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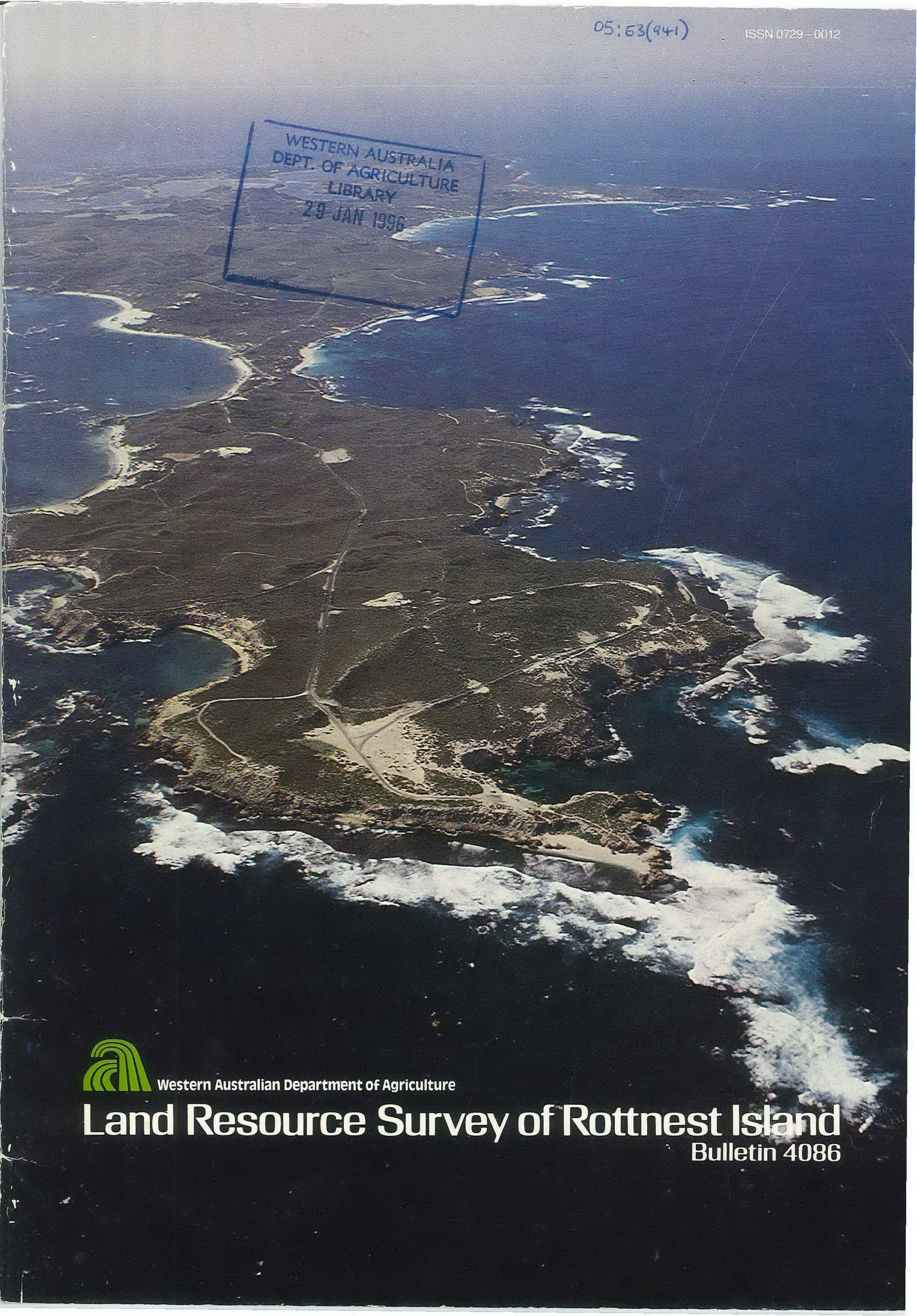

Western Australian Department of Agriculture

Land Resource Survey of Rottnest Island

Bulletin 4086

LAND RESOURCE SURVEY OF ROTTNEST ISLAND

An Aid To Land Use Planning

Bulletin No. 4086

by

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CONTENTS

SUMMARY

• A description of the land forms and soils of Rottnest Island and their capability to sustain development is presented. Vegetation communities of the island are also described and management options outlined. In addition, presently unstable areas are identified and rehabilitation guidelines are presented.

• Three broad landform groups are identified. These comprise Holocene coastal dunes, Holocene marginal lake flats and terraces and Pleistocene coastal dunes. Within these groups 18 landform units are identified, the processes operating on them described, and their capability to sustain development defined according to a five-state hazard classification as follows:

VERY HIGH DEVELOPMENT HAZARD: Beaches, fore-dunes, blow-outs and lake flats.

HIGH DEVELOPMENT HAZARD: Holocene parabolic dunes and swales, relict fore-dunes, Pleistocene high-relief parabolic dunes, development-associated sand patches.

MODERATE DEVELOPMENT HAZARD: A proportion of upper lake terraces, and low relief Pleistocene parabolic dunes.

MODERATE-LOW DEVELOPMENT HAZARD: Remaining upper lake terraces, Holocene and Pleistocene inter-dune swales.

LOW DEVELOPMENT HAZARD: Pleistocene hind dune flats.

An accompanying map (Figure 3.1) provides location details of each of the landform units and their associated capability rating.

• Eight vegetation communities are identified and described. The effects of fire, cultivation and quokka grazing are outlined, and guidelines for the management of each community are provided.

• Eroding and/or degrading areas on the island are identified and guidelines for their rehabilitation and management are provided. In all, six major groups are described, and include fore-dune/beach areas, blow-outs, headlands, development sites, road margins and cuttings, and mining pits.

1: INTRODUCTION

This report provides a description of the landforms, soils and vegetation of Rottnest Island. In addition, it provides a discussion of the relative capability of each of the landforms of the island to sustain various forms of development. The primary objective of this work is to direct development into areas of high capability (low risk of land degradation) in preference to areas of lower capability (higher risk of land degradation).

Rottnest Island is located approximately 30 km west of Perth. The proximity of the island to the capital city of Western Australia, its warm Mediterranean climate (see Appendix 1), and the subsequent likelihood of further development, mean that there will be increasing pressure on the natural resources of the island. This report details the nature and inherent stability of those natural resources, and provides a guide for their management.

2: LANDFORMS AND SOILS

For this survey the classification of mapping units is based primarily on the geological nature of the sediments as described by Playford and Leech (1977). Rottnest Island is composed of three major geological units. These are the Holocene (less than 10 000 years) coastal sand dunes (designated D), Holocene lake sediments (Herschell limestone, shell beds and limesand, designated H), and the Pleistocene (10 000 years to about 1.5 million years) Tamala limestone and limesand dunes (designated T).

In this report further division of these three geological units into 18 mapping units is made on the basis of landform or topographic differences. Topographically, most of the island is dominated by a complex system of dunes and swales of both Holocene and Pleistocene age with the former commonly overlying the latter. In the north-eastern sector a chain of saline lakes occur. These are fringed by low lying flats and terraces of the Holocene, Herschell limestone, limesand and shell deposits. The coastline consists of a series of exposed cliffed limestone headlands and low energy, reflective, sandy beaches and rock platforms.

With the exception of some minor clayey shell deposits comprising the lake terraces, and areas of dune limestone outcrop, the surface of the island is covered by calcareous sands. These occur either as dunes, or as a relatively thin cover over the Tamala limestone, or, in a few areas, over the Herschell limestone. These sands are all classified as Uc 1.11 soils under the factual key notation of Northcote (1979). They are characterized by uniform , coarse textured (sandy) profiles showing little or no pedological organization, except for some accumulation of organic matter at the surface. They are generally loose or only weakly coherent in the moderately moist state and are calcareous. Surface horizons vary in colour from very dark greyish-brown to light brownish-grey and subsoils are light grey to very pale brown.

Apart from the total depth of soil material, there appears to be no major morphological differences between the calcareous sands occuring in areas mapped as of Pleistocene age compared with those mapped as Holocene. Differences which do occur are related to slight variations in the degree of consistence or lithification of the soil material, the size and shape of individual sand grains and the percentage of calcium carbonate present. Within the Holocene dunes the sands are gradually becoming lithified below the surface, and consequently there is often a transitional contact with the underlying lithified dunes of Tamala limestone. Any marked differences in the depth of surface organic matter penetration, which might be expected due to differing ages of parent material have been masked by the effects of exposure to prevailing winds, external drainage conditions, and the history of vegetative cover.

Mapping units:

2.1 HOLOCENE COASTAL SAND DUNES

2.1.1 Beaches (B)

The beaches of the island are modally (or most commonly) low energy reflective beaches, which may experience occasional high wave energy events. Reflective beaches are so-termed because most of the incoming incident wave energy is reflected off the beach face, back out to sea (Short and Hesp, 1982). These beaches are characterised by low waves which plunge at, or near the base of the beach face, and then run up the beach face as swash. Beaches are relatively narrow and slopes range from 10-15% (5° to 8°) depending on wave energy and grain size. Beach sediments are highly calcareous ranging from 64% (Little Armstrong Bay) to 99% (Parakeet Bay) calcium carbonate. Nearshore (seaward of the very narrow surf zone) gradients are gentle.

In normal to moderate wave conditions, beach mobility (extent of wave erosion and accretion) is low. However, during storm conditions (particularly NW and SW storms), higher waves plunging or surging at the base of the beach face, result in accentuated swash run-up events. This accentuated run-up is often increased substantially by set-up (a rise in the mean water level at the beach face). Because the reflective beach is narrow, significant beach and dune erosion may occur during storm conditions.

The rate of aeolian (wind-blown) sand transport off the beaches on to fore-dunes is low due to the limited width of back-shore (dune base to high tide line) area available. There is some variation around the island and, in general, as exposure to the south-west increases, incident wave energy increases, mean beach width increases, and potential aeolian sand transport increases. Thus, the Salmon Bay beaches appear to have the greatest relative aeolian sand transport rates (Figure 3.1).

2.1.2 Fore-dune/blow-out complex (D1a and D1b)

Fore-dunes are the foremost vegetated dune ridges found on the back-shore limit of beaches. The fore-dune acts as a natural barrier and sand reservoir during high wave energy and storm surge events, and as a sand trapping unit during wind blown sand transport events.

Fore-dunes are commonly discrete, asymmetric ridges, and vary from very well vegetated, stable types to semi-erosional partially vegetated types. On Rottnest Island several D1a fore-dunes are ramp-type dunes which steeply abut the Holocene or Pleistocene parabolic dunes. These are particularly characteristic of the most exposed southern facing coastline (Figure 2.1, 2.2). The more common, discrete to semi-discrete fore-dune ridges (also D1a) occur on the relatively less exposed north-west, north and north-east facing coasts. Many are semi-erosional, displaying active blow-outs (erosional troughs).

Some of the fore-dunes (D1b) on the island are complex ridges having been built over a long period (e.g. the fore-dunes of Thomson Bay, Geordie Bay and Longreach). They are thus large, display phases of soil development and may be weakly cemented. Windward slopes are commonly steep (25-45%; 15-25°), and the ridges may overlie limestone and/or Pleistocene sands at variable depths. The leeward slopes and crests of these fore-dunes are largely inactive and relatively stable. Modern wind blown sand deposition, and wave erosion and accretion of the adjacent beach/dune toe is primarily restricted to the lower seaward faces of the fore-dunes.

Soils are highly variable. On the more exposed fore-dunes, soil development, as evidenced by surface organic matter build-up, is negligible. On the less exposed fore-dunes or fore-dune lee slopes and swales, surface sand horizons, darkened by the presence of organic matter to dark greyish-brown or greyish-brown, may be up to 15 or 20 cm thick. Beneath this the sand is usually light grey and devoid of structure. The profiles of all soils are highly calcareous throughout, with pH values of 8.5 or greater. They are excessively drained and have a very low water holding capacity.

2.1.3 Discrete blow-outs and sand sheets (D2)

Blow-outs are saucer-, cup-, or trough-shaped hollows or depressions formed by wind erosion on a pre-existing sand deposit. They comprise an erosional throat, and a downwind attached depositional lobe. Blow-outs may be initiated by (i) wave erosion and scarping of fore-dunes followed by wind erosion; (ii) devegetation or destabilization of sand surfaces by animals, fire, and man; (iii) wind erosion of natural areas of low vegetative cover (e.g. following fire or sand burial), or where wind flows are locally accelerated between obstacles (such as hills or bushes).

Small discrete blow-outs are present along the north-western coast (e.g. Ricey beach and Narrow neck). As exposure increases, the potential for blow-out formation increases; thus the largest number of fore-dune-associated blow-outs and discrete blow-outs occur along the south-west facing coast, a notable example being Barnett Gully. Cliff-tops are also very susceptible to erosion, being in a region of accelerating wind velocities and high salt spray inundation. Pedestrian trampling rapidly accentuates the high stresses plants are under in these environments. Several areas of cliff-top erosion presently occur on the island, and many are associated with, or accentuated by pedestrian traffic (e.g. Eagle Bay; West End).

One sand sheet occurs on the island at Stark Bay. This appears to have been

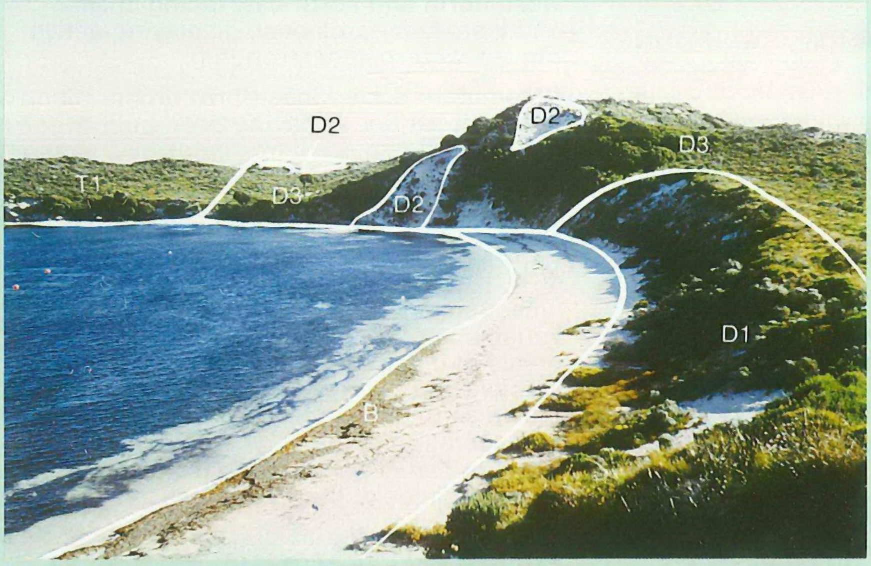


Figure 2.1. Low energy reflective beach (B), foredune (D1), blowouts (D2) and parabolic dunes (D3) at the western end of Porpoise Bay. Both foredune (D1) and adjacent parabolic dune (D3) are steep and highly susceptible to wind erosion.

Figure 2.2. Units B, D1, D3, D4 in Bickley Bay. The foredune (D1) here is wave scarped and is susceptible to wind erosion, despite its generally low relief. Relict foredune ridges (D4) occur between the foredune and steeper, high relief parabolic dunes (D3) on the far left.

Figure 2.3. Pleistocene parabolic dunes (Unit T1), south of the airstrip, displaying a characteristic high relief, limestone ridge.

Figure 2.4. Pleistocene dune terrain (Unit T2), looking NE from the lighthouse. The rolling dune limestone is of lower relief than the T1 unit.

Figure 2.5. Pleistocene dune flats (Unit T4) occurring inland from Porpoise Bay. These are characteristically flat to gently undulating and relatively protected from the prevailing south westerly winds.

initiated as a blow-out prior to 1955 (O'Connor *et al*, 1977), and has rapidly developed into a larger, more amorphous, landward advancing sand sheet (Figure 3.1).

2.1.4 **Parabolic dunes (D3)**

The parabolic dunes of Rottnest Island are semi-discrete and nested, U-shaped sand ridges. They are characterized by relatively long, parallel, juxtaposed trailing ridges which lead down-wind to a U-shaped or parabolic lobe. All are vegetated to various degrees, many are high (e.g. Oliver Hill), and lee and side slopes are steep. The trailing ridges (or arms) of the parabolic dune are commonly separated by an erosional trough or hollow known as a deflation basin (D6a). The dunes overlie Pleistocene limestone ridges and flats at variable depths. Parabolic dunes are commonly initiated as blow-outs, and evolve into parabolic dunes as the depositional lobe advances down-wind and away from the initial erosion source. The largest area of parabolic dunes is found on the most exposed south-west facing coast (e.g. Salmon Bay). The axes of the dunes parallel the direction of the main sand-moving winds (south-westerlies) (Figure 3.1).

The dunes are largely unlithified, although weak cementation may occur at depth. Soils are similar to those in unit D1 (fore-dune), with a dark greyish-brown sand surface passing into a light grey sand. These sands vary within the unit only with respect to the depth of the darker surface horizon, which will depend upon exposure, site drainage status, and fire/human interference history. Depth of organic matter penetration (surface horizon) was observed to be generally in the vicinity of 25-40 cm on dunes, and up to 105 cm within swales. A typical profile description is provided in Appendix 2.

2.1.5 **Relict fore-dunes and flats (D4)**

Relict fore-dunes are parallel, asymmetric dune ridges which were initiated as fore-dunes on the beach backshore. Progradation (or build-out) of the beach in front of an existing fore-dune, results in the formation of a new fore-dune to seaward, and the consequent isolation of the existing fore-dune. A series of events such as this results in the formation of a sequence of discrete fore-dunes.

Relict fore-dunes occur on the eastern margin of Phillip Point in Bickley Bay (Figure 2.2). Here, three fore-dune ridges run NE—SW for approximately 150 m, merging towards the middle of Bickley Bay. The ridge nearest the existing Army Barracks is the shortest and lowest ($\sim$5 m), whilst the more seaward two are higher ($>$ 10 m), longer, and display some minor erosional patches. Intervening swales are narrow and have a thin sand cover over limestone.

Dune flats, comprising slightly undulating, broad, aeolian sand flats, overlying Tamala limestone at variable depths, are present in City of York Bay (Figure 3.1). These flats are probably formed under conditions of very gradual aeolian (wind-blown) sand trapping on well vegetated back-shore regions. Soil depth is limited.

2.1.6 **Low parabolic dunes (D5)**

Low, undulating, subdued parabolic dunes associated with small interdune depressions (D6b), comprise this landform unit. These dunes have a similar initiation mechanism to the larger parabolic dunes, but are generally less well developed parabolas, and in most cases considerably lower ($<$ 5 cm). Slopes are lower than on the D4 and D3 dunes, and the areal extent is much less. The depth of surface horizon development on these low parabolic dunes may be slightly greater than on the D3 dunes (Figure 3.1).

2.1.7 **Interdune swales and depressions (D6a and D6b)**

In several areas within the parabolic sand dunes (D3 and D5), swales and depressions are formed as erosional deflation areas during dune formation and migration. In other cases, dunes may form around and adjacent to a former flat region, leaving it isolated as an interdune depression or dune flat. Where these occur within the steeper and higher D3 parabolic dunes they are designated D6a, and within the lower D5 parabolic dunes they are designated D6b. These swales and depressions display varying levels of sand cover over limestone depending on their origin and the degree of deflation during formation.

The swales (D6a) which occur within the higher parabolic dunes (D3) are generally narrow, access is poor, and off-site dune ridge stability is low. These factors are of much less significance for D6b swales and flats occurring within the lower D5 parabolic dunes.

2.2 HOLOCENE LAKE SEDIMENTS (H)

The Holocene lake sediments comprise the Herschell limestone, limesand and shell beds of Playford and Leech (1977), and are expressed as clayey, sandy and shelly flats and terraces fringing the lakes (Figure 3.1).

2.2.1 **Sand flats and salt marsh (H1)**

Sand flats and salt marshes (H1) immediately adjacent to the lakes. Whilst the salt marshes are minor in extent, marginal sand and mud flats may be extensive during lowered lake levels. Both flats and salt marshes may be inundated during high lake levels. The sediment is a saline, calcareous sandy mud containing algal remains and gastropod shells (McArthur, 1957, Playford, 1983).

2.2.2 **Upper flats and terraces (H2)**

Upper terraces occur about 0.2 to 1 m above H1 sediments, and are characteristically highly fossiliferous with an abundance of marine shells (Kendrick, 1977). These sediments were deposited in sub-tidal to inter-tidal environments, during a period when sea level was probably higher than present, and when the lakes had marine connections.

Unit H2a varies from gently inclined clayey flats (e.g. north-western margin of Lake Baghdad), to slightly higher, sand/shell ridges and terraces (e.g. northern margin of Government House Lake). In the former case, the unit consists of poorly drained, dark greyish-brown clays over light grey sandy shell beds, and in the latter case moderately well drained, thin grey sandy clays overlying light grey sandy shell beds (Appendix 1). In some cases massive shell beds are encountered (e.g. Herschell Quarry). Slopes vary only slightly (0-2%; ~1°).

Unit H2b occurs in a north-south lying corridor, north of Garden Lake. This area formerly provided one of several marine connections to the lakes (Playford, 1983), and the sedimentary sequence indicates regressive beach and dune sands overlying shell beds. The unit is characterized by up to 30 cm of very dark greyish brown to greyish brown sand overlying very pale brown sandy shell beds (appendix 2). These deposits are internally well drained, although external drainage is somewhat poor, with slopes across the terrace rarely exceeding 1.5% (~1°).

Unit H2c occurs in a north-east—south-west lying corridor north (and inland) of Henrietta Rocks. This low-lying region is characterized by a thin layer of very dark grey, light sandy clay loam overlying a thin, calcrete layer. Beneath the calcrete, sand and sandy shell beds occur. Surface slopes range from 0 to 1% (0.5°) and external drainage is rather poor. Internal drainage is restricted by the calcrete.

2.3 PLEISTOCENE COASTAL DUNE LIMESTONE

Pleistocene dune limestone dominates the landscape of Rottnest Island. The dunes vary from high, steep, lithified parabolic ridges to more gently undulating, lower relief terrain. The limestone is primarily aeolian calcarenite containing varying amounts of quartz sand, is dominated by high angle cross bedding, and displays various soil horizons and calcrete layers. The limestone (T1, T2) also forms prominent exposed headlands around the island. These are commonly associated with inter-tidal rock platforms of varying widths (Figure 3.1).

2.3.1 **Nested parabolic dune limestone (T1)**

Nested parabolic dune limestone (T1) occurs extensively over the island, and is characterized by relatively high relief, undulating, lithified Pleistocene parabolic dunes. In general, dune trend parallels that of the Holocene dunes with ridges lying approximately normal to the adjacent coastline. In places, however, strong limestone ridges parallel the coastline (e.g. inland from Porpoise Bay), and in many cases are only thinly over-lain by Holocene dunes.

Side-slopes of these dunes vary from 10 to 20% (5-11°), rarely to 30% (16°), and commonly have greater than 10 m relief. These areas are well drained (Figure 2.3).

Soils are somewhat excessively drained, uniform calcareous sands which vary greatly in depth. Note that it has not been possible to delineate the areas of rock outcrop on the following map (Figure 3.1). The soils are essentially similar to those forming on the Holocene dunes. Any differences which might be expected in terms of soil development as evidenced by the depth of organic matter penetration, have been masked by the effects of exposure, site drainage conditions, previous vegetation and fire history, and the deposition of a thin cover of modern aeolian sand across significant portions of the unit. The Pleistocene soils are however, characterized by a soft consistence compared with the loose nature of the Holocene sands. This minor factor coupled with the generally more extensive vegetative cover and slightly lesser degree of exposure is considered to place a lower degree of erosion hazard on these areas than on the corresponding landforms of Holocene age (D3). A typical soil profile is described in Appendix 2.

2.3.2 Undulating, low relief dune limestone (T2)

Extensive areas of the island are also dominated by lower relief, irregular, undulating dune limestone terrain. These dunes are not readily classifiable into dune types due to their greater uniformity and subdued topography and perhaps greater age. Relief is generally less than 10 m, dune side-slopes vary from 5-15% (2-8°) and the areas are generally well drained. Soils are similar to those described above for the T1 dunes (Figure 2.4).

Much of the T2 dunes are inland, and are more protected from prevailing south-westerly winds than areas of T1. For this reason the depth of soil organic matter penetration (A horizon) may be slightly greater than for T1 soils.

2.3.3 Swales and depressions within dune limestone (T3)

Where practical, discrete, relatively large swales and concave depressions occurring within areas of the T1 and T2 dunes have been delineated. The swales are generally formed as regions of minimal sand deposition within the dunes, or as erosional (deflation) depressions similar to those described for the D6 unit. Slopes are in the range of 1-3% (0.5-1.5°).

Soils of this unit are calcareous sands and are much finer than those of the D6 unit. The unit has poor external drainage, and this factor, in combination with low exposure and protection by vegetation, has resulted in soils with considerable (up to 50 cm depth) surface organic matter, and hence greater A horizon development. Soils are generally internally well drained. The total depth of soil material is variable, with limestone commonly occurring at shallow depth.

2.3.4 Hind dune limestone flats (T4)

Extensive, slightly undulating limestone flats occur to landward (or leeward) of the T1 and T2 dunes. Two areas occur on the southern side of the island near Nancy Cove and Porpoise Bay, whilst the remainder are found between the Pleistocene dunes and the Herschell Lake sediments. The T4 flats may have remained as essentially non-depositional areas during the formation of the T1 and T2 units (Figure 2.5).

General morphology is similar to that of the T3 areas, except that the area is greater, slopes may be slightly lower, and adjoining off-site steeper slopes do not bound the unit as closely as those of the T3 unit. Soils are also similar to those of the T3 landform unit, and are of variable depth often lying over highly cemented limestome. A typical soil profile is provided in Appendix 2.

3: POTENTIAL DEVELOPMENT HAZARDS OF ROTTNEST ISLAND

The preceding description of landforms and their soils and dynamics (as illustrated on Figure 3.1), provides the basis for classifying those landforms according to their capability for residential and recreational development. In detail, this classification takes into account the relative variation in soil depth and potential erodibility, exposure to winds and waves, and type, dynamics and slope of landforms on the island. It has not been possible to quantitatively include vegetation status in this assessment, although general qualitative statements are indicated, and are presented in the following chapter.

In the following chapter, the limitations of each of the landform units are briefly outlined, and a potential development hazard rating is assigned. The limitations are environmental characteristics which have an adverse effect on the potential land use. In some cases, these limitations express the potential hazard of soil erosion occurrence; in others, the limitations are imposed by off-site factors (e.g. adjacent steep slopes), or environmental factors (e.g. lake level variations). Table 3.1 summarizes the development hazard ratings for each landform unit.

Table 3.1 Potential development hazard ratings for Rottnest Island landforms: Summary

Map unit	Hazard rating	Limitations	Planning considerations
B D1a D2 H1	Very high	Wave erosion Wave/wind erosion Wind erosion Wave erosion; inundation	Areas with very severe physical limitations to development which are difficult to overcome. No development involving major site disturbance recommended.
D1b D3 D4 D6a T1 Sp	High	Wind/wave erosion Wind erosion Wind erosion Adjacent steep slopes; limited accessibility Wind erosion; gullying Wind erosion; gullying	Areas with severe physical limitations to development which will be difficult to overcome, requiring detailed site investigation and environmental design.
H2a T2	Moderate	Possible inundation; High water table Wind erosion; gullying	Areas with moderate physical limitations to development. These can generally be overcome by careful design, and by adoption of site management techniques to ensure site surface stability.
D5 D6b H2B H2c T3	Mod-Low	Wind erosion Adjacent unit wind erosion Minor inundation; drainage Minor inundation; drainage Poor drainage; and/or adjacent steep slopes	Areas with minor to moderate physical limitations to development. These may influence design criteria, and impose certain management requirements to ensure a stable land surface is maintained both during and after development.
T4	Low		Areas with few physical limitations to development provided the integrity of adjacent landforms is maintained.

3.1 AREAS OF VERY HIGH DEVELOPMENT HAZARD

3.1.1 HOLOCENE COASTAL DUNES: BEACH (B), FORE-DUNES (D1a) AND BLOW-OUTS (D2)

The beach and fore-dune (including associated blow-outs) lie within the zone of wave forces. Active wind-blown sand transport may also occur on the beach and fore-dune. The integrity of the fore-dune plant cover, especially adapted to the exposed, stressful environment must be maintained in order to preserve the natural shape of the fore-dune and its surface stability. Blow-outs and steep, semi-vegetated seaward slopes are particularly susceptible to mobilisation and enlargement if disturbed (Figure 3.1).

RECOMMENDATION: No development involving major site disturbance should take place on these landforms, and in high usage areas, steps should be taken to ensure adequate management and protection of the landforms takes place (e.g. fencing; designated paths etc.; see Chapter 5).

3.1.2 HOLOCENE LAKE SEDIMENTS: LOWER SAND FLATS/SALT MARSHES (H1)

The lowest sand flats and salt marshes which fringe the island's lakes are within the zone of lake level fluctuations and are therefore subject to inundation. Sediments are highly saline and uncompacted.

RECOMMENDATION: No development should take place within the unit. Care should be exercised in road siting, and construction and maintenance of batters to minimise the effects on lake margin environments.

3.2 AREAS OF HIGH DEVELOPMENT HAZARD

3.2.1 HOLOCENE COASTAL DUNES: FORE-DUNES (D1b), PARABOLIC DUNES (D3), RELICT FORE-DUNES AND FLATS (D4), AND PARABOLIC DUNE SWALES (D6a)

D1b: The fore-dunes of Geordie Bay, Longreach and Thomson Bay tend to be somewhat more stable and less active than those on the remainder of the Island (see section 2.1.2). Although development has taken place on portions of these fore-dunes, some problems are being experienced in maintaining stability (e.g. Geordie). Whilst the Thomson Bay and Longreach fore-dune developments appear to be stable at present, further development east-wards will be subject to greater exposure to winds and waves, and less stable foreshore environments.

D3: The Holocene parabolic dunes are high relief ridges, predominantly exposed to winds, and have steep slopes with negligible to poor cementation. Consequently vegetation cover and soil development are limited.

D4: Relict fore-dunes and flats (D4) occur on the eastern end of the island in Bickley Bay (fore-dunes) and in City of York Bay (flats). The relict fore-dunes are high, narrow ridges and swales with relatively steep slopes, and exposed crests. The vegetation cover is moderate, soil development is weak and cementation negligible. The flats are low-lying, shallow sand deposits associated with a low fore-dune.

D6a: Dune swales (D6a) occur throughout the Holocene parabolic dunes (D3) as semi-circular depressions or long, narrow ovoid deflation basins and swales. Within the D3 dunes they are surrounded by generally steep side slopes and hence have severe offsite problems. Many have limited access.

RECOMMENDATION: Any development on the fore-dunes (D1b) should avoid large-scale clearing, and reshaping resulting in either steeper slopes and/or extension of the frontal toe of the fore-dune further seawards. Intensive management would be required (Figure 3.1).

Note that if any development projects involving extensive engineering works and/or significant site disturbance takes place, the erosion hazard of the land unit involved, and adjacent land units is likely to be effected.

No development should take place in exposed areas within the parabolic dunes landform unit (D3). Limited development may be possible in less exposed areas with lower slopes, if great care is taken. Every effort should be made to maintain, and/or re-establish the integrity of the vegetation cover around present roads and future road developments.

No development should take place within D6a dune swales occurring within D3 dunes, and no development should take place on D4 landforms. Limited track access may be suitable within some larger D6a units if necessary (Figure 3.1).

3.2.2 PLEISTOCENE COASTAL DUNE LIMESTONE: HIGH RELIEF PARABOLIC DUNES (T1)

The Pleistocene parabolic dune limestone ridges exhibit high relief and steep slopes. Soil development is limited and the vegetation cover is variable. Both factors are influenced by the degree of exposure. Calcrete surfaces are common, and there is high variability in the depth of sand cover. Exposure to winds varies widely, with upper slopes and crests being highly exposed. The risk of gullying by rainwater runoff is high.

RECOMMENDATION: Development should be restricted to site dependent activities (e.g. lighthouses; wind vanes) and provision made for adequate stabilization following construction activities.

3.2.3 DISTURBED AREAS: SAND PATCHES (Sp)

On the accompanying map (Figure 3.1), mined areas, road batters and development associated clearings have all been grouped under sand patches. These vary from relatively stable sites (e.g. limestone dominated road margins) to erosional blow-outs. In their present unvegetated, partially to fully erosional state, many have characteristics which would be hazardous to development. Recommendations are provided in Chapter 5.

3.3 AREAS OF MODERATE DEVELOPMENT HAZARD

3.3.1 HOLOCENE LAKE SEDIMENTS: UPPER TERRACES, FLATS AND RIDGES (H2a)

The H2a flats, terraces and ridges vary from relatively low, landward sloping, seasonally wet areas (e.g. NW margin of Lake Baghdad) to slightly higher, drier, slightly ridged flats and terraces (e.g. North Government House Lake), to shelly terraces (eastern end of Lake Baghdad). In these environments the water table may be close to the surface.

RECOMMENDATION: Although portions of the H2a unit may be capable of sustaining some development, we feel the morphologic variability of the unit, and in particular its ecologic importance (e.g. *Melaleuca lanceolata* grove adjacent to Government House Lake) make it largely unsuitable for development.

3.3.2 PLEISTOCENE COASTAL DUNE LIMESTONE: LOW RELIEF DUNES (T2) AND INTERDUNE DEPRESSIONS AND SWALES (T3)

T2: The irregular, lower relief Pleistocene dunes (T2) generally have lower slopes and to some extent are less exposed (except near cliff tops) than the T1 dunes. Other characteristics are similar to T1 above.

T3: The depressions and swales (T3) which occur within the T1 and T2 dunes have a similar disposition to the D6 landform units. Many are limited in area and are bounded by steep slopes, or have very limited access. Of the larger ones, several are centered on wetlands, and many others are used for vegetation establishment or regrowth trial areas.

RECOMMENDATION: Any development within the T2 dunes should ensure that care is taken with clearing and stabilization of disturbed areas. In the T3 land units efforts should be directed towards protecting any adjacent wetland environments. The larger T3 units are suitable for use as revegetation and recreational areas.

3.4 AREAS OF MODERATELY LOW DEVELOPMENT HAZARD

3.4.1 HOLOCENE COASTAL DUNES: LOW PARABOLIC DUNES (D5) AND SWALES (D6b)

Low parabolic dunes (D5) occur in the Thomson Bay area. These are of lower relief than the D3 dunes, displaying lower slopes, greater degree of cementation in some cases, moderate soil development and generally low-moderate exposure. Interdune swales and depressions (D6b) which occur within the D5 terrain are surrounded by dunes of less relief and lower slopes and therefore have a lower hazard rating. They also tend to have low exposure and moderately developed soils.

RECOMMENDATION: Development is suitable within the D5 and D6b units, given that adequate precautions are taken to minimise the disturbance of adjacent units (particularly D1, D3 and D4), and extensive clearing of vegetation is avoided.

3.4.2 HOLOCENE LAKE SEDIMENTS: UPPER TERRACES, FLATS AND RIDGES (H2b, H2c)

The H2b flats occur in a north-trending corridor above Garden Lake. They have a greater depth of sand overlying shell beds and generally better drainage than the H2a unit. The water table is deeper although there is a decreasing south-wards gradient in both sand cover and water table depth.

The sandy H2c flats occur in a corridor extending south-westwards from the eastern end of the airstrip. The flats comprise shallow sand over thin calcrete over shell beds. Site drainage is poor and slopes are very low.

RECOMMENDATION: Limited to moderate development possible. Attention should be paid to the limitations imposed by adjacent offsite landforms, and to the aesthetic value of the vegetation on this landform.

3.5 AREAS OF LOW DEVELOPMENT HAZARD

3.5.1 PLEISTOCENE COASTAL DUNE LIMESTONE: HIND DUNE LIMESTONE FLATS (T4)

The flat to gently undulating limestone flats (T4) form quite extensive areas to the lee of the Pleistocene dunes. Exposure is generally low, and the sand cover may be moderate to deep.

RECOMMENDATION: Suitable for development given adequate precautions are taken to minimise the impact on adjacent landforms.

DEVELOPMENT HAZARD RATING (Figure 3.1)

- Low
- Moderate – Low
- Moderate
- High
- Very High

LAND FORMS

HOLOCENE COASTAL SAND DUNES

B	Beach
D1	Foredune and associated blowouts
D_1a	Active, partially unstable foredunes
D_1b	Less active, relatively stable foredunes
D2	Discrete, active blowouts/sand sheet
D3	Parabolic sand dunes
D4	Relict foredunes and flats
D5	Low, undulating parabolic sand dunes
D6	Interdune swales, flats and depressions
D_6a	Within D3 parabolic dunes
D_6b	Associated with D5 parabolic dunes

HOLOCENE LAKE SEDIMENTS

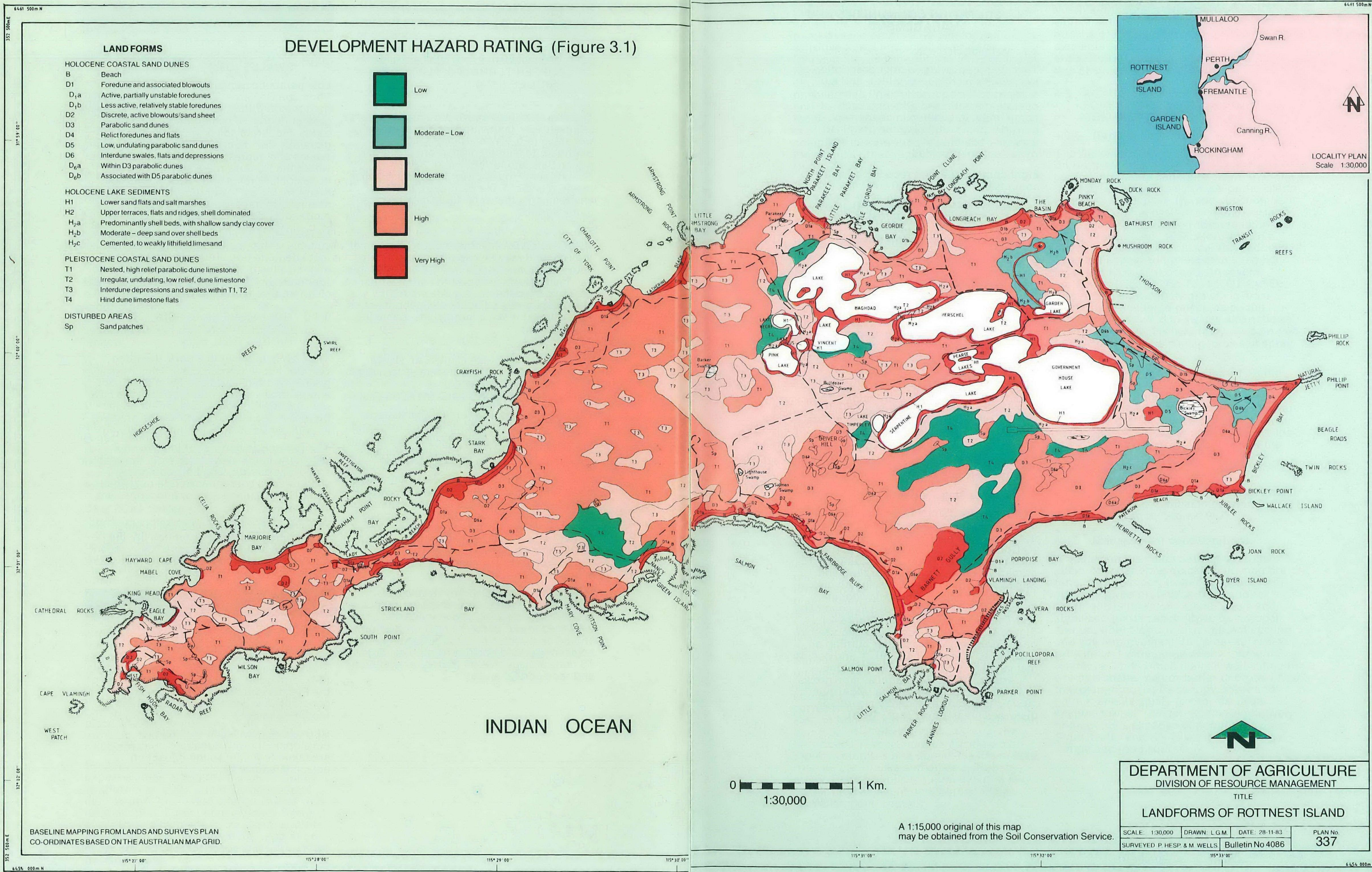
H1	Lower sand flats and salt marshes
H2	Upper terraces, flats and ridges, shell dominated
H_2a	Predominantly shell beds, with shallow sandy clay cover
H_2b	Moderate – deep sand over shell beds
H_2c	Cemented, to weakly lithified limesand

PLEISTOCENE COASTAL SAND DUNES

T1	Nested, high relief parabolic dune limestone
T2	Irregular, undulating, low relief, dune limestone
T3	Interdune depressions and swales within T1, T2
T4	Hind dune limestone flats

DISTURBED AREAS

Sp	Sand patches



BASELINE MAPPING FROM LANDS AND SURVEYS PLAN
CO-ORDINATES BASED ON THE AUSTRALIAN MAP GRID.

A 1:15,000 original of this map may be obtained from the Soil Conservation Service.

DEPARTMENT OF AGRICULTURE DIVISION OF RESOURCE MANAGEMENT			
TITLE LANDFORMS OF ROTTNEST ISLAND			
SCALE 1:30,000	DRAWN L.G.M.	DATE 28-11-83	PLAN No. 337
SURVEYED P. HESP & M. WELLS	Bulletin No 4086		

4: VEGETATION COMMUNITIES AND MANAGEMENT

4.1 INTRODUCTION

This chapter provides a brief description of the island's plant communities, and an analysis of the succession and dynamics operating within, and affecting each community. In addition, management considerations, outlining the practical aspects of community succession and dynamics are provided.

Eight communities are recognized and comprise:

- *Acanthocarpus-Stipa* low dense heath,
- *Acacia rostellifera* low forest or closed *scrub,*
- *Melaleuca lanceolata* low forest,
- Coastal dense heath,
- *Templetonia retusa* dense heath,
- Marsh and lakeside vegetation,
- *Nitraria billardieri* dense mat, and
- Succulent mat community.

The vegetation classification used in this report is based primarily on an unpublished classification by Pen (1982), but also draws on works by White and Edmiston (1974) and O'Connor *et al.* (1977). Other workers including Storr (1957), McArthur (1957), Storr *et al.* (1959), Storr (1963), Beard (1979), Heddle *et al.* (1979) and Pen and Green (1983) have also described various aspects of Rottnest Island's vegetation.

4.2 *ACANTHOCARPUS-STIPA* LOW DENSE HEATH COMMUNITY

4.2.1 **General description**

Of all the island's plant communities this is currently the most widespread, covering about one-third of the island's area (O'Connor *et al.* 1977) and occurring on a wide range of landform units. Comprised primarily of *Acanthocarpus preissii* and *Stipa variabilis*, the low dense heath also commonly contains *Thomasia cognata, Guichenotia ledifolia, Conostylis candicans* and *Trachyandra divaricata* (Figure 4.1, Figure 4.7 plate 1). *Thomasia* is reported to be the primary colonizer after burning or clearing (O'Connor *et al.*, 1977), and occurs mainly on shallow soils over limestone (McArthur, 1957). *Guichenotia* often grows in swale and valley situations (McArthur, 1957) and colonizes recently cleared or disturbed areas (Storr *et al.*, 1959).

4.2.2 **Management considerations**

The relatively recent and rapid increase in the distribution of *Acanthocarpus-Stipa* low dense heath is considered to be directly related to the progressive elimination of fire-sensitive forest and scrub species by frequent fire, and the subsequent grazing of regenerating seedlings and suckers by quokkas (*Setonix brachyurus*). The unpalatability of the heath's major species and their ability to regenerate and recolonize rapidly after burning, have also contributed to the success of this community at the expense and detriment of the island's other vegetation communities (Storr, 1963).

Aesthetically this plant community may have appeal because of the broad visually unrestricted vistas it provides, but because of the very spiny character of the dominant *Acanthocarpus*, its recreational value is low. It also serves as shelter for quokkas. The two main factors which affect the success of this community are fire and cultivation, although grazing can influence its species composition (see Figure 4.7).

4.2.2.1 *Fire*

The Acanthocarpus plant community establishes readily following fire (Figure 4.7 plates 2, 3) although frequent burning would undoubtably alter its species composition. Fire is already being employed on Rottnest Island as an *Acanthocarpus-Stipa* dense heath management tool in tree planting programmes. Burning the heath not only stimulates the germination of soil-stored *Acacia rostellifera* seeds, but also removes the competitive effect of *Acanthocarpus* (Figure 4.7 plate 3), (White and Edmiston, 1974).

4.2.2.2 *Cultivation*

Cultivation is used effectively in conjunction with fire as a tool in controlling *Acanthocarpus* competition in areas to be planted out to trees (Figure 4.7 plate 4), (White and Edmiston, 1974). Compared with uncultivated areas, cultivated areas have very little or no *Acanthocarpus* present (Figure 4.7 plate 5). In several Rottnest Island plantation areas which have been burnt and cultivated, the *Acanthocarpus-Stipa* dense heath has regenerated, but only on the outside of the fence in non-cultivated areas, does the *Acanthocarpus* occur in any abundance. It appears that cultivation serves to break up the *Acanthocarpus* root system from which new shoots initiate after being burnt. Cultivation also favours the introduced *Trachyandra divaricata* which rapidly colonises and dominates fire breaks, road verges, tracks and other disturbed areas. Once established, *Trachyandra* may also invade adjacent undisturbed areas (B. White, pers. comm.).

4.2.2.3 *Grazing*

Quokka grazing effects the composition of the *Acanthocarpus-Stipa* dense heath significantly. In areas subject to heavy quokka grazing pressure, the more palatable elements of the community (e.g. *Olearia*) are selectively grazed, and as a result are less common (Figure 4.7 plate 6).

4.3 *ACACIA ROSTELLIFERA* LOW FOREST OR CLOSED SCRUB COMMUNITY

4.3.1 **General description**

The *Acacia rostellifera* community occurs on Rottnest in two forms, firstly as a closed scrub community generally growing on the more exposed western portion of the island (Figures 4.2, 4.8 plate 1), and secondly as a low forest on the eastern end of the island. *A. rostellifera* was once widespread on the island (Storr, 1957, 1963; McArthur, 1957), but its range is now considerably reduced. It does not appear to be resticted to soil or landform type, as it occurs on several landforms (e.g. T1, T2, T3, T4, D1 and D3; Figure 3.1) although its growth is most vigorous in sheltered positions on the lee slopes of dunes and in swales and hollows. In exposed sites it is invariably wind pruned, and exhibits foliage damaged by salt spray (Figure 4.8).

The presence of ground cover within the *A. rostellifera* stand depends largely on the density of the canopy. Where the canopy is very dense, there is little ground cover and species of the *Acanthocarpus-Stipa* dense heath only penetrate a metre or so into the stand. In most other instances where the canopy is less dense, there is a sparse ground cover, containing species of the plant community surrounding the *A. rostellifera* stand. A fuller description of the annual and perennial understorey species is given by Storr (1957).

4.3.2 **Management considerations**

A. rostellifera is characterized by: (i) its ability to regenerate quickly following fire or other disturbances, from both seeds and suckers, given protection from quokka grazing. It is therefore valuable as a soil stabilizer; (ii) its capability to fix nitrogen and possibly play a role in nutrient cycling and soil improvement; (iii) a dense, rapid growth, and wide range of environmental tolerance limits which make it well suited for use as a shelter belt or buffer to protect new tree plantings; (iv) its canopy cover and colour, and its ability to provide visual aesthetic relief from an otherwise relatively homogenous expanse of *Acanthocarpus-Stipa* heath; and (v) its value as a quokka refuge and food source.

Figure 4.1. The *Acanthocarpus-Stipa* low dense heath community is dominated by *Acanthocarpus preissii* and *Stipa variabilis*. *Thomasia cognata*, *Guichenotia ledifolia* and *Conostylis candicans* are also common to this community.

Figure 4.2. The *Acacia rostellifera* closed scrub community, occurs on a range of landforms, and is illustrated here on Pleistocene dunes (T1) on the western portion of Rottnest Island.

Figure 4.3. Typical *Melaleuca lanceolata* low forest community growing on lake flats (H_2C) in a relatively sheltered site.

Figure 4.4. Coastal dense heath community dominated by *Olearia axillaris* and *Westringia dampieri* on Holocene coastal dunes (D1, D3).

Figure 4.5. The *Templetonia retusa* dense heath community is limited to the limestone ridges (T1) within the Pleistocene dunes surrounding the salt lakes at the eastern end of the island.

Figure 4.6. The succulent mat community comprises low spreading shrubs of *Mesembryanthemum crystallinum, Threlkeldia diffusa, Atriplex cinerea* and *Rhagodia baccata*, and grows on the exposed Pleistocene limestone headlands (T2) of the Cape Vlamingh area.

The *A. rostellifera* community is regarded as a seral stage of succession (White and Edmiston, 1974; Pen and Green, 1983) and hence is transitory in nature. Since it has a relatively short life span (~20 years), the main factor which will affect the persistance of an *A. rostellifera* stand is whether or not growth can be maintained through sucker and seedling regeneration.

On Rottnest Island the main factors which influence the longevity of *A. rostellifera* stands are burning (controlled and uncontrolled), quokka grazing, beetles and moths stimulating suckering and causing destruction of stands (A. R. Main pers. comm.), exposure to excessive salt spray and wind, natural senescence and land clearing.

4.3.2.1 *Burning and quokka grazing*

A considerable segment of Rottnest Island was devastated by a very hot fire in early February 1955 (Figure 4.8 plate 2) and as a direct result, a significant area of *A. rostellifera* was destroyed (Storr, 1957, 1963; McArthur, 1957; White and Edmiston, 1974). *A. rostellifera* regenerates well after burning with the bulk of the regrowth occurring by suckering (Figure 4.8 plate 3), and to a lesser extent by seedling propagation (Storr, 1957; White and Edmiston, 1974). Despite this, very little regrowth survives where a regenerating stand is not protected from quokka grazing (Figure 4.8 plates 3, 4, 5). As a consequence, significant areas of former *A. rostellifera* cover were lost in the 1955 fires through subsequent uncontrolled quokka grazing (McArthur, 1957; Storr, 1957). The only *A. rostellifera* to survive the effects of quokka grazing in these areas were those inside exclosures (Figure 4.8 plates 3, 4, 5). These exclosures were erected by the U.W.A. Zoology Department specifically to study the post-fire regeneration of different plant communities, and the effects of quokka grazing (or the lack of it) on their regeneration.

In areas of low quokka density the regenerating plant communities were subjected to less grazing pressure and consequently recovered more rapidly to their pre-fire state.

The effect of quokka grazing is two-fold; firstly the loss of areas of *A. rostellifera*, and secondly the resultant spread of the *Acanthocarpus-Stipa* heath.

Since quokka grazing is a significant factor in the suppression of *A. rostellifera* regeneration, the only option is to reduce the grazing pressure. The most economic method of achieving this is to fence the regenerating area in question, and exclude quokka grazing. The success of exclusion areas created by the Rottnest Island Board around the island, demonstrates the importance of this regeneration method (Figure 4.8 plates 5, 8, 9, 10).

4.3.2.2 *Senescence*

The general deterioration of *A. rostellifera* stands with age is common on Rottnest Island (Figure 4.8 plate 6). As an *Acacia* stand senesces (grows old and moribund) it is usually replaced by suckers and seedlings if quokkas are excluded (Figure 4.8 plate 7). In some instances the senescing stand continues to deteriorate without any regeneration, which eventually results in the death of the stand and its replacement by *Acanthocarpus-Stipa*. The factors which stimulate or induce suckering are not well understood. A lack of obvious suckering may be due not only to intense quokka grazing, but also to a lack of suckering stimuli. When a stand is deteriorating and no suckering is occurring, then its regeneration can be encouraged by: (i) burning, to stimulate sucker and seed germination; (ii) cultivation, to eliminate competition; and (iii) protection from grazing by fencing (Figure 4.8 plates 8, 9, 10).

4.3.2.3 *Exposure*

A. rostellifera may occasionally be found growing in very exposed locations (e.g. Salmon Point). Growth is generally depauperate, the plants commonly losing their spring growth at the onset of strong summer sea breezes, and the general community being severely wind pruned (Figure 4.8 plate 11). Although *A. rostellifera* can survive under these conditions, it is not recommended that it be planted at these locations.

4.4 *MELALEUCA LANCEOLATA* LOW FOREST COMMUNITY

4.4.1 **General description**

The *M. lanceolata* low forest community (Figures 4.3; 4.9) is generally confined to the eastern portion of the island where it occurs on Pleistocene dunes, Holocene dunes and lake margins (T1, T2, T3, T4, D3, H1, H2A and H2C landform units; Figure 3.1). It grows well on all of these units, though like *A. rostellifera* and the other tree and shrub species it becomes wind and salt-spray pruned in exposed situations, taking on a multistemmed form. Little or no understorey exists where *M. lanceolata* grows with a closed canopy. Normally the only groundcovers present are *Threlkeldia diffusa* and *Rhagodia baccata*, which extend about a metre into the stand. When a single tree or the stand is destroyed by fire, these two species may temporarily dominate the area around the fallen dead timber.

4.4.2 **Management considerations**

M. banceolata has a much longer life span than *A. rostellifera*, taking many years to reach its full stature (up to 10 m; White and Edmiston, 1974). Its rounded, dense, deep green canopy make it an attractive tree and certainly one of the more aesthetic elements of the island's vegetation (Figure 4.9 plate 1). Its growth habit, well developed root system, and deep leaf litter effectively protects the soil from wind and water erosion. It is also an excellent shade tree. These points emphasize the need to preserve the remaining stands and individuals of this species on Rottnest Island, and to promote its re-establishment through protection and planting. Factors which are detrimental to the species are fire, grazing of seedlings by quokkas, clearing for development, and exposure to extreme winds and salt spray.

4.4.2.1 *Fire*

M. lanceolata is more sensitive to fire than *A. rostellifera* because it regenerates primarily from seed. The increasing incidence of fire on Rottnest Island late last century and early this century (Storr 1957, Pen and Green, 1983) has probably contributed to the reduction in its range (Figure 4.9 plate 2). It is important that the interval between fires be greater than the time taken for the species to reach maturity and produce seeds. If burning occurs more often, the already diminished population will be reduced even further to the benefit of the *Acanthocarpus-Stipa* heath which vigorously colonizes space made available by the death of *M. lanceolata*.

4.4.2.2 *Grazing*

Storr (1957) reports that *M. lanceolata* is less palatable to quokkas than *A. rostellifera*, but points out that quokka grazing pressure can still prevent *M. lanceolata* from regenerating after a fire. This observation is supported by the lack of *M. lanceolata* outside quokka exclusion areas and the absence of any seedlings of younger and intermediate age trees amongst the unfenced *M. lanceolata* stands on the island (Figure 4.9 plate 3).

If the quokka grazing pressure is removed, *M. lanceolata* seedlings will establish, providing seed is available in the soil. In the Nancy Cove turnoff plot where the area was burnt, cultivated, and fenced in preparation for the planting out of *M. lanceolata* and *Callitris preissii*, many self sown *M. lanceolata* seedlings have established and are progressing well after only seven years.

4.4.2.3 *Clearing*

Whilst some species may respond vigorously after clearing (e.g. *A. rostellifera* which suckers profusely), *M. lanceolata* does not have the ability to sucker and relies on seedling establishment. It is therefore important to minimize clearing of this species.

4.4.2.4 *Exposure*

M. lanceolata which have been planted or are growing naturally in exposed situations are usually multistemmed, stunted and wind-pruned, with salt burnt foliage on their windward side. Although *M. lanceolata* can exist in exposed situations, they grow most vigorously in more sheltered positions (Figure 4.9).

4.5 *CALLITRIS PREISSII*

4.5.1 **General description and management options**

Callitris preissii currently does not exist as a separate community or association on Rottnest Island, because the species has experienced a considerable reduction in its former distribution. At present few naturally occurring *Callitris*, and no pure *Callitris* stands grow on the island and those that do are not self perpetuating. Some *Callitris* occur within the *M. lanceolata* stands on the east of the island, north of Paterson Beach. These are probably relics of a once more widespread population which is reported to have extended down to the beach at Salmon and Porpoise Bay (A. R. Main, pers. comm.), (Figure 4.9 plate 4). Like *M. lanceolata*, *Callitris* is fire sensitive, and although it regenerates well from seed, it needs protection from grazing for continued survival. Existing areas require protection from both fire and quokka grazing to maintain and extend their range.

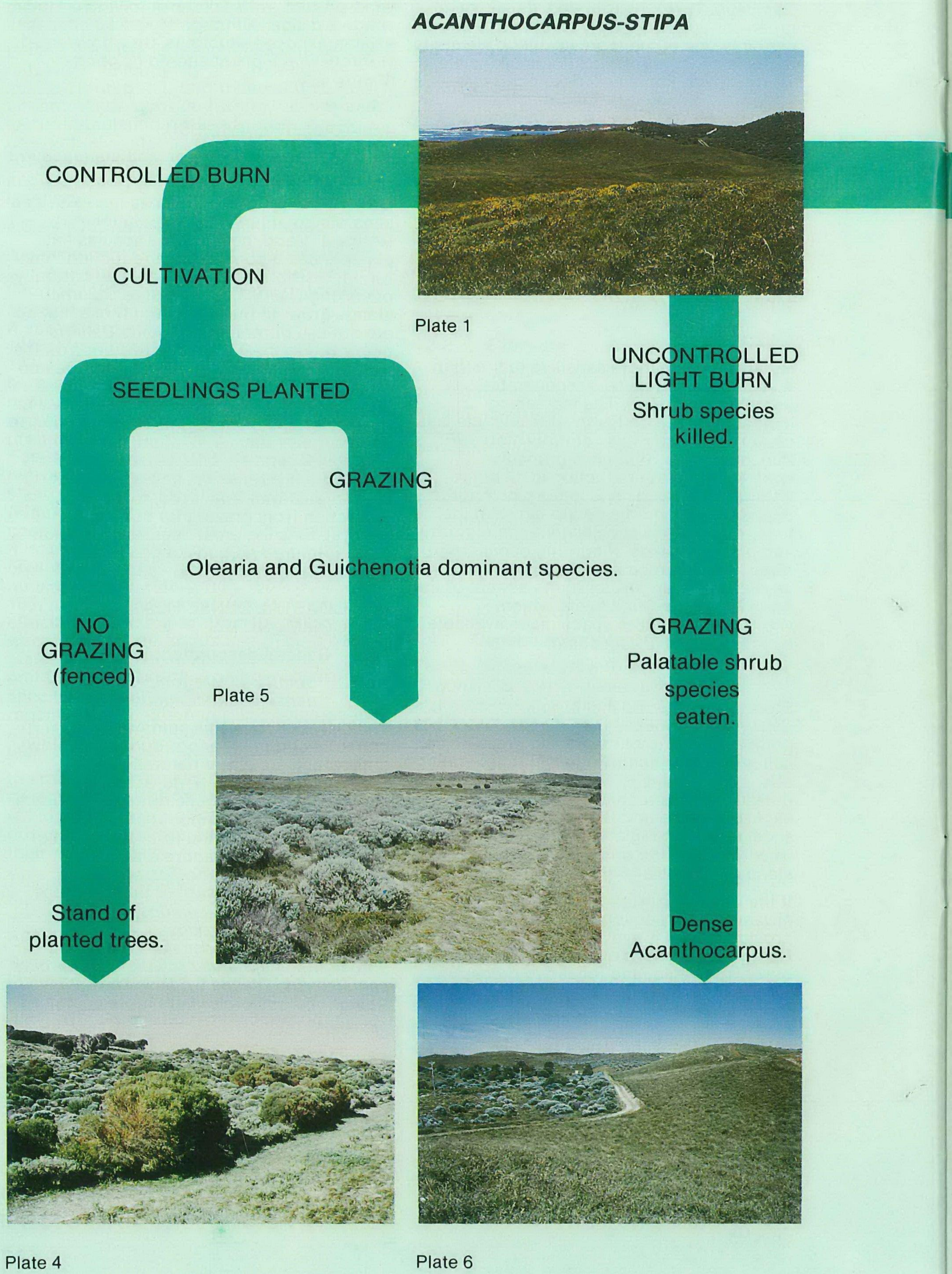
4.6 COASTAL DENSE HEATH COMMUNITIES

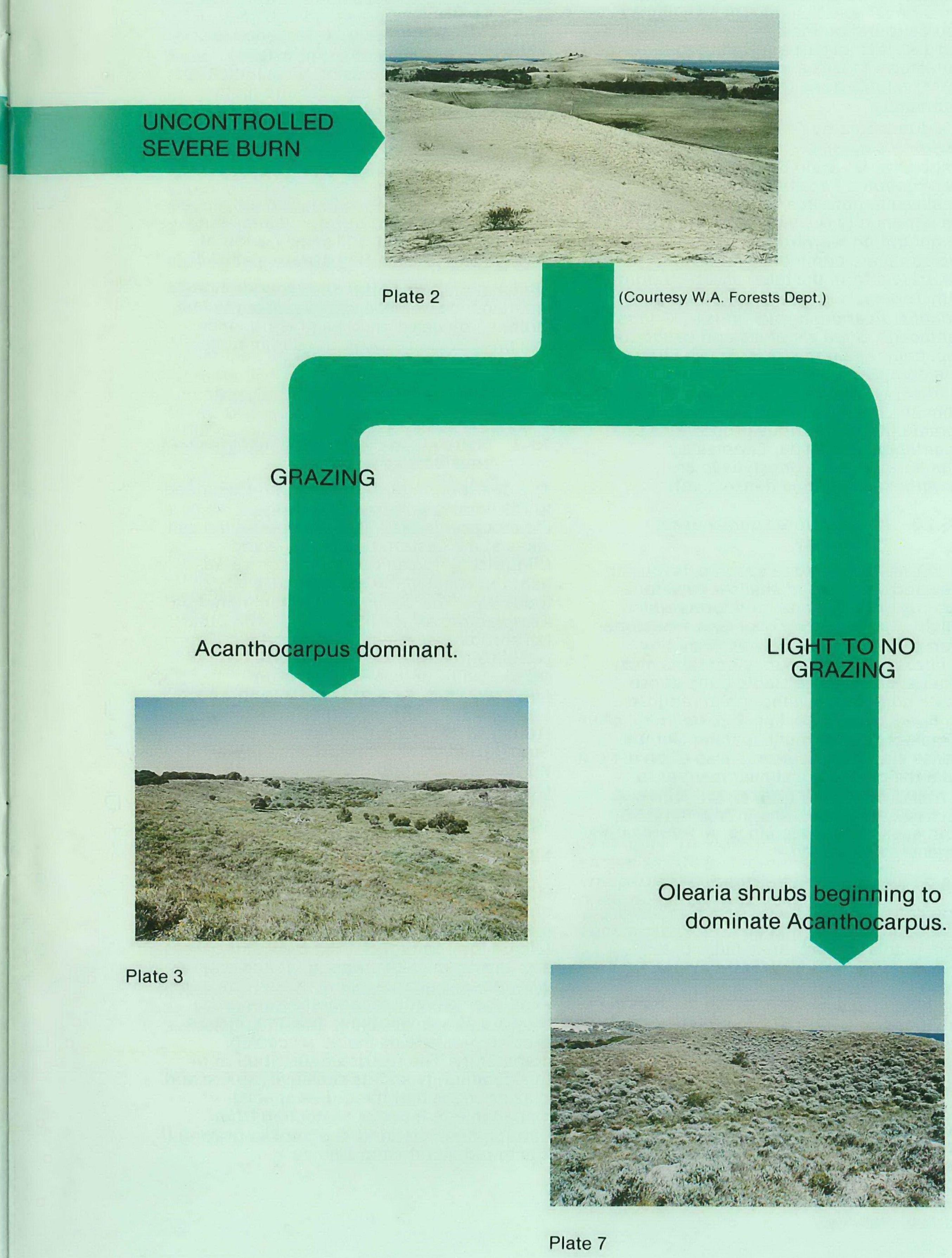
4.6.1 **General descriptions**

4.6.1.1 *Spinifex-Tetragonia-Scaevola dense heath community*

The distribution of this community is primarily confined to fore-dunes and blow-outs, which are either naturally or unnaturally unstable (Figure 3.1). It is equivalent to the "Mobile dune dense heath community" of O'Connor *et al.*, (1977). Species common to the fore-dune area of this zone are *Trachyandra divaricata*, *Spinifex longifolius* and *Tetragonia amplexicoma*. Landward of the fore-dune *Scaevola crassifolia*, *Lepidosperma gladiatum*, *Isolepis nodosus*, *Atriplex isatidea*, *Rhagodia baccata*, *Threlkeldia diffusa*, *Calocephalus brownii*, *Carpobrotus aequilaterus*, *Olearia axillaris* and *Acanthocarpus preissii* are more common.

Figure 4.7 Flow diagram of management and succession dynamics, for the Acanthocarpus-Stipa low dense heath community.





4.6.1.2 *Olearia—Westringia dense heath community*

This community extends from the lee of the fore-dune (D1), landwards to the *Acanthocarpus-Stipa* dense heath. Although it occurs primarily on Holocene coastal dunes (e.g. D3 predominantly, but also some on D1 and D2) (Figure 4.4), it may also be found on Pleistocene dunes (T1, T2 and T3). It is, in part equivalent to White and Edmiston's (1974) and O'Connor *et al.*, (1977) "stable dune dense heath community".

It is dominated by *Olearia axillaris* and *Westringia dampieri* which form an upper shrub stratum. Both *Scaevola crassifolia* and *Rhagodia baccata* also assume localized importance. In exposed situations the community is wind-pruned to a common height but on leeward slopes and swales, two strata are common. *Olearia* and *Westringia* form the taller shrub stratum with *Thomasia cognata, Guichenotia ledifolia, Acanthocarpus preissii, Conostylis candicans, Stipa variabilis* and *Leucopogon* spp. comprising the lower shrub stratum. The composition of this community gradually changes in a landward direction from an *Olearia-Westringia* dense heath community with various proportions of *Acanthocarpus, Stipa, Thomasia, Guichenotia* and *Conostylis* to an *Acanthocarpus-Stipa* dense heath.

4.6.1.3 *Acacia littorea dense heath community*

A. littorea is limestone specific, favouring the windward side of shallow limestone outcrops (T1, T3, and land forms which have a shallow sand cover over limestone (some D1 and D3)). Characterized by *A. littorea*, the community contains most other species of the stable dune dense heath community, although in reduced numbers. *A. littorea*, like *A. rostellifera,* often forms very dense monospecific clumps. Dense stands of *A. littorea* also often die out from the centre in a similar manner to *A. rostellifera* (O'Connor *et al.*, 1971) but whereas *A. rostellifera* can regenerate by both suckers and seedlings, *A. littorea* only regenerates by seed.

4.6.2 **Management considerations**

The coastal dense heath communities are susceptible to burning and quokka grazing and, in this respect, are similar to the island's other scrub and forest communities. However, they are much more resilient to the effects of wind and salt spray than the other communities. Susceptibility to burning can be high, although after fire the communities regenerate well from seed.

Of all the communities on Rottnest Island, the *Spinifex-Tetragonia-Scaevola* dense heath community is the most susceptible to degradation by both natural causes, and by pedestrian and vehicular traffic. Limited access, and well defined planned access to the beaches is necessary to maintain surface stability.

4.6.2.1 *Grazing*

Quokka grazing has the same general effect on these communities as it does on the island's other communities discussed so far. The more palatable elements of the island's vegetation are selectively grazed, and as a result seedling establishment is very low or even completely suppressed until the quokka grazing pressure is lessened or removed. The University of Western Australia quokka exclusion trials indicate that 18 months after the 1955 fire, in the absence of quokka grazing due to exclusion, *Olearia, Westringia* and *A. littorea* seedlings were well established, whereas outside the exclosure, where there had been heavy grazing, these seedlings were extremely rare (Storr, 1957). Similarly, in an area which had been burnt, but subject to only light grazing for the same period of time, young *Olearia* plants were plentiful.

Whilst in the short term, the regeneration or maintenance of these communities may be inhibited by heavy quokka grazing, once this pressure is reduced the communities readily re-establish themselves.

4.7 *TEMPLETONIA RETUSA* DENSE HEATH COMMUNITY

4.7.1 **General description and management considerations**

The distribution of this community is limited to the limestone ridges within the Pleistocene dunes (T1) surrounding the salt lakes at the eastern end of the island (Figure 3.1). It also occurs in some areas near the coast at the eastern extremity of the Island. The community is dominated by *Templetonia retusa* (Figure 4.5) with other tall shrubs assuming local importance in certain situations. *Callitris preissii, Melaleuca lanceolata, Pittosporum phylliraeoides, Beyeria viscosa,* and *Alyxia buxifolia* are some examples from the upper stratum. The understorey usually contains *Stipa variabilis, Acanthocarpus preissii, Westringia dampieri, Phyllanthus calycinus, Guichenotia ledifolia, Asphodelus fistulosus,* and *Clematis microphylla* (Storr, 1957; White and Edmiston 1974).

Most of the species present in this community are palatable to quokkas and are subject to grazing. Storr (1957) notes that quokkas are partial to seedlings of many plants of this community as well as any foliage they can reach. The bark of the trees and shrubs may be stripped off and eaten when food is scarce (Storr, 1957). Since the main species only regenerate from seed, they are as susceptible to fire and quokka grazing pressure as the *M. lanceolata* community. The restricted distribution of this community and its sensitivity to fire and grazing mean that it requires special management. It needs protection from development, clearing and quokka grazing if it is to regenerate and survive.

4.8 SALT MARSH AND LAKESIDE COMMUNITY

4.8.1 General description and management considerations

This community occurs around the edge of the salt lakes and margins of the brackish swamps and comprises *Sarcocornia quinqueflora, Sclerostegia arbuscula, Gahnia trifida, Isolepis nodosus* and *Sporobolus virginicus.* O'Connor *et al.*, (1977) provides a more detailed description of this plant community. This community is unique and limited in its range as well as being important to the quokka as a source of food and refuge, and needs protection from fire. After fire, these wetlands are capable of regeneration, but require some degree of protection from heavy quokka grazing.

4.9 *NITRARIA BILLARDIERI* COMMUNITY

4.9.1 General description and management considerations

This community is confined to coastal limestone cliff faces at West End, and consists of dense, homogenous stands of spreading shrubs (White and Edmiston, 1974). Owing to its habitat, it is only mildly influenced by factors such as fire, human disturbance and quokka grazing.

4.10 SUCCULENT MAT COMMUNITY

4.10.1 General description and management considerations

The succulent mat community is distributed on the most exposed headlands (T2 landform unit) of the Cape Vlamingh area and comprises *Mesembryanthemum crystallinum, Threlkeldia diffusa, Atriplex cinerea, Rhagodia baccata* and *Frankenia pauciflora* (White and Edmiston, 1974, Pen, 1982 unpub.) which form low spreading shrubs (Figure 4.6). Controlled access is necessary in and adjacent to this community to prevent soil erosion and destruction of the vegetation. This is particularly important considering the exposed position of the community. At least part of this community is used as a nesting site by the Wedge-tailed Shearwater (*Puffinus pacificus*) (O'Connor *et al.*, 1977) and reduced access to control soil erosion will be of benefit to the nesting birds. The succulent mat is also grazed by quokkas which are reported to obtain sufficient water from the leaves not to require a source of free water (Shield 1958, Storr 1963). Fire is not as significant a threat to this community as it is to others, nor are there the associated quokka grazing pressures.

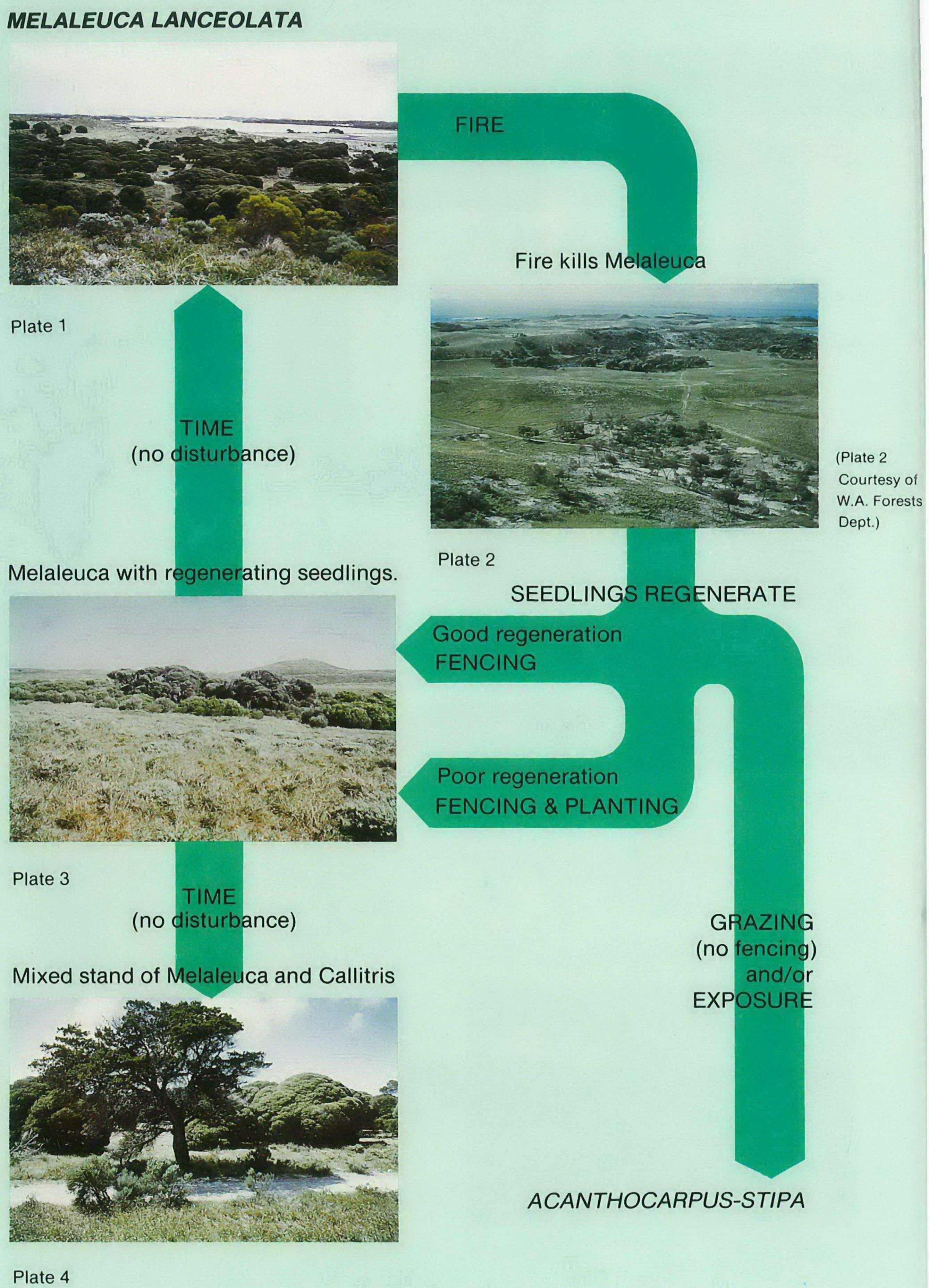
5: PRESENTLY UNSTABLE AREAS: IDENTIFICATION & MANAGEMENT

On Figure 3.1, currently unstable areas are shown as either fore-dune/blow-out complexes (D1), discrete blow-outs (D2) or disturbed areas (Sp; sand patches). Approximately half of these areas appear to have been formed by natural causes, perhaps with some unintentional aid from human use; the remainder are mostly man-induced mining pits, road cuttings and clearings. Many of these unvegetated and/or erosional sites are located adjacent to developed areas, roads or recreational areas, and further erosion is likely to occur if they remain unmanaged.

In the following discussion, these unvegetated and/or erosional sites are identified and shown on Figure 5.1, and general prescriptions and priorities for the revegetation and stabilisation of the sites are provided.

Figure 4. 8 Flow diagram of management and succession dynamics, for the Acacia Rostellifera closed scrub or low forest community.

Figure 4.9 Flow diagram of management and succession dynamics for the Melaleuca Lanceolata low open forest community.



5.1 BEACH-DUNE AREAS

5.1.1 **Fore-dune and fore-dune/blow-out complexes (D1a and D1b)**

Many of the fore-dunes on the island display semi-erosional seaward faces and have small blow-outs. As a general rule the vegetation of the fore-dunes must be maintained, access must be carefully planned and controlled with fenced walkways, and eroding areas stabilised. The following areas require particular attention:

(a) *The Basin.* The fore-dune is semi-vegetated and blow-outs are developing. The fore-dune should be fenced with a low pine rail fence at the seaward toe to reduce pedestrian pressure on the area, and "brushed". A fenced pathway is required on the western end of the bay.

Note that the term "brushing" here refers to laying cut branches of locally available trees (especially *Melaleuca*) on the disturbed area. Every effort should be made to bury the stem or trunk of each branch, and in border areas, the leafy portions of the brush should face outwards, or into the wind. (Fig. 5.1).

(b) *Eastern end of Longreach.* The fence at the seaward toe of the foredune should be renewed, and further *Spinifex* seed head planting could be carried out (see also section 5.1.2k).

(c) *Geordie Bay.* The lower line of chalets are sited too close to the beach, the seaward face of the fore-dune having suffered serious erosion in the 1983 winter storms. Several options are available: (i) fill the erosion scarp with sand, fence and revegetate. This should be viewed as a short term solution; (ii) attempt to reduce storm wave run-up by increasing surf zone dissipativeness. This might be achieved by nourishment of the surf-zone/near-shore zone; (iii) beach armouring, such as gabion mattreses. Both options (ii) and (iii) require extensive investigation before action is taken.

(d) *Parakeet Bay.* Access across the fore-dune needs to be controlled. Random access should be reduced by fencing the perimeter of the bitumen, and formalising a fenced, chain and board walkway across the dune. Unvegetated areas adjacent to the walkway require brushing.

(e) *Ricey Beach.* Access should be formalised across the fore-dune, and adjacent unvegetated slopes should be brushed.

(f) *Lady Edeline Beach.* There are blow-outs within the fore-dune and parabolic dunes (see also section 5.1.2). Some reshaping and brushing is required.

(g) *Salmon Bay.* The fore-dune is scarped and erosional seaward faces are common. Restrict access and monitor.

(h) *Little Salmon Bay.* The sandy flat at the rear of the beach is devegetating and eroding. Fence and brush.

(i) *Mid-western end Porpoise Bay.* The seaward face of the fore-dune is steep, erosional-prone and semi-vegetated. Restrict access and monitor.

Overall we consider it would be very worthwhile to set up a simple beach and fore-dune monitoring programme so that an accurate record of change may be collected. This would take the form of (a) setting up several permanent photographic sites on headlands from which dunes and beaches could be regularly photographed (say six-monthly), and (b) setting up approximately three (minimum) permanent beach survey sites on beaches with varying exposures to assess beach/dune topographic change.

5.1.2 *Blow-outs and sand sheets*

The larger, discrete blow-outs primarily occur adjacent to fore-dunes or within Holocene parabolic dunes (Figure 5.1). These are examined below. Those found adjacent to cliffed areas are discussed in section 5.2.

(j) *Pinky Beach.* The blow-out on the lee of the fore-dune requires brushing.

(k) *Longreach.* In this blow-out, the *Scaevola* and *Melaleuca* have regrown naturally following brushing. The blow-out requires more brush in the middle section, and a fenced, board and chain walkway leading to a lookout in the central Longreach area might be considered.

(l) *Ricey Beach.* The blow-out requires minor reshaping on the south-western margin and brushing. Erosional gaps in the adjacent fore-dune should be brushed.

(m) *Stark Bay.* The sand sheet at Stark Bay, although located well away from any development area or roads, is growing rapidly and has the potential to become much larger. Cereal rye should be established on the area and subsequent remedial treatment considered.

(n) *Lady Edeline Beach.* Blow-outs require some minor reshaping, and brushing. Offroad pedestrian access should be discouraged.

(o) *South of Marjorie Bay.* There is a blow-out lying approximately south-east of Marjorie Bay. The rate of change should be monitored.

(p) *Sticks Passage.* The blow-out on the steep seaward slope adjacent to Sticks Passage requires further brushing. Pedestrian access should be discouraged.

LOCATION OF PRESENTLY UNSTABLE AREAS. (Figure 5.1)

LAND FORMS

HOLOCENE COASTAL SAND DUNES

B	Beach
D1	Foredune and associated blowouts
D_1a	Active, partially unstable foredunes
D_1b	Less active, relatively stable foredunes
D2	Discrete, active blowouts/sand sheet
D3	Parabolic sand dunes
D4	Relict foredunes and flats
D5	Low, undulating parabolic sand dunes
D6	Interdune swales, flats and depressions
D_6a	Within D3 parabolic dunes
D_6b	Associated with D5 parabolic dunes

HOLOCENE LAKE SEDIMENTS

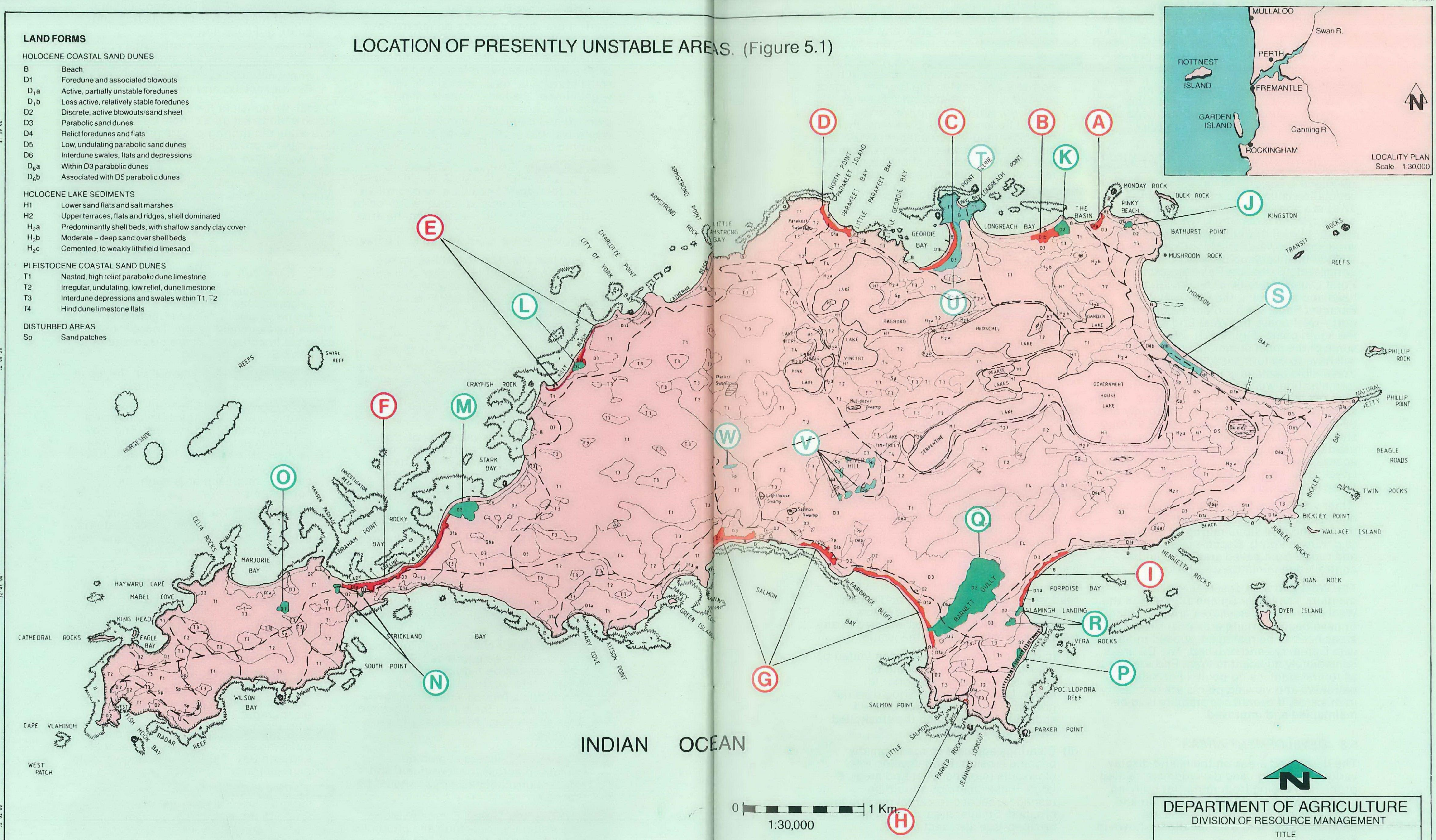
H1	Lower sand flats and salt marshes
H2	Upper terraces, flats and ridges, shell dominated
H_2a	Predominantly shell beds, with shallow sandy clay cover
H_2b	Moderate – deep sand over shell beds
H_2c	Cemented, to weakly lithified limesand

PLEISTOCENE COASTAL SAND DUNES

T1	Nested, high relief parabolic dune limestone
T2	Irregular, undulating, low relief, dune limestone
T3	Interdune depressions and swales within T1, T2
T4	Hind dune limestone flats

DISTURBED AREAS

Sp	Sand patches



DEPARTMENT OF AGRICULTURE
DIVISION OF RESOURCE MANAGEMENT

TITLE

LANDFORMS OF ROTTNEST ISLAND

SCALE 1:30,000	DRAWN L.G.M.	DATE 28-11-83	PLAN No.
SURVEYED P. HESP & M. WELLS	Bulletin No 4086		337

A 1:15,000 original of this map may be obtained from the Soil Conservation Service.

BASELINE MAPPING FROM LANDS AND SURVEYS PLAN
CO-ORDINATES BASED ON THE AUSTRALIAN MAP GRID.

(q) *Barnett Gully.* The stabilisation programme carried out by the Rottnest Island Board has been very successful, and the present programme of brushing and replanting unvegetated or poorly vegetated areas should be continued.

(r) *Porpoise Bay.* A blow-out and an adjacent dune crest erosional sand patch is present at the western end of Porpoise Bay. These both require brushing.

5.2 *HEADLANDS AND ADJACENT AREAS*

Headland areas are very exposed and the vegetation is under considerable stress. They are popular sites for unplanned pathways and lookouts. Many areas have tracks, several of which are undergoing wind and rainwater erosion. Examples include the headland between the Basin and Longreach, Bathhurst Point lighthouse area, Point Clune above Geordie Bay, the headland between Little Parakeet and Parakeet Bays, the headlands along the north-west coast, the West End area, and the south coast (Figure 5.1). We believe some of the most commonly utilised tracks will have to be formalised if potentially irreversible damage is to be avoided. Such formalisation will mean construction of low, pine rail fenced walkways. Limestone stabilised paths and steps will probably also be necessary. Further tracks in these areas should be closed and brushed. Other, less used tracks may be better left as informal access ways as long as an occasional status check is carried out, and remedial action taken if necessary.

Other vehicular access points adjacent to headlands also display eroding access tracks, and side slope rainwater gullying (e.g. Kitson Point). Beach—headland access and runoff from paved areas should be controlled to minimise water erosion.

The West End area deserves special mention. The larger Sp and D2 areas in the West End—Radar Reef area are becoming, or have become, quite erosional sites. These areas need to be reshaped, seeded initially with Cereal rye and brushed. The D2 areas immediately adjacent to West End are used as tourist sightseeing points. Formalised pathways and viewing points are necessary in this area, if overall site stability is to be maintained and improved.

5.3 *DEVELOPMENT AREAS*

The developed areas on the Island display various recreation and development related problems ranging from rainwater gullying, roadside wind erosion, track erosion and dune erosion. Site specific areas are detailed below, and their locations shown in Figure 5.1.

(s) *Thomson Bay.* The fill material forming a terrace in front of the chalets in the eastern portion of the Thomson Bay settlement erodes during winter by rainwater gullying, and in summer by pedestrian usage. This is the result of siting the chalets too close to the beach. This should be avoided in any further development.

(t) *Fay's Bay-Point Clune.* The roads and cleared areas around the chalets at the northern end of Geordie Bay are subject to wind and water erosion. These should be paved. Adjacent unpaved areas should be fenced with pine rails, the topsoil should be replaced, brushed and planted. Local native plants are *Scaevola* and *Olearia.* Attention should be given to minimising runoff from paved areas.

(u) *Geordie Bay.* The dune slope immediately south of the highest row of chalets is still eroding. Further reshaping, hydromulching (paper-pulp mulching) or hay mulching and planting is necessary to achieve stability. Note that an average slope for successful hydromulching is approximately 3:1 = 4:1.

(v) *Oliver Hill.* There are several bare sand patches adjacent to the Oliver Hill road. The Rottnest Island Board has implemented the Forests Department excellent redevelopment programme in this area (Herbert and Schmidt, 1982) and this work should be continued.

(w) *Lighthouse* (above Salmon Bay). There is a large partially eroding track leading from the base of the hill (to the east of the lighthouse) to the lighthouse. Consideration should be given to formalising this track.

(x) *Engineering/Construction activities.* In any engineering/construction activity, topsoil should be stockpiled and replaced following construction (e.g. the windvane sites).

5.4 ROADS

Many of the Sp areas are associated with road works either as cuttings or marginal clearings. As a general rule the following management aims should be adopted in any roadwork development on the Island.

(i) In road cuttings which are dominated by limestone, the topsoil should be removed and stockpiled prior to excavation. Side slopes should be not greater than 3:1, and once created should be covered with the stockpiled topsoil and brushed.

(ii) Clearings adjacent to roads rapidly become erosional and develop into blow-outs (e.g. the West End area). If large, these clearings should be reshaped, seeded to cereal rye and then brushed. Smaller areas should be brushed (see also section 5.2).

5.5 MINING PITS

There are several mining pits on the island, some of which have not been used for some time (Sp areas on Figures 3.1 and 5.1). Examples include three in the Thomson Bay area, the eastern Lake Baghdad area, Parakeet swamp south of Marjorie Bay, Salmon swamp and the western airstrip area.

Abandoned mining pits (e.g. Parakeet and Salmon swamps) should be rehabilitated, and all new mining pits should be planned with rehabilitation in mind. Some of the presently, apparently active pits (approximately eight) might be rationalised, so that the most visible ones were closed and rehabilitated. Smaller, poorly exposed examples such as the pit located on the roadside south of Marjorie Bay only require ripping (i.e. leave surface stony). Natural revegetation will hopefully proceed following ripping. Other pits will require reshaping and topsoiling.

This type of rehabilitation work is relatively inexpensive. In addition, the first stage of reshaping and topsoiling can be rapidly implemented.

5.6 CONCLUSION

A cursory glance at the list above indicates that there are a large number of small areas requiring attention, several immediately. We suggest that revegetation and rehabilitation works should be conducted in the following overall order of priority: Fore-dunes and blow-outs urgently require attention. Headland tracks, tourist lookouts and the larger road clearings to have the next highest priority. Areas adjacent to settlements, developed areas, roads, and mining pits have a moderate priority.

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Cover photograph by S. Chape, Department of Conservation and Environment.

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APPENDIX 1

THE CLIMATIC ENVIRONMENT OF ROTTNEST ISLAND

Rottnest Island is located approximately 30 kilometres west of Perth, W.A. It has a Mediterranean climate, having short, wet winters and extremely dry summers. Rottnest receives 93 per cent of its annual rainfall during the period April to October (McArthur, 1957). Mean annual rainfall is 736 mm, and evaporation 1500 mm (Playford and Leech, 1977). Winds are predominantly southerlies and south-westerlies (the latter as strong sea breezes in summer), with occasional north-westerly storm winds. Maximum temperatures range from 26° C in February to 16° C in July (Shield, 1958).

Deep water wave energy varies considerably around the Island, but is generally low in the surf-zone due to the presence of off-shore reefs and inter-tidal rock platforms. Tides are micro-tidal, maximum daily range being approximately 1 m, and the extreme range being 1.5 m (Hodgkin *et al*., 1959).

APPENDIX 2

DESCRIPTIONS AND ANALYSES OF SOIL PROFILES

Soil colours are given by Munsell notations. Organic carbon was determined by the Walkley-Black method (Piper 1950). Carbonate was determined by total acid digestion modified from (Piper 1950) and reported as calcium carbonate. pH determination by 1:5 H_2O method unless otherwise stated.

SITE NO. 23 (D3) Holocene Parabolic Dune—Calcareous sand Ucl.11
Location: Adjacent to Barnett Gully, 0.45 km NW of Parker Point.

Depth (cm)	Horizon	Description
0-25	A	Greyish brown (10YR 5/2) sand, dry loose consistence, apedal with grainy fabric, pH 8.7, 1.3% organic carbon, 96% $CaCO_3$, gradual boundary to:
25-100	B	Light grey (10YR 7/2) sand, dry loose consistence, apedal with grainy fabric, pH 8.7, 0.3% organic carbon, 97% $CaCO_3$.

SITE NO. 26 (T1) Pleistocene high relief dunes (largely aeolianite) Calcareous sand Ucl.11
Location: Inland, approximately 0.9 km SE of Crayfish Rock.

Depth (cm)	Horizon	Description
0-35	A	Very dark greyish brown (10YR 3/2) sand, dry soft consistence, apedal with grainy fabric and many fine roots. pH 8.7, 0.8% organic carbon, 95.3% $CaCO_3$, clear boundary to:
35-120	B	Light grey (10YR 7/2) sand, dry loose consistence, apedal with grainy fabric, pH 9.1, 0.4% organic carbon, 99.2% $CaCO_3$.

SITE NO. 25 (T4) Pleistocene hind dune flat—Calcareous sand Ucl.11
Location: Adjacent 0.2 km SW of western end of airstrip.

Depth (cm)	Horizon	Description
0-10	A11	Very dark greyish brown (10YR 3/2) sand, dry loose consistence, apedal with grainy fabric, pH 8.6, 1.4% organic carbon, 91.4% $CaCO_3$, gradual boundary to:
10-50	A12	Light brownish grey (10YR 6/2) sand, dry loose consistence, apedal with grainy fabric, pH 8.7, 0.9% organic carbon, 95% $CaCO_3$, gradual boundary to:
50-125	B	Light grey (10YR 7/2) sand, dry loose consistence, apedal with grainy fabric, pH 9.1, 0.2% organic carbon, 96.4% $CaCO_3$, overlying limestone.

SITE NO. 33 (H2a) Holocene Lake Terrace (upper)—clay over shell beds.
Location: Midway along north-western shore of Lake Baghdad.

Depth (cm)	Horizon	Description
0-10	A	Dark greyish brown (10YR 4/2) silty clay, moist plastic consistence, apedal with earthy fabric, pH* 9.0, clear boundary to:
10-30	B/C	Light grey (10YR 7/2) gritty sand with abundant marine shells, moist non-sticky consistence, apedal with grainy fabric, pH* 9.0.

SITE NO. 31 (H2b) Holocene Lake Terrace (upper)—sand over shell beds
Location: Approximately 0.35 km SW from Pinky Beach.

Depth (cm)	Horizon	Description
0-20	A11	Very dark greyish brown (10YR 3/2) sand with many fine roots, dry loose consistence, apedal with grainy fabric, pH* 8.5, clear boundary to:
20-30	A12	Greyish brown (10YR 5/2) sand, dry loose consistence, apedal with grainy fabric, pH* 9.0, gradual boundary to:
30-80	B1	Very pale brown (10YR 7/3) coarse sand, with minor marine shells, slightly moist friable consistence, apedal with grainy fabric, pH* 9.0, diffuse boundary to:
80-100	B2	As above but with many marine shells.

*Field pH determination.