaunihera a Rohe o Whanganui

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1 Background

In 2016 eCoast Marine Consulting and Research were requested to assist Wanganui District Council (WDC) in developing a coastal management strategy (Atkin *et al.,* 2016). The project covered a range of WDC concerns regarding the coastal environment at Castlecliff, including a review of existing literature and recommendations in terms of coastal processes; and preliminary work on coastal wetland areas, the potential for enhancing surfing amenity in the Castlecliff area; and, a discussion around the possibility of constructing tsunami defences from the existing dune scape.

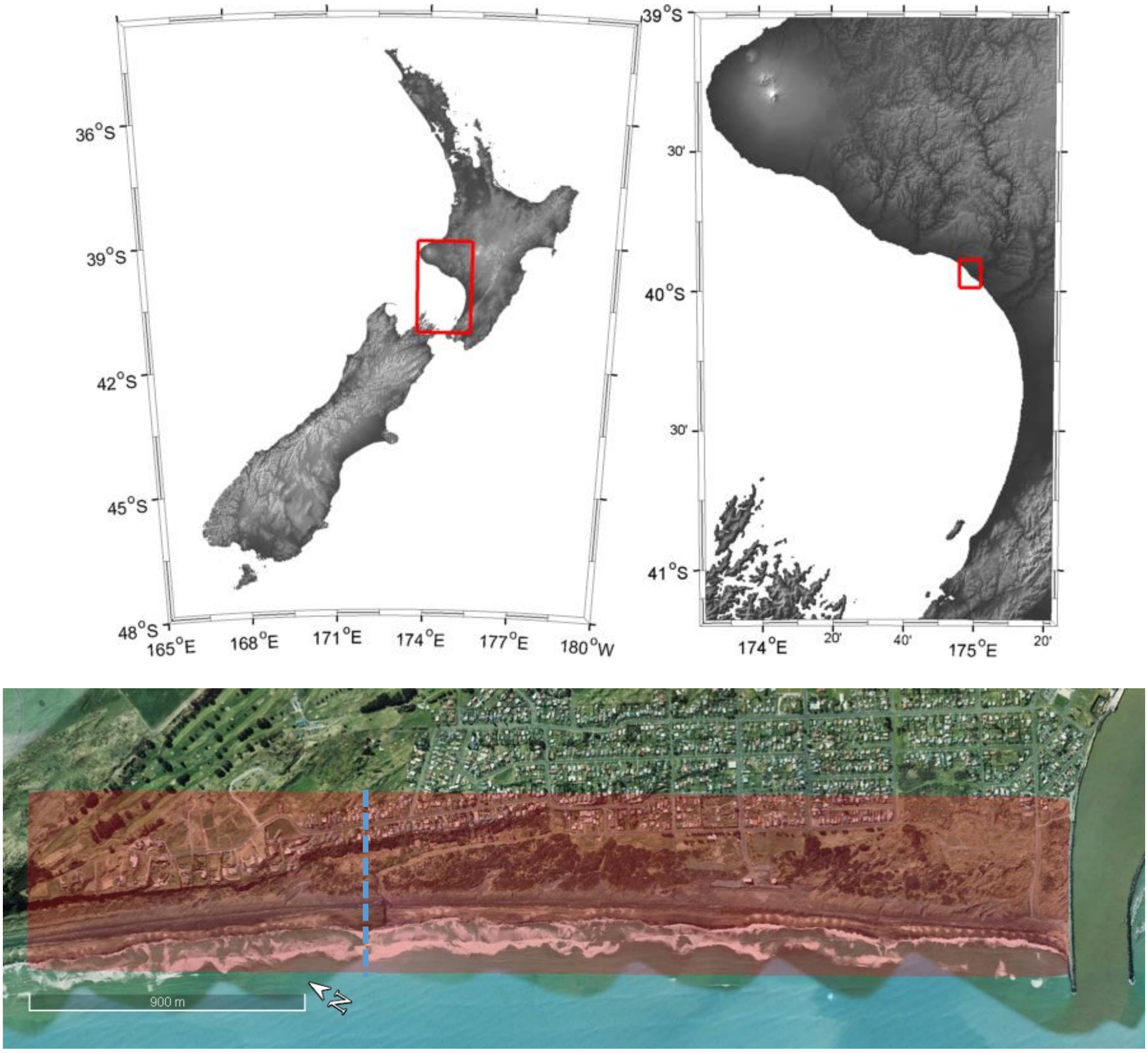

Figure 1.1: Study site location. Castlecliff (bottom), west coast North Island New Zealand (top left), central to the Taranaki Bight (top right); Blue dashed line demarks limit of current study.

The following is largely taken from Atkin *et al.,* (2016) to provide an introduction to the study site. Castlecliff Beach is situated at the northern flank of the Whanganui River mouth, central to the South Taranaki Bight, in the Manawatu-Whanganui region. The study site differs slightly from Atkin *et al.,* (2016) as is does not consider the coastal zone NNW of the stream that discharges at the end of Seafront Road (Figure 1.1).

The section of beach at the end of Rangiora Street is host to an extensive, tiered car park; the Whanganui Surf Life Saving Club (SLSC) operations room; and the Duncan Pavilion community building (Figure 1.2).

Approximately 300 m of beach/dune area has been traditionally “scraped” by plant machinery for ~15 years or more. Driftwood has been relocated further south along the beach and sand has been deposited, under consent from Horizons Regional Council, in to the adjacent surf zone. These maintenance operations are to allow access and a user-friendly beachgoer environment. The ongoing maintenance cost to do this is in the order of $40,000 to $60,000 per annum.

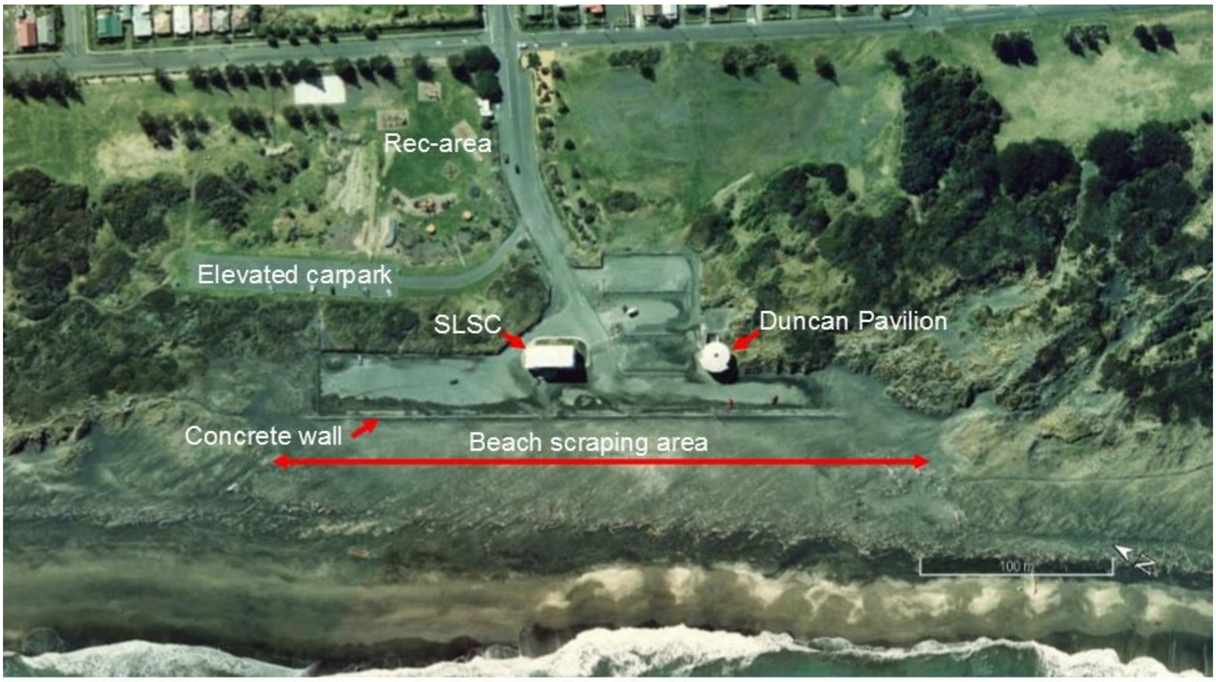

Figure 1.2: Rangiora Street infrastructure.

Overtopping of the concrete wall on the seaward edge of the carpark is known to occur during storm events (Shand and Grant, 2014). During these high energy events, and consistently driven by the predominant onshore winds, sand fills the carpark area, around the SLSC and Duncan Pavilion. The sand deposited inside the carpark is removed as part of the maintenance budget.

There are multiple stakeholders and users of the area and regardless of its reserve status, there is uncontrolled access across the dune system. In their current form, the Castlecliff dunes are considered unstable. The instability is compounded by uncontrolled access across the dunes, including walking, motor biking and horse riding, which negatively impacts on the vegetation required to stabilise them (WDC, 2005; Barrett, 2016; pers. Comm.).

The long-term vision of WDC is for the Castlecliff area, including the seafront, to develop into a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character.

Atkin *et al.,* (2016) concluded with the following:

1. This dune system is highly modified by multiple human impacts, it is basically a human-induced dune system, with human management intervention not being entirely successful.
2. The site is exposed to an energetic wave climate and is a highly active beach system that can transgress metres vertically and 10's of metres horizontally in a single tidal phase. It is not a benign coastal environment or inner harbour location, nor is it currently a user-friendly beach environment – it is a rugged and dynamic west coast beach environment.
3. The site continues to accrete, and is also constrained by residential development on the landward side.
4. Many community aspirations are mutually exclusive. For example, it is not possible to create a robust and stable dune system that is also open for motorbikes/motor vehicles; it is not possible to have a sandy beach up to a carpark or seawall and not have to undertake extensive management to remove wind-blown sand.

The recommendations of Atkin *et al.,* (2016) included:

1. The establishment of a more natural, native plant dominated dune system, with this landscape transitioning naturally into a coastal forest. This will require an expert in coastal dunes and vegetation to provide advice on the removal of marram grass and other exotic species and the systematic establishment of the correct mix of species in the correct areas.
2. Establishment of a foredune in front of the carpark at Rangiora Street with appropriate beach access for foot traffic. The lower carpark is in the active dune area, as such will always require maintenance. However, this situation is exacerbated due to the complete absence of indigenous sand-trapping and stabilising foredune vegetation in this area. This area is the main access point for the beach and so is a valuable community amenity that WDC and local people want to continue to use. At present,

the edge of the carpark is 45-60 m back from the edge of the adjacent dunes; this should be planted out to establish a low foredune and reduce the current level of maintenance in the carpark. This beach requires a diligently restored foredune to function as an aesthetic and attractive natural feature.

3. Prohibition of all vehicles on the beach, dune system and coastal forest. At present, there are many conflicting uses of the reserve – e.g. trail-bikes are destroying the dune system and potentially create conflicts with other users, while Coast Care and other groups are trying to manage impacts and create healthy, naturally stable and functional dunes.
4. Reduction of random pathways through the dune system. Together with systematic replacement of marram grass with native sand binders, a reduction in the large number of random pathways throughout the dune system will help to further stabilise the system and reduce unnatural and problematic blow-outs. Coastal trails and picnic areas should be kept landward of the dunes and within the more stable areas of lowland forest, patches of which are already present at the site.
5. Public education through public/iwi meetings/consultation and permanent (and preferably non-confrontational) signage.

In order to take the management of the Castlecliff Beach area to the next stage, the following project scope was recommended:

1. A coastal hazard assessment
2. Develop a potential management strategy with preliminary costing.
3. A stakeholder meeting to address and discuss the potential strategies and select a final option.
4. Detailed design and for final strategy and costing.

This report addresses scope points 1 and 2.

2 Coastal Hazard Assessment

A coastal hazard assessment is required to ensure that any new management plan will be successful in the long term with consideration to Sea Level Rise (SLR) and extreme met-ocean conditions. The coastal hazard assessment takes into consideration astronomical tides, wind and wave climate set-up during extreme events, and climate change. The protocol for the coastal hazard assessment set out in the New Zealand Ministry for the Environment's publication, *Coastal Hazards and Climate Change – A Guidance Manual for Local Government in New Zealand. 2nd Edition* (MfE, 2008).

2.1 Inverse Barometer Effect

Sea level variation caused by storm surge is associated with the Inverse Barometer Effect (IBE). A change of 1 millibar (mb) in pressure corresponds to a rise or fall of sea level of approximately 0.01 m; with lower pressure causing the sea level to rise. MfE (2008) states that IBE generally contributes 50 % or more to storm surge height (IBE and wind effects). For the purpose of this work, storm surge will be taken as twice the extreme IBE rounded to the nearest integer.

Figure 2.1 presents a 69-year pressure at mean sea level record, extracted from a point simulating 39.942°S / 174.96°E from the NOAA's NCEP reanalysis Sea Level Pressure (SLP) data; and data from the Spriggens Park (Whanganui) Electronic Weather Station (EWS; maintained by the National Institute of Water and Atmospheric Research). The data from the EWS validates the longer term NCEP data, which will be used to determine an extreme inverse barometer effect.

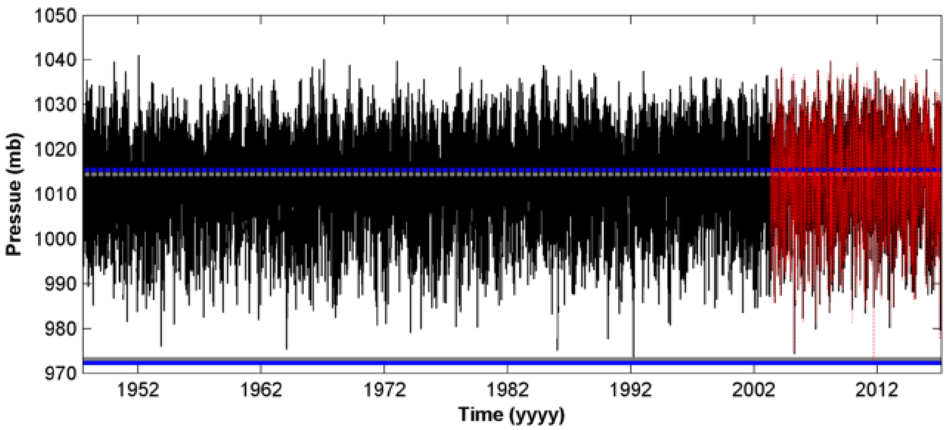

Figure 2.1: Sea level pressure from NCEP reanalysis data extracted at 39.942°S / 174.96°E (black) and Spriggens Park EWS (red).

A Peaks Over Threshold (POT) extreme value analysis, using a threshold of 990 mb, provides 50 and 100 year return period sea level pressures of 974.4 and 972.9 mb, respectively. These values are comparable with the barometric pressures documented in the "The Great Cyclone" of 1936 during which a low of 970 mb was reported (MfE, 2008). The mean SLP for this record is 1014.4 mb, which is consistent with MfE (2008) reporting of mean sea level pressures for the North Island. The resulting differences from the mean barometric pressure from this record are 40 and 41.5 mb, or 0.4 and 0.42 m, for 50 and 100 year return periods, respectively. A conservative extreme storm surge value for this work is taken as 1.0 m.

2.2 Tides

"Storm tide" is the sum of storm surge, wave set up and Mean High Water Spring (MHWS) tidal level. Storm tide is the total sea level during the storm event and is used to evaluate coastal inundation hazards (MfE, 2008).

Figure 2.2 presents predicted tides at 40°S/174.5°E. The record is 19 years long to encompass the moon's nodal cycle and find the minimum and maximum predicted tides which provide the offset between Lowest Astronomical Tide (LAT) and Mean Sea Level (MSL). These values are combined with other tidal datum, calculated from the primary tidal constituents (M2 and S2), and shown in Table 2.1. MHWS is 2.86 m above LAT, 1.27 m above MSL.

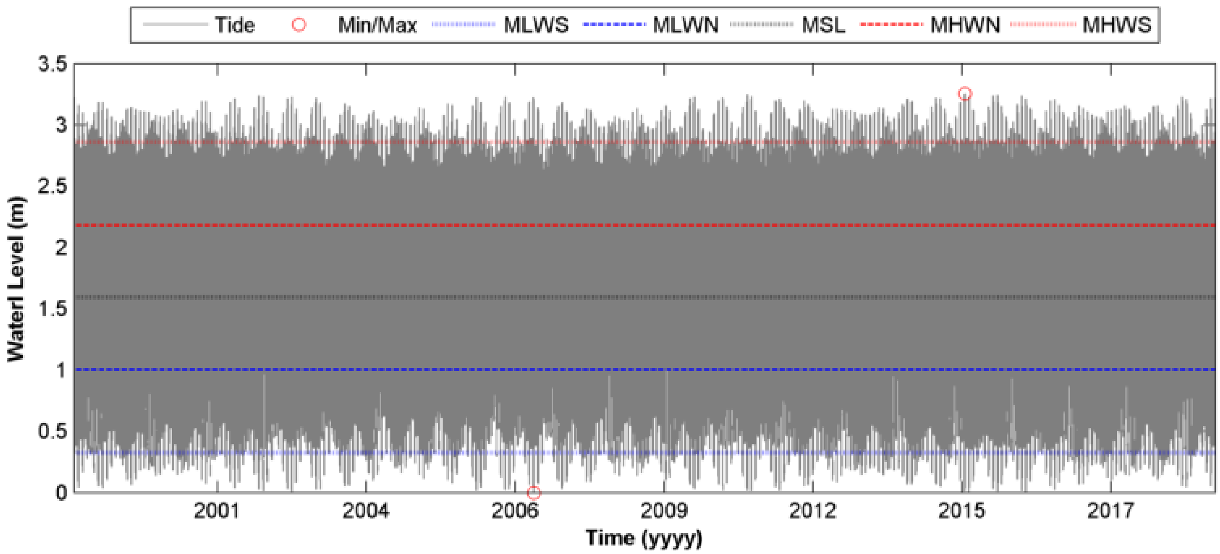

Figure 2.2: Predicted tides from 40°S/174.5°E with tidal datum reference lines.

Table 2.1: Tidal datum estimated from the 19 year tidal record.

Datum	Water Level (m)
HAT	3.25
MHWS	2.86
MHWN	2.18
MSL	1.59
MLWN	1.00
MLWS	0.32
LAT	0

2.3 Extreme Wave Events

Figure 2.3 presents long-term wave data from the global WaveWatch 3 model (WW3; Tolman, 2009) processed on a 0.5°x0.5° resolution model grid. Data has been extracted from a location representing 40°S / 174.5°E, ~40 km WbS of Castlecliff; in approximately 50 m of water. The maximum wave height in the record is 6.38 m.

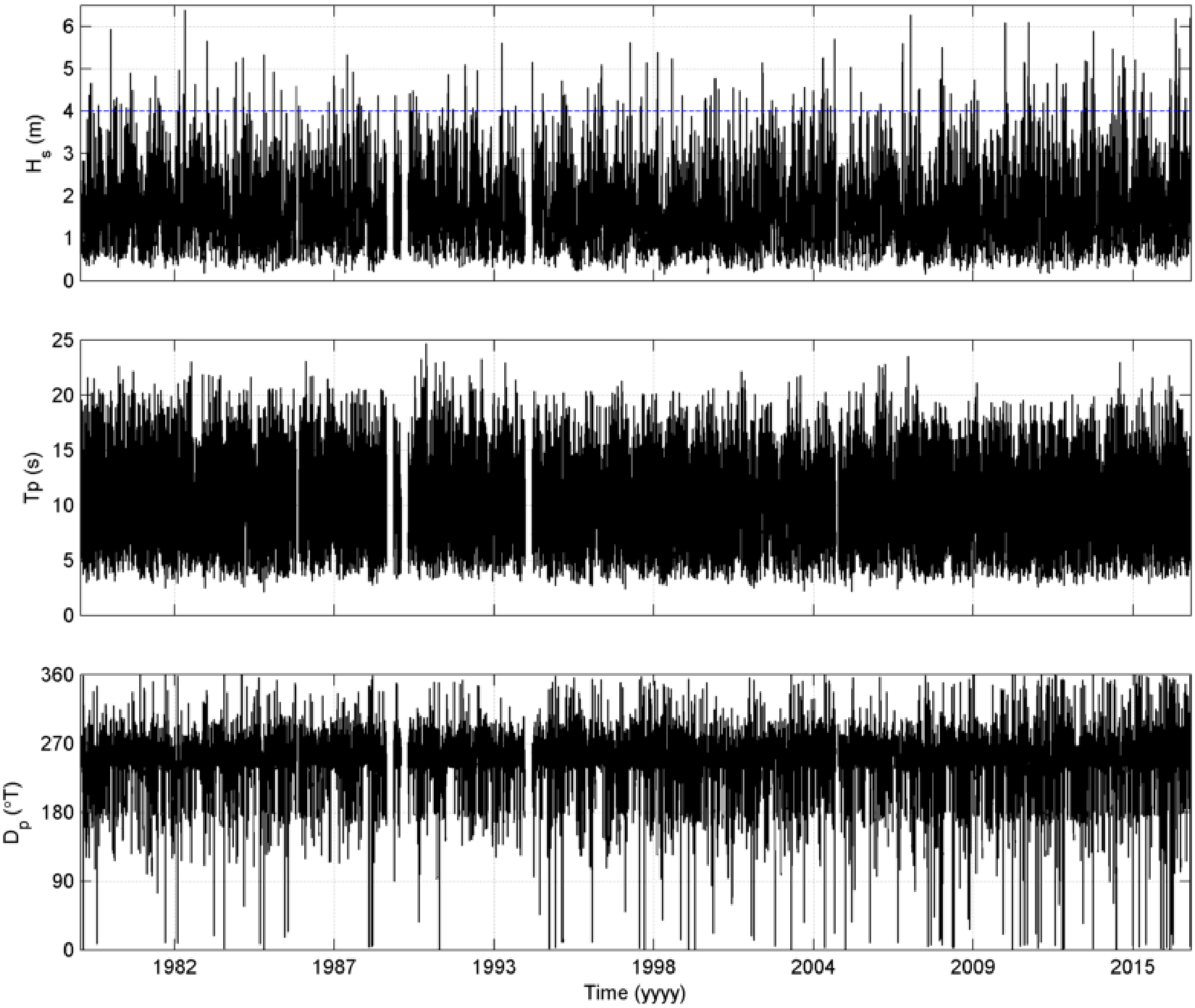

Figure 2.3: Long-term wave data from WaveWatch 3 extracted at 40°S / 174.5°E, Significant wave height plot (H_s; top) presents the extreme event threshold (blue).

Atkin *et al.,* (2016) provides details on the wave climate in the south Taranaki Bight proximal to Castlecliff; and the littoral transport regime along the Castlecliff coast. In this section the long-term wave data is used to determine extreme wave events. POT analysis uses a threshold of 4.0 m and minimum time between events of 3 days. Table 2.2 presents the return period values for wave heights at 1, 5, 10, 50 and 100 years. Figure 2.4 presents the joint occurrence between wave heights and wave periods.

Table 2.2: Extreme wave height event return period values.

Return Period	Wave Height (m)
1	4.9
5	5.66
10	5.96
50	6.54
100	6.74

Figure 2.4 indicates that where wave heights are in excess of 6.5 m the associated periods are in the 12 to 15 s range. For the purpose of this assessment, and a conservative approach, the period used for the assessment for both 50 and 100 year planning horizons is 15 s, which is chosen as the upper bound of the most indicative bins for an extreme wave event in excess of 6.5 m.

Wave Period (s)	Wave Height (m)												
	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	5-5.5	5.5-6	6-6.5
1-2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2-3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3-4	0.018	0.050	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4-5	0.008	1.044	0.252	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5-6	0.003	0.563	2.670	0.373	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6-7	0.006	0.230	2.450	2.857	0.373	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7-8	0.012	0.298	1.017	3.072	2.930	0.520	0.051	0.006	0.000	0.000	0.000	0.000	0.000
8-9	0.031	0.739	1.093	1.268	1.920	1.805	0.501	0.077	0.011	0.001	0.000	0.000	0.000
9-10	0.063	1.007	2.241	1.448	0.900	0.931	0.886	0.349	0.059	0.005	0.002	0.000	0.000
10-11	0.145	1.241	2.386	1.959	0.984	0.521	0.347	0.336	0.171	0.041	0.007	0.000	0.000
11-12	0.395	2.320	2.056	1.951	1.128	0.542	0.267	0.150	0.124	0.072	0.021	0.006	0.000
12-13	0.671	4.407	2.429	1.335	0.925	0.502	0.198	0.098	0.063	0.042	0.019	0.006	0.002
13-14	0.629	4.916	3.215	1.132	0.615	0.338	0.145	0.079	0.033	0.015	0.010	0.007	0.005
14-15	0.431	4.068	3.229	1.208	0.426	0.218	0.120	0.071	0.028	0.017	0.012	0.010	0.002
15-16	0.281	2.569	2.518	1.165	0.487	0.167	0.083	0.048	0.030	0.013	0.012	0.005	0.000
16-17	0.146	1.496	1.375	0.693	0.380	0.126	0.052	0.020	0.009	0.006	0.000	0.000	0.000
17-18	0.113	0.900	0.764	0.348	0.221	0.082	0.017	0.007	0.001	0.002	0.000	0.000	0.000
18-19	0.069	0.580	0.503	0.193	0.083	0.028	0.013	0.004	0.000	0.000	0.000	0.000	0.000
19-20	0.021	0.276	0.226	0.086	0.038	0.006	0.005	0.001	0.000	0.000	0.000	0.000	0.000
20-21	0.014	0.193	0.147	0.039	0.014	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
21-22	0.010	0.109	0.065	0.022	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22-23	0.003	0.046	0.012	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23-24	0.001	0.014	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24-25	0.000	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 2.4: Wave height and period joint occurrence table, blue highlight indicating likely (conservative) wave period.

2.4 Wave run-up

Wave run-up and set-up are calculated using equations from the coastal engineering manual (Smith, 2003). The formulae over-estimate wave run-up and wave set-up, and give maximum values which are considered conservative.

Calculation of run-up requires determining the deepwater wavelength:

$$Lo = gT^2/(2\pi) \qquad [1]$$

and, the surf similarity parameter:

$$\xi o = \tan\beta (Ho/Lo)^{-1/2} \qquad [2]$$

where, *o* a deepwater condition, and β is the beach slope. Maximum run-up is calculated:

$$R_{\max} = 2.32 Ho \xi o^{0.77} \qquad [3]$$

Significant run-up is calculated:

$$R_{1/3} = 1.38 Ho \xi o^{0.70} \qquad [4]$$

The wave set-up is calculated using the equivalent un-refracted deepwater wave height *Ho*` which can be found from the refraction coefficient:

$$Ho' = K_R Ho \qquad [5]$$

Estimated breaker height index is therefore:

$$\Omega_b = 0.56 (Ho'/Lo)^{-1/5} \qquad [6]$$

and estimated breaker height:

$$H_b(estimated) = \Omega_b Ho' \qquad [7]$$

Breaker depth calculation using the breaker index:

$$\gamma_b = a - bH_b/(gT^2) \qquad [8]$$

With

$$a = 43.8(1 - e^{-19\tan\beta}) \text{ and } b = 1.56/(1 + e^{-19.5\tan\beta})$$

$$d_b = H_b/\gamma_b \qquad [9]$$

At breaking simplified set-down at the breaker point is determined from:

$$\overline{\eta}_b = -1/16 \gamma_b{}^2 d_b \qquad [10]$$

Setup at the still-water shoreline is determined from:

$$\overline{\eta}_s = \overline{\eta}_b + \left[\frac{1}{1 + \frac{8}{3\gamma_b{}^2}} \right] d_b \qquad [11]$$

The gradient in the setup is determined as:

$$\frac{d\overline{\eta}}{dx} = \left[\frac{1}{1 + \frac{8}{3\gamma_b{}^2}} \right] \tan\beta \qquad [12]$$

and,

$$\Delta x = \frac{\overline{\eta}_s}{\tan\beta - \frac{d\overline{\eta}}{dx}} \qquad [13]$$

$$\overline{\eta}_{\max} = \overline{\eta}_s + \frac{d\overline{\eta}}{dx}\Delta x \qquad [14]$$

where Δx is the shoreward displacement of the shoreline and $ή_{max}$ is the setup at the mean shoreline.

Table 2.3 presents the results of equations 1 through 14 assuming a cross-shore slope of the nearshore at Castlecliff of 0.0092 (Shand, 2007); a wave period of 15 s and wave heights of 6.54 and 6.74 m for 50 and 100 year return periods; using a refraction coefficient (K_R) of 1.

Table 2.3: Summary table of wave run-up and setup coastal hazard components

Deepwater Wavelength (1)	351.29	351.29
Similarity Parameter (2)	0.07	0.07
Maximum Run-Up (3)	1.90	1.94
Significant Run-Up (4)	1.37	1.39
Un-Refracted Wave Height (5)	6.54	6.74
Breaker Height Index (6)	1.24	1.23
Estimated Breaker Height (7)	8.12	8.32
Breaker Depth Index (8)	0.82	0.82
Breaker Depth (9)	9.86	10.11
Simplified Set-Down (10)	-0.42	-0.43
Set-Up at Still-Water (11)	1.58	1.62
Set-Up Gradient (12)	0.0019	0.0019
Shoreline Shoreward Displacement (13)	215.79	220.90
Maximum Set-Up (14)	1.99	2.03

2.5 Sea Level Rise

SLR can exacerbate coastal erosion and threaten coastal infrastructure. Using likely predicted outcomes for sea level rise coastal engineers can provide more robust and sustainable solutions.

In 2013 the Intergovernmental Panel on Climate Change (IPCC) produced the fifth and most recent assessment report regarding SLR (AR5; Church *et al.,* 2013). The SLR predictions contained in the IPCC AR5 report (Church *et al.,* 2013) are based on the effects of increased global temperature. Global warming scenarios are then used to predict SLR.

The global SLR plot presented in the IPCC AR5 report is shown in Figure 2.5. The IPCC considered different warming scenarios known as Representative Concentration Pathways (RCP). Here we considered a conservative "worst case scenario", RCP 8.5 represents 8.5 w/m^2 of radiative forcing by the year 2100 relative to 1750, the product of continued GHG emissions and a continued increase in radiative forcing beyond 2100.

As a worst-case scenario, the upper margin of the prediction is considered (top of red shaded area in Figure 2.5). By digitising and interpolating the data presented in Figure 2.5 estimates of SLR can be determined. A value of 0.37 m for the current (2017) relative SLR is determined. A value of 0.77 m by 2067 (50-year planning horizon) is predicted; resulting in a current SLR scenario of 0.42 m.

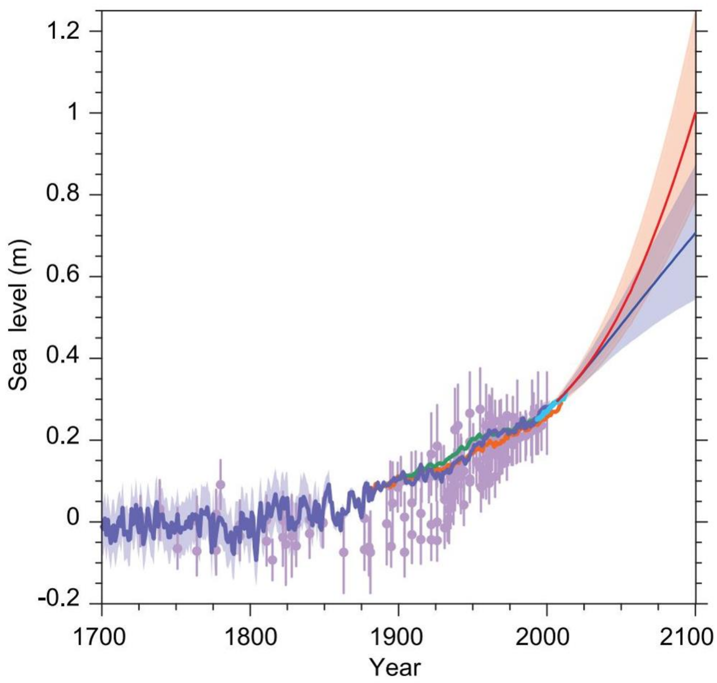

Figure 2.5: (Reproduced from IPCC AR5, Church *et al.,* 2013) Compilation of paleo sea level data, tide gauge data, altimeter data, and central estimates and likely ranges (shaded) for projections of global mean sea level rise for RCP2.6 (blue) and RCP8.5 (red) scenarios, all relative to pre-industrial values.

Church *et al.,* (2013) provides SLR scenarios up to 2100, which for the worst-case scenario is 1.25 m. The Ministry for the Environment recommends the addition of 10 mm per year for SLR projections beyond 2100. This provides a 2117 SLR value of 1.42 m, and a 100-year planning horizon, relative to the current sea level, of 1.00 m.

2.6 Extreme Water Levels at Castlecliff

Table 2.4 brings together the coastal hazard components and totals up to 6.55 m and 7.19 m for 50 and 100 year scenarios, respectively. Lidar points collected in 2013 (Appendix A) indicate the seaward edge of the sealed levels at both Rangiora Street and Morgan Street carpark parks are 3.5 to 4 m above MSL (Moturiki 1953). These areas would certainly be overtopped when considering the proposed extreme water levels, regardless of SLR scenarios. This is concurrent with reports in Atkin *et al.,* (2016).

Table 2.4: Coastal hazard components for 50 and 100-year events/scenarios.

Component	**50 year**	**100 year**
Storm surge (m)	1.0	1.0
MHWS (above MSL) (m)	1.27	1.27
Wave set-up (m)	1.99	2.03
Storm tide subtotal (m)	**4.26**	**4.30**
Wave run-up (m)	1.37	1.39
Water level that could impact on coastal properties or infrastructures (m)	**5.63**	**5.69**
SLR (m)	0.42	1.00
Sub-total (m)	**6.05**	**6.69**
Sea level variability (m)	0.25	0.25
Factor of safety (m)	0.25	0.25
Recommended minimum finished floor level (FFL) for buildings (m)	**6.55**	**7.19**

It is noted that these values are conservative due to the summative approach that is applied. While some values/events are interdependent, others are not. It does not take into account coastal processes that occur during extreme events such as the development of a berm/cut on the beach and bars in the nearshore formed by sand being eroded from the beach; both of which will reduce wave run-up and set-up. The wave run up component in this assessment is very large (~1.4 m). Wave run-up is variable even over a short length of coast, and varies as a function of beach material and beach slope, backshore features and the presence of any coastal defences (MfE, 2008).

3 Coastal Vegetation Management

3.1 Historical Context

Relatively late European colonisation of NZ (in the early to mid-19th century) allowed some limited technical inquiry into the degradational effects of fire and introduction of mammalian herbivores into natural dune environments previously devoid of these atypical and damaging effects.

Members of 'The New Zealand Institute' (later the Royal Society of NZ) became involved in "objective observations and informed opinions" facing colonial settlers as a whole (McKelvey 1999). These "objective observations" included "the threat of moving sands" exposed and set loose by the increasing activity of humans and their newly introduced herbivorous mammals on the low-stature palatable native dune plants.

Cockayne (1911), an early NZ botanist, reported on the natural dune buffer function and the likely consequences of the all-pervading and escalating degradation of the formerly stable NZ dunes: "coastal dunes … form a natural defence to the land against the encroachment of the sea, and, their movement inland is a national concern…and difficult to suppress".

The main impact in the early 20th century was grazing of the exceedingly vulnerable indigenous dune vegetation on coastal margins. Cockayne (1908) wrote: "The wind blowing inland from the foreshore carries with it, according to its velocity, more or less sand". However, these reports and those from other early interested parties (e.g. The New Zealand Institute) were mere observations of factual but disconcerting events, rather than deeper analyses or recognition of those effects on pivotal coastal processes.

Cockayne (1911) recommended importing a range of familiar but essentially alien plants to stabilise those human-induced problems, especially "the threat of moving sands". Those plants included European marram, Californian lupin, and Scots pines, while others imported South American pampas grass, East African kikuyu, South Carolina buffalo grass etc. These ineffectual plants are frequently destroyed by sea-water inundation.

The predominant and pivotal consequences of introducing European marram (*Ammophila arenaria*) to New Zealand are that narrow high-tide beaches are created (due to marram's lack of salt-water tolerance) and its construction of overly tall-dunes. The high dunes can both block views and access; and are also inherently prone to instabilities and blowouts.

3.2 Dune Restoration

The historical impacts described in Section 3.1 can be reversed to restore natural beach function of coastal margins. Restoration projects have been successfully completed on the active west coast littoral zone: at Opunake and Waitohu beaches, some 100 km from Castlecliff along the coast to the northwest and south, respectively (See Appendix B). Long-term restoration sites on both east and west coast sites have dunes that are now lower (< half of the marram-induced height) and wider (> twice the marram-induced width) than those same areas immediately prior to restoration.

The process of restoration requires the reinstatement, or encouragement of halophile (salt-tolerant) and psammophyle (sand-loving) indigenous littoral zone plants. Greg Jenks has developed the 'A-REST systems'.

'A-REST systems' aims to trap and bind all sediment delivered onshore naturally by normal diabathic processes (cross-shore exchange). The porous sand trapped and stored by these processes provide the essential ingredient for enhanced reliable beach progradation and width increases plus optimised dune resilience (de Lange & Jenks 2007, Müller 2011).

The restoration process requires detailed preparation, high quality plants, correct containers, fertilizer management and planting processes; and, critical weed exclusion, to ensure complete project success. In addition, pedestrian trampling, vehicle access and other factors that limit the growth and proliferation of low-stature indigenous dune plants need to be closely managed.

The benefits of having a native dune system include the enhancement of conservation and biodiversity values. Native dune forests are host to katipo spiders (*Latrodectus katipo*), sand-dwelling bees (*Leioproctus metallicus*), driftwood-eating sand scarab (*Pericoptus truncates*); various members the wētā family (*Anostostomatidae*); members of the gecko and skink families; and provide suitable habitat for avifauna such as kiwi, oystercatchers (*Haematopus unicolor*), dotterels (*Charadrius obscurus*), fairy terns (*Sternula nereis*), Caspian terns (*Hydroprogne caspia*) and bar-tailed godwits, (*Limosa lapponica*); some of which are critically endangered.

Trampling and Vehicular Impact Reduction

Damage can be readily reduced by provision of suitable public access-ways. In practice, increasing the frequency of accessways reduces the impacts. Awareness, through signage, local media items and community engagement, about the impacts of trampling and vehicular access, and how the habitat can be improved with their omission.

Weed Invasion Limitation

Natural foredune function is optimised by keeping the planted area completely free of all weed invasions. The method for maintaining a weed-free state is to ensure complete ground coverage by native species and to plant weed buffers at the rear of the foredune area. The buffer zone must be dominated by native mid-dune plant species that reduce weed invasion by innate dense growth habits, while also tolerating ecologically useful selective herbicides that control the majority of foreign weed invaders.

Pest Control

Suitable reduction of pest animal impacts (mainly rabbits) is essential. This component requires contractors and/or community members.

Foredune Proliferation

Foredune plants will only grow and function naturally where they are able to extend their range. The necessary plant protection barriers must be designed for easy uplift and progressive placement seaward of the burgeoning plant growth – to keep ahead of the plants as they grow. The local abundance of driftwood could put to good use to assist this goal.

3.3 Castlecliff Dune System

The Castlecliff dune system was briefly surveyed on the 4th of September 2017. The survey revealed that a singular species of the indigenous low-stature dune plant suite has successfully re-established on the seaward foredune slope. That species (kowhangatara, *Spinifex sericeus*) is now forming the prograding low slope and low dune height typical of its salt-tolerant (halophile) communal companions – pingao (*Ficinia spiralis*) and hinarepe (*Poa billardierei*).

Extreme herbivore palatability means the fourth low-stature indigenous halophile (waiuu atua – *Euphorbia glauca*) remains impractical to restore on these Castlecliff dunelands. Assiduous littoral refurbishment experience reveals that wherever possible all four (or three most practical) indigenous low-stature halophile plant species must be restored to truly recreate all the beneficial effects of those perfectly and long-evolved psammmophile plants.

The invasive plants on dunes include marram, lupins, many species of pine, Sydney golden wattle, Italian buckthorn, gazanias, Arctotis, kikuyu, buffalo grass etc. The back dune is densely covered with higher stature plants, particularly golden wattle.

4 Management Areas

While much focus has been given to the Rangiora Street amenities and infrastructure, successful coastal management requires a holistic approach and the wider coastal environment needs to be considered.

Rangiora Street area hosts the Surf Life Saving New Zealand building, the Duncan Pavilion, and ~12,000 sqm of parking areas. North northwest of the Rangiora Street amenities, the heavily vegetated dune system runs for ~1km, largely back by Seafront Road, up to the stream that discharges on to the beach. This area contains ~380 m of managed grass area between the dune system and Seafront Road, up to the end of the tar seal. There are at least 8 access routes to the back of the dune system from the landward side.

South southeast of the Rangiora Street area the dune runs for ~900 m up to the Whanganui River. The dune is bisected by Morgan Street that extends all the way in to the littoral zone. Morgan Street provides a suitable delineation for management areas; with the Southeast dune system to the north and North Mole to the south.

The North Mole management area contains a strip of vegetated dune that is landward of the tar seal and carpark. There is little to no foredune seaward of the carpark which means there is no buffer zone. This area is also requires ongoing maintenance to keep the carpark and road free of sand.

The North Mole area is one of Castlecliff's and Whanganui's premier surf breaks. The North Mole is a component of the surf break, acting to influence seabed morphology and through wave reflection. At present, the North Mole is comprised of tipped concrete rubble and rock; and is the subject of another ongoing project to improve Whanganui's river front.

Tonkin and Taylor have been engaged by WDC to address renovations required to the lower Whanganui River training structures (Shand and Pearce, 2017). In February 2017 Tonkin and Taylor reported on the physical works required at the North Mole, which includes:

- Raising the area between the North Mole and the North Mole carpark to reduce wave overtopping; formalise a barrier between beach and infrastructure using concrete blocks; armouring of this area. It was recommended that existing material should be removed or crushed and used under proposed works.
- Formalise the carpark edge with concrete blocks. In the longer term raising and sealing of the carpark could be considered to reduce wave overtopping during storms.
- Seaward of the North Mole carpark the structure should be maintained where required with similar size concrete blocks; and/or, widening of the base to the north and building up the breakwater with a 2:1 slope.

Also of note in Shand and Pearce (2017), and Shand and Pearce (2016) are the concerns for the South Mole and the groynes that control the extent of the Tanae Bank. Shand and Pearce (2016) conclude that the Tanae Bank is important to maintaining navigable depths in the Whanganui River, and that reduction in the banks size and associated breakdown of the groyne structures on the southern bank can compromise the amenity values of infrastructure on the northern bank due it increased wave penetration.

Opportunities to incorporate these recommendations have been considered in this current project.

Another consideration for this area is the terminus of Whanganui's Urban Cycleway programme, part of the National Great Rides 'Mountains to Sea Cycle Trail'. The preliminary route for the cycle way, which starts at the western end of the river docks and runs along the river bank to the North Mole, does not appear to affect shoreline and dune management options (Figure 4.1). The preliminary cycleway plan will, however, prevent vehicular access along the river bank adjacent to the existing strip of dune – with vehicular access being diverted northwest to Morgan Street. A cycleway link from Morgan Street to Seafront Road through the back dune is also being considered.

Figure 4.1: Proposed cycleway (solid orange) from Tregenna Street to the north mole; vehicular access limited and diverted (red dashed); and a cycleway link (dashed orange) to Seafront Road.

Figure 4.2 summarises the 4 management areas previously discussed: the northwest dune system area; Rangiora Street area; southeast dune system area; and the North Mole area. While the management areas extend as far landward as Seafront Road, options and recommendations made as part of this work, especially dune restoration, are largely concerned with the area seaward of the upper Rangiora Street carpark. This approach has been taken as management options concerning the landward areas of the Castlecliff domain are on timescales in excess of ten years.

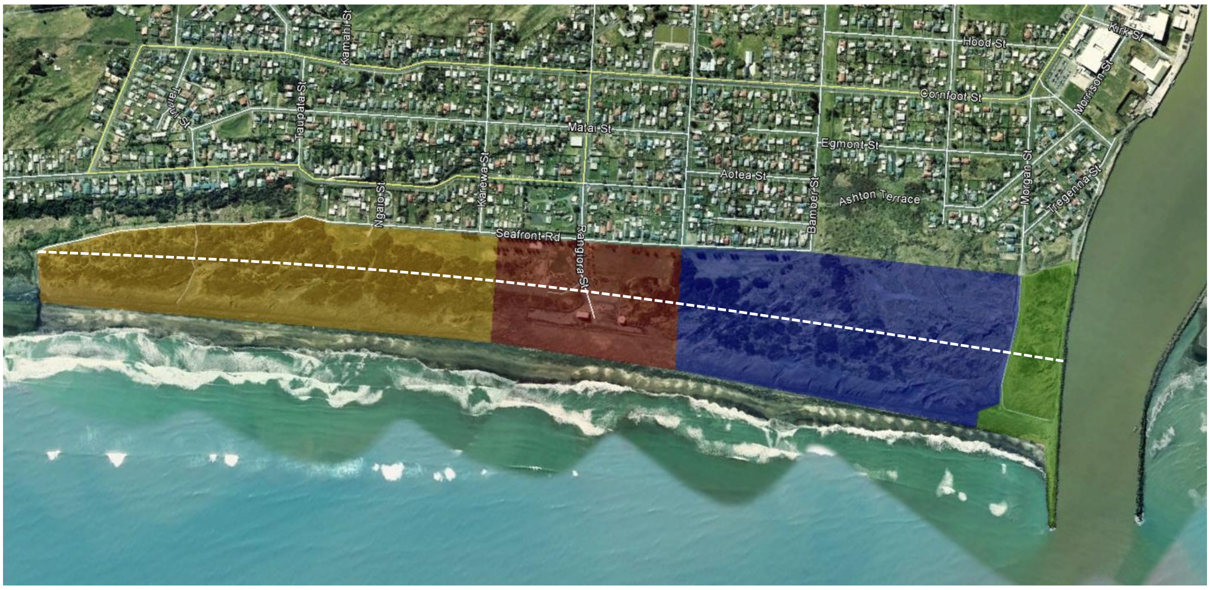

Figure 4.2: Google earth aerial image of the study site with coloured polygons to show the 4 management areas: the northwest dune system area (orange); Rangiora Street area (red); southeast dune system area (blue); and the North Mole area (green). White dashed line denotes primary cross shore management zone.

5 Management Options

There are consistent components in the options for the management areas, for example, the rehabilitation of the dune; installation of accessways and monitoring. The following subsection summarises the management practices concerning management components; this is followed by management options for the different coastal areas.

5.1 Management Components

5.1.1 Weed control and dune reduction

Weed exclusion is a critical component of dune restoration. Weed exclusion is either through physical removal (by hand or machinery) or treatment with suitable herbicides. Part of the A-Rest system is to establish a weed exclusion buffer at the rear of foredune plantings to keep the majority of threatening weeds at bay. The buffer is comprised of indigenous plant species that tolerate both the environmental conditions and a precise range of selective herbicides. Herbicidal control is most effective when applied in two rounds. The first application in early summer in the year prior to planting, and the second in late autumn.

In some cases, particularly the mid and back-dune areas where specimens are robust and well established, these weed species will require mechanical removal and mulching prior to herbicidal application. The aim is to reduce the height of those existing weed species. The benefits are 2-fold, less spray will be required to treat the reduced plant mass; and the resulting mulched/dead material will degrade more completely.

In the case of the overly large marram dunes, excavation plant will be required to scrape and clear out surface layers of marram. The top surface of these dunes must remain uncontaminated and completely free of any vegetation so planting can follow immediately after sand removal; and graded in to the remaining indigenous vegetation and dune volume to leave no scarp faces.

As these unnaturally tall dunes were created by European marram, their crests can be lowered. If this course of action is undertaken, there may well be a substantial volume of sandy material removed from Castlecliff dune system. Heights in the management areas could be reduced to 5 meters above MHWS, ~6.3 m MSL. Reduction of the landscape in the management areas to 5 m above MHWS, based on the 2013 lidar survey, would result in the removal of ~1,013,000m^3 over ~579,000 m^2. The approximate volumes of material over 6.3 m MSL in management areas are as follows:

- Northwest: 487,459 m^3
- Rangiora Street: 175,,916 m^3

- Southeast: 336,994 m^3
- North Mole: 13,618 m^3

These areas are inclusive of the landward backdune area and therefore overestimate the volume for a shorter-term management plan; in addition, large tracts of Rangiora are very unlikely to be reduced in height (e.g. the upper carpark). Short-term , seaward volumes of the mid-dune and seaward back dune (Figure 5.1), are as follows:

- Northwest: 123,990 m^3
- Rangiora Street: 55,917 m^3
- Southeast: 88,040 m^3
- North Mole: 5,009 m^3

Figure 5.1: management areas with mid-dune and back dune operational areas and subsection demarcation (white).

Options for the disposal of clean sand include transporting to the southern, down drift side of the Whanganui River, where it can be used to either assist in the rejuvenation of the Tanae Bank and fill in the associated scour holes around the South Mole and other control structures (this could be done by barge from the northern bank); or, depositing in a convenient intertidal location to continue the sediment transport pathway south. Dune reduction in areas dominated by marram grass has been successfully applied in Christchurch for some 20 years (Black and Mead, 2002).

5.1.2 Dune Planting and Establishment

Dune lands are naturally successional - from the most salt-tolerant seaward frontal zones to the least salt-tolerant rear landward dunes - so logically, there is a unique and successfully-evolved range of indigenous flora (and attendant fauna) that formerly populated each of these very distinct zones.

The methodology is one of working landward through the foredune zone with kowhangatara, pingao and hinarepe plants, then in to the mid-dune and finally the back-dune zones with psammophyle indigenous species: pōhuehue, wiwi, tarakupenga, autetaranga, anawhata, tauhinu, taupata, karamu, mapou, harakeke, ngaio, kawakawa and karo, etc. A staged approach is employed utilising a full year between implementing strategies between these distinct dune zones.

Back-dune zones often reveal an even greater NZ-wide impact extent than foredunes. Recent estimates put this coastal ecosystem problem into contextual reality: “more than 99% of indigenous forest on stabilised sand dunes has been removed” (Williams 2010, in Jenks (unpub).

Landward Backdune and Coastal Forest

Once seaward areas are stabilised (foredune, mid-dune and seaward edge of the backdune), then work can progress to the more sheltered landward areas. Restoration of the furthest landward back-dune zone is in excess of a 10-year plan and will be excluded from options and budget information.

Restoration and promotion of the backdune and coastal forest increases security from invasive weeds and enhances the coastal habitat while promoting vastly increased coastal biodiversity. The indigenous plants and shrubs that naturally inhabit this relatively warm bioclimatic zone frequently produce a plethora of nectar and/or fruit during periods of natural forage scarcity – in the cold winter season when plant flowering or fruiting in colder zones is suppressed or completely absent. Sufficient populations of suitable indigenous winter-fruiting plants in this coastal zone is one of the predominant impediments to complete a necessary full year forage supply for many frugivorous and nectarivorous faunal species. Suitable faunal reintroductions should be undertaken in collaboration with the Department of Conservation

5.1.3 Accessway

All access ways should be angled across the prevalent wind to reduce wind-blown sand loss and funnelling during extreme wave events, and to increase the effectiveness/robustness of the dune system. Figure 5.2 shows examples of dune access way options (Bergin and Bergin, 2011).

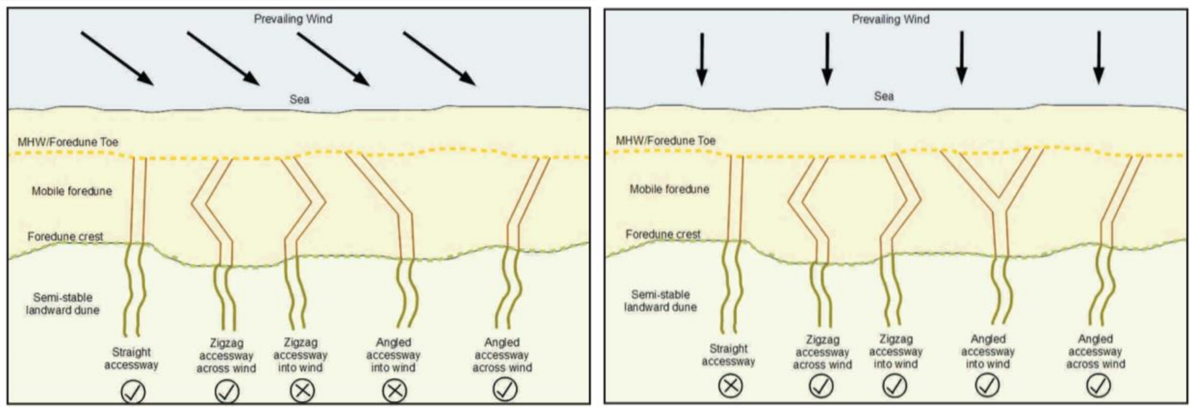

Figure 5.2: Examples of angled dune accessways (from Bergin and Bergin, 2011).

Accessways will require simple barriers or fencing to discourage beach users from diverting from established tracks and trampling dune plants, particularly those that are being promoted and/or reinstated.

Establishing accessways may well require a staged approach, particularly where existing accessways run through dune blowouts. An example of this is show in Figure 5.3. Accessway barriers will also require extending as dunes progressively grow seaward (minor ongoing maintenance). Utilisation of the abundant driftwood could help to minimise costs while cultivating aesthetic local character.

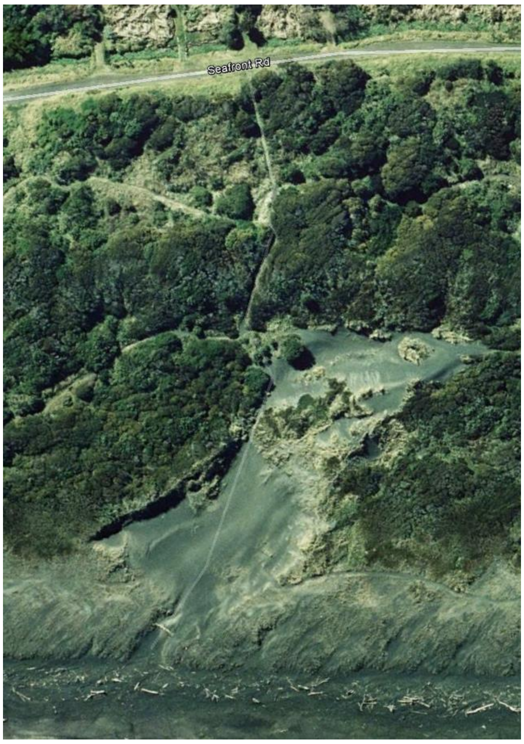

Figure 5.3: Google Earth image to show example of access root running through a dune blow out.

5.1.4 Vehicular and Other Damage

It is not possible to create a robust and stable dune system that is also open for motorbikes, motor vehicles, nor heavy regular foot traffic or equestrian pursuits. As per Atkin *et al.,* (2016), there are many conflicting uses of the reserve – e.g. trail-bikes are destroying the dune system and are potentially unsafe for other beach users, while Coast Care and other groups are trying to manage and create a healthy and naturally protective dune system.

There are few places where motor vehicles are acceptable in dune areas in New Zealand. In other areas of the country, no vehicles are allowed in the dunes, beach or public reserve areas. At Muriwai Beach on the Auckland west coast, vehicles have been prohibited from using the beach in front of the regional park for over a decade, although they are allowed beach access to the north. If restoration to a native dune setting is sought, then vehicles will require prohibiting from the beach adjacent to restoration areas.

Riding motocross and trailbikes is a recreational activity in the area. Recognition that riders are also members of the community and regard the dune scape with amenity value needs to be considered. Motocross is a well-recognised extreme sport and any talent that has developed in the Castlecliff Domain will require nurturing as opposed to stifling.

If restoration to a native dune setting is sought, then riding motocross and trailbikes will require prohibiting from the beach adjacent to restoration areas and from the dune interior completely. This topic should be addressed through community education channels, public advisory meetings (especially with user groups) and by publication of pre-approved media items.

An appropriate area within the Castlecliff community for riding motocross and trailbikes should be designated; an option is discussed in Section 5.4. A set of local rules regarding use of a designated area (closure times, behaviour etc.) should be established. Failing agreement about a locally accessible venue, a site should be set up further afield. This poses transport issues for many riders (information gathered during an eCoast/WDC meeting), therefore a council endorsed club structure will be required to ensure safe transport.

Pedestrian traffic is considered in Section 5.1.3, and accessways comprehensively address the associated trampling issues. Signage, education and guidance is covered in Section 5.1.7. Regarding equestrian pursuits, then main longshore accessway could be designated a bridleway, with no access through the actual dune field to the beach (or to Castlecliff beach itself), while retaining access to the stream and the beach to the north.

Community engagement reported that the stream is an important play space for children and it needs to be safe and vehicle free. With access to the beach north of Castlecliff a requisite, making the stream area vehicle free is unlikely unless Seafront Road (unsealed) is redirected north over the stream and a vehicle/bridal accessway to the beach is established north of the stream.

With all the above, bylaw's and pre-approved and regular media items and supportive community interviews will assist to dissuade users from practices that damage natural landscapes and reduce the amenity values of the area. Bylaws will need to be discouraging e.g. fines and/or requisition of equipment.

5.1.5 Monitoring

Absolutely critical to all sustainable decision making and development is regular monitoring. Collecting data on the status quo of dune environments and how it responds to change is critical in ensuring that responsible decisions are made.

Monitoring may take the form of:

- beach profile data - given the positive sediment input setting and historical growth of this coast, beach profile data should be collected regularly along this coast (and on the southern side of the river);
- data on foredune expansion;
- estimations of weed density/volume – need to establish a baseline for each management area to determine the effectiveness of this beach methods – e.g. quadrats;
- the changing size of existing blowouts/bare sand areas – e.g. drone survey.

5.1.6 Driftwood

Notes from Atkin *et al.,* (2016) and community survey:

- *Driftwood is an attraction to the beach – the youngest and the most senior members of communities find driftwood incredibly fun and useful*
- *Driftwood has been relocated further south along the beach and sand has been deposited, under consent from Horizons Regional Council, in to the adjacent surf zone.*
- *Want more building of sand and drift wood.*
- *Use large driftwood off beach to protect access areas to beach from motorbikes etc. Allowing plant growth to stabilize sand around access areas.*
- *For a safe recreational/swimming area the beach must be clear of debris*
- *debris removed completely*

Driftwood maintenance work will always be a requirement at Castlecliff if the management plan is designed to have a debris free beach. Some driftwood could be utilised for construction of aesthetic and readily relocatable access-way barriers. SLSC comments raise health and safety concerns; and desire a debris free location. Given the conflicting opinions with respect to driftwood, engagement with this group to address specific concerns will be required.

5.1.7 Education, Signage and Community

Work with local community groups (e.g. service clubs, local schools, iwi, business groups etc.) will openly inform the public of the aims, aspirations and need for beach restoration work. This will provide an opportunity to answer any lingering doubts or questions about the project and the positive outcomes for Castlecliff. Harder still, but just as important is reaching out to those not affiliated with official community groups (e.g. motocross riders). Media items in community weekly papers, and where appropriate, in national daily newspapers; will help inform the wider area. Furthermore, a school education kit that complies with national unit standards for schools could be adopted. By understanding the various aspects of the management strategy and the reasoning behind it, the community can begin to take ownership.

Signage is extremely important for education, highlighting the correct access ways and discouraging poor dune care practices. Some examples are presented in Appendix C.

5.2 Rangiora Street Options

The following presents the management options for the Rangiora Street management area. This area is somewhat different form the rest of the study site as it has a substantially larger budget dedicated to existing management.

5.2.1 Maintain Status quo

The main aspect requiring ongoing maintenance is beach scraping to clear sand and debris (mostly driftwood), to allow access and a user-friendly beachgoer environment; and removal of sand from the carpark. Approximately 300 m of beach/dune area has been traditionally “scraped” by plant machinery for ~15 years or more. These operations are currently estimated at costing $40-60,000 per annum. Community feedback indicates that there is a conflict in support for the current regime with the supporters and detractors.

Maintaining the current management strategy does not address the long-term vision of WDC for Castlecliff beach to develop into a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character.

5.2.2 Do-Nothing

A do-nothing approach would certainly retain quasi-natural shoreline character as the lower carparks, the SLSC and Duncan Pavilion would become engulfed in sand and eventually vegetated in line with the rest of the Castlecliff dune system. Whilst negating maintenance costs, this outcome is not in line with WDC’s vision to retain the amenity value of existing infrastructure.

5.2.3 Managed Retreat

Relocating the Whanganui Surf Life Saving Club (SLSC) operations room and Duncan Pavilion would preserve the infrastructure and amenity value. A do nothing approach can be applied to the space left behind (as described above), it can continue to be managed (at a potentially reduced cost), or transformed in to an easily maintained native landscape. A beach front operations tower will likely be required in this scenario.

5.2.4 Restoration

In order to reduce the maintenance costs of clearing sand from the lower Rangiora Street carpark, a dune can be established seaward of the amenities and infrastructure to capture landward moving sand (windblown and overtopping driven). This option was also recommended by Grant and Dudin (2006).

Northwest and southeast of the scraped area directly in front of the amenities, one of the three functional halophile indigenous foredune species (kowhangatara, or spinifex) is found in good numbers in the foredune. The initial planting zone will be ~350 m in length and a ~5 m wide and link into the existing kowhangatara foredune.

Follow up work will encourage proliferation of growth down the beach to a position aligned with the existing foredune. The usual seaward expansion rate for restored foredunes is 2-3 m per annum. Higher growth rate is expected at Castlecliff given the positive sand supply setting. Complete protection of the fragile seaward growing points is critically important to maximise this growth potential. That is achieved by keeping the plant protection barriers 3-4 meters seaward of existing plant extension. The full 40m (+/-) of barren sand should be covered by these indigenous halophile plants in about 12 years. Further circular plantings on the currently barren seaward extent would accelerate the above plant coverage scenario.

The established foredune requires access routes to the beach. One access route should be designed and constructed wide enough for emergency vehicular access and operationally effective for Wanganui SLSC during operational periods (December-February; i.e. board and chain sand ladder with narrow gaps).

Accessways and planted areas will require delineation and protection. Posts with rope can be used. In the case of Whanganui, the abundance of free driftwood can also be utilised to demark accessways and planted areas.

It is envisaged that a low-profile dune seaward of the carpark will be established in year one of the project; restoration of the mid dune in years 2-3, and the back dune in years 3-4, both following height reduction of vegetation a full year before planting out (i.e. years 1 and 2) and herbicide application at 8 and 4 months prior to planting out. A primary objective of mid and back dune work is to reduce dune height, particularly around the Duncan Pavilion. Excess sand will need to be removed.

The monitoring in the Rangiora Street management area will include photo-point observations of changes of sand deposition in the car park area; the expanding width of the foredune; and, a record of storm inundation events. Plus, any marram and buffalo grass encroachment onto planted out areas.

Should monitoring indicate the seaward carpark area is stable (no inundation and little to no windblown sand), and following local consultation, and a survey of use, the area may be altered. This could be:

- to improve amenity values (e.g. grassed areas, picnic benches). Should the 7,000 sqm of beach/dune front parking still be required, and there be a sufficient desire for increased amenity value, additional carparking could be created landward of the terraced carparks.
- Complete assimilation in to the indigenous dune system, this could be applied for all or a section of the parking area e.g. the north-western side of the SLSC. This option could be considered in conjunction with possible relocation of the SLSC building and Duncan Pavilion.

The Rangiora Street management area will require complete exclusion of vehicles (expect emergency and SLSC); plant and animal pest eradication.

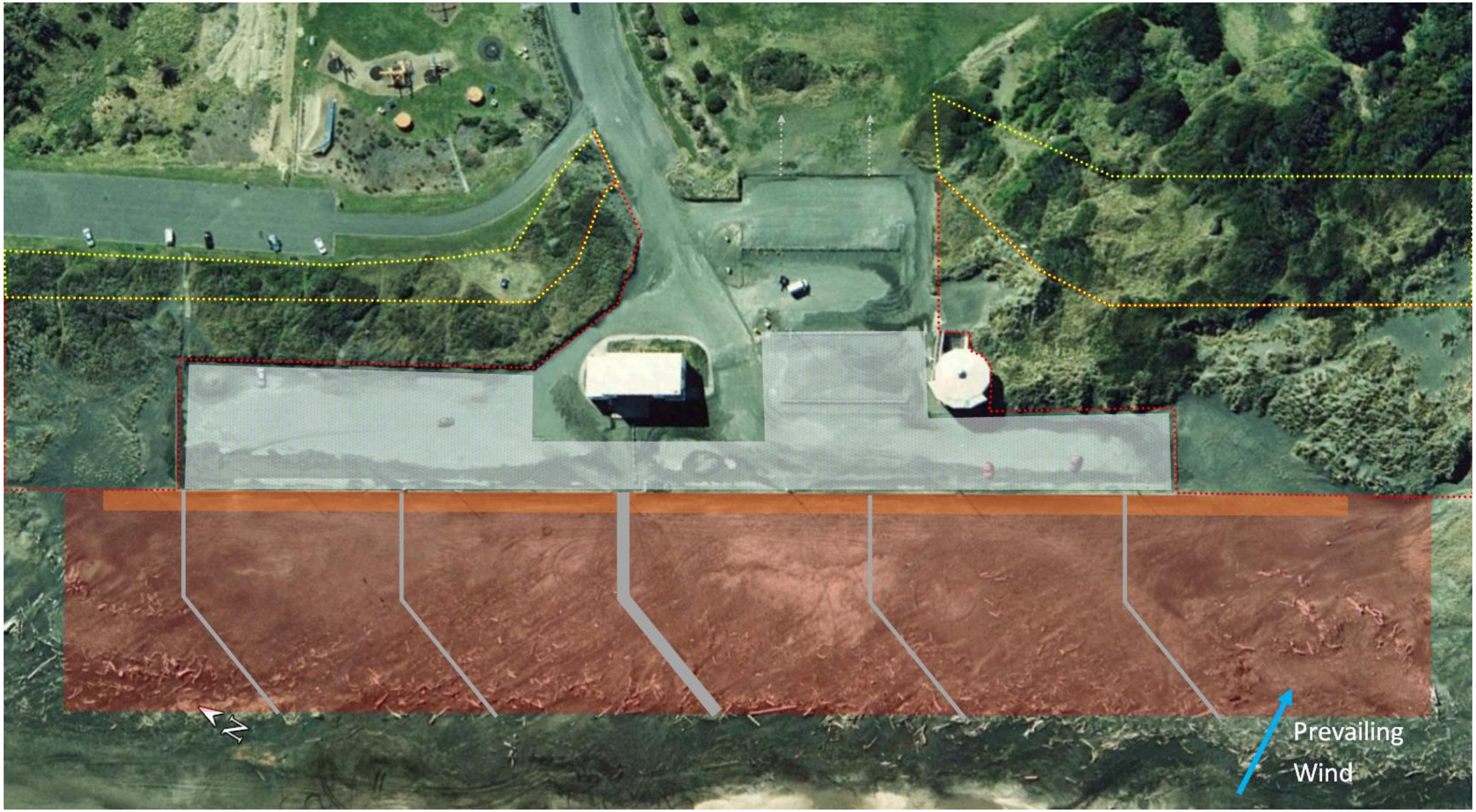

Figure 5.4: Rangiora management area showing potential management options including: the initial planting zone for foredune establishment (orange overlay); expected foredune width (red overlay); hypothetical angled accessways through the foredune, including vehicular access (grey lines); years 2-3 working zones (red dotted area); years 3-4 working zones (yellow dotted area); parking area available for transformation (greyed); and, carpark expansion direction if required (grey dotted arrows).

5.3 Northwest Dune System

This section runs from the Rangiora Street management area up to where the stream drains on to the beach at the end of Seafront Road. This is the largest and most heavily vegetated management area. Following destruction of the native dune habitat and subsequent stabilisation with foreign plant species, combined with a positive sand supply, the dune has grown excessively tall and the invasive plants have consolidated – there are extensive areas of the tall hybrid form of Sydney golden wattle, lupin, periwinkle, gazania, Arctotis, Agapanthus, buffalo grass, marram, *Euonymus japonicus* etc.

5.3.1 Do-Nothing

This option is retaining the status quo as little to no management of this area exists beyond attention from coastal care groups. Do nothing will not affect the current amenity value of the area (walking tracks), but will ensure the persistence and further expansion of non-native invasive weeds Failure to manage this area may not be conducive to establishing a wider native plant dominated setting or assist biodiversity gains at other sections along the coast, with pressures from aggressively growing invasive weeds and further aeolian dissemination of non-native weed species.

The requirement to transform and restore the dune scape is not one out of necessity for immediate erosion prevention as this environment is currently in a positive sand supply setting and has a historically prograding coastline. However, with extreme event inundation levels for 100-year return period and sea level rise scenarios potentially in excess of 7 m above MSL, a dune system vegetated with salt-intolerant species increases the chances for coastal erosion.

5.3.2 Restoration

The three-staged approach will provide foredune, mid-dune and back-dune restoration over successive years. However, given the size of the area and the vigour of the non-native weedy vegetation established in mid and back dune zones means mechanical methods for weed removal will be required and the overall area will be broken in to subsections that will also be addressed at different times.

A likely scenario is to address 2 subsections (the length of the management area will be split in half), working from the Rangiora Street end to the stream end. This will ensure at least one of the two prominent existing access ways (Figure 5.5) remain open at all times, however, the accessway may require reorientation in some part. Three additional paths from main longshore path will also be established.

Figure 5.5: Google Earth image to highlight accessways in the north-western management area (red); with two major transverse routes (blue).

The seaward edge of the foredune of the northwest management area has encouraging quantities of kowhangatara and limited pingao. Foredune work could be completed from Rangiora Street to the stream comprehensively (rather than over 2 subsections) with the requirement to supplement and diversify existing indigenous low-stature halophyte communal foredune species – approximately 1 km in length.

This area is host to several dune blowouts with little to no vegetation due to the mobile nature which is attributed to the overly steep marram dunes; in some cases, these blowouts are unsurprisingly associated with existing accessways. Blowouts can be easily repaired in this area of abundant kowhangatara by the judicious and constrained application of a suitable broadcast fertiliser. These accessways may need to be closed during restoration work, and then properly delineated with posts and ropes, and/or drift wood. Current accessways will be utilised where appropriate, and using the existing tracks as a proxy for user requirements, it is likely that this area will require 7 or 8 delineated accessways through the foredune. It should be noted that the bulk of accessways are directed along the dune system length parallel to the beach, which may indicate that track users enjoy the back-dune environment and so do not use the tracks simply for beach access.

Ongoing maintenance includes regular relocation of seaward barriers (each 2 to 3 years) to accommodate the expanding protective dune, adjustment to access way lengths as the foredune progrades, and continuance of vigilant pest control in the medium term.

Monitoring will involve identification of unwanted plant species, and timely maintenance will be required to remove the identified specimens. Monitoring will begin prior to removal of weeds to establish a baseline of the pest plant species present, from which the effectiveness of restoration can be measured.

A restoration area of this size will require a dedicated working group (or groups) with core objectives of education, inclusive guidance and implementation. Completion time and acceptance/restoration is likely to be more effective with ongoing, from day one, removal of more prolific invasive species, so encouragement and support of any existing Coast Care initiatives will be very beneficial and critical for enduring success.

It is recommended that after work in the first subsection is completed (~year 3); the methodology and monitoring data should be evaluated. Restoring the northwest area is likely to improve the effectiveness of re-establishing natural character at Rangiora Street, and potentially reduce maintenance costs for its upkeep.

5.3.3 Stream Area Considerations

The stream at the northern end of the beach has amenity value, and some members of the community wish to make this area vehicle free. With dune wide prohibition of vehicles the beach access that runs parallel to the stream will become the default access point for vehicles heading north. To address this conflict, a culverted crossing of the stream could be established to divert traffic from the stream “play” area, and allow vehicular access north.

5.4 Southeast Dune System

The southeast dune system is less vegetated than the northwestern side of Rangiora Street. Vegetation, particularly the large mid and back-dune species, decrease in numbers with distance to the river. The reality is that there is several hundred metres of relatively new land that is yet to be extensively colonised by the mid and back-dune species. This area is also heavily frequented by pedestrians, animals (horses) and vehicular traffic evident by the plethora of tracks crisscrossing the dunescape (Figure 5.5); and this is particularly evident in the sand “quarry” area. The quarry area is relatively flat and shrubs are scarce compared to the rest of the Castlecliff domain. The area would be ideal for improving amenity values.

The foredune, the mid-dune and back-dune exhibit large areas that are not vegetated, particularly at the southern end. Here the open and mobile sand can migrate on to Morgan Street, clearance of which is another ongoing maintenance expense.

5.4.1 Do-Nothing

This option just maintains the status quo as little to no management of this area exists beyond attention from Coast Care groups. Doing nothing will not affect the currently poor amenity value of the area (walking tracks), but will ensure the persistence and further spread of non-native weed plants, and continuance of sand relocation on to Morgan Street.

The requirement to transform and restore the dune scape is not one of necessity for immediate erosion prevention as this is currently in a positive sand supply environment and on a historically prograding coastline. However, with extreme event inundation levels for 100-year return period and sea level rise scenarios potentially in excess of 7 m MSL, a dune system vegetated with salt-intolerant species increases the chances for coastal erosion.

5.4.2 Dune Restoration

While the three-staged diligent restoration approach can be implemented in a similar manner to the north-western and Rangiora Street areas, the landward back-dune and coastal forest aspect is more complex given the extent of the south-eastern management area.

The most likely scenario is to address 2 subsections, defined by the primary cross dune access route (Figure 5.6), over a 10-year period, working from Rangiora Street toward Morgan Street; and the foredune work should be completed from Rangiora Street to Morgan Street comprehensively (rather than over 2 subsections). An additional area that requires focus is the land running parallel to Morgan Street. This will also require restoration planting.

A very clear benefit of securing the southern part of this management area is the natural stabilisation of sand moving toward Morgan Street, and ultimately obstructing the road. Figure 5.7 shows this area on the 22nd of September 2016. Barren and exposed sand conditions clearly abut the road, and much of the mid and back dune areas are unvegetated and blown out; but note the stable kowhangatara foredune which should be further enhanced to increase this natural stability.

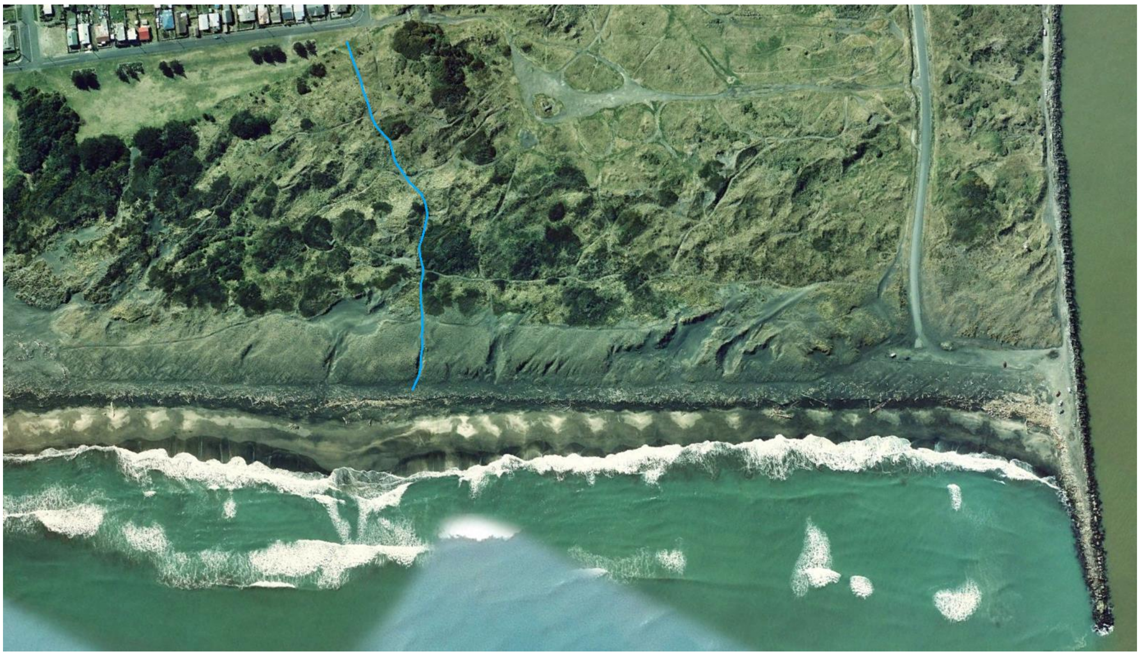

Figure 5.6: Google Earth image to highlight the major transverse beach accessway in the south-eastern management area (blue).

Figure 5.7: Google Earth Image from the 22nd of September 2016 showing exposed sand clearly abutting the road at Morgan Street

5.4.3 Landward Usage Options

There is a vast amount of space landward of the current seaward dune system, but this area also has an established foredune, mid-dune, backdune, and even coastal forest. The site of sand excavation (quarry) has left a relatively flat space of land, with lower populations of larger plant species (e.g. Sydney golden wattle, lupin, *Euonymus japonicus* etc). This could be adapted in to a substantial coastal forest or used as a space to consolidate motorbike/cross user who frequent the wider dune area.

5.5 North Mole

The North Mole area hosts a carpark that directly abuts the beach. The carpark provides the opportunity for residents and visitors to view the coast and sea from the comfort of their vehicles, particularly when the weather is adverse.

This carpark requires ongoing maintenance to remove sand and keep the carpark clear. There is no foredune in this area and instead an abundance of open sand and debris; and the carpark is situated in a cross-shore location that occupies much of the former foredune. In recent times, a small patch of spinifex foredune has established itself close to the junction between the carpark and the mole.

Landward of the carpark is a vegetated area, around 300 m in length and 100 m wide. This area appears to be little used; but hosts a navigational beacon.

5.5.1 Do-Nothing/Maintain Status quo

The current management strategy is to clear this sand (and likely that from Morgan Street) as and when required. These activities are reported to come under the $40,000-60,000 per annum budget associated with the Rangiora Street works.

Maintaining the current management strategy does not address the long-term vision of WDC to reduce maintenance costs. If the removal of sand is ceased, and given its current state with a poor density of appropriate vegetation, it is likely that the seaward end of Morgan Street and the carpark would become engulfed in sand. This would also promote the aeolian delivery of sand to the Whanganui River, which has the potential to affect navigational channels. This outcome also fails to retain the amenity value of existing infrastructure.

5.5.2 Restoration and Relocation

In order to reduce the amount of material entering the Morgan Street carpark, a suitable seaward natural halophile vegetation buffer needs to be established. This will be achieved by relocating the carpark landward, and assimilating the area back in to the natural profile of the shoreline and establishing a low profile foredune made up native halophytes (Figure 5.8).

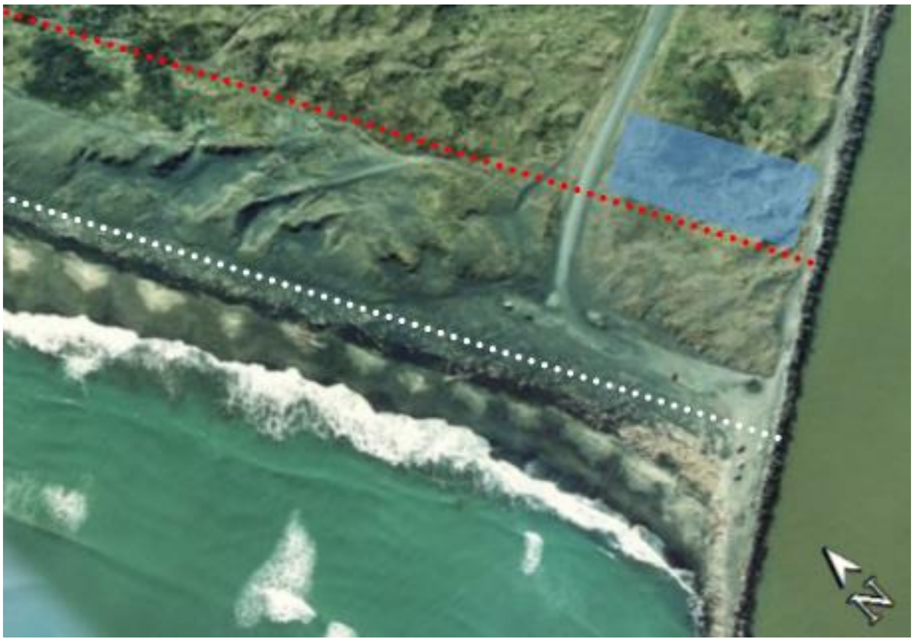

Figure 5.8: Google Earth image annotated with current foredune toe position (white dashed), potential native dune field extent (red dashed) and likely recommended carpark relocation position (shaded blue).

Because an established foredune will increase the ground height seaward of the carpark, and there is a requirement to maintain existing amenity value, a new carpark should be elevated to maintain views of the coastal seascape. The recommendation would be to design this carpark above the 100-year return period/SLR scenario inundation level. A suitable comparison is the northern, elevated carpark at Rangiora Street.

A three-staged restoration approach can be implemented from the foredune to abut the seaward edge of the relocated carpark; in a manner similar to the other management areas. Given the along shore length of this area (~100 m), the seaward restoration work is likely to be completed in a 3-4 year window.

In the latest Google Earth image of the North Mole management zone there are areas of bare sand landward of the relocated carpark. The bare sand areas are in line with larger, dune wide blowouts. This area will likely require restoration plantings to stabilise mobile sand. Landward of the carpark there is some 200 x 100 m of riverside area that could be put to some further amenity use (e.g. mountain/BMX bike track, skateboard park, picnic area, playground etc.).

6 Options Summary, Indicative Costs and Timelines

Castlecliff beach is a heavily modified environment so there will always be an aspect of management as the natural equilibrium is disturbed to a point beyond normal reconciliation. The drift wood case is essentially beyond WDC's control and so will continue to accumulate until land management practices elsewhere (forestry, farming etc.) are improved.

Full restoration will likely need some early, minor maintenance largely in the form of limiting weed invasion. Once the native dune sequence is fully restored, any early maintenance will rapidly diminish as the indigenous plants become increasingly dominant once more. In the long term, experience suggests that maintenance will be minor and confined to just the exterior and easily managed narrow edges of the landward back-dune forest. The new predominantly indigenous plant areas will become largely self-sustaining, similar to the expansive native forests in national parks.

Recommended remediation and management components for the Castlecliff coast include:

- Weed control and dune reduction;
- Native dune planting and establishment;
- Formalization of accessways;
- Restriction/prohibition of damaging practices (e.g. no vehicles);
- Pest control;
- Comprehensive monitoring to enable the application of adaptive management;
- Driftwood management, and;
- Community and visitor education.

Note potential options for the remediation and management of the Castlecliff coast also include 'do nothing' and 'status quo'. However, it should be noticed that these options do not advance the WDC and community's long-term vision to create a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character. The recommendations to remediate and manage each area of the Castlecliff coast detailed in previous Sections are summarised below.

Rangiora Street:

1. Maintain Status Quo. Continue to clear sand and debris to allow access and usage.
2. Do Nothing. No management of the beach area.
3. Managed Retreat. Remove/relocate the SLSC operations room and Duncan Pavilion and manage the beach and foreshore (at a reduced cost), or transform it into an easily maintained native landscape.

4. Dune Restoration. Establish a native dune system in front of the lower carpark over a 5 year period, with designated accessways to the beach, with a view to improve the back beach area.

Northwest Dune System:

1. No Nothing. This is the status quo.
2. Dune Restoration. A 3-stage approach to restore the foredune, mid-dune and back-dune to a native/natural state.
3. Divert beach access traffic over the stream at the end of Seafront Road.

Southeast Dune System:

1. Do nothing. This is the status quo.
2. Dune Restoration. A 3-stage approach would be applied to allow the restoration to be manageable.
3. Adapt the 'quarry' to a native coastal forest.
4. Develop the 'quarry' for uses not compatible with dunes (e.g. motorbike/cross users).

North Mole

1. Maintain Status Quo. Continue to clear sand and debris to allow access and usage.
2. Do Nothing. No management of the beach area.
3. Dune Restoration and Relocation. Restore the frontal dune and move the carpark landward.
4. Develop Public Amenities. Develop the riverside area for amenity use (e.g. mountain/BMX bike track, picnic area, playground etc.).

Dune restoration to a native functioning system is the best fit with the WDC and community's long-term vision to create a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character. To successfully restore a native functioning dune system along the Castlecliff coast, restriction/prohibition of damaging practices (e.g. vehicles, motocross, etc.), restriction/delineation of access, on-going monitoring, community and tourist education, and on-going management will be required:

- Dune systems are damaged with unrestricted access and especially where motorised vehicles are concerned.
- Multiple access tracks, and accessways that do not account for aeolian sand movement reduce the dune system's ability to function as a buffer zone and store of beach sand.
- Monitoring is critical to the long-term success of a restoration programme. While strategic planning, best practise approaches and on-going maintenance can be

applied, it is not possible to exactly predict how the existing system will respond to restoration and at what pace restoration will occur. Through a comprehensive monitoring programme, the principles of adaptive management can be applied to modify the programme to achieve the favoured outcomes.

- Education through multiple methods (meetings, the internet, signage, etc.) is also an important aspect to ensure the success of a dune restoration programme, and can lead to the local community taking ownership of the process.

Castlecliff beach is a modified environment, and so there will always be an aspect of management.

Table 6.1 provides a preliminary timeline for each individual management area. If the decision was made to initiate restoration at all management areas then a staggered approach would be required, which likely to be in the order of 20 years.

One management option not included in Table 6.1 is the option to divert traffic over the stream at the end of Seafront Road. It is likely the works required to achieve this option is in the order of $ 15,000. The potential works would include culverts, unsealed metal surfacing for the culvert, clearing and removal of vegetation, and demarcation of the access route. Figure 6.1 presents a hypothetical plan, with the seaward end of the access route sufficient distance from the stream area and orientated across the prevailing wind direction.

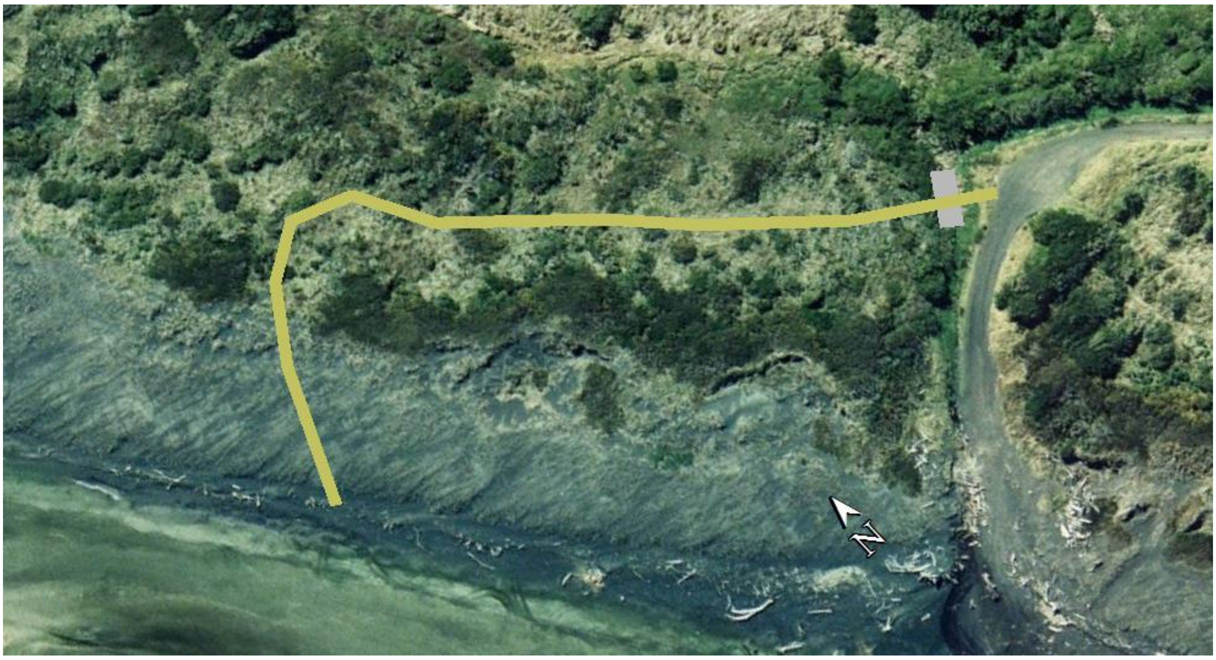

Figure 6.1: Google Earth image with hypothetical plan for stream crossing (grey) and access route (yellow).

The recommendations presented here will be further refined through stakeholder engagement to address and discuss the potential strategies and select final options for each area (Stage 3) in order to develop detailed designs and a final strategy and costing (Stage 4).

Table 6.1. Preliminary timelines and costing for the Castlecliff coastal remediation and management strategy.

	Northwest	**Cost**	**Rangiora St**	**Cost**	**Southeast**	**Cost**	**Northmole**	**Cost**
Year 1	Foredune Planting	$60,000	Foredune Planting	$25,000	Foredune Planting	$60,000	Relocation of Morgan Street carpark	$500,000
	Walking Accessway: 5 by 200 m	$25,000	Walking Accessway: 4 by 5 m	$1,000	Walking Accessway: 5 by 200 m	$25,000		
	Seaward Protective Fencing	$15,000	Seaward Protective Fencing	$6,000	Seaward Protective Fencing	$15,000		
	Mid-dune Mowing	$70,000	SLSC Sand Ladder	$1,000	Mid-dune Mowing	$55,000		
			Mid-dune Mowing	$55,000				
Year 2	Sand removal/complete clear	$1,020,000	Mid-dune Sand removal	$255,000	Sand removal/complete clear	$725,000	Planting	$10,000
	Mid-dune Planting	$140,000	Backdune Mowing	$40,000	Mid-dune Planting	$110,000	Walking Accessway: 4 by 5 m	$5,000
	Backdune Mowing	$85,000	Mid-dune Planting	$105,000	Backdune Mowing	$55,000	Seaward Protective Fencing	$3,000
							Mid-dune Mowing	$20,000
Year 3	Section 1 - Backdune Sand removal	$555,000	Backdune Sand removal	$170,000	Section 1 - Backdune Sand removal	$505,000	Mid-dune Sand removal	$25,000
	Section 1 - Backdune Planting	$165,000	Backdune Planting	$80,000	Section 1 - Backdune Planting	$110,000	Backdune Mowing	$20,000
	Section 2 - Mid-dune Mowing	$75,000	Protective fence relocation and accessway extension	$8,000	Section 2 - Mid-dune Mowing	$55,000	Mid-dune Planting	$35,000
Year 4	Section 2 - Mid-dune Sand removal	$960,000	Monitoring; Protective fence relocation and accessway extension	$8,000	Section 2 - Mid-dune Sand removal	$495,000	Backdune Sand removal	$25,000
	Section 2 Mid-dune Planting	$150,000			Section 2 Mid-dune Planting	$110,000	Backdune Planting	$35,000
	Section 2 Backdune Mowing	$95,000			Section 2 Backdune Mowing	$65,000		
Year 5	Section 2 - Backdune Sand removal	$260,000	Monitoring	NA	Section 2 - Backdune Sand removal	$265,000		
	Section 2 Backdune Planting	$185,000			Section 2 Backdune Planting	$125,000		
Year 6	Overall Evaluation of Restoration and Monitoring	TBA	Evaluate monitoring data; Develop Potential options for amenity based alteration	TBA	Overall Evaluation of Restoration and Monitoring	TBA		
			Protective fence relocation and accessway extension	$8,000				
Year 7	Coastal forest restoration	TBA	Implement Options	TBA	Coastal forest restoration	NA		
Totals		**$3,860,000**		**$762,000**		**$2,775,000**		**$678,000**

7 Conclusion

Restoration to a native functioning system is the best fit with the WDC and community's long-term vision to create a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character. A beach restoration project of this scale and complexity is not easily implemented. Final results will, however, be welcomed by the community and seen as an exemplar by the rest of the nation, and potentially internationally. There is a unique opportunity for Castlecliff to establish a native coastal habitat that is essentially extinct in New Zealand. The undertaking will create scientific interest for ecologists, conservationists, coastal geomorphologists, the climate science community, and eco-tourism.

Further foredune restoration projects are strongly recommended for stabilising dune areas south of the Whanganui River entrance. The most concerning areas requiring input include the '1941 dune breach' area on south spit, and the dune area adjacent to Whanganui airport. Both those zones are currently dominated by marram, so are fragile and will be subject to potentially catastrophic failure.

Finally, it is important that some consideration is given to the long-term holistic management of Whanganui's coast. The beach/dune restoration and management project described here is focussed on the WDC's vision for the Castlecliff area to develop into a user-friendly environment by retaining the amenity value of the existing infrastructure, whilst reinstating natural shoreline character. It is recognised that this area has been largely impacted by human interaction for more than a century, with one of the dominating factors being the construction of the training moles to provide a more navigable river entrance, and the consequent rapid accretion of sand

Although accretion in the Castlecliff area has reduced from 3.3 m/yr to 0.7 m/yr since sand started to bypass the northern mole in the middle of the last century (Burgess, 1971), the training moles and the need to maintaining navigable depths in the Whanganui River mean that the Whanganui coast north and south of the river entrance will always be impacted without management. That is, the dominant sediment transport pathway alongshore is directed to the south, and so, with the training moles and other measures to maintain navigable depths in the Whanganui River, the northern coast accretes/advances and the southern coast erodes/retreats.

The most obvious solution is to move sand from the northern coast to the southern coast. Consideration of the methods available to achieve this (i.e. trucking sand, bypassing sand with a pump system (either permanent or periodically), dredging sand and pumping ashore, etc.)

and the associated costs should be investigated as part of a long-term coastal management strategy for Whanganui's coast. Similar to how present land management impacts on the coast with respect to poor water quality (i.e. high concentrations of suspended silt from run-off which dampens primary production; eroding river banks inputting large volumes of driftwood along with silt; etc.) and require a holistic approach to rectify the environmental damage that has occurred over large areas of New Zealand, a holistic approach should be expanded beyond Castlecliff to incorporate Whanganui's coast.

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Appendix A. Lidar Data

Figure A-1: Google Earth image of Rangiora Street with overlay of Lidar points and values. Note only 10% of the total available points, randomly selected, is used.

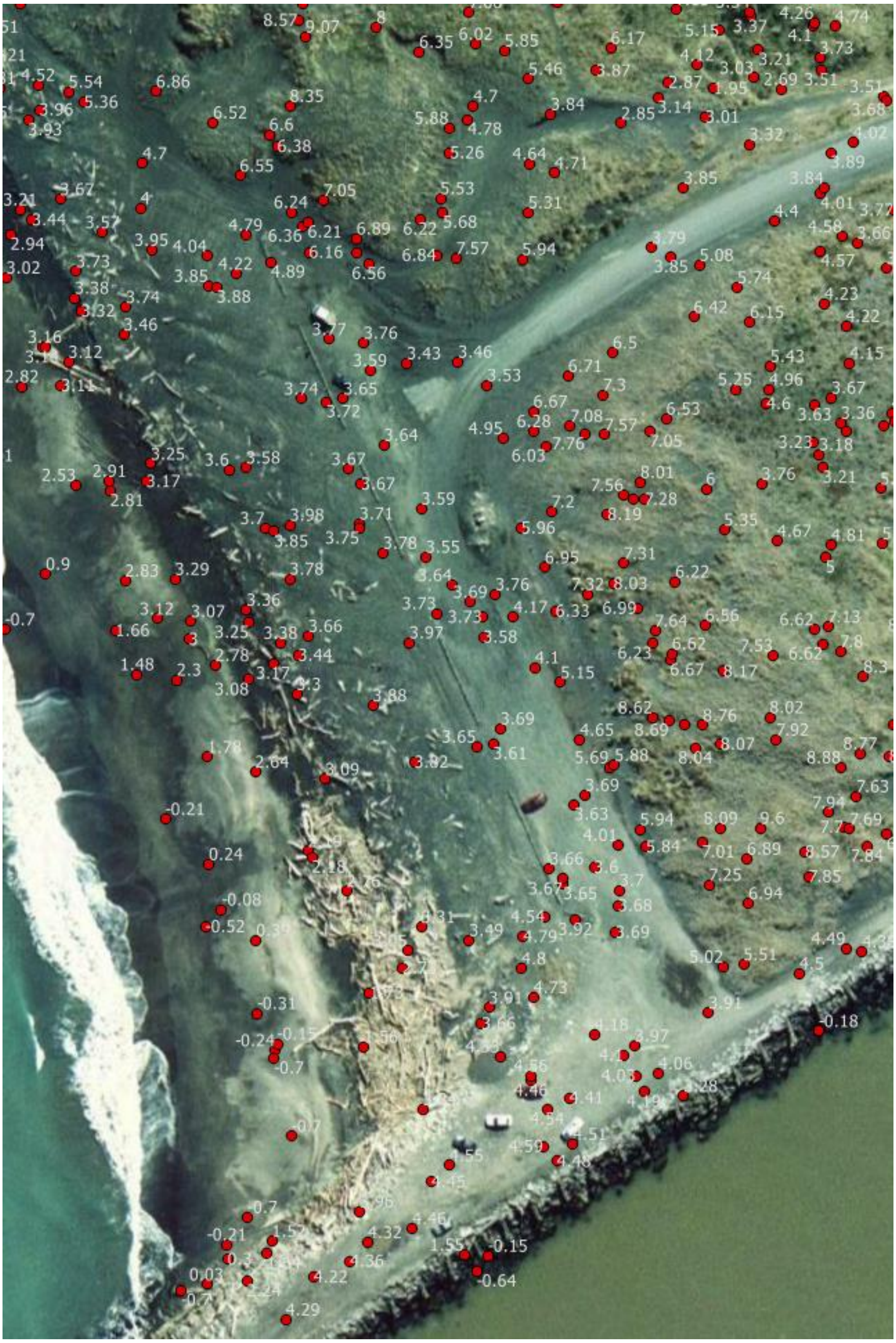


Figure A-2: Google Earth image of Rangiora Street with overlay of Lidar points and values. Note only 10% of the total available points, randomly selected, is used.

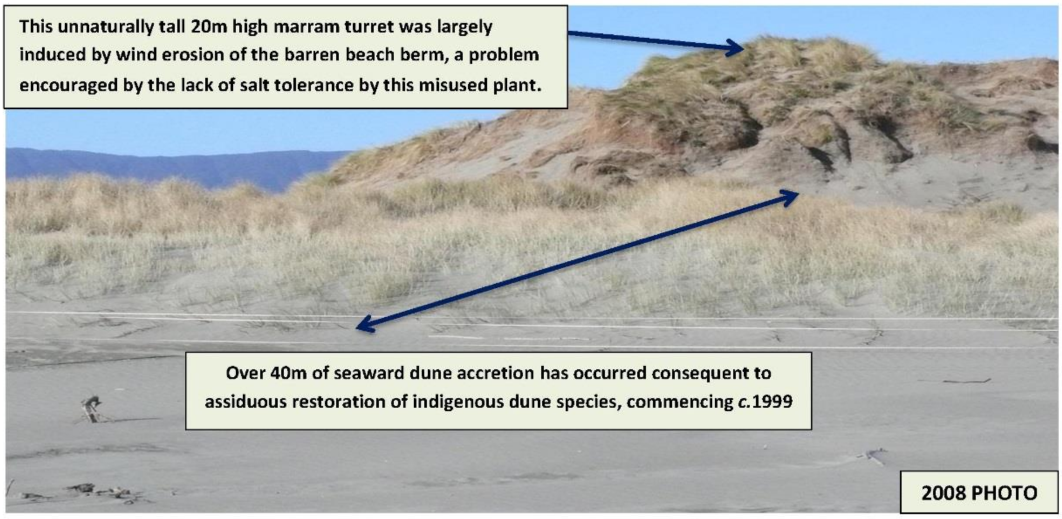
Appendix B. Restoration Examples

THE 21ST CENTURY PARADIGM FOR SUSTAINABLE COASTAL MANAGEMENT
3. Assiduous low-cost and enduring natural restoration successes on many divergent New Zealand beaches

1. DUNE RESTORATION, KAPITI COAST

- moving naturally & economically from human-induced beach _retreat_ to sustainable beach _advance_

Waitohu beach, Kapiti Coast: New Zealand has a relatively recent history of coastal impacts induced by human activities, but these have seriously impaired natural dune integrity and resilience. An early NZ botanist reported his observations of natural dune buffer function and the likely consequences of escalating and potent degradation of the formerly stable NZ dunes: *"coastal dunes … form a natural defence to the land against the encroachment of the sea, and, their movement inland is a national concern … while yearly further destruction takes place,* ***the evil*** *… becoming more difficult to suppress"* (Dr L. Cockayne 1911). Surprisingly this was some 4 centuries **after** King Christian II first became alarmed by comparable dune degradation issues in his native Denmark and consequently drafted the world's earliest Sand Drift Act, in **1539**. Cockayne affirmed the use of foreign coastal plants to control this induced "*sand menace*", plants like marram grass and lupins. Regrettably, these new plants are not salt-tolerant, and the unintended consequences of those unsuitable plants are demonstrated below. These unfortunate dune-modifying plantings resulted in sand being only modestly stabilised, with valuable sand most often now contained in abnormally steep and still erosion-prone tall sand-hills. Sadly this is the most familiar coastal state observed on many littoral margins today. However, the photos below also reveal the many new and remarkable benefits of economical restoration utilising our superior indigenous salt-tolerant (halophyte) dune species. The first example is a dune project by the Waitohu Beach Care group, led by Drs. Richard Herdegen and Jo Rosier, senior environmental planning lecturers from Massey University. Dr. Rosier also reviewed the NZ Coastal Policy Statement, in 2004.



The new community-led planting (shown above) preferentially utilised only **salt-tolerant** indigenous pioneer dune species (like spinifex and pingao). These plants have frugally re-established truly natural form and function to this and other NZ beaches. These dunes now have a more natural height of only about 5-6m, and have gained important extra width of *c.*40m. Unconstrained growth of these halophyte plants has thus increased the width and function of this now naturally-effective storm buffer; in total contrast to the poor performing lupins and marram that dominated previously. New information reveals that increased percolation of wave swash (storm surge) into this now porous sand means that dunes dominated by native plants absorb high-energy waves in a superior manner evolved by natural forces. The <u>average rate</u> of sand accumulation here now is about **4 metres/year** of continuing lateral dune extension **<u>seaward</u>**, due to native dune plant restoration and their characteristic, superior sand colonising ability and induced porosity. This compares very favorably to previous records of coastal retreat. This action has reversed those earlier induced erosion trends and ensures this beach, and others similarly and sustainably restored, will continue to provide increasing security from storm impacts through ongoing accumulations of sand (- **Dunes never sleep!**)

This should only be the start of further restoration efforts on NZ coastal margins; at least 35 species of indigenous plants are suitable for increasing natural floral biodiversity in the coastal zone – from coastal shrubs grading through to back-dune climax forest species, and their intimately associated but rare faunal populations. These forest types are extremely suitable for carbon-sink zones, as this dry coastal land is often drought-prone and relatively unproductive in a traditional farming sense. Forests of this nature are exceptionally rare currently - the remnant areas cover less than 1% of the original total area of indigenous NZ dune forest (Source: NZ Landcare Research).

The photo below reveals another nearby dune restored with native spinifex & pingao, just south of Waitohu Beach. This new-dune has similarly accreted significant quantities of fresh beach sand, resulting in the dune toe being currently **30 metres seaward** of old marram scarp seen in the background. This dune is also still ***increasing*** in width.

ABOVE: Restored spinifex & pingao new-dunes in 2008, now at least 30m seaward of old marram scarp at Waitohu beach. As with the previous photo, this area was planted with indigenous beach species *c.*1999.

ABOVE: The new but typical coastal landform and improved storm resilience when again dominated by the indigenous spinifex: gentle new-dunes & associated wide high-tide beach at Peka Peka beach, Kapiti Coast.

2

2. OPUNAKE BEACH RESTORATION, TARANAKI

The eroding beach at Opunake, with early and failed erosion 'protection & management' measures still in place. Sand is simply being blown off the beach and lost to wide areas further inland, outside the beach compartment.

This is the same beach area as in the above 2010 photo: now just 2 years after restoration with NZ indigenous halophyte dune plants by local community members. The restoration plan was provided and supervised by Greg Jenks. Precious and porous sand is increasingly being trapped on the upper beach face and foredune areas, now kept entirely ***within*** the beach compartment. This ***renewed*** reality is increasing beach and dune width, storm resilience and function of this natural storm buffer. This restored dune now economically and successfully protects the previously impacted surf club, nearby road, car park & other infrastructural assets at this hostile Taranaki location.

3

3. TAHUNANUI BEACH RESTORATION, NELSON

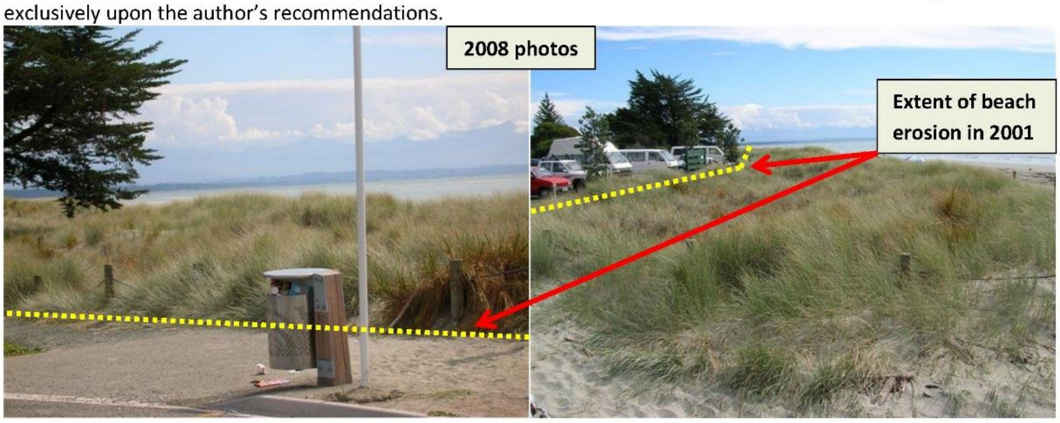
Regrettably, no 'before' photos are available for this beach, but the ensuing extract comes from a report prepared by the writer for Nelson City Council:

"The field visit to these dune systems on September 2001 left an abiding impression of the paucity of functional dune plants throughout this region. The on-going erosion of many of these dune systems would seem to be directly related to this almost-total absence of native **[salt-tolerant]** ***sand trapping plants. In the Bay of Plenty, diligent restoration the four functional native foredune species of plants (spinifex, pingao, beach spurge, and golden sand tussock) has graphically demonstrated superior abilities to trap and stabilise mobile sand far more effectively than introduced plants like marram, ice plant and lupin.***

Dune restoration programmes focus on harnessing community enthusiasm to re-plant these four native species to effectively remedy and reverse existing serious erosion problems, with considerable success.

It is therefore suggested that similar use of all four of these native sand-trapping plants occurs in the Nelson/Golden Bay areas, by harnessing the obvious existing enthusiasm of local communities."

NOTE: the car park and macrocarpa trees behind the marram-dominated foredunes (shown below) were all in serious and imminent danger of falling into the sea before restoration commenced in 2002 - this project based exclusively upon the author's recommendations.



The new and expanding dunes above are now dominated again by indigenous halophyte plant species that continue to proliferate on these formerly and seriously eroding beaches, seaward of the old erosion lines above. A routine visit in 2016 reveals these dunes have increased in protective buffer width by >12m since planting in 2002.

The <u>ONLY</u> factor that has changed here (and in **<u>all</u>** of the preceding examples) is simple affordable and diligent restoration and unconstrained growth of original indigenous halophyte dune vegetation. The subsequent considerable dune expansions and truly sustainable dune stability benefits are a completely natural ecosystem response consequent to this simple and inexpensive procedure. This new science technique also reveals that such ecosystem restoration endeavours typically costs less than 1% of the common alternatives (seawalls and beach nourishment) and significantly is the most sustainable, enduring and low-cost beach erosion solution known (IPCC 4th Assessment Report, Jenks et al 2007).

These ecosystem restoration benefits are found on both coasts of New Zealand, and on both main islands – as demonstrated above. These results depend solely on the quality of the restoration effort, rather than the happenchance of location. Such restoration success shows that this work should be duplicated globally - anywhere that locally indigenous halophyte dune vegetation can be assiduously and successfully restored on erosion-affected beaches, for the combined benefit of beach ecology and dependant humans.

4. CASTLEPOINT BEACH RESTORATION, WAIRARAPA COAST

Regrettably, 'before' photos are again not available for the restoration project on this beach, but work in partnership with the Department of Conservation (DOC) and local residents has again revealed the many beneficial advantages of restoring indigenous salt-tolerant dune plants on eroding NZ beaches. The clear trend for improvements to dune function **AND** sand volume should be emulated by further restoration work throughout this heavily degraded area.

The introduced marram plants (commonly used to replace the impacted native species) are obviously poorly adept at trapping and binding sand volumes where the sediment is required – on the lower beach and foredune. That limiting issue is completely resolved by re-introducing native salt-tolerant beach species, like spinifex and pingao, as shown below. Just compare the marram dominated dune with its large area of oddly tall barren beach on the left with the burgeoning dune tongue dominated by native salt-tolerant functional dune plants in the photo below right.

Source: Garry Foster, DOC (both photos, taken on same day)

The photo above plainly demonstrates the failings of imported marram – this introduced mid-dune plant does not tolerate salt water contact and so is typically confined to areas removed from the reach of normal storm surges. That scenario also means that if salt water does reach these plants, then all the growth contacted will be destroyed – forcing the plants plus their beaches and dunes ever landwards. That is the erosion process observed commonly where plants that do not tolerate salt water are utilised (i.e. on most NZ coastal margins).

This photo reveals the significant advantages of restoring native salt-tolerant low-stature dune plants. These grow unimpeded onto the beach berm due solely to their salt-tolerance feature. This means they trap more sand than any other plant available in NZ, and that sand is also usefully more porous. Those advantages are naturally provided by evolutionary forces that honed and tested these superior plants over many millennia to now provide the most helpful, reliable, least-expensive and best sand-accumulating coastal buffer option available in NZ.

The obvious improvements provided by the above nationwide coastal exemplars are unequivocal. Affordable, unconstrained and enduring restoration of indigenous halophyte coastal plant species by local communities and the consequential effect on natural dune function is now proven by 20 years of operational-scale research. This small effort provides increasingly secure beaches with maximum amenity space while also enhancing coastal biodiversity values. Why would you not want to employ these low-cost benefits for your local beach?

REFERENCE: Jenks, G. K., et al, 2007. *Coastal Systems and Low-lying Areas,* Chapter 6, IPCC 4th Assessment Report.

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Appendix C. Signage an Education Examples

Figure C-1: Education sign examples from the Bay of Plenty.