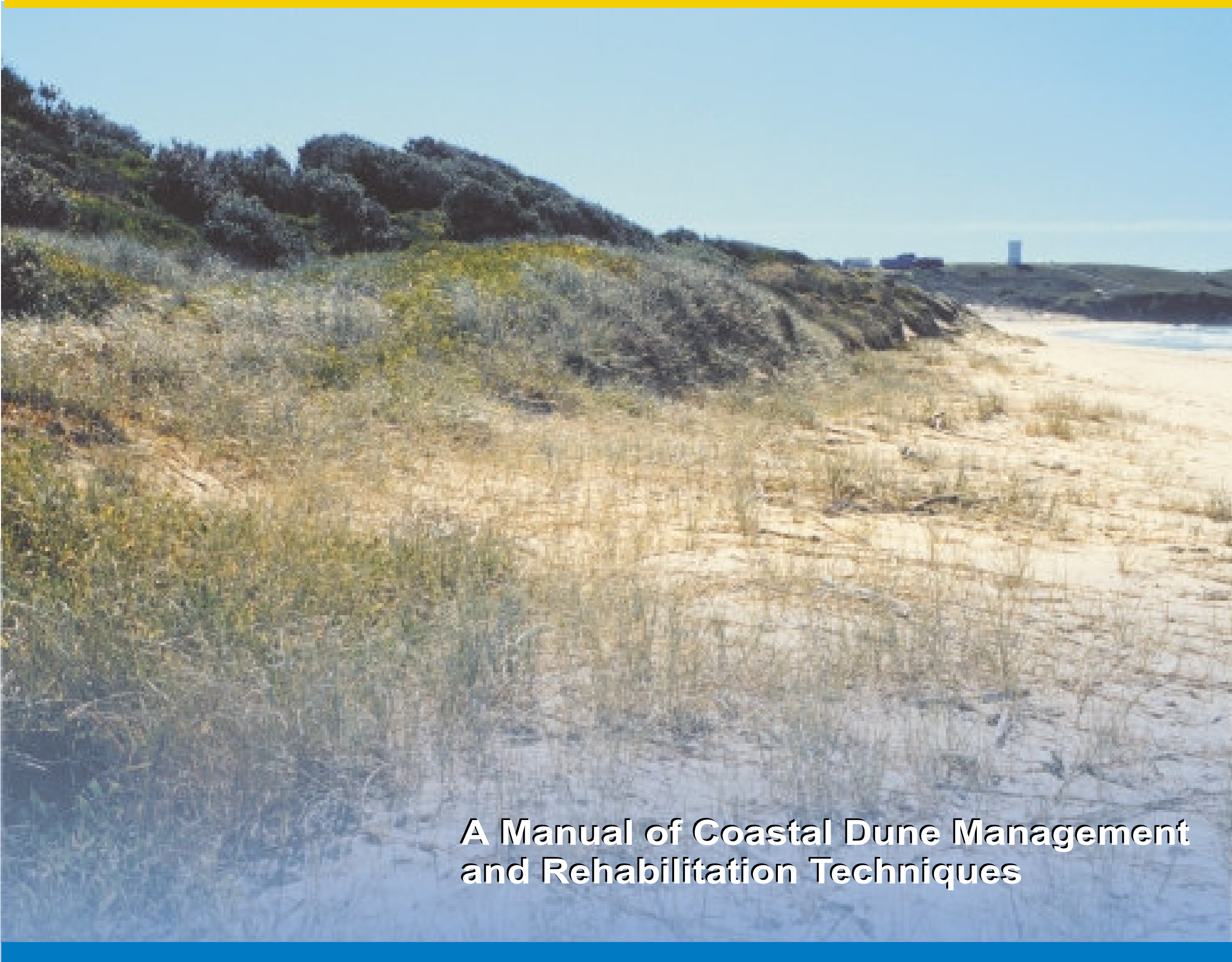
Coastal Dune Management



A Manual of Coastal Dune Management and Rehabilitation Techniques

Department of Land and Water Conservation

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A Manual of Coastal Dune Management and Rehabilitation Techniques

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Acknowledgements

Since the first Coastal Dune Management Manual was produced, there has been a huge investment of resources in rehabilitating NSW coastal dunes. Improved techniques have emerged and have been accompanied by changing attitudes as communities and government embrace the practicalities of integrated environmental management and Ecologically Sustainable Development.

Expertise from a range of organisations has been drawn upon freely in compiling this revision of the manual. The knowledge and skills of community-based practitioners have also been of great value, as have those of officers in other agencies.

This is reflected in the membership of the Advisory Committee that has guided the production of this revised Manual -

Maureen Baker & **Elizabeth Hood**, Eurobodalla Landcare Management Committee
Peter Chapple, Coastcare
Rus Glover, Coastcare
David Hanslow, NSW Department of Land and Water Conservation
Rod Kidd, NSW Department of Land and Water Conservation
John King, Coastcare
Marita Macrae, Friends of Avalon Beach Dune Care Group
Ruth Readford, Ballina Lighthouse Beach Community Dune Care Group
Neil Rendell, NSW Department of Land and Water Conservation
Jeff Thomas, NSW National Parks and Wildlife Service

Lorraine Beal undertook all the graphic design with great skill, enthusiasm and patience.

The Committee has also been helped greatly by Michael Fiedler, Noel Butler, Melissa Bradbury and Phil Heaton. Many others kindly reviewed various drafts.

Sadly, Ruth Readford died before this Manual could be completed. Ruth was the driving force for Dune Care in New South Wales for approximately ten years, inspiring new groups to form, never hesitating to offer constructive advice, always welcoming new ideas and sharing experiences with others. This approach culminated with Ruth's establishment of the biennial NSW Dune Care conferences.

The Committee was privileged to have Ruth as a member; we hope this Manual will be another lasting tribute to her commitment to rehabilitating degraded coastal dunes and enhancing the broader coastal environments of New South Wales.

LAND & WATER CONSERVATION

DUNE CARE

COASTCARE

NATIONAL PARKS & WILDLIFE SERVICE NSW

Foreword

The New South Wales Coast is blessed with an amazing variety of coastal dunes. Over the past several million years quartz sand has accumulated on the continental shelf and been moved landwards into embayments as a result of sea-level rise and wave and wind action. Some of the most majestic transgressive dunes have marched over old land surfaces forming precipitous ridges comparable to any coastal dunes of this type in the world.

Sand barriers are often flanked on the seaward side by towering foredunes. These features are more sparsely vegetated than other dunes and represent a delicate balance between forces of wind and wave on the one hand, and the spread of sand-binding plants on the other. Where disturbed, these dunes become free-moving and form extensive mobile sand sheets thus creating a world apparently devoid of life.

In 1770 Captain Cook observed bare sand patches and smokes from the fires of Aborigines. Whether burning helped to destabilise the dunes is unknown. But we do know that over the past 200 years diverse human activities have disturbed natural dune landforms. Cattle grazing, military exercises, sand mining, and the ever-growing spread of human settlement and traffic impact severely on fragile vegetation.

Ever since the former Soil Conservation Service commenced its experiments, and sand mining companies, local councils and more recently Dune Care/Coastcare groups took an active interest in dune management, there have been attempts to overcome abuses of the past.

This manual represents a renewed effort by the Department of Land and Water Conservation to present an up-to-date document on how we can best manage our dune landscapes. It builds on the many efforts of past dune managers and offers the community practical advice on the ways we can care for the plants, animals and topographic features within the dunes of coastal NSW.

It is also a tribute to all those marvellous people who freely give their time to look after these landscapes. In particular, we recognise the efforts of the late Ruth Readford who provided so many others with the inspiration and support needed to tackle the challenges of coastal dune management.

Bruce Thom

Chair,
NSW Coastal Council

1. INTRODUCTION

Dunes are an integral part of our coastal environment. Not only do they provide a reserve supply of sand for use by waves during storms, they are the basis of important ecosystems, supporting valuable communities of plants and animals. As such they initially provided resources and shelter for aboriginal people, generating cultural values that remain important today. More diverse activity resulted from European settlement, providing the basis for another set of social values.

Unfortunately, many coastal dunes have been degraded over the years due to residential development, grazing, mining and recreational activities. The resultant dune instability and sand drift remains a serious problem along parts of the New South Wales coast as wind-blown sand continues to advance inland, threatening both natural and built environments. At some localities the sand drawn from beach systems may also represent a significant loss to coastal sediment budgets, leaving beaches and their frontal dunes less able to withstand erosion initiated by storm waves, and prone to sustained long-term retreat.

The severity of this problem has long been recognised and prompted the production of a *Manual of Coastal Dune Management and Rehabilitation Techniques* (Soil Conservation Service of NSW 1990). Since then there has been a very considerable investment of resources in stabilising and revegetating coastal dunes. The Soil Conservation Service of NSW (SCS) has played a pre-eminent role, developing a pool of expertise that is now incorporated largely within the Department of Land and Water Conservation. Much of the work has also been undertaken in conjunction with local councils.

One very encouraging development has been the rapid emergence of widespread community involvement in hands-on dune rehabilitation work, initially through Dune Care and Landcare projects. Readford (1997) suggests that by the early 1990s there were almost a hundred Dune Care groups spread along the NSW coast, drawing strongly on SCS support and forging strong community/ government partnerships. Much of the NSW coastline is also managed by the National Parks and Wildlife Service, which is increasingly fostering partnerships with community groups to protect and rehabilitate coastal dune environments.

All these relationships have been reinforced and broadened by the National Landcare Program and more recently by the jointly funded Commonwealth/ State Coastcare Program.

Many of these advances have been accompanied by and in some cases driven by benchmark movements in public policy that have incorporated a new emphasis on integrated management, on community and government partnerships, and on Ecologically Sustainable Development. ESD principles are embraced formally by the 1995 Commonwealth Coastal Policy and the 1997 NSW Coastal Policy. Both provide strategic frameworks for coastal management within which coordinated, integrated strategies to address issues such as sand drift can be developed.

The NSW Coastal Policy policy in particular provides quite specific goals for preserving coastal amenity and biodiversity, and unequivocally seeks to protect beaches and foredunes. Policy implementation will be facilitated by revision of technical manuals for coastline and estuary management into a single coastal zone management manual.

These trends have also been accompanied by a marked shift in attitudes to management of sand drift. The broader values of coastal dunes are now more widely acknowledged and dune stabilisation is no longer seen solely as a mechanical operation on an isolated landscape component. Dunes are now recognised as integral parts of our beach systems with intrinsic biodiversity values. The challenge is to preserve these, as well as protecting the cultural values that derive from beach settings.

Restoration of sand dune ecosystems and securing their biodiversity involves protecting the relatively undisturbed vegetation that remains as well as trying to restore what has been lost, ideally to a condition that prevailed before disturbance. Conversely, where significant sand mobilisation has occurred due to non-human disturbance, the justification for stabilisation should be given careful consideration, noting that mobile dunes are also natural landscape features in their own right.

Another persistent challenge is promoting wider community acceptance of beach erosion as a natural phenomenon. During the latter half of the 1990s beach erosion by storm waves was a fairly common occurrence, with quite dramatic loss of beach amenity at some locations. This was a new experience for many beach users, especially for those who were too young to remember the last prolonged erosion phase of the mid-to-late 1970s. It is essential that local communities understand that severe beach erosion *will* occur again and that frontal dunes will play a vital role in mitigating erosion initiated losses.

This Manual therefore seeks to provide the information that is required for successful rehabilitation and protection of coastal dunes. It describes the role of coastal dunes within the broad dynamics of the NSW coast and it reviews both the characteristics and some of the regional variability of NSW coastal dune environments. Most importantly it describes the techniques currently favoured in stabilising, revegetating and maintaining these sensitive environments.

The benefit of planning at all levels is emphasised. This ensures that rehabilitation projects are compatible with broad strategic planning objectives at state, regional and local level. It also ensures that individual efforts are carefully planned before work starts, thus maximising the likelihood of success. The value of communities developing a sense of stewardship for their local beach environments is another underlying theme.

While the revised manual draws much from the 1990 edition, it also incorporates recent changes in attitude, new approaches and current methodologies. Like its predecessor, it is not a static document. Future improvements in management of coastal dune environments will inevitably need to be incorporated. Nor should it be used in isolation, as it links directly to the NSW Coastal Policy and NSW Biodiversity Strategy, as well as to technical manuals that focus upon other coastal environments.

The Manual specifically targets people and organisations that are actively involved in dune rehabilitation work, including those contemplating such action. This includes officers of several government agencies, all coastal councils, community groups and individuals. The Manual is also a valuable educational resource to be accessed by students from many disciplines and by beach users generally.

Consequently, another important goal in preparing this revision was to make it as user-friendly as possible, bearing in mind the wide-ranging backgrounds of readers. Information is therefore provided as succinctly as possible, but it includes references to more detailed technical material at the end of each chapter. These references also direct readers to other valuable stand-alone guides, which because they are readily accessible, have deliberately not been duplicated in preparing this Manual.

Users will also be able to access the Manual on the Internet. This medium will facilitate more timely updates and it will also provide more ready access to related resources such as the NSW Coastal Plant Database and other technical references.

Finally, some cautionary notes.

While the guidelines contained in this Manual represent current best practice and will be applicable to the majority of situations, local circumstances may necessitate departures from them. Community expectations will also increase as time passes, new products and techniques will emerge, new standards will be adopted and occupational health and safety requirements will become more strict.

Practitioners must always endeavour to minimise risk to themselves and beach users by adopting appropriate designs and procedures, and ensuring that effective maintenance programs are implemented.

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2. DUNES AND THE COASTAL ZONE

2.1 Introduction

On sandy shorelines, coastal dunes represent the last line of defence against erosion by providing a reservoir of sand for waves to utilise during storms.

As well as limiting the landward intrusion of waves, wind and salt spray, dunes act as a barrier to oceanic inundation and they provide for an important morphological and ecological transition from marine to terrestrial environments (Figure 2.1).

At many locations dunes have been removed, replaced or otherwise adversely affected by human activities. These include grazing, heavy mineral sand mining or sand extraction for construction, uncontrolled pedestrian or vehicular access, installation of protective works such as seawalls, and residential development. Where there is an inadequate dune, properties and facilities near the back of the beach may be subject to inundation from the ocean, to structural damage from wave attack, undermining by foreshore erosion, or to sand drift. The presence of a stable dune system provides a natural defence mechanism against these hazards.

While coastal dunes are the focus of this Manual, it would be shortsighted to develop plans for their protection or rehabilitation at a specific site without some understanding of their place within the broader coastal landscape. Recurring phases of beach erosion and accretion are natural phenomena and a sound understanding of relevant processes is essential if the values of coastal dunes are not to be compromised by future land use.

Moreover, while there are some general principles on the role and dynamics of coastal dunes to guide our planning, there are also significant variations in environmental attributes at different geographic scales that need to be taken into account. It is also important to have some understanding of how the systems have evolved over thousands of years and may change in the future, for example in response to changing atmospheric or wave climates.

At the simplest level, the diversity of NSW coastal landscapes can be reduced to distinguishing between the sandy (depositional) shorelines of beaches, dunes, barriers and estuaries, and shorelines developed in bedrock that feature sea cliffs and shore platforms. At another scale we can distinguish further between the long, relatively straight beaches that characterise much of the North Coast, where large rivers and broad depositional plains prevail, and the South Coast where shorter beaches are typically set more deeply between prominent bounding headlands (Figure 2.2). These sorts of distinctions are largely a legacy of geologic and geomorphic processes that have been operating for millions of years.

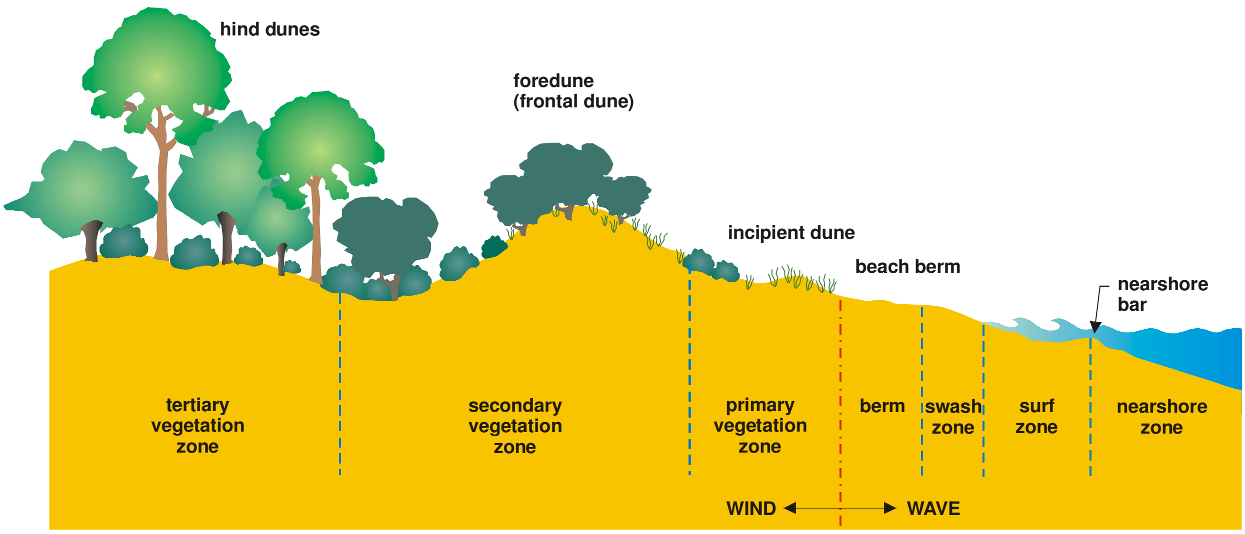

Figure 2.1 Typical features of a dynamic beach system.

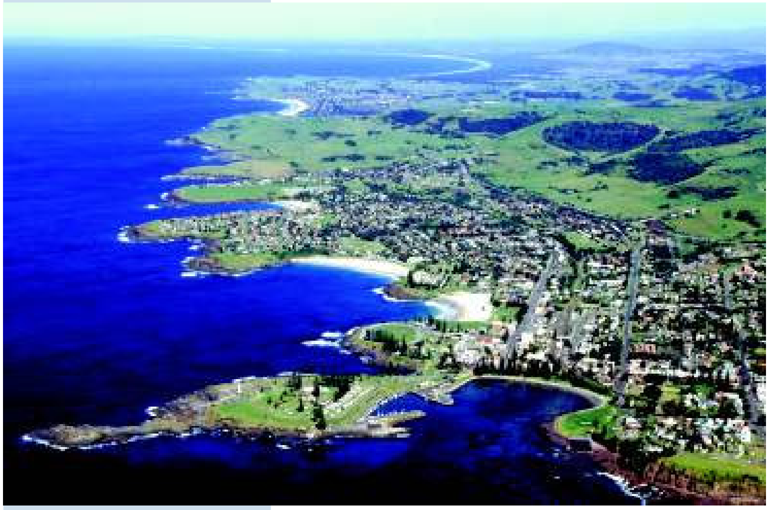

Figure 2.2 Contrasting coastal landscapes provide a variety of settings that impact upon dune management strategies. The examples illustrated are Ballina (top) with a broad depositional plain commonly found on the North Coast, and Kiama (below) on the South Coast where beaches and dunes are more often confined within relatively small embayments.

Within all these landscapes, waves, wind and tide combine with other surface processes to mould the coastal landforms we see today, although the intensity and effectiveness of these processes varies over time and space. For example, from a long-term perspective we can identify high energy and low energy beaches, but during a single storm event high-energy waves may temporarily mask such distinctions. Within individual bays, a prominent headland may affect prevailing waves so strongly that there are persistent significant variations in wave and wind energy, in beach sediments and in beach/dune topography along a single beach.

Additional complexity arises at many localities where coastal rivers meet the sea, with considerable variation in the resultant interactions between river flow and waves. These in turn reflect variations in the size, topography, geology and vegetation of the catchment, the size of the estuarine basin and the influence of tidal flows, combined with the relative strength of the incident waves.

Climatic variations also add complexity at various scales, with for example, the North Coast tending to be both warmer and wetter, and a greater proportion of winds arriving from the north-east (see Section 2.7). For a given part of the coast, topographic variability may also initiate quite significant climate differences at the local level. Not surprisingly such variations are also evident in the sorts of plants that grow along parts of our coast. This is directly relevant to planning of dune rehabilitation projects.

Ultimately the combination of all these factors has resulted in the development of diverse but characteristic assemblages of coastal plants as well as the valuable fauna habitats they provide. Conservation of this biodiversity is a core objective for coastal dune management.

The challenge is to protect, rehabilitate and restore coastal dune ecosystems as well as maintaining the aesthetic and social values of these landscape components.

2.2 Coastal evolution

To understand present day coastal landscape features, it is also helpful to take into account the different conditions that have existed during the past, particularly the fluctuations in sea level that have occurred due to global climate change. For most purposes it is sufficient to go back 120,000 years or so when sea level was possibly a few metres higher than it is at present and a powerful, constructive south-easterly swell was the dominant component of NSW wave climate. At that time these waves were helping to move large volumes of sand both alongshore and onshore to form the mix of beach and dune sands that are preserved today, at least on the North Coast, as the Inner or Pleistocene barrier.

With the onset of the last Ice Age or Glacial, sea level fell until it was approximately 130 metres below its present position. This left the Pleistocene barrier stranded inland and part of the continental shelf was transformed into a coastal plain. For most of NSW the coastline was several tens of kilometres seaward of its present position. Coastal rivers were flowing out onto the shelf and depending on catchment characteristics were delivering sediment to the coastal plain. Coastal headlands were less prominent, facilitating longshore sediment transport.

Climatic warming at the end of the Glacial prompted sea level to rise until about 6500 years ago when it was close to its present position. The rapid rise in sea level, in conjunction with the prevailing south-easterly swell regime, prompted more onshore and longshore movement of large amounts of sediment to form an Outer or Holocene barrier. These most recent barriers generally ceased development around 2000 years ago when transport of sand from the continental shelf apparently ceased.

As there is little additional sand being supplied to the coast today, only a relatively small, finite amount is available to form beaches and dunes. At many localities the limited supply of sand, combined with strong longshore sediment transport, has resulted in a reversal of the Holocene phase of sediment accumulation to one where the shoreline is steadily receding. On much of the North Coast, for example at Broadwater near Evans Head, waves are now reworking Inner Barrier sediments.

Many landscape variants have developed within this very generalised scenario. Thom et al. (1978) distinguished several different types of barriers based on their distinctive landforms and underlying sediments. Subsequent research has attempted to explain these variations primarily in terms of sediment supply and embayment and continental shelf characteristics. At the broadest scale, a much greater abundance of sediment is thought to explain the much more prolific and complex barrier development that has occurred on the North Coast.

2.3 Coastal processes

The prevailing force shaping the NSW coastline is wave energy. Waves, in conjunction with surf zone currents are primarily responsible for the recurrent cycle of erosion and recovery of our beaches.

The NSW wave climate is characterised by a powerful, constructive southeasterly swell regime. These high-energy waves are generated by storm depressions passing to the south of Australia. Larger waves moving northwards into the Tasman Sea eventually reach the NSW coast after travelling many hundreds of kilometres. This wave regime is responsible for producing the depositional shorelines seen today and for the world-renowned surfing environment.

Other waves are superimposed on this background swell. They include waves from the east and north-east generated by tropical cyclones in the Coral Sea, shorter waves from the same direction generated by onshore sea breezes, and high energy storm waves that arrive primarily from the south. The latter are generated by more localised storm depressions (East Coast Lows) in the Tasman Sea. Easterly waves are also generated by slow-moving Highs in the northern Tasman Sea (Short 1993).

When data on wave height, period and direction are combined, it is apparent that deep water waves from the southeast and south account for approximately three-quarters of the energy reaching the NSW coastline.

The tidal regime of the NSW coast is semi-diurnal, with two high tides and two low tides in just over 24 hours. It is also micro-tidal, with a difference in elevation between mean low tide and mean high tide of only one metre. Even at Full and New Moon (Spring tides) the difference is only two metres.

Combined with the relatively steep inshore gradients this means that wave action is generally concentrated within a fairly narrow elevational range.

Waves are crucial in stirring up sand in the nearshore and in generating currents in the surf zone. In deep water they have little interaction with the seabed but as they approach the coast, friction begins to slow them down and they become increasingly capable of moving sediment. Variations in direction of wave approach, combined with irregularities in sea floor topography results in refraction or bending of wave crests and this in turn initiates variations in energy levels received along a shoreline. At many localities along the NSW coast, the southern ends of beaches have significantly lower average wave energy levels that are matched by narrower surf zones and beaches, and lower berms and dunes.

On breaking, the waves are able to move sediment shorewards but they also cause a piling up of water against the beach called wave setup. This landward movement of water is balanced by undertow and rip currents that move sediment seawards beyond the line of breaking waves. Also, when waves approach the shore obliquely, longshore currents can be generated within the surf zone, driving water and sediment parallel to the shore. The direction and strength of movement changes according to the direction of wave approach but on the North Coast in particular there is a prevailing nett longshore sediment transport to the north.

During calm weather waves run up the beachface towards the berm crest (Figure 2.1). However, under storm conditions the water level adjacent to the beach can be much higher allowing storm waves to break further up the beach. This increases their potential to erode the beach and dunes.

Estuaries also have an influence on sediment movements in the coastal zone, particularly during floods when sediment is flushed from coastal rivers into the nearshore. This sediment is predominantly fine mud or silt, but marine sand from the lower portion of the rivers may also be flushed out. After floods, wave and tide action will move sand back into the river entrances, but the silt and some of the finer sands can be carried so far offshore that they are lost permanently from the contemporary coastal system.

2.4 Beaches

Beaches are accumulations of wave deposited sediment and for the purposes of this manual, discussion is necessarily restricted to sand beaches. On oceanfront beaches in NSW, high wave energy precludes deposition of very fine sediments such as silts and clays within the surf zone. However they are found in some beaches within sheltered estuarine environments, as well as in deep water offshore on the continental shelf. Cobble and boulder beaches are not uncommon on rocky shorelines but dunes are not developed from these deposits. Some only become visible after very severe storms have stripped away the beach and dune sands that may overlay them.

Sandy beaches are one component of a larger dynamic coastal system that begins offshore in water depths often greater than 20 m and extends landward to encompass the nearshore bars, the surf zone, the beaches themselves and the adjoining dunes. As waves approach the shore from deep water they progressively interact with the sea floor, slowing down and losing energy. The most dramatic changes occur in the surf and swash zones where breaking waves and subsidiary currents are continually mobilising nearshore and beach sediments.

Beach changes within this dynamic system are cyclic. Storm waves move sand from the beach and dune to build storm bars. Subsequent calm weather favours onshore movement of the sand to re-establish the beach, and prevailing onshore winds blow sand beyond the beach where it can be held by surface vegetation to create stable dunes. Short-term fluctuations of the shoreline are often quite dramatic and may mask long-term accretion or recession that occurs at much slower rates. The difference between short-term erosion and long-term recession is illustrated in Figures 2.3 and 2.4.

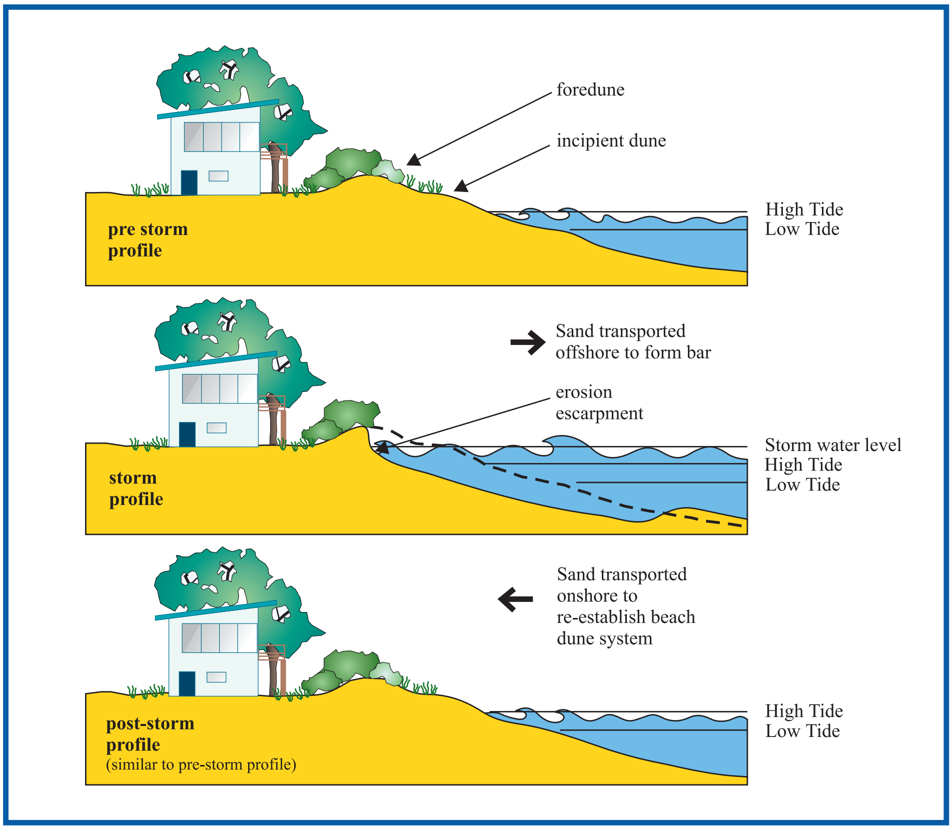

Figure 2.3 Beach erosion/accretion cycle - no permanent sand loss or shoreline retreat.

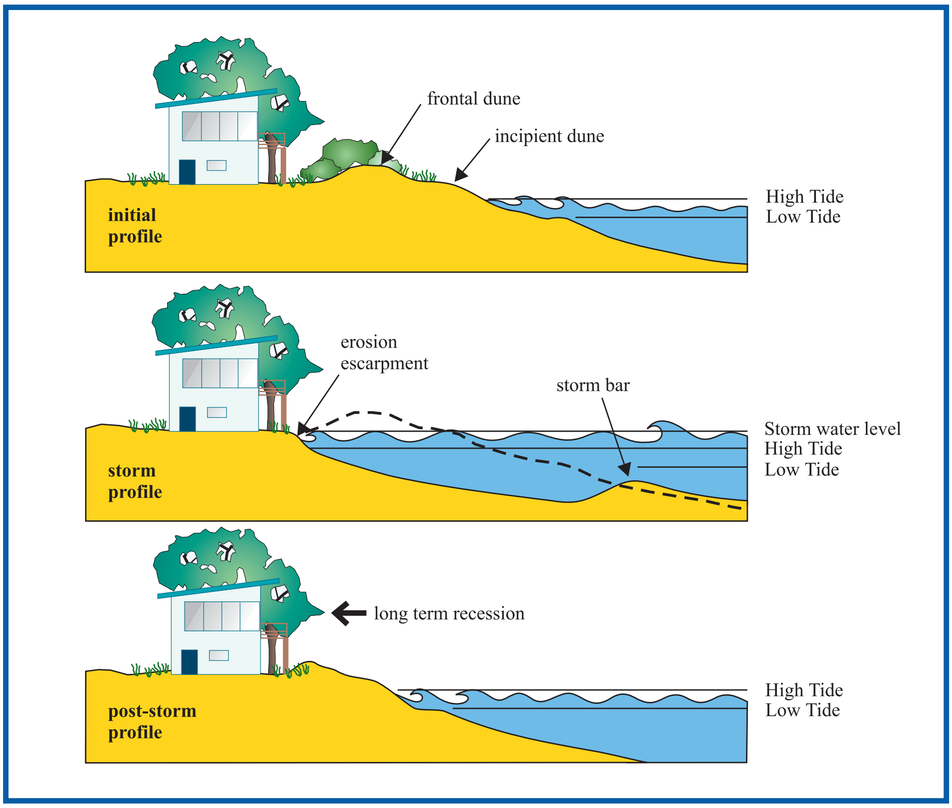

Figure 2.4 Long term beach recession - profile displaced landward due to permanent sand loss.

Whether long term recession occurs depends primarily on the state of the sediment budget for a particular part of the coast. Coastal sediment compartments can gain and/or lose sediment from several sources (Figure 2.5).

If the losses persistently exceed the gains, then the depositional shorelines within that compartment must recede. This situation prevails at many North Coast beaches.

For example, recession may result from persistent landward movement of sand due to dune instability. Similarly, a shoreline can recede where sediment inputs are reduced by dredging, sand extraction, or installation of shoreline structures such as entrance training walls. Recession could also be initiated by a prolonged rise in sea level and by increased storm frequency and intensity. Both these phenomena are predicted to occur as a consequence of global warming (the enhanced Greenhouse Effect).

In contrast, beach systems grow seawards in compartments where sediment inputs have substantially outweighed losses. Jetty and Boambee Beaches at Coffs Harbour and Letitia Spit at Tweed Heads are examples of where this phenomenon has occurred since breakwater construction interrupted longshore sediment transport, effectively trapping large volumes of sand within these compartments.

Beach sands vary considerably both in size and composition. Grain size especially is an important factor in determining the type of beach that is most commonly observed at any locality. Quartz is the most abundant mineral constituent at most NSW beaches, often making up more than 90% of the sand grains. These deposits are therefore often referred to as siliceous sands (see Section 2.6.1).

Calcareous material such as shell fragments is often an important secondary component and at some sites close to rich shell sources, it may be the predominant component. Where high concentrations of calcium carbonate are also preserved in nearby dune sands, the resultant high pH (alkalinity) is a significant factor to be considered in dune revegetation projects.

Other beach sand constituents include the heavy minerals such as rutile, zircon and ilmenite. The large concentrations of these minerals in many beach and barrier deposits north of Newcastle has sustained a mineral sand mining industry for several decades. After severe storms, thin layers of these dark minerals are often visible in the eroded faces of beach dunes, and often mantle the back-beach surface.

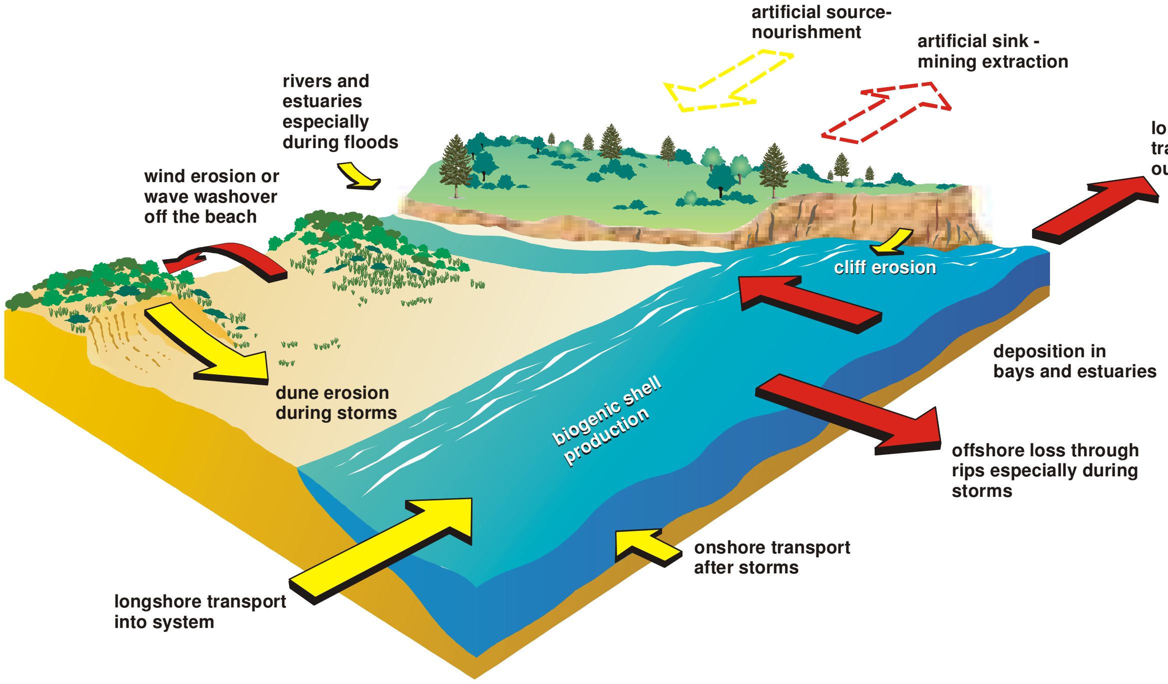

Figure 2.5 Model sediment compartment showing potential sediment inputs and losses.

Near headlands, weathering and erosion of bedrock delivers small volumes of rock fragments to the beach but overall this is a minor component of NSW beach sand. It should also be noted that with a few exceptions, NSW beaches do not receive sand-sized sediment from the coastal rivers. The overwhelmingly dominant constituents are well-rounded, often iron-stained quartz sands that have survived many thousands of years of reworking by wave action.

Beaches can be classified according to their "beach type"- the prevailing characteristic form and dynamics of the beach itself and of the adjoining surf zone. For a micro-tidal coast such as NSW, Short (1993) categorises beach types as dissipative, intermediate or reflective - a continuum representing the interaction of wave height, wave period and particle size. Seventy percent of NSW beaches belong to the intermediate category while 30% are reflective.

Dissipative beaches represent the high-energy end of this continuum. They are characterised by larger waves and finer sands with gentle beach and nearshore gradients, wide surf zones and multiple nearshore bars. No NSW beaches consistently match this type although many beaches approach this state during storms.

Reflective beaches are typically narrow with coarse sands, steeper gradients and no surf zone or nearshore bar. They are restricted to low-energy environments such as sheltered, semi-enclosed bays or the strongly protected southern ends of some ocean beaches.

Intermediate beaches are the most common beach type in NSW and are characterised by a surf zone with rips and bars (Figure 2.6). While this dominant beach type reflects the combined prevalence of fine to medium grained sands and moderate to high wave energy, there is sufficient variation to define four "beach states" within this overall beach type. They are the Low Tide Terrace, Transverse Bar and Rip, Rhythmic Bar and Beach and Longshore Bar-Trough; representing another transition from lower to higher energy environments (Short *ibid*).

Figure 2.6a Transverse Bar and Rip morphology, Cudmirrah.

Figure 2.6b Longshore Bar and Trough morphology, Lake Cathie.

While these terms are usually assigned to a particular embayment according to the most commonly occurring conditions, beaches also respond to changes in wave energy by progressively developing features characteristic of other beach states (Figure 2.7).

During erosion episodes for example, surf zones widen, rips strengthen and beach gradients are flattened as sand is moved offshore to form bars - a general shift towards a dissipative condition. The extent of these changes depends primarily on the severity and duration of storm conditions.

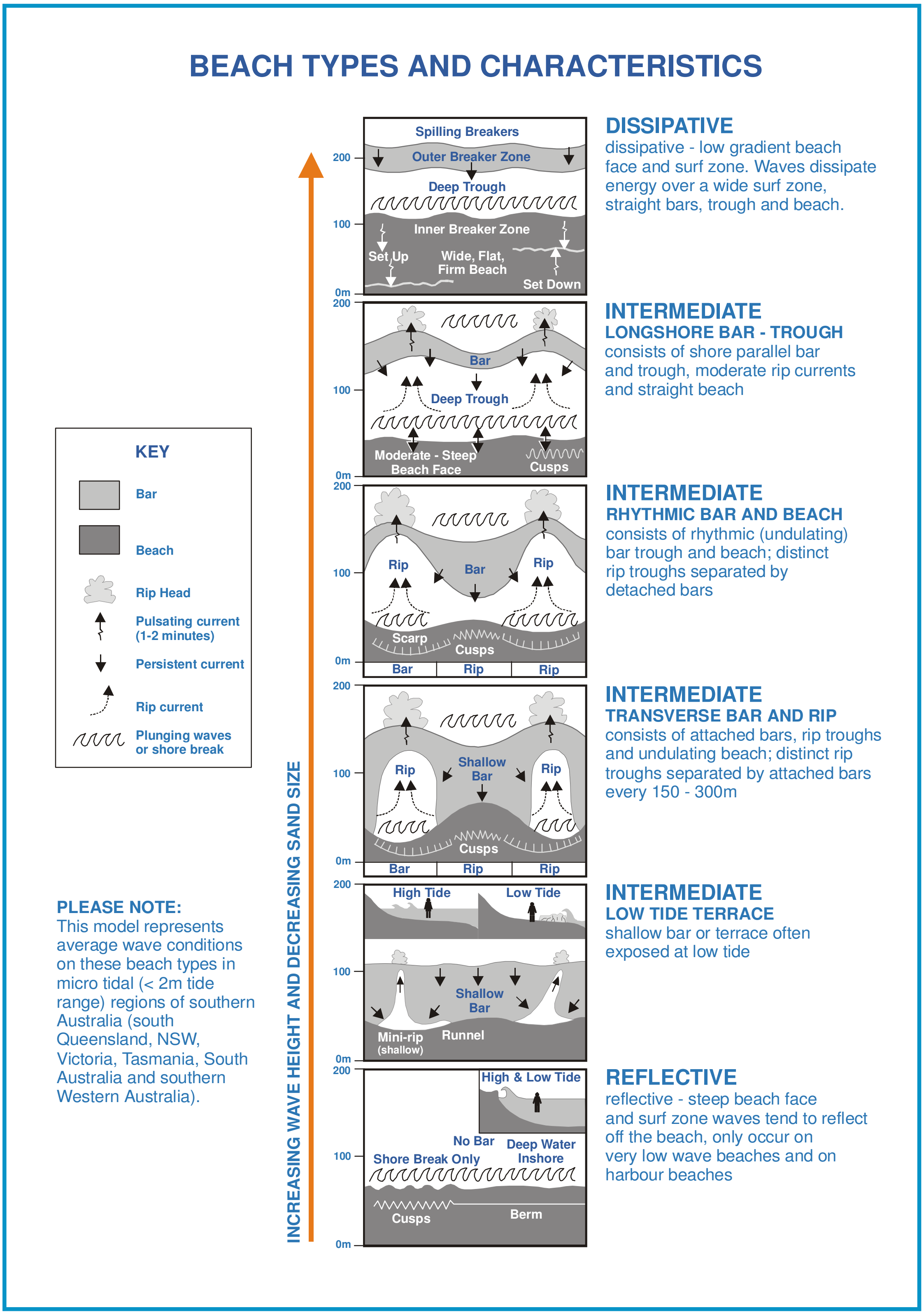

Figure 2.7 Beach types and characteristics (adapted from Short and Wright 1984)

2.5 Coastal Dunes

Coastal dunes are accumulations of wind blown (aeolian) sand located behind the beach. Near their seaward margins aeolian deposits are intermixed with wave deposited beach sands but as distance from the shore increases, wind action becomes the dominant force. The nature and extent of dune development at any location is governed by a number of factors including the amount and size of sand currently being supplied to the beach itself, patterns of wind strength and direction, embayment topography and orientation, and the type of beach. Other factors being equal, dissipative beaches with finer sands and more gentle beach gradients are more conducive to wind blown sand transport and growth of dunes.

Typically, an undisturbed beach will be backed by a foredune (also known as a frontal dune) and hind dunes. During a prolonged accretionary phase such as occurred during the 1980s and early 1990s there might also be an incipient foredune immediately seaward of the established foredune. An incipient foredune is a small bench or platform of windblown sand at the rear of a beach. During accretion dominant phases these can grow rapidly, both upwards and seawards and are progressively colonised by grasses and creepers. Hesp (1984) describes several main variations in their method of establishment. Their seaward margins are attacked intermittently by storm waves and in major erosive episodes they are often removed completely.

Vegetation cover is a crucial element in the evolution of dune landscapes (see Section 2.8). Wind velocity is generally reduced by plant cover, encouraging deposition and trapping of wind borne sand. However it may also accelerate locally in gaps between plants, especially those having a clumpy form. Where erect plants like Marram Grass (*Ammophila*) or Bitou Bush (*Chrysanthemoides*) predominate, a more hummocky dune surface is likely to develop compared to sites where a carpet of low, spreading plants like *Spinifex* or Beach Morning Glory (*Ipomoea*) prevail.

The established foredune lies between the incipient dune and the hind dunes. They are a more massive and persistent beachscape feature although their attack by waves during severe or prolonged storm episodes is a naturally recurring phenomenon. Their size, shape and stability are also controlled strongly by vegetation cover. Woody shrubs and trees typically dominate the seaward and landward slopes respectively although species can vary according to local conditions (see Chapter 6 and Clarke (1989a) or Chapman 1989). In embayments that have a limited sand supply or are suffering long term coastal recession, narrow dune fields are typical and often consist only of a foredune. In broad, shallow embayments where there has been an abundant sand supply, beaches and foredunes may have formed successively over several thousand years to form a beach ridge plain. These ridges lie more or less parallel to the coastline and may extend several kilometres inland. Plant successions and time-dependent trends in soil differentiation are well developed on these plains.

Without the stabilising effect of vegetation, sand is easily moved by the wind and the resultant sand drift can progressively bury both natural and built environments. Weakening or destruction of foredune vegetation can be induced by natural events such as drought, lightning-initiated fires or storm waves, and by disturbance due to a variety of human activities, including trampling, and introduction of weeds such as bitou bush.

Very localised disruption of vegetation on a foredune may result in formation of a blowout, whereby strong onshore winds extend a tongue of sand inland, beyond the general line of the remaining vegetated frontal dune (Figure 2.8a). A blowout is usually “U” shaped and aligned away from the direction of strong winds. When blowouts form, a lowered section of the foredune acts to concentrate and funnel wind, increasing its velocity and its sand transport capacity. Consequently the blowout becomes deeper and with the gradual collapse of the sidewalls, it can become a significant landscape feature as well as a loss to the coastal sediment compartment.

Some blowouts may extend landward in elongated fashion bounded by prominent trailing sidewalls - these features are often referred to as parabolic dunes. Air photographs of the NSW coast reveal the presence of older but currently stable, vegetated parabolic dunes that are indicative of other episodes of dune sand mobilisation earlier in the Holocene.

A much greater degree of disturbance may result in more widespread sand movement and the development of transgressive dune sheets. These are very large areas of bare sand upon which a variety of dunes more commonly found in desert environments can form (Figure 2.8b). Direction of sand movement often varies with seasonal changes in wind direction.

Fig. 2.8a Foredune blowouts, Myall Lakes

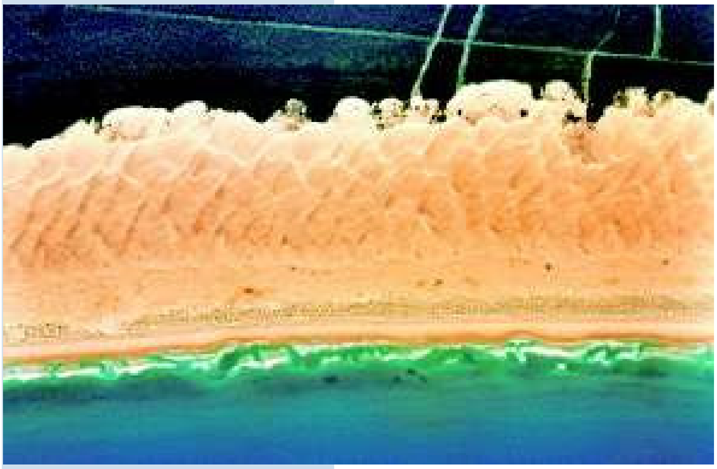

Fig. 2.8b Northward moving sand sheet with eastward moving surface dunes, Stockton Bight.

Natural dune formations are normally found only in areas away from major population centres. In and around many large towns and cities, growth pressures have resulted in dune systems being completely covered by development. Developments sited on top of the foredune, with only a sand slope down to the water level, restrict the amount of sand freely available to the active beach system and are at risk of being undermined during storms. Where seawalls have been constructed seaward of the frontal dune, sand in the hind dune area is completely alienated (eg. Bondi Beach).

In some situations, the lack of a dune to act as a natural buffer to wave and wind action and to provide a sand source for the beach can result in the beach being lost from time to time and development threatened, unless long-term maintenance is carried out. Nourishing the beach with sand brought in from another source is one method of long term maintenance in these circumstances.

2.6 Dune soils

Despite a relative uniformity in parent material, soils developed from unconsolidated littoral sands are usually quite fragile and may be quite complex. These differences are reflected in the variety of vegetation communities that occur. At the start of any dune rehabilitation program an examination of soil types and environmental conditions is essential to identify any special characteristics that may be present. Techniques used in revegetation can then account for soil properties once the relationships between plants and soils are understood.

Soils developed on littoral sands reflect the various soil-forming factors that operate near the coast. These factors are climate, parent material, topography, vegetation and time. They are not independent; they interact closely to produce the resultant soil. Their influence can be seriously interrupted by external factors such as grazing, repeated burning of vegetation, clearing, extractive industries, sewage disposal and other disruptive land uses. If vegetation is to be established permanently as part of a dune rehabilitation project and have continuing low maintenance requirements, it is important, where practicable, to reproduce the natural soil environment as closely as possible.

2.6.1 Soil types

The soils of depositional shoreline environments in eastern Australia are derived from marine sands. These are predominantly quartz (siliceous) with minor (generally less than 10%) amounts of heavy minerals such as rutile and ilmenite, and small lithic fragments. Three major soil types are readily distinguished - siliceous sands, sand podsols and acid peats (Charman and Murphy 1991). As a general rule soil profiles are better developed with increasing distance from the sea (Figure 2.9).

Siliceous sands are essentially deposits of quartz sand that make up the beaches and frontal dunes. With the continual reworking of beach sands by wave action, there is no opportunity for profile differentiation. Even in the frontal dunes there has been so little time for soil forming processes to work that the only profile differentiation likely to be detected is the presence in vegetated areas of a thin, light grey horizon of decayed organic matter.

These sands are usually fawn to creamy grey in colour and are loose with no soil structure. They are free draining, have a low water holding capacity and are very low in nutrients. Quite often these sands are utilised in dune reconstruction. It is important that when they are used for this purpose they be given time to consolidate before revegetation. Initial percolation by rainwater or irrigation after placement will reduce salt levels but as the sand compacts, porosity will be reduced and the moisture retaining capacity will be increased.

Dune sands located further from the beach are likely to have been undisturbed for much longer and will support much more advanced plant communities, often with tertiary tree species (see Chapter 6). Leaching by rainwater of dissolved organic and mineral elements down through these well-drained sands allows recognisable sand podsol soil profiles to develop. These feature a deeper organic A_1 horizon at the surface, beneath which a lighter A_2 horizon grades into the relatively unaltered parent sands. Within young, wooded dune fields, organic horizons may be even better developed at the bottom of inter-dunal depressions or swales. These basins are ready collectors of organic debris washed into them by surface flows during storms, particularly soon after bushfires have destroyed much of the ground cover. The water table is also generally closer to the ground surface at these sites. In some cases, it may be so persistent and organic accumulation rates so great that acid peats develop.

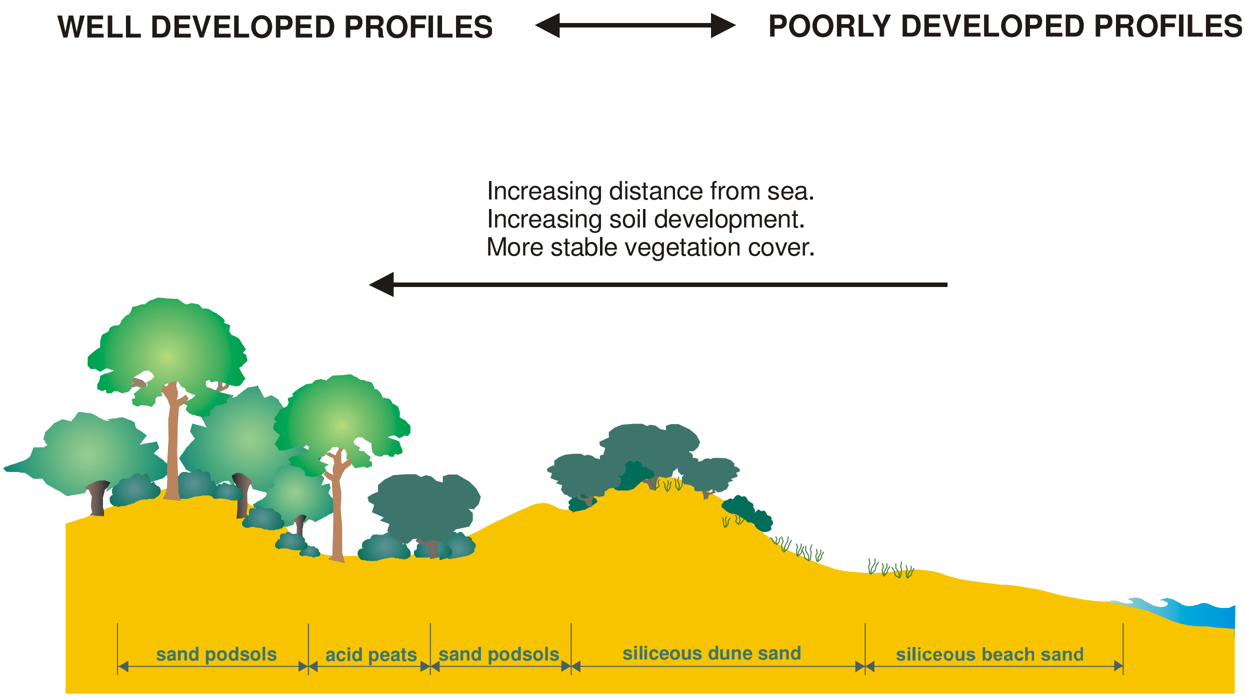

Figure 2.9 Schematic representation of soil types within a coastal dune system

Where good drainage exists however, and sufficient time has passed for substantial woody vegetation cover to become established, the profiles of sand podsols become more differentiated. These are also acidic soils but have been subjected to stronger or more persistent leaching. A grey organic surface A_1 horizon is easily recognised, beneath which a whitish A_2 horizon more sharply overlies an orange coloured B_2 horizon (Figure 2.10).

Figure 2.10a Immature sand podsol in Outer Barrier dune sand (c.2000 yrs) with little profile differentiation.

Sharpest profile differentiation is evident where Pleistocene Inner barrier sands are present. At these sites there are usually very sharp boundaries between soil horizons and the colour differences are quite stark. Most obvious is the white, bleached A_2 horizon; at some sites the silica concentrations are so pure and so thick, that they are mined to produce glass. Underlying B_2 horizons are typically dark brown, containing high levels of organic colloids and iron oxides known as humate. Often, fluctuating water tables can produce such high concentrations that the uppermost part of the B_2 becomes cemented into an indurated (hardened) pan known colloquially as coffee rock.

These hardpans inhibit water infiltration, affect water table levels and restrict root and air penetration. At disturbed sites where the overlying A horizons have been eroded or removed, revegetation can only be undertaken successfully if the pan is deep ripped and then covered with 300mm to 500mm of unconsolidated sand.

Within each of these major groupings there are innumerable minor variations in the physical and chemical characteristics of the soil. These result from differences in the soil forming factors such as elevation, drainage, slope gradient, aspect, distance from the sea, texture and composition of parent sands, vegetation cover, and the effects these have on leaching and the mobility of organic and mineral ions within the sand mass. These differences in turn generate differences in pH, fertility, moisture retention capacity and erodibility, all of which combine to support vegetation communities of varying floristic composition and structure.

Exceptions to the generality of Figure 2.9 should also be acknowledged. For example on a receding coastline undifferentiated siliceous sands may directly overlie well-developed podsols. The Department of Land and Water Conservation has prepared Soil Landscape Maps with comprehensive accompanying notes for many parts of the NSW coast. These provide valuable descriptions of soil, vegetation and landform assemblages.

Figure 2.10b Strongly differentiated podsol in Inner Barrier dune sand (>50,000yrs). Note the sharp boundary between the bleached A_2 horizon and the underlying B horizon which is enriched with organic matter and iron oxide.

2.6.2 Soil characteristics

Particle size, moisture retention and drainage

Most NSW coastal sands are fine to medium grained. At most sites, they are well sorted, with a relatively small range in particle size. Porosity is therefore quite high, which limits moisture retention capacity. In deep foredune sands, the high percentage of pore space facilitates free drainage, with any salt or nutrients present at the surface being readily leached down through the sand mass.

As vegetation becomes established, organic matter from the vegetation and associated fauna is incorporated into the surface of the soil. Moisture holding capacity is closely dependent on organic matter content and as time progresses, organic matter builds up and moisture-holding capacity increases. As a general rule, soils low in organic matter will also generally dry out more quickly. This has important implications for revegetating dune soils. Older dune soils have developed under vegetation over a longer period of time than younger sands to seaward and therefore have a higher moisture retention capacity. Field moisture capacity may vary from 7 per cent (by volume) in young dune sand to 33 per cent in old dune sand.

Soil Fertility

Soil fertility is governed by two factors: physical factors such as water availability, air porosity and structural strength, and chemical factors such as pH, nutrient availability, salinity and organic content.

Dune soils are generally considered to have low fertility. Their fertility decreases as the depth from surface organic layers increases. This restricts plant roots to the top horizons of the profile and increases the plant's reliance on frequent rainfall or on moisture stored by organic matter.

Although dune plants are well adapted to growing in low nutrient soils, and a few species may even be harmed by the application of inorganic fertiliser, revegetation programs generally benefit from the addition of fertilisers and mulch to assist in plant establishment and growth. The types and application rates of fertiliser used are discussed in Chapter 6.

Erodibility and erosion hazard

Erodibility is an intrinsic property of soil materials and refers to their potential for erosion. Grain detachability is the major determinant. For water erosion, moisture absorptivity is also an important factor whereas for wind erosion, surface roughness is more relevant. In addition to inherent erodibility, other site characteristics such as slope length, slope steepness and vegetation cover are used to predict the likelihood of erosion (erosion hazard).

Coastal sand dunes, by virtue of their mode of formation and their position, are susceptible to wind erosion. Grains are readily detached from each other and their shape, size and density aid movement by the wind. Sand drift resulting from wind erosion can cause considerable economic and environmental damage (Figure 2.11).

Figure 2.11 Sand drift at Anna Bay near Newcastle threatens both built and natural environments.

In contrast, unconsolidated dune sands, despite their non-cohesive nature, are not generally considered at risk of water erosion as their high water absorptivity reduces runoff and removes the potential for transport of detached grains.

However, at locations such as stormwater outlets, where large volumes of water are diverted to dune areas, the risk increases markedly since the infiltration capacity of the surface is readily exceeded. Runoff from concrete paths and car parks with impervious surfaces can have similar effects.

Erosion control

Control of wind erosion on coastal dunes relies primarily on maintaining a uniform protective cover of suitable vegetation. Mulch, synthetic aggregates or access control structures such as board and chain walkways can also limit wind erosion.

Impermeable surfaces that generate water runoff such as concrete paths, hard-topped roads and car-parking areas create management issues that need careful consideration. As a general rule flexible absorbent surfaces that are harmonious with unconsolidated sand are recommended for use in dune areas. Note that vegetation does not remove the hazard of stormwater erosion; developments must not concentrate stormwater runoff on dunes. Stormwater should be directed via erosion resistant surfaces to detention basins or other storage and treatment facilities (NSW Department of Housing 1998).

2.7 Climatic influences

Climate plays a crucial role in coastal landscapes generally and through wind, air temperature and rainfall it impacts either directly or indirectly on coastal dunes. Although the NSW coastal climate is generally temperate due to the moderating influence of the Tasman Sea, climatic parameters vary appreciably from North to South (Figures 2.12, 2.13, 2.14) and this has implications for dune stabilisation and rehabilitation projects. This is especially true for vegetation cover, with prevailing climatic conditions dictating both the naturally occurring range of plant species and the survival and growth of rehabilitation plantings. Additional climatic variability is also imparted by localised factors such as topography.

2.7.1 Wind

Wind directly influences waves, currents, water levels and sand transport and thereby moulds many coastal features into shapes that reflect wind strength, direction and duration. Coastal dunes are a specific expression of local winds. Local wind patterns also play a critical role in dune rehabilitation through their effect on plant establishment and survival.

The NSW coastline experiences an annual wind regime that features several distinct components. These result from the persistent west to east passage of High and Low pressure cells across Australia and the seasonal variations in their tracking latitude. The latter facilitate the ingress of warm, moist tropical air masses during summer and incursions of cold Southern Ocean air during winter.

In addition, localised differential heating of the land and sea generates onshore afternoon sea breezes and cool offshore early morning land breezes.

Figure 2.12 uses wind roses to illustrate the seasonal wind patterns for three stations on the NSW coast. The length of each bar on any wind rose is proportional to the frequency with which wind arrives from the nominated direction. The widths of the bar segments indicate wind strength. The diameter of the central circle in each wind rose is proportional to the frequency of calms.

It should be noted that these are long-term average values and that in any year there can be significant departures from the general patterns. Only afternoon values are shown as this is the time of day when winds are often strongest. Long term evening wind data are generally unavailable and while winds generally drop at night, strong storm winds that occur at that time escape inclusion in wind averages.

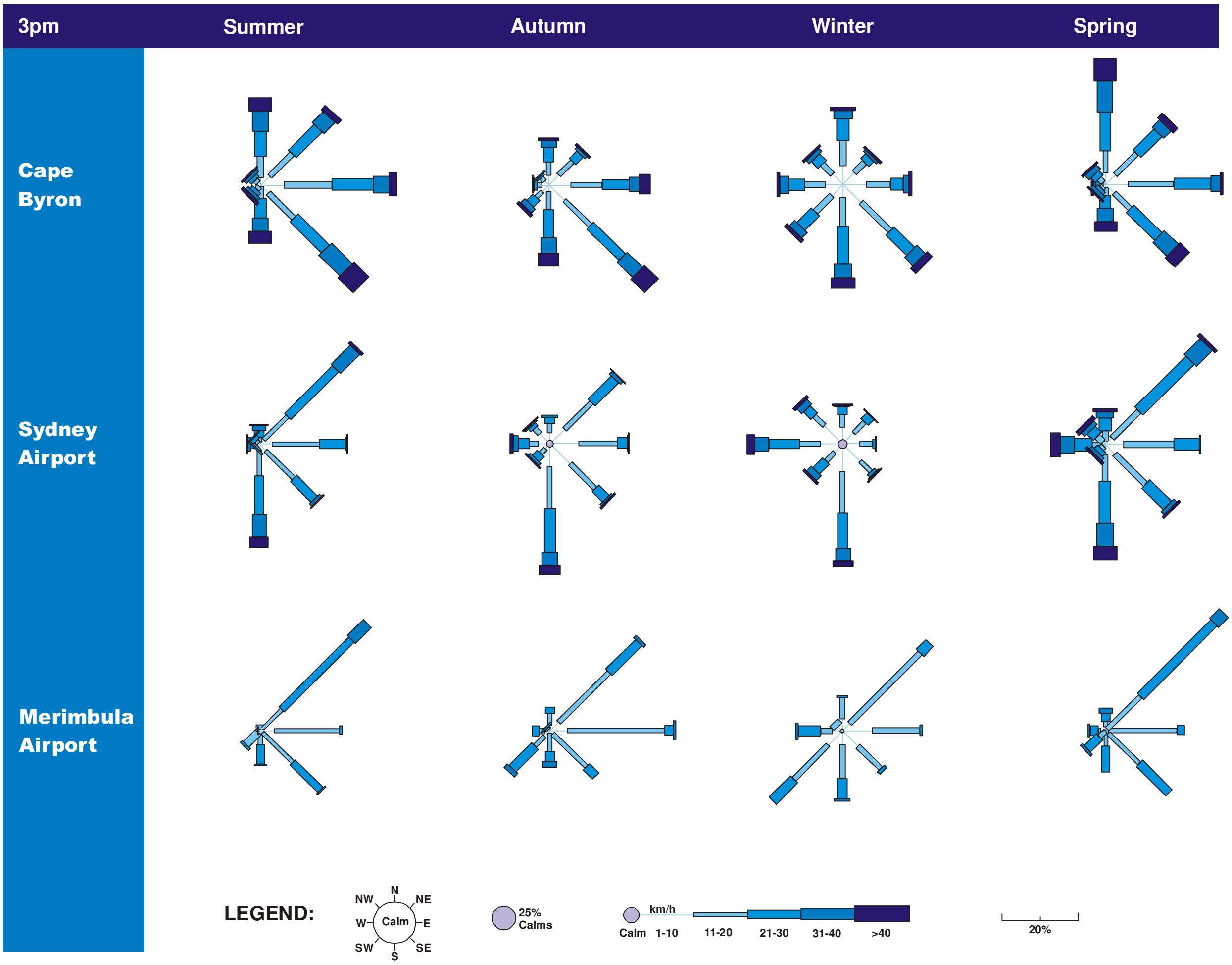

Figure 2.12 Seasonal wind roses showing afternoon wind patterns at three stations on the NSW coast
(Original data courtesy Commonwealth Bureau of Meterology)

It is also emphasised that the selected stations are indicative only. Other localities, even those close to the selected ones may experience different conditions. The Cape Byron station for example is located at a very exposed site 95m above sea level, on a headland that protrudes seawards well beyond the general line of the adjoining coast.

Winds are generally weaker during the morning and commonly blow offshore. Wind strengths increase during the day, typically to a late afternoon peak. Cape Byron is noticeably more windy overall (due in part to the elevation of the recording station) than the Central or South Coast.

Overall the stronger, more persistent winds arrive from the SE or NE. Because of the general alignment of the NSW coast this means that winds are usually onshore and this is reflected in the orientation of most foredune blowouts (eg. Figure 2.8a). This has implications for dune accessway alignments (see Section 4.7.3).

The wind rose suggests that southeasterly and southerly winds are important throughout the year at Cape Byron and Sydney respectively, but not as significant at Merimbula. It should be noted however that the Merimbula airport station is sheltered from southerly winds and the wind rose for that location may indicate a deceptively high proportion of northeasterly winds as a result.

Winds with a westerly component are generally more common during Winter and Spring when the anticyclones are following their northernmost tracks. They can be a seasonally important mobilising force on larger sand masses, such as at Stockton Bight on the central coast.

There are significant localised departures from these generalised patterns of wind and shoreline interaction. They result from variations in coastal alignment and topography and need to be incorporated in planning any dune rehabilitation project.

2.7.2 Rainfall

Rainfall along the NSW coastline varies in both amount and distribution. Average annual rainfall increases northwards, from around 750mm in the south to over 1900mm in the north. Byron Bay for example has an average annual rainfall of 1910 mm compared to 860mm at Eden (Figure 2.13). This is primarily a response to the moisture input from tropical air masses. At most localities rainfall is distributed fairly evenly throughout the year, although small late summer/autumn maxima are evident north from Sydney.

Rainfall is an important consideration for dune management as the higher and more reliable the rainfall, the greater the opportunity for vegetative growth to occur and for revegetation to succeed. Again, changes over time need to be taken into account, as prolonged periods of less than average rainfall are common and additional watering of newly established plants may be required. Prolonged dry periods also leave vegetation more susceptible to fire.

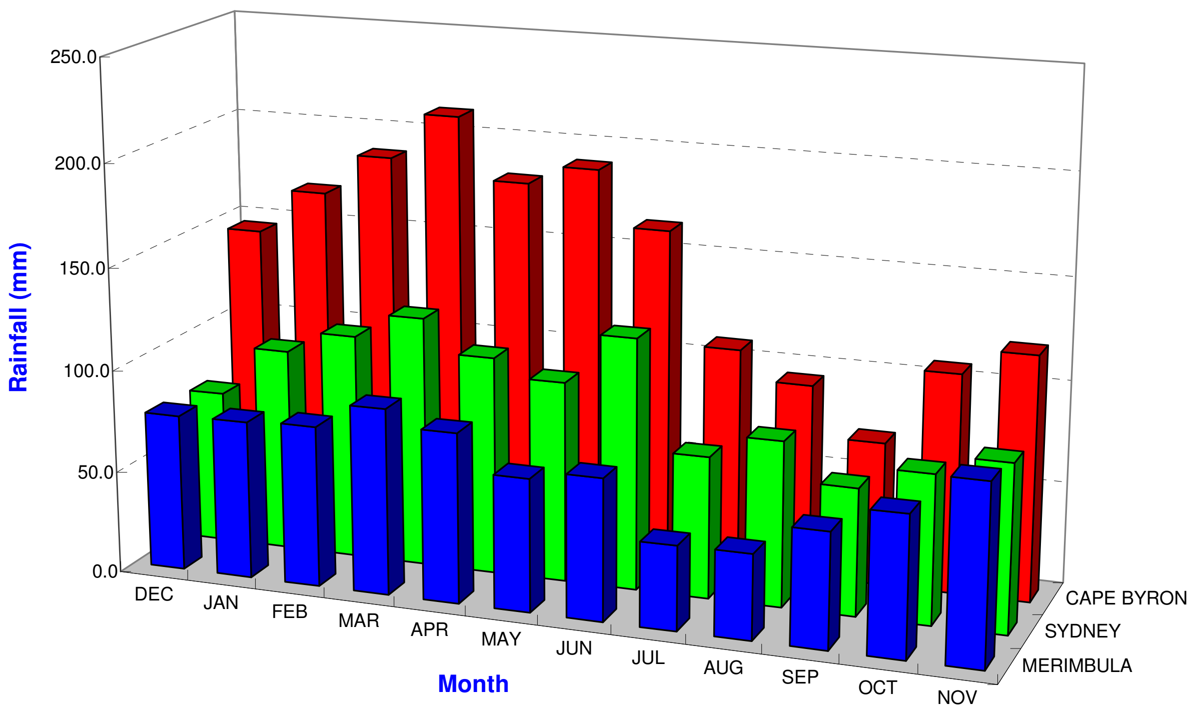

Figure 2.13 Variation in mean monthly rainfall along the NSW coast.
(Original data courtesy Commonwealth Bureau of Meteorology)

2.7.3 Temperature

Temperature also varies along the NSW coast (Figure 2.14). Both average monthly minimum and maximum temperatures increase northwards with mean monthly maximums at Cape Byron three to four degrees warmer than at Merimbula.

Temperatures peak in January/February while the coldest month is July, when frosts have been known to occur within grassed areas of foredunes on the Far South Coast. The daily temperature range is also greater in the south.

Temperature governs the time of year when dunes can be replanted. While there are grasses that can be planted throughout the year, the cooler conditions of autumn and winter are preferred for planting of shrubs and trees, since these enable the water requirements of young plants to be better met at this critical time.

Cooler temperatures in the south also result in later flowering times for many plants and thereby affect the timing of seed collection. Seasonal temperature extremes should also be taken into account when scheduling rehabilitation project work that requires hard manual labour, especially where volunteers are involved.

2.8 Vegetation, ecosystems and biodiversity

Native coastal vegetation is well adapted to withstand harsh conditions such as strong wind, salt spray and sand drift. For example, growth of some plants such as Spinifex (*Spinifex sericeus*) and Beach Fescue (*Austrofestuca littoralis*) is actually stimulated by sand accretion, while others such as Coastal Wattle (*Acacia sophorae*) can withstand slow, partial burial by developing roots on buried branches. However on highly mobile dunes, vegetation is lost as the dune moves and buries it. Loss of sand from the root area is generally fatal, and is a major cause of decline in dune vegetation.

Low nutrient levels have led to other adaptations. Plant leaves for example are very efficient collectors of salt spray. Coastal Banksia (*B. integrifolia*) has masses of fine proteoid roots that are very efficient in collecting whatever phosphorus is available, while Coastal Beard Heath (*Leucopogon parviflorus*) has bacteria growing in its root area that serve the same purpose. Peas and wattles can fix atmospheric nitrogen with the aid of bacteria in root nodules. Most plants grow in association with mycorrhizal fungi. These fungi act as extensions of the root systems and greatly enhance the ability of plants to use scarce soil nutrients.

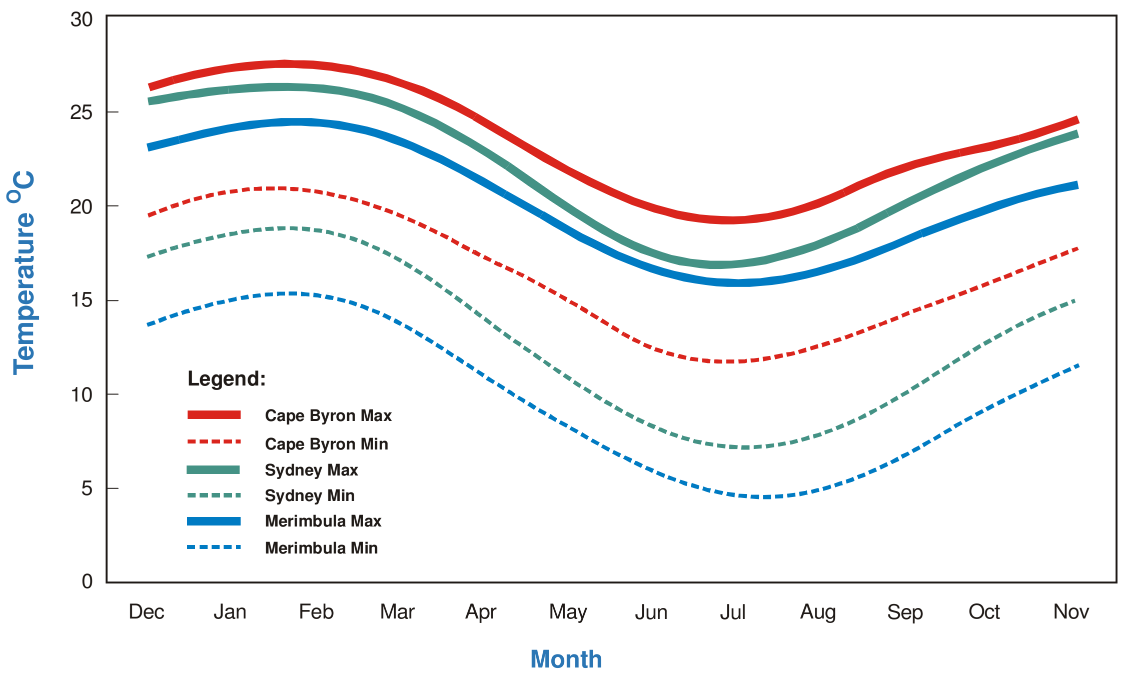

Figure 2.14 Variation in mean monthly coastal temperatures
(Original data courtesy Commonwealth Bureau of Meteorology)

The effectiveness of dune plants in stabilising dunes and resisting erosion has traditionally been seen as their main value. This perception has arisen primarily from the property losses and damage due to sand drift and later from recognition of the impact of unstable dunes on coastal sediment budgets and shoreline stability.

Dune vegetation is recognised widely as an integrated botanical system exhibiting interdependence in both community structure and floristics and providing food and shelter for a variety of fauna. The need to protect, maintain and restore these intrinsic ecosystem values is a key element in conserving biodiversity.

Conservation of biodiversity is a fundamental principle of ESD and provides one of the foundation stones upon which the NSW Coastal Policy was developed (NSW Government 1997). The priorities and actions for conserving biodiversity are described in the NSW Biodiversity Strategy (NSW National Parks & Wildlife Service 1999).

Successful implementation of this strategy specifically requires management of threatening processes by identifying, preventing and mitigating the causes of biodiversity loss. In the coastal dune environment this includes minimising modification of natural ecosystems, minimising habitat loss, and improving fire, weed and pest animal management.

Ecosystem rehabilitation and conservation of biodiversity are integral components of contemporary dune management.

2.8.1 Vegetation zonation

At localities where dune vegetation has not been disturbed significantly by human activity, distinctive plant zonation is routinely observed, irrespective of topographic differences (Figure 2.15). This plant zonation or succession reflects the progressively more sheltered environments that are created with increasing distance from the shoreline.

Although it is a continuum extending landward from the backbeach, three plant zones are usually recognised: primary, secondary and tertiary. Reproduction of this succession is a primary objective of revegetation projects (see chapter 6).

Figure 2.15 Vegetation zonation and canopy streamlining on different beach-foredune topography. Front Beach, South West Rocks (top) and Narrawallee (below)

An analogy can be drawn between the protection afforded by a well vegetated dune system and that of a well constructed and maintained cyclone-proof house. Primary zone species (grasses and creepers) colonise lower parts of the beach and trap abrasive sand particles forming a "foundation". The foredune represents an elevated "wall" that can be colonised by secondary zone species (mainly shrubs) to provide a wind deflecting "shutter" near the shoreline. Finally a "roof" forms from the growth of tertiary species (taller shrubs and trees), further elevating the wind and providing increased shelter to vegetation further inland. When exposed to persistently strong, salt-laden winds, remarkably streamlined canopy surfaces often develop (Figure 2.16).

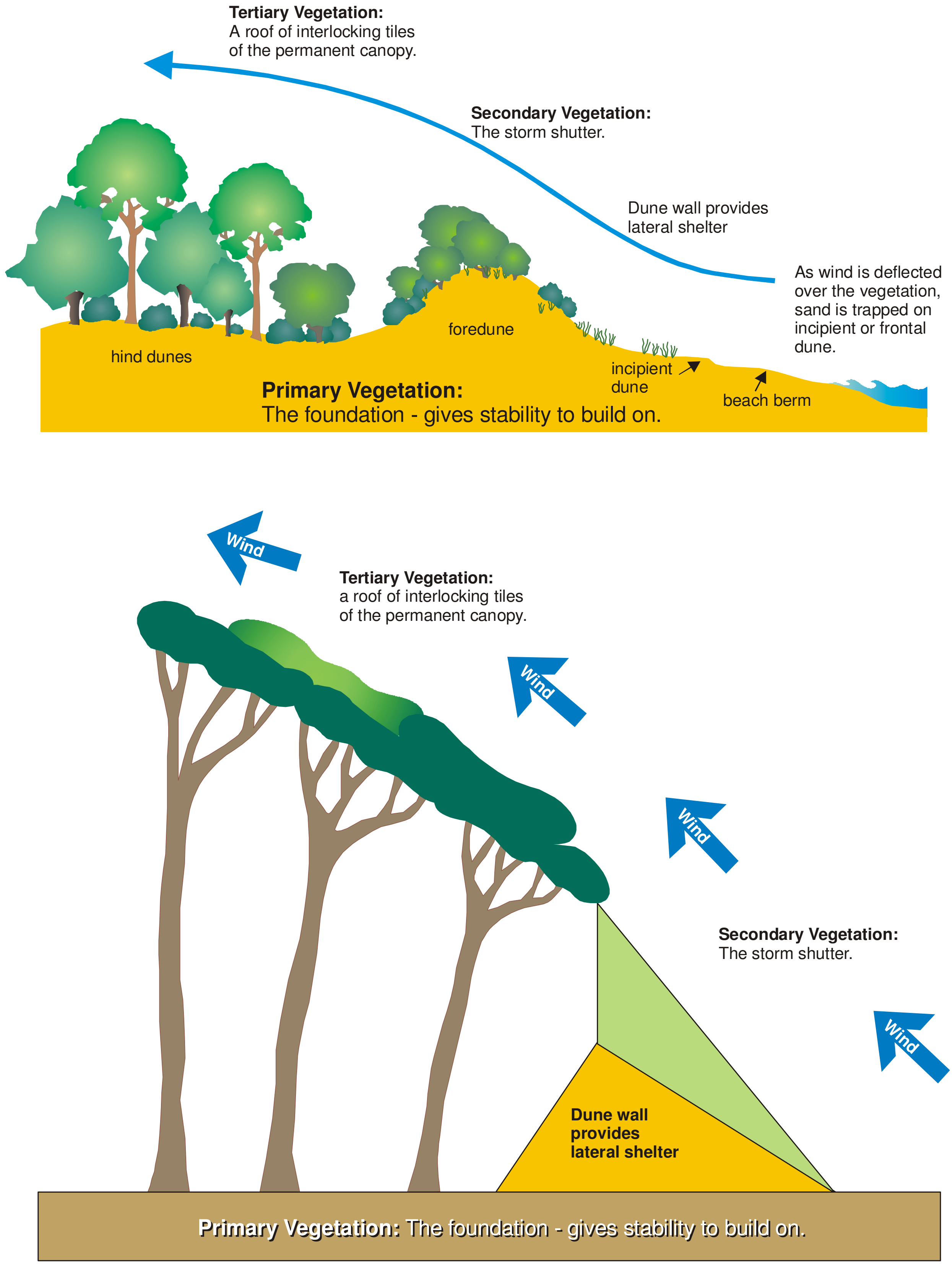

Figure 2.16 Functional model of dune vegetation - streamlining: analagous to a storm proof house.

While well adapted to withstand harsh conditions, native coastal vegetation is also fragile and easily damaged. Dune stability relies on keeping the whole structure - “foundations”, “wall”, “shutter” and “roof” - intact. Damage to any component can cause deterioration in other parts.

While the vegetation pattern described above occurs along the entire coast, the plant species contributing to it vary, primarily as a response to temperature variations. For example, Spinifex occurs right along the coast within the grass and creepers that characterise the incipient foredunes. However on the North Coast it is accompanied by Beach Morning Glory, whereas on the South Coast Beach Fescue is its partner.

Even greater variation in species prevalence occurs on the foredune and beyond as climatic and topographic controls interact in a much more complex manner (see Chapter 6). Significant variations may also occur within individual embayments. For example littoral rainforest species may only occur in a very small area where the combination of topography and climate provides a suitable environment.

Plants also provide habitat for a diverse range of fauna, from invertebrates (eg. worms, insects and crabs) through to reptiles (eg. skinks, snakes and goannas) and to birds and mammals. Like plants, the animal species occupying particular habitats also vary geographically.

2.8.2 Biodiversity

Biodiversity is the variety of all species of living organisms (plants, animals and micro-organisms), the genes they possess and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity (Commonwealth of Australia 1996).

Biodiversity provides all our food and the raw materials for a wide range of products including clothing and medicinal goods and the means to control pest plants, animals and diseases. It is highly valued for aesthetic, scientific, recreational and cultural reasons.

Australia is one of the most biologically diverse countries on earth with more than one million species of plants and animals estimated to occur. A large number of species is found nowhere else and there is a wide range of ecosystem types. This biodiversity combines with landscape to impart a special character of the coastal zone, producing an environment with which many Australians identify.

Biodiversity is threatened. Within NSW over 80 species of plants and animals are extinct and over 600 species are considered endangered or vulnerable. The main threats to biodiversity in the coastal zone are:

- the loss and fragmentation of habitat through clearance of native vegetation
- impacts of human activities on soil and water
- pressures caused by increasing population growth
- impacts of weeds and feral animals and
- inappropriate fire regimes

Protection of biodiversity requires consideration of an ecosystem as a whole; how different species interact with other species, with the non-living environment and with other ecosystems. For example, although many animals have fairly localised habitats, their mobility generally imparts complexity to dune ecosystems.

Ghost crabs establish deep burrows above high water mark on the backbeach and incipient foredunes, but feed on the open lower beach at night. Seabirds such as dotterels and pied oystercatchers commonly feed at the waterline but also fossick and roost above the high water line amongst the spinifex. Birds, reptiles and mammals that usually reside in dune scrub or woodlands often fossick amongst the grasses of incipient foredunes (Figure 2.17).

Figure 2.17 Dunes provide food and shelter for a variety of fauna including some listed as Threatened Species.

Mutton bird carcases along the strandline provide seasonal feasts for ravens that normally reside in the wooded areas beyond the foredune. Dead plants and animals also support decomposing bacteria and soil microfauna at the lower end of this coastal food chain.

It is important to recognise the links between the dune ecosystems and those of other coastal landscapes nearby. Beaches and dunes may host fauna that visit from nearby headlands, rock platforms and wetlands as they seek food and nesting material or take refuge during fires. The converse also occurs.

Coastal heaths for example, provide habitat for endangered species and are also important for migratory and nomadic nectar and insect feeding birds because they contain many plants that flower in autumn and winter, thereby providing a food resource generally unavailable elsewhere.

Clearly, disturbance of the foredune environment impacts adversely on both flora and fauna, with the potential to disrupt or destroy sensitive ecosystems. Littoral rainforests for example have suffered to the extent that remnants are now protected by State Environmental Planning Policy 26. Some individual plant and animal species are threatened with extinction and are protected by legislation. Examples include a Coastal Spurge *(Chamaesyce psammogeton)* and the Little Tern *(Sterna albifrons)*; Species Recovery Plans are gradually being prepared for those at greatest risk.

Figure 2.18 Chamaesyce psammogeton is classified as Endangered. It is threatened by storm waves, pedestrians, vehicles and Bitou Bush.

The return of native fauna to revegetated dunes is a rewarding indicator of an ecologically successful rehabilitation project.

2.9 Fire management

Naturally occurring fires are not considered to be a regular feature of the coastal dune environment. Relatively low fuel levels, humid conditions and absence of ignition sources preclude fires occurring in most circumstances. Most dune vegetation species are able to reproduce themselves in the absence of fire, and the development of littoral rainforests in hind dune areas indicates prolonged fire free periods.

All natural areas have a fire regime to which the native plants and animals have adapted over a long period. The fire regime for any one location is made up of three components, how often it is burnt (frequency), how hot (intensity and duration) and what time of year (season). Varying any one of these factors will produce changes in the plants and animals which occur at that location.

Some dunal areas appear to have been burnt too frequently with consequent changes in the vegetation and loss of species. Dune areas with thick swards of Blady Grass (*Imperata cylindrica* var *major*) and/or Bracken Fern (*Pteridium esculentum*) and an absence of trees such as Coastal Banksia can indicate a pattern of over frequent burning. Removing vegetation cover can also lead to dune instability and assist weed invasion.

It is recognised that active fire management may be required to reduce the risk of wildfire to life and property that has been built in the dune environment. Fire protection measures need to balance the requirements for hazard reduction and environmental protection. Any fire protection measures are required to be identified in bushfire risk management plans, and only measures approved in these plans are permitted.

While many strategies are available and will necessarily vary with local circumstances, both objectives can usually be met. This may mean establishing fuel free and/or fuel reduced zones immediately adjacent to property as opposed to repeated burning of larger areas. Construction of fire trails needs special consideration due to environmental and safety problems and should be avoided wherever possible.

2.10 Overview

This chapter has presented an overview of the NSW coastal environment; how it has evolved; the character of the main landscape elements especially the beaches and coastal dunes, the soil and vegetation assemblages they support and the environmental factors and processes controlling the diversity of these. Readers interested in further detail about any aspect are directed to the recommended references.

The first point to emphasise is that all the nominally discrete components of this complex coastal environment are part of an integrated biophysical system. They are all linked directly or indirectly with varying degrees of interdependency. Interference in one part of the system will initiate change(s) elsewhere. Some changes may be immediate and dramatic; others may have no obvious immediate consequence but may contribute to significant cumulative impact in the longer term.

The second major point is that successful dune rehabilitation projects need to acknowledge the dynamic nature of the coastal environment. Severe storms periodically erode foredunes, incipient foredunes are often removed completely, and it is likely that climate change will initiate more frequent disturbances of this nature. Recovery prompts changes too, but as a longer term phenomenon, it can generate a false sense of security amongst the unwary.

The third major point is the need to acknowledge the impacts of human activities. While many of these impacts are no longer accepted by many in today's society, dune rehabilitation cannot be undertaken successfully without addressing human needs and aspirations. The next chapter therefore reviews the social and cultural values of the coastal beach and dune environment so that they can be accommodated appropriately in future management programs that embrace the principles of Ecologically Sustainable Development.

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3. DUNES AND PEOPLE: Planning for working on the dunes

3.1 Introduction

While coastal dune systems have experienced recurring periods of natural stability and instability for thousands of years, present day instability at many sites is due primarily to human impacts at varying scales.

The NSW Coastal Policy (NSW Government 1997) states clearly that only developments which do not compromise the natural and cultural values of an area should be permitted on beaches and foredunes. It envisages only developments for essential public purposes.

However, there is still a wide range of other human activities that threaten these fragile landforms and their vegetation. The dilemma for coastal managers is that although dunes are extremely fragile landforms, they are an integral part of an increasingly popular community resource.

These demands can only grow as population growth, combined with new recreational pursuits reinforces traditional affinities for the beach. Accordingly, this chapter begins by identifying the main human interests and activities that may need to be considered when planning a dune rehabilitation project. This sets the scene for developing another of the major themes of this manual - the value of planning.

A carefully developed plan should lay the foundation for achieving successful rehabilitation and at the same time help to resolve conflicting expectations. An ad hoc approach may not achieve lasting benefits.

The principles addressed in this chapter are relevant to both government and community dune rehabilitation projects, and complement material contained in the booklet *Volunteers Working on the Coast* (DLWC 1997). The practicalities are reviewed primarily to assist community groups, but they are also relevant to council and state agency projects where active community involvement is likely. Discussion also seeks to improve all land managers' awareness of how some aspects of current management systems can frustrate community group enthusiasm for environmental rehabilitation.

3.2 Potential beach users and conflicting values

Use of beachfront land is likely to be the object of disparate views within a community. In planning any rehabilitation project it is essential to identify the different social and cultural values assigned to the beach system by a wide range of human users. If these values are not addressed properly then the project is almost guaranteed to face ongoing difficulties with less likelihood of success.

While most people will value a coastal area highly, their expectations may still conflict. For example, residents living adjacent to coastal dunes often incorrectly regard them as an extension of their own properties. The need to rehabilitate degraded native vegetation may be perceived by some as a potential threat to their use of the area. Successful revegetation also has the potential to restrict views. Alternatively, the land may have considerable cultural or spiritual value for local Aboriginal people as well as commercial development potential.

Broader community interest in rehabilitation and management of a coastal reserve will impact upon all these perceptions. This may result in real and unwelcome constraints such as restricted beach access or the exclusion of companion animals.

In short, people can assign different values to the same piece of land. Recognition of these differences is essential in minimising or avoiding conflict and encouraging community support for a project.

At the very least, residents and beach users need to be assured in their own minds that their needs have been carefully addressed. Where these have been judged incompatible with dune rehabilitation objectives, it is important that they understand why that position has been adopted.

Interested parties and activities that may need consideration at a nominated site include:

- the Land Manager (Council, DLWC, NPWS or private owner)
- general beach users (sunbathers, swimmers and surfers, including residents and visitors)
- owners of adjoining land
- indigenous people, either through active use of the site, or through a passive spiritual link
- surf Life Saving Clubs (patrols, rescue, training and competition)
- specialised recreational users (sailboarding, surf kites, jet skis, nude sunbathing, hang gliders landing from adjoining headlands)
- recreational and commercial fishers (beach hauling)
- off-road recreational vehicles
- commercial development
- commercial activities (horse and camel rides, eco-tours etc)

3.2.1 Indigenous aspects

Indigenous groups have traditionally lived and travelled along the coast for thousands of years. Their activities have included habitation, food gathering and hunting (especially fishing), burial sites and ceremonies. Coastal middens are the most common evidence of indigeneous use and occupation. Many areas are regarded as sacred and include ceremonial rain-making, food increase and initiation sites.

Indigeneous activities have occurred over many thousands of years, during which time Aboriginal society has had to accommodate environmental and social change. The National Parks and Wildlife Service (NPWS) maintains a register of Aboriginal sites. It also employs Site Officers to oversee them and to work with indigenous groups to protect and rehabilitate them.

Many Aboriginal people and groups are already involved in projects dealing with the problems that impact on the coastal environment. Projects include weed control, dune stabilisation, provision of access, protection of sites and archaeological investigation of indigenous use and occupation. They draw upon their traditional knowledge of the local coastal environment, how it changed with the weather and with the seasons, how it changed in response to European settlement. Their ancestors' survival depended upon that knowledge.

Much of the NSW coastal zone is affected by federal Native Title claims or land claims based on the NSW Aboriginal Land Rights Act. In some areas Native Title has been extinguished; in others Title has been granted.

Recognition of indigenous concerns together with respect for indigenous rights should be a high priority when planning or carrying out community or agency work in the coastal zone.

Funding programs such as Coastcare require evidence of consultation with the appropriate indigenous groups. In some areas it is important to be aware of divisions between those people who regard themselves as Traditional Custodians and those who are members of the Local Aboriginal Land Council. Often these two groups of indigenous representatives are the same but where this is not the case, care is needed to ensure that all stakeholders are consulted. Often there are Aboriginal people with a wealth of knowledge about the coastal environment who work independently of land council and other bureaucratic frameworks. Advice regarding these aspects should be obtained first from local offices of the NPWS.

Should any evidence of Aboriginal use or occupation be discovered during site works, on either public or private property, the National Parks and Wildlife Act requires that work cease and that the NPWS be advised of the discovery. Known or newly discovered sites cannot be disturbed without the consent of the Service.

3.2.2 Surf and Beach Safety

Beaches are primarily recreational assets especially near urban centres. During warmer months the intensity of public activity within an often dangerous natural environment has generated a need for supervision and control. This is provided by both volunteer-based Surf Life Saving Clubs and Beach Inspectors employed by local councils.

In some instances the preferred means of servicing beach safety needs may appear to conflict with dune management objectives, especially re-establishing a stabilising vegetation cover. It should be noted however, that Surf Life Saving Australia acknowledges the environmental sensitivity of coastal dunes and beaches and has adopted an "EcoSurf Code of Practice" (SLSA 1998). This code specifically encourages lifesavers to help protect coastal habitats and wildlife. ESD is also specifically included within the NSW Local Government Act that guides local government activities.

Three main functions need to be addressed when considering beach and surf safety:

- observation of surf conditions and guidance of bathers
- provision of First Aid and Rescue
- training and competition

The facilities needed to properly service these functions can often be separated, thereby significantly reducing the potential impacts on the sensitive dune environment (Figure 3.1). There are also many examples along the coast where expensive facilities have been lost or are threatened regularly by beach erosion and recession. The inappropriate siting of solid, all-purpose structures on frontal dunes can rarely be justified in light of current knowledge of beach and dune processes.

Observation towers to augment on-beach patrols are now routinely constructed in a variety of styles that are transportable and/or demountable. With sensitive siting they can fulfil beach patrol needs without impacting significantly on the dune environment.

Figure 3.1 Only essential surf life saving structures need to be located right at the beach. Other facilities can be located behind the dunes provided suitable beach access is provided.

Rescue and First Aid equipment and materials can be deployed readily on the beach itself. Space for backup equipment, other storage and servicing requirements can be provided away from the beach and dunes if suitable access to the beach is also provided and maintained.

Other Surf Club facilities such as training rooms, gym etc and public facilities such as toilets, showers, kiosks, picnic areas and car parking can also be sited behind the dunes provided there is appropriate beach access.

Surf competitions (surf life saving and board riding) can generate short-lived but intense pressure on beach space, especially if the beach is already unusually narrow following an erosive period. Encroachment upon the incipient or frontal dunes often occurs in these circumstances, with lasting damage. This can be avoided with better event planning and management (eg. use an alternate date or location), improved siting, construction and maintenance of dune fencing and beach accessways, and improved public awareness of the sensitive nature of the dune environment.

Dune rehabilitation proposals at heavily used, patrolled beaches must be developed with meaningful input and support from the local Surf Club.

3.2.3 Off-road vehicles

Vehicular use of beaches is a controversial issue within most coastal communities where it is still permitted. Where public facilities are provided, vehicular access is required to service emergencies, and effective Surf Life Saving patrols of longer beaches often depend on the use of quad bikes and four wheel drives. At some localities, beaches have a long tradition of off-road vehicle use, primarily by recreational and commercial fishers.

The NSW Coastal Policy recognises the use of vehicles in beach environments when such activity is approved under relevant legislation. However careful management of these activities is required to ensure that the practice does not compromise the ESD principles upon which the Policy is based (Figure 3.2). Geomorphic and ecological impacts on dunes include:

- Sand is moved down hill on bare slopes, lowering dune crests and infilling depressions. Blow-outs may occur where deep wheel ruts cross dune crests.
- Stabilising surface crusts in bare areas are destroyed, with resultant changes to sand temperatures, moisture levels and mobility.
- Physical damage to plants, both above and below ground.
- Impeded regeneration and growth of new plants that are particularly sensitive to disturbance.

Particularly significant impacts occur between high water mark and the established dune vegetation line, where pioneer plants grow and may be readily damaged or killed by vehicles. Biological activity is high in this area, often initiating development of incipient foredunes that are vital to the stability and growth of the entire dune system. Beach erosion may be much more severe if it is damaged repeatedly.

Vehicle impacts are probably most severe along the drift line where floating material such as seeds and driftwood is deposited. Pioneer plants such as sand spinifex and sea rocket (*Cakile* spp.) are most susceptible. Maximum germination of sand spinifex seed occurs on the upper portion of the backbeach at the limit of the spring tide drift line. The seaward growth of spinifex runners also extends into this zone. Lines of sea rocket seedlings commonly establish along the same drift line.

Vehicles also disturb or kill animals that use or occupy the beach environment. Insects, reptiles, migratory and resident birds and some mammals are commonly encountered on the backbeach and incipient foredunes. The Little Tern *(Sterna albifrons)* and the Pied Oystercatcher *(Haematopus longirostris)*, two threatened species of shore birds that lay their eggs in shallow scrapes in bare sand, are at particular risk from vehicles.

The beach itself, between high and low tide levels, also supports a diverse range of small organisms such as worms, shell fish, crabs and other microfauna. These are important in their own right and also support the many birds that gather on the lower beach to feed. Because they are concentrated in the uppermost 30cm of the beach they may also be at risk of being crushed by vehicles.

Other important environmental and social impacts are relevant to the use of vehicles on beaches. They are not addressed in this manual, but may warrant consideration at some localities when developing management plans for the beach environment.

Figure 3.2: Off road vehicles often have adverse impacts upon beaches and dunes.

In the context of dune stability, the principles for the management of vehicles are relatively straightforward:

- vehicles should be kept off vegetated sand dunes except at formalised beach access points.
- accessways should be adequately protected by board and chain or an equivalent surface to prevent dune lowering, development of blowouts and damage to adjoining vegetation.
- where a local community agrees that vehicles should be permitted on beaches, travel should be restricted to below high water mark to protect and encourage development of incipient foredunes. Speed limits and/or temporary closures may be needed to protect fauna and other beach users.
- when heavy seas remove considerable quantities of sand and travel is not possible at high tide, the beach should be closed until sand returns and an adequate beach width is restored.
- consideration might also be given to promoting more responsible off-road vehicle use with a permit system that requires demonstrated environmental awareness from permit applicants.

3.3 Planning

The value of thorough planning before committing any funds or commencing on-ground works cannot be over-emphasised. In essence planning means:

- defining the problem(s) clearly
- involving all stakeholders
- establishing achievable objectives
- developing strategies or actions that achieve projected outcomes
- incorporating these components within a specific project plan

Effective planning generates numerous benefits:

- everyone, whether actively involved or not, has or can easily gather a clear understanding of what is going to be achieved and how long it will take.
- the project is likely to complement rather than conflict with other local, regional or higher level plans and policies.
- project goals and costings are more likely to be realistic.
- mistakes, duplication of effort, and other unnecessary costs are avoided.
- projects are more likely to attract funding.
- project completion with optimal benefits is more likely.
- continuity is enhanced; changes in staff or group membership do not prevent project completion.

When planning a dune rehabilitation project, the following issues and questions need to be considered carefully:

- what has caused the instability or degradation? Is it a natural phenomenon or is it due to human activity? Are the causes still relevant? Is control justified? Is it feasible?
- does the land owner or Land Manager share the concern?
- what future pressures on or uses of the land are anticipated? Will the rehabilitated site be compatible with these? Are there related land use issues that need to be addressed?
- what are the broader community expectations for the site? To what extent can they be built into the plan?
- how can the community be involved in the project? What communication or awareness strategies are needed?
- is the project compatible with existing plans and policies?
- what specific work or actions are needed?
- what standards apply, especially for structures?
- how long will it take to complete the project?
- how much and what sort of maintenance will be required? Who will undertake it?
- what resources will the project need?
- what administrative requirements need to be satisfied?
- project documentation and record keeping.

More detailed comment on these points is set out in the following sections.

3.3.1 Identifying the problem

Dunes may be degraded physically and/or ecologically and it is important to understand the processes at work before targeting apparently degraded sites for stabilisation or rehabilitation. While bare areas of sand are readily identified, some may result from natural phenomena and intervention may not be justified. Intervention may even compromise the natural values and significance of an area.

Unstable dunes are naturally occurring landforms and periodic instability has been responsible for shaping much of the NSW coast. A few sites have remained naturally unstable for hundreds or even thousands of years. A prime example is Stockton Bight near Newcastle where a massive and topographically complex mobile sand sheet is valued highly for its geomorphic, conservation, aesthetic, cultural and recreational attributes.

Other areas that may not require or warrant intervention include the spits at river or estuary entrances and those protruding seawards in the lee of nearshore islands or headlands. These features often have accumulations of wind blown sand that are continually changing in response to the prevailing wave conditions. It is not uncommon for them to all but disappear temporarily after a severe storm or flood.

Attempting to stabilise or revegetate these deposits is unwarranted. Such areas support their own specialised ecosystems and trying to establish vegetation on such areas is not justified in an ecological sense. Disturbance of ephemeral washover areas near estuary entrances may also destroy Little Tern nesting sites.

Secondly, revegetation work and any accompanying infrastructure will eventually be destroyed by waves and if works are successful in limiting sediment transport, then there may be unintended beach erosion in an adjoining embayment due to interference with the sediment budget.

In these circumstances, management may best be limited to community awareness and monitoring. If however it is clear that a natural dune ecosystem has been degraded by human activities then rehabilitation is more readily justified, but the causes and impacts of instability should still be assessed carefully.

For physically degraded sites, rehabilitation may involve dune reshaping, fencing, accessway construction, signage and a community awareness program. For physically stable but ecologically degraded dunes, management may only involve weeding and measures to avoid future physical damage. In both instances a plan should be prepared so that rehabilitation is undertaken in an efficient and effective manner (see Section 3.4).

Expert advice should be sought to ensure that the problem and causes are identified correctly in relation to the processes at work at the site.

Discussion with long term residents of the area, examination of old photographs and other records at the local library will help to develop a picture of how a particular area has evolved over time, particularly the links that may exist between landscape changes and human settlement.

Aerial photographs of the NSW coast extend back to the 1940s for many areas - the availability of images can be checked directly with *Land and Property Information NSW* or via their Internet site (http://www.lpi.nsw.gov.au/). Regional DLWC offices often have comprehensive air photograph collections, as well as staff who may assist with technical appraisals of relevant sites. Local councils will often have many of these photographs too, and are increasingly investigating and documenting degraded sites as part of their annual State of Environment reporting responsibilities.

3.3.2 Consult the Land Manager

Having identified a problem the next step is to determine if anyone else shares that concern and is planning to address it. There is no point investing a lot of time and energy in developing a rehabilitation project if it is already being tackled by the council, another state government agency or a community group.

The first point of enquiry should be the Land Manager. This is most likely to be the local council or the Department of Land and Water Conservation (DLWC). In some cases it may be a Trust managing a Crown Reserve, it may be the National Parks and Wildlife Service or State Forests, or title may have passed to a Local Aboriginal Land Council. Alternatively the problem site may be undeveloped land that is owned privately by a company or an individual, in which case rehabilitation may be problematic.

Local councils maintain current details of land tenure and ownership in their property information systems, while information about tenure and management of Crown Land and of Aboriginal Title claims is available from Crown Lands Access Officers based in the Regional Offices of DLWC.

Consulting the appropriate land manager will establish quickly if anything is already being done or is planned in terms of rehabilitating the problem site. In the event that an opportunity exists for a third party to develop a rehabilitation project, the Land Manager will be ideally placed to facilitate that activity.

The Land Manager should be able to advise whether initial support can be given, pending submission of more specific project plans. He/she should be able to identify the range of activities that can be undertaken, the approvals that may be required, and the potential sources of funding or in-kind support that may be available within an organisation.

In projects driven by community groups, rehabilitation is invariably going to involve working on land that is owned and/or managed by someone else. Their rights and responsibilities must be respected and these are reviewed very clearly in *Volunteers Working on the Coast* (DLWC 1997).

3.3.3 Community consultation and participation

Strong community interest and involvement can generate a sense of stewardship that is invaluable in successfully completing and maintaining a dune rehabilitation project. To this end, rehabilitation planning must address the needs and expectations of all users, including local residents and visitors.

Both existing users of the site and potential stakeholders need to be identified (see Section 3.2) and their views determined. The earlier this occurs the more likely the project will attract sustained community support. Ideally, efforts will extend beyond basic consultation to having users help formulate and implement the project plan. The success of these efforts relies upon an effective community consultation exercise.

It is especially important to have local residents on side. They will tend to be more “possessive” of a site, especially if they are neighbours - land owners adjoining the targeted lands, and are therefore more likely to become actively involved in “hands-on” activities. They are also probably the ones who will eventually have a more direct interest in ongoing maintenance and in reporting and deterring vandalism.

Visitors’ needs and expectations should also be canvassed. Having travelled further, they are more likely to spend whole days at the beach and/or even longer periods during their holidays. Their expectations in terms of access and facilities and the recreational experiences that they are seeking may also differ from those of local residents. While the more remote users may be targeted indirectly through regionally based awareness programs, direct contact should be attempted at the time(s) they are most likely to visit the area, such as weekends or holiday periods.

Variations in usage patterns should also be considered. Beach hauling for example may only occur once a year for a short period when a target fish species is present.

Identification of future uses within at least a five-year time frame should also be attempted when developing the objectives of the rehabilitation project.

In short, any dune rehabilitation and management strategy should include a carefully planned procedure to achieve and maintain strong awareness and support within the broader community.

Techniques to achieve this include:

- the use of local media to publicise and promote the proposed works
- letter box drops in the beach neighbourhood containing informative advisory material, including progress reports
- public meetings and talks to specific community groups such as Service Clubs
- addressing local schools - this can reduce vandalism and help establish a lifelong appreciation of the coastal dune environment and the efforts of volunteers
- the correct use of signs. As a general rule signs should be polite, informative and directional (Chapter 4.8). They should conform with the land manager's requirements and they should appeal to people's better instincts.
- the use of temporary signs like sandwich boards to explain the purpose of the project when work is actually being carried out.
- ensuring that workers involved in the program are sufficiently aware of project objectives, methods and outcomes so that they can handle casual public enquiries.

Carson and Gelber (2001) describe the principles of community consultation and present a useful comparison of favoured consultation procedures. The merits of being neighbourly are also reviewed in *Volunteers Working on the Coast* (DLWC 1997).

Local community involvement has been an integral part of dune management over the last decade. Activities by Dune Care, Coastcare and Landcare groups working in partnership with local councils with assistance from state and federal governments have contributed greatly to the improvement of the coastal environment. Many rehabilitation projects would simply not have occurred without this community input.

3.3.4 Compatibility with other plans and policies

Local councils and state government agencies undertake coastal planning at several different levels. Any proposal to rehabilitate a parcel of coastal land should not conflict with those plans that have local relevance.

The NSW Coastal Policy (NSW Government 1997) is the umbrella policy for coastal management in NSW. In conjunction with the Environmental Planning and Assessment Act 1979 (EP&A Act) it guides local government in the planning and management of the coast and in works and activities impacting on the coast.

The policy has nine goals including:

- protecting, rehabilitating and improving the natural environment of the coastal zone.
- recognising and accommodating the natural processes of the coastal zone.
- protecting and enhancing the aesthetic qualities of the coastal zone.
- protecting and conserving the cultural heritage of the coastal zone.
- providing for ecologically sustainable development and use of resources.
- providing for ecologically sustainable human settlement in the coastal zone.
- providing for appropriate public access and use.
- providing for information to enable effective management of the coastal zone.
- providing for integrated planning and management of the coastal zone.

Copies of the Policy can be obtained from the NSW Department of Urban Affairs and Planning.

The Policy can also be accessed at http://www.coastalcouncil.nsw.gov.au. Given that this policy is based on ESD principles it is unlikely that properly formulated coastal dune rehabilitation projects will conflict with it.

Land use planning in NSW is implemented primarily through planning instruments such as Local Environmental Plans (LEPs), Regional Environmental Plans (REPs) and State Environmental Planning Policies (SEPPs). These instruments are prepared and implemented in accordance with the NSW Environmental Planning and Assessment Act 1979 (EP&A Act).

Each council has its own LEP that establishes land use zonings for all land within the local government area and the land uses that are permissible within each zoning. REPs and SEPPs are state government instruments and LEPs must be consistent with them. The NSW Department of Urban Affairs and Planning (DUAP) has prepared a useful review of the plan making process in NSW (DUAP 2001).

Development Control Plans (DCPs) may provide additional guidance about a council's requirements.

Practically all coastal land on which dune rehabilitation is likely to be undertaken is zoned for Open Space or Environmental Protection. The majority is Crown Land that is managed either directly by the Department of Land and Water Conservation (DLWC), by the local council under a Care and Control agreement, or by a Reserve Trust.

Some coastal land is also owned and managed directly by councils and is classified either as "community" or "operational" land. The classification that applies is crucial when considering rehabilitation potential.

The Crown Lands Act 1989 and the Coastal Crown Lands Policy 1990 provide that Plans of Management be prepared for all coastal Crown Land based on assessment of the lands' values. Similarly the NSW Local Government Act 1993 requires that councils prepare Plans of Management for "community land". These plans provide varying opportunities for rehabilitation; some are site specific, many others are generic. Dune rehabilitation projects need to be consistent with these plans.

Local councils also zone coastal land belonging to the National Parks and Wildlife Service (NPWS) but land management remains the Service's responsibility. NPWS activities are undertaken in accordance with a Plan of Management prepared for each Park. Increasingly, the NPWS is undertaking rehabilitation projects in partnership with members of the local community.

Coastal processes and hazards are specifically recognised and accommodated through the NSW Coastline Hazard Policy 1988. This provides for the development of Coastline (Coastal) Management Plans by councils. These plans are developed following the procedure outlined in the Coastline Management Manual (NSW Government 1990). The NSW Coastal Policy endorses the preparation of these Coastal Management Plans but encourages councils to extend their scope more broadly.

The coastal management plan process is managed by local councils and encourages community involvement and ownership. The process includes assessment of coastal processes and hazards, consideration of all available management options and selection of the best options having regard to all social, economic and ecological issues.

While an initial task in preparing these coastal management plans is undertaking a hazard definition study, these are increasingly comprehensive studies of specific sections of the coast. They are often an invaluable source of background reference material that can be used in planning a dune rehabilitation project. Many plans specifically identify dune areas that require rehabilitation.

3.4 Preparing a Rehabilitation Plan

Once the bounds to the dune rehabilitation problem have been broadly determined and initial consultation with the land manager and the community has identified the main opportunities and constraints that are relevant, together with any approvals that are needed, then it is possible to begin more formal planning of the project.

Preparation of a specific project plan is recommended for two reasons. Firstly it should secure the benefits identified earlier (see 3.3); secondly, such a document is invariably required when seeking formal approvals and to support applications for funding from other sources. Buchanan (1989) also provides some valuable advice on this planning process.

The plan should include the following elements:

- concise objectives or goals
- specific strategies or actions needed to achieve those objectives and maintain the outcomes
- some performance measures; things that objectively demonstrate success
- regular review of the plan.

Many councils and other Land Managers now require preparation and submission of project plans before any works begin. Varying levels of assistance are provided. The formats also vary according to local requirements but all address a common set of core items. An example from Coffs Harbour is included at the end of this chapter (Figures 3.4a,b).

3.4.1 Setting some goals

Having identified a problem area, it should be fairly easy to develop a "vision" for what the area will look like in say two, five or ten years time when the rehabilitation work has been completed. This should be developed with the broader community, having considered likely future usage patterns.

The next step is to turn this vision into a number of concise objectives. These need to be clearly stated and realistic. In more complex projects a series of staged objectives should be established, building progressively upon each other. This approach is especially valuable when work is being undertaken by members of the community; the resultant sense of achievement at each stage is invaluable in maintaining or building motivation and commitment.

It is strongly recommended that a site map is prepared to accompany the written plan, based on a thorough understanding of the assessment. This will assist greatly in setting priorities and project objectives. As time progresses, revised versions of the map are also useful for recording and displaying progress.

While maps can be prepared effectively by freehand drawing, they should always be drawn to scale and have their orientation marked. Usually the local council will have maps at suitable scales that can be used as a basis for the project mapping. Aerial photographs, especially the more recent colour and large-scale versions can also help here (see Section 3.3.1).

3.4.2 What specific works or actions are needed?

This will be determined by the extent of site degradation and the standard of rehabilitation deemed necessary. More often than not it will be constrained by the resources that are available.

At a low-usage site, the only work needed may be weed control followed by monitoring of natural regeneration. At sites where there has been severe physical and ecological damage, and where high intensity recreational use is expected to continue, a large range of resource-intensive work may be required over several years. This may involve dune reconstruction and stabilisation, fencing, provision of access, signage, weeding, revegetation, community awareness and education, as well as ongoing maintenance of all components. Subsequent chapters of this Manual enlarge on these specific practicalities.

All works require maintenance. This has often been neglected in the past, with the result that the benefits of project completion diminish, much of the work invested in the project is wasted and liability for injury to users increases. Maintenance tasks need to be identified and given priorities, a time line and adequate resources. Maintenance needs to be considered at the beginning of a project, rather than at the end.

Many elements of dune rehabilitation projects will need to comply with various regulations developed by councils and state agencies. These range from obtaining formal approvals for works to safe application of herbicides. There is also an even greater array of standards and guidelines for many products, works and structures. These have varying legal status and failure to comply with them may breach the "Duty of Care" and expose organisations and/or individuals to future claims for liability.

Occupational health and safety (OH&S) aspects need careful consideration. Issues are wide ranging and include simple ones such as exposure to the sun, risk of snake bite and use of protective clothing, through to more complex ones such as use of chainsaws and poisons. A risk assessment should be undertaken for all projects, identifying the risks and preparing strategies to address them.

Increasing numbers of councils require that an OH&S accredited person be on site whenever work is being carried out. Many councils also offer OH&S training for volunteers.

Guidance on some of the current standards is provided in the next chapter. Given that new and often stricter standards and guidelines are constantly being introduced, advice should always be sought to ensure proper compliance. The local council or relevant state agencies such as NPWS should be able to assist in this regard.

The skills required to carry out particular tasks also need to be considered. If children are keen to help as part of their school activities, or as members of community youth groups such as Scouts, tasks that are within their capabilities need to be identified. In some instances engaging a contractor may be the best way of providing specialist skills or satisfying a duty of care. For example, a sensitive area such as littoral rainforest may need the services of a specialist bush regenerator. Different specialists might be needed to carry out particularly hazardous tasks such as herbicide application on steep slopes, or to provide OH&S training for project workers.

3.4.3 Project duration

Realistic estimates of time needed to complete a project and its various tasks need to be prepared. Is the project a short-lived weeding program over a few months, or is it a much more complex series of tasks that need to be staged over several years? The duration of projects will be affected by many variables.

Some estimates will be straightforward. For example if two people can install 100m of plain wire fencing in one day, it becomes fairly easy to estimate how long that particular task will take when the total length of fencing and the number of available workers is known.

Some tasks will be restricted to particular seasons. Aerial bitou spraying for example is restricted to winter when native plants are dormant. Seed gathering is restricted to summer, but will be later in that season the further south collection takes place. Year to year variations in climate will also impact on this task. Planting of seed and seedlings must obviously be matched to optimal growing conditions. These too will vary along the coast. If community labour is an important component, participants' availability and capabilities will need to be considered. Monitoring and maintaining a rehabilitated site may be needed for several years after completion of site works.

In many projects, commencement of one task depends on another one being completed first. For example, grant funds may be needed before fencing materials can be purchased, or new plantings may depend on the successful propogation of tubestock grown from seed gathered the previous year.

All planning needs to provide for contingencies such as funding delays, worker illness and unfavourable weather conditions.

Preparing time lines can be a great help (Figure 3.3). They help to check progress, to co-ordinate different activities and to keep an eye on future tasks. They can be prepared at different scales. For example, a broad one covering an entire project lasting several years could be broken down into more detailed ones covering shorter, fixed budgetary periods, or revegetation tasks to be carried out during a particular season of the year.

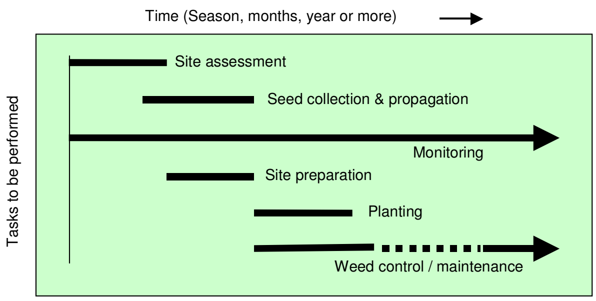


Figure 3.3 Schematic project time line

3.4.4 Project resources

Obvious resources are materials and the funds to acquire them. Less obvious ones may include other practical items like vehicle and tool maintenance, access to water, or funding of administrative items such as incorporation, approvals, insurance, photocopying, telephones and report production. Consultants and contractors providing services such as weeding or OH&S training may also need to be budgeted for. These, together with product costs and service charges such as plant hire need to be assessed carefully so that accurate budgets and funding proposals can be prepared. This will also help to ensure that the public funds that often support dune rehabilitation projects are used effectively.

Councils undertaking coastal improvement works are eligible for matching funding from the Department of Land and Water Conservation under the state Coastal Management Program. The criteria governing the operation of other state and federal programs should also be examined carefully to see if funds can be obtained for a project or for a component of it.

Community groups often take advantage of various funding sources for their coastal projects. The size of the project is likely to determine the source of funding. For example, small projects may be funded through a local government *Bushcare Program* or by a Coastcare *Seeding Grant*. Local businesses will often provide materials at attractive prices, or sometimes as a donation. Many Service Clubs also provide valuable support.

Larger community based projects are usually funded by Coastcare under the Natural Heritage Trust (NHT) program. State and federal government programs are often reviewed and modified and new ones introduced. It is recommended that contact be made with the local DLWC Reserves Manager, the regional Coastcare Facilitator and/or the local Landcare Co-ordinator.

Contact details for Regional Coastcare Facilitators and Coastcare funding can be found by accessing http://www.ea.gov.au/coasts/

Information about the Natural Heritage Trust is also available on the World Wide Web at: http://www.nht.gov.au/

Contact details for local Landcare Co-ordinators can be obtained at: http://www.landcare.nsw.org/

Success in attracting funding or other support depends on the quality of the grant application or project proposal. Generally, a successful proposal will:

- concisely address all the criteria specified by the funding body
- show evidence of appropriate consultation
- relate clearly to and be consistent with other relevant policies, plans and regulations
- have clearly stated objectives that are achievable within the specified time frame
- have a sound methodology
- have a proposed budget set out clearly
- demonstrate availability of and access to the expertise required
- show that it will deliver good value for money
- be presented clearly and succinctly.

Funding programs are competitive and rely on independent assessment of project proposals to establish grant priorities. Because assessors have many proposals to evaluate within short time frames, proposals that do not meet funding bodies' objectives or guidelines are quickly eliminated.

3.4.5 Evaluation and review

This is an essential component of any successful project. Regular review should be built into the project plan. Unscheduled reviews may also be useful following unexpected events such as a storm removing part of the dune system. Both successes and shortcomings should be examined. Lessons learned can initiate changes that save time and/or money and which generate a higher probability of success in the future. If documented carefully, the lessons and benefits can be shared with others.

The value of simple, achievable objectives will become evident during this process, especially if the project is guided by a time line.

3.4.6 Project documentation and record keeping

All aspects of a project should be documented carefully (Buchanan 1989, DLWC 1997). Fundamental record keeping involves compiling minutes of meetings, especially recording any decisions made, documenting income and expenditure so that project funding can be acquitted properly, and retaining copies of approvals and all correspondence. Even small projects will benefit greatly from careful and regular documentation.

The project plan, progress reports and any plan reviews should be preserved in secure formats that are easy to reproduce. An activity register that identifies tasks, when they are undertaken and who is responsible, assists greatly in assessing progress and provides evidence that tasks have been undertaken. For example an activity register should be kept to demonstrate that appropriate training, insurance, OH&S requirements, and special project or site requirements were provided or explained to project workers. Working bee time sheets, sign on/ sign off sheets and notes describing the location and extent of works each day should also be retained. These records not only provide a useful running record of project achievements, they provide valuable data for inclusion in council State of Environment Reports and in funding applications.

On-site progress should also be recorded, preferably with "before" and "after" photographs of key sites. As time passes it is often easy to lose track of how an area has been transformed. A series of photographs of the same fixed point over a period of time can overcome this.

Comparison of photographs is easier if they are taken at the same time of day. Overcast skies help reduce extreme contrasts of light and shade, making vegetation pictures clearer. Photo points can be marked on the ground with a post and flagging tape; and can also be recorded on site maps if they have a sufficiently large scale. Multiple copies of prints should be requested when processing film.

Visual reminders of progress and achievements help greatly to maintain participants' enthusiasm for a project; they can encourage others to join, and they can be used at public meetings, workshops or in annual reports and subsequent grant applications to demonstrate project successes.

Comprehensive project reporting also assists transparency - other people and agencies can see more easily that the project is being managed with maximum propriety.

3.5 Getting help

New community groups have a wealth of expertise to draw upon when preparing their project plans. Councils are an obvious source of current information on favoured products, costings, plant hire, construction times etc. but other expertise should also be drawn upon. Other established Dune Care, Coastcare and Landcare groups are often willing to share their experiences and provide advice, and there are increasing numbers of regional co-ordinators and facilitators who have a primary responsibility to encourage and support new community groups and their initiatives.

It is also a good idea to look carefully within the local community for people with specific skills. Retired professionals and trades people, photographers and those with administrative and bookkeeping skills are examples of people whose expertise may not be immediately apparent.

Coffs Harbour City Council
Parks and Recreation Branch

COMMUNITY 'CARE' GROUP PROJECT PLANS

INFORMATION REQUIRED:

1. Group and Project Details:

Project Name: ....

Location: ....

Group: ....

Current Group Contact Details: ....

....

2. Overall Group Plan:

Objectives: ....

....

....

Specific area of land covered (show on site plan): ....

....

....

Short to Long term works (show on site plan with lists and descriptions where required):

Bush Regeneration:

- Areas for regeneration, revegetation/planting, weed control
- Vegetation types, native and weed species present

Access and facilities:

- Fencing
- Paths and beach access
- Drainage
- Signs
- Seats
- Other

Priorities for the above (use 1st, 2nd and 3rd priority - no time frame required)

....

....

....

If you have an existing plan that sets out the necessary information, please let us know.

Figure 3.4a Project Plan information sought by a Land Manager

1. Priorities and Funding 99/00:

What works would your group like to see achieved this financial year (July 99 - June 00) ?

....

....

Do you have funding for these works? Please specify.

....

....

What additional funding do you require? Do you intend applying for any specific funding programs?

....

....

Prorities and Funding 00/01

What works would your group like to see achieved next financial year (July 00 - June 01)?

....

....

....

Please specify whether you need to apply for funding for these works.

....

....

....

Other Information:

This information would be helpful to complete our records:

- Brief outline of works achieved in 1998/99 financial year ....

  ....

  ....

- Total volunteer hours contributed 1998/99 ....

- What year was your group formed? ....

- Have you had any studies or plans completed for your area (eg. flora & fauna studies, bush regeneration plans)?

  ....

  ....

- Are there any specific issues you would like to let us know about your group area or land care in general?

  ....

  ....

Coffs Harbour City Council - Parks and Recreation Branch
COMMUNITY 'CARE' GROUP PROJECT PLAN
February 2000

Group: Sawtell Beach Community Dunecare

Project Name: Sawtell Beach Rehabilitation Project

OBJECTIVES

- To control weeds on Sawtell Beach Reserve in particular target weeds (Bitou Bush, Glory Lily, Cassia, Lantana, Mile a Minute)
- To restore native vegetation communities including foredune complex, hind-dune forest, littoral rainforest, swamp forest and headland communities.
- To collect seed, propagate and plant local native species
- To assist in the provision and maintenance of pedestrian access to meet local needs and protect the natural environment.

SITE

The project is located Coastal reserve R93475 (Council Reserve No 21) adjoining the northern portion Sawtell Beach. The group project covers approximately 1ha. It adjoins Council bush regeneration projects sites that focus on littoral rainforest and headland restoration and the Ulitarra Conservation Society restoration site south of Boambee Headland.

Site impacts include prior sand mining and bushfire, extensive weed invasion, eroded pedestrian access and litter.

The site and adjoining beach is a major recreational focus for residents of Sawtell and Toormina (population 11,000 approx) and visitors for walking, swimming, surfing, dog exercising and general beach recreation.

PRIORITIES (See also Related Council Works)

Current ('00-01)

- Maintain regenerated areas established to date with follow up weed control.
- Collect seed, propagate and plant local native species
- Collect beach litter
- Control Cassia and other weeds surrounding 22nd Avenue steps.
- Additional sign needed near steps
- Prune track side shrubs to assist access when possible

Future

- Complete primary weeding and replant areas as required.
- Continue maintenance of areas regenerated to date

RELATED COUNCIL WORKS*

Current (00-01) / Ongoing

- Weed control and regen programmes (see plan):
  – Bitou Bush Programme
  – Littoral Rainforest Restoration 18th Ave to Boronia Park.

Future

- Completion of Boambee Headland walkway
- Headland vegetation restoration Boambee Headland, Bonville Headland
- Littoral rainforest restoration Boambee Headland

* main items only, subject to funding and current works programmes. Please contact the Parks and Recreation Branch if Council you are concerned about any Council works in your area of interest. Council will endeavour to advise your group in advance of any works in or around your project area.

FUNDING

Current Funding / Applications Pending

- 99/00 Dunecare Landcare Vote (tools etc, mulch, plants as required, propagation materials, contract regeneration)

Future Funding Projects

- EL, Coastcare (materials, regeneration and weed control)

OTHER GROUP COMMENTS

Issues / Suggestions

- Drain litter trap requires regular maintenance
- Mowing encroachments from 18th Ave a concern
- Low level signs vandalised

History and Achievements

Group formed in 1992 and has been instrumental in the control of weeds, regeneration and the construction of pedestrian access throughout the area of interest. A number of successful funding programmes have been implemented on the site in partnership with Council including extensive dunal replanting and weed control in the Twenty Second Avenue area.

PLAN REVIEW

This plan is to be reviewed annually or as required to ensure it remains relevant. To discuss revision of any aspect of the plan please contact the Parks and Recreation Branch.

INFORMATION PROVIDED TO GROUP

- Sign on / off sheets

To be provided

- CHCC Guidelines for volunteers
- DLWC Volunteers Working on the Coast
- Attack of the Killer Weeds
- Aerial photo
- Species lists and mapping, Coffs Harbour Vegetation Study 1996

Please contact us if you require any additional information, sign on sheets etc.

CONTACT DETAILS

Sawtell Beach Community Dunecare

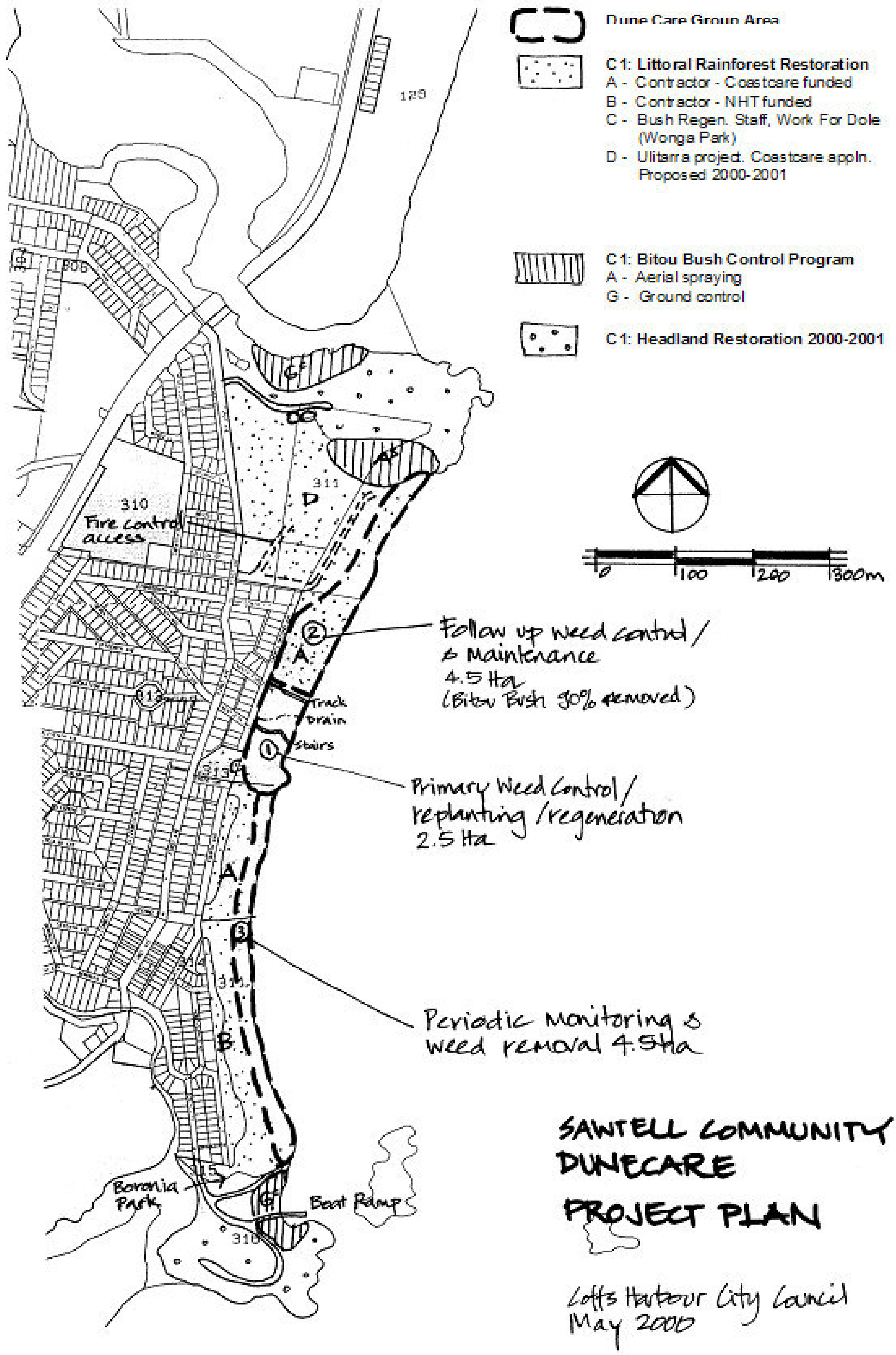
Name — Ph: number
Name — Ph: number

Coffs Harbour City Council

Parks and Recreation Branch — Ph: number
Name — Ph: number

Thank you for your valued assistance in the management of natural areas and native bushland on Council managed Crown Reserves.

Figure 3.4b Example of Project Plan


Dune Care Group Area
C1: Littoral Rainforest Restoration
A - Contractor - Coastcare funded
B - Contractor - NHT funded
C - Bush Regen. Staff, Work For Dole (Wonga Park)
D - Ulitarra project. Coastcare appln. Proposed 2000-2001
C1: Bitou Bush Control Program
A - Aerial spraying
G - Ground control
C1: Headland Restoration 2000-2001
0
100
200
300m
310
311
Fire control access
D
Follow up weed control / & maintenance
4.5 Ha
(Bitou Bush 90% removed)
Track
Drain
Stairs
Primary Weed Control / replanting / regeneration
2.5 Ha
Periodic Monitoring & weed removal 4.5ha
Boronia Park
Boat Ramp
SAWTELL COMMUNITY DUNECARE
PROJECT PLAN
Coffs Harbour City Council
May 2000

3.6 References and further reading:

Buchanan R.A. 1989, *Bush Regeneration: Recovering Australian Landscapes,* TAFE Student Learning Publications, Sydney.

Carson L. and Gelber K. 2001, *Ideas for Community Consultation,* NSW Department of Urban Affairs and Planning, Sydney.

DLWC 1997, *Volunteers Working on the Coast,* NSW Department of Land and Water Conservation, Sydney.

DUAP 2001, *PlanFirst, Review of plan making in NSW White Paper,* NSW Department of Urban Affairs and Planning, Sydney.

Greening Australia 1995, *Local Greening Plans: A Guide for Vegetation and Biodiversity Management,* Greening Australia, Canberra.

Malmberg C. and Devine P. 1996, *Succeeding with Plans of Management, A guide to the Local Government Act and Crown Lands Act,* NSW Department of Land and Water Conservation and Manides Roberts Consultants, Sydney.

NSW Government 1990, *Coastline Management Manual,* Sydney.

NSW Government 1997, *NSW Coastal Policy 1997: A Sustainable Future for the New South Wales Coast,* Department of Urban Affairs and Planning, Sydney.

Surf Life Saving Australia Limited 1998, *EcoSurf Code of Practice,* SLSA and Coastcare.

4. DUNE RECONSTRUCTION AND PROTECTION

4.1 Introduction

Dune rehabilitation projects vary greatly in scale and complexity depending primarily on the extent to which the existing dune system has been degraded.

At all sites a primary goal is to try to establish a landscape that resembles as closely as practible, the dunes that were present before the degradation began (see Section 3.3.1).

At some sites, erosion or other damage may have been so severe that the first task is to reshape the sand mass into a landform that might reasonably be expected to have developed naturally. At other sites the dunes themselves may not have suffered any erosion, and degradation may be limited to invasion by weeds, in which case rehabilitation may only involve some access and weed control. Variations in visitation levels affect the type and level of control structures that may also be needed, such as fencing, accessways and signage.

While all these aspects are addressed here, it is emphasised that they do not all apply to every project site.

Caution: *In planning any dune works, from large scale reconstruction through to minor weed control or erection of signs, the possibility of personal injury arising directly or indirectly from such work, or from deficiencies in ongoing maintenance in the future must always be considered.*

This and subsequent sections of the Manual provide general guidelines and advice for effective dune management. It is stressed that local conditions or changing technological or regulatory environments may require departures from these guidelines.

4.2 Reforming (rebuilding and reshaping) dunes

Any revegetation program proposed for degraded coastal dunes requires a landform that encourages the establishment and survival of grasses or shrubs and trees. In badly degraded areas, preparing a suitable landform may involve rebuilding or reshaping the dunes. This may involve filling of small blowouts, or on a larger scale, the reconstruction of hundreds of metres of dune. The appropriate level of environmental impact assessment must precede such work.

Natural dunes vary in slope, size and shape depending on the combination of factors that have controlled their formation. This topographic variability also contributes to subtle but valuable variations in microclimate and habitat. Therefore, reconstructed dunes should also vary in slope, size and shape just as natural dunes do. However unnatural protruding hummocks or steep-sided undulations that may interrupt or concentrate wind flow should be avoided. These large irregularities can also make vegetation establishment difficult or even impossible, and frequently lead to the formation of even larger blowouts.

The dimensions of the reconstructed dunes will depend on those of the remnant dune, the location of the dune and the type and availability of sand to be used for reconstruction. Dimensions may be constrained by the location of structures such as buildings, car parks or roads. This problem is common in urban areas where it is often only possible to reconstruct the seaward face of the foredune. In areas where these limitations are absent, it may be possible to reconstruct an entire dune system.

Several methods can be used to reshape dune contours depending on the scale of degradation. They include the use of earthmoving equipment or sand trapping techniques such as dune-forming fences, the spreading of brush matting and revegetation. The following guidelines address the factors to be considered when reforming dunes.

Note that coastal dunes often contain sites and materials of Aboriginal significance (see Section 3.2.1). These cannot be disturbed or destroyed without prior approval of the NPWS. The local Aboriginal community should also be consulted. It may be necessary for an Aboriginal representative to be on-site during dune reshaping.

Consultation with local Aboriginal communities and the NPWS should be undertaken early in the planning process to determine the presence of any cultural or archaeological sites and the extent of any restrictions upon their disturbance (also see Section 3.2.1).

4.2.1 Material

The sand used in dune reconstruction should match the grain size of the sand in the adjacent remaining dune. Finer material will be more mobile and the new dune may be eroded more rapidly than the existing dunes. If the new grain size is larger, revegetation may be difficult because the increased porosity leads to increased drainage and problems of low moisture and nutrient retention. Foreign material such as rubble, rubbish and earth fill should not be used as it is unlikely to provide the right conditions for establishment of a coastal dune ecosystem, and often creates more problems with introduced weeds.

Sand dredged from bays, river mouths and estuaries may be suitable sediment but will require careful examination of its suitability. The Port Botany Development Project (Sydney) and the Kooragang Island Project (Newcastle) are two examples of large-scale development involving the use of dredged material for land reclamation. Sand dunes may also be artificially constructed from dredged material but will need to be stabilised with vegetation.

Experience has shown that dredged material may:

- have a low pH
- have acid sulfate potential
- harden when dried
- not retain adequate moisture for plant growth
- be chemically infertile

It has been recommended that any such material be carefully analysed for heavy metal concentrations, nutrient levels, moisture retention, salinity, pH and acid sulfate potential prior to use. Analysis will provide invaluable assistance when planning and implementing revegetation programs. Problem areas can be isolated and solutions found before the costly step of revegetation is commenced.

The salinity level of recently dredged sand does not pose many problems because salt is leached out of the top few centimetres of sand after about 50mm of rain has fallen (or the equivalent in irrigation), provided that infiltration and drainage is normal.

4.2.2 Position

The position of a reconstructed dune is governed by that of existing dunes in the area and by the location of any structures it may be designed to protect. An adequate beach berm width must be maintained to permit normal coastal processes, especially at elevated high water levels during storms.

A reconstructed dune should be integrated with any remnant dunes and should run approximately parallel with the beach berm. Allowance should be made for normal variations in berm width due to increasing wave exposure and occurrence of rips. Major inflections in the seaward face of the dune should be avoided as these will cause the wind to eddy and remove sand, and they facilitate wave incursions. Too many bends in the dune also adds to fencing costs.

4.2.3 Slope and shape

Natural dune gradients range from zero to 1 in 1.5 (1 Vertical :1.5 Horizontal) and vary considerably at any site. The primary objective in reforming degraded dunes should be to re-establish the diversity of landform that existed before initial disturbance. This should also assist re-establishment of an appropriate dune ecosystem.

While gentle gradients are easier to work upon and maintain, and may assist moisture retention and subsequent revegetation, reconstruction of steeper versions should not be avoided altogether. Examples of steeper slopes include the naturally revegetated seaward faces of many foredunes that were steeply scarped during the storms of the mid-1970s, and some landward slopes sheltering older littoral rainforest communities. Where space is limited, steeper slopes may be unavoidable.

Reconstructed dunes should have aerodynamically stable shapes. Seaward faces of foredunes should be flat to slightly convex in shape. This helps to deflect onshore winds in an upward direction, which then provides a sheltered area on the lee side of the dunes. This in turn helps the establishment of vegetation.

Where space permits, an incipient foredune may also be incorporated on the seaward side of the reformed dune. This provides additional protection for the foredune and its emerging vegetation.

4.2.4 Height and width

The height and width of a reconstructed dune depends on a number of factors including:

- the height and width of existing dune remnants
- the availability of sand
- available space
- the degree of landward protection required.

It may be desirable to reconstruct the dune to a height that will prevent wave overtopping during storms. Expert on-site advice on these aspects of dune reconstruction should be sought from the appropriate coastal section of the Department of Land and Water Conservation during the project-planning phase.

4.3 Dune-forming fences

The principal function of a dune-forming fence is to reduce the wind velocity, thereby causing drift sand to be deposited in the vicinity of the fence (Figure 4.1). This technique can be used for small blowouts, for larger scale dune formation and at sites where it is not feasible to import new material. However, these fences are generally used on smaller isolated blowouts that are still surrounded by functional dunes and vegetation. Dune-forming fences are particularly useful in environmentally or culturally sensitive areas where it is undesirable to use earthmoving equipment or where access is difficult.

The major disadvantages of dune-forming fences are their susceptibility to vandalism and the uncertainty of how long it will take for the desired dune profiles to become established. Dune-forming fences are useful if the rehabilitation program is of long duration, although their re-exposure some years later may create new hazards or beach debris.

Dune-forming fences can be installed during the non-planting season to allow for a gradual build-up of sand (although in some cases the fences may fill in a matter of hours). Planting can commence when the fences have filled with sand. This allows greater long-term utilisation of labour and provides work during the non-planting season.

Dune-forming fences are most commonly made of a porous material such as a woven synthetic cloth with approximately 40% porosity. This material is attached to plain wire strained between treated pine posts (Figure 4.2a).

Figure 4.1 Dune-forming fences, Kurnell

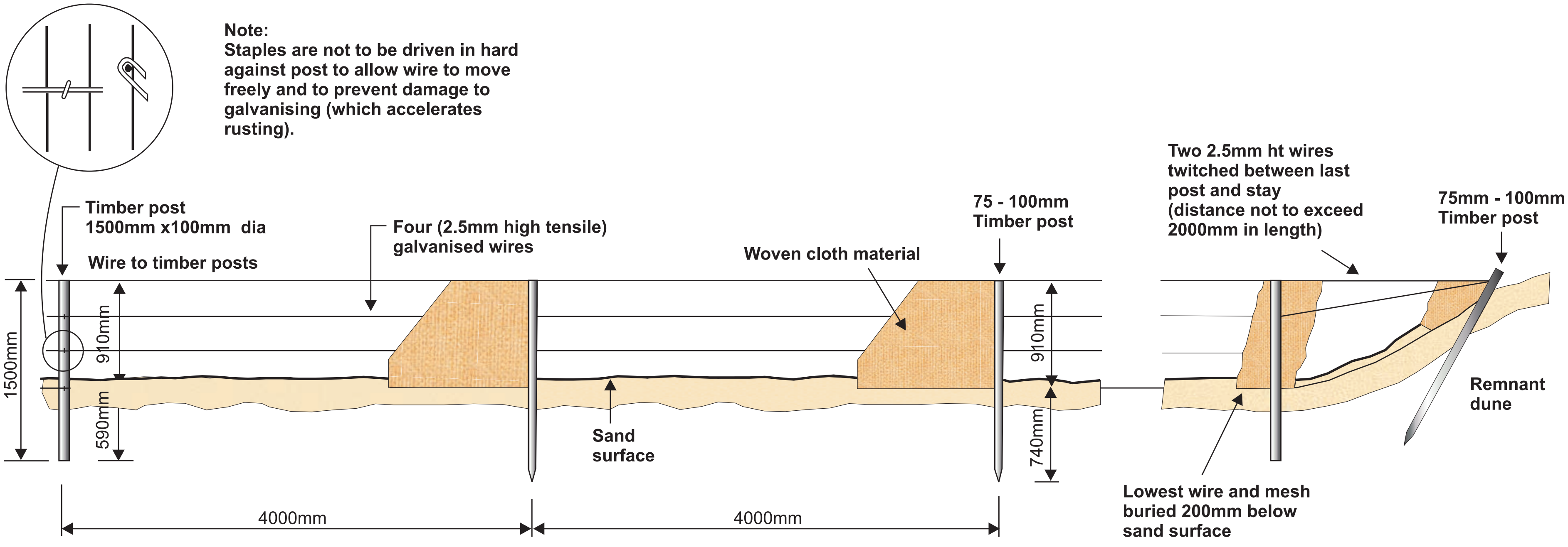


Figure 4.2a Dune forming fence design

Notes:

1. Wire and mesh to go on seaward or prevailing weather side of fence.

2. Mesh to be fastened to all wires using ring fasteners at 100-150mm intervals on top wire and 300mm intervals on other wires.

3. Use one wooden post every 4000mm.

4. Metal posts should be avoided.

Various other designs have been used depending on local circumstances and availability of materials. Almost any very porous material that can reduce wind speed and trap sand can be used. Originally, natural materials such as driftwood or brush were used to great effect. Wooden slats laced together and hessian have also been used. Overall however, modern synthetic cloth materials afford flexibility of design, ease of construction, durability and economy.

The woven cloth needs to be secured at the base by digging it at least 200mm into the sand and attaching it to the top, intermediate and bottom wires. The ends of the fence also need to be firmly embedded and anchored within a stable object such as the side of the blowout to prevent sand from moving under or around the fence.

Dune-forming fences need to be positioned at right angles to the prevailing wind to be most effective. They should be straight where possible. Side wings or zigzag patterns are not recommended. The fence and the material are designed to be buried by drifting sand. Do not attempt recovery of the fence.

In planning fence installation, sand can be expected to accumulate in a zone whose width is 5-10 times the fence height. The actual width will vary according to wind and sand characteristics. To build a very wide dune, a series of parallel fences can be constructed at 2-5 metre spacings. To build up dune height, additional fences may need to be constructed above the original fences when they have filled with sand (Figure 4.2b). This should be repeated until the height of the sand trapped by the dune fences approximates the height of the surrounding dunes.

A 2-person team can erect approximately 50 metres of dune forming fence per day.

4.4 Dune rebuilding with earthmoving equipment

In some circumstances earthmoving equipment can be used to rebuild dunes. This is an expensive option but it can have the advantage of reconstructing large sections of eroded dunes to desirable size, shape and location within a short time frame. It can sometimes be undertaken effectively on an “opportunity basis”, in conjunction with another project for example. This sort of work is usually part of a large-scale project that is designed and managed by full time professional staff.

Several aspects need to be considered but special care should be taken not to disturb significant areas of existing vegetation. This option will invariably require approval and environmental impact assessment.

4.4.1 Survey

Whenever possible, survey the dune to be reconstructed at 1:500 scale. This will show where available sand is situated, where blowouts are and where fill is required. The survey information, together with on-site inspections, allows accurate planning of reconstruction methods, sand movement, the type of earthmoving machinery required and estimation of costs. A second survey after construction will confirm the amount of sand moved and also forms a base upon which future accretion or erosion can be measured.

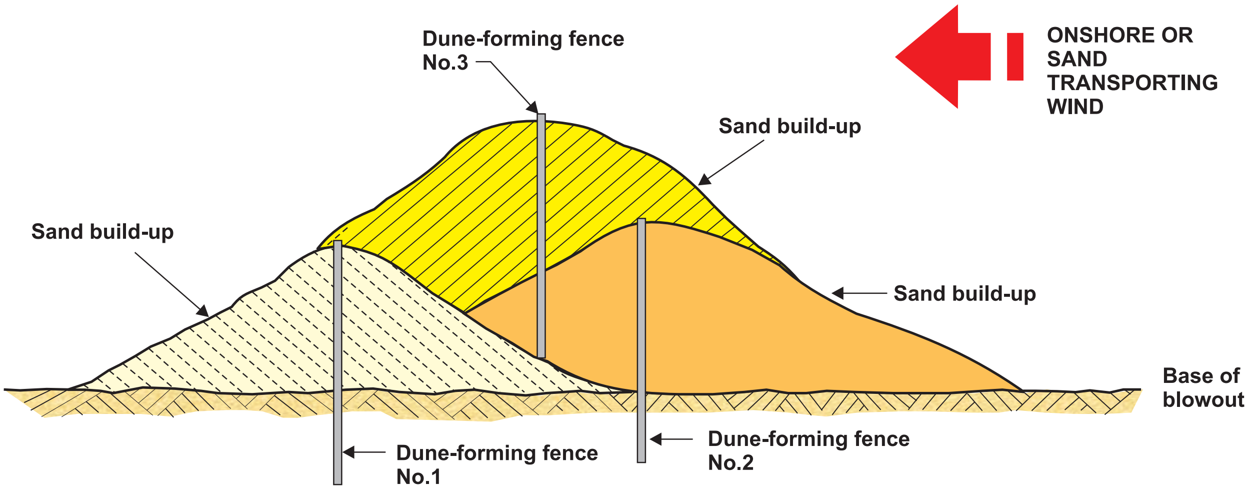


Figure 4.2b Sequence for progressive installation of dune-forming fences.

4.4.2 Sand Sources

Ideally, sand that has drifted inland from the eroded foredune should be used in the reconstruction process. This brings the sand back into the natural coastal system. Dune nourishment from off-site sources can also be used successfully, provided particle size and salt content is assessed (see Section 4.2.1). Sand obtained from the beach berm and below high water mark should be considered only as a last resort where drift sand is unavailable. As this may have adverse effects elsewhere within the beach system an environmental impact assessment and permission from the DLWC will be required. Approvals will also be required from other stakeholders such as NSW Fisheries.

4.4.3 Type and use of equipment

Earthmoving equipment that can be used in dune reconstruction includes:

- **Bulldozer** - Used where sand is readily available, extensive reshaping is required and pushing distance is short.
- **Front-end loader** - Used for carrying smaller quantities of sand moderate distances. They are valuable for accurately placing sand where required with minimal environmental disturbance and for transplanting primary vegetation.
- **Scraper** - Used for carrying large quantities of sand long distances. Scrapers require open space with low slopes and also need a bulldozer to push fill.
- **Excavator** - Used for pulling down eroded dune batters.

Before choosing the size and type of equipment to be used in dune reconstruction, also consider hire rates and the experience and efficiency of the operator. In many cases smaller equipment with an experienced operator will result in a better, less expensive job than larger equipment.

When moving sand with a bulldozer, short pushes are best. Where possible, push sand from the eroded dune crest downhill to form the seaward slope. Push drift sand from behind the dune uphill to form the dune crest and landward slope. Move sand in trenches by slot dozing. This stops sand from being lost around the ends of the dozer blade. Once the majority of the sand has been moved through the trenches, it becomes a simple task to push out the windrows and smooth off the slopes.

4.4.4 Timing of reconstruction

Dune reconstruction works using earthmoving equipment should be timed carefully so that completion of the various stages of reconstruction coincides with the appropriate season for planting primary dune stabilising vegetation. If the works are completed too far in advance of planting, the likelihood of dune erosion by wind is extremely high. This will necessitate further dune reconstruction leading to cost overruns on the project.

However, if planting is undertaken too soon after the dune has been constructed, the vegetation may fail to establish because there was insufficient moisture in the reworked sand, the sand was not suitably consolidated to aid plant growth, or salt had not yet been leached from the plant root zone.

The correct timing of dune reconstruction work depends greatly on climatic conditions, planting season, availability of planting materials and the experience of the program managers and supervisors. Between reconstruction and revegetation the use of a temporary stabiliser may be necessary (see Section 4.5).

4.4.5 Dune reshaping after storms

The erosion scarps that are produced along the seaward face of foredunes during severe or prolonged storms are inherently unstable. Even when bound together strongly by plants they will eventually slump to a more stable surface. Until this occurs, they may present a hazard to beach users, especially near more populated centres where children delight in jumping from or tunnelling into them. In these circumstances, intervention to reduce the risk may be warranted, for example by erecting warning signs and temporary exclusion fencing.

If the risk is deemed to be particularly high, slumping may be induced by judicious use of machinery. This activity should be kept to the minimum necessary to create a stable sand surface. Damage to vegetation should also be minimised as the exposed plant roots and spinifex runners that often end up being draped down the face of the scarp play a crucial role in trapping wind blown sand and repairing the damaged foredune.

Erosion may expose sites of Aboriginal significance that have not been previously identified. Evidence of such sites (middens, artefacts etc) should be reported to the NPWS and the Local Aboriginal Land Council.

4.5 Temporary dune stabilisers

In many situations an immediate stabilising cover is required on bare sand to prevent drift. Examples may vary from small blowouts starting where dunal vegetation has been damaged, to larger areas of bare sand resulting from the reforming or repairing of a dunal system by earthmoving machinery. In the latter case, the capacity of machinery to reform a dune can often far outstrip the rate of planting of suitable primary stabilising vegetation.

Temporary stabilisers can be used to establish a cover in an emergency situation or to provide a surface cover until more permanent vegetation becomes established. They protect the sand surface and can encourage sand trapping.

In broad terms, there are four main types of temporary stabilisers:

- brushes and mulches
- liquid sprays
- cover crops
- geo-textiles

These four categories, described below, are not mutually exclusive; a combination of methods may be used depending on site conditions and the level of erosion.

Note*: Marram grass has often been used in the past as a temporary stabiliser. Contemporary use of this plant is discussed in Section 6.8.1.*

4.5.1 Brushes and mulches

As brushes and mulches are harvested from donor areas, the first step in any program using these materials must be to obtain the approval of the landowner or land management authority controlling the donor land before harvesting commences.

Brushes or mulches act as a surface wind barrier. They prevent loss of surface sand from the seedbed, retain moisture and provide shelter for developing seedlings, and enhance sand accretion. Accreting sand stimulates the growth of primary colonising grasses such as spinifex. This is one of the advantages of this type of material over liquid stabilisers that are generally only used in association with other types of wind barriers.

A range of materials is available for use as surface wind barriers. Selection of a particular type generally depends on its availability, the propagating material being used and the climatic conditions anticipated. Materials generally need to be heavy enough not to blow away. This makes coarse fibrous materials the most favoured. These include hand-laid brush matting and chipped plant materials. Meadow hay with bitumen tacking is used in some situations but extreme care must be exercised to ensure that wind does not get underneath and lift it in sheets. For this reason it is not recommended for exposed positions.

Brush matting using branches cut from coastal shrubs is a time-honoured technique and is most successful, particularly in foredune situations with sown spinifex (Figure 4.3). Any area can be treated and the technique is not restricted to any particular zone of the dune system. In practice, the areas treated by this method tend to be small. In more populous areas, it can be hard to find donor areas for brush harvesting due to urban encroachment, while in other areas environmental sensitivity may preclude it.

Figure 4.3 Brush matting is essential at exposed sites to protect bare sand until new plants are established.

The technique is straightforward. Small branches of coastal shrub species are gathered from well vegetated donor areas. Coastal tea tree (*Leptospermum laevigatum)* is particularly suitable. Care is needed when harvesting to ensure that no shrub is denuded and harvesting is limited to one to four limbs per shrub taken from the leeward side. Smaller branches should be broken off larger limbs to make the brush cover a larger area. Brush length should be at least 600mm, but less than 1000mm. The butt end is pushed 150-300mm into the sand at a horizontal angle of 10-15 degrees. The butt end should face the prevailing wind direction. When laid the brush should cover at least 60-80% of the sand surface. If brush availability is limited, it can be laid in rows 2-3 metres apart.

As the wind passes the brush and leaf tips, velocities are reduced and the sand surface remains intact. Wind blown drift sand drops through and is trapped beneath the brush. The amount of sand that can be accreted by brush is significant and the degree of protection it affords an otherwise bare sand surface is excellent.

As most coastal shrub species are very woody, brush breakdown is slow. Depending on the time of harvesting, the brush may also present an excellent seed source to introduce secondary and tertiary species in hind dune areas, provided they occur natually in the area. Care must be taken to avoid introducing seed from plants that are not locally endemic. For example, Tea Tree seed should not be introduced north of Nambucca Heads (see Section 6.8.3).

Chipped plant material has been used successfully where materials were readily accessible. This can occur when rehabilitation coincides with clearing for power lines, subdivisions or other developments. The mineral sands industry has often used chipped heath to protect sand dunes after mining. The technique has also been used successfully in the rehabilitation of quarries within coastal heath areas. Unwanted vegetation such as bitou and lantana can also be used to protect small surface areas, provided it is not in seed.

Dead seagrass has proved successful on the Central Coast. Normally seagrass that is washed naturally from an estuary should be left intact as part of the estuarine ecosystem. In this instance however, it was legally removed from a coastal lagoon as part of an approved estuary rehabilitation project and used to mulch seedlings that had been planted on the landward side of a newly graded foredune.

4.5.2 Liquid sprays

Liquid sprays such as emulsified bitumen or dispersed organic polymers provide temporary stabilisation by aggregating or cementing sand grains so that they cannot be moved by the wind.

Unlike brushes and mulches, these products do not enhance sand accretion; mobile sand simply passes over the surface and continues until intercepted by other obstacles. Recommended sprays do not interfere with the germination or with the growth of seedlings, transplanted culms or runners. Most allow reasonable air and water exchange between the atmosphere and stabilised sand.

The sprays are diluted in accordance with manufacturers' recommendations and are applied using a bitumen pump. Application rates are critical and coloured dyes are available to assist in this regard. Once cured, the crusts can be damaged by traffic so it is essential to fence treated areas.

Bitumen emulsion of the slow-breaking anionic type has also been used extensively for sand stabilisation, usually in conjunction with other techniques. It is relatively stable and easy to handle but 2500 litres is needed for each hectare. It is diluted 4:1 with fresh water and combined with sufficient emulsifier to retard breakdown and provide about 50mm penetration. The treatment is visually obvious and has the advantage of deterring pedestrian traffic.

Conversely, the black, oily appearance of treated areas can be a disadvantage if it generates adverse public reaction, particularly on popular beaches valued for their aesthetic amenity. More importantly, the darkness of bitumen treated sand considerably increases surface temperatures, which can cause root damage and seedling mortality in hot weather. However, bitumen can be a valuable material for treatment of remote sites. Once applied the mixture generally breaks down and disappears after 3-6 months.

Dispersed organic polymers: Various dispersed organic polymer derivatives of petroleum are suitable for use as temporary sand stabilisers. They have several advantages over bitumen emulsion:

- they can be applied at much lower rates of active ingredient (around 600 L/ha) therefore requiring less cartage to site
- they are generally colourless to white, which is more aesthetically acceptable and less heat absorptive
- they have a distinct advantage in beach situations of remaining dispersed in saline waters, which allows usage of ocean or spear point supplies for mixing and avoids the need to cart water to the site

Diluted organic polymers are applied with high volume spraying equipment. Careful planning is required before undertaking large jobs as large volumes of water are required. Some products are not always available and have a short shelf life. Pumps and spray equipment ***must be cleaned*** during and immediately after use, as the polymers congeal rapidly.

4.5.3 Cover crops

Cover crops are generally intolerant of strong winds, salt spray and significant sand burial. Thus, where there is no migrating sand to accrete and it is a matter of holding the sand surface in place while secondary or tertiary species are established, then a living plant mulch or cover crop is appropriate. By necessity, cover crops must germinate rapidly and grow vigorously to provide a dense vegetative cover capable of reducing wind velocity at the sand surface.

Cover crops are not successful on foredunes, but can be used in swales or other protected areas of a dune system. They can also be used in artificial dune environments, for example to stabilise large tracts of land created by dredging sand from bays or estuaries.

Cover crops may be used to provide sand surface stability, to protect emerging secondary species or they may be used in their own right as a longer term surface stabiliser. The length of time they persist can be controlled by species selection and by management of fertiliser inputs.

Crops are established from seed and are either machine or hand broadcast onto the sand surface or drilled into the sand using an agricultural type combine seeder. This offers the options of either incorporating the seed of the secondary coastal species with the seed of the cover crop and direct sowing the lot, or planting nursery-raised tube stock after germination and satisfactory growth of the cover crop has stabilised the site.

Direct seeding of both cover crop and secondary/ tertiary native species is possible because of the significant difference in time from sowing to germination of agricultural type cover crops compared to most native coastal species. However, as all the factors that trigger the germination mechanism of many native coastal species are not fully understood, the final composition of a vegetative cover established this way can vary considerably.

If a specific vegetative composition is required, the introduction of nursery-raised tube stock into an established cover crop will give the desired result.

Selection of the correct species of cover crop is essential. Broadly speaking there are two main sowing seasons, warm and cold. Species may be annual, ie. they germinate, grow, set seed and die within a twelve month period; or they may be perennial, whereby the original plant continues to live year-in year-out and may or may not set seed. Given that a primary goal of contemporary dune rehabilitation is the establishment and enhancement of natural ecosystems comprising locally indigenous plants, use of exotic cover crops should only include hybrid species that do not set viable seed.

Recommended cover crops include cereal rye (*Secale cereale*), a cool season annual species and hybrid forage sorghum (*Sorghum vulgare*), a warm season species.

4.5.4 Geo-textiles

Over the years many different types of geo-textiles have become available. Products include coconut fibre matting, open-weave nylon cloth and softwood shavings contained in fine nylon mesh. Most are relatively expensive and of limited use for this purpose.

Some of these products inhibit the growth of vegetation that is established by seed. All create additional work in planting vegetative material such as culms or runners, therefore resulting in additional labour costs. A further disadvantage is that these products can only cope with a very small amount of sand accretion. Once the fabric is filled, sand continues to travel over the buried fabric. They are also subject to a high risk of vandalism.

While the initial purchase price of these products is high, they should be considered when other techniques are not appropriate. For example, they may have application in difficult sites, or where urgent, rapid repairs are necessary over small areas in order to maintain beach use. They have also been used successfully over large areas during mine site rehabilitation. Material that breaks down over time is preferred.

4.6 Protective fencing

Dune vegetation is particularly susceptible to damage from pedestrian and vehicular traffic. Fences are therefore used in dune areas to preserve both revegetated and naturally vegetated areas. The type of fence used depends on the:

- usage of the beach area
- location of the fence
- maintenance requirements
- public acceptability
- area to be protected
- material available
- finance available

The type of fence used should be suited to the area where it is to be constructed and should be functionally and visually acceptable to the users of that area.

4.6.1 Fence position

Two major fence lines are generally used in dune rehabilitation projects, one along the seaward margin of the dune field, and another landward fence that protects hind dune areas. Designated accessways (Section 4.7) provide controlled opportunities for beach users to cross the dune field and these are also usually fenced.

The seaward or frontal fence should be located near the toe of the foredune, well above high water wave runup levels (Figure 4.4a). It should also be more or less parallel to the toe of the dune. Its purpose is to protect sensitive vegetation but positioning is problematic.

The further forward the fence is sited the more vegetation it will protect but the likelihood of damage or its removal by storm waves also increases. Conversely, they may be partially or completely buried by sand. Where there is a high risk of this occurring, the fence used should be of simple construction and easily maintained. At remote sites a seaward fence may not be needed.

The location of fences in hind dunes will vary according to constraints imposed by the landform, existing vegetation and the presence of developments such as car parks and caravan parks. Where possible, these fences should be constructed behind vegetation that will screen them from view, thus maintaining a low visual impact (Figure 4.4b). Alternatively, denser growing vegetation can be planted adjacent to the fence to provide both visual relief and an additional barrier to traffic. If this vegetative barrier develops sufficiently the fence may not require eventual replacement.

Figure 4.4 Siting of front fences is a challenge. The further seaward they are located the more vegetated sand they can protect, but the risk of loss or damage during storms increases (top). Well planned revegetation can merge successfully with landward fences (below) for very effective but less obtrusive protection.

In areas of low usage and dense dune vegetation where complete fencing of the dunes is not required, fence "wings" can be constructed to direct traffic to an accessway. These "wings" can run for 10-20m from the accessway before ending in the surrounding vegetation.

4.6.2 Fence type and construction

This is dictated by local site characteristics. Different types of fence have particular advantages and by careful selection, time and money can be saved on construction and maintenance costs. Potential for personal injury is always an important consideration, particularly on steep or awkward sites.

The common types of dune protective fencing used are:

- plain wire fence
- Bayco® type fence
- wire mesh fence
- post and rail wooden fence

The key features of these fences are summarised in Figure 4.5 while design and construction recommendations are detailed in Figures 4.6a-d. Additional comments are provided in the text.

Fence posts can be made from treated pine or from hardwood grade timber. Pine is easier to work and lighter to carry but hardwood grade timber can also make durable posts.

Plain wire fence: Plain wire fences are being used more frequently in recent times because they are relatively inexpensive and easy to construct and maintain (Figure 4.6a). Plastic-coated wire is no longer favoured as it rusts quickly when water penetrates weakened coating and it is prone to theft.

Plain wire fences are well suited to both low and high usage areas, to areas where there is a rapid accumulation of sand, and to areas where there is a high probability of damage or destruction by waves. Their simplicity encourages different and innovative means of installation. All plain wire fences need straining and various techniques are available for doing so. Gripples for example, can eliminate the need for more elaborate strainers. Particular care is needed on undulating surfaces, as straining will tend to lift posts out of depressions. Star picket droppers can be hazardous and will eventually rust; plastic ones need to be assessed carefully for strength, UV resistance and the likelihood of theft. The latter are expensive, become brittle with time and are very sharp when broken.

A 2-person team can erect approximately 100 metres of plain wire fencing per day.

FENCE TYPE	RECOMMENDED LOCATION	ADVANTAGES	DISADVANTAGES
Plain Wire	Seaward side and along toe of access tracks on all beaches where wave damage or sand burial is likely.	Cheap. Simple to erect. Easy to maintain.	Lesser deterrent capability. Subject to rust.
Bayco®	Alternative to plain wire.	Does not rust. Simple to erect.	Slightly more expensive easily vandalised & may be more prone to theft.
Wire Mesh	Seaward & landward sides and along access tracks on medium to high use beaches where there is negligible risk of damage.	Height offers greater deterrent. Strong.	Expensive. High maintenance. Poor appearance. Subject to rust. Difficult to lift.
Post and Rail	On medium use beaches where there is minimal risk of wave damage or burial. Around Surf Clubs & public amenities.	Excellent appearance. Strong. Durable. Low maintenance.	Very high initial cost.

Figure 4.5 Comparison of dune fences.

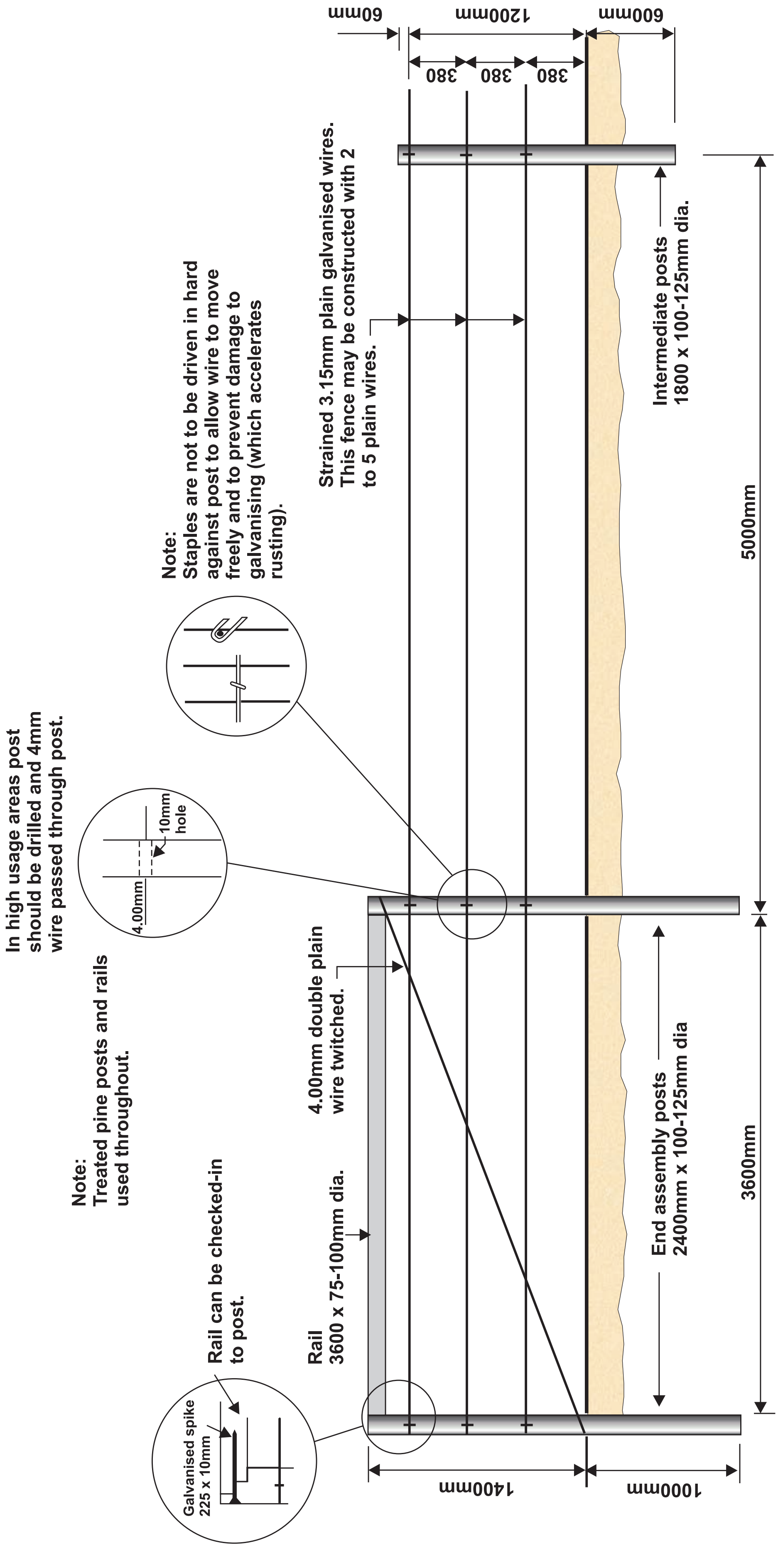


Figure 4.6a Plain Wire Fence

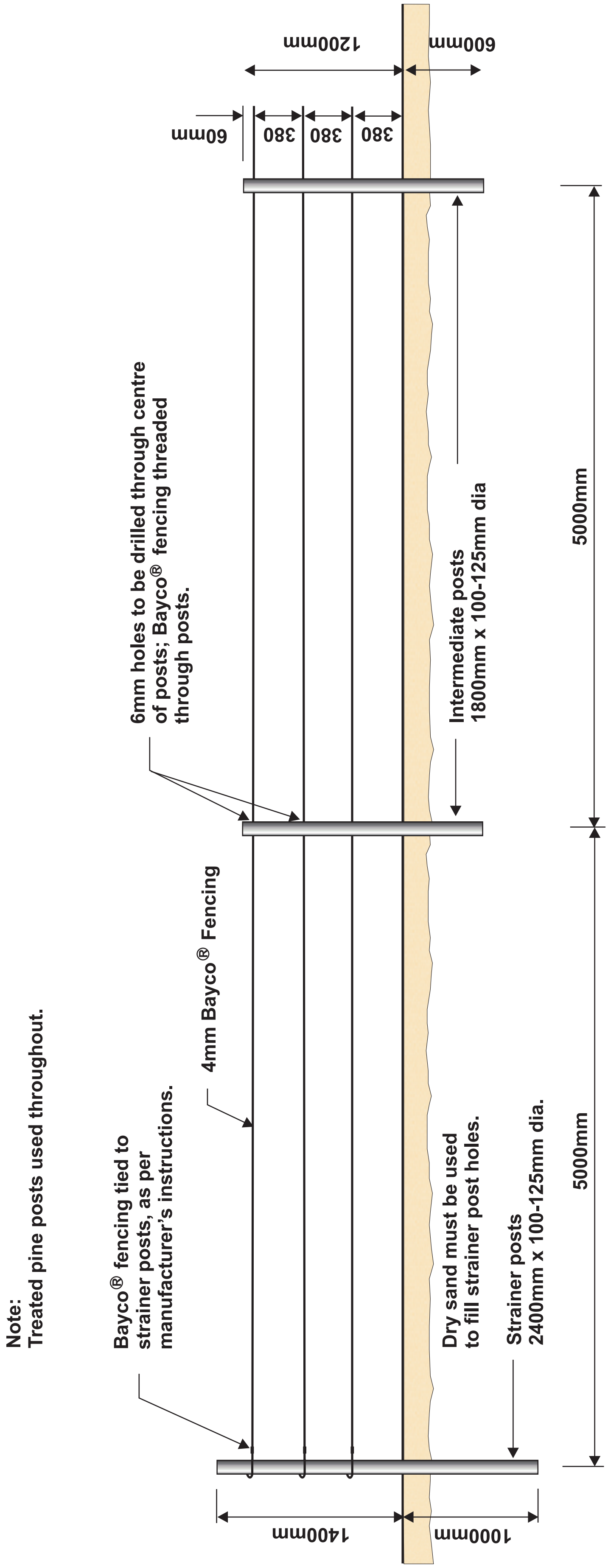


Figure 4.6b Bayco® fence

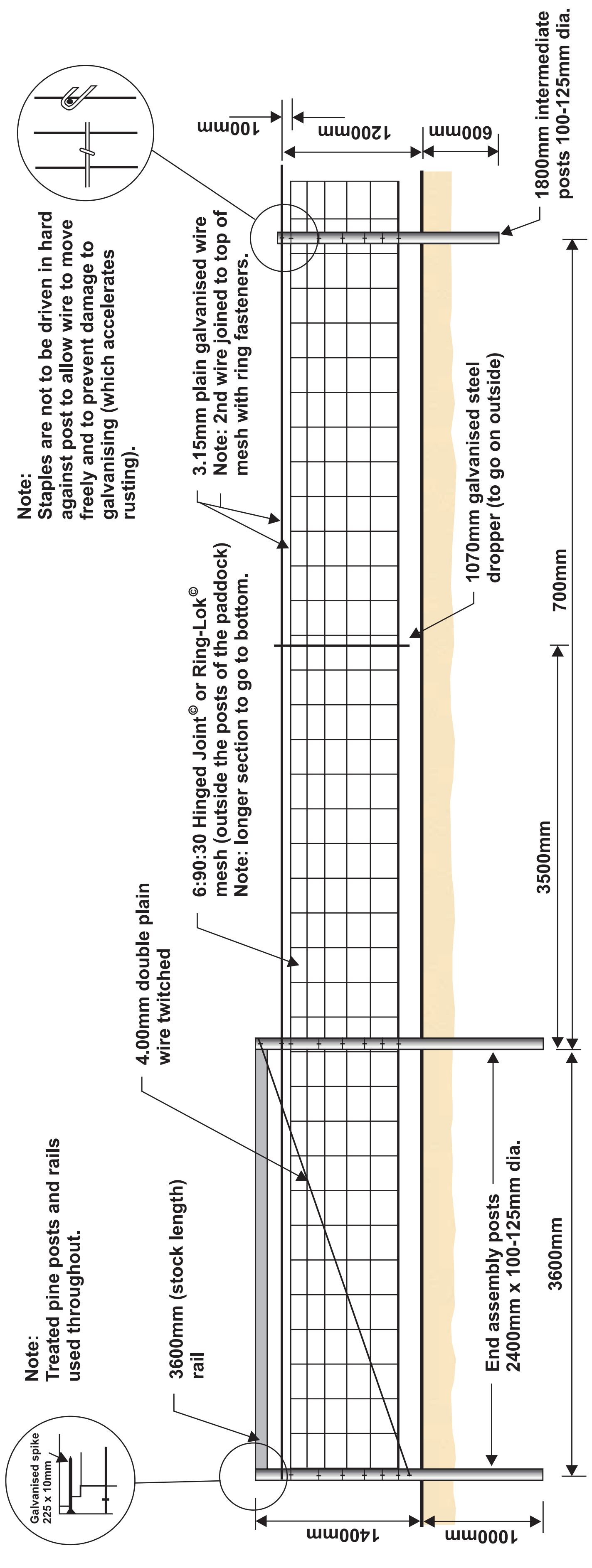


Figure 4.6c Wire Mesh fence

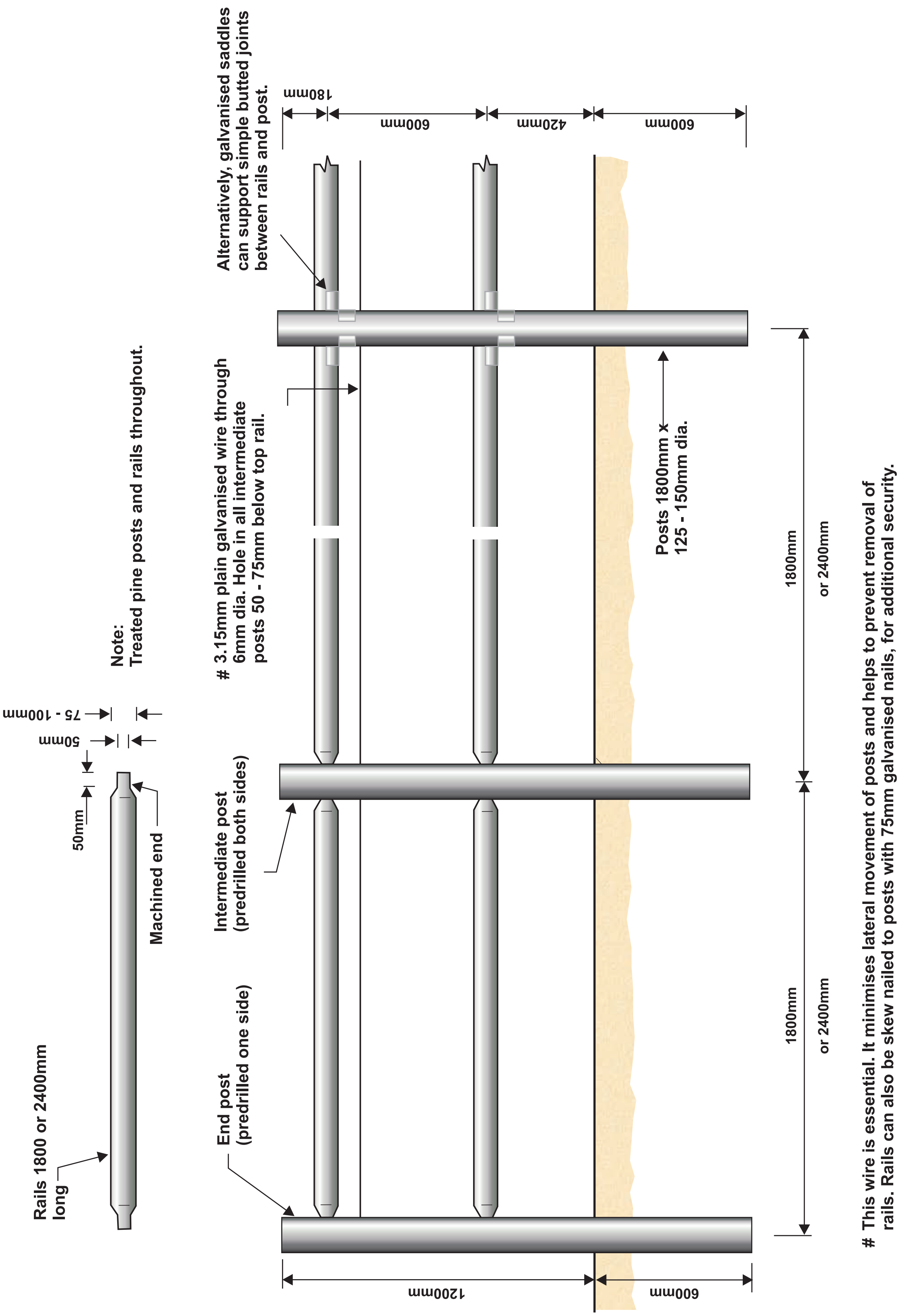


Figure 4.6d Post and rail wooden fence

Bayco® type fence: Bayco® type fencing is a modern product that may be used as a substitute for white plastic coated wire (Figure 4.6b). It comprises solid strands of high-density low-expansion polymer monofilament. It is white in colour, light, strong, and flexible and will not rust.

The Bayco® type fence may be used in the same locations as the plain wire fence, but has several advantages. Apart from its rust resistance, Bayco® fencing maintains its strain, and if constructed according to design sheet specifications, does not require the relatively more elaborate end assembly of the plain wire fence. The fencing may be strained and tied by hand, and can be constructed along minor deviations in line and contour without loss of strain or the need for additional strainer posts. The disadvantages include vandalism, theft and damage by fire.

A 2-person team can erect approximately 100 metres of Bayco® fencing per day.

Wire mesh fence: Wire mesh fences have been used in high usage areas along foredune and access tracks (Figure 4.6c). It is important that these fences are lifted regularly in areas where sand accumulation occurs, otherwise recovery is difficult due to burial and to vegetation growing through the mesh of the fence. This is a distinct disadvantage of this type of fence. If used on the backbeach they can also trap seaweed and other flotsam, leading to accelerated sand accumulation and burial. Fabrics should never be attached to these fences where burial is likely, as it will not be possible to recover them.

A 2-person team can erect approximately 80 metres of wire mesh fencing per day.

Post and rail wooden fences: Post and rail fences can be used adjacent to surf clubs, car parks, public amenity areas and along heavily used access tracks where sand burial or wave damage is not a problem (Figure 4.6d). They have high aesthetic appeal and they blend in well with landscaping works that have been undertaken in public areas.

Uneven ground surfaces can be accommodated by using galvanised saddles. These are right-angled brackets with curved faces that provide greater flexibility in butting rails to a post.

A 2-person team can erect approximately 60 metres of post & rail fencing per day (2 rail).

Disadvantages of this type of fence include vandalism, high cost and potential public liability due to breakages.

Figure 4.7a Plain wire fence, Birdie Beach

Figure 4.7b Bayco® fence, Angourie

Figure 4.7c Wire mesh fence, Shoalhaven Heads

Figure 4.7d Post and rail fence, Angourie

4.6.3 Fence Maintenance

All fences must be subject to an on-going maintenance program. Inspections and repairs should be undertaken on a regular basis and after storm periods to ensure that fences are kept in good repair, and retain their function of protecting vegetation and keeping the area safe for the public. Maintenance work should be documented thoroughly in case of future litigation.

Fences subject to sand burial need regular lifting and restraining once sand has accumulated to a depth of about 150mm. In the case of plain wire fences, lifting should occur before the bottom wire is buried.

Continual maintenance will increase the life expectancy of fence materials, maintain the protective function of the fences and defer the cost of complete replacement. Front fence wires will usually require replacement in time due to sand blasting and salt corrosion.

4.7 Beach Accessways

Accessways are used to encourage pedestrian and authorised vehicle access across dunes to the beach in a manner that protects both the dunes and adjoining vegetation. They are usually fenced to direct and confine the movement of pedestrian and vehicular traffic. The track surface is usually protected to prevent sand blowing from it and to provide traction for traffic. It is important to note that there is no single method that can be applied universally because beach variability is too great. Provision of access must be very carefully matched to the prevailing environmental character and usage patterns, so as to minimise adverse impacts. An invaluable publication is the NSW National Parks and Wildlife Service's *Walking Track Construction Guidelines* (Gorrell undated).

Careful consideration of accessway design can also ensure meaningful dune and beach experiences for people with a wide range of disabilities. Australian Standard 1428 *Disabled Access Code* (Standards Australia 1992) provides specific guidance and this is incorporated in the NPWS walking track guidelines referred to above.

Issues to be addressed include path and ramp widths, gradients and camber; provision of rest stops, seating and shelter; surfacing requirements; requirements for handrails; and the provision of suitable car-parking spaces at the beginning of accessways.

Attention is also drawn to draft *Australian Standard 2156.2* (Standards Australia 1999). Publication of this standard on walking track infrastructure design is scheduled for 2001. It is expected to include significant changes to existing guidelines, especially requirements for public safety.

4.7.1 Design

The primary design objective is to maintain continuity in the elevation of the dune surface to avoid wind funnelling and the subsequent development of new blowouts. Low spots also predispose the dune to inundation by waves during storms. Materials used in accessway construction must therefore be adjustable so that the accessway can accommodate sand accretion or erosion at the same rate as occurring on the adjacent dune. Careful consideration must also be given to the positioning of accessways, to minimise erosion potential and to accommodate user preferences.

4.7.2 Position

Accessways must be located at points that provide maximum possible protection to vegetated and other sensitive areas such as sites of Aboriginal significance as well as optimising convenience for users. If possible, accessways should be constructed where the public usually crosses the dunes. This will lead to greater public acceptance of these structures.

Like fencing (see 4.6.1), seaward termination of accessway structures is problematic. The further down onto the beach they are constructed, the more likely they are to be damaged by storm waves. Termination further back reduces the risk of wave attack but may leave sensitive vegetated areas more exposed to uncontrolled pedestrian movements. A compromise position needs to be determined for specific localities.

In certain situations numerous, closely spaced accessways may be required within the immediate vicinity of major recreational facilities to provide adequate access for the public, surf club members and emergency vehicles. In more isolated and lower usage areas the distance between the accessways can be increased.

Vehicle accessways for emergency purposes are needed where local councils are providing other services that invite public use of the beach. At some localities, vehicular access is also provided for recreational and commercial fishers. These accessways should be isolated as far as possible from pedestrians, thereby minimising the risk of injury.

4.7.3 Alignment

Ideally, accessways should cross the dunes at right angles to provide the shortest route to the beach. However this orientation must be modified if it leaves the accessway exposed to prevailing onshore winds.

Such exposure is likely to cause wind funnelling at the seaward entrance and encourage the development of new blowouts. If wind is funnelled through a low point in the foredune, sensitive vegetation communities behind the foredune may also be harmed. Modification may involve major re-orientation or simply inclusion of a “dog leg” in the accessway to avoid these impacts.

4.7.4 Gradients

Construction of accessways with acceptable slopes is a major consideration, as a large cross section of the community will be using them. Ideally they should match the configuration of the dune, but if the slope of either the remnant or reconstructed dune is steeper than 1 in 4 (1 Vertical : 4 Horizontal) then construction of timber steps or switchback ramps may be necessary. For vehicular traffic, slopes up to a 1 in 3 (1V:3H) are possible, but more gentle ones are preferred.

Consideration must also be given to children, aged and disabled people.

4.7.5 Surfaces

A surface cover is generally required in order to protect accessways from wind erosion and the physical movement of sand downhill by feet or tyres. The type of material used will vary according to usage but all need to provide an appropriate degree of safety and comfort for users, bearing in mind that the majority are barefoot.

Materials may vary from wood chips in lightly trafficked areas to hardwood boards bound by chain (“board and chain”) in areas subjected to intensive use. In all circumstances the material used must be adjustable so that it does not interfere with the natural processes operating within the dune environment. Rigid materials such as asphalt or concrete can be used in some very high use sites but should not be used in exposed or sloping areas as they can be buried by drifting sand, initiate erosion of the dunes by concentrating runoff, or be undermined and damaged by wind and waves.

If paths traverse very sensitive areas, surface materials should be selected that do not alter soil pH or introduce toxins. Aesthetics should also be considered, including aural aspects. (eg. crunching gravel underfoot may detract from opportunities to appreciate quiet surroundings or observe wildlife). Board and chain is the most commonly used method on active dune surfaces. In more stable areas such as the hind dunes, materials such as crushed sandstone or woodchip are preferred. In well-protected, lightly trafficked areas no cover material is used - bare sand forms the accessway surface.

***Board and Chain Accessways*:** Board and chain accessways have been designed to adjust to the changing dune profile. They are flexible and the spaces between the boards act as sand traps (Figure 4.8). With proper maintenance they can accommodate sand loss due to erosion, as well as gains due to wind. They can be designed for both pedestrian and vehicle access and should be kept to the minimum practical length. Hind dune areas with gentle gradients need not have board and chain accessways; woodchip or sawdust is sufficient.

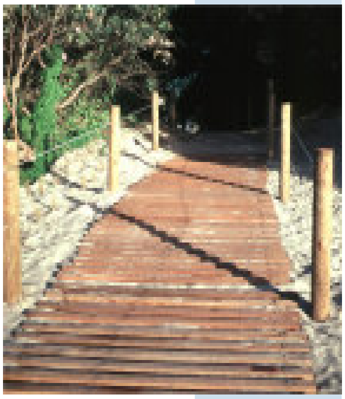


Figure 4.8 Pedestrian board and chain access. Note how the bounding fence is positioned close to the boards.

When constructing pedestrian board and chain accessways high priority must be given to safety and ease of use. As a general guide spacing should be increased on steeper slopes. On gentle slopes board and chain can be dispensed with in favour of surface coverings of wood mulch or its equivalent. Fencing that adjoins board and chain walkways needs to be installed as closely as practicable to the walkway so that tracks are not worn along the fence line.

Several pattern variations in board spacing have been used. A continuous line of closely spaced boards provides the most comfortable walking surface but material costs and construction times are significantly greater and it is more difficult to raise the walkway if sand begins to bury it. One popular pattern omits every third board. The intervening two boards accommodate both adult and juvenile feet and pace length. Planing of the top surface and bevelling of the top edges of the boards adds to user comfort and safety. Hardwood is preferred as treated pine often warps, leaving potentially dangerous protrusions. Construction details are illustrated in Figures 4.9a and b.

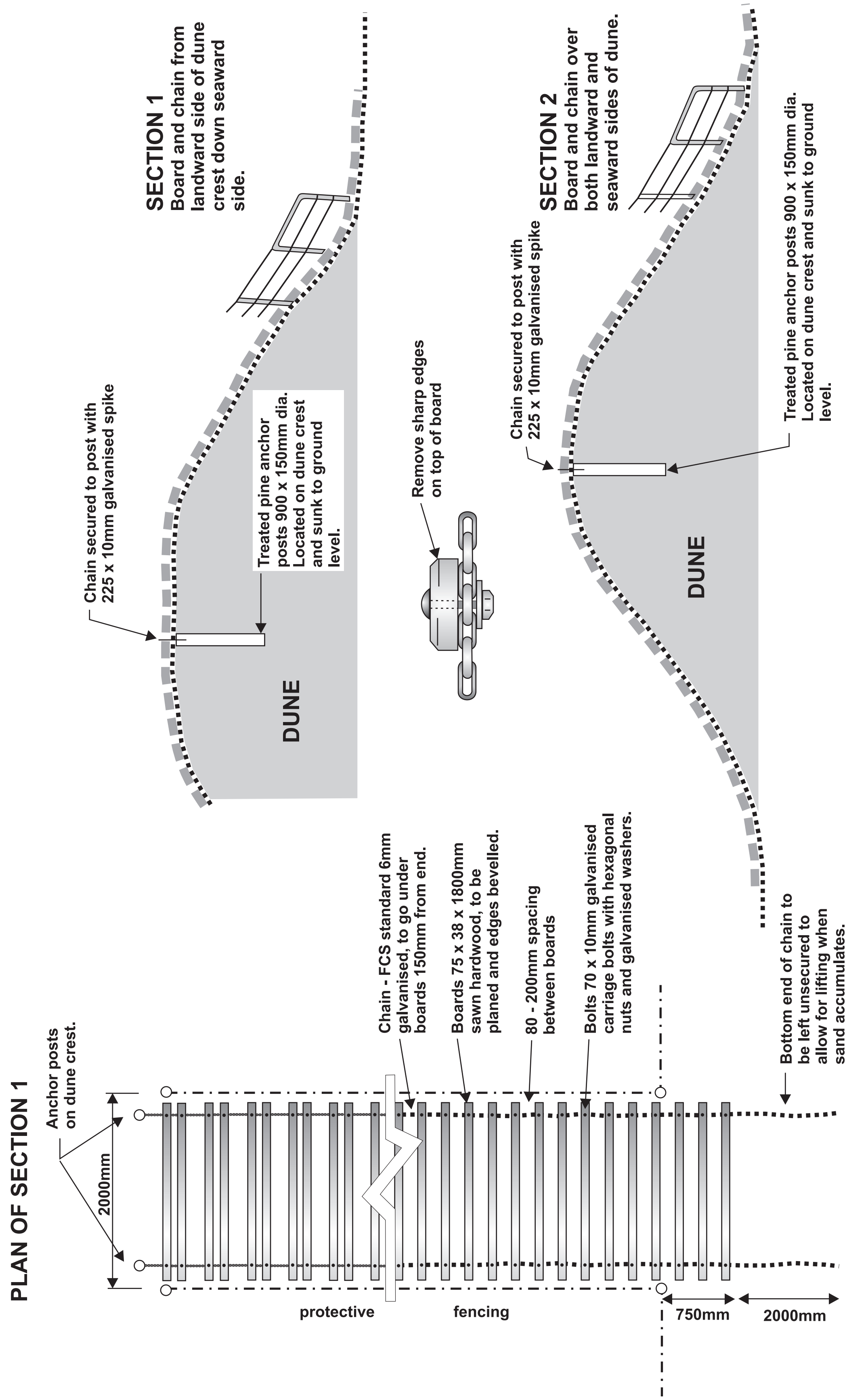


Figure 4.9a Pedestrian board and chain

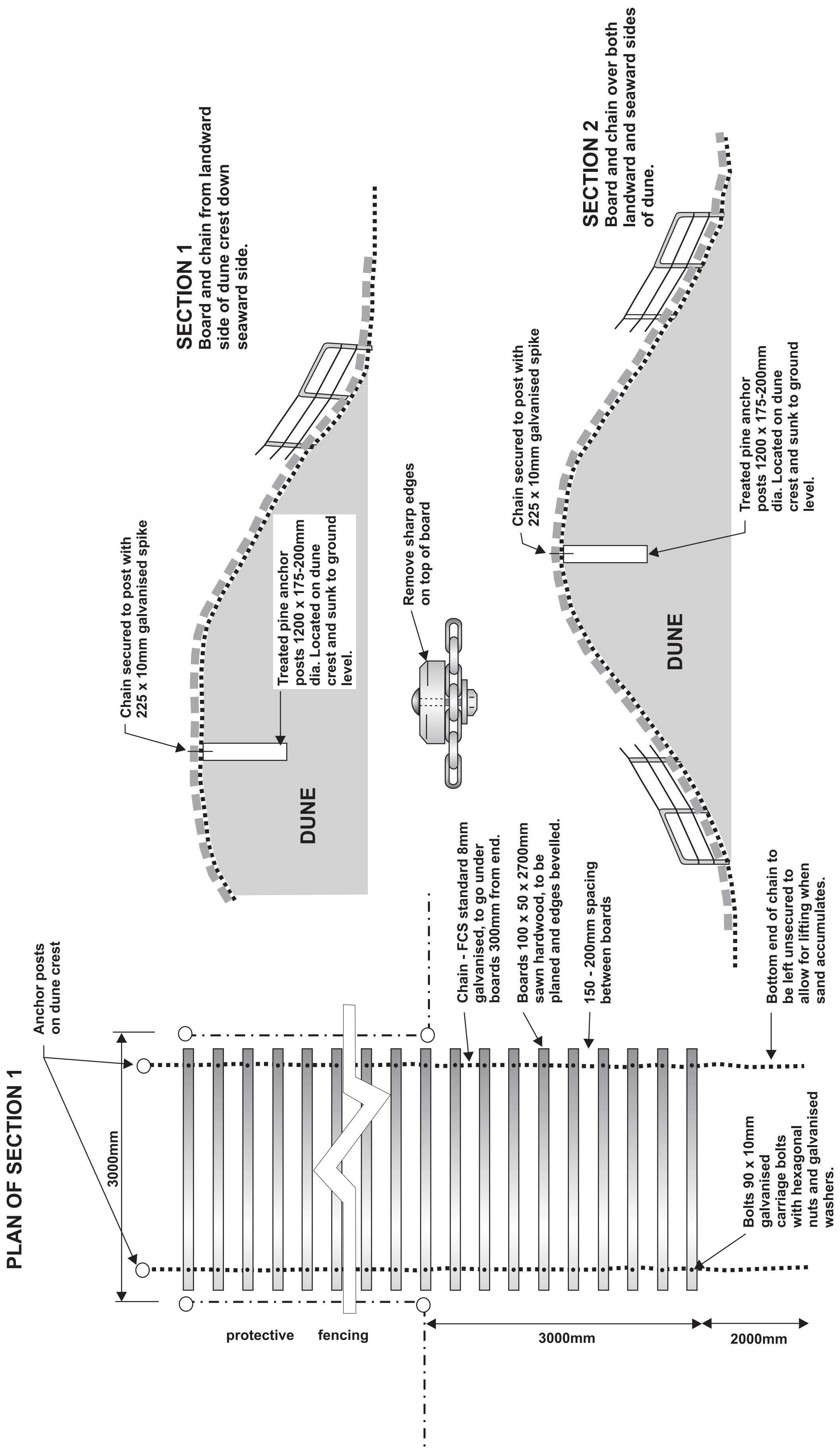


Figure 4.9b Vehicle board and chain

Vehicular board and chain accessways can be provided on the seaward slope, crest and landward slope of the foredune or wherever additional traction for vehicles is required. Recommended designs provide high strength to accommodate the heavy loads.

The risk of board breakage is minimised if the distance between the chains matches the track width of the vehicles that use the accessway most frequently. The objective is to have the chains bear much of the vehicle load, rather than the boards doing so alone.

***Woodchip, Mulch and Sawdust Accessways*:** Woodchip, mulch and sawdust can be used on access tracks that are level, where vegetation disturbance has been minimal and where sand drift is not occurring. It should be laid at a thickness of approximately 75-100mm. This allows it to pack firmly onto the sand base. If spread too thinly it will break up and with the movement of the sand will be buried and completely lost. Once laid it provides a comfortable walking surface and grass can grow amongst the chip, helping to bind it. It also enhances the aesthetic appeal of vegetated dunes.

Mulch and sawdust are cheap and easy to apply and also impart a more natural appearance to an accessway (Figure 4.10a). It tends to be shortlived, requiring replacement and is therefore only really suited to low traffic areas.

Woodchip and mulch should always be selected carefully to avoid coarser, angular and poorly sorted material that is uncomfortable or dangerous to walk upon.

***Crushed sandstone*:** Crushed sandstone can be used to provide a reasonably erosion resistant track surface on low gradient accessways landward of the foredune (Figure 4.10b). It should not be used on steep dune faces, as rainstorms will wash the fines away, leaving a very rough surface unacceptable to bare footed pedestrian traffic. It is also not suitable for areas experiencing frequent erosion or accretion. Maintenance costs are often high.

***Conveyor (holey) belt*:** An accessway surface with considerable potential is a conveyor belt that has been recycled from use in collieries. It can be obtained in different widths up to 1.4 metres. Holes are stamped through it prior to use, to facilitate drainage and maintenance lifting (Figure 4.10c). It is very easy to lay and is much cheaper than board and chain. It is also well suited to temporary use and subsequent removal, for example during a surf carnival. Its flexibility allows it to conform closely to undulating dune surfaces and it can be cut easily to suit turns or corners.

It appears suitable for pedestrians on grades up to 1 in 14. This gradient can also be negotiated by wheel chairs. However on steep slopes it may become slippery if a thin layer of sand accumulates on its surface. Attaching additional 100mm wide strips as step treads 200mm to 300mm apart on steeper slopes provides a more secure footing. Steeper grades (up to 1 in 4) have been used successfully by vehicles. On steeper slopes it can also be anchored using 500mm long D-bars.

Its main disadvantage is that it is only 1.4m wide. This is a little narrow to allow two people to pass readily; on higher usage accessways two strips may need to be laid beside each other. Its main use so far has been to provide 4WD access to some North Coast beaches, although an extended trial with pedestrians has also proved successful. It is no more slippery than timber when wet, and it has not generated any user complaints about being hot to walk upon.

***Asphalt, concrete and paving stones*:** Rigid materials such as these can provide very durable surfaces, but they are really only suited to very heavily trafficked areas that are reasonably stable (Figures 4.10d,e). They should not be used in exposed or sloping areas as they can be buried by drifting sand, initiate erosion of the dunes by concentrating runoff, or be undermined and damaged by wind and waves. They can also become slippery when wet and an artificial appearance may be a significant aesthetic distraction.

They can be useful in hind dune areas where an accessway leads to a viewing platform. Here they provide excellent surfaces for wheelchair access, but may also attract cyclists and skateboarders. In these circumstances width and sight distances need careful consideration to minimise the risk of collisions between users.

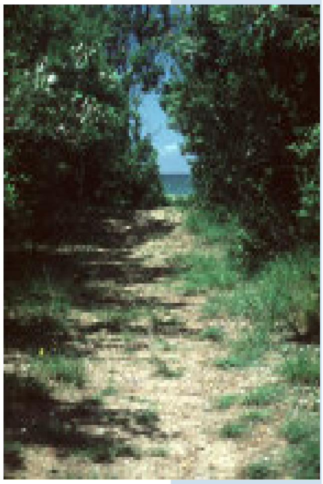


Figure 4.10a Low traffic accessways lend themselves to woodchip surfaces.

Figure 4.10b Crushed sandstone surface provides disabled access and blends with vegetation.

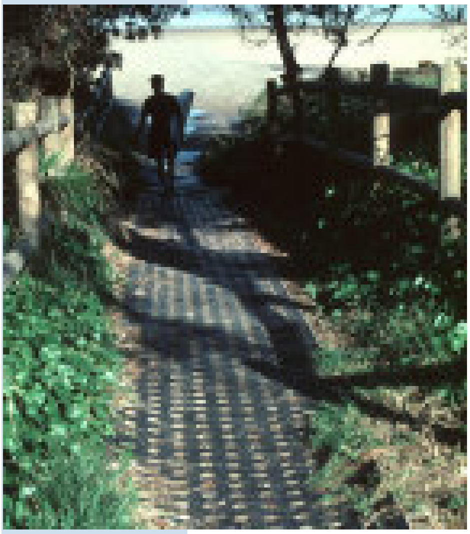


Figure 4.10c Recycled conveyor belt provides flexible, durable surface suitable for disabled access.

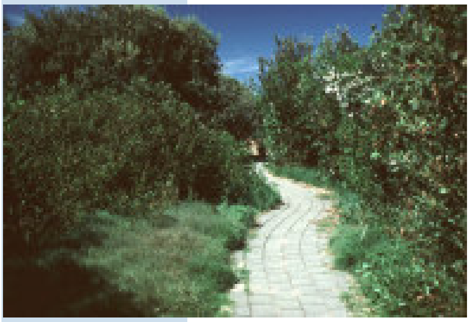


Figure 4.10d Pavers provide durable and attractive access through hind dune areas.

Figure 4.10e Asphalt provides access to a hind dune crest; bare sand extends to the beach.

4.7.6 Steps and stairs

These should be avoided if possible as they are generally not favoured by users and can become relatively expensive structures, both to construct and maintain. Designs should address the risks of erosion by wind, runoff and storm waves. Council approval will invariably be required.

In low traffic areas flights of log terraces may be sufficient to facilitate access across short slopes. Risers are constructed with treated timber logs or railway sleepers (Figure 4.11a). In these situations sand or other material is placed behind the timber to act as a step (Figure 4.11b). Risers should be anchored firmly, preferably by driving reinforcing rod or galvanised pipe through them into the ground (Figure 4.11c). Round treated logs should be avoided, as they can become very slippery when covered with sand.

Figure 4.11a Log terrace provides access in an area of moderate traffic.

Figure 4.11b Timber steps provide access across foredune, protecting vegetation.

DIMENSIONS FOR RISERS AND TREADS

SLOPE	HEIGHT OF RISER	DEPTH OF TREAD
1 in 5	100	475
1 in 4	115	450
1 in 3.5	125	425
1 in 3	135	400
1 in 2.5	150	380
1 in 2	165	330
1 in 1.5	175	280

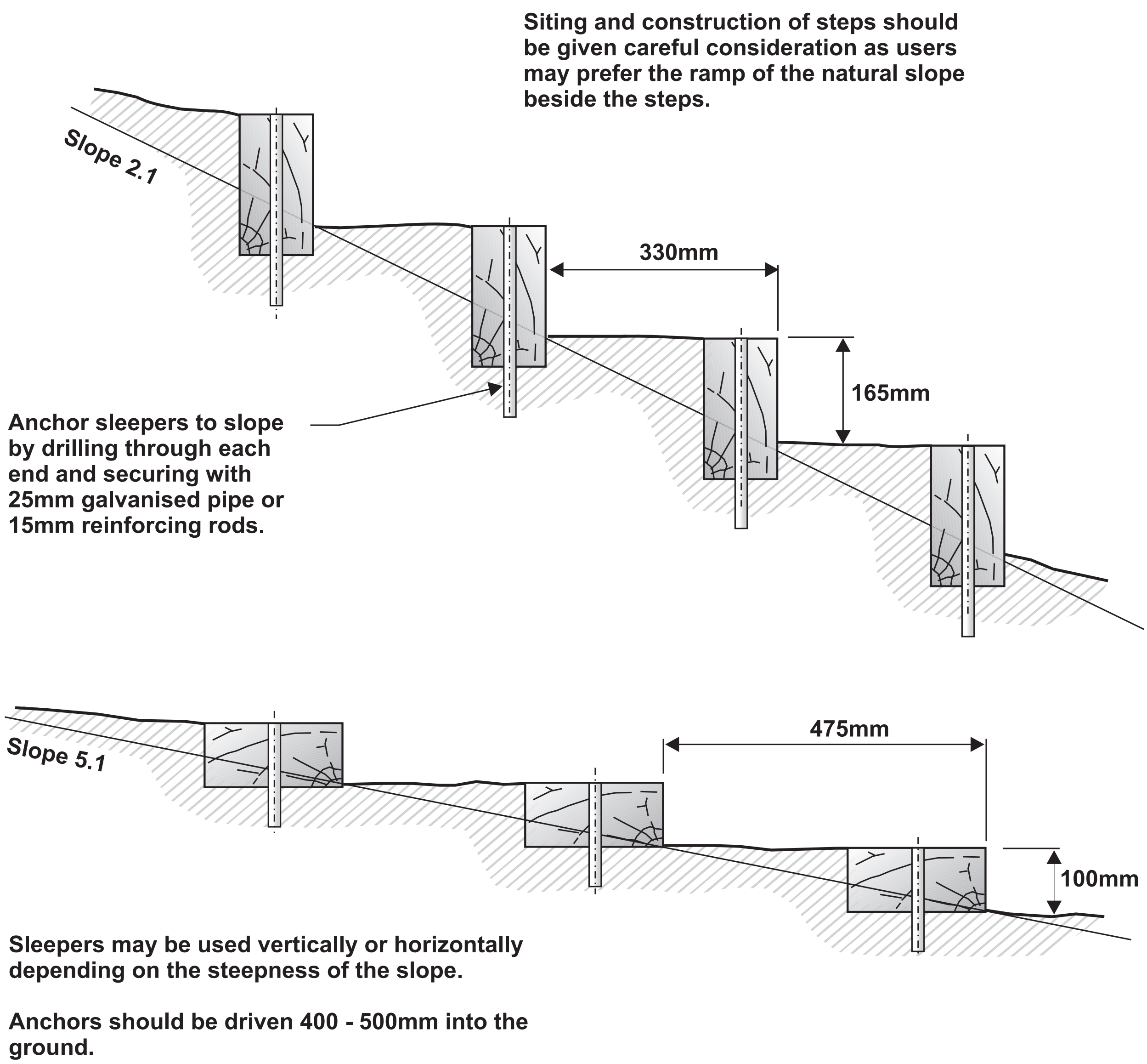


Figure 4.11c Step Designs

Standards Australia (1999) recommends that stairs and ladders should be avoided wherever possible. It specifies that stairways may only be used to control potential environmental damage (avoid erosion, protect vegetation). These circumstances can be encountered at steep or heavily trafficked sites (Figure 4.12).

Figure 4.12a Stairway providing access across a steep foredune.

Figure 4.12b Seaward ends of stairways need to accommodate erosion.

Figure 4.12c Staircase provides access across hind dune, protecting vegetation.

Stairs are usually constructed from timber and ideally they will be founded at a depth that will continue to provide safe and comfortable beach access if the beach surface is lowered dramatically by storm waves (Figure 4.12b). In these circumstances the durability of the materials used is especially important.

It is also preferable to locate such structures at the more protected ends of beaches where severe wave erosion is less likely and where there are opportunities to base the steps on bedrock. At these sites they are also unable to act as a groyne and interfere with sand movement along the beach.

On the dunes themselves, steps can be elevated above the ground surface to allow for sand movement or the establishment of vegetation cover.

Where it is intended to provide disabled access, appropriately designed ramps are necessary (Figure 4.13a). Design criteria incorporating Standards Australia's *Disabled Access Code* are addressed in the NPWS walking track guidelines (Gorrell undated).

Figure 4.13a Ramps provide easier gradients for all users and can blend well with bounding vegetation.

4.7.7 Elevated walkways

These are relatively expensive structures that can usually only be justified in highly trafficked areas and/or where access is to be provided across particularly sensitive environments (Figure 4.13b). They can also provide another dimension to site interpretation for users if the design and appearance blends well with the landscape they are traversing. Elevated walkways require careful design incorporating hand rails for public safety. These aspects are also addressed comprehensively by Gorrell (undated).

Figure 4.13b Elevated walkways provide access across poorly drained hind dune swales and through sensitive vegetation.

4.7.8 Viewing platforms

Viewing platforms can provide additional opportunities for visitors to appreciate the dune environment and for specialist users such as fishers and surfers to assess beach and surf conditions (Figure 4.14). If sited appropriately, they should discourage random, uncontrolled exploitation of vantage points elsewhere within the dunes. As they are not cheap structures their value should be maximised. This might be aided by providing a shade roof, or by ensuring that future revegetation growth does not obscure the views.

As relatively new features in rehabilitated areas, a variety of designs have emerged. Some are based on prefabricated galvanised metal components. The key aspects should be to ensure public safety by adopting properly engineered designs. These should also incorporate safety rails and walking surfaces that comply with current standards (Gorell undated).

Figure 4.14a Viewing platforms offer scenic access as well as protecting the dune vegetation.

Figure 4.14b Shade shelters on viewing platforms provide increased user comfort.

Figure 4.14c Viewing platforms provide opportunities for site interpretation.

4.7.9 Fencing

Fencing on either side of accessways (vehicular and pedestrian) is usually required, as uncontrolled traffic tends to divert from the defined route. This is particularly evident with pedestrians. If accessway traffic is not confined to the tracks, significant damage can occur to both mature and establishing dune vegetation.

Fences along board and chain accessways should allow enough room (approximately 100-150mm each side) between the ends of the boards and the fence to enable the boards to be lifted. Too much room will allow pedestrians to walk off the boards beside the fence, which in turn leads to lowering of the sand level and possibly to sand drift problems along the accessway. In some areas applying board edge mulches can help alleviate this.

Accessway fences should also be lifted if inundated with sand.

Elevated walkways require railings, primarily for user safety, but also to discourage users from taking shortcuts through the adjoining vegetated areas. Railing design (strength, height, rail spacing etc) must minimise the risk of users falling from the accessway and must satisfy the current Australian Standard.

4.7.10 Maintenance

It is imperative that all accessways be maintained regularly so that they continue to function correctly and they do not become a hazard to the public. It may be necessary to temporarily close public access in the interest of public safety if accessways become eroded, undermined or otherwise damaged. A systematic maintenance program should be implemented and documented by the land or project manager. This issue must be resolved before construction begins.

Maintenance often represents a considerable ongoing and unavoidable expense. Sound project planning can reduce these costs significantly. For example minimising the length of accessways (while still satisfying other project objectives) not only reduces initial installation costs, it helps limit future maintenance costs. Choice of appropriate materials is also crucial, for example to resist the impacts of salt corrosion and vandalism.

In areas where sand is accumulating, board and chain accessways require regular lifting so that the boards sit on the sand surface. If this is not done the boards can become so deeply buried that recovery without disturbing adjacent vegetation is extremely difficult and time consuming. In some situations deeply buried boards cannot be easily recovered, thereby requiring complete replacement of the boards and chain. This replacement is an expensive operation and can be avoided by regular maintenance. Board and chain with broken, splintered or undermined boards require urgent repair as they can injure pedestrians and damage vehicles.

Crowbars may be suitable for minor lifting work, but if burial is more widespread a suitable lifting hook may be needed. Accumulated sand should be spread out evenly to make lifting easier. The board and chain is then lifted and shaken, allowing the accumulated sand to fall between the boards. With two people using the hook on either side of the accessway, the board and chain can be lifted very efficiently.

Another problem with accessways is maintaining a functional link between their seaward ends and the beach, especially after severe or prolonged wave erosion that often leaves a scarp or cliff at the back of the beach. In this circumstance part of the accessway is simply lost; often the board and chain is left hanging uselessly over the scarp. On other occasions large, persistent swell waves may quickly bury the seaward end of the accessway. It is therefore important that access is restored as soon as possible after the event. A tractor or front-end loader can quickly remove sand from buried board and chain; alternatively a ramp of sand can be pushed up quickly and the board and chain can be relaid upon it. The non-boarded lengths of chain at the seaward end of a walkway facilitate mechanical lifting.

4.8 Signage

Signage on or near beaches has become an increasingly common feature of the coastline. Often it is an essential component of a rehabilitation project, especially if it advises users of potential hazards. While responsibility for erection and maintenance of signs usually lies with land managers and other authorities, some also devolves to volunteer groups working on coastal projects.

Signage can serve several purposes and it can be designed as a temporary or lasting component of the rehabilitated dune landscape. Good signage is valuable; poor signage is probably worse than none at all. With the latter, messages are unclear and will not generate respect from the community nor from visitors to the area; the audience “tunes out” and as a result may ignore other important messages being conveyed to them.

During the project planning stage, signage matters to be considered include the purpose of the signage as well as its design, construction, material, durability, maintenance and its compatibility with the aesthetics of the area. Some general recommendations for developing good signage are set out below. They should be tailored to suit individual sites and where they are part of a community-based project they should always be developed in partnership with the appropriate land manager. All councils have a signs policy, usually requiring formal approval prior to installation.

4.8.1 Purpose: why is it needed?

Most signage is used to enhance public safety, to control undesirable behaviour or to educate the community by raising awareness and understanding. Unnecessary signage is poor signage.

Safety**:** Minimising public risk is an ongoing task for land managers. Protection of the public interest or satisfying a duty of care may impose a legal requirement to erect warning signs alerting beach users to potential dangers (Figure 4.15).

These may relate to semi-permanent natural phenomena (deep or shallow water, rip currents); to temporary natural hazards (fallen trees, occurrence of high seas, a scarp cut into the dune face by storm waves); or to hazards that may arise from human intervention in the landscape (uneven surfaces, risk of theft, night closure).

There may also be temporary emergency signage, perhaps accompanied by fencing, and erected by the Police, State Emergency Services (SES), Council or other authority, effectively excluding the public from a defined site or area.

Information**:** Other signs serve to control public movement and behaviour within a longer time frame. This may be to make it easier for users to find their way to the beach, to encourage use of newly established facilities or to protect sensitive areas and resources. They may also directly or indirectly raise community awareness and understanding of the local environment and of efforts to protect or enhance it.

4.8.2 Design

This should be arresting whatever the purpose. Clarity of image and lettering is essential. Signs must be clearly discernible from a distance of at least five metres. Within any one area some uniformity in design is encouraged.

Where a sign must be obeyed in the interests of safety the picture and/or wording must be unequivocal; there must be no likelihood of misinterpretation. At many localities signs may also need to be multilingual. In some instances universally recognised symbols without lettering may be appropriate. Council sign policies will specify state and local requirements.

Signs seeking to deter nominated actions should be worded positively and if possible they should be accompanied by an explanation for the constraint. “Please stay on path; dune rehabilitation

Figure 4.15 Examples of good signage

in progress" is more likely to generate compliance than "Keep out" or "No beach access". Informative signage should be clear, concise, simple to understand, and appealing (Figures 4.15).

4.8.3 Position

Consideration must be given to the location of a sign to ensure its visibility without compromising public safety. While needing to be visible to passers-by there are also minimum clearances from walkways, roadways and services to be determined before erecting any sign. These should be readily available from land managers and local authorities.

Where signs need to be erected at erosion prone sites, care should be taken to minimise loss, and if damaged or removed they should be repaired or replaced promptly.

4.8.4 Materials

There is a great variety of materials to choose from in planning signage. The final choice will reflect the relative importance of factors such as prominence and durability, as well as production, installation and maintenance costs. Local NPWS or council offices can provide advice on contemporary preferences and pricing (eg. NPWS undated). Ongoing sign maintenance must always be considered.

Timber: The painted, treated-timber Dune Care signs have become a distinctive feature at many beaches but they become shabby unless repainted. Seasoned hardwood makes strong, durable signs that are routed easily. They are vandal resistant and repairable. Unpainted treated pine can be very effective with routed lettering and it usually blends well with the landscape. It is not as hard or as stable as hardwood but it is lighter and easier to transport.

Timber shelters protecting multiple signs are very effective in high usage areas and are often very attractive - as in a number of National Parks (Figure 4.16).

Composition board made from wood fibre and resin is easily worked but it must be sealed effectively for outdoor use. It is easily vandalised.

Metal: Reinforced aluminium is the preferred material for durable metal signs within coastal environments. Screen-printed aluminium readily incorporates graphics but it is relatively expensive, particularly for single orders. Wording can be obscured by condensation if perspex or lexan covers the sign.

Plastic lettering and symbols are now used in many signs and these may prove to be the most durable of all. Some sign-writers are offering twelve-year guarantees for these materials.

Many signs now use a combination of materials and technological advances are constantly providing new products with improved durability at lower prices. It is recommended that the local NPWS or council office is contacted regarding favoured materials.

Figure 4.16 Shelters protect signs from rain and direct sunlight and can encourage site interpretation by visitors.

4.8.5 Stability

Signs also need durable supports. Powder-coated galvanised pipe, shaped appropriately, or sturdy treated pine posts are preferred. Most signs have their supports set well into the ground - as much as a third or even half of the total height. In unconsolidated sand particularly, large signs will require stabilising below the surface, for example with concrete. The difficulty of replacing signs with massive footings that are badly damaged by vandalism should also be considered.

4.8.6 Permanence

The durability of signs depends on the materials chosen, the degree of exposure (eg. fading and discolouration from ultra-violet rays) and the incidence of vandalism. Where vandalism (either defacing of signs or physical damage) occurs, prompt repair is essential, however frustrating. If ongoing repair is judged to be too great a burden, consideration should be given to removing the sign completely.

4.8.7 Temporary signs

Local authorities may erect temporary signs during emergencies or to warn beach users of temporary hazards. Other temporary signs might target a particular project or even an afternoon working-bee. On the Central Coast, the latter have proved very effective in explaining the work being undertaken and in encouraging new people to join the group. With all temporary signage it is essential that it be removed as soon as its relevance is lost.

4.8.8 Responsibilities

Signs should never be erected without formal approval of the land manager. Groups and/or land managers could be liable for personal injury arising from a poorly constructed or erected sign.

When considering signage in areas that are being revegetated care should be taken to ensure that any signs erected will not be obscured by growth of plants. As with new plantings, new signs should not obscure lines of vision (sight lines) for cycle and walkways. Weed control may also be required.

Any group deciding to make or purchase an informative sign should also be sure the decision has been reached democratically, as the group will then have a sense of ownership and ongoing maintenance will be easier.

4.8.9 Costs

The cost of signs sometimes seems prohibitive but experience indicates that it is better to spend a large sum on a sign that will give years of service than to economise with a cheaper item. Provision for signage costs should be made when applying for grants.

4.8.10 Number: how many signs?

Beware “sign fever”. Too many signs will not be effective and adds unnecessarily to both installation and maintenance costs. They will not be read and they can destroy the whole ambience of an area.

4.8.11 Maintenance of signs

As is the case for other structures, it is imperative that signs be well maintained. It should also be noted that some land managers may be reluctant to accept responsibility for maintenance of a sign erected by a group. Repair or have repaired any damaged sign as soon as possible. Sometimes a touch-up with suitable paint will give a sign an appearance of freshness.

If at all possible, remove all traces of graffiti quickly. As a last resort remove a damaged sign.

4.9 References and further reading

Buchanan R.A. 1989, *Bush Regeneration: Recovering Australian Landscapes,* TAFE NSW, Sydney.

Gorrell S. undated, *Walking track construction guidelines,* NSW National Parks and Wildlife Service (c. 1996).

NPWS undated, *Signage Design Standards,* National Parks and Wildlife Service, Sydney.

Standards Australia 1992, *Disabled Access Code,* Australian Standard 1428

Standards Australia 1992, *Fixed platforms, walkways, stairways and ladders - Design, construction and installation,* Australian Standard 1657.

Standards Australia 1999, *Walking tracks Part 2: Infrastructure design,* Draft Australian Standard 99196 (to be AS2156.2).

5. WEEDS

5.1 What are weeds?

Weeds are pests that cause a range of environmental, social and economic problems. There are many definitions of weeds: from a plant growing where it is not wanted, to a plant for which no economic use has yet been found.

Along the coastline, weeds are best thought of as plants that do not occur naturally in the area under consideration and which pose a threat to the values of that area. The more threatening weeds reproduce readily and can spread quickly from their original source or point of introduction to invade other areas, damaging natural ecosystems that are desired to be weed free.

The term "noxious weed" is also used when discussing weeds. This has a specific meaning and refers to weeds listed under the *Noxious Weeds Act* 1993. Control of noxious weeds is a legal obligation of landowners with various actions required depending on the classification. Control is enforced by local authorities - either by local councils or by regional weed authorities.

Successful management of NSW coastal dune environments requires attention to both noxious weeds and a wide range of other weeds. At some sites, where physical degradation is quite minor, a weed management program may be the only element required for successful dune rehabilitation.

Weeds can include both exotic (non-Australian) and native flora. For example, Bitou Bush (*Chrysanthemoides monilifera* ssp *rotundata*) is a South African shrub, which is now prolific along most of the New South Wales coastline. Coastal tea tree (*Leptospermum laevigatum*) is a native plant that occurs naturally from the mid-north coast to southern Australia. It was commonly used for dune stabilisation on the Far North Coast but has subsequently established and spread in a number of other areas in an unwanted manner.

Weeds can have a variety of vegetative forms. They can be shrubs (eg. Bitou Bush), trees (eg. Coral Tree), vines (eg. Madeira vine), herbaceous plants (eg. Cape Weed) or grasses (eg. Spiny Burr Grass).

5.2 Impacts of weeds

Weeds cause many problems in coastal and other environments because they often grow faster than native plants and successfully compete for sunlight, water, nutrients and pollinators. They can prevent or interfere with natural regeneration and planned revegetation programs.

Their capacity to establish and spread leads to invasion and displacement of native plant communities, thereby reducing biological diversity. Floristically and structurally diverse natural vegetation can be changed dramatically to a much-simplified state where one or several weeds may dominate. Examples include monospecific stands of Bitou Bush (Figure 5.1) or ground covered by Asparagus Fern. Native fauna are also adversely affected by the loss of plants that provide shelter, food and nesting habitat, or by other animals that thrive in response to the changed conditions.

Figure 5.1a: Monoculture of Bitou Bush on foredune at Stuarts Point

Figure 5.1b: Hummocky terrain induced by Bitou Bush, Birubi Point

Figure 5.1c: Bitou Bush flower and fruit

Other weeds are illustrated in Attack of the Killer Weeds (Williams & Fiedler 1998)

Weeds may also directly threaten rare or important individual species and communities. For example, in the Coffs Harbour area an endangered prostrate plant *Zieria prostrata* is threatened by Bitou Bush and a number of significant littoral rainforest communities are threatened by Bitou Bush, Asparagus Fern, Lantana and other weeds.

Other potential weed problems include:

- providing habitat or a food source for feral animals
- altering dune sand mobility by changing the vegetation cover eg. creation of a weed monoculture
- increasing the cost of servicing beach accessways and maintaining weed-free plantings in revegetation programs
- increasing fire risk by raising available fuel levels in fire danger periods
- reducing visual amenity and aesthetics of natural landscapes
- financial cost of control programs

5.3 Introduction and spread

Weeds are introduced to the natural environment either accidentally, for example by movement of contaminated soil containing weed seeds, or through deliberate introductions for agriculture, horticulture or utility, for example early plantings of Bitou Bush for dune stabilisation.

Weeds have often escaped from their original source and spread into the natural environment. Many weeds in coastal dune ecosystems have their origins in nearby gardens.

The spread of weeds is often favoured by disturbance. Disturbances include physical disruption of the environment such as constructing and maintaining roads, tracks and powerlines, changes in surface runoff and drainage, and fire. These create conditions that often favour weeds over native plants such as higher light levels adjacent to roads or increased soil nutrients resulting from urban runoff.

The seeds of weeds are usually easily transported and many weeds have parts such as bulbs, corms, leaves and stems from which reproduction occurs. There are also numerous ways in which weed propagules can be dispersed. For example, wind is very effective in dispersing seeds of the daisy family and many grasses, while water is very effective along drainage lines and down broader slopes. Animals such as foxes and birds, both native and introduced, are also effective dispersal agents with seeds stuck to fur or feet or being transferred through consumption and later defecation. Humans are important too, through attachment of weed propagules to clothing, footwear, machinery and vehicles and by movement of contaminated soil.

Dumping of garden waste at the edges of bushland is a major source of weed infestations and is particularly serious as it allows the establishment of many weeds that would otherwise have no means of spreading.

5.4 Management

Clear objectives must be set when deciding to do something about weeds in a particular area. Sometimes weed control has been undertaken without a complete understanding of the local environment or of the requirements for follow-up or maintenance works to prevent re-invasion. In many cases the initial successes have not been able to be sustained and resources have been wasted.

In many instances the objective of simply controlling weeds is too narrow and fails to consider broader environmental requirements. Controlling weeds should be seen as part of a wider obligation to retain, protect and restore natural dune ecosystems.

The following principles should be considered when planning a weed management program.

a) Understand the nature of the problem.

- what weed(s) are present?
- where do they occur?
- at what densities do they occur?
- what threats do they pose?
- why are the weeds there; are they a symptom of a larger problem?
- are the weeds serving an ecological function of value?
- what other land management issues are there?

b) What can be done about the problem?

- who owns or manages the land; are they doing anything or do they have any plans to address the problem?
- are there any groups, organisations or individuals who are interested or can help?
- are suitable control techniques available?
- what are the effects of the controls (positive/negative)?
- how much can be done?
- who will do the work and when? What is the best time of year?
- are special skills, methods or equipment required?

- what is the weed's classification? This may determine the type and amount of funding that can be sought for a control program.
- what happens after initial control efforts, will other (worse) weeds invade?
- is revegetation required or is natural regeneration adequate?

c) Getting results.

Preventing new infestations is usually cheaper and more successful than dealing with established infestations. This requires an awareness of weeds and monitoring of the area to detect new outbreaks.

Generally work in lightly infested areas first. This will help contain the spread of weeds, is cheaper and there is a higher chance of success. Participants in the program will feel a sense of achievement. Heavily infested areas require more work over a longer period and some may have changed substantially so that re-establishing original native vegetation is unrealistic.

Decide whether to treat priority weeds in an area or systematically treat all weeds. Both approaches can be valid and depend on the nature of the infestations, the threats posed, the condition of the surrounding vegetation and the desired outcome.

Set realistic limits. It is better to concentrate resources to achieve fewer outcomes than to spread too thinly and only partially complete more. Break up the area into manageable sections so what initially may be daunting can be achieved by working a section at a time. Allocating workers to a given area can build ownership and pride in their achievement.

Work together. Some of the best work is done where groups, individuals and land managers come together and provide a range of expertise, labour and equipment to deal with problems.

Think ahead. Most weed work requires follow-up to deal with re-infestation from the soil seedbank or dispersal from nearby areas. How big an area can be realistically maintained in the longer term? Who will do this? If revegetation is required, then seed collection and propagation often needs to commence well before weed control is commenced.

Be aware that other weeds may invade or colonise an area after initial weeds are removed. This needs to be planned for.

Be flexible. Use appropriate control techniques for the particular weed in that situation. What works in one area is not always applicable everywhere else.

Community support and awareness. This is important to let people know what the problem is, what is being done about it and how they could help. This can be done with signs, brochures, posters, newsletters and media (radio, TV, newspapers), and through interaction with the wider community and passers-by at working bees and field days.

Document results. Take before, during and after photographs of the work area and record what has been done. This is often necessary to remind yourself and others of how much has been achieved. Photographs should be taken from the same fixed, marked point each time and a permanently fixed reference object should be included in each image frame.

d) Following a plan

It is essential to have a plan that considers all of the matters itemised above. A plan can be a very simple document, sometimes one page, or a very detailed document depending on the scale and complexity of the problem (see Chapter 3 for more detailed discussion of the value of proper planning).

An approved plan will ensure that everyone involved knows what is going to be done, that it has backing from the land manager, that a consistent approach will be adopted and that if key people move on then the program still has a high chance of succeeding.

Good planning will help to achieve the objectives of other weed management initiatives. These may be contained in a weed control strategy prepared by the local council, they may be contained in a state strategy such as the *NSW Bitou Bush Strategy* (NPWS 2001), or they may relate to higher level plans such as the national *Bitou Bush and Boneseed Strategic Plan* (A&RMC of Aust. & N.Z. 2001). Good planning will also encourage compliance with Best Practice Management guidelines (eg.Vranjic 1999).

The planning process should also identify other issues that may need consideration. This should include assessment of the wider ecological role played by the pest species. For example, some weeds provide shelter for endangered species from predatory feral animals. Weeds may also form part of the overall vegetation canopy, preventing intrusion of salt laden winds into sensitive ecosystems. Abrupt removal of the weeds in these circumstances could have adverse consequences.

When threatened species are present, the impact of weed control on those species needs to be considered in terms of the Threatened Species Conservation Act. NPWS can provide advice on the requirements for impact assessment. Other environmental protection instruments also preclude removal of vegetation without prior environmental impact assessment and formal approval. State Environmental Planning Policy 14 (SEPP 14 Coastal Wetlands) and SEPP 26 (Littoral Rainforest) are two examples of such restrictions.

5.5 Control techniques

Various control techniques are available for treating weeds. These are usually grouped into physical, chemical and biological controls.

Physical weed control techniques can range from use of machinery for clearing major infestations to very labour intensive techniques such as the Bradley method (Buchanan 1989).

Chemical control techniques can also range from the broad-scale use of spray machinery including aircraft to the selective but labour intensive use of backpack sprays or stem injection implements.

Although attracting growing interest, application of biological controls by pathogenic diseases or insects is only available for a very limited number of plants with variable success.

Choice of control techniques depends on:

- weed growth stage and the size and nature of the infestation
- presence of non-target plants and animals and the effect of control technique on them
- site characteristics such as soil type slope, erodibility, access, exposure and prevailing winds
- legal requirements governing the use of herbicides
- available equipment
- expertise and experience of available labour
- cost
- personal preferences

New control methods and products are constantly being introduced. Occupational Health and Safety standards, especially for handling herbicides and pesticides, are also becoming increasingly rigorous.

Advice on specific controls for particular weeds can be found in the list of references at the end of this chapter and by contacting local council weed officers, bush regenerators and National Parks and Wildlife Service staff.

Weed control is moving towards an integrated approach where the appropriate control technique is used for a particular situation. Physical, chemical and biological controls are used in a co-ordinated way to provide the most effective control at the least cost and to minimise off target impacts, whilst retaining a stabilising vegetative cover on the dunes.

5.6 Weeds occurring along the coastline

The following is a list of weeds that are known to occur on the NSW Coastline. Not all weeds are present everywhere and some plants may behave as weeds in one area and be relatively benign in another area. There will be other weeds not on this list such as newly emerging weeds or weeds that are poorly known and/or restricted to small isolated locations.

Acacia saligna	Golden Wreath Wattle or Willow Wattle
Acetosa sagittata	Turkey Rhubarb
Agave americana	Yucca Plant
Ageratina adenophora	Crofton Weed
Ageratina riparia	Mist Flower
Ageratum houstonianum	Blue Billy Goat Weed
Anredera cordifolia	Madeira Vine
Araujia hortorum	Moth Plant
Arctotheca populifolia	Cape Weed
Arundinaria spp.	Bamboo
Asparagus aethiopicus	Ground Asparagus
Asparagus plumosus	Climbing Asparagus Fern
Baccharis halimifolia	Groundsel Bush
Bidens pilosa	Cobblers Peg
Bryophyllum delagoense	Mother of Millions
Bryophyllum pinnatum	Resurrection Plant
Buddleja madagascariensis	Buddleja
Canna indica	Canna Lilly
Cardiospermum grandiflorum	Balloon Vine
Catharanthus roseus	Madagascan Periwinkle
Celtis sinensis	Chinese Elm
Cestrum parqui	Green Cestrum
Chloris gayyana	Rhodes Grass
Chrysanthemoides monilifera	
subsp. *monilifera*	Boneseed
subsp. *rotundata*	Bitou Bush
Cinnamomum camphora	Camphor Laurel
Commelina benghalensis	Hairy Commelina
Conyza albida	Fleabane
Coprosma repens	Marble Plant or Mirror Plant
Coreopsis lanceolata	Coreopsis
Cortaderia selloana	Pampas Grass
Cotoneaster spp.	Cotoneaster
Crocosmia X crocosmiiflora	Montbretia
Cynodon dactylon	Common Couch (native with weedy characteristics)
Delairea odorata	Cape Ivy
Desmodium uncinatum	Silver Leaf Desmodium

Eragrostis curvula	African Love Grass
Erythrina X sykesii	Coral Tree
Eleusine indica	Crows Foot Grass
Euphorbia cyathophora	Painted Spurge
Euphorbia paralias	Coastal Spurge
Ficus elastica	Indian Rubber Tree
Foeniculum vulgare	Fennel
Gazania rigens	Gazania
Genista spp.	Broom
Gladiolus gueinzii	Coastal Gladiolus
Gloriosa superba	Glory Lily
Hydrocotyle bonariensis	Pennywort
Ipomoea cairica	Mile a Minute
Ipomoea indica	Common Morning Glory
Juncus acutus	Spiny Rush
Lantana camara	Lantana
Leptospermum laevigatum	Coastal Tea Tree (native with weedy characteristics on Far North Coast that occurs naturally south of Nambucca)
Ligustrum lucidum	Large-leaved Privet
Ligustrum sinense	Small-leaved Privet
Lilium formosanum	Formosa Lily
Lonicera japonica	Japanese Honeysuckle
Lupinus luteus	Lupin
Lupinus hirsutus	Lupin
Lycium ferocissimum	Boxthorn
Macfadyena unguis-cati	Cats Claw Creeper
Macroptilium atropurpureum	Siratro
Melinis repens	Red Natal Grass
Myrsiphyllum asparagoides	Bridal Veil Creeper
Nephrolepis cordifolia	Fishbone Fern (native plant with weedy characteristics; does not naturally occur on coast)
Ochna serrulata	Mickey Mouse Plant
Oenothera stricta	Evening Primrose
Olea europea ssp africana	African Olive
Opuntia stricta	Smooth Tree Pear or Prickly Pear
Panicum maximum	Guinea Grass
Parietaria judaica	Pellitory
Paspalum spp.	Paspalum
Passiflora edulis	Passionfruit
Passiflora foetida	Stinking Passionfruit
Passiflora suberosa	Corky Passionfruit
Passiflora subpeltata	White Passionfruit
Pennisetum clandestinum	Kikuyu
Phyllostchys spp.	Bamboo
Phytolocca octandra	Inkweed
Pinus ellioti	Slash Pine
Pinus radiata	Radiata Pine
Polygala myrtifolia	Myrtle-Leaf Milkwort
Psidium cattleianum	Cherry Guava
Psidium guajava	Red Guava
Psidium littorale	Yellow Guava
Pyrostegia venusta	Golden Shower
Ranunculus repens	Creeping Buttercup
Ricinus communis	Castor Oil Plant
Rivina humilis	Coral Berry
Rubus fruticosus	Blackberry
Sansevieria trifasciata	Mother in Law's Tongue
Schefflera actinophylla	Queensland Umbrella Tree
Schinus terebinthifolia	Broad-leaved Pepper Tree
Senecio madagascariensis	Fireweed
Senna pendula var. *glabrata*	Cassia or Winter Senna
Setaria sphacelata	Setaria or Pigeon Grass
Solanum mauritianum	Tobacco Bush
Solanum nigrum	Blackberry Nightshade
Solanum seaforthianum	Climbing Nightshade
Sorghum halepense	Johnson Grass
Sporobolus indicus	Parramatta Grass
Stenotaphrum secundatum	Buffalo Grass
Syagrus romanzoffianam	Cocos Palm
Tagetes minuta	Stinking Roger
Tecoma capensis	Cape Honeysuckle
Thunbergia alata	Black-Eyed Susan
Tithonia diversifolia	Japanese Sunflower
Trachyandra divaricata	Dune Onion Weed
Tradescantia fluminensis	Wandering Jew
Tropaeolum majus	Nasturtium
Watsonia meriana	Watsonia
Wedelia trilobata	Singapore Daisy
Zantedeschia stricta	Arum Lily
Zebrina pendula	Variegated Wandering Jew

For additional information and illustrations, dune managers should consult *Attack of the Killer Weeds* (Williams and Fiedler 1998) distributed by Coastcare.

5.7 Three worst weeds of the NSW coastline.

Many weeds have become strongly established along the coastline. New weeds are being introduced to coastal bushland and most existing weeds are expanding their range. Conferring "worst" weed status on a plant gives regard to three main factors; distribution, impact and difficulty of control. Local priorities may differ.

The 2000 NSW Dune Care Conference considered this question and because of geographic variations provided regional lists of weeds that were worse than bitou or persistently replaced it after initial control. From this and other information the three worst weeds for the NSW coastline as a whole are **Bitou Bush, Asparagus Fern** and **Lantana.** All three extend from the Far South Coast of NSW into Queensland, occupy a wide range of habitats and require repeated control. Bitou Bush and Lantana are listed as "Weeds of National Significance".

5.7.1 Bitou Bush

Bitou Bush (*Chrysanthemoides monilifera* ssp *rotundata*) is a South African shrub that was used in NSW to stabilise sand dunes for over twenty years. Its rapid growth rate and voluminous production of long-lived, readily dispersed seeds (up to 48,000 per plant) has facilitated its invasion of most of the NSW coastline. It has the capacity to establish and dominate both disturbed and undisturbed bushland and achieve over 90% coverage in some areas such as parts of the Tweed Coast. In recent years a more coordinated and better resourced effort has begun to successfully reduce the impacts of this plant in a number of small areas. However, this still falls far short of what is required, given the magnitude of the problem.

A NSW Bitou Bush Strategy provides the framework for continuing control (NPWS 2001).

5.7.2 Lantana

Lantana (*Lantana camara*) is a scrambling or climbing shrub that forms dense thickets. It is a plant with many forms and varieties, often of obscure origin. The most widespread pink flowered form was introduced into Australia from Europe in the 1800s after more than a century of introductions from South America into Europe. By the late 1800s lantana was described as a very serious weed in the Brisbane and Sydney areas. It is now found from the south coast to northern Queensland with scattered infestations in other states. It can become the dominant plant in a wide range of habitats, readily establishing and dominating the understorey of disturbed forests and abandoned or poorly managed farmland. In coastal bushland it is especially prevalent in sheltered hind dune and headland vegetation, often growing with Bitou Bush and replacing it in heavier shade conditions.

5.7.3 Ground Asparagus

Ground Asparagus (*Asparagus aethiopicus*) is a low growing shrub from South Africa with sprawling stems up to 2m long. Originally introduced and still available as an ornamental plant, it has spread rapidly in recent years and is now regarded as a serious problem along the NSW coastline. It can completely dominate the groundcover of dunal and headland vegetation to the exclusion of other vegetation. Control is slow and laborious and continual follow up is required to prevent reinfestation.

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http://www.weeds.org.au
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6. REVEGETATION

6.1 Introduction

There are two major objectives in deciding to revegetate a degraded dune:

- To restore and maintain biodiversity through establishing native coastal vegetation appropriate to its geographical area and its position within the dune system - vegetation that is self-sustaining with minimal maintenance required once fully established.
  A healthy dune ecosystem will display a range of plant communities and locally indigenous species that reflect the geographical distribution of species along the coast, zonation within the dune system and the age of the dunes. These communities provide habitats for a diverse range of native fauna, providing them with resources such as food, breeding sites and protection from predators.
- To provide sufficient plant cover to protect fragile dunes against wind erosion. Species that are native to the coastal dunes are adapted to survive the hostile environment of drifting sand, strong winds, salt spray and infertile soils. They provide long term stability.

Revegetation with native coastal species increases wind protection for landward areas and for infrastructure such as accessways, picnic areas and car parks, as well as enhancing beach amenity.

Dune vegetation has the ability to:

- prevent wind erosion by decreasing wind speed at ground level and by providing a protective cover over the dune
- build up sand dunes and thereby increase the sand reserve for storm waves
- reduce but not prevent damage from wave erosion
- regenerate naturally after storm damage and facilitate natural dune recovery
- tolerate gradual movements of the dunes both vertically and horizontally
- provide habitat for native fauna

This chapter discusses revegetation in terms of four themes:

- Planning and Development
- Implementation Methods
- Maintenance
- Monitoring.

6.2 Guiding principles

Revegetation is a general term that includes stabilising a land surface with plants that need not be native. In coastal dune rehabilitation the emphasis is on regeneration; re-establishing a range of locally indigenous plants that would occur normally in that environment. Another distinction can be made between natural and assisted regeneration.

Natural Regeneration**:** Remnant native plants already in the system can usually regenerate after removal of weeds that compete for light, water and nutrients. They can then improve in vigour, flower and set seed. Following the disturbance of weed removal, seeds in the soil seed bank may also be stimulated to grow. These seeds may be the only representatives of short-lived plants no longer growing on the dunes. Plant species diversity is increased. The aim with this approach is to restore and maintain an ecosystem in which natural regeneration can occur.

Assisted Regeneration**:** On highly disturbed dunes, natural regeneration may occur too slowly to prevent erosion, or too few species may be represented. Planting species that are suited to the geographical area and dune zone will speed the regeneration process. Whether, when, how and what to plant are discussed below.

The difference between rehabilitation and restoration should also be noted. Restoration means getting back to the "original" vegetation cover. It is the ultimate goal but is much more difficult to achieve. It relies on knowing the characteristics of the vegetation that existed before degradation occurred. Getting back to that condition is invariably very demanding of resources.

Rehabilitation is often an unavoidable but worthwhile compromise. Successful rehabilitation results in a stable landscape that blends with surrounding areas but does not necessarily feature the character of the original vegetation. It is a more readily achieved condition and it can contribute greatly to the broader goal of conserving biodiversity.

Use locally indigenous species: *Locally indigenous* is a more specific term than *native* or *endemic*. A locally indigenous species is characterised by the slight variations that occur between different plants of the same species from area to area. These variations are a response to different local physical conditions to which the plants have adapted (Coastcare undated).

The use of locally indigenous species has many benefits in a revegetation project. Plants in their natural communities have evolved to suit local environmental conditions and have a desirably broad genetic base (Mortlock 2000). Using plants grown from local seed in revegetation complements other native plants and animals in the area and is thought to promote genetic and ecological sustainability in local vegetation. Better performance of local plants in terms of survival and growth has also been reported. It is therefore important when collecting seed and other plant material to do so as close to the rehabilitation site as possible. For further information refer to the FloraBank website and the Coastcare Factsheet *Locally Indigenous Species*.

6.3 Planning and development

This section builds upon Section 3.3 on project planning. It expands on some of the specific points in relation to revegetation and highlights many of the important questions to be answered through comprehensive site assessment. As with the overall project, planning is the most important part of a revegetation exercise and if done well, is reflected in the lesser degree of effort expended during a project (Figure 6.1).

6.3.1 Assessing the site

After an initial site assessment has been made and it has been established that some form of revegetation is necessary, a number of more specific questions need to be answered.

Is planting necessary? Look at what regeneration is already happening. The history of vegetation on the site may indicate whether natural regeneration may occur. If the site has been infested with bitou bush for thirty years, the soil seed bank of native species will be low. If erosion is a concern, waiting several years for natural regeneration may not be wise. Conversely, some seed will germinate best on bare sand eg. Coastal Tea Tree (*Leptospermum laevigatum*), Coastal Correa *(Correa alba)* and Coastal Pelargonium (*Pelargonium australe*), so some bare sand may be desirable. Consider if the variety of species is suitable for the zone. Are nearby native species likely to assist naturally by shedding seed or spreading by vegetative means?

When selecting species to plant, it is often helpful to examine old photographs and oral histories to establish which plants were present before physical degradation and/or bitou bush took over. This information will augment any species selections that are based on the geographical location of the site and its biophysical zones (Fiedler in preparation).

Also note that some sites may be naturally bare sand, eg. the small spits protruding from the shoreline in the lee of near or offshore islands where stabilisation and revegetation is unwarranted (see Section 3.3.1).

What is the fire history of the site? How long ago was the last fire? Which plants are likely to regenerate after fire by resprouting or by smoke or heat promoting seed germination? A fire may be useful in stimulating germination of bitou seed,

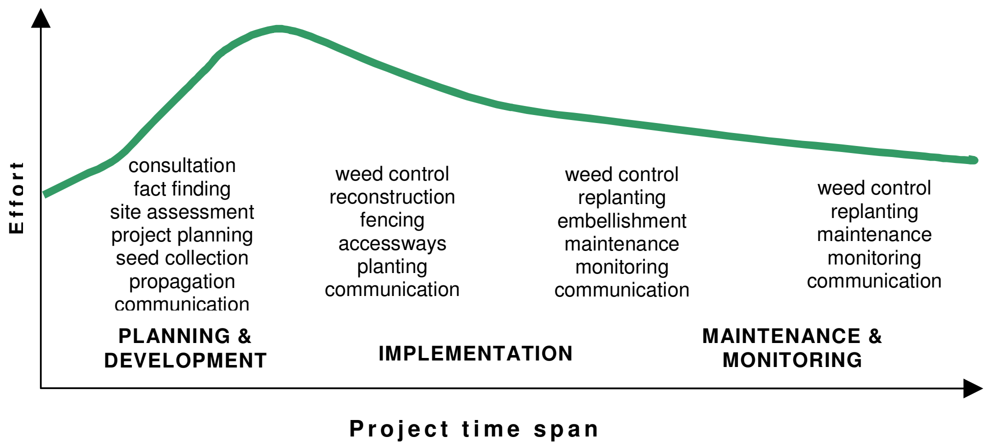


Figure 6.1 Schematic representation of effort expended in a rehabilitation project.
(Adapted from Greening Australia 1995)

shortening the bitou seedling removal process by several years. Fires that are too frequent will destroy native vegetation before it has had a chance to set seed. Consult local authorities to find out when the last fire occurred and observe the age of the native vegetation. NPWS offices can provide advice on ecological burns.

If planting is deemed necessary, consider the following:

- which areas need planting? Consider the site's location on the coast and its position within the dunes when compiling a list of suitable species. Include as many species as are needed to recreate an appropriate vegetation structure (including trees, shrubs, climbers, and ground cover plants).
- all emerging dune plants will need protection from trampling. Provide for this before planting as native coastal plants are sensitive to disturbance around their roots. Dune fencing and clearly defined tracks are essential. Selective placement of fallen branches can discourage walkers taking short cuts.
- will tube stock be used?
- is brush matting an option?
- where will the plants be sourced?
- be aware of seasonal constraints - planting success is more likely if plants go into moist soil and the weather is not too hot and windy. The best seasons generally are autumn and winter.
- allow for maintenance of plantings - perhaps watering, certainly weeding. Tree guards for pest control and wind protection may also be needed.

Many aspects of a revegetation project are season dependent and will need long time frames. Developing a calendar for a project is often a useful way to help manage revegetation tasks (Figure 6.2). The calendar can be developed within a broader project time line (see Section 3.4.3) or it can be a separate project schedule, provided it is not used in isolation from other calendars. If grant funding has been applied for, the availability of funds also needs to be considered in developing a calendar. If funds are unavailable until autumn for example, there may not be sufficient time to grow tube stock that will be ready to plant at the best time and it may be necessary to postpone planting until the following autumn.

YEAR 1	SPRING	Monitor which plants are setting seed.		
	SUMMER	Collect seed. Store.	**OR**	Treat seed and propagate in trays.
	AUTUMN	Direct plant seed in place.	**OR**	Tube up propagated seedlings.
	WINTER	Monitor direct planted seed area.	**OR**	Maintain tube stock.
YEAR 2	SPRING			Plant tube stock (if water is available)
	SUMMER	Collect seed.	**OR**	Maintain tube stock.
	AUTUMN			Plant tube stock (if water is limited)
	WINTER	Monitor both direct planted & tubestock planted areas.		

Figure 6.2 Example of revegetation planner based on plantings of Coastal Wattle.

6.3.2 What plants go where?

Recognition of geographical area, zones, and plant succession will guide selection of species for planting. Choosing locally indigenous plants grown from local plant material is the way to preserve genetic integrity and maintain maximum biodiversity. Choosing such plants means a project will have a better chance of success. Use of inappropriate species is effectively introducing weeds to a project area.

How local is local? Fleshy-fruited seeds such as those from Lilly Pilly (*Acmena smithii*) are spread far and wide by bats and fruit eating birds. However plants such as Eucalypts may develop local populations in small areas. Seed is not distributed very far, so it should be collected from within a few kilometres if possible or from similar communities nearby.

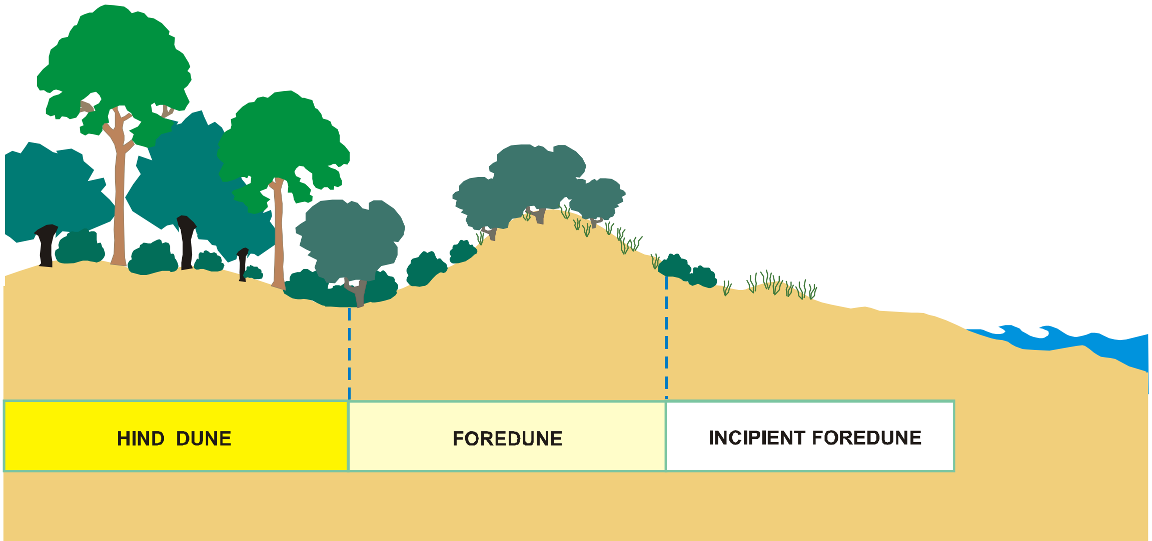
Only a few plants grow along the whole length of the NSW coast. Some coastal native plants have a wide geographical distribution north to south; others are native only to limited areas of the coast (Figure 6.3).

The various zones of dunes are vegetated by plants adapted to conditions in these zones. Typically there are three zones that grade into each other. These are:

- an unstable incipient foredune zone of colonising herbs and grasses
- a semi-stable foredune zone of shrubs and associated ground plants
- a stable hind-dune zone dominated by trees, with an understorey of shrubs and ground plants

The combinations of plants and zones shown in Figure 6.3 represent the typical assemblages that are encountered. Some of these are quite strongly defined. For example, while spinifex is characteristic of the incipient foredune zone, flourishing with prolonged exposure to sun, strong wind and saltspray, plants of the littoral rainforest can only survive in the protection of the hind-dune area. Other associations are not as strong. *Lomandra* spp.) and Guinea Flower (*Hibbertia scandens*) for example can occasionally be found on incipient foredunes.

Plant succession occurs when plants themselves change growing conditions over time and compete with each other. This is represented simplistically in Figure 6.4, which assumes a continuing supply of sand and no intervention by storms. Where topography permits, littoral rainforest or open forest may eventually develop to represent a climax community with a complex structure of canopy, shrub, climber and ground layer species. On the incipient foredune spinifex grass, often the only survivor in such conditions, will form the climax community for that site and zone.



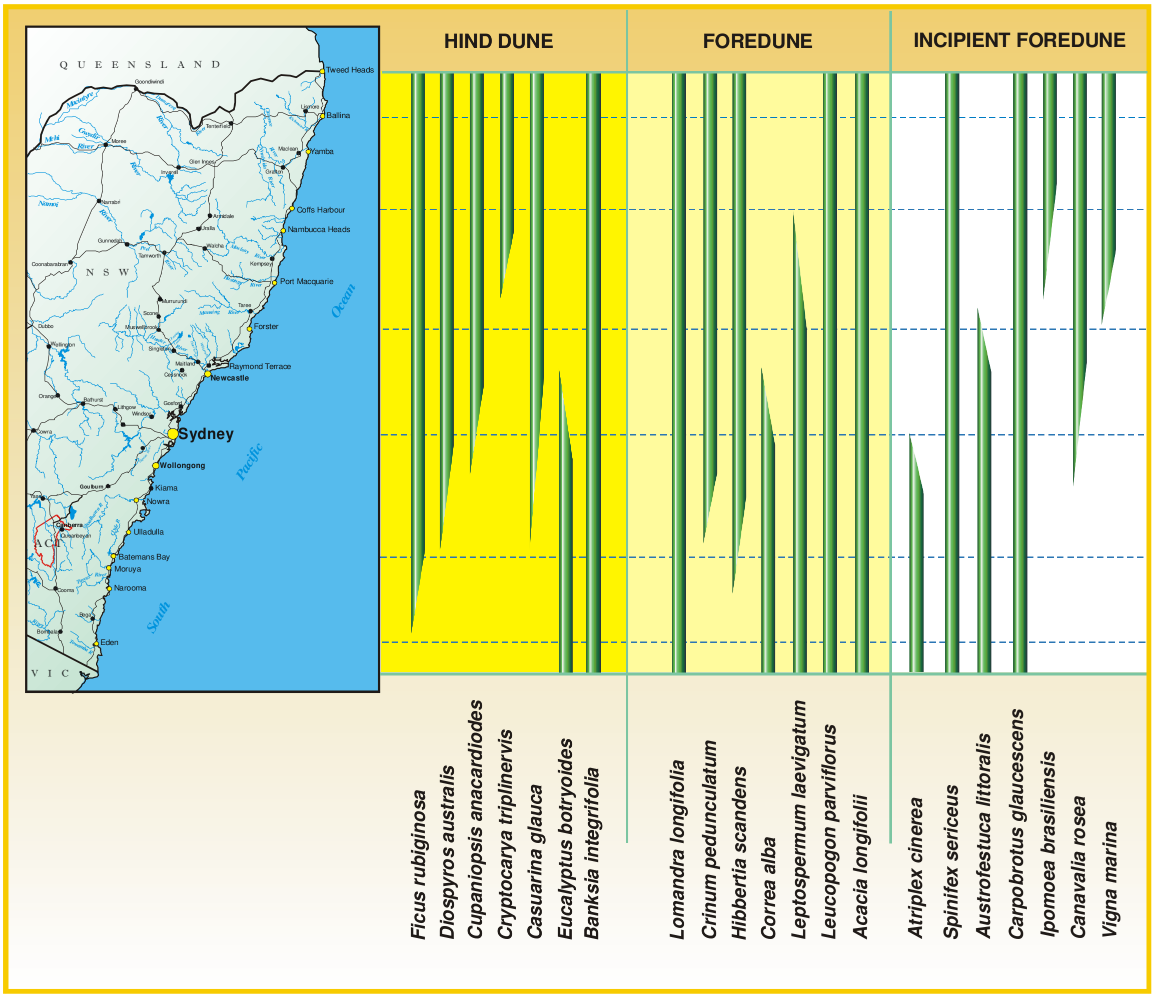
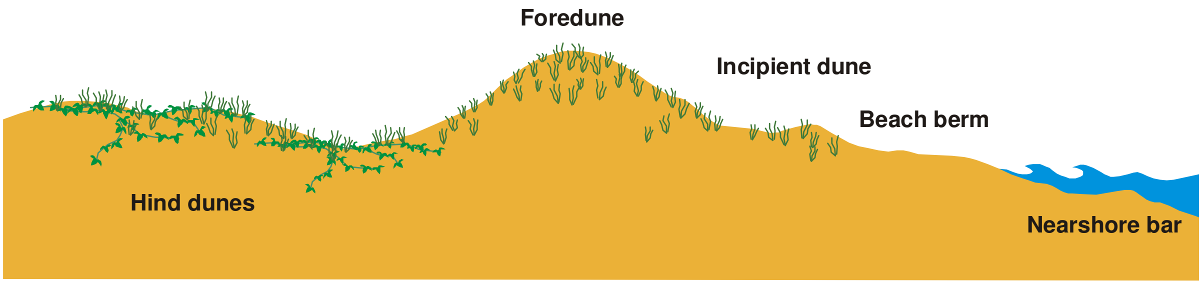
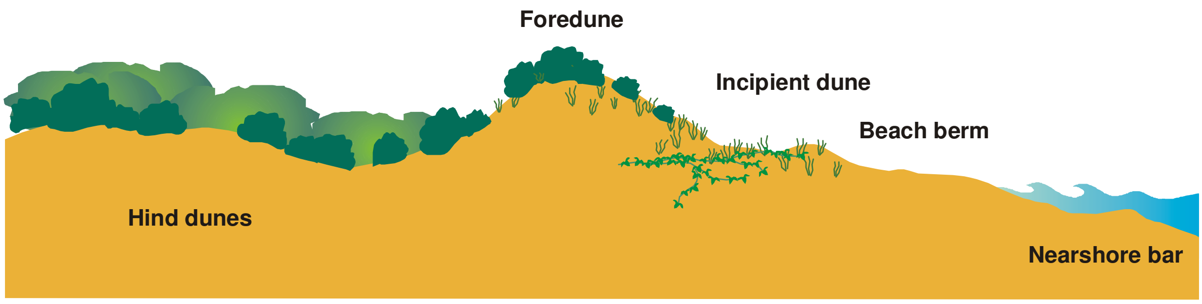


Figure 6.3 Typical geographical range of some common dune plants along the NSW coast.

Stage 1 - Grasses and creepers (primary species)



Stage 2 - Shrubs and short-lived trees (secondary species)



Stage 3 - Long-lived trees (tertiary species)

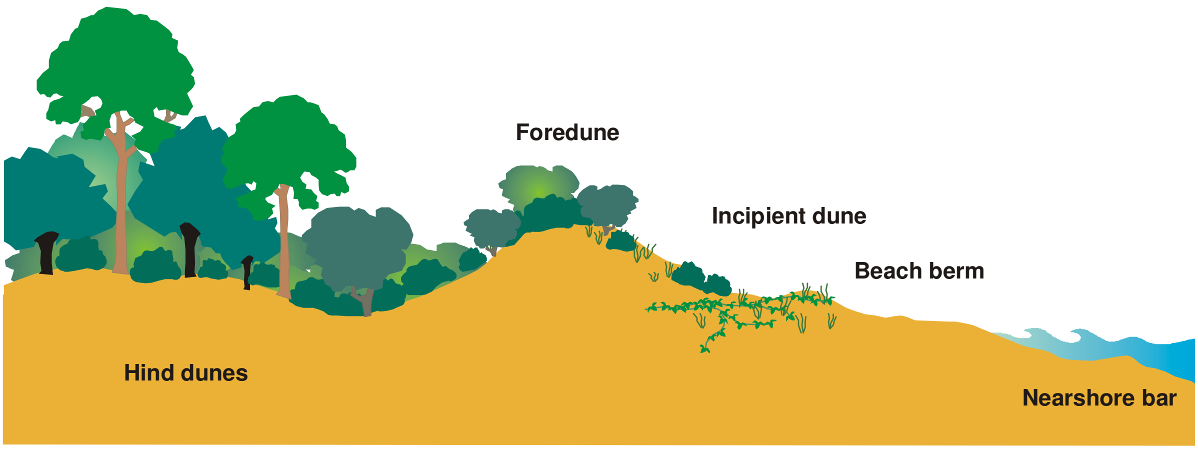


Figure 6.4 Idealised vegetation succession on coastal dunes.

Secondary species are capable of withstanding considerable exposure to strong winds and salt spray, but are relatively intolerant of burial by sand and are therefore dependent on the protection afforded by primary species. They are suitable for planting on coastal dunes landward from the seaward toe of the foredune, but are most commonly planted from the toe to the foredune crest. In this position they provide protection to tertiary species landward of the crest.

Most tertiary species are relatively intolerant of strong winds and salt spray, and can be subject to wind pruning and dieback when exposed to these conditions. They cannot tolerate sand accretion. Hence tertiary vegetation is dependent on the combination of dune form and primary/secondary zone vegetation for protection and survival.

Tertiary species are generally planted landward of the foredune crest. A wide range of species is adapted to growth on sandy coastal soils in this location, with communities such as woodlands, heathlands, swamplands and littoral rainforest all found quite close to the coastline. The more important species used in dune rehabilitation programs include Coastal Banksia (*Banksia integrifolia*), Swamp Oak (*Casuarina glauca*), Swamp Mahogany (*Eucalyptus robusta*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), Bangalay (*Eucalyptus botryoides*) and Tuckeroo (*Cupaniopsis anacardioides*).

In order to develop and maintain an aerodynamically stable dune profile it is essential to have secondary species evenly distributed over the dune and it is preferable to plant tertiary species in a similar pattern. However, clumped plantings of tertiary species, while not aerodynamically ideal, can be considered if funds are limited or if enhancement of visual amenity of the site is important. They can also form a valuable seedbank.

Some guidance about the more common plants that might be selected for planting is provided in Sections 6.7 and 6.8.

A full range of species matched to location is included in the *NSW Coastal Plants Database* (Fiedler in preparation). Local experts in DLWC and NPWS regional offices, Botanical Gardens, local councils and established community groups can also provide advice. The Australian Plants Society (formerly SGAP - the Society for Growing Australian Plants) may also be able to assist.

6.3.3 Seed collection

Seed collection requires consideration of the following points:

- Permission should be obtained from the land owner/manager, even for public land.
- Certification. A licence must also be obtained from NPWS if any target species is listed on Schedule 13 of the *National Parks and Wildlife Act* or on the schedules of the *Threatened Species Conservation Act*.
- Plan - select the target plants, establish their locations, understand their fruiting times and the logistics of gathering their seed. Collect local progeny from naturally occurring remnant vegetation as close as possible to the project site.
- Obtain good genetic quality for each species by collecting from healthy, vigorous plants.
- Ensure that plants and populations are not over exploited. Collect small amounts of seed from a large number of individual plants that are well separated from each other.
- Keep records of seed collection and storage.

If it is not possible to collect within close range of the project site it is best to speak to the regional NPWS office where staff should be able to provide advice on the location of the next most appropriate collection area. Usually, an area of similar landscape and climatic characteristics should be suitable.

Another important point to consider is how natural the existing vegetation is at the site and other nearby areas. Many large areas of coastal dunes have been modified ecologically by activities such as sand mining. Often the vegetation found in these areas is unnatural, with monocultures of species such as coastal tea-tree and horsetail she-oak. Seed should always be collected from areas that are representative of the project site prior to disturbance.

Further advice about seed collecting is available from the FloraBank and Greening Australia websites. They provide detailed information about codes of practice, methods, current suppliers and other relevant organisations and links to other useful websites.

6.3.4 Propagation

The main propagation methods are from seed, cuttings and division. Many of the common coastal plants will propagate readily from one or more of these methods (Figure 6.6). Additional information on plant propagation may be found in Buchanan (1989) and in the *Coastal Plant Propagation Manual* (EnviTE 1998) which is available from local Coastcare Facilitators or DLWC. Local specialists from councils, NPWS, DLWC, Botanic Gardens and nurseries can also be consulted.

6.4 Implementation

The planning and development phase of a revegetation project is followed by implementation. Site preparation is the first task and at the very least this will involve weed control, often removal of bitou bush (chapter 5). Where degradation has been especially severe, dune reshaping or reconstruction may be necessary (chapter 4). However, because sand is so easily worked there is usually little to do in terms of soil preparation. Because of its high porosity though, it is often best to wait for wetter periods of the year when the sand is moist. This will help reduce the amount of water needed in the early stages of the project.

There are several revegetation methods to choose from.

6.4.1 Revegetation techniques

Direct seeding: Seeds or individual fruits are scattered in the area to be revegetated. This is labour intensive and requires a nearby source of parent plants. Germination of seeds of fleshy-fruited plants is inhibited by the soft part of the fruit. Lilly Pilly (*Acmena smithii*) and Seaberry Saltbush (*Rhagodia candolleana*) are two examples. Crush the fruit carefully to reveal the seeds and wash them in several changes of water, then scatter the seeds onto damp sand. Warrigal Spinach (*Tetragona tetragonioides*) can be pruned lightly to collect branches with mature berries and then thrown about. Hardcoated seed such as from peas and wattles germinates quickly after scarification or heat treatment. To increase the chances of germination over a longer period, scatter half the seeds untreated. These will become part of the soil seed bank, germinating perhaps over the next 5-10 years. Treat the remainder to stimulate germination and scatter onto damp sand immediately after treatment. Beach Bean (*Canavalia rosea*) can be established in this way. See section 6.7.1 for planting Spinifex seed. Mulching or brush matting may be needed to conserve sand moisture levels.

Planting tube stock: Use of nursery-raised tubed seedlings is the most common method of establishing secondary and tertiary zone plants on the foredune and hind dune. Planting should avoid hot weather and drought periods. The best time is from April through to September. Autumn plantings are generally preferred, as there is an opportunity for some growth following planting, followed by settling-in during winter.

Estimate the area to be planted. Allow one plant per square metre or more depending on species, for instance one tree or shrub and one or two grasses or ground level plants. Try to plant species in proportion to how they would occur naturally and stagger plants to mimic natural locations - avoid planting in straight rows. Make use of natural depressions when placing tube stock - even the smallest will hold moisture. Try to establish successional planting where possible and appropriate.

Seedlings should be well watered some hours before planting out so that the soil around the roots is moist. First scrape aside any surface litter. Then dig a hole a bit deeper and twice as wide as the tube. Fill the hole with water and allow to drain. Remove the plant from its tube and position it so that it is in the centre of a slight depression to catch water, backfilling with sand or soil to the same level as the top of the soil in the tube. Placing a handful of composted mulch (eg. mushroom compost) into the hole with the plant has been shown to be beneficial in pure sands. However, note that if the mulch is not composted its breakdown in the sand will deprive the plant of nitrogen. The sand should not be piled up around the stem. Replace any surface organic matter to act as mulch on the surface. Water in with about half a bucket of water, ensuring the water soaks in around the root area and does not run away from the plant (Figure 6.5).

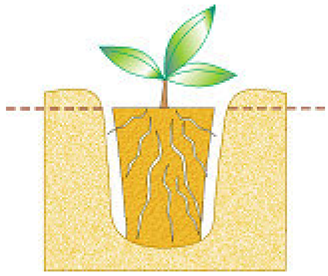
Planting and Maintenance Guidelines

Not to scale

- Holes should be dug slightly deeper than the size of the container and twice as wide.
- Check by placing container into hole.
- Fill hole with water and allow to drain.
- Trim any roots that are protruding from the bottom of the tube. If this is necessary, the plant itself should be tip pruned to reduce stress and dehydration.

- Squeeze the base of the tube firmly.
- Place stem between fingers, turn upside down and firmly but carefully remove the tube.
- If pot bound, gently tease out roots by running a knife down the inside of the tube.

- Place plant in hole so that the surface of the tube soil is level with the original ground surface (dashed line in diagram). If a fertiliser pellet is used, place it in soil 20 - 50mm from the base of the root ball.
- Back fill around the plant, taking care not to damage the roots.
- If water crystals are used, ensure they are mixed thoroughly with the soil. Finger down firmly so there are no air pockets around the plant. Make sure there is no mulch mixed with soil at this stage.
- Do not build the soil level up against the exposed plant stem as this will encourage stem rot.



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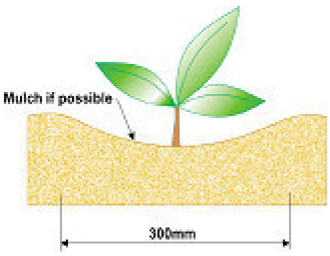

- Shape the soil surface to produce a shallow depression approximately 300mm around the plant to collect water from rain and hand watering. The depression should be able to hold at least half a bucket of water.
- Water in gently, up to half a bucket per plant depending on soil dampness. Apply water upslope from the plant, not directly onto the root area.

- Check that roots are not exposed after watering. Add more topsoil if necessary.
- Mulch lightly around plant. Avoid heaping mulch against the plant as this leaves it prone to stem rot and insect attack.

Maintenance

- Water newly planted tube stock at least once a week - half a bucket of water or more.
- In hot weather, water every 2-3 days for the first month or so until the plants settle in.
- It is best to water early in the morning or late in the evening.
- Less frequent deep soaking is better than more frequent light watering. A good soak encourages plants to develop strong, deep roots. Shallow, light watering encourages roots to grow towards the surface, leaving the plants less resilient to dry periods.
- It is best not to stake plants. Staking can alter growth shapes and encourage smaller root systems. Mature plants are then prone to being blown over by the wind.

Figure 6.5 Tube stock planting and maintenance guidelines

The importance of Soil Microbes: When planting tube stock it is beneficial to introduce the correct soil microbes into the planting soil. Some of the main microbes that are known to be beneficial are mycorrhizal fungi and rhizobium bacteria. These enhance plant growth by enabling the plant to either absorb water and nutrients more readily or to fix atmospheric nitrogen into the soil. It has been demonstrated in many revegetation projects that plants have an increased survival rate if correct soil microbes are introduced.

Surface soil and leaf litter endowed with good microbes can be obtained from healthy vegetated areas that are close to the project site. It is best to take the material from the same species intended for planting. Soil should be removed very carefully to ensure minimal disturbance of the established plants. Only a very small handful of soil is necessary to introduce enough microbes to be effective. This can be combined with the mulch and applied together when planting.

Brush mulching: Another way of assisting revegetation is by brush mulching. Depending on availability of suitable plant material, branches of various sizes, with seed capsules or fruits can be strewn about. Seeding habits need to be established before use. Some fruits stay mostly unopened on the branch until it dies (eg. Tea Tree). Others release seed each year - in December-January in the case of *Coastal Banksia,* or soon after flowering, eg. *Grevillea* sp. Ensure no seed from exotic or non-indigenous plants is introduced.

Transplanting: Transplanting is also an effective means of re-establishing vegetation. It is often easy to source appropriate plants adjacent to the project area. Species such as spinifex and pigface are readily transplanted and are available on the foredune. Some specific transplanting techniques are discussed in the following sections. Additional information is available in the *Coastal Plant Propagation Manual* (EnviTE 1998).

6.4.2 Watering management

The sand should be moist when planting but this is not always possible. A common scenario …. *the plants were ready to plant a couple of months ago, the working bee is on this Sunday and the weather has turned dry and windy*. Each hole should be watered with about half a bucket of water before planting. If the weather remains dry and windy, water should be applied again within a week if possible. Dune plants quickly develop very deep roots, so once they have been in the ground for a few weeks and growing actively they will need no further watering.

Sometimes when sand has dried out it becomes hydrophobic - difficult to wet. Water runs across the surface but will not soak in. A wetting agent may be added to overcome this problem for a few weeks. Worth considering are water crystals which are added to the soil when planting. These should be mixed thoroughly throughout the soil prior to planting so that plant roots do not become dependent on crystals in one small area just below the plant. There are several brands readily available from most commercial nurseries. Each brand has varied application methods so it is important to follow the product's instructions. Water crystals are especially useful if planting during extended dry periods cannot be avoided. They are also very useful in more remote locations where the plants will not be attended to for long periods.

In some dune areas organic mulch may be available. Dead bitou trash or other weed material without seeds is suitable. It will help reduce water loss and erosion and may protect plants from wind. It also acts as a long-term slow release fertiliser as it eventually breaks down to release humus into the soil. At some localities dead seagrass gathered following authorised rehabilitation work in coastal lagoons has also been used successfully.

6.4.3 Tree guards

Tree guards may be necessary for the successful establishment of some species. They are used to protect plants from grazing animals, wind and frost. There are numerous brands available on the market that can be purchased through a local nursery and other organisations. They generally comprise an open-ended plastic bag that is staked in three corners to form a small greenhouse about 300mm wide. During installation a 25mm cuff can be folded on to the lower inside of the guard. This can retain sufficient water to provide a more moist microclimate within the guard. This type of plant guard is particularly useful for establishing littoral rainforest and other hind dune species. For shoestring budgets other materials such as milk cartons and cardboard tubing can also be used with great success.

Tree guards often attract vandals so it is best to use them in more remote locations or areas where vandalism is less likely to occur. Some practitioners recommend that two 1.8m lengths of 4mm wire be used as stakes - the bamboo stake alternatives are frequently stolen. Each wire is bent to form a rectangular hoop 220mm wide across the top, with both ends inserted approximately 300mm into the ground. Plastic tree guards should be secured firmly. They may harm marine life if blown into the sea.

6.4.4 Fertiliser

Established natural vegetation cover on undisturbed coastal dunes does not require the application of artificial fertilisers. Dune plants have adapted naturally to a relatively impoverished growing environment characterised by very slow build up of humus due to decay of organic matter. Inorganic fertilisers are harmful to some dune plants eg. those that rely on mycorrhizal fungi to assist nutrient uptake. As a general rule, application of fertiliser should be restricted to judicious stimulation of primary sand-binding grasses (Section 6.7.1).

However, where primary, secondary and tertiary species are being planted for the first time, the addition of fertiliser can assist in their initial establishment. The addition of fertiliser will also aid in the recovery of partially damaged areas of existing dune vegetation.

The amount and type of fertiliser will depend on the plant species to be fertilised, the nutrient content of the soil, frequency of application and climatic conditions. Generally, a slow release native formulation (low Phosphorous) is preferred. A fertiliser program may need to be developed, as the composition of vegetation communities can be manipulated to some extent by the application of fertilisers. Fertilising beyond initial planting is unnecessary and is not recommended.

Time of application: This has an important bearing on the effectiveness of the fertiliser. For example, because nitrogen is leached rapidly from the sand more benefit is gained by applying nitrogen fertiliser to primary grasses twice a year as opposed to a heavy application once a year.

The precise time of application will vary according to local rainfall patterns and the experience of the program supervisors. Fertiliser applied before heavy rain may be leached completely from the soil before uptake by the plants is possible. This is where “local knowledge” plays an important part in the success of fertiliser programs. For this reason frequent applications of fertilisers at a lower rate than normal may be more successful.

Rate of application: The application of different fertilisers at different rates can achieve the desired level of nutrients. Before a fertiliser program is worked out, consideration must be given to the unit price per kilogram of the required element. Some fertilisers may appear to be expensive but an analysis of their percentage elements will determine the unit price of that element. Additional specific guidance on fertilising is included in Section 6.7.

Method of application: Most fertilisers are granular, making application by hand and mechanical methods quite simple.

Hand broadcasting is used most commonly over small areas. A worker with a plastic bucket loaded with fertiliser walks around the planted vegetation in a predetermined pattern casting the fertiliser out by hand so that all areas receive the appropriate amount. It is often helpful to first mark out an area, say 10m by 10m (0.01ha) and spread the required fertiliser in this area. Practice soon makes the worker competent at assessing the right application rate. Note: use of gloves is recommended.

Machine spreading through a tractor mounted fertiliser spreader can also be quite useful. However, damage to vegetation such as grasses and young shrubs is generally considerable and because of this hand broadcasting is preferred.

For large areas aerial application of fertilisers should be considered. Costs vary a lot and depend strongly on the proximity of the project area to a suitable airstrip. Both fixed wing aircraft and helicopters can be used. When applying fertiliser by air, care must be taken to ensure that requirements of relevant legislation and regulations are satisfied.

6.5 Maintenance

As in any rehabilitation project, maintenance is a crucial aspect in achieving successful revegetation. Maintenance is an on-going element that will need to be continued for several years after the vegetation has been established (Figure 6.1). It is fairly easy to have a very good implementation phase but if it is not nurtured in the early stages to a point where it is self-sustaining then the probability of wasted effort and resources is very high.

Many areas that have been rehabilitated in the past are now in urgent need of maintenance to remove weeds and to enhance biodiversity.

Some of the main activities that require ongoing follow-up work include watering, fertilising, weeding, maintenance of infrastructure (walkways, fences) and deterrence of pests such as grazing animals.

Maintenance needs to be factored into all revegetation projects. Long term goals must be set in the early planning stages to ensure there is enough time and money committed to this component when the need arises.

6.6 Monitoring

Monitoring is another important aspect to consider. It is strongly recommended that comprehensive records of progress be maintained (see 3.4.6). This monitoring will then provide the feedback needed to determine maintenance requirements and will help to measure the effectiveness of the revegetation.

Record keeping can be done through simple means such as photography and note taking. It should include “before” and “after” photographs and should document plant survival rates, annual plant growth, watering and fertiliser regimes, vandalism etc. It can also take on more elaborate scientific assessments and statistical analysis to gain an insight into the ecological variations over time.

Most revegetation projects generally use photographic diaries and notes as this is the cheapest and easiest method to maintain. For more scientific methods refer to the Greening Australia website.

6.7 Species commonly used for revegetation

The majority of plants on coastal dunes are drawn from a relatively small number of species, especially on and seaward of the foredune. However the relatively rich biodiversity of these environments also relies on the presence of numerous other species, even though they may be represented by only a small number of individual plants. Successful revegetation projects will strive to reproduce this diversity as closely as practicable.

Achieving this goal is difficult. Often there is incomplete knowledge of the original vegetation at a disturbed site, while all sites can suffer from incomplete knowledge of propagation and growth characteristics of many of the less common species. A guide to some of the dune plants and their characteristics is presented in Figure 6.6. It combines geographical variation with cross-section zonation as well as providing summary information on plant utility. It is emphasised that this table is selective and that not all the species listed occur on all beaches. Clarke (1989a), Carolin and Clarke (1991) and the *Coastal Plant Database* (Fiedler in preparation) provide more detailed information. The most recent specialist advice should always be sought from local practitioners within the community, local council or state agencies. Propagation experiments with different species are encouraged, provided the results are reported widely for others to use.

6.7.1 Spinifex

Spinifex (*Spinifex sericeus*) is the most important sand stabilising plant on the NSW coast. While it occurs along the entire coast, it is a summer growing species that is favoured by warm conditions and hence it performs particularly well along the coastline north from the Hunter River. However dense cover can also be established in cooler areas, as is evidenced by much of the coastline of the North Island, New Zealand (Bergin 1999).

Planting: Spinifex is best established between October and March inclusive. It is normally established by hand planting either entire seed heads harvested directly from the plant, or runners. Two other methods of establishment are transplanting and sprigging, and sowing of threshed seed. Spinifex trials at Budgewoi on the Central Coast (Budgewoi Dune Care 2000) showed that planting small clusters of seeds directly into the dune early in Spring was the most successful technique (Figure 6.7).

Seed Heads: Spinifex seed heads mature during November-December, detach from the parent plant and are blown about the dune where they gather in hollows or against other vegetation. Collection should occur sooner rather than later or birds will have consumed much of the seed. Seed should be stored in a dark, dry place, preferably in hessian bags in a vermin-proof area for later planting. Plastic bags allow seed to rot. A small proportion of seed is viable for up to six years, but is preferably used no later than the following season.

Budgewoi Dune Care recommend that one third to one half of a seed head cluster be sown 600mm apart, although other workers recommend three or four seed heads planted together in more widely spaced holes. Seeds should be buried 30-100mm, preferably in moist sand.

New Zealand experience suggests that if nursery facilities are available, raising tube stock from seeds can provide sufficient plants for large scale projects (Bergin 1999).

Grown cuttings: Runners are cut into lengths immediately below a node, leaving one or two nodes and the runner tip for eventual exposure above the sand surface. Budgewoi Dune Care dip these cuttings in hormone prior to planting in trays of moist sand. They report root development within approximately three weeks any month except during winter. Success rate with this method is quite good, but it is more time consuming. It is most useful if seed stock is unavailable.

Runners: In some situations spinifex established from runners can provide adequate ground cover within twelve months of planting. This compares favourably with the 12-24 months generally required for satisfactory establishment of cover from seed. Runners or tip cuttings 400-600mm long should be planted on a 1000mm grid into moist sand at a depth of 200-300mm. Runners or tip cuttings with root buds on the nodes are best. Stolon material with established roots on nodes will not grow and should not be used.

Dune zone	Botanical Name	Common Name	Form	Propagation	Northerly limit	Southerly limit	Comments
Primary	*Austrofestuca littoralis*	Beach Fescue	Tussock grass	Seed, division	Port Macquarie	Victoria	Native substitute for marram grass.
	Canavalia rosea	Beach Bean	Twiner (vine)	Seed, cutting, division	Queensland	Shellharbour	
	Carpobrotus glaucescens	Coastal Pigface	Prostrate herb	Seed, cutting, transplant	Queensland	Victoria	Succulent spreading stems, good cover.
	Ipomoea pes-caprae subsp. brasiliensis	Beach Morning Glory	Sprawling scrambler	Seed	Queensland	Port Macquarie (and Broken Bay and Port Hacking)	Provides ground cover with spinifex on incipient foredune platforms.
	Spinifex sericeus	Beach Spinifex	Stoloniferous grass	Seed, cutting, division, transplant	Queensland	Victoria	Primary sand stabiliser and binder. Provides seed for birds. See chapter 6.7.1
	Vigna marina	Yellow Beach Bean	Twiner (vine)	Seed	Queensland	Port Macquarie	
Secondary	*Acacia longifolia subsp. sophorae*	Coastal Wattle	Shrub	Seed	Queensland	Victoria	Very successful sand coloniser; high exposure tolerance. See chapter 6.8.2
	Correa alba var. alba	White Correa	Shrub	Seed, cutting	Port Stephens	Victoria	
	Crinum pedunculatum	Swamp Lily, River Lily	Erect herb	Seed, division	Queensland	Ulladalla	Prefers high water table areas.
	Hibbertia scandens	Climbing Guinea-flower	Vine	Seed, cutting	Queensland	Narooma	
	Leptospermum laevigatum	Coastal Tea Tree	Shrub	Seed	Nambucca Heads	Victoria	Mammal and bird habitat, nectar. Not as exposure resistant as Coastal Wattle. Useful as brush matting. Some problems from past use - see chapter 6.8.3
	Leucopogon parviflorus	Coastal Beard Heath	Shrub	Seed, cutting	Queensland	Victoria	
	Lomandra longifolia	Sword or Mat Grass	Perennial herb	Seed, division	Queensland	Victoria	Spikey character may help deter pedestrians.
	Westringia fruticosa	Coastal Rosemary	Shrub	Cutting, or from seed	Queensland	Victoria	Suits decorative planting for public facilities.
Tertiary	*Banksia integrifolia*	Coastal Banksia	Tree	Seed, cutting, but best results from planting tube stock.	Queensland	Victoria	Very important tree. Bird attractant. Juveniles need protection from salt spray, more so on South Coast but mature plants are very hardy.
	Casuarina glauca	Swamp Oak	Tree	Seed and cuttings; will also spread from suckers.	Queensland	South Coast	Prefers wet areas; can withstand periodic inundation. Seed is an important food source for birds.
	Cryptocarya triplinervis var. triplinervis	Three-veined Cryptocarya	Tree	Seed	Queensland	Smoky Cape	
	Cupaniopsis anacardioides	Tuckeroo	Tree	Seed, cutting & division, but best planted from tube stock.	Queensland	Gerroa (Nowra)	Small to medium spreading littoral rainforest tree. Hardy; tolerant of some salt spray; slow grower.
	Diospyros australis	Black Plum	Tree	Seed, cutting	Queensland	Batemans Bay	
	Eucalyptus botryoides	Bangalay	Tree	Seed, but tube stock plantings are better.	Hunter River	Victoria	Very adaptable medium-large tree. Quick growing. Provides nectar for birds and mammals; valuable habitat.
	Ficus rubiginosa	Port Jackson Fig, Rusty Fig	Tree	Seed, cutting	Queensland	Bega	Valuable habitat for mammals, birds and insects; fruit is important food source for fruit bats, birds.
	Melaleuca quinquenervia	Broad-Leaved Paperbark	Tree	Seed, but best results from tube stock	Queensland	Botany Bay	Large tree, tolerant of a range of soil conditions and suited to hind-dune swales subject to waterlogging and brackish conditions.

Figure 6.6 Some common dune plants and their characteristics

Experience with use of runners suggests that complete burial of the runner is not desirable. Rather the runner tip (if it is available) or one or two nodes of the runner should be left exposed to provide satisfactory establishment.

Spinifex runners should be planted between April and September provided soil moisture is adequate. Budgewoi Dune Care found that runners delivered the poorest success rate in their trials. Temporary soil surface stabilisation is necessary, for example with brush matting.

Transplanting: A technique successfully employed by Port Stephens Council is the complete transplant of spinifex material and sand. The technique requires an adequate nursery area maintained by heavy fertiliser application. This is considered to be particularly suitable where the nursery area is located very close to the revegetation site. Here the planting material is placed in rows spaced 2m apart and fertilised. Further advice on this technique may be obtained from the Council.

Another transplanting technique used successfully by the Queensland Beach Protection Authority is to establish spinifex from sprigs. Sprigs of grass which have established from seed or runners and which show vigorous leaf and root growth are spade harvested, separated into 30-50mm diameter sprigs and planted.

Fertilising: Spinifex responds very well to high nitrogen fertiliser broadcast 2-3 weeks after planting and early in both Spring and Autumn to take advantage of best growing seasons. It can be applied in Spring to enhance established plants. Where spinifex is being established from seed in an area that has been temporarily stabilised by brush matting, fertiliser application should be deferred until after germination.

Brush matting: Extensive spinifex plantings, especially using seed, must be accompanied by brush matting (Section 4.5.1) in exposed sites.

6.8 Some special revegetation issues

Increasing awareness of biodiversity values has encouraged the development of more sophisticated revegetation projects that attempt to re-establish functional ecosystems. Today, some of the plant species used in the past are viewed with caution if not concern. Marram grass, the exotic but very successful sand-binder for example, has demonstrated a much longer persistence than was originally anticipated. Even some natives have displayed weed-like attributes. With this in mind it is important to have mixed plantings and not to over-use one favoured species.

6.8.1 Marram Grass (*Ammophila arenaria*)

This plant is a native of the Mediterranean area that is found commonly on cooler coastlines of Europe, North America, South Africa and Australia. It was introduced to Australia in the 1880s as a primary sand-binding grass. Its rapid growth in response to sand burial made it ideal for stabilising degraded dunes and it has been used extensively for this purpose in NSW, especially south of the Hunter River.

It is very easy to harvest and plant and its tussocky form allows it to begin trapping sand as soon as it is planted. New growth usually appears within a couple of weeks of planting. Although acknowledged as an exotic, its widespread use in NSW was justified in terms of its excellent sand stabilising capability and the expectation that it would die off within a few years and not establish itself.

Figure 6.7 Succesful Spinifex planting at Budgewoi.

Marram planting is now not encouraged. It persists in the landscape for many years longer than expected, encouraging development of a more hummocky dune surface, and there is evidence from the South Coast that its persistence is impacting adversely on re-establishment of natural dune biodiversity (Webb *et al.* 2000). In Victoria and Tasmania, longer day lengths have allowed it to produce viable seed and it has spread profusely at the expense of native primary grasses such as the Beach Fescue (*Austrofestuca littoralis*) and Spinifex. There are reports of it producing non-viable seed in southern NSW but there is no evidence of it reproducing there.

Because of these concerns, and noting recent success in establishing dense spinifex cover (Section 6.7.1), marram planting can now only be considered where severe degradation is affecting a large area. In these circumstances, co-planting and follow-up planting of locally indigenous primary zone species is essential. Removal of persistent marram tussocks as the native plants establish themselves may also be required.

More widespread use of Beach Fescue is also encouraged, especially along the southern half of the coast. It can be established from seed and larger clumps can be divided and replanted, but more detailed assessment of its growth rates and its response to fertiliser is needed before it can be considered a viable alternative to marram grass.

6.8.2 Coastal Wattle (*Acacia sophorae*)

Coastal wattle has been one of the most successful and widely used secondary species in coastal dune revegetation programs. The plant is a legume that “fixes” atmospheric nitrogen and converts it to a form available to both the wattle and other dune plants growing in the sand within its root zone.

It is quite tolerant of salt spray and is distributed right along the coast. However the extent of this Acacia’s natural geographical range is a matter of contention. It was widely planted following sand mining on the North Coast and its very successful establishment in such areas may be masking its natural distribution.

In exposed locations coastal wattle develops a typically prostrate spreading habit, establishing roots on the nodes of branches that are in contact with the soil surface. These characteristics make it particularly suitable for planting seaward of the foredune crest.

Coastal wattle can be established from seedlings or by direct seeding. Unlike many other secondary and tertiary species, coastal wattle seed is relatively large, easily harvested and cleaned. Its hard seed coat and the ability of small seedlings to withstand salt spray and some sand movement, are survival mechanisms that allow the species to successfully establish from seed. This allows coastal wattle to be established during the primary revegetation phase.

While the hard seed coat is a survival mechanism, it is recommended that half the seed receive heat treatment before sowing in order to break the seed coat and facilitate field germination. Rapid germination and establishment of treated seed will occur if good rain follows sowing, while the reserve of hard seed provides for extended subsequent germinations. This is particularly useful if the initial germination fails to establish due to a lack of follow-up rains.

The recommended heat treatment is to place the seed in a sieve and pour boiling water over it. Complete immersion of the seed in boiled or boiling water is not recommended, as excessive heating may kill the embryo. The seed should be sown on the day of treatment. Heat-treated seed should not be stored.

Seed can be mixed with equal parts of sand and should be broadcast at the rate of 3kg of seed/ha. The seed should comprise a mix of 1.5kg of heat-treated seed and 1.5kg of untreated sand.

Best establishment from seed is given by sowing into a well-established primary grass cover. However if time is limited, seed may be sown immediately prior to the planting of spinifex provided there is adequate protection. This allows much of the seed to be trodden into the sand during grass planting operations. This may require more closely spaced grass planting or some brush matting.

Cautionary note: In some areas, particularly on the North Coast, prolific germination of *Acacia sophorae* has followed removal of bitou, resulting in a dense Acacia monoculture with many plants of similar age. As Acacia can fix atmospheric nitrogen, it outgrows many other species that might otherwise help to form a more diverse and resilient plant community. Most Acacia plants will die after 8-10 years, leaving large dead areas and unprotected dunes that are then exposed to erosion and weed invasion. In these circumstances, emergent seedlings could be removed and older plants pruned to prevent a monoculture developing. Some regard it as a useful nursery plant to help establish other species and argue that a monoculture is not necessarily a bad thing.

In South Africa this plant is equivalent to Bitou Bush in Australia in terms of its undesirability.

6.8.3 Coastal Tea Tree (*Leptospermum laevigatum*)

This plant is distributed widely along the coastline of New South Wales where it occurs mainly in closed communities. Its natural range in NSW is thought to be from Nambucca Heads south to Victoria. It is generally found on more stable beach formations with low relief. It has a moderate tolerance of salt spray but prefers less exposed sites than those favoured by Coastal Wattle.

Coastal Tea Tree has been extensively planted as a regeneration species, especially by mineral sands mining companies on the North Coast. At some of these sites it has formed dense monocultures that exclude locally indigenous species and is regarded as a weed. For this reason it is recommended that any proposal to use this plant outside its range be given very careful consideration. Coastal Tea Tree is best established from seedling stock as direct seeding has not been particularly successful.

6.8.4 Horsetail She-oak (*Casuarina equisetifolia* subsp. *incana*)

This is a fast growing native tree whose natural range extends northward from Laurieton into Queensland. It has been used extensively in past dune rehabilitation projects, especially after sand mining. Its natural habitat in New South Wales is rocky headlands, with rare occurrences on dunes. With a few exceptions, the extensive rehabilitation plantings do not accurately reflect the natural vegetation of those sites.

6.9 Overview

Attempting to re-establish functional ecosystems on coastal dunes is a major challenge but it is an essential element in the broader task of conserving biodiversity. Selection of plants that match their geographical range and their place within the dune-beach zonation has always been a fundamental consideration but a more recent and enduring challenge is to ensure that only locally indigenous species are used in revegetation. Some traditionally successful but exotic sand stabilising plants are no longer recommended and experimental work is needed to more carefully assess the growth, function and cultivation of native plants such as the Beach Fescue. Effective rehabilitation of coastal dune ecosystems will increasingly draw upon the results of such research.

The other enduring challenge will be to maintain the rehabilitated dunes, protecting their biodiversity, limiting new weed incursions, and at the same time providing safe and informed access to the beaches.

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7. Glossary of technical terms and abbreviations

accretion	Process of accumulation or buildup of sand.
acid peat	Poorly differentiated acidic soil characterised by black, peaty organic matter. Occur in swales behind the foredune where the water table is near the surface.
acid sulfate soil	Soil containing concentrations of iron sulphide which when oxidised combines with water to produce sulphuric acid.
aeolian	Wind blown
anticyclone	An area of high air pressure around which winds blow anticlockwise.
barrier	Extensive deposits of sand impounding coastal water bodies. Inner and Outer barriers on the NSW coast are of Pleistocene and Holocene age respectively.
berm	An ephemeral beach feature - a bench of sand deposited by constructive waves.
biodiversity	The variety of living organisms, their genetic makeup and ecological communities.
BMP	Best Management Practice
climax community	The “stable” ecological community that marks the endpoint of a plant succession.
coffee rock	See humate
compartment	Part of the coast within which sediment movements are confined. May include a single embayment or a series of adjoining ones.
DLWC	Department of Land and Water Conservation
DUAP	Department of Urban Affairs and Planning
dune	An accumulation of wind blown sand.
ecosystem	A community of living things that interact with each other and with their environment.
EP&A Act	Environmental Planning and Assessment Act
ESD	Ecologically Sustainable Development
foredune	The first and often prominent ridge of sand behind and parallel to the beach, usually well vegetated with shrubs.
frontal dune	See foredune
geomorphic	Land forming …. As in geomorphic processes
Holocene	Most recent period of geologic time commencing approximately 10,000 years ago. A relatively warm period characterised by rising to high sea levels.
humate	Coherent (often hard) dark, orange-brown to black concretion formed by concentration of dissolved organic matter and iron oxide within a sand podsol.
impervious	Resists penetration by water.
incipient foredune	Low, undulating accumulation of wind blown sand between the backbeach and foredune. They are often eroded by storm waves.
leaching	Movement of dissolved organic and mineral matter downwards through a soil.
LEP	Local Environmental Plan
littoral	Related to a shoreline environment (sea or lake).
locally indigenous	Plants that have adapted to local conditions without losing their species identity.
midden	An accumulation of empty shells, sometimes accompanied by charcoal and stone implements, that indicates Aboriginal use of the site.
Neap tide	Fortnightly tides occurring near first and last quarter phases of the moon. The tidal range is smaller because high tides are lower and low tides are higher than average. Compare with Spring tide.
NHT	Natural Heritage Trust
NPWS	National Parks and Wildlife Service
OH&S	Occupational Health and Safety
pH	A measure of acidity. Values less than 7 indicate acidity; values greater than 7 indicate alkaline conditions.
plant succession	Sequence of ecological changes as a vegetation community develops with time.
Pleistocene	Second most recent period of geologic time extending from about two million years to 10,000 years ago. Characterised by prolonged Ice Ages or Glacials with low sea levels.
recession	Persistent long term landward retreat of a shoreline.
regeneration	Re-establishing a range of locally indigenous plants. Can be natural or assisted.
rehabilitation	Works that repair a damaged landscape, but which fall short of restoration.
REP	Regional Environmental Plan
restoration	Returning something (vegetation) to its original character and condition.
sand podsol	Acidic sandy soil with strongly differentiated profiles due to strong leaching.
SCS	Soil Conservation Service (renamed DLWC Soil Services)
semi-diurnal	Two high tides and two low tides in approximately 24 hours.
SEPP	State Environmental Planning Policy
SES	State Emergency Services
siliceous	Sediment composed primarily of quartz (silica).
SLSA	Surf Life Saving Australia
SOE	State of Environment (report)
soil horizon	A distinct band within a soil profile.

soil profile	Vertical differentiation of a soil due to leaching.
Spring tide	Fortnightly tides occurring near Full and New Moon. Increased gravitational attraction produces a higher tidal range with high tides higher and low tides lower than average.
stolon	Plant stems that rest on the ground surface and develop roots at stem nodes.
swale	A low area or depression within a dune field.
swell	Longer waves of regular form & spacing that have travelled beyond the area of generation.
wind rose	A graphical representation of wind speed, strength and direction.

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