PATEA BEACH SAND MANAGEMENT PROJECT

SUMMARY REPORT   2008 to 2015

including

SAND MANAGEMENT GUIDELINES

A report prepared for the South Taranaki District Council

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TABLE OF CONTENTS

1. BACKGROUND

Patea rivermouth is controlled by stone jetties (moles) which were completed in 1921 and have resulted in shoreline accretion and dune development for some 900m along the northern coast (see Figure 1). The characteristics of this particularly dynamic system have been described in detail in the Coastal Systems (2006) report: *Coastal Change and Historical Sand Stabilization Works*. Because of the physical characteristics and processes operating in this area the potential for dune instability is very high and some ongoing management will always be required if the beach settlement, sited downwind, is to avoid the sand hazards (wind-blown sand nuisance and burial) which impacted in the 1950s and 1980s.

Several sand conservation schemes have occurred in the dunes since the 1940s and during the 1990s and 2000s stability was maintained by continually applying green waste provided by the local community. However, in the mid 2000s the Taranaki Regional Council required a management plan for such a process if green waste discharge consents were to be reissued. Coastal Systems Ltd provided the report in 2006 on the coastal change and also a report in 2007 on future sand management approaches. *The Patea Beach Management Plan* was written by an independent consultant who used, amongst other material, the information contained within the CSL reports. CSL were then engaged to manage the *Patea Beach Sand Management Project* which began in 2008. **The AIM of the Project is to provide long-term stability in the North Beach dune system while meeting the requirements of the Patea Beach Management Plan (2007).**

Because of the site-specific nature of the (a) high energy/man modified environment coupled with (b) available management resources, sand stabilization guidance was not available and site-specific trials were necessary. A range green waste application coupled with planting alternatives were been carried out as part of the project and green waste was found to play a fundamentally crucial conservation management role in this extreme environment. The results of the various trials have been reported in CSL Progress Reports and Annual Reports.

Green waste application must meet conditions set out in the Taranaki Regional Council (TRC) *resource consent 6088* (copy attached as Appendix A) which permits the STDC to discharge domestic green waste onto land on the north western side of the Patea Rivermouth for the purpose of sand stabilization until a June 2022 with a review to occur in June 2016. Special Condition 2 of the consent requires that management be carried out in accordance with the *Patea Beach Management Plan.*

The *Patea Beach Management Plan* appliers to the beach and dune area immediately north of the Patea River, and Section 2.11 requires the Plan be reviewed as more information becomes available on natural processes and management techniques. As understanding of the physical and biological processes and management techniques have progressed considerably since the project began in 2009, the Management Plan is being reviewed. <u>To assist that review process</u>, CSL were instructed in May 2014 to prepare a

report summarizing the sand stabilization methods used/developed over the past 7 years, including the incorporation of green waste and the required volumes. In addition, sand management guidelines were to be included to ensure the most effective methods are used in the future. The draft report was completed in June 2015, and this final version includes environmental conditions and sand management for 2015.

This Summary Report begins (**Section 2**) by describing the relevant coastal processes and historical change which show the system's inherent potential for sand erosion. The various management methods used up until 2008 when the sand stabilization project commenced are described in **Section 3. Section 4** describes green waste application methods trialed during the project, i.e. since 2008, and also describes the various planting trials, access control approaches and drainage matters. **Section 5** contains guidelines for future sand management.

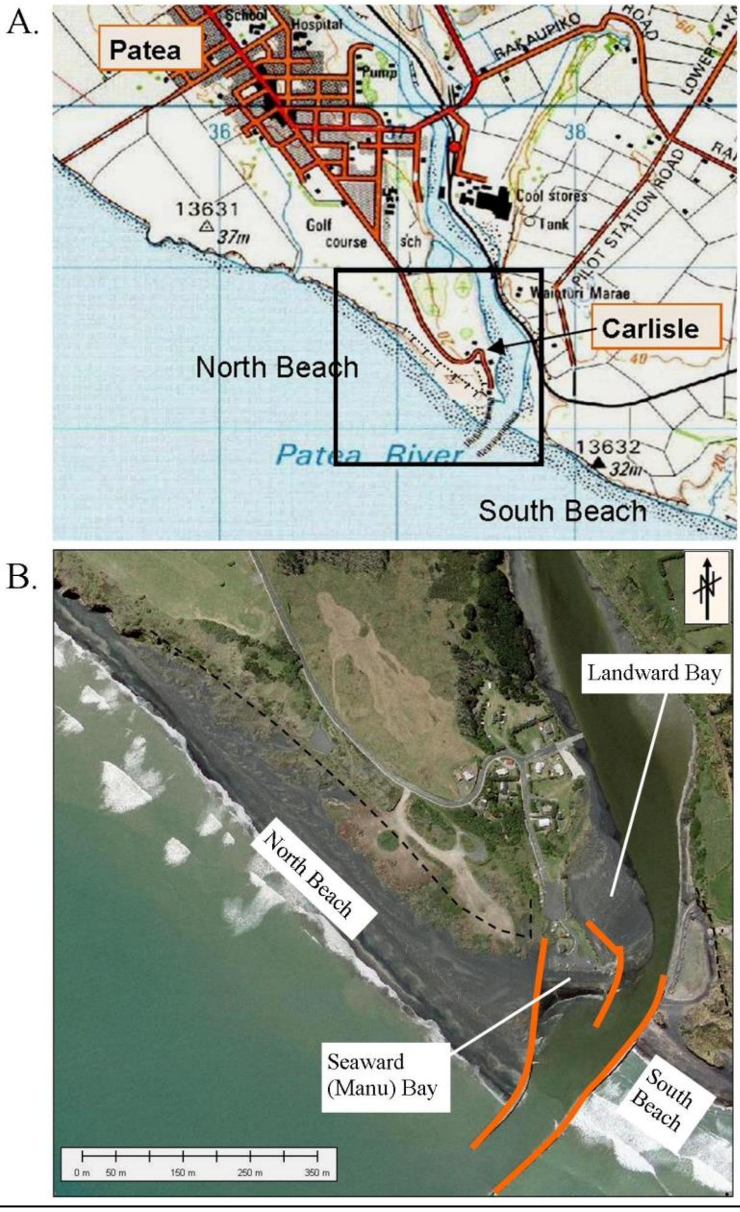


Figure 1 Location map (A) showing Patea township and beach settlement (Carlisle), and aerial photo (B) depicting river control structures (moles and guidewall) in orange, and the pre-colonial shoreline (dashed black line).

2. COASTAL PROCESSES AND HISTORICAL CHANGE

The Patea coast experiences high levels of wind and wave energy which drive sediment transport within the surfzone (subtidal), beach (tidal) and backshore (above tidal). Based on numerical modelling using 20 years of hindcaste wind data, the mean (significant) wave height is estimated to be 1.97 m in 30 m depth, with waves in excess of 5 m occurring 55% of the time (Gorman et al., 2003). The energy spectrum is dominated by periods of 12 second "swell" waves with a secondary set of 7 second "sea" waves with waves approaching predominantly from west to southwest. Note the southwest is at right angles to the shoreline in Figure 1. Winds predominately occur from the west to northwest with a secondary southerly component (Wanganui airport data). The resultant direction for winds responsible for tranporting sand (>10 kts) is 274 degrees and this sand moving potential is classified as "high" (Freyberger, 1979).

Beyond the Patea Inlet, the coast is characterized by 30 m high actively eroding sea cliffs comprising silt and sandstone formations. Erosion rates determined from the 1949 and 2012 aerial photos (processed by CSL) for a 500 m reach of active sea-cliff to the northwest of the Patea Rivermouth ranged between 0.16 and 0.37 m/yr (mean 0.22 m/yr). By contrast, erosion rates along a 200 m section of active cliff southeast of the rivemouth ranged between 0.67 to 0.89 m/yr (mean 0.77 m/yr).

Beach sand is characterised by titomagnitite that is primarily sourced from poorly consolidated andesitic "larhas" originating from Mt Taranaki; these mud/debris slides outcrops along coastal cliffs and stream/river banks. Littoral currents transport the sediment to the Patea area and while no transport studies have been undertaken, a broad range can be appreciated by calculations for New Plymouth where the net southwest to northeast rate is 110 to 160 m^3/yr (Tonkin and Taylor, 2001), and for Wanganui where the net northwest to southeast rate is about 300 m^3/yr (Patterson 1992). The higher value for the south coast possibly reflects the additional input from the inner shelf, coastal cliffs and rivers. Note that while the Patea River also contribute to the coastal sediment budget, construction of the Patea hydro dam in the 1980s likely intercepts sand size sediments and affects the hydrodynamic regime in the tidal reach possibly resulting in a greater contribution of littoral sediment in that area.

To assist colonial navigation, a 325 m long North Mole and 450 m long South Mole were constructed in stages between about 1880 and 1920 (Figure 2). The Moles acted as a sand trap and the shoreline data presented in Figure 3 shows each side of the rivermouth was characterised by a period of seaward shoreline adjustment to mole construction that reflected the NW to SE net littoral drift on the northern side and infill of the pre-mole river channel on the south. Contrasting long-term shoreline behaviour occurred thereafter: with erosion on the south side (Figure 3A) and approximate equilibrium on the north coast (Figure 3B), although an extensive recent episode of foredune erosion (discussed later) is resulting in the slight negative trend from 1949.

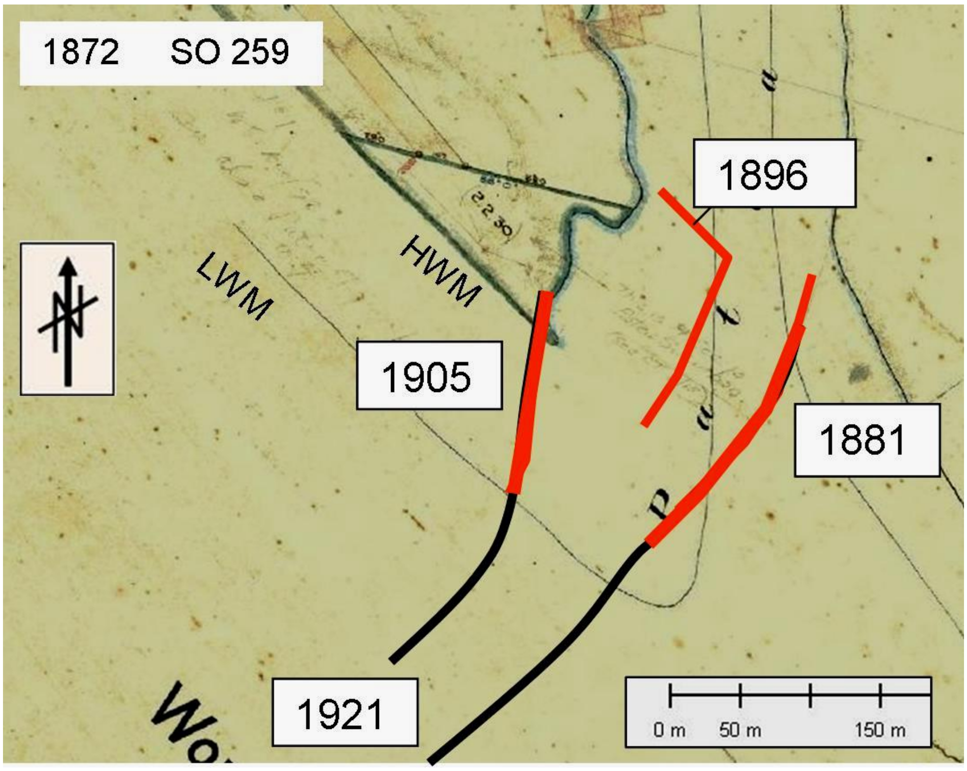


Figure 2 Early survey plan depicting the 1872 shoreline and rivermouth configuration (offset to southeast), along with the location and construction timing of future control structures.

While the inter-tidal beach and shoreline adjusted relatively quickly to the modification in marine processes associated with moles, the consequences for **wind-blown sand** were both unexpected and far reaching. With the spring high tide line moving seaward from the cliff, wind-blown sand was able to both accumulate within this newly created 'back-shore' (accreted land above tide level). From early plans, paintings and photographs, it seems that some back-shore sand accumulation occurred on the north beach prior to the 1921 mole extensions. However, dunes were well established prior to this on the south beach as significant accretion had been occurring in the exposed riverbed following river diversion by the first stage of the south mole construction in the early 1880s (see Figure 2 and 3A).

On the northwestern side of the rivermouth, the developing back-shore facilitated the transport of wind-blow sand into the river at Manu Bay (Figure 4), and over time, sand accumulated about debris and dune grass (marram) thereby enabling the process of dune development to begin (see Figure 4). In addition, a sand ramp formed against the cliff as illustrated in this 1947 photo. Wind-blown sand was now able to reach the clifftop and present a hazard to the dwellings beyond (one of which was apparently buried), and other utilities at the beach settlement (Carlisle, see Figure 1A). This lead to a range of sand stabilizations works which are described in Section 3.

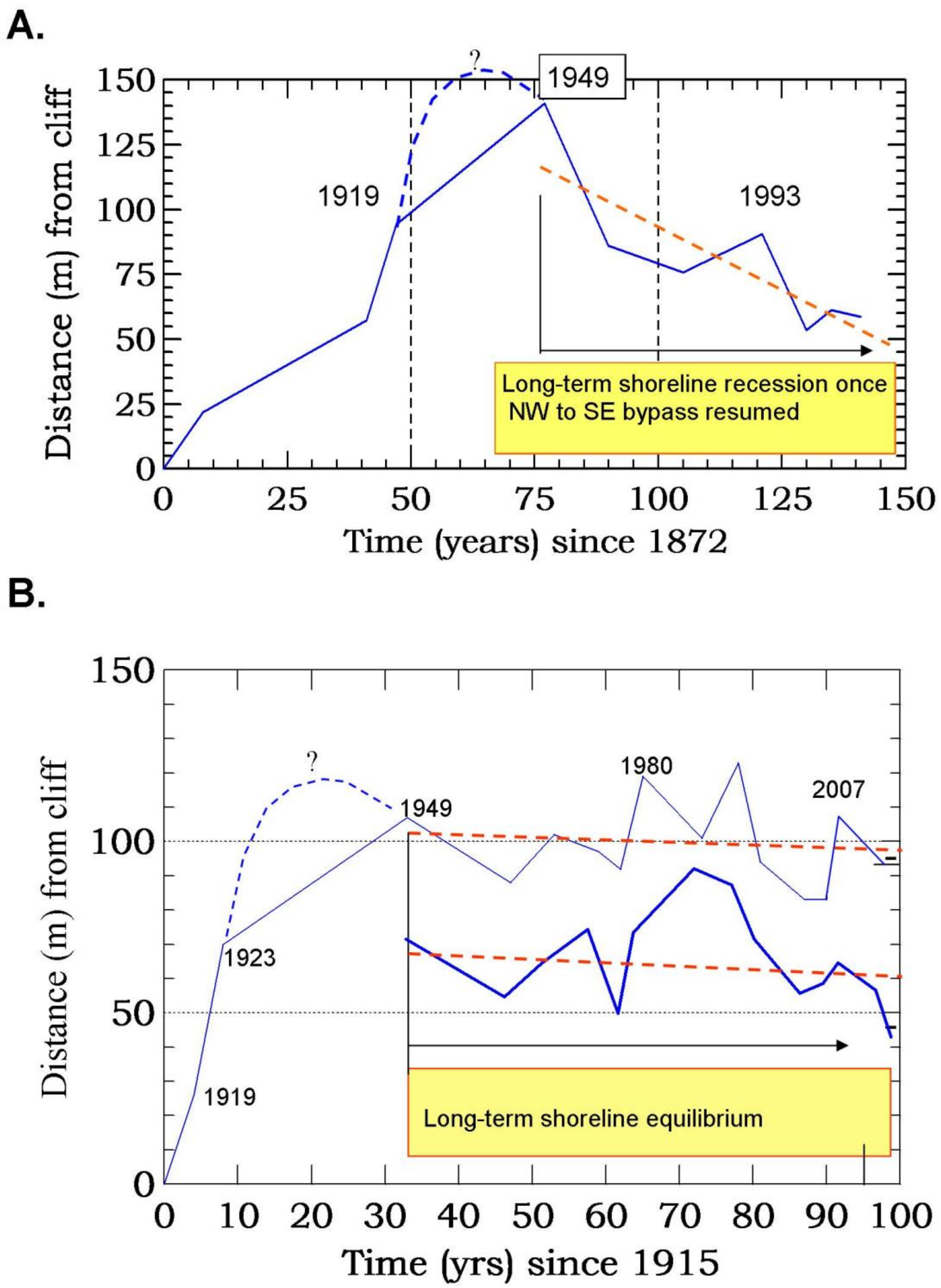


Figure 3 Shoreline change for transects 100 m southeast of the rivermouth (A) and 250 m (thin line) and 700 m (bold line) northwest of the rivermouth (B). The pre-mole cliff is the origin in each case. The dashed curve indicates possible behaviour not detected due to lack of data. Each data set is characterised by a period of shoreline adjustment to mole construction and then contrasting long-term behaviour: erosion in A and approximate equilibrium in B although recent erosion is giving slight negative trends in the aerial data (from 1949).

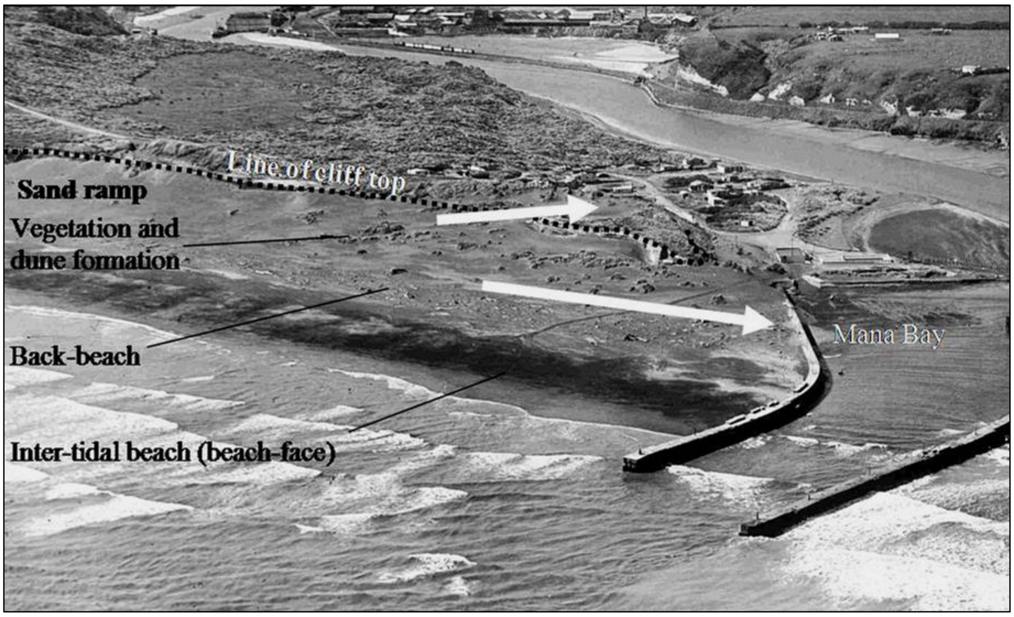


Figure 4 Some 26 years after completion of the moles, the North Beach has moved seaward some 60 m (Figure 3B) and a wide back-beach area defined by debris (driftwood) is evident in this 1947 oblique aerial photograph (Wrights Aviation collection). Vegetation (between the arrows) indicates the establishment of sand dunes, and a substantial sand ramp is evident against the cliff. The white arrows indicate wind-blown sand transport pathways, into Manu Bay (lower) and across the original headland and down onto the beach settlement (upper arrow).

Recent erosion

As alluded to above, the most recent shoreline data points in Figure 3B indicate the northern shoreline has been undergoing a significant episode of erosion and this is the case (e.g. see Figure 5). This episode has been closely monitored using both aerial and terrestrial photographs, and profile surveys. Results have been reported in Annual Reports since 2012 and the current situation is covered in Section 4.6 (Monitoring) of this report (Monitoring), along with consequential stabilization issues. Briefly, this erosion was initiated in 2011 by storm waves cutting into the base of the dune in the north of the dune system (900 m from the mole) and has been migrating southward with the leading edge now being some 300 m from the North Mole. In the north, the dune front has eroded landward some 30 m and the erosion face is up to 15 m high with wind-blown sand from the scarp face blowing inland to bury existing vegetation. Even when wave erosion of the scarp base ceases, and there are just now indications this may be occurring in the far north, the steep slope must adjust (under gravity) back to the stable angle for sand (34 degrees). Wind erosion results in retreat of the scarp top, i.e. surface instability will progress further into the dune system burying existing plants and leading to further wind erosion/wind drifts. If left unmanaged this process could affect the road, farmland and the beach settlement as occurred in the 1950s and 1980s. Additional monitoring has been carried out over the past few years to better understand and respond to this current episode of erosion.

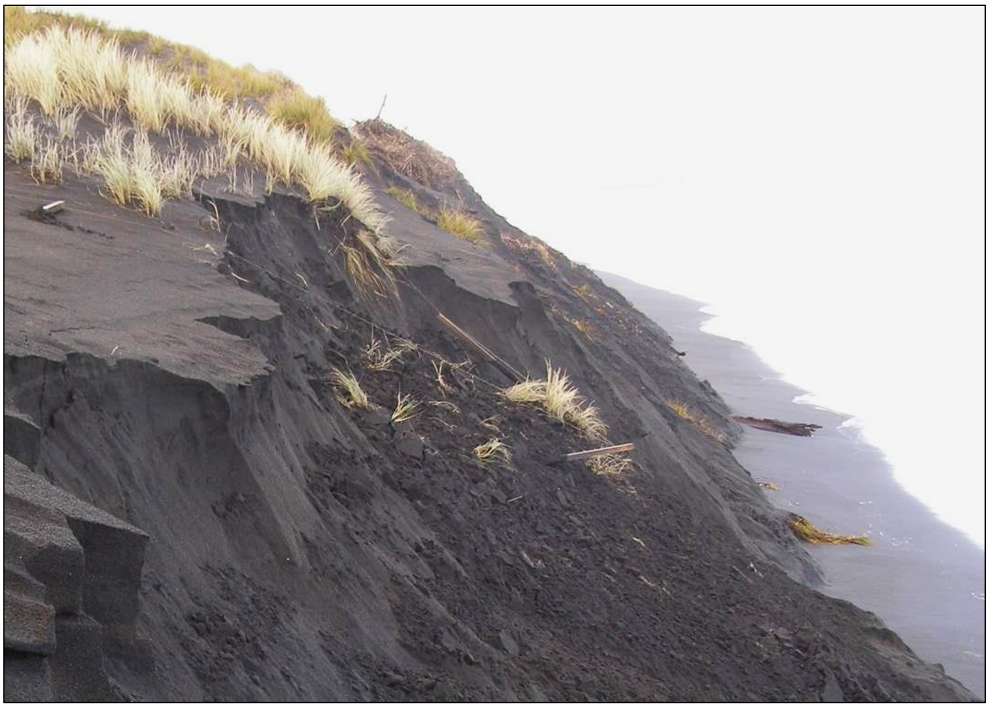


Figure 5 An example of foredune erosion taken on 12-8-2014. The slip-face is 20 m long. A trial plot of spinifex on the left (light coloured grass) is being lost along with the protective fence (battens and rope evident in centre of photo). Pingao grass (yellow) is the predominant foredune plant cover and can be seen in the background where the litter the slip face.

3. EARLIER (pre-2008) SAND STABILISATION WORKS

Early aerial photography (Wrights Aviation 1958 and New Zealand Aerial Mapping 1962) show a shore-parallel windbreak fence in the southern and central area (location marked in Figure 6C); this was constructed of vertically driven mill slabs, some of which are still visible today (Figure 11). Subsequent aerial photos (1968, 1970, 1974, 1977 and 1980) show that a continuous and stable foredune developed (CSL (2006), Figures 5 and 6).

Shorter diagonal wind fences were constructed in the northern area (see Figure 6C at left side of photo). However, this did not result in the formation of a significant and continuous foredune, rather the fencing configuration contributed to the development of easily destabilized discrete dunes orientated diagonally across the beach and parallel to the prevailing wind.

Fed by a continual supply of wind-blown sand, the stable shore-parallel foredune (covered with marram grass) along the central-southern area of the beach increased in volume and height and this increase in wind exposure eventually lead to the development of erosion guts (blowouts) which rapidly expanded and allowed substantial quantities of sand to move inland. This is the typical growth process for marram sand dunes in this type of setting. Note the shape of mature marram grasses shape can also contribute to sand dune instability and this is discussed further in Section 4.3.1. The critical instability situation at Patea was reached during 1987 (El Nino), if not somewhat prior, and is illustrated in the 1987 and 1988 photos in Figure 6 below. At that time wind-blown sand was an ongoing nuisance and the leading edge of the sand drift was about to descend upon the beach settlement. A government (NWASCO) subsidized sand stabilization scheme was designed and coordinated through the Taranaki Catchment Commission (predecessor to the Taranaki Regional Council). These works and their repercussions are now described.

The mobile sand problem facing the community by the late 1980s was significant in terms of both the hazard and the effort that would be required to bring the situation under control. The extent of bare sand, the topography and the wind strength resulted in the TCC having to trial several techniques. In the foredune (southern-central) area, clay capping was unsuccessfully applied. A more successful technique involved blocking large erosion guts (blowout throats) with pine trees thinned from a nearby plantation and marram grass was planted between these wind-breaks – this is illustrated in Figure 7A.

By the early the 1990s the extensive sand drifts in the southern/central area had been controlled although erosion guts in the foredune were still active (Figure 8A).

In the northern area, similar wind breaks and plantings were constructed across the unstable dunes and ramp (see Figure 7B). However, this work was only partially successful, possibly due to the wind-breaks being at a lesser angle to the prevailing wind direction. A proposal for further windbreaks in 1994 did not eventuate.

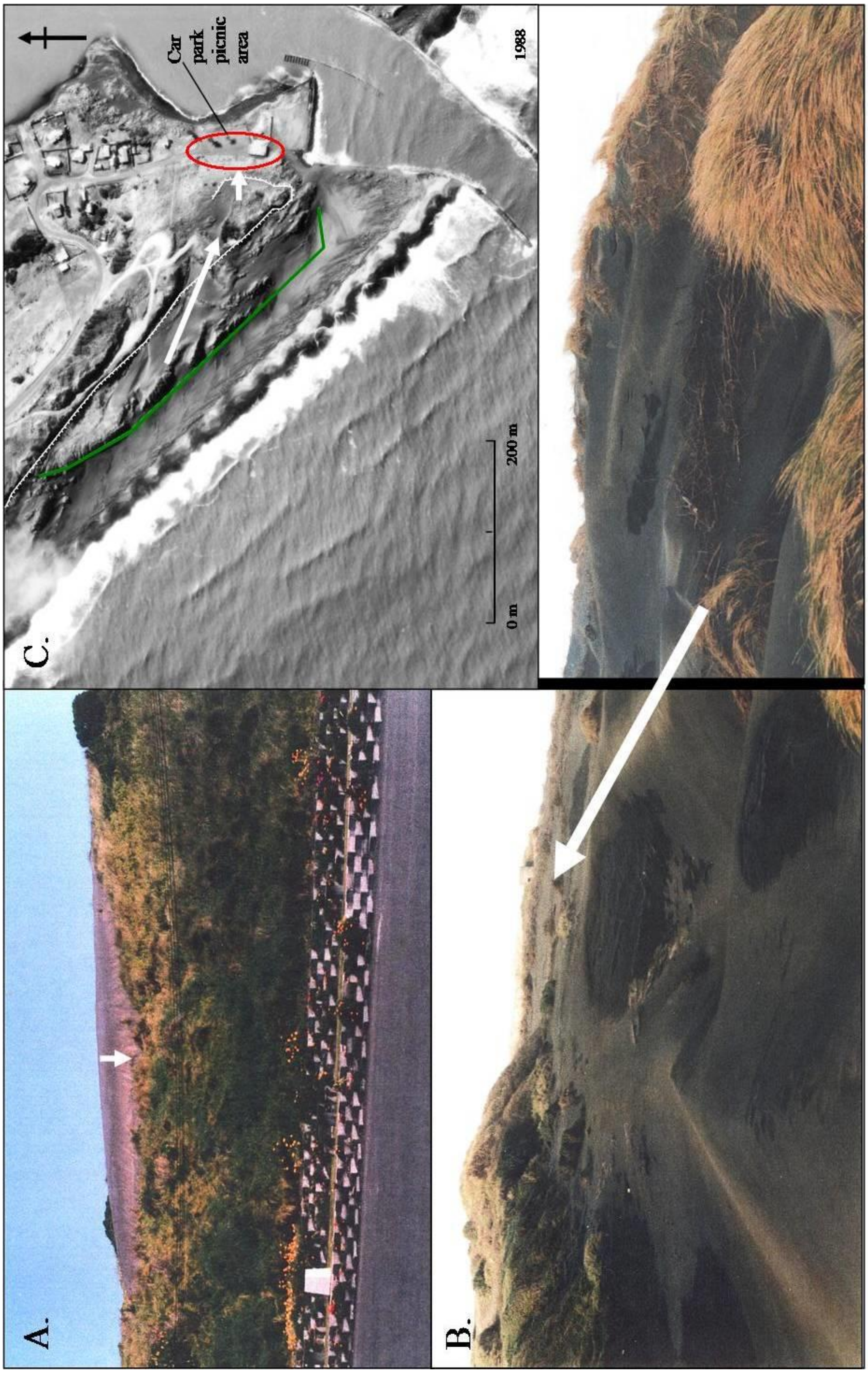


Figure 6 Widespread wind erosion and sand drifts in 1987/88. Figure 6A shows drift sand in 1987 about to descend into the car park/picnic area by the Surf Club building, after sand eroded from the then unstable foredune (Figure 6C) and formed wind drifts (Figure 6B). The green line in C locates the earlier mill slab wind-break fence that helped earlier dune establishment and growth.

A.

B.

Figure 7 Upper photo (A) shows sand stabilization works in the eroding foredune area (NB C in Figure 6) where pine thinnings were placed in guts and orientated across the path of the prevailing wind (arrow),with marram grass planted within the intervening spaces (photo 1988). In the northern area (lower photo B) sand instability was wide-spread and pine thinings were used to erect rectangular fencing with marram planted in between (photo 1992).

During 1990s, protecting the central/southern area with green waste began and quickly expanded to become a district-wide operation. The swale (valley) between the cliff and original foredune-crest (Figure 8A) was infilled with green waste (Figure 8B) and wind-blown sand and then overlain with clay cut form from the original cliff. In effect a 'green waste platform' had been created with its seaward face displacing the original cliff-face seaward by some 50 to 70 m. This feature will be referred to as the ***Green Waste Platform or GWP*** in this report.

In the late 1990's, the native pingao (grass) was planted on the foreshore-backshore margin along the central/northern reaches. The plants were given green waste protection and thrived in this harsh environment; a new foredune developed (see Figures 8C and 9),and this is referred to as the ***Pingao Foredune*** in this report.

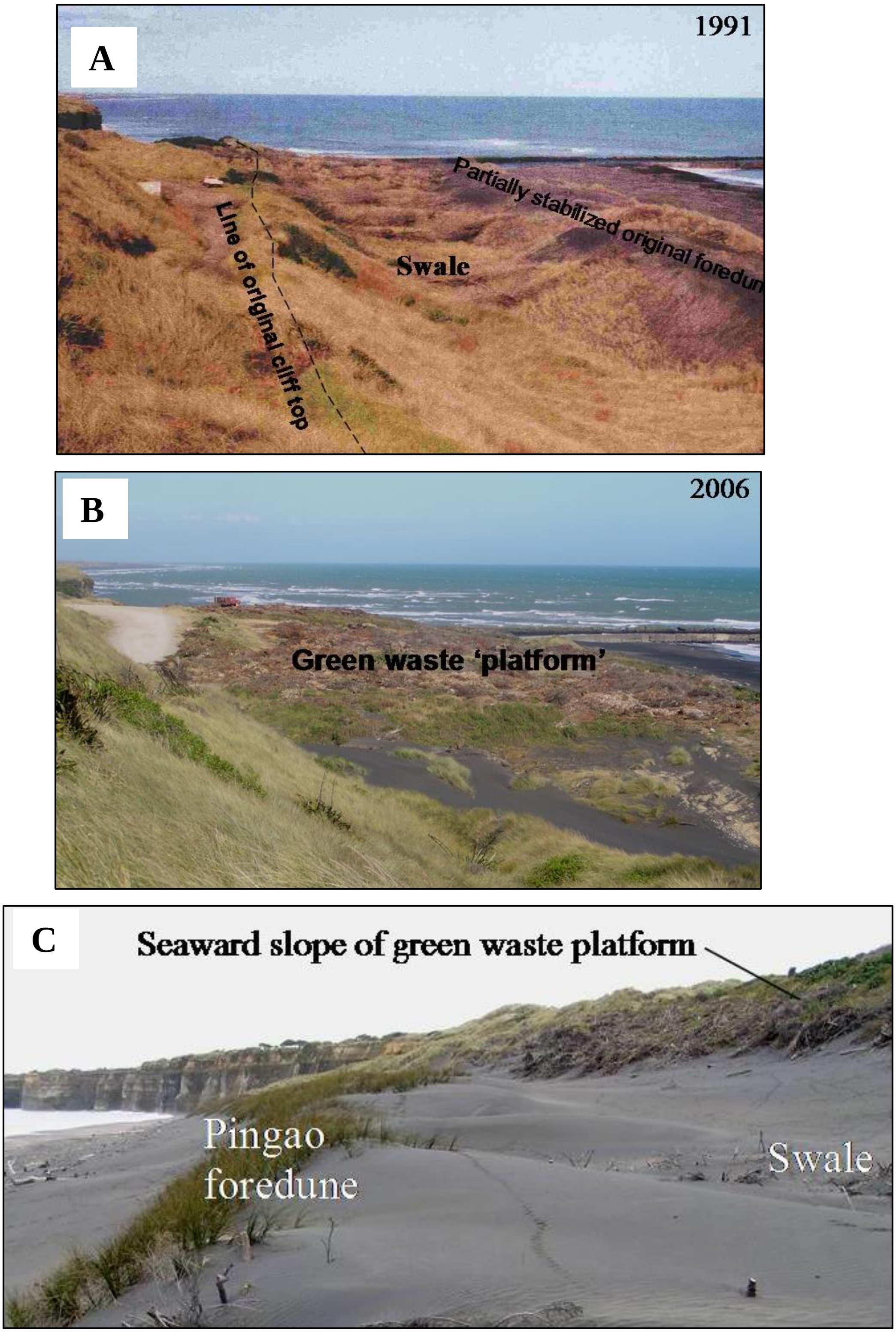


Figure 8 Relatively stable dune-scape in the early 1990s (Figure 8A), although some instability on the seaweard side remains; this was stabilized by green waste which eventually produced a platform-like feature (Figure 8B) referred to as the "green waste platform". The well established Pingao Foredune is shown in Figure 8C, backed by an infilling swale. Dried green waste mantles the green waste platform face at the rear of the lower photo.

By the mid 2000s the beach and dune system on the northern side of the rivermouth could be divided into three sectors based on topography, developmental history and management regime. The longshore extents of these sectors are marked on the 2002 aerial photo below (Figure 9).

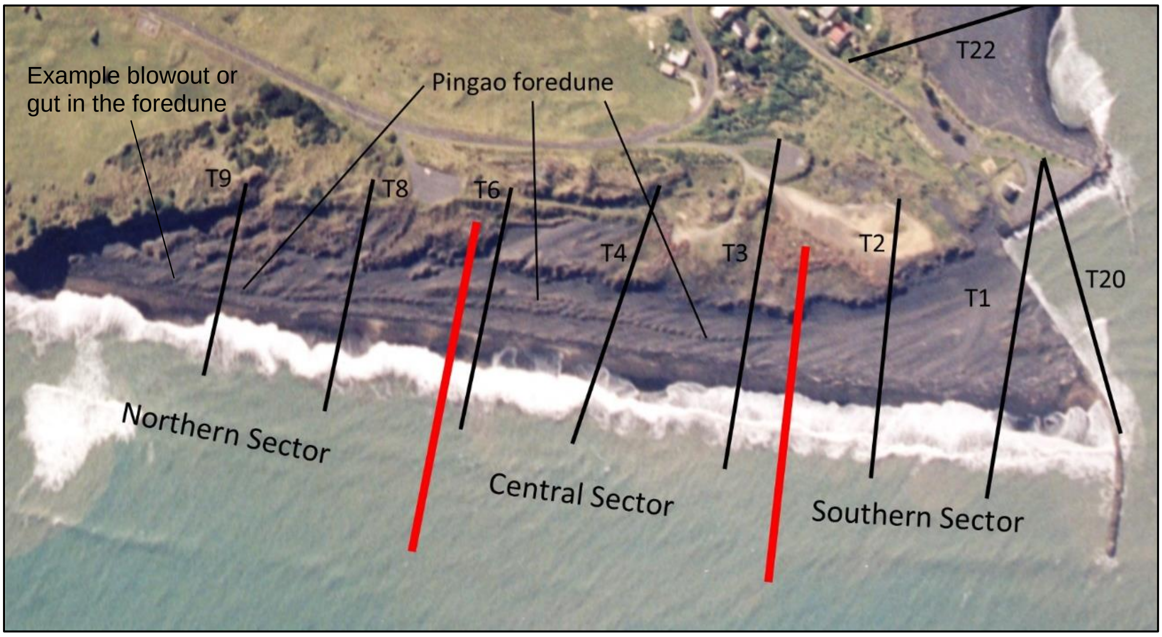


Figure 9 The three sectors of coast with contrasting physical characteristics and management requirements (described in text) have been marked on this 2002 aerial photo. Monitoring transects area also marked. The new Pingao Foredune stretches along the northern and central sectors. Note how this new feature is located increasingly closer to the shoreline along the northern sector and blowouts (guts) are evident by the distinct gaps in the foredune where sand blows through from the beach to the rear.

The Northern Sector dunes were characterized to seaward by the Pingao Foredune (marked in the 2002 aerial photo in Figure 9. The foredune was severely "blown out" (gutted) in several locations and this is likely associated with storm-wave erosion creating a scarp (cliff) on the dune face; such scarps can actually be seen as black lines (shaded cliffs) in the subsequent 2005 aerial photo (Figure 10). Behind the foredune were discrete and hummocky marram dunes and erosion troughs broadly aligned with the prevailing wind. In some instances foredune blowouts have merged with erosion troughs to the rear which extend up the ramp to the clifftop and upper car park (between T6 and T8 in Figure 9).

The Central Sector was also characterized by the Pingao Foredune but here it had a more stable form, i.e. more continuous with only small guts; this probably resulted from the original pingao plants being positioned in a more landward location relative to the then shoreline (see Figure 9) which made storm wave erosion less likely. Behind this foredune, a swale occurred which broadened and lowered toward the south (Figure 8C). To the rear of the swale was the seaward face of the original foredune, referred to as the face of the Green Waste Plantform (GWP); this slope being characterized by patches of green waste and marram interspersed with bare sand. Some of these bare sand areas could potentially develop into guts and sand then drift across the top of the GWP. The boundary of the northern and central sectors was particularly unstable and is discernable by the bare sand in the foreground of Figure 8B and this area is marked orange in Figure 10. Ongoing green waste placement was required to control erosion and sand drifts.

The Southern Sector lacked a continuous foredune, but rather comprised isolated dune hummocks of pingao located on the seaward side of the broad back-shore area (Figure 11). Behind the backshore lay the GWP face characterized by areas of marram grass, bare sand and decaying (dry) green waste, and included several large guts. The clay capping across the top of the platform would result in future drainage issues which affect the platform face (Section 4.5).

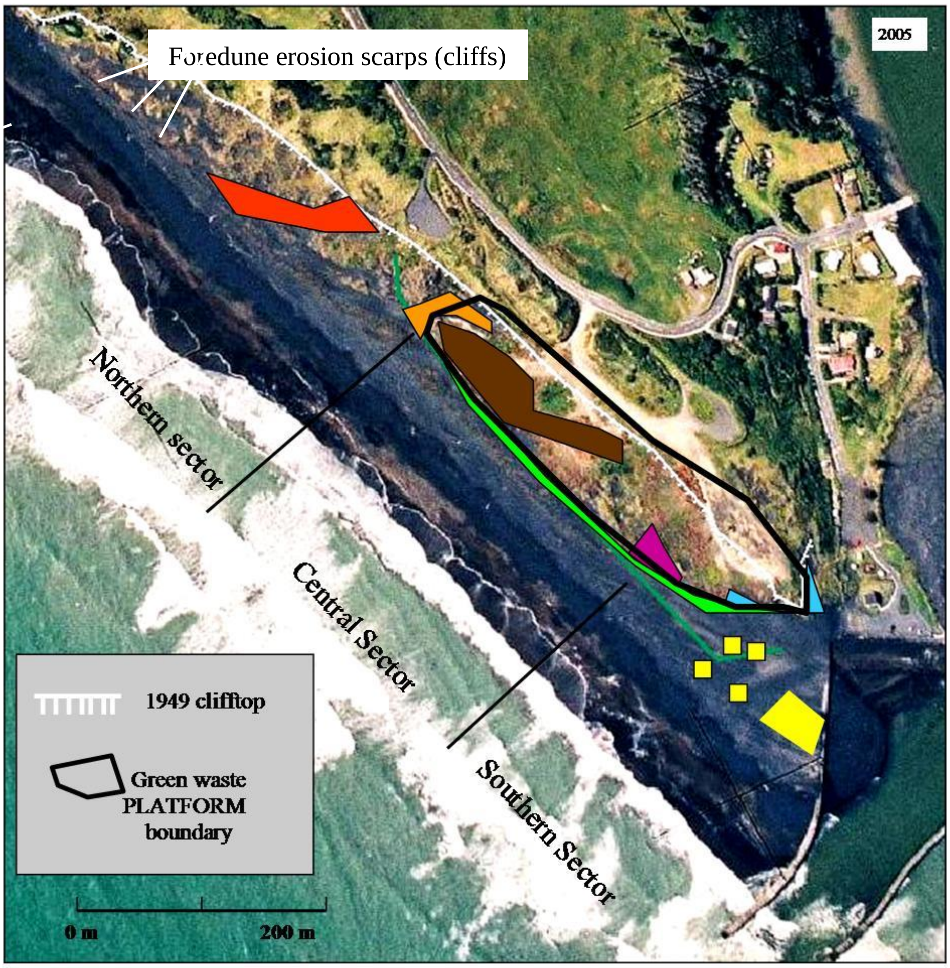


Figure 10 Physical features and areas requiring management at the beginning of the sand management project. Brown is the green waste drop-off area at 5 June 2008, orange required immediate stabilization, red, purple, aqua required stabilizing in the near future. Green marks the face of the GWP. The three sectors are based on differing physical characteristics and require differing management regimes. Yellow denotes areas of isolated dunes to be removed (to facilitate rather than obstruct sediment transport) and their vegetation transplanted to unstable areas. Note the dark green line locates the early the (1950s) mill slab wind-break fence and a foredune scarp in the Northern Sector is marked.
From CSL (2008) Interim Report

Figure 11 Southern Sector view in 2006. On right hand side, discrete pingao dunes are establishing along the seaward side of the wide backshore. To the left is the platform face with marram on upper slope and dry green waste spread down the face. The arrow depicts wind flow and the dotted line locates remnants of the early (1950s) mill slab wind-break fence which facilitated growth of the original marram foredune.

4. SAND STABILISATION PROJECT

4.1 Introduction

The Patea Beach Sand Stabilization Project was established as a means of complying with conditions of the TRC Resource Consent 6088-3 (October, 2007) for managing green waste. This required operations be consistent with the Patea Beach Management Plan (2007). In June 2008, an Interim Report on sand management objectives and methods was prepared by CSL. Matters of significance are marked in Figure 10 (taken from that report). While the Patea Beach Sand Management Project contract with CSL was not signed until April 2009, the project effectively began in 2008.

Management for the sand stabilization project can be broken into the following categories:
- Green waste placement
- Plantings
- Access control
- Drainage
- Monitoring

It is noted that during the first two years, several Inspection Reports were produced with conservation works recorded on a plan (aerial photo). During later years, an Annual Report (including a plan) was produced. The 8 plans are reproduced as Appendix B1 to B8. The rationale, methods and results will now be considered.

4.2 Green Waste

4.2.1 Volume

In the 1990s, locally produced green waste was used to stabilize exposed sand. By the early 2000s the site had become a regional landfill with 5 to 10 commercial trucks plus the public using the site each day (NB Figure 8B). As the resource consent only permitted green waste for sand stabilization, the STDC banned commercial operators in late 2007 and this had a dramatic effect on odour, flies, dust and the volume of waste needing to be subsequently placed (mechanically spread). Between April 2008 and August 2009, the average daily volume of uncompacted green waste deposited at the site by Patea residents was measured at 22.4 m^3, or 8176 m^3/yr (CSL Progress Report 2008-2009) and this was considered to be quite adequate for sand stabilization.

4.2.2 Placement

Prior to the sand management project, green waste dropped at the site was simply pushed off the seaward edge of the platform where it trapped, and partially was buried by, wind-blown sand (Figures 8C, 12A). This practice of "pushing off" systematically moved the GWP face seaward and essentially facilitated further erosion and wind drifting across the GWP surface once sand infill about the waste occurs, thus requiring further applications of green waste, i.e. the procedure did not lead to sustainable management. A fence was erected in 2012 to control waste getting onto the face which was then planted in marram (see Section 4.3 below). After this, only the amount of green waste necessary to prevent erosion/gut development on the face occurred.

During placement, green waste often spilled into the swale between the GWP face and the crest of the Pingao Foredune (Figure 12B); this presented an obstruction to the swale's function as a conduit for sand transport toward the rivermouth. An objective of the sand management project [CSL (2007) Figure 4 and CSL (2010) p6] was to maximize sand storage capacity on the platform face while facilitating alongshore transport via the swale to the river. Swale obst-ructions which occurred during placement were therefore periodically removed (Figure 12C).

Figure 12 Green waste placement. Recently pushed to the front of the platform face in the Central Sector (A) with an earlier placement and sand infill in foreground. Green waste spilling down face of platform and across swale (B), and subsequent swale clearance (C) with waste being placed in guts on top of the pingao foredune (D)

4.2.3 Spot placements

Green waste is particularly effective at infilling and stabilizing hollows/guts along the top of the Pingao Foredune (Figure 12D) and along the GWP face, as well as on areas of drift sand across the GWP surface. In the case of foredune hollows and guts, the digger driver also placed pingao growing nearby (in non-critical areas) on top of the green waste to provide longer-term protection. Note that green waste is primarily used for sand stabilization in the Southern and Central Sectors due to machine access, with planting being the primary control used in the Northern Sector.

Spot placements were also (unsuccessfully) trialed as a means of controlling dune traffic, this is described further in Section 4.4.

4.2.4 Foredune scarp control

The current episode of foredune erosion that is affecting the Northern and Central Sectors, as discussed in Section 2. To minimize landward destabilization from gutting and landward vegetation burial, the scarp face and crest should have uniform relief with protective cover. However, this is not possible given the hummocky nature of sand dunes and their characteristic irregular vegetation, but a recent green waste trial is promising.

Figure 13 Green waste being placed along the scarp-top (A) in July, 2014. NB the extent of this scarp is evident in Figure 5. The stabilizing effect of the green waste treatment compared with vegetation (pingao) cover is indicated in B (October, 2014) where the pingau area in the foreground has greater scarp retreat and associated landward wind-drift.

During the winter of 2014, green waste was placed along the top of, and immediately to the rear of such a section of scarp (Figure 13A) located in the boundary region of the Northern and Central Sectors. Results show not only less wind-drift and burial to the rear, but less scarp-top retreat compared with adjacent pingao covered foredune. Topping up with green waste is straightforward and extending coverage is planned for late 2015 along the pingao foredune crest and swale in the Central Sector.

Green waste management summary

*Green waste plays a fundamental role in maintaining sand stability, in conjunction with other procedures described in this report.

*The volume of green waste dropped at the site by Patea residents exceeds the amount required to maintain sand stability.

*While the practice of placing green waste by "pushing off" the face of the GWP using an excavator or bulldozer was effective in containing wind-blown sand, it had disadvantages:

- natural sand transport processes were modified (sand less able to reach the river),
- after decomposition, bare sand on the face blows across the platform surface with wind drift potential to bury vegetation means sand could encroach upon pasture and the beach settlement unless controlled,
- ongoing green waste to top up precious applications was required.

Note, GWP face is now managed primarily through strategic planting that is described in the following section (4.3.2)

*Green waste is now used to:

- stabilize large areas of drift sand which can occur following extreme wind conditions,
- fill erosion guts and depressions which may develop along the GWP face and foredune.
- cap foredune erosion scarps to limit the landward extent of wind-blown sand.

Note, green waste uses are combined with vegetation establishment as described in the following section (4.3.2)

4.3 Planting

4.3.1 Background

For sand dunes to establish, in addition to abundant wind energy, sediment supply and a backshore area free of wave disturbance upon which deposition can occur, is the existence of vegetation.

- Any obstacle, for example driftwood, will disrupt wind flow and cause scour/deposition, but this process is essentially limited to the height and form of the obstacle.
- Where vegetation is present, sand deposition occurs in the wind shadow behind the plant and the plant can continue to grow (unless buried), and facilitate further deposition.
- Different types of vegetation have different leaf and stem shapes and dimensions, and this causes different wind-flow disruption, hence different shaped dunes develop and these have different sand stability characteristics.

The most common sand binding grasses used for sand conservation in New Zealand are marram, spinifex and pingao (Figure 14A, B, C). Kikuyu grass (Figure 14D) is a weed that has particular sand stabilizing qualities. All species have been used in our various trials and observations at Patea.

Marram (*Ammophila arenaria*)
Marram grass is native to Europe and was likely introduced at Patea for sand stabilization in the 1940s or 1950s (NB this was a newly accreted area so may have had no native grasses growing). Marram has rhizomes and a dense root system to a depth of 1 to 2 m with leaves growing in tussocks up to 1.7 m high. Marram spreads via tillers at the tussock periphery. However, rates of lateral spread are slow (in excess of 0.6 m in all directions and in hostile locations such as the foredune face in high energy environments, plant dieback can occur and thus retreat of the vegetation-front. Tussocks can present a significant obstacle to air flow and promote wind funneling around individual plants and between adjacent plants which leads to localized erosion and a hummocky dune appearance. These processes occur at Patea where uniform marram grass once extended out to the wood paling wind fence. But as the dune grew its susceptibility to such processes increased and guts developed (Figure 6C), along with landward retreat of the vegetation front which is now located 15 to 30 m to landward (N.B. Figures 10 and 11).

While marram has some issues as a sand conservation plant, its attraction comes with plant stock which are easily and inexpensively obtained by breaking tillers from local tussocks, and secondly, survival rates (at Patea) were observed to be in excess of 90% with failure often due to root scour or burial. Marram grass was the preferred sand conservation plant in New Zealand until relatively recently when aerodynamic advantages of spinifex became recognized along with popularity for the use of native species.

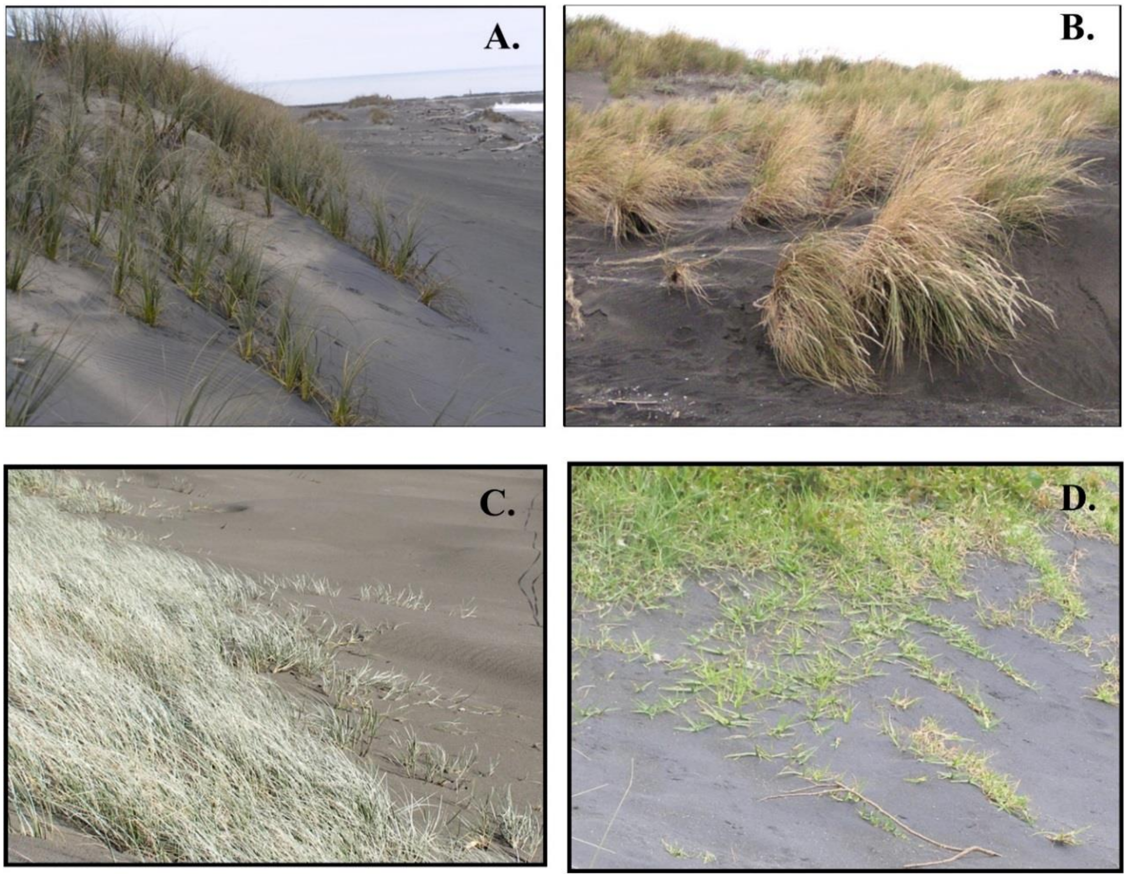


Figure 14 The three types of dune grass typically used for sand stabilization, pingao (A), marram (B) and spinifex (C), have been planted in the Patea Beach dunes. In addition, the weed kikuya (D) was introduced with green waste dumping and is well adapted and invasive to this environment

Pingao (*Desmoschoeneus spiralis*)

Pingao is a native plant with distinct yellow/orange leaves that can grow up to 0.9 m in height and has woody surface runners that can grow metres per year (Bergen 1998). Pingao's uniform shape promotes sand deposition but suffers die-back in areas of very high wind exposure. Pingao was introduced to Patea Beach in the late 1990s by local contractor Mr Noel McCole (Figure 15B) who transplanted lengths of woody rhizome from a nearby source at Waitotara and planted them within a green waste cover along the top of the foredune/backshore zone. These plants flourished and are clearly discernable in the 2002 aerial photo (NB Figure 9). Pingao were observed to cope with foredune exposure better than marram but suffered wind desiccation in the most extreme foredune locations (see Figure 15C). At Patea, Pingao plants will self-seed (Figure 15A). However, for use in sand conservation new plants were obtained by simply transplanting material from nearby established plants using a mechanical digger; this was cost-effective when carried out as part of green waste placements. Associated plant survival rates at Patea are estimated at 60 to 80% with root scour and burial often the cause of failure.

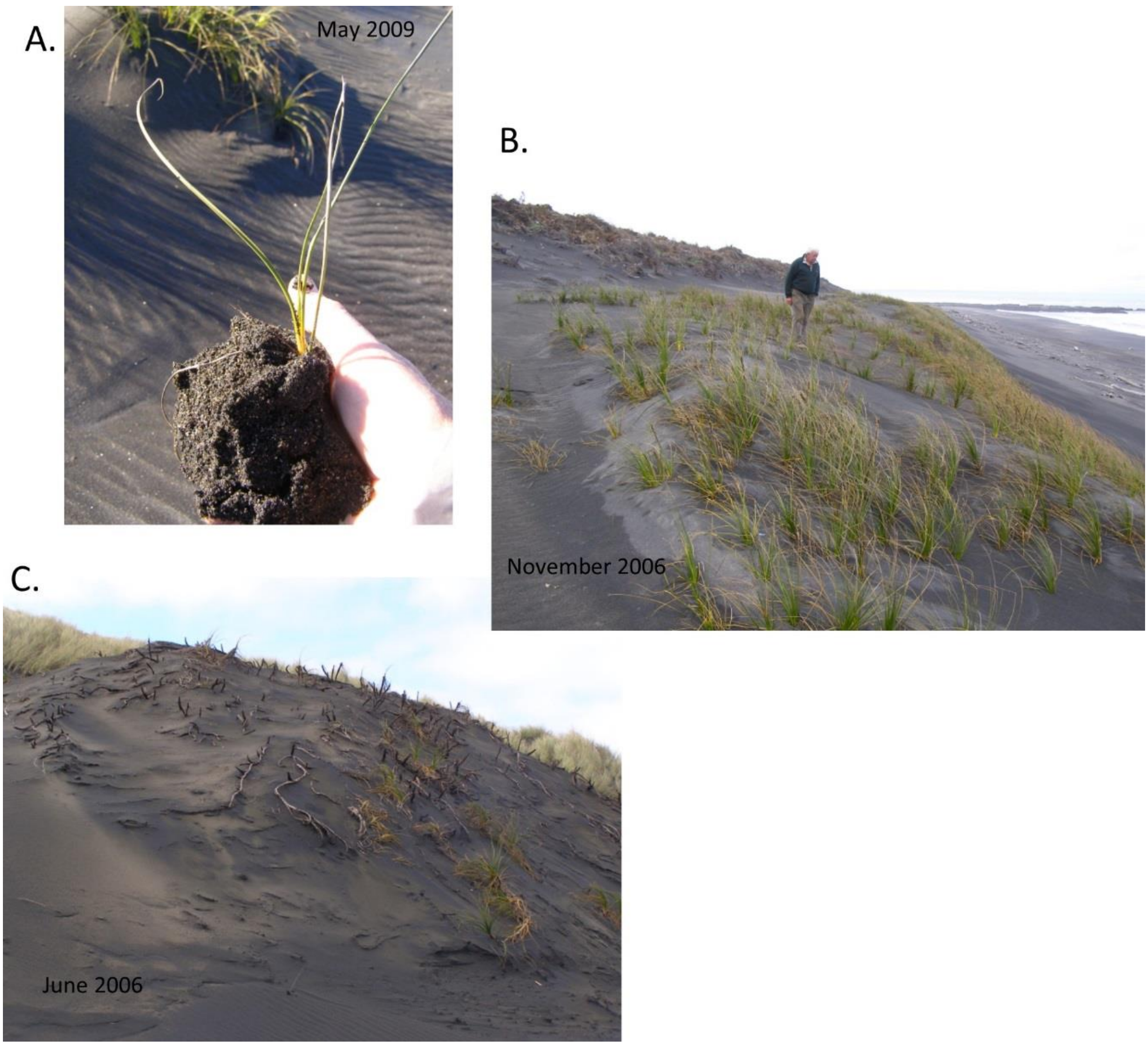


Figure 15 Pingao at Patea. New self-sewn seedling (A), foredune originator Mr Noel McColl inspecting healthy plants in the Central Sector (B), and wind desiccation in the Northern Sector (C)

Spinifex (*Spinifex sericeus*) is also a native sand binder and was introduced to Patea during the present sand management project. Spinifex is a low-growing plant with leaves up to about 0.4 m and surface runners that may extend up to 20 m (Bergen, 1999). Plant growth is stimulated by new sand deposition. Spinifex's low uniform shape promotes deposition, but its surface runners are susceptible to wind exposure and drying out in eroding areas. Spinifex was trialled at Patea primarily to test its resilience to wind desiccation in the most exposed locations. While spinifex is becoming the preferred conservation plant in New Zealand, it is difficult to germinate and plants needs to be obtained from a nursery thus making it a much more expensive option than marram. Plant survival during trials at Patea was high (95%) with root scour and burial usually the cause of failure.

Kikuyu grass *(Pennisetum Clandestinum)* is native to Africa and was formally introduced into New Zealand for pasture purposes in the early 1920s. By the 1950s its infestation characteristics were well recognized spreading by both seed and stem. Kikuya grass probably arrived at the Patea site via green waste. Kikuya is a perennial grass and well adapted to the cool to warm temperatures at Patea. Kikuya spreads by producing a network of thick, fleshy stems that will produce roots at nodes. The stems often form a thick mat or thatch above the soil surface (stolons) and/or a network of underground stems (rhizomes). Surface leaves are light green and up to 25 cm long. Vegetation turns brown and is dormant during winter then resumes growth in late spring with shoot growth exceeding 2 cm per day where there is no competition. Kikuya is well established on the green waste platform in the Southern and Central Sectors and appears able to survive high wind exposure.

4.3.2 Project plantings

Planting has been carried out each winter since 2009 and the initial trial sites, the subsequent block planting areas, and the types of plant have been illustrated and described in File Notes, Progress Reports and more recently in Annual Reports; the relevant plans, are reproduced as Appendices B1 to B8.

4.3.2.1 Marram planting

For all the marram plantings, bunches of tillers (approximately 25 mm diameter) were taken from established tussocks growing on top of the GWP. Optimal plant spacing determined from the trials was 0.5 x 0.5 m and this was adopted for the 2013 and 2014 block plantings.

2010 Trial on upper platform face in the Southern Sector – no preparation required
This Southern Sector site is marked I in Appendix B4 and was on bare sand that was surrounded by an established field of kikuyu **(**see Figure 16A)

<u>Results</u>
Very high strike and survival rates (Figure 16B), occurred with marram plants able to establish, compete and co-exist with the subsequent spread of kikuyu and this situation prevails today.

2011 Initial trial on the GWP face in Central Sector – mechanically prepared
Along the Central Sector on the upper <u>platform face, a 35 m long by 8 m wide (cross-shore) section</u> was planted in 2011 (see area marked yellow in Appendix B5). This site had been covered by very uneven green waste and this was contoured by digger to a slope of 20 to 25 degrees and smoothed with sand prior to planting. Plants were set about 0.5 m apart (see Figure 16C).

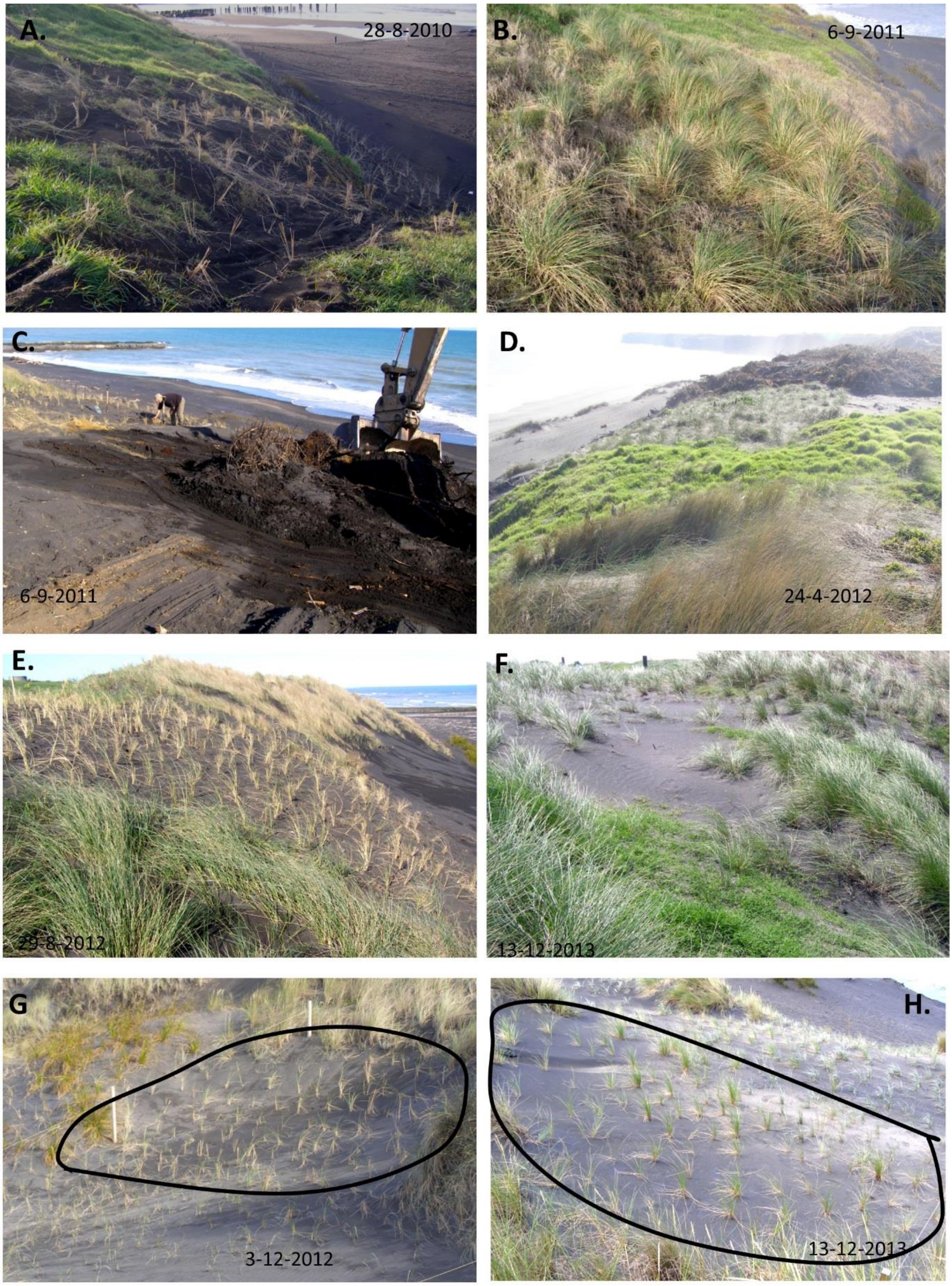


Figure 16 Marram trials. A and B show planting and follow-up photos for Site I (location in Appendix B4). C and D show planting and follow-up for initial GWP face planting (location yellow area in Appendix B5). The bright green area centre photo in D is kikuyu and this was mechanically removed and replanted with marram (E) with the result shown in F. G shows Lower Basin backslope planting trial and H the follow-up a year later (site marked in Appendix B6).

Results

*Westernmost 25 m: excellent strike/survival/growth (upward of 90%), despite its high exposure to wind-blown sand and periods of severe dryness (Figure 16D).
*Easternmost 10 m of the trial area (shown bright green in Figure 16D) failed to establish, being **outcompeted** and suppressed by kikuyu grass that had been dormant and not detected when the site was initially prepared and planted in 2011 (NB Figure 16C).

2012 GWP face remedial (mechanically prepared)

*A remedial trial for the 2011 kikuyu-affected area (Figure 16D) was carried out in 2012 by mechanically removing the surface 0.5 to 1 m of sand containing kikuyu roots and rhizomes and replacing with clean (kikuyu-free) sand, then replanting with about 75% marram and 25% spinifex (Figure 16 E).

Results

The strike/establishment rate reduced to about 50% due to burial and root scour associated with wind funnelling between the now established marram on the western side and the existing marram to the east (Figure 16E). By the end of 2013 kikuyu was re-establishing from the margins and some bare areas persisted. The invading kikuyu did not suppress the surviving new marram which were by then sufficiently well established (Figure 16F).

2012 Lower basin upper slope trial (natural bare sand)

The lower basin (300 m^2) fronts the upper carpark (depicted in Appendix A6). In 2012, 400 marram were planted around the steeper back area with 750 spinifex planted on the lower slope (Figure 16G with marram encircled).

Results

Both species established successfully in their respective environments: marram on the upper slope and spinifix on the lower slope (Figure 16H with marram encircled) despite very windy conditions during late spring/early summer then a prolonged drought during late summer and autumn. However, this site was affected by foredune erosion during 2014 and this is described in the spinifex section (4.3.2.2) which also contains additional photos of the combined marram and spinifex planting.

2013 and 2014 marram block plantings in the Central Sector – mechanically prepared

Based on the 2011-12 trial results for the GWP face, more of the GWP face in the Central Sector was planted in 2013 (96 x 8 m) and 2014 (50 x 8 m) making a total planted length of 181 m (see Appendix B7 and B8 for locations). A two wire fence had been erected in 2012 to protect the area from inadvertent green waste burial during drop-off and/or placement. Preparatory contouring was also carried out as for the trial, i.e. a slope of 20 to 25 degrees (Figure 17 A to C). The excavator placed whole marram turrets between the fence and the top of the planting face (slope) and bunches of tillers were divided off by hand for planting. What remained of the turrets was left in-situ giving the seaward platform surface same plant cover.

<u>Results</u>

Despite the 2013 plantings being subject to very windy conditions during late spring/early summer then a prolonged drought during late summer and autumn, these marram appeared to establish and grow unhindered ! Areas of kikuyu occurred in several places in the prepared areas, and where it was well established the newly marram struggled.

The 2014 planting occurred during extreme winter condition, but again they established and grew remarkably well. It is noted, however, that under extreme wind conditions sand blows through the planting and reaches the top of the platform surface where it is carried further across the platform; this area will slowly build up over time with the deposition needing to either be mechanically smoothed or completely removed from the site if necessary.

2015 localised marram planting in North and Central Sectors – hand preparation

No mechanised equipment was available during the growing season so two plots (small blocks) were prepared by hand and marram tillers obtained from nearby tussocks by hand – a time consuming and relatively expensive exercise. The northern plot was in a rapidly expanding deflation hollow driven by wind circulation from the retreating scarp-face (see site in Fig 22C lower left). The second plot involved planting over a gut on the GWP face that had been previously (last year) infilled with green waste (following the technique described as Guideline 5 in Section 5).

Marram Summary

Marram was used throughout the project, firstly in trials and later in successful block plantings on the GWP face. The trials showed that:
f

***** Infill planting can be effected by background topographic flow concentrations and localised scour/deposition.

* Marram may be able to withstand somewhat steeper slopes than spinifex

* Marram planted within an existing kikuyu plot will be suppressed, but if marram planted on bare sand and kikuyu subsequently establishes then both can co-exist.

* Block planting was successful on a pre-prepared contoured ground with a slope of 20 to 25 degrees and at 0.5 x 0.5 m spacing with establishment rates in excess of 90%. The new block should butt up against existing plants and any plant failures replaced as soon as possible to avoid funnelling and wind desiccation/scour.

Figure 17 Marram block planting. Site preparation (A to C) carried out in December 2012 (fence and surface contouring). The 2013 planting is shown in D, after 4 months growth in E, and after 15 months in F. The 2014 planting after 4 months is shown in G with the 2013 planting visible in the distance. Locations are shown in Appendix B7 and B8.

4.3.2.2 Spinifex plantings

For all spinifex plantings, seedlings grown in individual planters were obtained from the Naturally Native Nursery in Whakatane. These plants are raised in a "plantation-like environment", i.e. close together so they grow long stems and leaves rather than the stocky plants that self-seed and grow in the natural environment. Stem and leafs were 0.5 to 1 m high and by planting with the lower 1/3 plus the root below the surface, these plants were better able to avoid burial or scour after planting; these processes can be severe in the unstable areas where protection planting is typically carried out. Trials were carried out in 2010 and 2011, then block planting in 2012 after which spinifex was no longer used; rather, the effects of the various plantings were monitored with a view to continued use in the future if results showed this is warranted.

2010 Five spinifex trials in differing environments

In 2010, 500 spinifex plants were used for five trials; the locations are marked in Appendix B4 and consisted of Site C in the Southern Sector, and sites D, E, F and G in the Northern Sector. Sites C, E and F were to test the resilience of spinifex in particularly strong wind and high exposure environments, while the two more landward locations (D and G) were to test runner growth potential in more sheltered locations.

<u>Results</u>

All trials were initially successful with very high strike and establishment rates (about 95%), with most plants having grown runners some 1 to 3 m long after the first year. (Figure 18). However**,** the spinifex runners at site C were unable to extend down the foredune much below the existing planting front as indicated by the lower photo in Figure 18 due to wind desiccation. Nonetheless, these spinifex have survived and form a fluctuating vegetation front. Spinifex runners at foredune sites E, F and G grew well (Figure 18). Site E was the first to be lost by the eroding Pingao Foredune during 2012. Before Site F was lost in mid 2013 (Figure 19) there was evidence that the spinifex runners were exposing and drying before the more woody nearby pingau runners were being affected. The exposed and drying spinifex runners are just discernible in the lower right portion of the white enclosure line in Figure 19. Site G was fully exposed by this foredune erosion by late 2013 and the site is likely to be completely destroyed before dune stability eventuates. At Site D, the plants survive but growth is compromised by pedestrian traffic which was directed through this area by fencing in 2012; this being carried out to (successfully) protect planting in the upper bowl fronting the upper car park (discussed below).

2011 Spinifex perimeter planting trials

In 2011, spinifex were planted around some of the margins where existing vegetation fronted bare sand at Southern and Northern Sector sites shown in Appendix B5 (see Figure 20). The objective being to further test how effective spinifix is to extend the vegetation-front downslope as proposed in the initial 2007 Management Proposal (see Appendix A1).

Site C Spinifex

Site F Spinifex

Site G Spinifex

Figure 18 2010 spinifex trial examples from Sites C, F and G (for locations see Appendix B4). 2011 results also shown

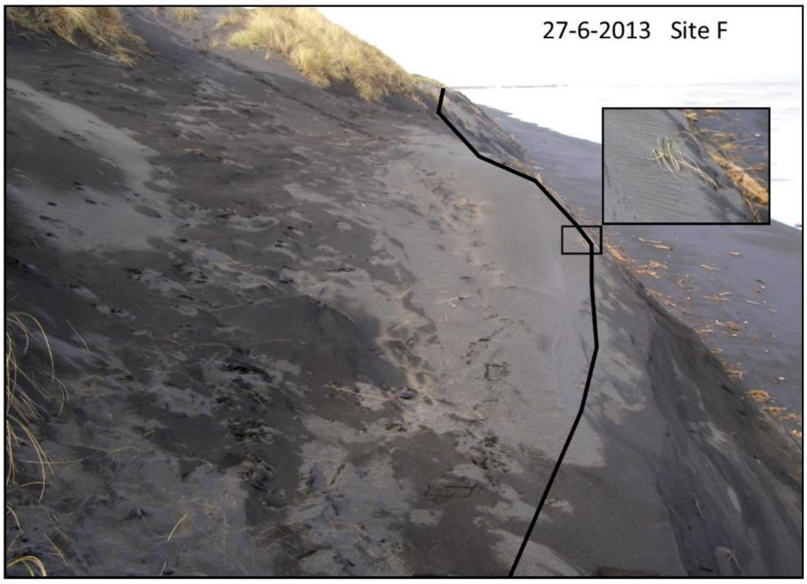


Figure 19 Site F continuing to establish in 2012 (top photo) with dashed white line locating the then scarp top and the dashed black line the scarp top a year later as depicted by the bold black line in the lower photo where a loan spinifex plant remains.

<u>Results</u>

Where plants were located within existing kikuyu at the vegetation front they were suppressed (Figure 20C). When planted in bare sand below existing vegetation (Figure 20A) growth and runner development occurred on lesser sloped areas where sand deposition could occur (Figure 20B in background), but on steep (erosion prone) locations, runners became exposed and the plants struggled to even survive (Figure 20B in foreground)**.** However, the spinifex grew well within existing pingao (Figure 20 D).

Figure 20 Spinifex trials from 2011 around seaward margins of existing vegetation (sites shown in Appendix B5). A shows new plants with B, C and D showing results for different types of described as described in the text.

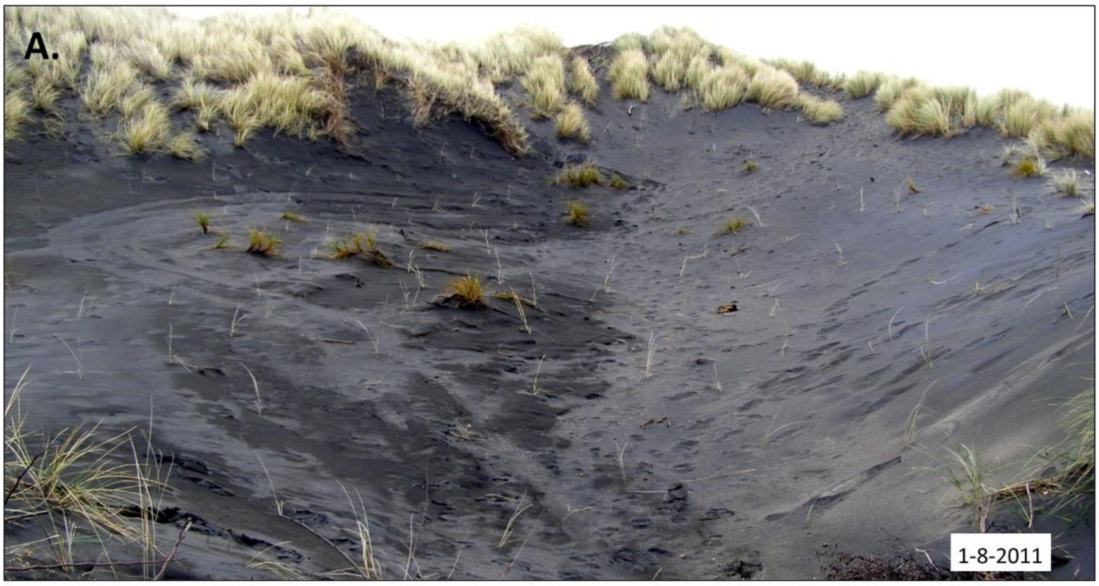
2011 Upper Basin spinifex trials

In 2011 a further spinifex trial was carried out in the so called Upper Basin which is just below the Upper Carpark (See Appendix B5). In this case planting was at 1 to 2 m spacing (Figure 21A) with the objective being to see if runners were able to cover the intervening space.

Results: Many of the trial plants established at this site, but wind exposure coupled with pedestrian and motor traffic took their toll (Figure 21B). It was this result that made it clear protective fencing would be required in the future. Surviving plants did produce runners as can be seen in later Upper Basin photos of Figure 22C.

2012 Block spinifex planting in Upper and Lower Basins

Block plantings within the upper and lower basins in the Northern Sector (Appendix B6) were carried out in 2012 with 1250 spinifex in the upper basin (Figure 22A) and 750



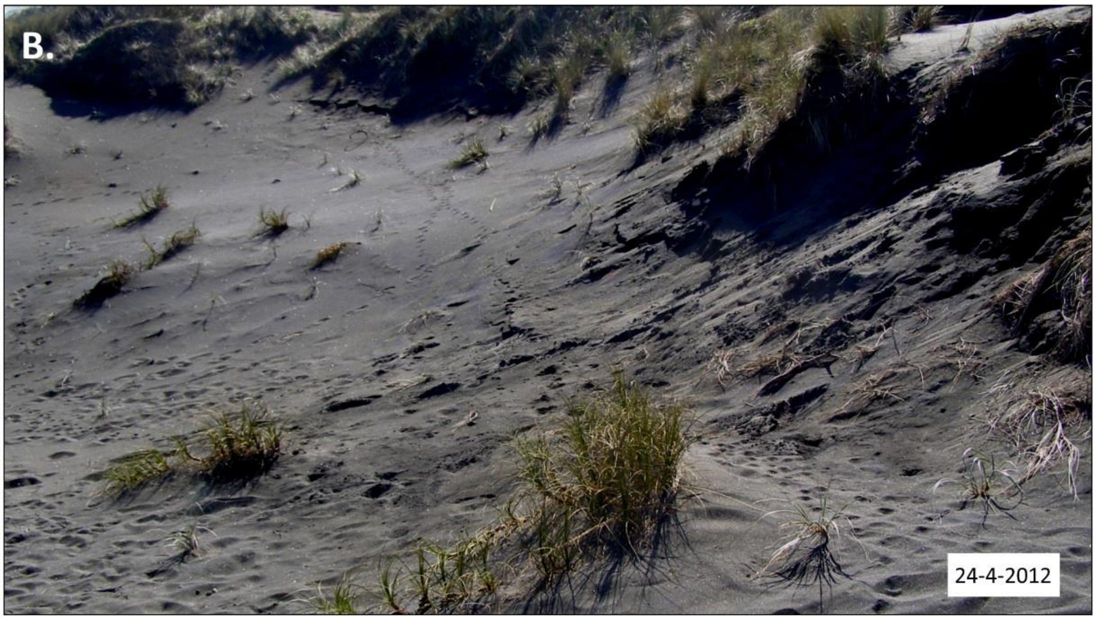


Figure 21 Upper Basin (see Appendix B5) spinifex trial planting in 2011 (A) and result in 2012 (B). Note the heavy vehicle and pedestrian imprints. Also note the surviving pingau which were planted in 2009 and further illustrated in Figure 22. Pingao plantings are described in the following Section.

Spinifex in the Lower Basin (Figure 23A). Plants were spaced 0.5 m apart to provide mutual protection against scour and wind burn. The central part of the upper basin was left bare with the expectation that runners (which preferentially grow downslope) would later infill this area. In the lower basin 400 marram were planted on the backing slope (left side of planting in photo of Figure 23A) and described earlier in Section 4.3.2.1. At both sites pedestrian fencing was erected to protect the plantings.

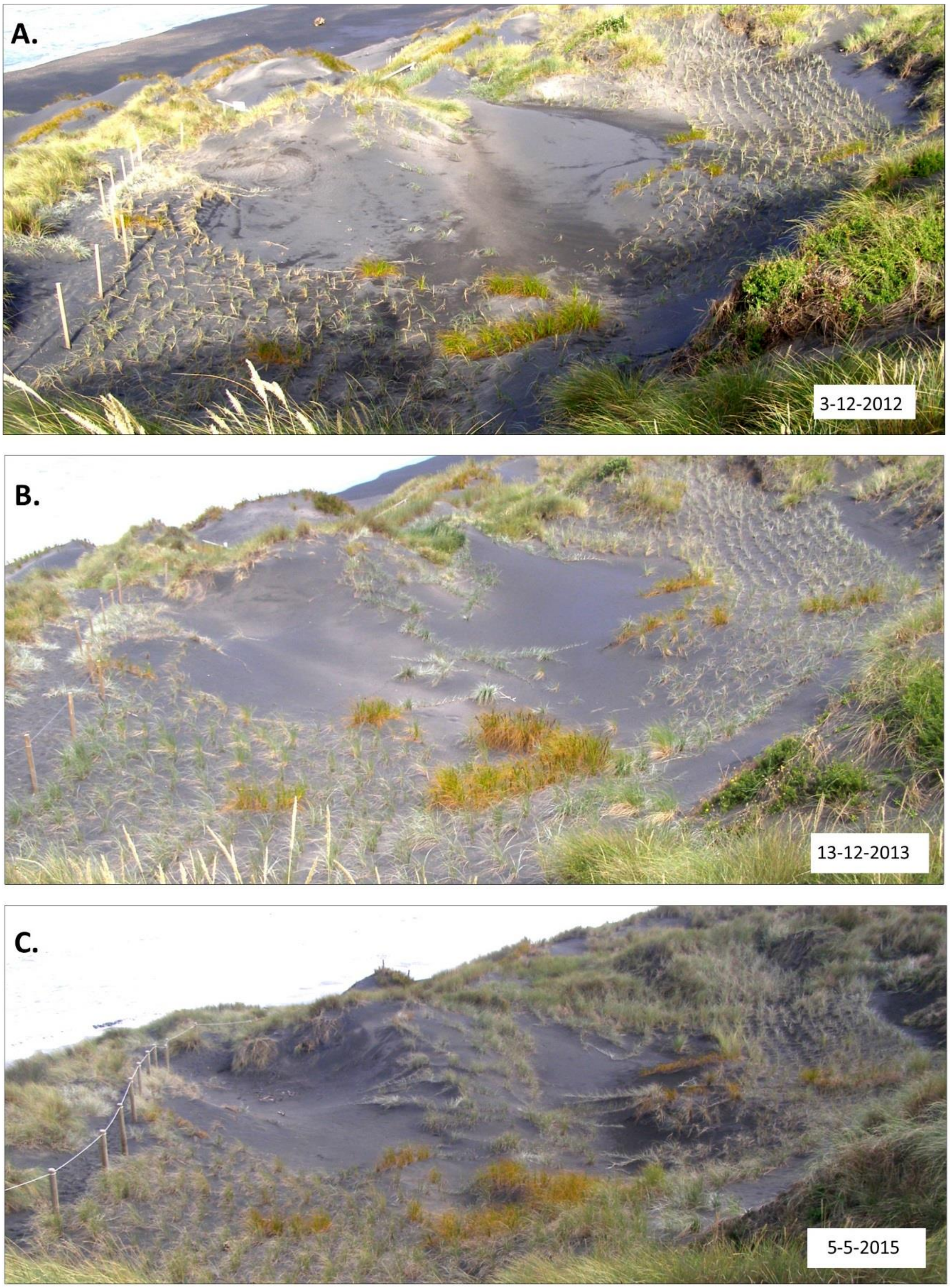


Figure 22 Block planting spinifex in Upper Basin in 2012 (A) and subsequent photos in 2013 (B) and 2015 (C). The rope and batten fences were erected at the time of planting in 2012. Note also the pingau transplantes from 2009, and the spinifex runners from the first 2011 planting. Few of the 2012 spinifex produced runners.

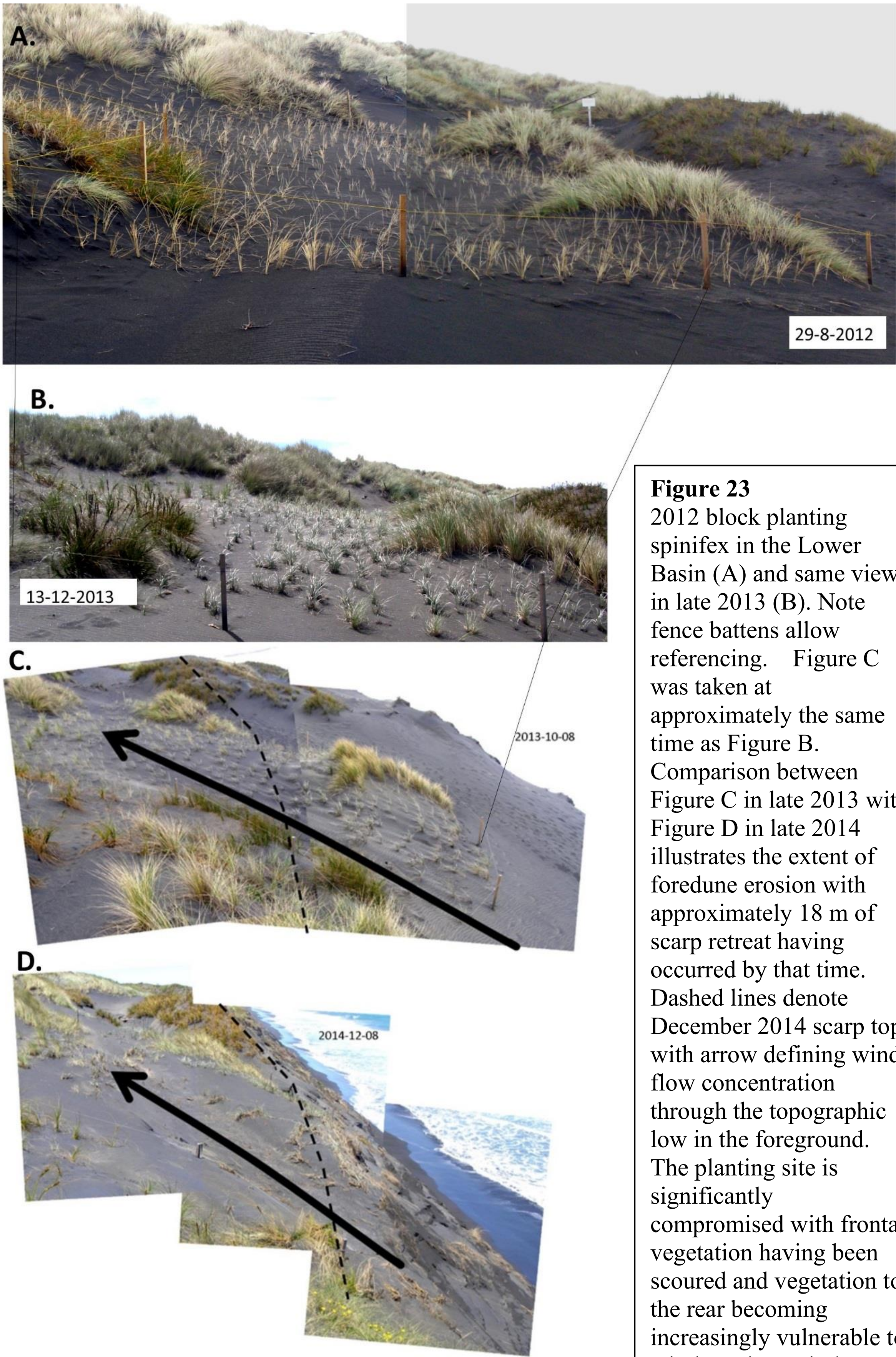


Figure 23
2012 block planting spinifex in the Lower Basin (A) and same view in late 2013 (B). Note fence battens allow referencing. Figure C was taken at approximately the same time as Figure B. Comparison between Figure C in late 2013 with Figure D in late 2014 illustrates the extent of foredune erosion with approximately 18 m of scarp retreat having occurred by that time. Dashed lines denote December 2014 scarp top with arrow defining wind flow concentration through the topographic low in the foreground. The planting site is significantly compromised with frontal vegetation having been scoured and vegetation to the rear becoming increasingly vulnerable to wind erosion, wind desiccation and burial.

<u>Results</u>

The spinifex established well despite very windy conditions during early summer then the prolonged drought during late summer and autumn (Figure 22B and 23B). However, unlike the earlier spinifex trials virtually no runners grew. This behaviour was noted by plant ecologist Dr David Bergin to have also occurred in new plantings on other coasts and he speculated that it may be associated with the sustained high temperatures and moisture stress during the growing season. It appears there has been little additional runner occurrence by 2015. This was disappointing as runners were expected to spread onto adjacent unplanted areas. Nonetheless, runners from the 2011 planting in the Upper Basin are spreading into the central unplanted area, as illustrated in the 2015 photo (Figure 22C).

A further blow to these spinifex planting trials was the impact for foredune erosion during late 2013 and 2014; this affected the Lower Basin site with topographic wind funneling (Figure 23 D). Leaf desiccation, root scour or burial has affected much of the planting. The burial of landward vegetation is clearly illustrated in Figure 23C; this process has had a significant consequence of dune erosion at Patea as illustrated in Figure 6) so requires intervention management.

Spinifex Summary

Spinifex plants were nursery-propagated specifically for planting on coastal sand dunes. At sites where planting occurred in bare sand the establishment rate was exceptionally high (~95%) with failure usually due to wind-scour of roots or burial. However, the cost per established plant is high at about $3.00.

Runners established during 2010 and 2011 but failed in 2012, possibly due to drought and wind stress.

Unfortunately the most exposed trial sites were lost to foredune erosion so the direct test of spinifex vs pingau in the harshest environment was not resolved. Spinifex's dune-front resilience was tested to some extent at trial site C on the lower front of the GWP in the Southern Sector; during several years, including some extreme conditions, spinifex runners would only grow a few metres beyond the vegetation front before succumbing to wind desiccation.

Spinifex did not take well to erosion-prone sites where runners typically became exposed and dried out. Spinifex grew most vigorously where there was moderate wind and a continual supply of sand which it trapped and this stimulated growth. Spinifex grew well when block planted 0.5 m apart on lower slopes

When planted amongst established kikuyu, spinifex was suppressed, but established well when planted amongst existing pingau.

4.3.2.3 Pingao plantings

As noted above in Section 4.3.2, new pingao were obtained by simply transplanting a 1 m lengths of woody runner containing roots at one end and leaf growth at the other from nearby established plants, or transplanting entire plants using a mechanical digger.

2009 Runner transplant trials

The first transplanting of pingao was carried out in 2009 (Figure 24) when isolated pingao dunes located on the backshore in the Southern Sector (NB Figure 11), including the so called Dome Dune (see Appendix B3), were mechanically removed to facilitate natural alongshore sediment transport processes and transplanted on the bare sand face of the GWP at Site 4b (Appendix A3). Approximately one metre long lengths of runner were planted by laying the runner in the trench with the rooted end some 0.5 m deep and the leafy end exposed (Figure 24A); often several such runners were bunched together when planting. Pingao planting also occurred in the Upper Basin of the Northern Sector (Site 3a in Appendix B3) and illustrated in Figure 24C, where wind-blown sand was frequently reaching the Upper Carpark. Planting was also occurred in the swale between the Pingao Foredune and GWP face of the Central Sector (Appendix B3, Site 4a). However, the swale planting had been carried out at the contractors discretion and these were removed in 2010 to facilitate this natural sand transport route toward the rivermouth.

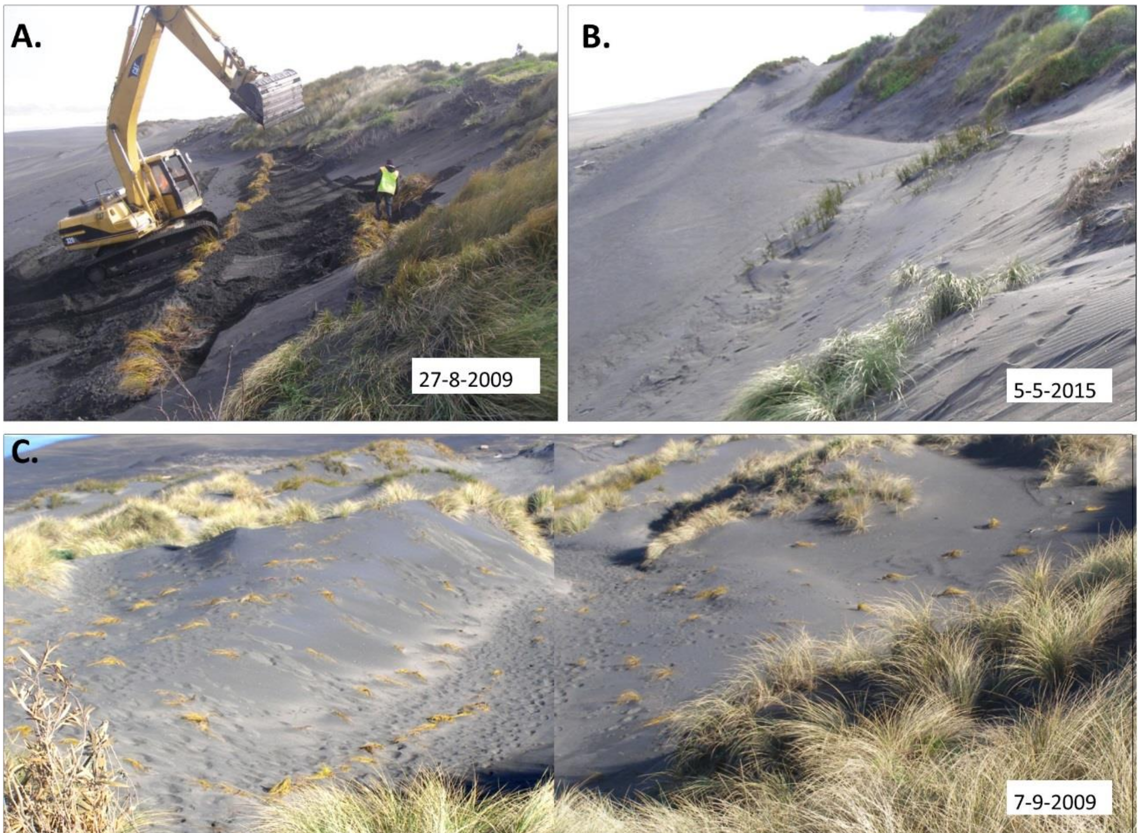


Figure 24 Pingao runner transplant trials in 2009 at Site 4b (Appendix B3) are shown in Figure A and what remains today in Figure B. The other trial site of note was in the Upper Basin (Site 3a in Appendix B3) and this is shown in Figure C with results for this site being illustrated in Figure 22.

Results

The Upper Basin planting had been unsupervised with overly wide plant spacings up to 3 m. About 2/3 of these plants eventually succumbed to exposure (root scour or wind burn), but the others grew well within the spinifex planted in 2011 and 2012 (see Figure 22). About 20% of the 2009 planting on the GWP face in the Southern Sector survive today in this particularly exposed setting (Figure 24B), with the western half of the plants (furthest from the camera in Figure 24A) being lost during the first year. Today these survivors form a hummocky dune on the face (Figure 24B). Note also in the foreground in Figure 24B several marram turrets that have broken from the vegetation-front further up the slope and rafted to their present location. Isolated hummocks, regardless of vegetation type, can promote wind funneling which further facilitates erosion. This site will require additional treatment in the near future.

2010 pingao trials

An infill planting was carried out at Site 4b on the GWP face (Figure 25A) which was renamed Site K in Appendix B4 for the 2010 planting season.

Also in 2010, guts forming along the top of the pingao foredune in the Central Sector had pingao clumps mechanically placed on green waste infill (Figure 25D).

Results

At Site K on the GWP face, the two months following planting experienced very strong winds and the westernmost plants were buried as illustrated in Figure 25B. Note the erosion trough marked by the dashed white line and the white line showing the wind-flow pathway. This is an example of topographically controlled wind flow and explains the difficulty plants had in establishing at this location. By mid 2013 there were only a few plants remaining and this situation remains today (Figure 25C). These remaining plants are in close proximity to the surviving 2009 plants which must be growing is a somewhat less hostile location. Planting on an exposed mid-face section of the GWP was essentially unsuccessful and showed that an alternative sand stabilization method would be required. The marram block plantings described in Section 4.3.2.1 were then developed for this situation.

The practice infilling guts along the pingao foredune and capping with pingao clumps was successful.

2011, 2012 and 2014 pingao capping

The green waste infill and pingao capping of foredune guts was also carried out in 2011, 2012 and 2014, and in each case the plants established successfully.

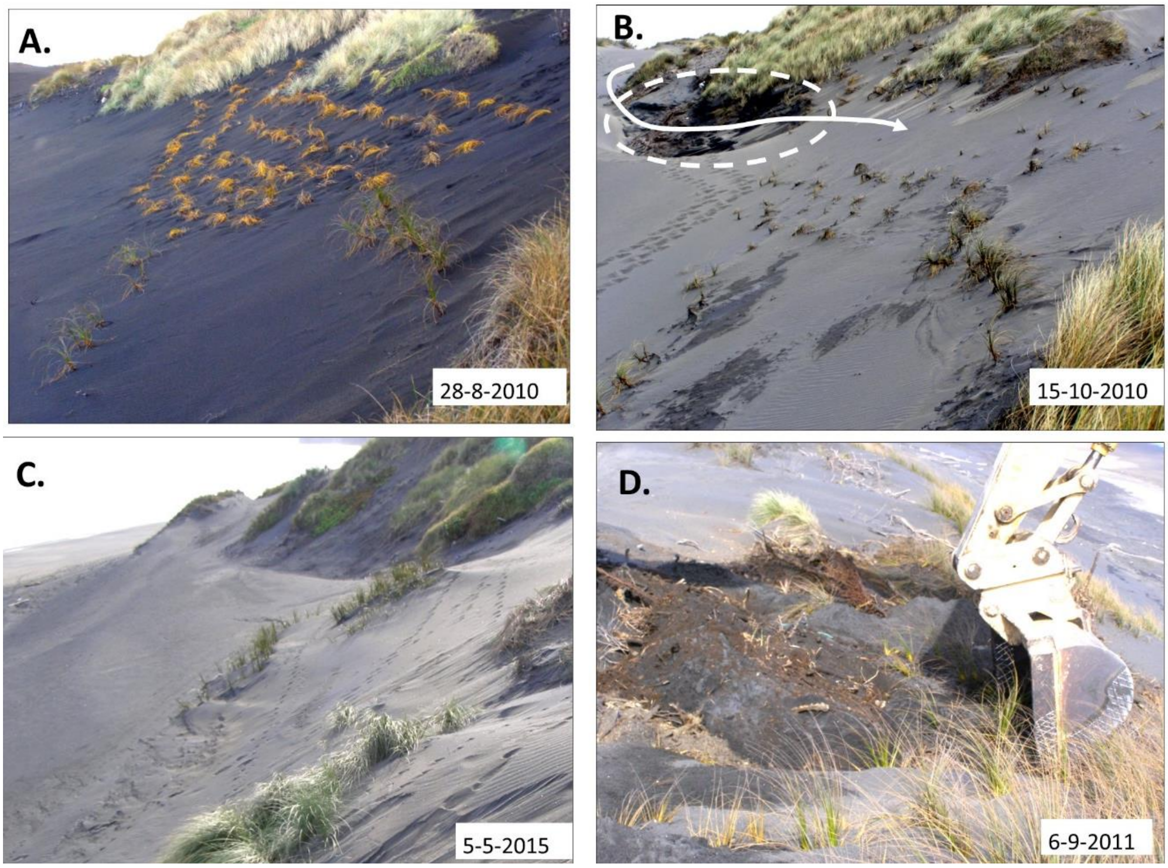


Figure 25 Pingao transplant trials 2010. At the GWP face (Site 4b) the western portion was replanted (Figure 25A). This site was renamed Site K for the 2010 planting (Appendix B4). Figure 25B was taken two months after planting and shows significant burial. Note the scour trough located within the dashed ellipse and the arrow defining the topographically controlled wind-flow pathway. Figure 25C (same as Figure 24B) shows the survivors today and their limited vegetation cover. Figure D shows the digger laying pingao clumps over previously placed green waste infilling an erosion gut along the crest of the Pingao Foredune.

Pingao Summary

Pingau was introduced to the Patea Beach in the late 1990s by way of growing a new foredune. Pingao thrived in this environment and spreads via runners and natural seeding.

Establishment too close to the shoreline has led to frequent foredune erosion in the Northern Sector and to a lesser degree in the Central Sector; this makes for ongoing sand stability issues.

… continued

Pingao Summary continued…

During the present project, several trials and observations have been undertaken which show pingau can be successfully transplanted from runners or as a clump, using a hydraulic excavator (this is done during green waste placements).

Pingao favours low to moderate slopes and can exist on the foredune front. However, the very harshest conditions (incorporating wind funneling) cause desiccation and die-back. We observed the plant itself to recover.

Comparison with spinifex sites in the most exposed areas indicate pingao may be more resilient.

4.3.2.4 Kikuyu grass trials and observations

Kikuyu was initially considered a hindrance and trials in 2010 and 2012 were more concerned with its replacement. More recently, its infestation characteristics and resistance to the hostile salt and sand-laden storm winds at Patea were recognized and its behavour has been observed with a view to determining how this plant can be incorporated within the sand conservation programme.

In the Southern Sector, kikuyu grass is now the predominant plant covering the platform face (there being no pingao foredune in this sector) and across the top of the platform. Our photographic record going back to 2006 when the site was being used as a regional green waste dump show that at that time green waste dumping and placement were focused in both the Central and Southern Sectors (NB Figure 8B).

Figure 26 shows a comparative section of the Southern GWP face with photos from 2006, 2008 (when placement had stopped in this area) and 2010. In 2006 (Figure 26A) greenery within decaying green waste is quite possibly kikuyu. In the 2008 photo (Figure 26B) kikuyu appears to be well established along the top of the platform and spreading down the face. Coverage of the upper and mid faces was largely complete in the 2010 photo (Figure 26C), taken when the spinifex and marram trials (at Sites C and I) were carried out on two areas of bare sand (i.e. not yet colonized by kikuyu). At the time the objective of Site I was to see if marram could co-exist with kikuyu, a concern being that under severe burial, kikuyu would die first (being shorter), so the taller marram could be relied on to maintain sand stability.

By 2012 kikuyu had extended down the face at least as far as existing marram and the spinifex runners of Site C (Figure 27A and B) Note these photos were taken after a period of strong winds and all three plant types had suffered wind burn and/or scour. These images show kikuyu can survive on the mid-lower dune front at least as well as marram (which succumbs to wind scour and slumping) and spinifex (which succumbs to runner scour and desiccation). Photos are also included (Figure 27 C and D) showing kikuyu at the vegetation-front undergoing burial and scour from which it can recover.

In the Central Sector, kikuyu grass is the predominant vegetation on top of the platform. This area has been the focus of green waste operations during the current project with continual disturbance prevents permanent vegetation cover across much of the area. As noted earlier, most of the GWP face is now stable and planted in marram; however, there are several areas of existing kikuyu within the new marram.

The first available photos are from 2008 (Figure 28A) shows green waste on the face trapping wind-blow sand with vegetation (a range of weeds including kikuyu) higher up the slope. The inserted photo shows an area of kikuyu established on the face.

Figure 26 Kikuyu spreading across the GWP in the Southern Sector between 2006 and 2010. Note green waste placement was still occurring in 2006 but not in the 2008 photo. In the 2010 photo workers are planting spinifex and marram on remaining bare sand (sites C and I, Appendix B4).

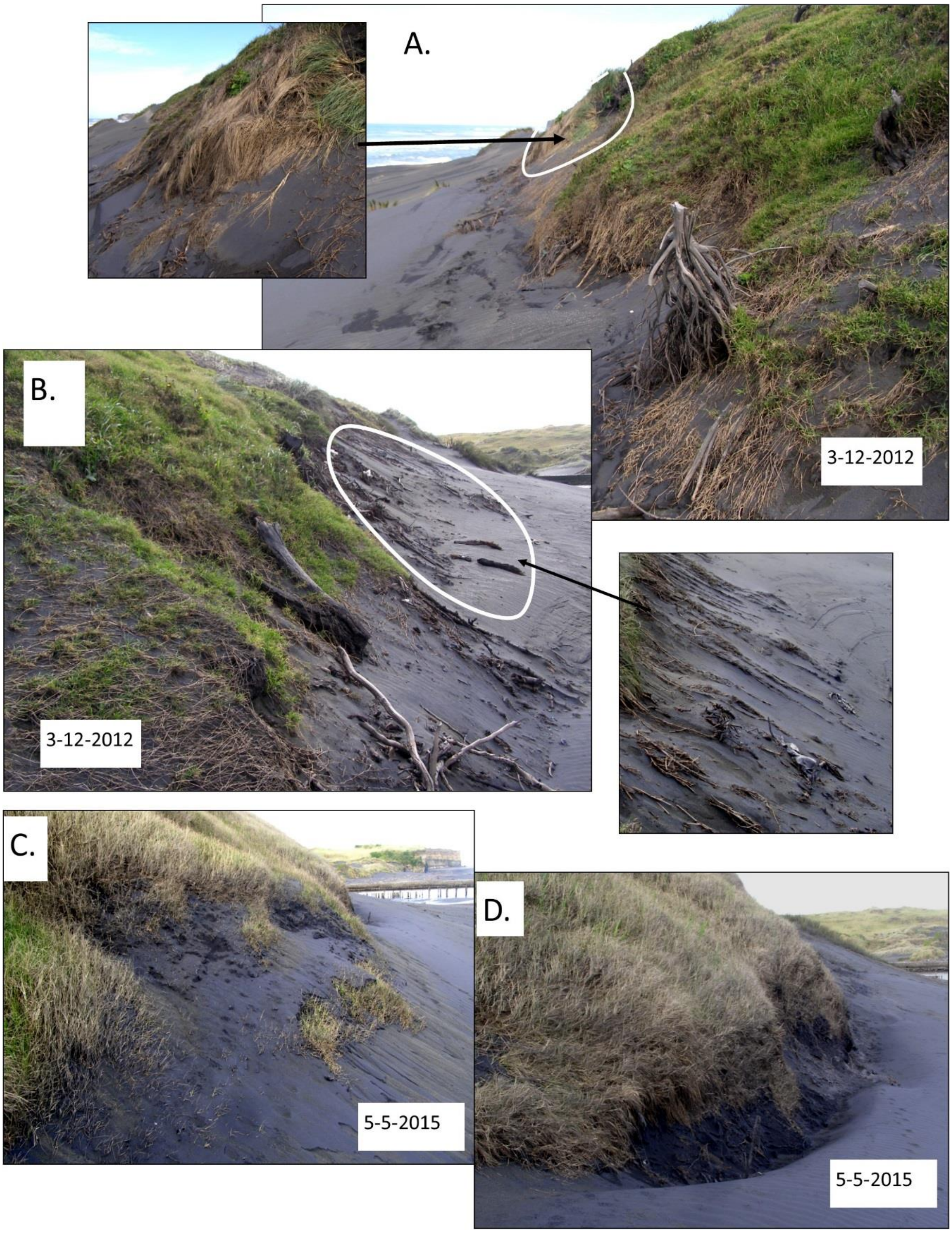


Figure 27 Kikuyu growth on the mid to lower slope of the GWP face after high winds, compared with marram (A) and spinifex (B); kikuyu coped at least as well if not better than the other grasses. Figure C shows kikuyu burial at the vegetation front and Figure D shows kikuyu wind scour, in each case the kikuyu recovers.

Figure 28 The Central Sector GWP in 2008 was characterised by green waste with vegetation along the crest (a range of garden weeds including kikuyu) and areas of kikuyu establishing on the face (see inset)

As described in Section 4.3.2.1, in 2011 the first trial marram planting occurred on the platform face (Figure 16C) and the easternmost portion was suppressed as it was underlaid by established kikuyu (Figure 16D); this was undetected at the time of planting due to winter dormancy and obscurity due to contouring. As described in Section 4.3.2.1, the kikuyu quickly suppressed the new marram. The following year (2012), the kikuyu-affected soil in this area was mechanically replaced and replanted with marram (Figure 16E). Marram establishment was affected by wind funneling leaving bare areas by 2013. Kikuyu subsequently infested the area, spreading from the edges of the plot and possibly some interior growth from remaining root segments. However, the kikuyu had been delayed such that the marram plants had to time to establish and could co-exist with kikuyu into the future (Figure 16F). This was an important result and consistent with the earlier marram planting in Site I in 2010, a plot surrounded by kikuyu.

In 2013, a further section of the GWP face in the Central Sector was contoured and planted with marram. As with the initial trial, in areas where established kikuyu existed the marram struggled to survive, while where kikuyu was absent the marram established well. Kikuyu is expected to spread into these areas but not threaten the now established marram plants.

In 2014, while preparing the face for marram planting, a large area of established kikuyu grass was scraped off and replaced with clean sand (Figure 29A) with the discarded kikuyu grass placed in guts on the adjacent pingau foredune (Figure 29B). The objective of this exercise was to test kikuyu’s resilience on the high exposure foredune compared with the existing pingao.

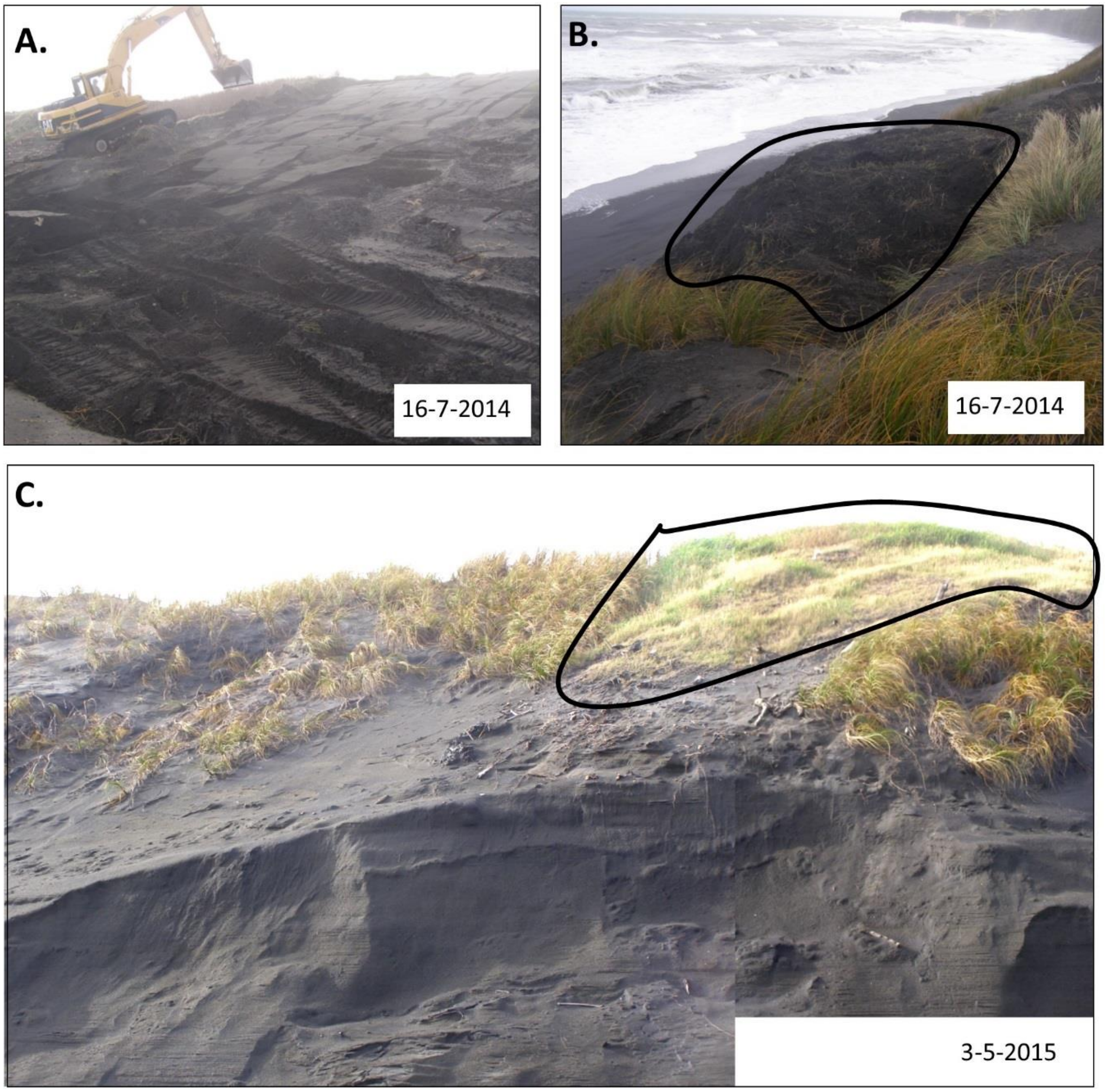


Figure 29 Preparing GWP face for marram planting in the Central Sector 2014 (A) by removing kikuyu cover that was about 0.5 m depth, then (B) placing excavated material in an erosion gut on the adjacent pingao foredune (encircled), C is the resulting kikuyu growth 10 months later (encircled)..

Results

Observations in May 2015 (Figure 29C), indicates the low and uniform kikuyu cover appears better able to deter wind funneling and internal instability compared with the more open-- growing pingao. The kikuyu also appears as resilient as pingao to wind desiccation, although extreme conditions capable of effecting pingao, as observed in the Northern Sector (NB Figure 15C) in 2006 when the project was being scoped, have yet to be experienced.

The Northern Sector is relatively free of kikuyu.

Kikuyu summary

Kikuyu arrives with green waste and is mechanically spread further during placements

Kikuyu at Patea appears able to grow laterally several meters per year if unconstrained.

Growth is constrained by mechanical displacement/removal, or burial from green waste placements and wind-blown sand.

Kikuyu is an infestation plant that cannot practically be eradicated in this environment.

The low, uniform plant structure allows wind-blown sand to evenly deposit and this is less likely than marram, or even spinifex and pingao, to initiate funneling and gut development.

A fatal burial depth has not been determined, although it is likely less that the other dune grasses due to the lower plant height. However, if fatality occurs, recolonization can be expected to occur from the margins.

The plant's browned off leaf cover remains during winter dormancy, offering some resistance to wind effects, with remarkable recovery occurring during spring.

Kikuyu is able to with withstand wind desiccation and root scour at least as well as the other dune grasses

Kikuyu did not smoother the other dune grasses if they had already established, but new plants were suppressed and often died where kikuyu had already established.

Kikuyu appears able to occupy as seaward a location as the other dune grasses and can support steeper slopes. Overloading (upper deposition/lower scour) will eventually lead to failure by slumping (as occurs along riverbacks); however, rapid re-establishment can be expected.

4.4 Access Control

Sand dune traffic consists primarily of motorbikes and small 4WD vehicles together with pedestrians with users staying within the dune system and/or accessing the beach. Traffic can damage existing dune vegetation and thus enhance erosion, or destroy new plantings.

Dune traffic was seen to affect the first pingao plantings in the Upper Basin in 2009. This was not unexpected as the basins lie along the main beach accesssway from the upper carpark to the beach (NB Figures 22 to 24).

However, the impact of dune traffic was realised in 2010 when it was difficult to select unaffected sites for the planting trials. In February 2011, green waste barriers were mechanically placed within the North and Central Sector dunes at strategic locations (see Appendix B5 and Figure 30 A). While these were effective in reducing traffic the effect was temporary as they infilled with wind-blown sand. Later in 2011, spinifex planted in the upper basin were once again severely impacted by traffic soon after planting (NB Figure 21). Post and pole barriers were erected at the upper and lower exits, and signs also errected (Figure 30 B). This largely eliminated vehicular traffic but foot traffic still affected the planting.

In 2012, the upper and lower basins were fenced off using 2 m long battens and nylon rope prior to block planting with spinifex and some marram grass (NB Figures 22 and 23). This lightweight fencing was remarkably successful with all pedestrians using the marked access track.

In 2012, a two wire fence was erected some 8 m landward of the contoured face (NB Figure 17C), to prevent the misplacement of green waste that could affect the block marram plantings which were to follow in 2013 and 2014. This was also effective.

In 2014 the lightweight fencing around the upper basin planting was reaching the end of its life so was replaced with more durable materials (Figure 30C) and the upper carpark barrier extended to allow for better views while protecting the plantings (Figure 30D). By this time much of the Lower Basin had succumbed to foredune erosion processes and the original plant protection fencing was converted to hazard fencing which, along with signage, warned pedestrians of the erosion escarpment (Figure 30E and F).

Access summary

Access control is necessary to protect existing vegetation and to allow new plantings to establish. Post and rope fencing around plantings is adequate for pedestrian control. Post and pole barriers at exists/entranceway along with signage proved effective at stopping vehicles. Beach users respected these simple controls.

Figure 30 Access control using green waste barrier (A), post and pole barrier and sign at Upper Carpark entry to Upper Basin (B), and perimeter pedestrian fence around Upper Basin (C). Expanded barrier fence and upper car park entrance to allow for view (D). The hazard fencing along top of erosion scarp (E) and hazard sign at top of erosion scarp (F) has had to be relocated on several occasions as erosion progresses landward.

4.5 Drainage

Managing storm water at the northern end of the GWP has required minimal intervention; however, at the southern end it has been an ongoing issue for the Council for several years due to storm water erosion of the clay surface cover. This erosion affects vehicle access and also causes guts to develop on the GWP face which in turn destroys vegetation and plantings on the steep (sand dune) slope; this is followed by wind erosion and sand drifting across the platform surface. The matter was discussed in the CSL 2009 Inspection Report #2 (from which Appendix B 3 was obtained) and described in some detail in the CSL 2011 Annual Report (from which Figure 31 below was obtained). At that time the simplest and cheapest option was carried out: this involved diversion by several earth bunds to reduce flow velocity. The result was relatively effective in the short term, but by 2014 the bunds had subsided and erosion was again occurring and by the end of 2015 severe gullying into the face of the GWP is once again occurring (similar to Figure 31C and D). As the resource consent requires effective storm water control, CSL were instructed in July 2014 to investigate a more permanent alternative in which surface water drains away to the rear of the green waste site. The draft report was competed for the council in September 2014 (CLS, 2014c) and is summarized below.

A topographic survey was first undertaken to define the present relief and the proposed design was based on analysis of these data. Key characteristics of the proposal are illustrated in Figure 32 and consist of:

1) Recontouring of the southernmost 50 m of the GWP surface such that water drains to the inland side at non-scour velocities. Estimated maximum cut and fill volumes are 36 and 252.5 m^3 respectively.

2) Storm water drainage is collected and redirected into soakage areas located on low slope areas beyond the platform rim.

3) For full retention, dimensions would need to be able to accommodate about 150 m^3 of drainage water.

4) The seaward side of the current access loop is closed off from above the existing bunds, covered with sand and vegetation to allow for infiltration, and this area is then being able to be excluded from future drainage management while incurring no compromise to current access for green waste management.

Drainage Summary

Storm water drainage in the Southern Sector has a significant effect on sand stability on the GWP face. Earth bunds only provide a temporary solution. A preliminary investigation into a more permanent solution was carried out in 2014; this involves re-contouring to divert flows to the rear of the platform and disposal via soakage areas and possible piping into the village infrastructure and river.

Figure 31 Photos illustrating drainage issues on the GWP in the Southern Sector. Surface runoff (white arrowed lines in A) and channel development on access road to southern (river) lookout (A). Channels cut into vegetation at top of platform (B) and this develops into gullies (or guts) as water flows down the upper face, thereby scouring plants (C and D) and facilitating later wind erosion. Eroded material is deposited as alluvial fans on the bare sand surface (E) as water flow slows due to infiltration.

From CSL (2011) Figure 10

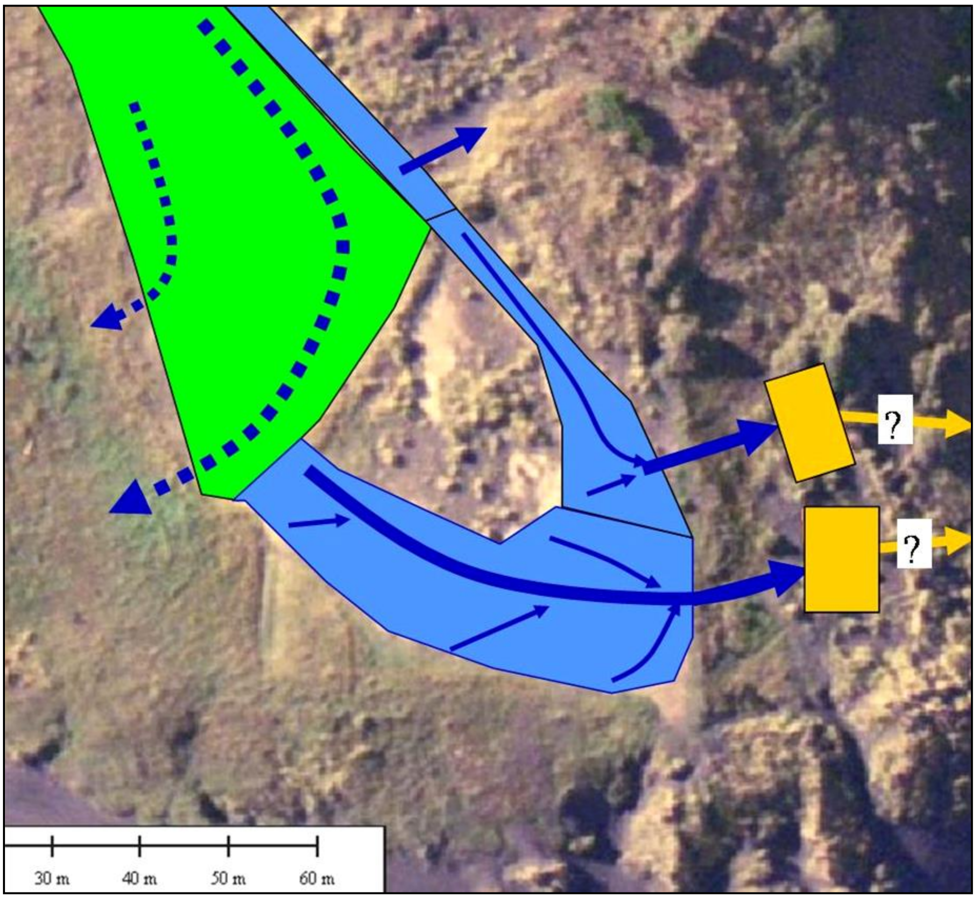


Figure 32 Concept design plan from the CSL 2014 draft Drainage Report. Green area is retired from vehicle access, covered with sand as required and then planted. Dashed blue lines on the green area indicate expected subsurface flow pattern. Blue areas are re-contoured as specified with drainage water flowing landward then collected in "soakage areas" (yellow) in which water is retained to enable infiltration/sediment deposition with possible release down to beach settlement's storm water drainage system (yellow arrows) and river outflow.

4.6 Monitoring

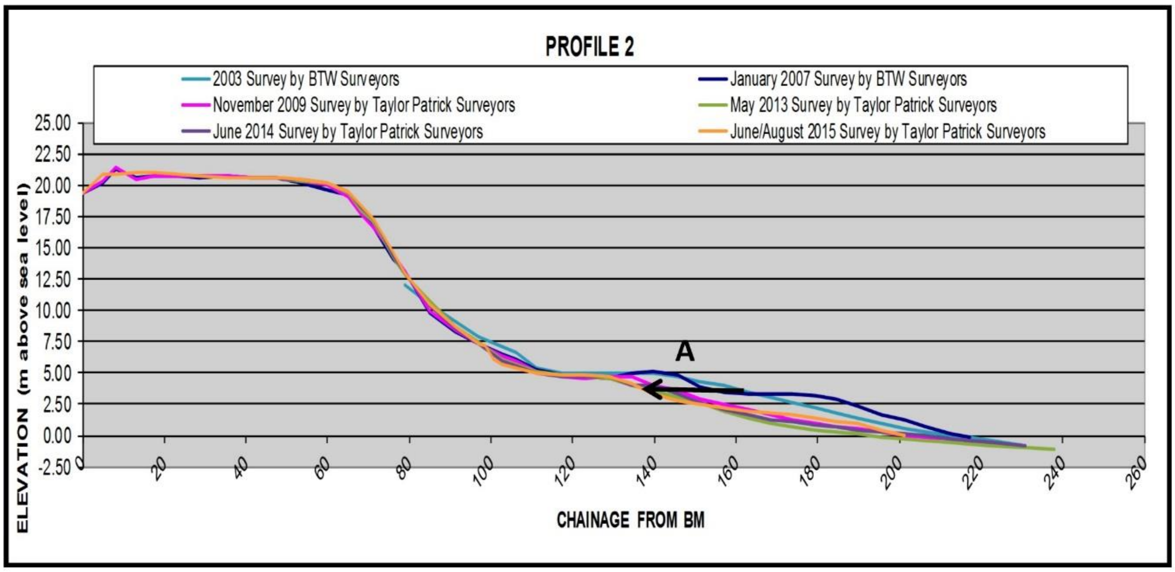
The South Taranaki District Council's Patea Beach Management Plan (2007) Sections 2.4 and 2.5 requires ongoing monitoring, in particular, profile surveys are required at 2 yearly intervals and aerial photography at 5 yearly intervals. Monitoring between 2007 and 2013 was described in the CSL Monitoring Report (CSL 2014a), the June 2014 profile results were included in the CSL 2014 Annual Report (CSL 2014b), and the June 2015 results are superimposed upon all the earlier profiles in Figure 33 for the coast with slope adjustment processes illustrated in Figure 34. Superimposed inlet profiles are shown in Figure 35.

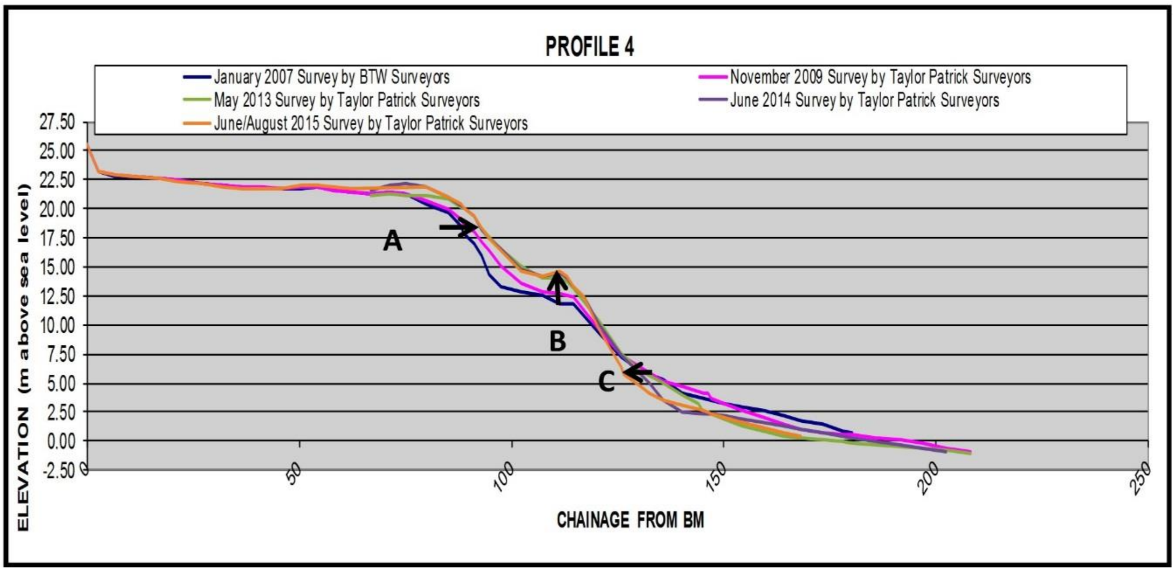
Northern Sector shoreline have, so far, been most effected by the current episode of erosion. The superimposed profiles for representative transect 8 (Figure 33), show the base of the foredune has retreated some 30 m since 2009 with the largest increment (10 m) occurring between June 2014 and June 2015. The retreating erosion scarp is some 10 to 15 m high. In addition, analysis of these data show that up to 200 m^3 has been eroded off the front of the foredune (see Arrow A on Transect 8 profiles), about 1/3 of which has been blown inland 2/3 has been lost seaward. The current scarp slope is ~45 degrees which is well above the stable slope for sand (34 degrees), so down slope (gravity-driven) and upslope (wind-driven) surface instability will continue.

Down-slope adjustment processes include sliding, avalanching and block slides all under gravity to form a (stable) debris slope or talus (that may in turn be removed by wave action). Upslope processes include sand blown landward over the crest or via guts that develop as wind funnels through low areas along the scarp crestline, often forming sand drifts that can migrate 100s of m per year and only stabilize once sand is covered by vegetation (or green waste). These processes are illustrated in Figure 34

Rising of the foredune/beach intersection is evident at Arrow C on the 2015 profile (Transect 8) and this could indicate (the expected) onset of beach recovery. Accumulation *of driftwood at and to the west of Transect 8 in evident in late 2015 site inspections and this supports the indication in the June 2015 profile of upper beach/dune base stability. However, wind erosion and landward wind-drifts will continue regardless of the slope angle until covered by vegetation or other materials.

The Central Sector fronts the GWP and is represented by Transect 4 (Figure 33). Seaward advance of the platform face (Arrow A) occurred between 2007 and 2013, with current stability reflecting the management change, planting c.f. ongoing green waste placement. The swale between the platform face and the foredune crest has consequently become narrower. The foredune crest (Arrow B) has been relative static after increasing in elevation 2007 and 2013. The most recent profiles show increasing erosion about the upper beach/lower dune (Arrow C), with ~4m of retreat occurring between July 2014 and





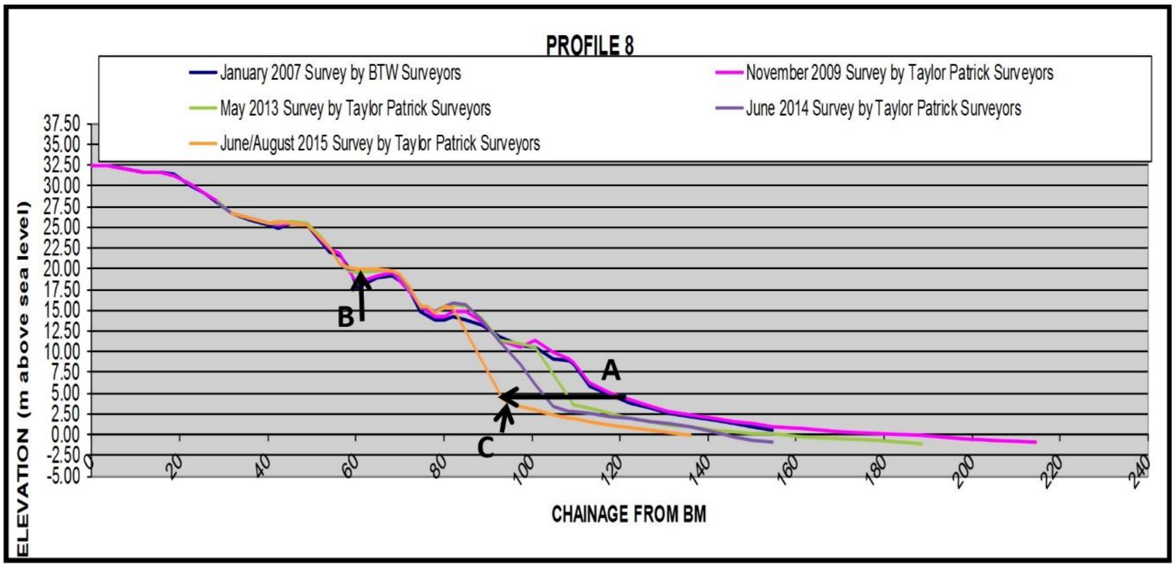
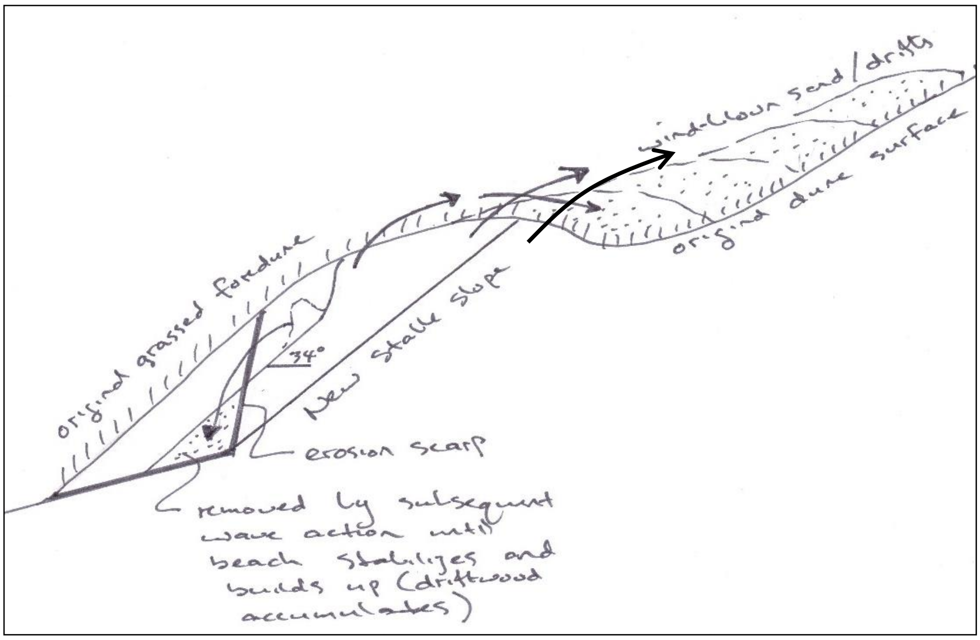


Figure 33 Superimposed profiles representing Transects 2 (Southern Sector), 4 (Central Sector) and 8 (Northern Sector) to June 2015, with transect locations shown in Figure 9. Arrows locate changes which are described in text.

July 2015 resulting in an oversteepened slope of ~45 degrees. Subsequent slope adjustment could consume the entire swale and thus put pressure along the GWP face, presently well covered in marram grass. **The situation in the Central Sector is becoming a critical**. Placement of green waste in the swale is being contemplated but safety of machinery and operator is fast becoming an issue.



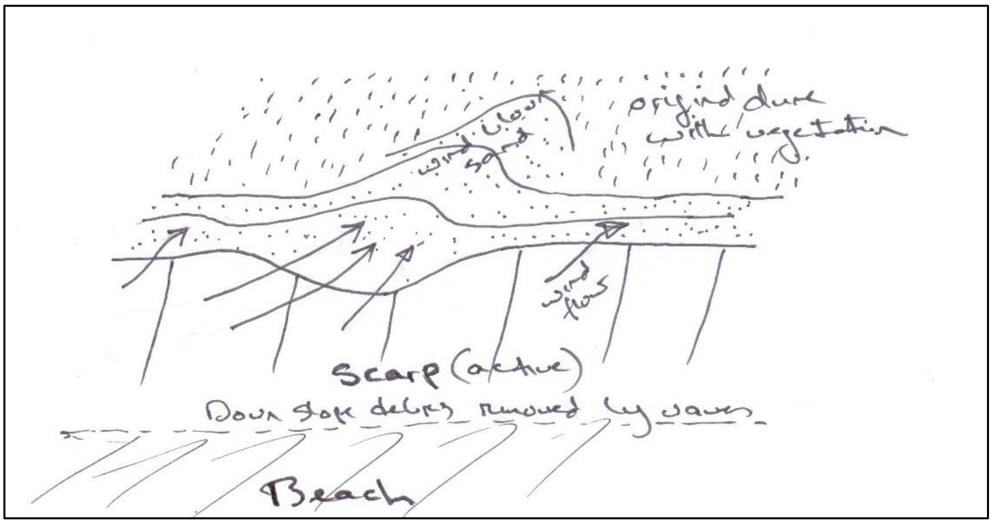


Figure 34 Upper figure shows profile (cross-section) view of slope adjustment processes following foredune erosion by storm wave action. The new stable slope is achieved by downslope movement of sediment under gravity (sliding, avalanching and block glides). Upslope processes are driven by wind erosion and inland loss of sediment which results in burial of vegetation and wind drifts migrating inland. Note upslope processes continue until the sand surface is protected by vegetation (or other material) regardless of slope angle.
The lower figure shows an oblique view of wind processes removing sand from the scarp face and depositing it on the stable inland dune surface. Wind flow funnels through low points along the scarp crest line, and guts develop with additional capacity for localized erosion and landward deposition.

The Southern Sector profile graph (represented by Transect 2) shows ~25 m of upper beach erosion since 2003 (Arrow A), but has been relatively stable over the past few surveys. Some surface lowering is evident across the backshore/lower GWP face, but the mid/upper face and platform surface are notably stable.

Inlet data are depicted in Figure 35 with an inner bay graph (Transect 22 at the upriver end of this bay) and an outer (Manu) bay graph (Transect 20). Manu bay appears to have been systematically infilling with sediment, possibly with sediment lost from the northern beach/dune system. However, the June 2015 flood dramatically lowered the profile some 1.5 to 2 m. The inner bay profiles show the landward side reducing in size by about 20 m upon the formation of a foredune coinciding with a very large accumulation of sediment across the bay in 2009. Sediment was systematically lost thereafter (in contrast to the outer bay), and again there was a dramatic loss of sediment during the June 2015 flood when outer edge retreated some 20 m and the profile lowered by about 1 m. A reverse relationship is indicated between the two bays and a tide-driven mechanism is plausible given the modified flow regime caused by the Patea Dam. However, the graph for the inner bay also shows the channel (right side of graph) moving landward (eroding) and this may also be related to river control works (raising the southern training wall) on the opposite side of the river.

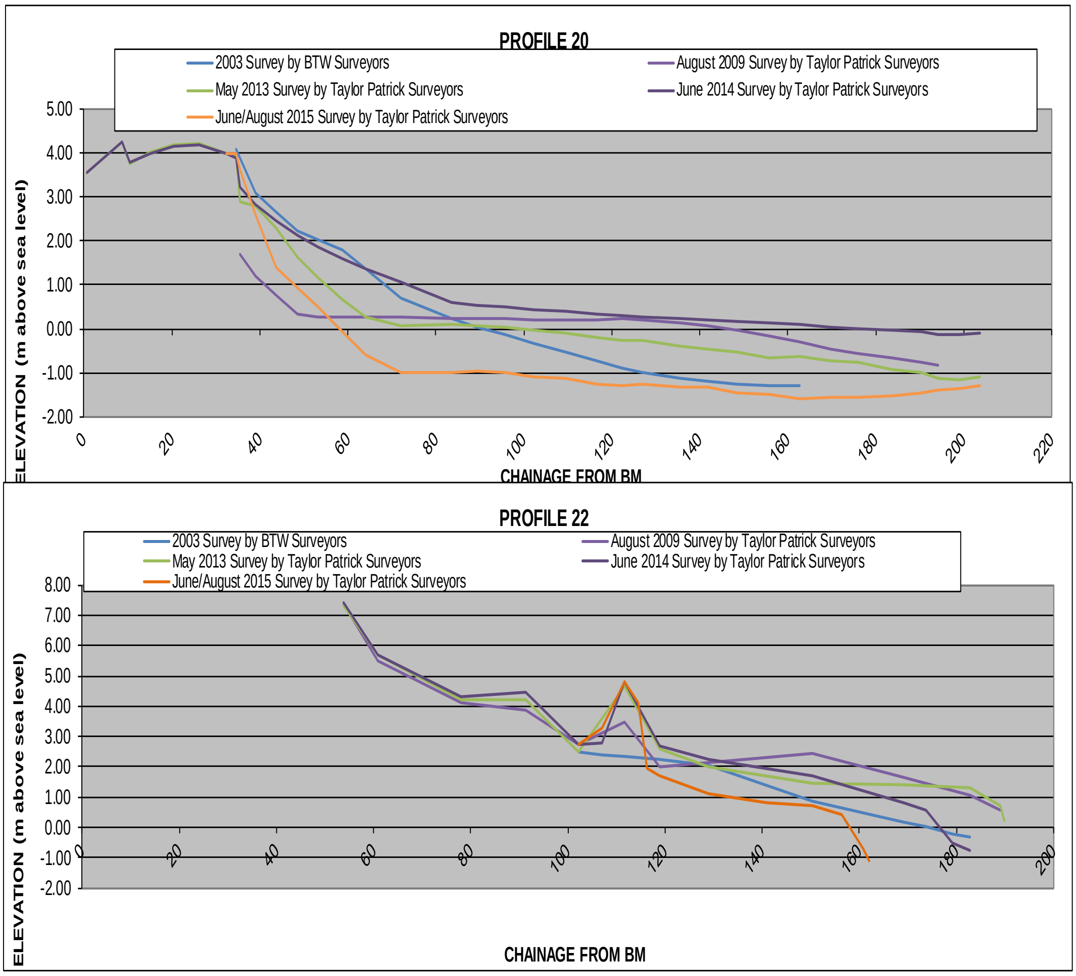


Figure 34 Superimposed profiles for Transects 20 (seaward bay) and 22 (landward bay) see Figure 9 for locations. Changes are described in the text.

5. SAND MANAGEMENT GUIDELINES

The Patea Beach Sand Management Project has been operating for 8 years and conservation techniques have been developed for sand stabilization. However, the Patea Beach sand dunes are easily activated, this being an inherent characteristic of the anthropogenically modified environment, so some management will always be required if repeats of the 1950s and 1980s (when sand drifts reached the beach settlement) are to be avoided.

The present episode of foredune erosion reflects natural variation in sediment supply and energy input and such episodes can be expected to occur from time to time. In addition, the nature of processes in the future are likely to change due to variation in sediment supply associated with land use change - the past centuries where characterized by bush to pasture conversion (releasing sediment) and then catchment control schemes (reducing sediment availability), and the future may witness changes in climate be they natural or man induced.

For example, predicted climate change over the next 100 yrs consists of extreme wind and wave regimes increasing by ~10% and sea-level rise of 0.5 to 1 m, and each of these changes can impact dune stability. More frequent higher wind speeds increase vegetation desiccation, root scour and burial and hence dune instability. More frequent higher waves increase foredune scarping and associated dune instability, and sea-level rise causes the shoreline to retreat, hence an increase in scarping and system instability. In addition, sediment supply reaching the study area can change with varying rates in cliff erosion. Rainfall changes in the hinterland will also modify water and sediment discharges and models are currently being developed to quantify the effects such catchment change will have on coastal processes.

The purpose of this section is to provide guidelines for managing the dune system at Patea Beach based on the knowledge gained during the project and described in the preceding sections of this Summary Report. The management guidelines will also be helpful in adapting to future processes changes. However, our understanding is limited and expert revision is recommended from time to time to further adapt sand conservation methods to process and landform change.

The guidelines relate to sand management zones which are defined below and spatially located in Figure 36.

Unless otherwise stated, a hydraulic excavator (digger) is used to perform the various operations.

Note in Section 4.3.2.4 it was shown that kikuyu assists in sand stabilization; however, there are risks in a single species plant cover maintaining stability in a highly variable (present and future) environment, so ensuring some biodiversity with other dune stabilizating grass species is desirable. To that end, our trials found that when stabilizing sand in kikuyu-dominated areas, existing kikuyu should be mechanically removed to root depth (about 0.5 m) and other species planted: subsequent infestation by kukuyu is then unlikely to outcompete the planted grasses.

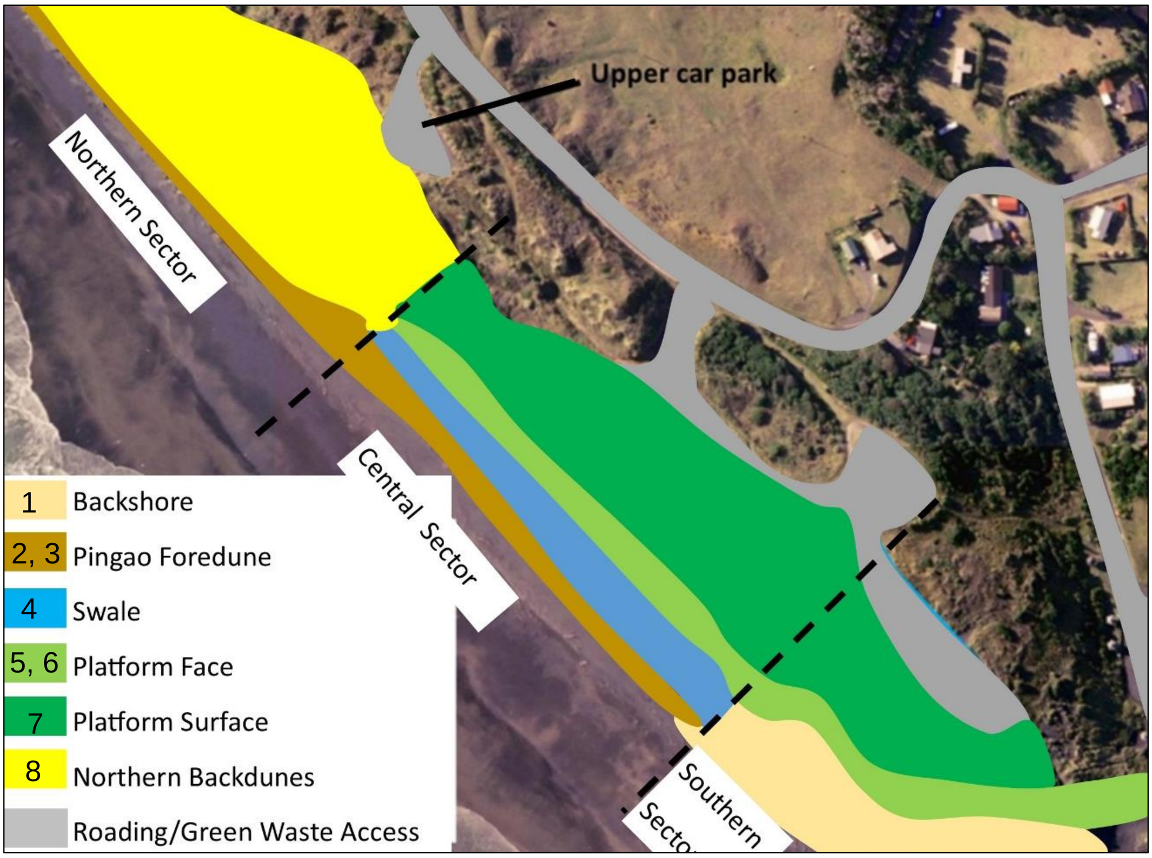


Figure 36 The eight Sand Management Zones as defined in the Sand Management Guidelines. Numbers in the key refer to the relevant guideline reference numbers.

Guideline 1 Backshore (Southern Sector) vegetation/dune development

- Remove self-sewn plants (pingao, spinifex or marram) and transplant into other areas requiring vegetation.
- If significant sand accumulation has occurred about the plants (dune development), this could be mechanically spread. Lesser accumulations will dissipate naturally by winds once the plant material has been removed.

Guideline 2 Pingao foredune – localized erosion

- Remove existing vegetation and stock-pile any non-kukuyu grasses (likely pingau).
- Place green waste in guts and other low-lying erosion-prone areas.
- Place stock-piled vegetation, plus additional nearby pingau (from noncritical areas), carefully on top of green waste using excavator and manual assistance.
- Following season, as necessary, top-up green waste and place additional plants from non-critical areas by excavator and manual assistance.
- Erect fence (rope and post) if traffic is an issue. Note posts may need to be raised/lowered over time as sand surface elevation may change.

Guideline 3 Pingao foredune – laterally extensive erosion

- Frontal scarp active: place one metre thick layer of green waste along the scarp-top and stretching several metres to landward. NB this is to minimize the amount of sand blown up/off the face and burying landward vegetation.
- Once scarp inactive (may take years), place further green waste as required required then carefully replant existing nearby pingao (from noncritical areas) using excavator and manual assistance.
- After a period of settlement and plant establishment (next planting season), infill plant using (bunches of) 1 m long pingau runners with root buried up to 0.5 m and leaf end exposed, and marram tillers taken from exiting turrets growing in non-critical area, such that plants are spaced at 0.5 to 1 m intervals. Note, pingau runners maybe obtained with an excavator, but same planting may need to be done by hand to minimize disruption over a wide area.
- Erect fence (rope and post) if traffic is an issue. Note posts may need to be raised/lowered over time as sand surface elevation may change.

Guideline 4 Swale – sediment transport obstructions

- The objective is to have the existing swale between the foredune and platform face in the Central Sector obstruction-free to facilitate wind-blown alongshore sediment transport.

- Remove vegetation and sand buildups, placing excavated materials in low erosion-prone areas along adjacent foredune.

- Note fencing is not required here as traffic will help keep this area open.

- The cross-shore swale dimension is reducing and may disappear at some time in the future. **Guidelines 2 and 3 (foredune) and 5 and 6 (GWP face) will then need revision**

Guideline 5 Platform face – localised erosion

- Remove any existing vegetation and stock-pile non-kikuyu grasses. Note that affected areas may already be free of vegetation.

- Ensure treatment area is relatively uniform, then cover with green waste to a depth of about 1 m.

- Any stock-piled vegetation, together with nearly vegetation (probably marram) from non-critical areas, to be carefully placed on top of green waste using excavator and manual assistance.

- Following season, as necessary, top-up green waste and place additional plants from non-critical areas by excavator and manual assistance.

- Erect fence (rope and post) if traffic is an issue. Note posts may need to be raised/lowered over time as sand surface elevation may change.

Guideline 6 Platform face – widespread erosion

- Remove any existing vegetation and stockpile non-kikuyu grasses, infill with green waste and then smooth with clean sand to a slope of 20 to 25 degrees.

- Plant with marram at 0.5 m spacing.

- Follow-up planting should be unnesessary, but if gaps occur then replant as soon as possible with large bunches of tillers to avoid wind funneling.

- Erect fence (rope and post) if traffic is an issue. Note posts may need to be raised/lowered over time as sand surface elevation may change.

Guideline 7 Platform surface - wind-drift sand

- Wind-drift sand may accumulate several centimeters (or more) closer to the GWP face in a single storm. Kikuyu can recover by growing through, or if too deep then growing in from the periphery of the sand deposition.

- If extensive sand deposition occurs and kikuyu cannot achieve cover before wind drifts occur, then management options are to either cover the drift with green waste, or physically remove drift sand to expose the buried kikuyu.

Guideline 8 Backdunes instabilities (Northern Sector) from wind scour and wind drifts

- It is important to maintain a vegetation cover in this area to minimize sand drifts associated with foredune erosion. This is the situation being faced at the present and methods are still being developed. In the meantime the following is suggested.

- Once an area is identified as needing stabilizing, contour the area (smooth shape with the lowest possible slope angles), by hand if and excavator cannot gain access.

- Plant marram along with pingau runners and self-seeded spinifex as available. On steeper slopes just plant marram. Spacing at 0.5 m and spinifex and up to 1 m if pingao runners are used (the closer the better).

- Erect a rope and pole fence. Note that for the Northern Sector in particular, posts may need to be raised/lowered over time as significant sand surface elevation changes can be expected.

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COASTAL SYSTEMS LTD
Hazard, Management and Research Consultants

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Dr Roger Shand
Senior Coastal Scientist

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APPENDIX A Taranaki Regional Council Consent 6088-3

Consent 6088-3

TARANAKI REGIONAL COUNCIL

CHIEF EXECUTIVE
PRIVATE BAG 713
47 CLOTEN ROAD
STRATFORD
NEW ZEALAND
PHONE: 06-765 7127
FAX: 06-765 5097
www.trc.govt.nz

Please quote our file number on all correspondence

Discharge Permit

Pursuant to the Resource Management Act 1991 a resource consent is hereby granted by the Taranaki Regional Council

Name of Consent Holder:	South Taranaki District Council Private Bag 902 HAWERA 4640
Consent Granted Date:	30 October 2007

Conditions of Consent

Consent Granted:	To discharge domestic green waste onto land for the purpose of stabilising sand dunes at or about 2637357E-6158276N
Expiry Date:	1 June 2022
Review Date(s):	June 2010, June 2016
Site Location:	Patea Beach, Beach Road, Patea
Legal Description:	Sec 137 SO 2680 SO 6641 Pt Lot 6 DP 648 Pt Sec 74 Blk VII Carlyle SD
Catchment:	Patea

For General, Standard and Special conditions pertaining to this consent please see reverse side of this document

www.trc.govt.nz

Doc# 370202-v1

Working with people • Caring for our environment

Consent 6088-3

General conditions

a) On receipt of a requirement from the Chief Executive, Taranaki Regional Council the consent holder shall, within the time specified in the requirement, supply the information required relating to the exercise of this consent.

b) Unless it is otherwise specified in the conditions of this consent, compliance with any monitoring requirement imposed by this consent must be at the consent holder's own expense.

c) The consent holder shall pay to the Council all required administrative charges fixed by the Council pursuant to section 36 in relation to:

i) the administration, monitoring and supervision of this consent; and
ii) charges authorised by regulations.

Special conditions

1. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimise any adverse effects on the environment from the exercise of this consent.

2. The exercise of this consent shall be undertaken in accordance with the documentation submitted in support of application 4491. Specifically this includes *Patea Beach Management Plan, South Taranaki District Council (June 2007)*. If there is any contradiction between the documentation submitted in support of the application and the conditions of this consent, the conditions of this consent shall prevail.

3. Dumping of green waste by the public shall be limited to specific designated areas identified by signs. The consent holder shall regularly remove the green waste from the dumping area and deposit it in the quantities and at the locations necessary to achieve the purpose of this consent.

4. For the purposes of this consent, domestic green waste is defined as: leaves, grass clippings, hedge trimmings, sticks/branches/logs with a diameter no greater than 100 mm, and other similar material all in quantities consistent with maintenance of a residential garden. Specifically excluded from the definition are: sticks/branches/logs with a diameter greater than 100 mm; timber (treated or not); and any viable plant identified in the *Pest Management Strategy for Taranaki: Plants.*

5. The consent holder shall ensure that signs at the dumping points clearly describe the waste that may be dumped.

6. The consent holder shall remove any dumped material from the site that is not green waste (as defined in condition 4).

7. The consent holder shall comply with the requirements of the *Pest Management Strategy for Taranaki: Plants* at the site.

8. The consent holder shall ensure that no waste discharged to the site is placed at or below the mean high water springs mark.

Consent 6088-3

9. The discharge to land shall not result in any contaminant entering surface water.

10. The consent holder shall control and maintain all stormwater at the site to minimise erosion or scour of the adjacent foredune area to the satisfaction of the Chief Executive, Taranaki Regional Council.

11. This consent shall lapse on the expiry of five years after the date of issue of this consent, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

12. In accordance with section 128 and section 129 of the Resource Management Act 1991, the Taranaki Regional Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent by giving notice of review during the month of June 2010 and/or June 2016, for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time.

Signed at Stratford on 30 October 2007

For and on behalf of
Taranaki Regional Council

Director-Resource Management

APPENDIX B CSL Sand Management Plans for Patea Beach

Appendix B 1. 2007 Sand Management Report

Concepts for Sustainable Sand Management

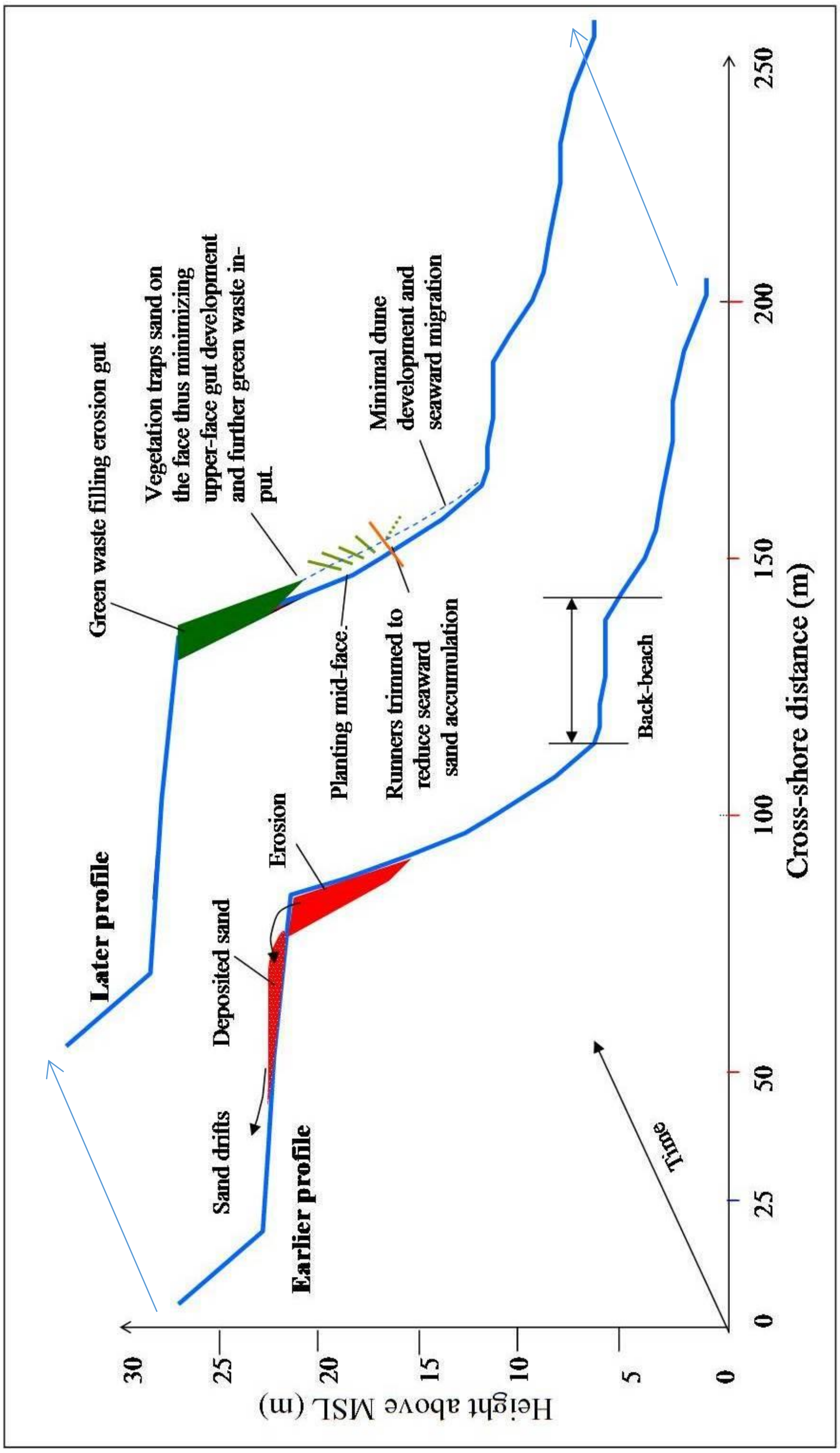


Figure 4 The 'earlier profile' shows present erosion-deposition patterns on the platform face, while the 'later profile' shows green-waste infill to reduce wind speeds, and plantings on the mid-face to minimise erosion and improve amenity values (visual appearance). Runners are trimmed to minimise seaward sand accumulation-dune development which can subsequently lead to an erosion cycle being induced by wave cut (see text).

Appendix B 2a. 2008 Interim Report

From sand management project contract

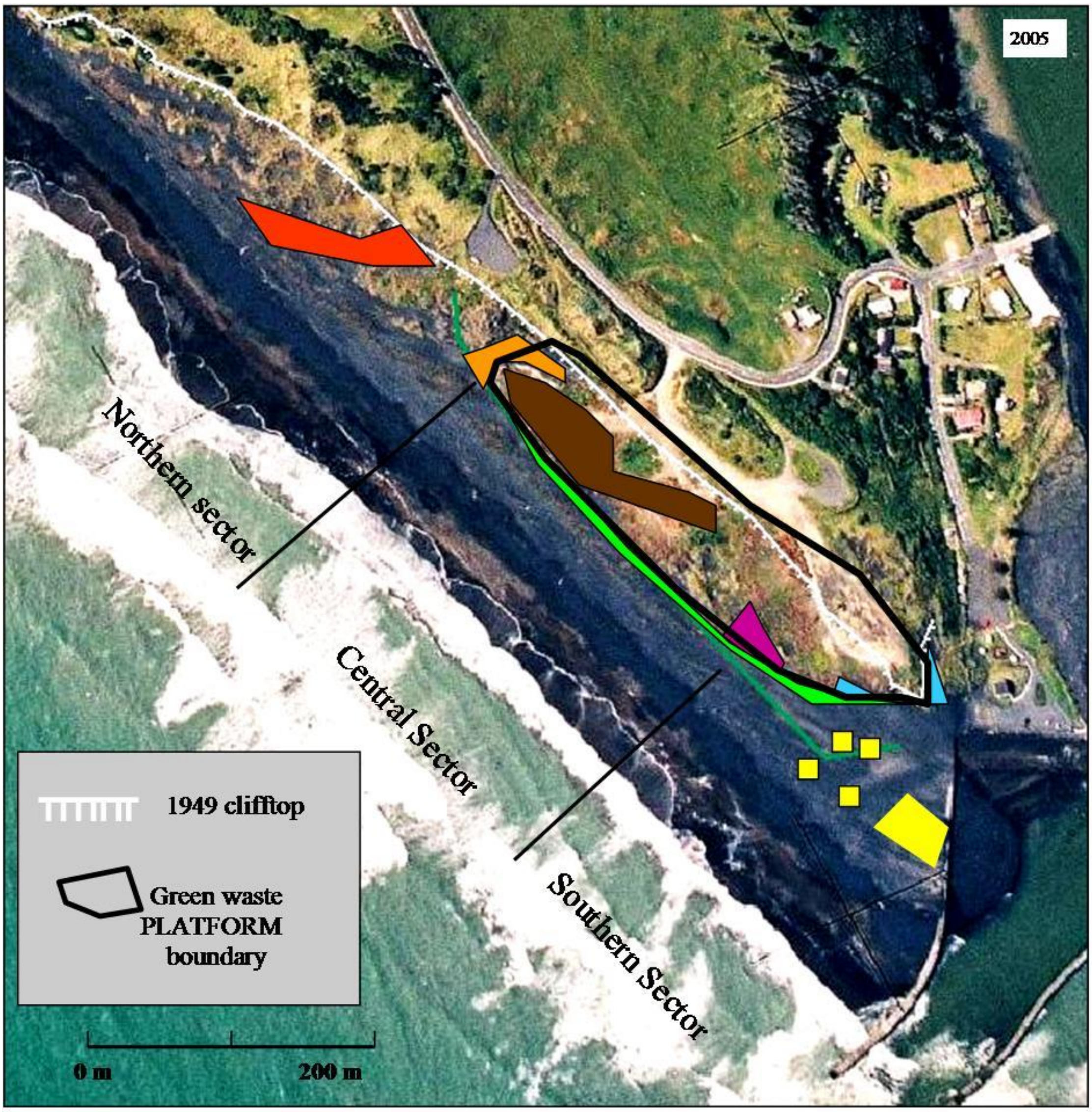


Figure 1 Area of green waste dumping as at 5 June 2008 (brown), areas requiring sand stabilization now (orange) or in near future (red, purple, aqua), area for mid-face planting (green) and areas of isolated dunes to be removed and vegetation relocated (yellow). See text for discussion.

Appendix B 2b. 2008 Inspection Report #2

Management Summary

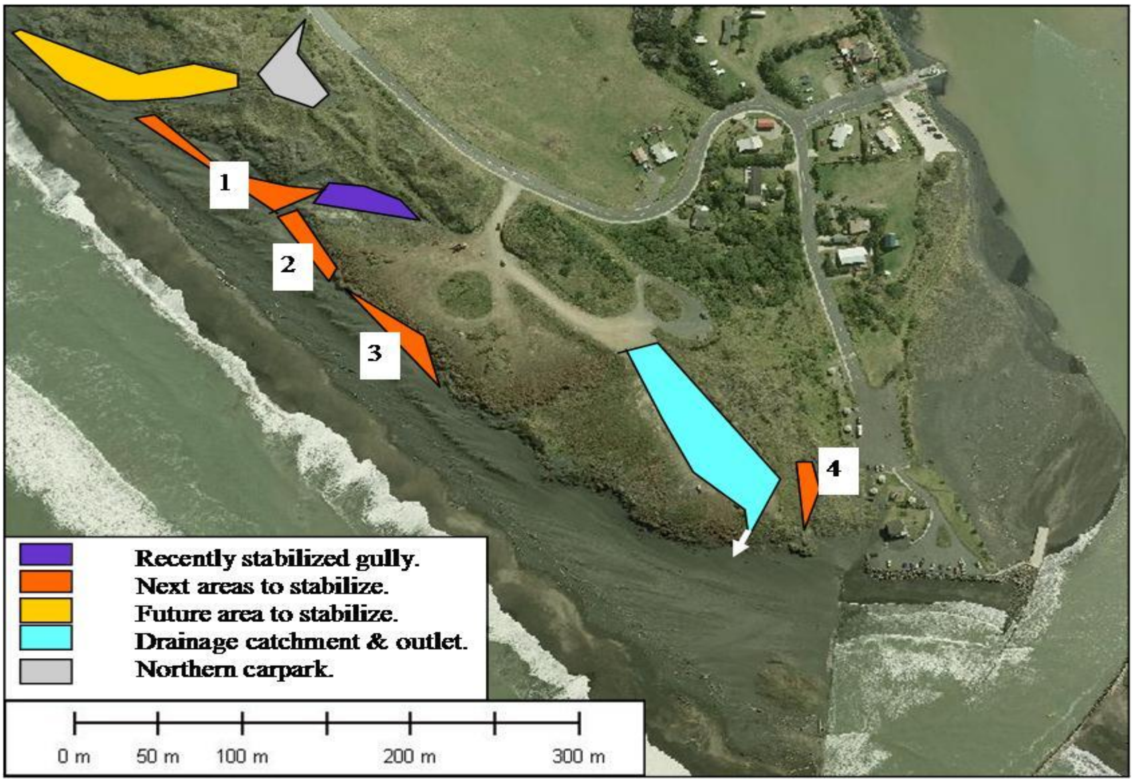


Figure 1 *Features and locations referred to in this report. Numbered erosion sites referred to in text.*

Report Text

While about 75% of the gully at the northern margin of the green waste platform has now been satisfactorily stabilized, the landward area “feeding” sand into the gut still requires stabilizing (depicted as [1] on Fig 1 below. In addition, areas [2] and [3] fronting the central platform, along with a smaller area at the southern end of the platform [4] require treatment. Stabilizing some of these areas will take several years as sand must deposit within and about the stabilization materials.

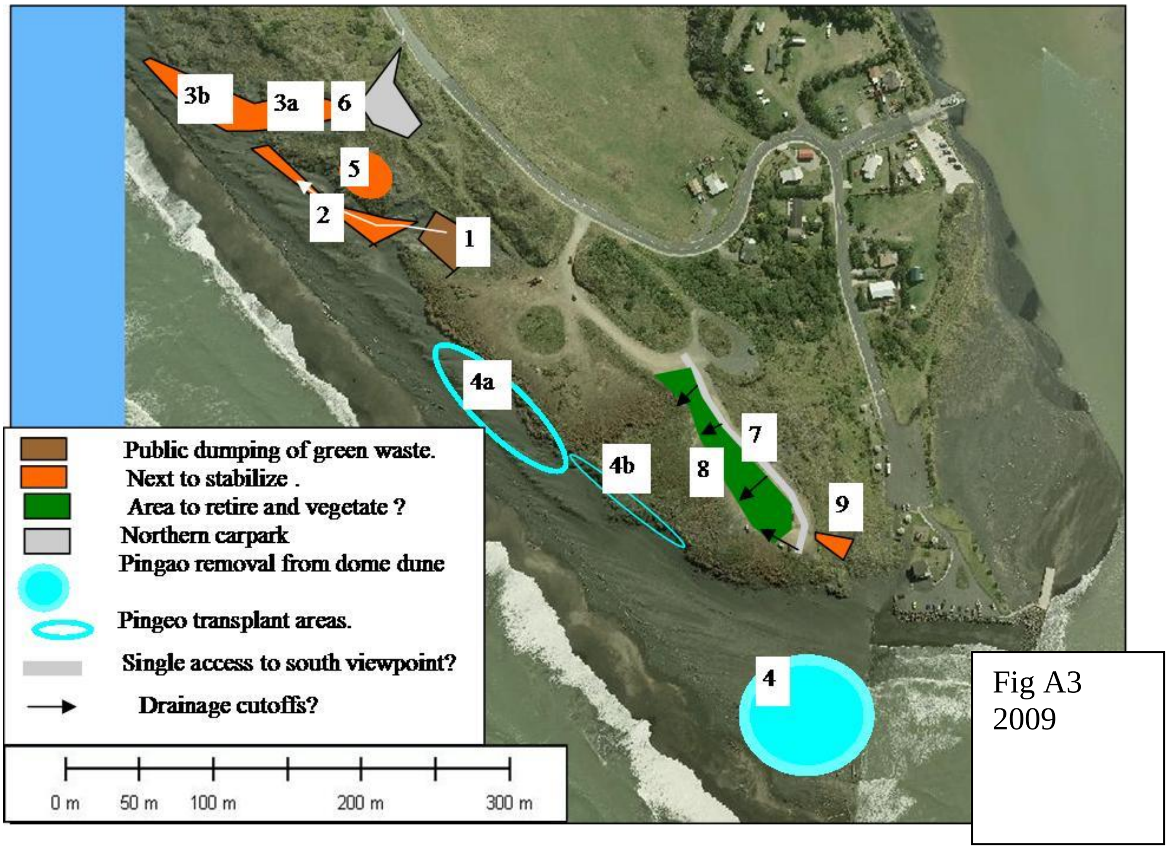
In the future, a large area fronting the northern car park (see Fig 1) will required treatment. However, treatment area [1] first needs to be stabilized as it will provide the access route.

Our analysis shows that about 3000 m^3 yr of green waste can be utilized for these purposes over several years. Two methods are available: “pushing off” with subsequent wind-blown sand infill (the usual method), or construction of wind rows from green waste, brush or netting, to trap sand. For each option, strategic planting to maintain peripheral stability could also be carried out during the winter

planting programme. Given that “pushing off” has been used successfully at this site, is easily carried out and is the cheaper option, it is recommended even though it may have somewhat greater visual impact than wind rows.

Appendix B 3. 2009 Inspection Report #5 (Figure 3A)

Management Summary



1. On 7th September, 2009 I inspected the site in conjunction with supervising a contour survey carried out in the vicinity of recently removed vegetation from the "dome" dune (#4 in diagram below). Note that the numbers in this diagram are same as those used in previous inspection reports. The survey was carried out to monitor environmental response as the dune-sand blows into the river over coming months. The contour plan is included with this report. The survey was carried out by Taylor Patrick and used the same survey control as earlier 2003 and 2007 surveys to enable temporal comparison with previous/subsequent surveys. Analysis will be carried out after the forthcoming 2 yearly monitoring (profile) surveys.

2. On 26 August local contractor Noel McCole relocated the pingao cover from all but the north end of the dome dune (#4), the remnant being left to help regulate the subsequent sand dispersal into the river. Smaller nearby self seeded dune hummocks of pingao were also removed; this area needs to remain vegetation-free as dune growth will compromise long-term stability in this area.

3. The pingo were replanted in the dip (4a) between the platform face and the pingao foredune and on the upper face (4b) of the platform. The plants were left in the swale as an experiment and will be monitored as such. As an experiment, some pingao were replanted in the upper bason (3a) which is just below the upper carpark (6).

4. An “incident report” was completed following a “heated” site meeting between Patea Library/Museum staff and the contractor during the operation on 26th August. Mr Denton (STDC) and myself subsequently met with staff and explained the situation. I then drafted a media release to inform the public of the dune management programme. .

5. The seaward side of the upper carpark (6) was stabilized with green waste. While this does not look good, it will suffice until the basin (upper basin =3a and lower basin =3b) is stabilized. The upper basin may need to receive green waste via the upper car park. This will be part of next winters programme.

6. How to get green waste into the lower basin (3b) is still being considered; however, at present the plan is to form an accessway from the northern end of the platform, which is the present green waste drop off point, and then along the swale (#2).

Green waste is presently being pushed into this swale/valley and this will then trap wind-blown sand to make a solid acessway. However, natural sand infill is lagging the rate of green waste application, ie the application rate is too high.

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7. Sites 5, 9 have yet to be stabilized with green waste.

8. STDC staff are addressing the drainage matters (7 and 8).

Appendix B 4. 2010 Update Report: February to September 2010

Management summary diagram

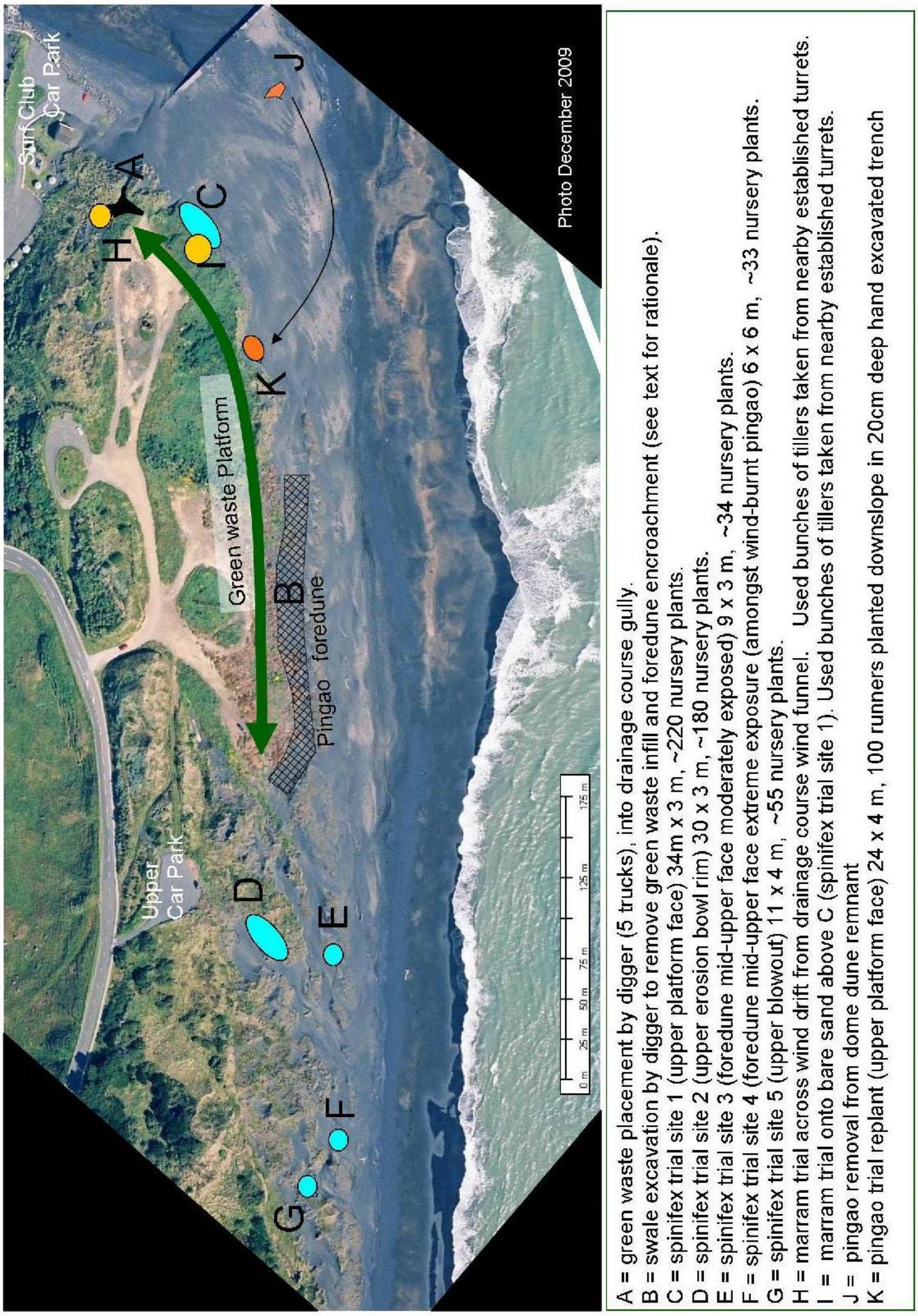

Figure 2 Green waste management sites (A and B) and trial planting sites (C to K) August 2010

Appendix B 5. 2011 Annual Report

Management summary diagram

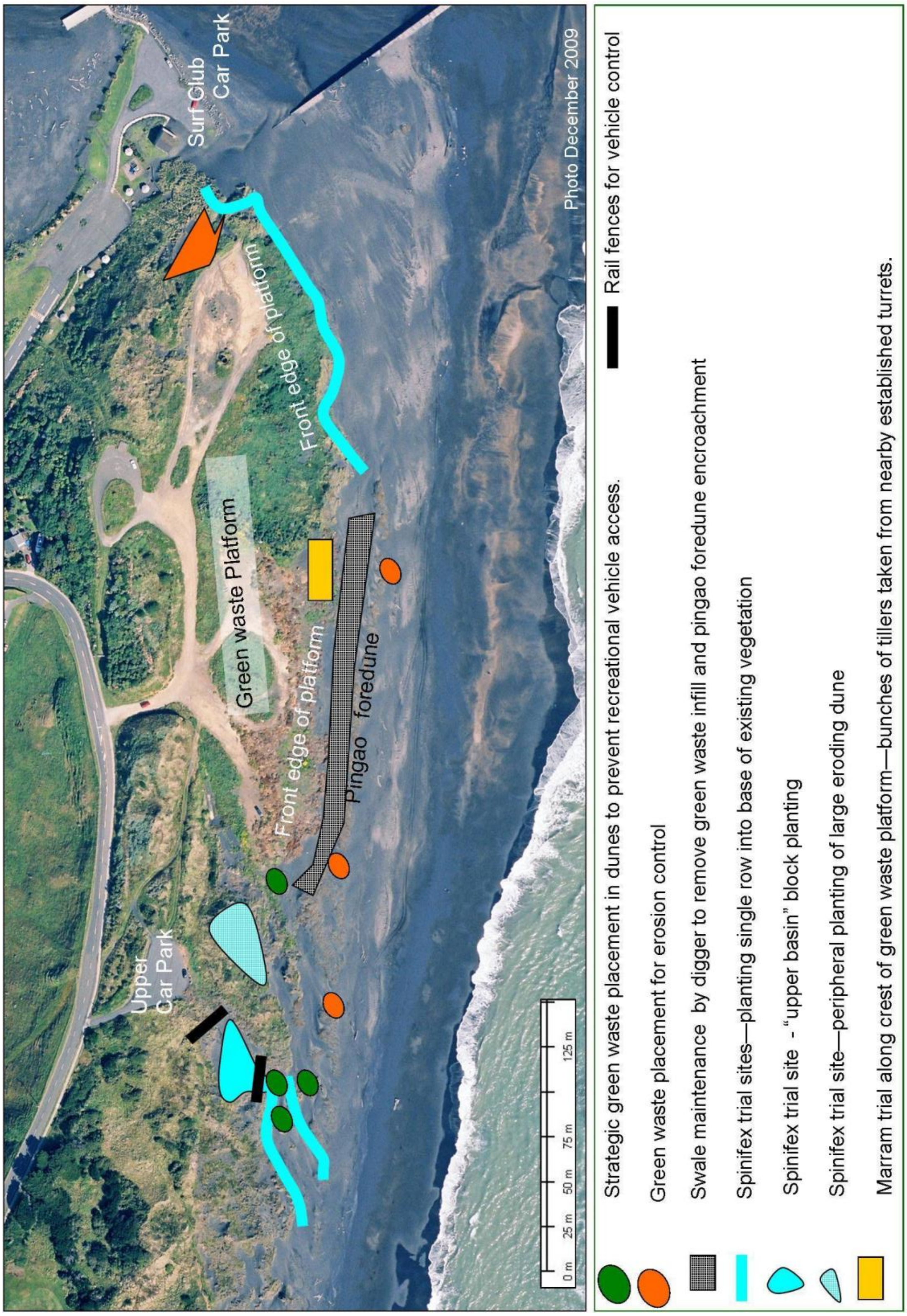

Figure 6 2011 planting sites and strategic green waste management sites.

Appendix B 6. 2012 Annual Report

Management summary diagram

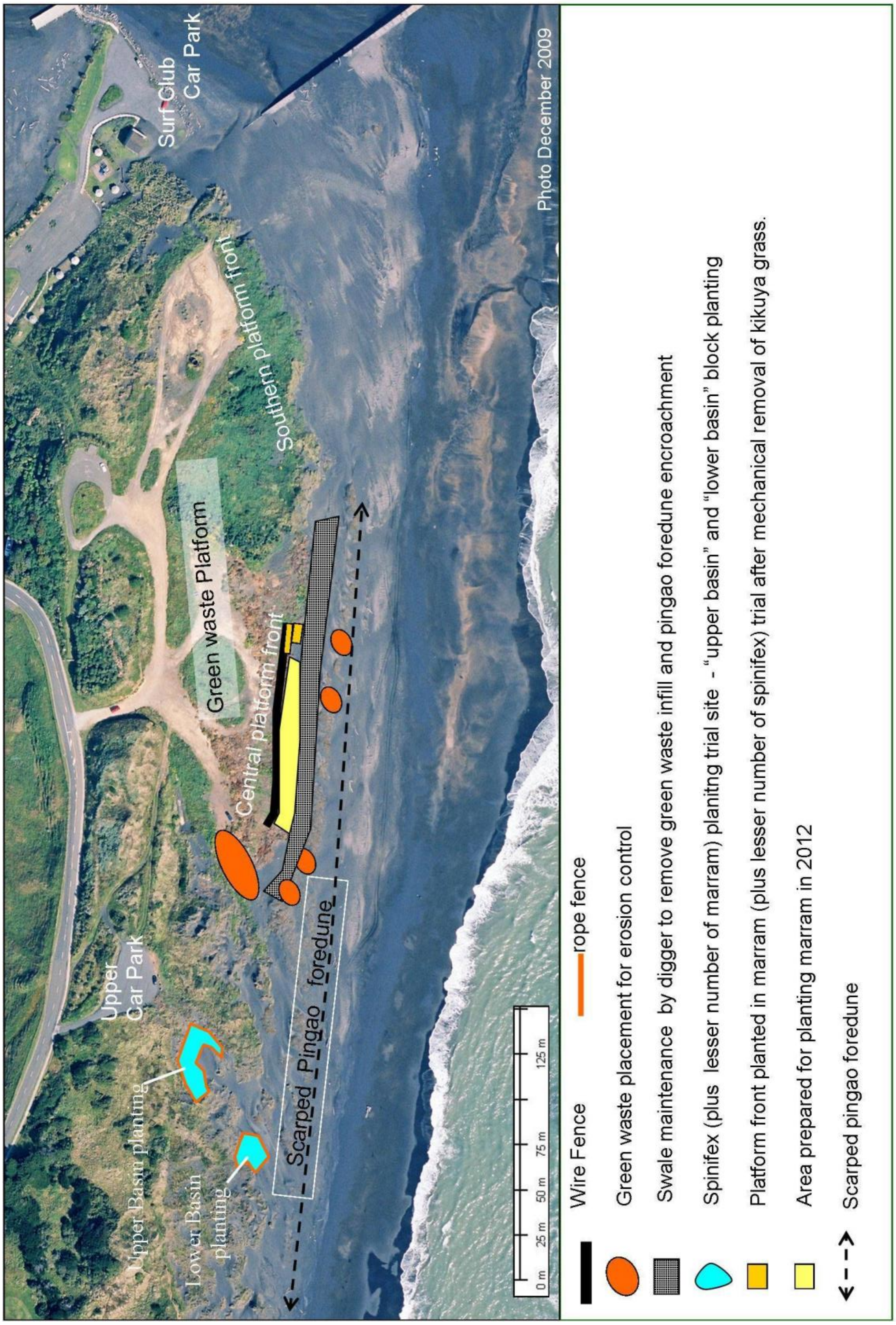

Figure 4 2012 planting sites, strategic green waste placement sites and other relevant features

Appendix B 7. 2013 Annual Report
Management summary diagram

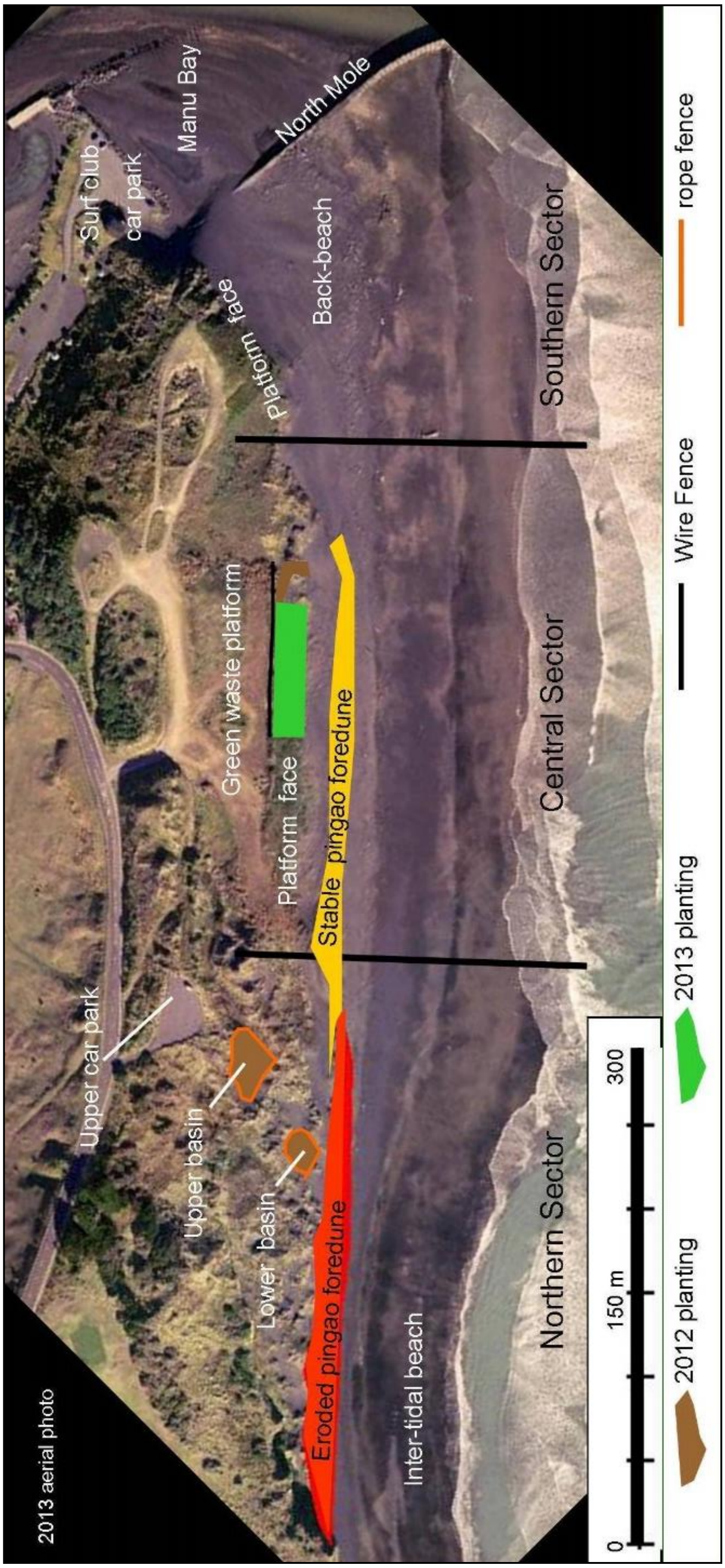

Figure 1 Patea Beach sand management area. Main physical features are marked along with sectors defining areas with different characteristics and management requirements.

Appendix B 8. 2014 Annual Report
Management summary diagram

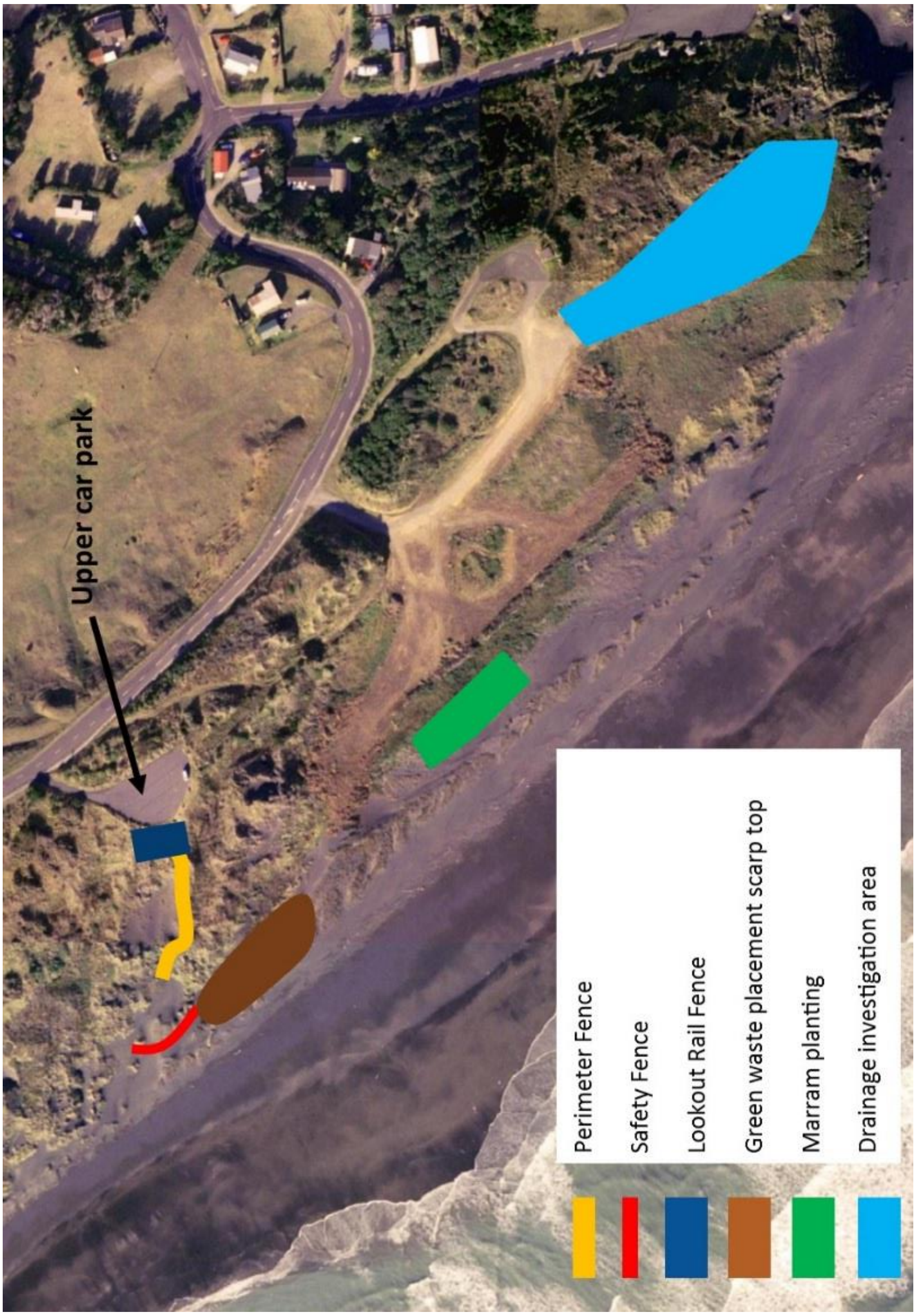

Figure 8 Location of management works carried out in 2014 superimposed upon the March 2013 aerial photo.