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Name: Appendix C - Vascular Plant Species Recorded on the Vegetation Monitoring Sites for the Gnangara and Jandakot Mounds
Date: 29/25/2006
Capture Author: Thomas Leong / Euan Sutherland

Comments:
Polygon
Created to match documented study area with low level of accuracy

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MATTISKE

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS
(Note: * - Denotes Introduced Species)

Family		Genera	Species
ZAMIACEAE		Macrozamia	riedlei
TYPHACEAE	*	Typha	orientalis
POACEAE	*	Aira	caryophyllea
	A	Amphipogon	turbinatus
	*	Avena	?fatua
	*	Briza	maxima
	*	Briza	minor
	*	Bromus	diandrus
	*	Cortaderia	selloana
		Cynodon	dactylon
	M	Danthonia	setacea
	*	Ehrharta	calycina
		Microlaena	stipoides
	M A	Neurachne	alopecuroidea
		Paspalum	sp.
	*	Polypogon	monspeliensis
	ME	Stipa	compressa
	*	Vulpia	bromoides
CYPERACEAE		Baumea	articulata
		Baumea	juncea
		Cyperus	polystachyos
	*	Cyperus	tenellus
	M A	Lepidosperma	angustatum
	A	Lepidosperma	longitudinale
		Lepidosperma	scabrum
		Lepidosperma	tenue
	M	Mesomelaena	graciliceps
	M	Mesomelaena	pseudostygia
		Mesomelaena	stygia
	EA	Schoenus	curvifolius
		Schoenus	?globifer
		Schoenus	grandiflorus
		Schoenus	nitens
	A	Schoenus	pedicellatus
	MEA	Schoenus	rodwayanus
	ME	Schoenus	?subflavus
	A	Tetraria	capillaris

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS

Family		Genera	Species
RESTIONACEAE	ME	Alexgeorgea	nitens
	ME	Hypolaena	exsulca
	A	Leptocarpus	scariosus
	MEA	Loxocarya	cinerea
	M	Loxocarya	flexuosa
	MEA	Lyginia	barbata
	M	Restio	stenostachyus
CENTRO.		R centrolepis	SP. drummondii
JUNCACEAE		Juncus	pallidus
		Colechasia	cyanea
DASYPOGONACEAE	MEA	Dasypogon	bromeliifolius
	MEA	Lomandra	caespitosa — endlicheri
	M	Lomandra	hermaphrodita
		Lomandra	nigricans
	EA	Lomandra	preissii
	ME	Lomandra	purpurea
	MEA	Lomandra	sonderi
		Lomandra	spp.
XANTHORRHOEACEAE	MEA	Xanthorrhoea	preissii
PHORMIACEAE		Dianella	revoluta
		Arnocrinum	preissii
ANTHERICACEAE	M	Caesia	parviflora
		Chamaescilla	corymbosa
		Corynotheca	micrantha
		Dichopogon	capillipes
	A	Hensmannia Laxmannia	turbinata ramosa
	M A	Laxmannia	squarrosa
		Sowerbaea Thysanotus	laxiflora dichotomus
	EA	Thysanotus	multiflorus
	M	Thysanotus	patersonii
	M	Thysanotus	thyrsoideus
	MEA	Tricoryne	elatior
COLCHICACEAE	MEA	Burchardia	umbellata
HAEMODORACEAE		Anigozanthos	humilis
	E	Conostylis	aculeata
	MEA	Conostylis	juncea
	M	Haemodorum	laxum
	MEA	Phlebocarya	ciliata
			filifolia
IRIDACEAE	*	Gladiolus	caryophyllaceus
	MEA	Patersonia	occidentalis

Many
quiver
setigera

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS

Family		Genera	Species
ORCHIDACEAE		Microtis	unifolia
		Pterostylis	sp.
	M A	Orchidaceae	spp.
CASUARINACEAE	M E	Allocasuarina	fraseriana
		Allocasuarina	humilis
PROTEACEAE		Adenanthos	cygnorum
	M A	Adenanthos	obovatus
	M E A	Banksia	attenuata
	M E A	Banksia	ilicifolia
	M E A	Banksia	littoralis
	M E A	Banksia	menziesii
	M E A	Petrophile	linearis
		Stirlingia	latifolia
		Synaphea	spinulosa
LORANTHACEAE	M E A	Nuytsia	floribunda
AIZOACEAE	*	Carpobrotus	edulis
PORTULACACEAE		Calandrinia	liniflora
		Calandrinia	sp.
CARYOPHYLLACEAE	*	Petrorhagia	velutina
LAURACEAE		Cassytha	flava
	E	Cassytha	racemosa
		C.	sp
DROSERACEAE	M	Drosera	erythrorhiza
		Drosera	glanduligera
	E	Drosera	paleacea
		Drosera	pallida
	M E	Drosera	sp.
CRASSULACEAE	M A	Crassula	colorata
		C.	sp
MIMOSACEAE	M E	Acacia	alata
		Acacia	aff. barbinervis
	M E A	Acacia	huegelii
	M A	Acacia	pulchella
	E A	Acacia	saligna
	E A	Acacia	stenoptera

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS

Family		Genera	Species
PAPILIONACEAE	ME	Aotus	?gracillima
	EA	Aotus	procumbens
	MEA	Bossiaea	eriocarpa
	M	Burtonia	conferta
	A	Burtonia	scabra
		Daviesia	nudiflora
		Daviesia	physodes
	MEA	Euchilopsis	linearis
	MEA	Gompholobium	tomentosum
		Hardenbergia	comptoniana
	MEA	Hovea	trisperma
		Jacksonia	densiflora
	MEA	Jacksonia	furcellata
	E	Jacksonia	sternbergiana
		Kennedia	prostrata
	*	Lotus	angustissimus
	*	Lotus	uliginosus
	A	Oxylobium	capitatum
	A	Pultenaea	ochreata
	M	Pultenaea	reticulata
		Viminaria	juncea
RUTACEAE	M A	Boronia	crenulata
	A	Boronia	dichotoma
	A	Boronia	ramosa ssp. anethifolia
	MEA	Eriostemon	spicatus
TREMANDRACEAE	A	Platytheca	galioides
POLYGALACEAE		Comesperma	calymega
		Comesperma	virgatum
EUPHORBIACEAE		Monotaxis	occidentalis
	A	Phyllanthus	calycinus
	E	?Poranthera	huegelii
ANACARDIACEAE	*	Schinus	terebinthifolius
DILLENIACEAE	M A	Hibbertia	aurea
		Hibbertia	aff. helianthemoides
	EA	Hibbertia	huegelii
		Hibbertia	hypericoides
	EA	Hibbertia	racemosa
	EA	Hibbertia	subvaginata
	M	Hibbertia	vaginata

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS

Family		Genera	Species
THYMELAEACEAE		Pimelea	angustifolia
	A	Pimelea	imbricata
		Pimelea	rosea
MYRTACEAE	MEA	Astartea	fascicularis
	E	Calothamnus	lateralis ← Beaufortia elegans
	MEA	Calytrix	flavescens
	MEA	Calytrix	fraseri
		Eremaea	pauciflora
	A	Eremaea	sp.
	ME	Eucalyptus	marginata
		Eucalyptus	rudis
	A	Eucalyptus	todtiana
	MEA	Hypocalymma	angustifolium
		Hypocalymma	robustum
	ME	Kunzea	ericifolia
	[illegible]	Melaleuca	lateritia
	MEA	Melaleuca	preissiana
		Melaleuca	rhaphiophylla
	EA	Melaleuca	seriata (scabra)
		Melaleuca	teretifolia
	MEA	Melaleuca	thymoides
	ME	Pericalymma	ellipticum
	A	Regelia	ciliata
	A	Regelia	inops
	MEA	Scholtzia	involucrata
		Verticordia	nitens
		Verticordia	sp.
HALORAGACEAE	A	Gonocarpus	cordiger
APIACEAE	M	Actinotus	glomeratus
	M E	Homalosciadium	homalocarpum
		Hydrocotyle	sp.
	A	Platysace	compressa
	MEA	Trachymene	pilosa
	MEA	Xanthosia	huegelii
EPACRIDACEAE	MEA	Conostephium	pendulum
	M	Conostephium	preissii
	MEA	Leucopogon	conostephioides
	M	Leucopogon	?conostephioides
	A	Leucopogon	polymorphus (Lysinema)
	E	Leucopogon	propinquus
		Leucopogon	racemulosus (pulchellus)
	A	Leucopogon	sprengelioides
			strictus (Astroloma)

APPENDIX C : VASCULAR PLANT SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS

Family		Genera	Species
PRIMULACEAE	*	Anagallis	arvensis
LOGANIACEAE		Mitrasacme	paradoxa
MENYANTHACEAE		Villarsia	?albiflora
CUSCUTACEAE	*	Cuscuta	epithymum
SOLANACEAE	*	Solanum	nigrum
RUBIACEAE		Opercularia	vaginata
LOBELIACEAE	MEA	Lobelia	alata
		Lobelia	tenuior
GOODENIACEAE	MEA	Dampiera	linearis
	A	Lechenaultia	biloba
	A	Lechenaultia	floribunda
STYLIDIACEAE		Levenhookia	stipitata
	M	Stylidium	amoenum
	MEA	Stylidium	brunonianum
		Stylidium	calcaratum
	M	Stylidium	carnosum
	M	Stylidium	junceum
	MEA	Stylidium	piliferum
	MEA	Stylidium	repens
	MEA	Stylidium	schoenoides
	M	Stylidium	sp.
ASTERACEAE	M	Asteridea	pulverulenta
		Asteraceae	sp.
		Cotula	cotuloides
	*	Dittrichia	graveolens
		Gnaphalium	sp.
	A	Helichrysum	cordatum
	M A	Helipterum	cotula
	*	Hypochaeris	glabra
	E	Ixiolaena	viscosa
		Pithocarpa	pulchella
	M	Podotheca	chrysantha
		Senecio	?diaschides
		Senecio	sp.
	MEA	Siloxerus	humifusus
	*	Sonchus	sp.
	*	Ursinia	anthemoides

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS.

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Acacia alata		+	+			
Acacia aff. barbinervis	+					
Acacia huegelii		+	+	+	+	+
Acacia pulchella	+			+	+	+
Acacia saligna		+				
Acacia stenoptera			+	+	+	+
Actinotus glomeratus	+	+				
Adenanthos cygnorum	+					
Adenanthos obovatus		+		+	+	
* Aira caryophyllea		+	+	+	+	+
Alexgeorgea nitens	+					
Allocasuarina fraseriana		+	+	+		+
Allocasuarina humilis						+
Amphipogon turbinatus					+	+
* Anagallis arvensis						+
Anigozanthos humilis						+
Aotus ?gracillima		+	+			
Aotus procumbens			+	+	+	
Astartea fascicularis	+	+	+	+	+	+
Asteraceae sp.						+
Asteridea pulverulenta		+		+		
* Avena ?fatua						+
Banksia attenuata	+	+	+	+	+	+
Banksia ilicifolia	+	+	+	+	+	+
Banksia littoralis				+		+
Banksia menziesii	+	+	+	+	+	+
Baumea articulata						+
Baumea juncea						+
Boronia crenulata		+		+	+	+
Boronia dichotoma					+	
Boronia ramosa ssp. anethifolia					+	
Bossiaea eriocarpa	+	+	+	+	+	+
* Briza maxima		+	+	+	+	+
* Briza minor			+	+	+	+
* Bromus diandrus						+
Burchardia umbellata		+	+		+	+
Burtonia conferta		+				
Burtonia scabra					+	

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS. (Continued)

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Caesia parviflora		+				
Calandrinia liniflora						+
Calandrinia sp.						+
Calothamnus lateralis			+	+		
Calytrix flavescens	+	+	+	+	+	+
Calytrix fraseri		+	+		+	+
* Carpobrotus edulis						+
Cassytha flava	+					
Cassytha racemosa	+		+	+		
Chamaescilla corymbosa				+		
Comesperma calymega	+			+		+
Comesperma virgatum						+
Conostephium pendulum	+	+	+	+	+	+
Conostephium preissii		+				
Conostylis aculeata			+			+
Conostylis juncea	+	+	+	+	+	+
* Cortaderia selloana						+
Corynotheca micrantha						+
Cotula cotuloides				+		
Crassula colorata		+			+	+
* Cuscuta epithymum						+
Cynodon dactylon						+
Cyperus polystachyos						+
* Cyperus tenellus						+
Danthonia setacea		+				
Dampiera linearis	+	+	+	+	+	+
Dasypogon bromeliifolius	+	+	+	+	+	+
Daviesia nudiflora						+
Daviesia physodes	+					+
Dianella revoluta						+
Dichopogon capillipes						+
* Dittrichia graveolens				+		+
Drosera erythrorhiza		+				
Drosera glanduligera						+
Drosera paleacea	+		+			
Drosera pallida						+
Drosera sp.		+	+			+
* Ehrharta calycina		+	+			+
Eremaea pauciflora	+					
Eremaea sp.					+	
Eriostemon spicatus	+	+	+	+	+	
Euchilopsis linearis	+	+	+	+	+	

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS. (Continued)

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Eucalyptus marginata		+	+			
Eucalyptus rudis						+
Eucalyptus todtiana	+			+	+	
* Gladiolus caryophyllaceus						+
Gnaphalium sp.				+		+
Gompholobium tomentosum	+	+	+	+	+	+
Gonocarpus cordiger	+			+	+	
Haemodorum laxum	+	+				
Hardenbergia comptoniana						+
Helichrysum cordatum					+	
Helipterum cotula	+	+		+	+	
Hibbertia aurea	+	+			+	
Hibbertia aff. helianthemoides	+					
Hibbertia huegelii	+		+		+	
Hibbertia hypericoides						+
Hibbertia racemosa			+	+	+	+
Hibbertia subvaginata	+		+		+	
Hibbertia vaginata		+		+		
Homalosciadium homalocarpum		+	+	+		+
Hovea trisperma	+	+	+	+	+	
Hydrocotyle sp.						+
Hypocalymma angustifolium	+	+	+	+	+	+
Hypocalymma robustum						+
* Hypochaeris glabra		+	+	+	+	+
Hypolaena exsulca		+	+	+		
Ixiolaena viscosa			+			
Jacksonia densiflora	+					
Jacksonia furcellata		+	+	+	+	+
Jacksonia sternbergiana	+		+			+
Juncus pallidus				+		
Kennedia prostrata						+
Kunzea ericifolia		+	+	+		
Laxmannia ramosa	+				+	+
Laxmannia squarrosa		+			+	
Lechenaultia biloba					+	+
Lechenaultia floribunda					+	+

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS. (Continued)

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Lepidosperma angustatum		+		+	+	+
Lepidosperma longitudinale				+	+	
Lepidosperma scabrum						+
Lepidosperma tenue	+			+		
Leptocarpus scariosus	+				+	+
Leucopogon conostephioides	+	+	+		+	
Leucopogon ?conostephioides		+				+
Leucopogon polymorphus					+	
Leucopogon propinquus			+			+
Leucopogon racemulosus	+					
Leucopogon sprengelioides	+				+	
Levenhookia stipitata						+
Lobelia alata	+	+	+	+	+	+
Lobelia tenuior						+
Lomandra hermaphrodita	+	+	+	+	+	+
Lomandra nigricans		+				
Lomandra preissii				+		+
Lomandra purpurea			+		+	
Lomandra sonderi	+	+	+			
Lomandra spp.		+	+		+	
* Lotus angustissimus						+
* Lotus uliginosus						+
Loxocarya cinerea	+	+	+		+	+
Loxocarya flexuosa		+				+
Lyginia barbata	+	+	+	+	+	+
Macrozamia riedlei						+
Melaleuca lateritia				+		
Melaleuca preissiana		+	+	+	+	+
Melaleuca rhaphiophylla						+
Melaleuca seriata	+		+		+	
Melaleuca teretifolia				+		
Melaleuca thymoides		+	+	+	+	
Mesomelaena graciliceps		+		+		
Mesomelaena pseudostygia		+				
Mesomelaena stygia	+					
Microlaena stipoides						+
Microtis unifolia				+		+
Mitrasacme paradoxa				+		
Monotaxis occidentalis	+			+		
Neurachne alopecuroidea		+			+	
Nuytsia floribunda	+	+	+	+	+	

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS. (Continued)

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Opercularia vaginata						+
Orchidaceae spp.		+			+	+
Oxylobium capitatum	+				+	
Paspalum sp.						+
Patersonia occidentalis	+	+	+	+	+	+
Pericalymma ellipticum		+	+	+		
Petrophile linearis	+	+	+	+	+	+
* Petrorhagia velutina						+
Phlebocarya ciliata	+	+	+	+	+	+
Phyllanthus calycinus					+	
Pimelea angustifolia				+		
Pimelea imbricata					+	
Pimelea rosea						+
Pithocarpa pulchella		+				
Platysace compressa					+	
Platytheca galioides	+				+	
Podotheca chrysantha						+
* Polypogon monspeliensis				+		+
?Poranthera huegelii			+			
Pterostylis sp.						+
Pultenaea ochreata					+	
Pultenaea reticulata		+		+		
Regelia ciliata	+				+	
Regelia inops	+				+	
Restio stenostachyus		+				
* Schinus terebinthifolius						+
Schoenus curvifolius			+		+	
Schoenus ?globifer						+
Schoenus grandiflorus						+
Schoenus nitens						+
Schoenus pedicellatus					+	
Schoenus rodwayanus	+	+	+	+	+	+
Schoenus ?subflavus		+	+			
Scholtzia involucrata	+	+	+		+	+
Senecio ?diaschides						+
Senecio sp.						+
Siloxerus humifusus		+	+	+	+	+
* Solanum nigrum					+	+
* Sonchus sp.				+		+
Stipa compressa		+	+	+		+
Stirlingia latifolia						+

APPENDIX D : ALPHABETICAL LIST OF SPECIES RECORDED ON THE VEGETATION MONITORING SITES FOR THE GNANGARA AND JANDAKOT MOUNDS. (Continued)

Species	Gnangara P50	Modong West	Modong East	Liddelow	Airport	Thomsons Lake
Stylidium amoenum		+				
Stylidium brunonianum	+	+	+	+	+	
Stylidium calcaratum				+		
Stylidium carnosum		+				
Stylidium junceum		+		+		
Stylidium piliferum		+	+	+	+	
Stylidium repens	+	+	+		+	+
Stylidium schoenoides	+	+	+		+	
Stylidium sp.		+				
Synaphea spinulosa						+
Tetraria capillaris					+	
Thysanotus dichotomus						+
Thysanotus multiflorus	+		+	+	+	
Thysanotus patersonii	+	+				+
Thysanotus thyrsoideus	+	+				
Trachymene pilosa		+	+	+	+	+
Tricoryne elatior	+	+	+	+	+	+
* Typha orientalis						+
* Ursinia anthemoides	+	+	+		+	+
Verticordia nitens	+					
Verticordia sp.	+					
Villarsia ?albiflora				+		+
Viminaria juncea						+
* Vulpia bromoides			+	+		+
Xanthorrhoea preissii	+	+	+	+	+	+
Xanthosia huegelii		+	+	+	+	

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Name: Floristics of Reserves and Bushland Areas of the Perth Region Parts XI - XV
Date: 17/05/2006
Capture Author: Thomas Leong

Comments:
Polygon
Created to match documented study area with acceptable level of accuracy

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- Acceptable = Document contained visual and or described spatial references with complex boundaries, resulting in minor boundary errors
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Attributes
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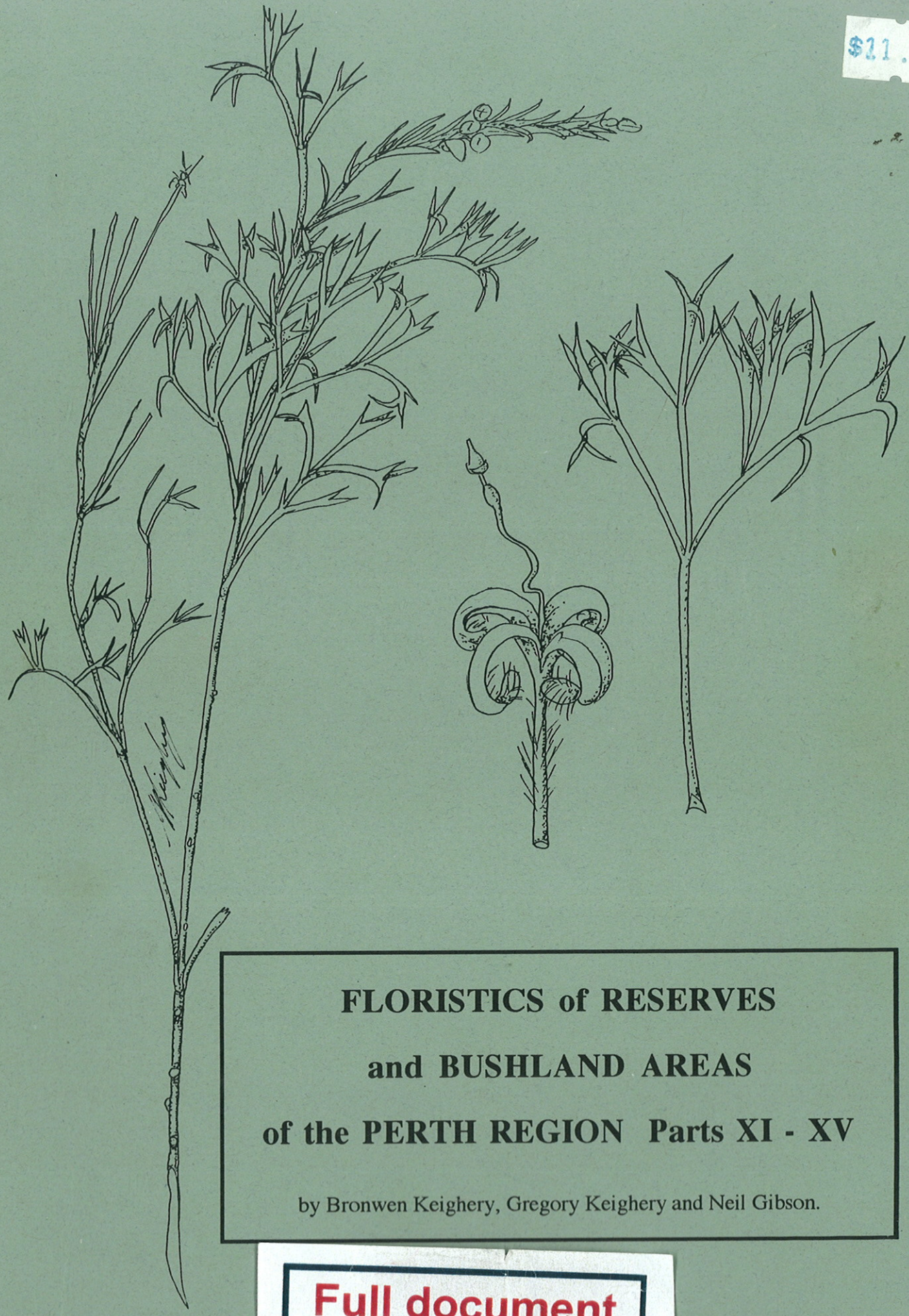
Content – Captured without problems

$11.00



FLORISTICS of RESERVES and BUSHLAND AREAS of the PERTH REGION Parts XI - XV

by Bronwen Keighery, Gregory Keighery and Neil Gibson.

Full document available on request

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Name: The Quindalup Dunes: the Regional System, Physical Framework and Vegetation Habitats

Date: 01/06/2006

Capture Author: Thomas Leong / Ian Steward

Comments:

Polygon

Created to match documented study area with acceptable level of accuracy

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RON VAN DELFT

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The Quindalup Dunes: the regional system, physical framework and vegetation habitats

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Abstract

The Quindalup Dunes contain a variety of aeolian landforms developed by regional climatic, geomorphic and sedimentologic factors, as well as local coastal/strandline processes, and vegetative and pedogenic processes. Superimposed on these are factors of distance from the strandline (which determines the degree of wind effects), soil salinity, and height above water table (which is related to height above sealevel). These factors and processes have resulted in a range of geomorphic units, habitats and vegetation responses that can be recognized at various scales of reference.

A consistent terminology for geomorphic units and habitats has been developed in order to compare tracts of Quindalup Dunes along the various sectors of the southern west coast of Western Australia. The large to medium scale geomorphic units include parabolic dunes, chaots (chaotic dune terrain), shore-parallel ridges, blowouts, undulating plain and flats. The small scale geomorphic units, that essentially equate with the basic vegetation habitats, are subdivisions of the larger scale geomorphic units; these include various slope units; crests and depressions of the larger scale units.

Each of the five sectors of the south west coast of Western Australia contains distinct associations of geomorphic units and vegetation habitats that reflect a difference in the regional sedimentological and geomorphic setting, as well as gradients in climate and other edaphic factors. Changes in dominant habitat types from sector to sector, together with the climatic gradient, favour smaller scale heterogeneous distribution in the structure and floristics of the vegetation units along the extent of the Quindalup Dunes. Our analysis of the distribution of reserves for flora and fauna within the Quindalup Dunes indicates that the regional variety of landforms and vegetation habitats is not adequately represented. In particular, there is no reservation of Quindalup landforms and habitats representative of Geographe Bay, the barrier dunes of Leschenault-Preston Sector, and the cuspate beachridge plain exemplified by Point Becher.

Introduction

The Holocene coastal dune zone of the Swan Coastal Plain is generally a relatively narrow assemblage of landforms formally termed the Quindalup Dunes (McArthur & Bettenay 1960). The zone extends from Dunsborough in the south to Dongara in the north along the south west coast of Western Australia. Within this zone various authors have described and mapped vegetation, or landforms related to vegetation.

Smith (1973) provided a guide to the flora of the coastal habitats and subdivided the flora of dunes into 4 types: foredune vegetation; mobile dune vegetation; stabilized dune vegetation; and tall closed dune scrub. Smith (1985) later subdivided the dune vegetation into 3 types, apparently excising the tall closed dune scrub from the classification. A number of later authors, particularly in unpublished government reports, adopted the subdivision of Smith (1973) as the basic vegetation units of the Quindalup Dunes. Speck (1952) and Seddon (1972), on the other hand, provided maps of the dune zone, generally treating the vegetation complexes within the Quindalup Dunes as a single unit. Heddle (1979), Heddle et al (1980) and Beard (1976, 1981) similarly mapped the flora of the zone, treating the unit essentially as a homogeneous system although recognizing at least 2 alliances, namely a strand and foredune alliance, and

McArthur & Bartle (1980a,b) described various stages of Quindalup dune landform evolution (Q1, Q2, Q3 and Q4) and its stabilization by vegetation, and related vegetation assemblages to these landforms. More recently Cresswell & Bridgewater (1985), utilizing a floristic and landform/soil approach, incorporated the Quindalup Dune System into their overall treatment of vegetation of the Swan Coastal Plain. They subdivided the Quindalup Dune vegetation into eight units, which were then related to geomorphic location.

However, the Quindalup Dunes present a much more variable system of habitats than perhaps has been appreciated. The variability in habitat is due to: processes and stages of landform development as determined by regional factors; processes and stages of landform development as determined by local geomorphic history; relative position of landform units with respect to the strandline; relative relief of the various small scale landform units with respect to water table; degree of development of soils and calcrete; and soilwater salinity.

These interacting factors have developed a wide range of small scale geomorphic units each with its own distinct relief, slope, soil cover, and location relative to sea effects. Because geomorphic processes, and the resultant geomorphic units (variable in time, space, intensity of development, and scale), are the

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Origin of yellow sand from Tamala Limestone on the Swan Coastal Plain, Western Australia

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There has been considerable debate concerning the origin of the Spearwood Dunes on the Swan Coastal Plain in Western Australia. In general, it is believed that the Spearwood Dunes are a complex of calcareous coastal dunes deposited during the Quaternary and now consist of an aeolianite core (the Tamala Limestone) plus tracts of surficial residual sand from dissolution thereof. However, in the mid-seventies a counter view was presented suggesting that the sand was not residual but was transported by aeolian processes from inland sources. At 11 sites on the Swan Coastal Plain a combination of grainsize analysis and heavy-mineral analysis was used to demonstrate that the sand of the Spearwood Dunes has evolved as a result of *in situ* weathering of the underlying Tamala Limestone. This supports previous work on the Swan Coastal Plain and other sandplains in Western Australia, suggesting that there has been very little long-range aeolian transport of sands during the Late Pleistocene.

KEY WORDS: grainsize analysis, heavy minerals, sandplains, Swan Coastal Plain, Tamala Limestone.

INTRODUCTION AND BACKGROUND

Around the southern and eastern coastline of Australia there are a number of dune systems showing chronological sequences of development. Studies by Thompson (1981), Tejan-Kella *et al.* (1991a, b), Urushibara-Yoshino (1996) and Chittleborough *et al.* (1998) have concentrated on areas in eastern and southern Australia using methods such as rates of heavy-mineral weathering and calcite content to differentiate dune ages. These studies all show prograding shorelines with the oldest dunes furthest inland. Early studies of the dunes on the Swan Coastal Plain in Western Australia also suggested that in this region the dunes were the result of a prograding shoreline since the late Tertiary (Playford *et al.* 1976).

It has been generally held that the Spearwood Dunes (McArthur & Bettenay 1974) are a complex of calcareous coastal dunes deposited during the Quaternary and now consist of an aeolianite core (the Tamala Limestone: Playford *et al.* 1976) plus tracts of surficial residual sand from dissolution thereof. These sands comprise part of a series of sands on the Swan Coastal Plain (Figure 1) that are related to geological formations deposited during changes in sea-level from the Late Tertiary to the present day. The oldest deposits in this region were considered to be the Ridge Hill Shelf sands that occur sporadically at the foot of the Darling Scarp. More recent work by Kendrick *et al.* (1991) has also supported the idea that the Bassendean Dune System (Playford & Low 1972) was of Early Pleistocene origin, the Spearwood Dune System (McArthur & Bettenay 1974) Mid to Late Pleistocene, and the Quindalup Dune System still active at the present (Figure 1).

During the Pleistocene, southwest Western Australia was affected by significant periods of aridity (Wyrwoll 1979, 1993), with the most recent arid period coinciding with the last Glacial Maximum, a time when widespread dune-building activity occurred both in coastal and inland Australia (Bowler 1976; Wyrwoll 1979; Williams 1984). Wyrwoll and Milton (1976) attributed this aridity to the dominant presence of powerful anticyclones blocking winter rainfall and generating easterly winds.

Partly because of the emerging palaeoclimatic record, Killigrew and Glassford (1976) and Glassford and Killigrew (1976) suggested that Perth Basin yellow sands are the result of an 800 km expansion of Australian desert conditions to the Indian Ocean in southwestern Australia during the Pleistocene. The alternative hypothesis put forward in their studies was that 'Perth Basin yellow sand is a relict aeolian desert sediment derived from Yilgarn Block weathered granites, gneisses and alluvial derivatives' (Glassford & Killigrew 1976 p. 395). The main lines of argument in support of this idea were the presence of kaolin spheres in the coastal sands that are similar to those found in inland desert sands, and apparent differences in grainsize frequency and mineralogy between the yellow sand and artificially leached limestone. The colour difference between the surficial Spearwood Sands and Bassendean Sand was attributed to 'various post-depositional processes' (Glassford & Killigrew 1977 p. 56).

Lowry (1977) challenged this idea and provided a number of reasons in favour of a coastal origin for the coastal sands. The parallel nature of the dunes to the coast and the absence of any such sand between the inland sandplains and the coastal sandplains were his major lines of argument. Glassford and Killigrew (1977) rejected Lowry's criticisms suggesting that he had misinterpreted their hypothesis and stated that their hypothesis was not suggesting large-scale migration of sand from the inland

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Origin of sandplains in Western Australia: a review of the debate and some recent findings

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Views on the origin of sandplains in Western Australia remain controversial with debate focusing around three different models of formation. These are *in situ*, aeolian and *in situ* formation with local remobilisation by wind or colluvial transport. The only recent work on the subject to date espouses a dominantly aeolian origin. New work from a detailed study on the Victoria Plateau is described and demonstrates the applicability of utilising a range of evidence in understanding the origin of sandplains in Western Australia. Field investigations show a strong association of sandplain with sandstone and an absence of sand on non-arenaceous geology in similar and adjacent topographic settings. Grainsize, mineral magnetic analysis and heavy-mineral spectra show the Victoria Plateau to be a heterogeneous body of sand. These findings coupled with a lack of internal sedimentary structures are not consistent with an aeolian origin for the sandplain. Furthermore, scanning electron microscopy, grainsize and heavy minerals also demonstrate a clear link between bedrock and overlying sandplain. These data support the hypothesis that Western Australian sandplains are mostly the product of *in situ* weathering. Such findings question whether the origin of sandplains can be satisfactorily deduced without such a range of data.

KEY WORDS: grainsize analysis, heavy minerals, regolith, sandplain, Western Australia.

INTRODUCTION

Extensive sand terrains comprising ergs, dunes and sandsheets covering hundreds of square kilometres, occur in the arid and semi-arid environments of the Sahara, Arabia, central Asia, southern Africa and Australia. Long-distance aeolian transport is agreed by many workers to be a dominant force in the origin of these large occurrences of sand (Wilson 1973; Fryberger *et al.* 1979; Breed *et al.* 1987).

Much of the arid and semi-arid zone in Australia is characterised by the occurrence of sandsheets or sandplains. In recent years there is increasing evidence that this deep sandy regolith, in Australia and also in Africa, is largely a stable landscape feature and is either only locally derived or is the product of *in situ* weathering (Pell & Chivas 1995; Besler 1996; Pell *et al.* 1999). At the same time, in many parts of the world, the origin of extensive sand terrains has proved a difficult problem to resolve without systematic assessment using a range of techniques (Gardner 1981; Thomas 1987; Khalaf 1989; Pell *et al.* 1999).

Sandplains are an integral, but poorly understood, part of the geomorphology in Western Australia. Most workers have drawn a well-defined distinction between sandplains that are associated with the coastal margins and those that occur further inland. The coastal sands accompany marine deposits and are generally attributed to global changes in sea-level (Bettenay 1984; Kendrick *et al.* 1991; Bastian 1996). Distinct from this are the inland occurrences of large sandplains (Figure 1) which have traditionally been viewed as *in situ* sand with or without variable degrees of local reworking (Prescott 1931, 1944; Bettenay & Hingston 1961, 1964; Prider 1966; Brewer & Bettenay 1973). The distinction between the two has previously been quite clear but a recent report has reopened the debate with claims that both inland and coastal sandplains are derived from desert aeolian processes (Glassford & Semeniuk 1995).

New work on the origin of sandplains on the Victoria Plateau, in the central-west coastal area of Western Australia contributes further to this debate by postulating that the sandplain is derived from local underlying rocks (Newsome 1998; Newsome & Ladd 1999). Nevertheless, because of the presence of sand dunes, the origin of sandplains in Western Australia remains controversial and three models prevail. Moreover, it would seem that considerable uncertainty surrounds sandplain genesis because of a lack of data. For example, there has been a heavy reliance on field and soil survey work without supporting laboratory data in attempting to elucidate the origin of sandplains. In some cases particle size data are reported (Mulcahy 1960); elsewhere there is some mineralogical work (Carroll 1939; Prider 1966) and chemical data (Churchward 1970) to further the case. Although some soil micromorphology has been used (Brewer & Bettenay 1973), very little scanning electron microscope work has been offered as supporting evidence. Nowhere have these avenues of information and potential evidence been combined to strengthen the argument either way. In particular, it seems that a lack of sedimentological evidence significantly hinders our understanding of sandplain evolution in Western Australia.

In contributing to this debate, this work first provides a review of the current state of knowledge and arguments surrounding sandplain genesis in Western Australia. Second, the utility of using a range of techniques is demonstrated with an emphasis on whole profile and, where possible, bedrock analysis.

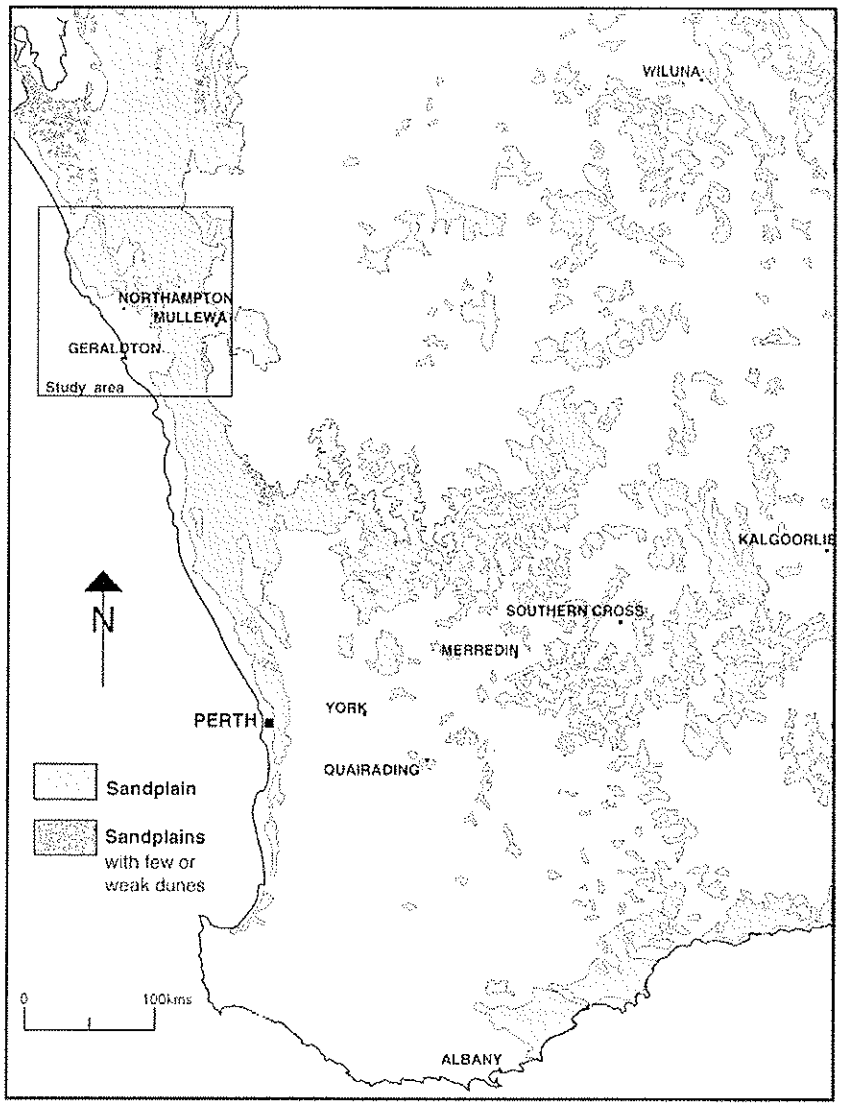

Figure 1 Occurrence of inland sandplains in the southwest region of Western Australia (after Beard 1984).

SANDPLAINS IN THE CONTEXT OF WESTERN AUSTRALIAN REGOLITH STUDIES

In southwest Western Australia the most continuously extensive sandplain areas are closely associated with the arenites of the northern Perth Basin and southern Carnarvon Basin. Sandplains on the granite and gneissic rocks of the Yilgarn Craton although widespread across a large area are relatively smaller and more discontinuous than those on Phanerozoic sedimentary rocks. All of these sandplains, however, would be included in the lateritic sandplain classification of Bettenay (1984). These lateritic sandplains, as described by Bettenay (1984), are generally considered to be underlain by laterite and ferruginous nodules and closely associated with deeply weathered laterite profiles. They are generally considered to have been evolving since the mid-Tertiary (Butt 1981; McArthur 1993).

There are problems in understanding the frequently reported relationship between sandplain and laterite. These problems are largely embodied in the uncertainty surrounding the definition and interpretation of laterite profiles, laterite and lateritic weathering in Western Australia. For example, the terms 'laterite' and 'lateritic' have been widely used and applied to a range of weathered products, soils and sediments (Ollier 1988, 1991; Ollier & Galloway 1990; Bourman 1993). Problems in the way that different workers have applied the term laterite have been highlighted by Bourman (1993) who pointed out that ferruginous zones in weathering profiles, complete weathered profiles and ferruginised, mottled and bleached sediments and rocks have all been called laterite. He goes on to further state that 'some authors do not always make clear the nature of the material they call laterite'.

In Western Australia the laterite profile has traditionally been considered to be an *in situ* deeply weathered profile. It is generally regarded as comprising a downprofile sequence of sand and gravel, and then duricrust followed by mottled zone and pallid zone horizons. Most profiles have been described from the granitic and metamorphic rocks of the Yilgarn Craton in the southwest (Mulcahy &

Hingston 1961; Bettenay & Hingston 1964; Prider 1966; Mulcahy 1967; Brewer & Bettenay 1973; Butt 1981; McArthur 1991).

Playford (1954) studied lateritic deep weathering in Precambrian granites and Jurassic sedimentary rocks in the northern Perth Basin and Northampton Block. Precambrian rocks were found to be completely altered, beneath 'laterite', to depths of 30 m. In this study, Playford (1954) often makes a distinction between 'laterite' and the underlying mottled and pallid zones. Butt (1981), based on his work on the Yilgarn Craton, referred to the whole profile (ferruginous, mottled and pallid zones) as a lateritic weathered profile.

Playford's (1954) interpretation of deep weathered Jurassic sedimentary rocks provides some insight into the nature of laterite profiles on sedimentary rocks in Western Australia. For example, he found the Newmarracarra Limestone in the northern Perth Basin completely altered at depths of up to 30 m beneath the 'laterite'. Playford (1954) also noted that the limestone is frequently altered to depths of around 6 m to a sandy claystone or siltstone with hematitic patches immediately beneath the 'laterite'. He referred to this as the mottled zone of the lateritic profile. Sandstones are also important members of the Jurassic sequence in the Geraldton area; in this case Playford (1954) observed that sandstones were somewhat less altered than the Newmarracarra Limestone. However, a mottled zone and then a bleached zone could be identified beneath 'laterite' developed over sandstone.

Playford (1954) also observed that whole sequences of sedimentary strata in the northern Perth Basin have been deeply weathered. However, it appears that the intense ferruginisation at the surfaces of some sedimentary rocks especially sandstone, and its association with mottling and the bleaching of iron from underlying rocks, has been referred to as laterisation. Such highly altered rocks have also been called laterites (Playford *et al.* 1970; Hocking *et al.* 1982).

The *in situ* model for the entire laterite profile presented here contrasts with that of Ollier and Galloway (1990) and Ollier (1991) who argued that most ferruginous horizons (ferricretes) are not genetically linked to the underlying material. Anand *et al.* (1994) also recognised that some laterites in Western Australia are developed in colluvial and alluvial sediments. Other laterites are observed to have formed as a result of lateral transport and accumulation of iron in low-lying areas. Anand *et al.* (1994) concur with Ollier and Galloway (1990) and Ollier (1991) in the assertion that such areas can then stand higher in the landscape as a result of relief inversion.

Davy and Gozzard (1995) described lateritic duricrusts from the Leonora area in the semi-arid zone of Western Australia. They concluded that duricrusts that have no genetic link with the underlying material may be more widespread than was previously thought. This argument is taken further by Glassford and Semeniuk (1995) who contended that the typical laterite profile of the Yilgarn Craton is a sequence of altered desert-aeolian sediments which unconformably overlies saprolite.

In summary it appears that, depending on the specifics of the situation, the laterite profile may be a deeply weathered *in situ* accumulation differing according to factors of lithology and location. The profile may be truncated and covered with superficial deposits or may consist of altered sedimentary material. These arguments have largely focused on the rocks of the Yilgarn Craton. Less work has been carried out on the effects of deep weathering and laterisation on sedimentary rocks in the Perth Basin. It seems, however, from the work that has been done, that highly altered and ferruginised strata have also been called laterite profiles.

In view of these remarks care needs to be exercised in interpreting some of the earlier work on the relationship of sandplains to laterite profiles. The main issue at stake here, in elucidating the origin of sandplains in Western Australia, is whether the sand is essentially *in situ, in situ* with colluvial transport or the product of long-distance aeolian transport.

PREVIOUS INVESTIGATIONS INTO THE ORIGIN OF SANDPLAINS IN WESTERN AUSTRALIA

In situ model for sandplain formation

Early investigation of inland sandplains and their association with laterite gave rise to the idea that the sand was the eluvial horizon of a laterite profile. Prescott (1931) described sandplain materials as ranging from clay-rich gravel to deep yellow sands and suggested that large areas of sandplain were preserved fossil soil profiles and that where laterite duricrust was exposed at the surface the overlying cover of sand had been eroded away.

A study of mineralogy, grainsize and grain shape data from sandplains at Southern Cross (Figure 1) led Carroll (1939) to conclude that the sandplain in that area was residual. Carroll (1939) also noticed that sandplains occupied the higher parts of the landscape and that an underlying laterite horizon was a constant feature. The sandplain materials were found to be poorly sorted when compared to dune and beach sand and the sand contained little clay. In addition, the heavy mineral content of the sands reflected the underlying lithology and the occasional rounding of quartz grains was explained as inherited from underlying metasedimentary rocks. She concluded that the sandplains in the Southern Cross area were residual pre-weathered soils and were preserved due to low relief and the relatively low rainfall of the region.

The conclusions of Mulcahy (1959, 1960, 1964) and Mulcahy and Hingston (1961), in the York–Quairading area, that short-range transport played a significant role in the origin of sandplains, were challenged by Prider (1966) who maintained the sandplains were part of an *in situ* weathered laterite profile. He used studies of heavy minerals to investigate the relationships of sandplain overlying deeply weathered laterite materials. For example, at one site on the Yilgarn Craton andalusite schist could be traced through from the underlying parent rock to the sandplain that overlay the laterite. In this case Prider (1966) argued that andalusite in the sandplain clearly indicates that the sandplain is part of the *in situ* laterite profile.

Baxter and Lipple (1985), Hocking *et al.* (1987) and Payne *et al.* (1987) have supported the residual origin of sand overlying sedimentary rocks of the Perth and Carnarvon

Basins. There are, however, very few data from, for example, heavy mineral or other studies to support the *in situ* breakdown of sedimentary rock as the origin of the sandplain in these areas.

Local derivation with colluvial reworking of weathered materials as a model for sandplain formation

The view of sandplains as locally reworked materials is not radically different from the *in situ* origins put forward by Prescott (1931), Carroll (1939) and Prider (1966). The fundamental difference lies in the suggestion that sandplain materials have been transported from their site of origin only a short distance under the influence of gravity. Sand is considered to be largely derived from the laterite profile, but in this case has accumulated as colluvial deposits. Mulcahy (1960) asserted that it is the sand profiles that form the Quailing and Monkopen soil-landscape units that comprise the sandplains of Western Australia and that the pre-weathered ferruginous zone of the laterite profile is the source of sand in these landscapes.

Mulcahy (1959, 1960), Mulcahy and Hingston (1961) and Mulcahy (1964) studied soil-landscape relationships in the York–Quairading area (Figure 1). The work of Mulcahy and Hingston (1961), in particular, provides detail and ideas on the development of soils and the origin of sandplains. It was found that yellow sand, consisting of sand or sandy loams over iron concretions, occupied the highest parts of the landscape in association with mottled zone or pallid zone materials of the laterite profile.

Mulcahy (1959, 1960) and Mulcahy and Hingston (1961) described the Quailing soil-landscape unit as including both shallow and deep sands. The shallow profiles, Quailing erosional, consist of up to 1 m of yellow-brown sandy loam containing gravel overlying the ferruginous zone (which is the upper part of the laterite profile and ferricrete of Ollier 1988). In terms of their relative geomorphological position these soils occur in the highest parts of the landscape, often forming the surface of mesa-shaped lateritic residuals.

Downslope of the Quailing erosional land surface is the Quailing depositional soil-landscape unit consisting of undifferentiated deep-yellow sands up to 7 m in depth. The sand was thought to be derived from weathering and disintegration of the ferruginous zone of the laterite profile (Mulcahy 1960; Mulcahy & Hingston 1961). A link between the ironstone and overlying sand was based on the presence of small quantities of easily weathered minerals that were found to occur in both, although no details were provided. Mulcahy and Hingston (1961) noted that smaller amounts of these minerals occur in the deeper sands. It was presumed that the processes of 'ironstone' formation had protected these minerals from weathering and that their presence in the sand is a result of disintegration of the ironstone to form sand. The sand has subsequently been transported downslope to accumulate as colluvial deposits forming sandplains.

Other deep accumulations of sand, which change colour from grey to yellow with depth have been assigned to the Monkopen soil-landscape unit. These sands can be up to 15 m deep and often contain bands of ferruginous concretions. These features, in combination with particle size analysis, have been viewed as evidence for a series of local depositional events (Mulcahy 1959, 1960; Mulcahy & Hingston 1961).

Mulcahy (1960) completed particle size analysis on Monkopen sands that occupy hollows, which were observed to shed sand downslope from the highest points in the laterite landscape. The sorting coefficients of Monkopen sand decreased downslope. The degree of sorting also increased with depth in a profile some 7 m deep, which was investigated at another site. These findings are taken as supporting evidence for a local colluvial origin for sandplain materials. Unfortunately, there are no similar or later detailed particle size studies on the adjacent Quailing depositional sands to further strengthen the argument.

The observations of Mulcahy and Hingston (1961) also showed a field relationship between deep-yellow sand and fresh rock. Such a relationship is also evident in the upland divides of the Merredin area. Mulcahy (1967) expressed the opinion that such fresh rock outcrops, flanked by yellow sand, are what remain after the destruction of the Tertiary laterite landscape.

Soil survey work in the Merredin area has revealed a similar soil landscape pattern to that of the York–Quairading area, except in this case the soil-landscape units have been given different names (Bettenay & Hingston 1961, 1964). Sandplains occurring over laterite and occupying divides in the Merredin area are referred to as the Ulva soil-landscape unit. As with the Quailing surface, in the York–Quairading area the Ulva surface has been divided into erosional and depositional phases. The Ulva erosional is shallow sandy loam and is considered by Bettenay and Hingston (1964) to be produced by the erosion of laterite down to the mottled zone, which then formed a resistant duricrust on dehydration. The depositional phase of the Ulva land surface consists of sandy materials up to 5 m deep. Bettenay and Hingston (1964) mention that the Ulva surface soils have developed from both *in situ* and transported lateritic materials. They conclude that *in situ* weathering has supplied the sand by disintegration of the upper laterite profile and that this sand has then been transported downslope. Brewer and Bettenay (1973) have also supported such findings for the Merredin sandplain.

Churchward (1970), based on studies of laterite development on sedimentary rocks on the Dandaragan Plateau, concluded that sands and gravel in upland areas are locally derived by colluvial transport of pre-weathered lateritic materials. On the other hand, Lowry (1974, 1977) considered that these sandplains were essentially residual sands with very minor local reworking. Lowry's (1974, 1977) conclusions were based on the close correspondence in grainsize and shape of sandplain materials with the quartz fraction in the underlying sedimentary rocks. Such a relationship is quite persuasive of an *in situ* origin, although a companion study showing similar heavy-mineral content between sand and the underlying rock would have strengthened the case for the sand being the product of *in situ* weathering.

The colluvial model is at some variance with the views of Carroll (1939) and Prider (1966). These authors concluded that the ferruginous zone considered being the source of sand by Mulcahy (1960, 1964) actually lies beneath the sandplain. Prider (1966) agrees there may be some colluviation

but feels the evidence (particle size data and bands of 'ironstone' in the deep sands) presented by Mulcahy (1960), for a widespread colluvial origin, is not sufficiently convincing. Prider (1966) asserted that it did not allow the conclusion that all sandplains in the York–Quairading area result from disintegration and transport of the ferruginous zone of the laterite profile. Prider (1966) went on to claim that the evidence presented by Mulcahy (1964) was, in fact, proof that the lateritic ferruginous zone underlies the sandplain and is not a major source of the yellow sand. He also suggested that the bands of ironstone and gravel beneath the sandplain investigated by Mulcahy (1964) are, in fact, an *in situ* lateritic ferruginous zone and not transported material.

Desert aeolian sediment model for sandplain formation

Researchers (Bettenay & Hingston 1961, 1964) favouring a colluvial origin have concluded that aeolian activity was mostly not implicated in the formation of sandplain. Mulcahy (1973) went on further to state that aeolian activity and dune formation were not common on sandplain surfaces, except in the arid interior, implying that minimal aeolian activity had taken place. While this may be true for the York–Quairading and Merredin areas of the southwest Yilgarn, there is widespread evidence of dune formation associated with inland sandplains on the northern Perth and southern Carnarvon Basins (Wyrwoll & Milton 1976;

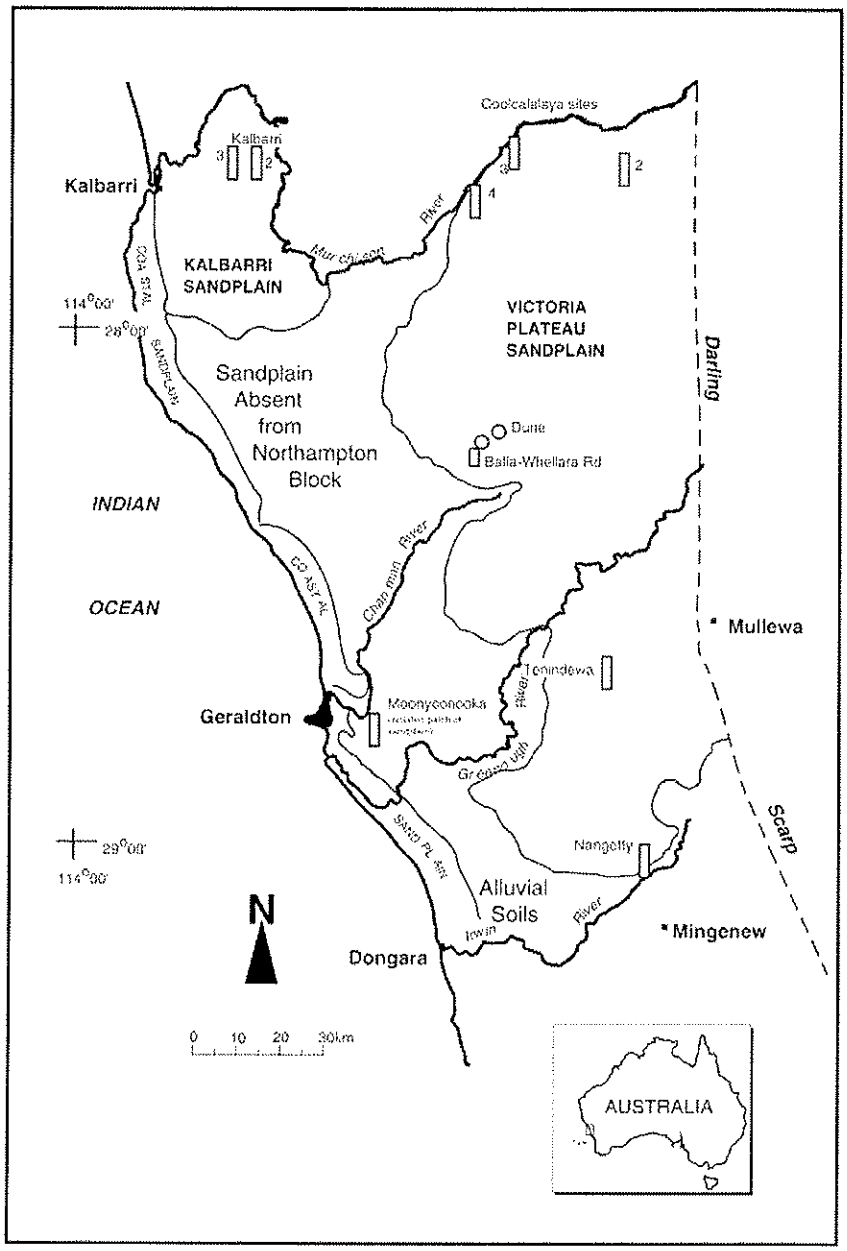

Figure 2 Extent of sandplain and location of selected profiles on the Victoria Plateau.

Wyrwoll 1979, 1993; Wyrwoll & King, 1984; Wyrwoll *et al.* 1993; Newsome 1998). These dunes provide convincing evidence of former Pleistocene arid phases (Wyrwoll 1979, 1993; Newsome 1998).

A central issue in the sandplain debate in Western Australia is whether the dunes in these regions, including the Victoria Plateau, are mostly locally reworked sandplain material or are derived from further afield. Glassford and Semeniuk (1995) claimed that Western Australian sandplains are not mostly *in situ* or local colluvial deposits but aeolian sedimentary deposits, which were formed in a desert environment. If this is the case, the rejection of an autochthonous or locally reworked origin implies sources from further afield and the possible long-range transport of sediments. Glassford and Semeniuk (1995) therefore appear to propose a view of sandplain evolution that is more in line with the long-range transport of sands as mobile ergs as described by Wilson (1971, 1973) in the Sahara Desert.

The thrust of Glassford and Semeniuk's view is that the upper part of the deeply weathered profile, considered by others to be largely *in situ*, is in fact a sequence of sedimentary materials which unconformably overlie weathered saprolite. Glassford and Semeniuk (1991, 1995) maintain the view that the sandplains are mostly desert aeolian sediments with the sand representing the remnants of a once mobile erg, which extended into the coastal parts of southwestern Australia during former arid phases of the Late Quaternary. Such ideas, as presented by Glassford and Semeniuk (1995), are intended to explain the nature and origin of sandplains occurring on the fringe of the current arid zone through to the Swan Coastal Plain fringing the west coast.

VICTORIA PLATEAU CASE STUDY

Study area

The primary aim of the work was to explore the evidence for an *in situ*/local origin versus an aeolian/far-travelled origin of a large sandplain area in Western Australia. A comprehensive study, involving the application of a number of techniques, was carried out on the Victoria Plateau (Figure 2). This area has an extensive expanse of sandplain with fixed sand dunes associated with sedimentary rocks.

Methods

A range of sedimentological techniques was applied in investigating the Victoria Plateau sands namely: grainsize analysis (Bascomb 1974), quartz grain microtextures (Newsome & Ladd 1999), mineral magnetic analysis (Walden *et al.* 1999) and heavy minerals (Mange & Maurer 1992). The main dataset is drawn from three sandplain sites (Kalbarri, Balla-Whellara Road and Nangetty) selected from contrasting areas of the Victoria Plateau sandplain (Figure 2).

Geomorphology and regolith characteristics

The regolith characteristics of the study area strongly reflect the underlying geology (Figures 3, 4) in that deep sand regolith is essentially missing from the Precambrian rocks of the Northampton Block, with sand being present only where small patches of younger arenite are preserved. The lack of deep sandplain on the granite/gneiss rocks of the Northampton Block and the occurrence of shallow, patchy sandplain on the adjacent Yilgarn Craton, which lies to the east, point to a limited sand supply from these rocks relative to the potential large source from the arenites that form the solid geology of the Victoria Plateau.

Widespread deep-weathering events, which are seen by various authors (see above) as being of Tertiary age, have resulted in the extensive alteration of rocks into 'laterite profiles'. The weathering of quartz-rich sandstone on the Victoria Plateau appears, therefore, to have resulted in the formation of deep sandplain profiles. Rock weathering on the Northampton Block and adjacent Yilgarn, on the other hand, appears to have yielded much less sand than that potentially supplied by the adjacent arenites. Sequences of quartz-rich sandstones on the Victoria Plateau thus provide an obvious provenance for the sandplain, which blankets its surface.

Individual sandplain profiles range from 30 cm to >7 m deep. Although no lithological details are given, unpublished hydrogeology bore data records show that the sand is commonly 3–7 m deep, with depths of up to 15 m of sand overlying sandstone in some areas. Sandplain profiles can be differentiated from one another according to variations in sand colour, the degree of soil surface horizon development, slight downprofile colour changes, the presence of clear boundaries between sand and rock, and the amount of clay and gravel in the profile. Figure 5 depicts examples of the major sandplain profiles present on the Victoria Plateau.

There is a clear distinction between the Kalbarri sandplain and elsewhere, as much of the Kalbarri sandplain occurs at altitudes of 160–180 m. Sand covers the remainder of the Victoria Plateau at 220–290 m asl. The Kalbarri sandplain is part of an extensive cover of sand which occurs

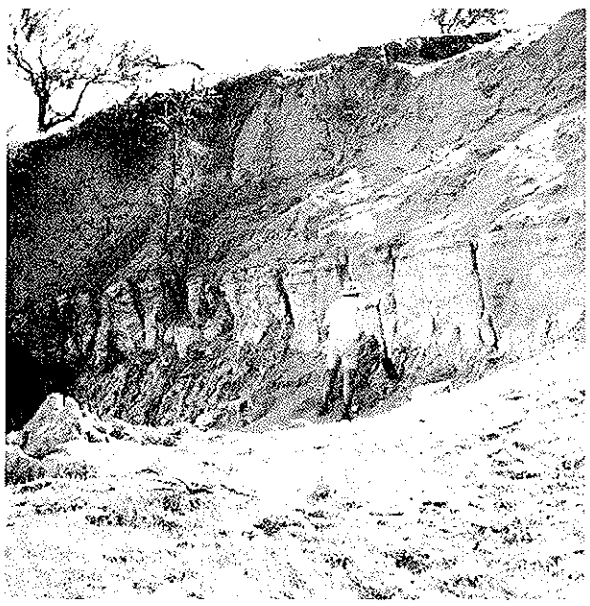

Figure 3 Nangetty showing massive undifferentiated sand overlying sandstone (115°24'E, 28°59'S).

north and south of the Murchison River valley. Further east a combination of yellow (Hue 10YR) and red sands (Hues 5YR and 2.5YR) which occur in the vicinity of the Murchison River valley are referred to as the Coolcalalaya yellow and red sands (Figure 2). This sandplain becomes indistinct and largely absent once the geology changes from the sedimentary rocks of the Perth Basin to the Archaean geology of the Yilgarn Craton. Further south from the Murchison River Valley there is widespread yellow sandplain (Hue 10YR).

Widespread sandplain continues south of the Greenough River. Balla-Whellara Road is a shallow profile (120 cm in depth) occurring in an area of deeper sands and degraded sand dunes. The surface sand is massive and crusted with a texture consisting of loamy sand to sand loam. Indurated gravel is present at 50 cm+, which in turn overlies highly altered sandstone. This site lies a few kilometres north of a low-lying area, which is part of the Chapman River drainage system, where yellow sandplain and dunes are absent.

In the south the extensive elevated yellow sandplain becomes fragmented and gives way to the clayey soils related to the non-sandstone lithologies that are largely associated with dissected country drained by the Irwin River system. The termination of the plateau sandplain, in the form of an escarpment in this area, provides the geomorphic setting for the Nangetty site (Figure 2). The Nangetty profile consists of 3 m of sand overlying a ferruginised sandstone at the very southern edge of the elevated Victoria Plateau Further south and east across to the Coalseam Reserve lie isolated remnants of the Victoria Plateau in the form of mesas with

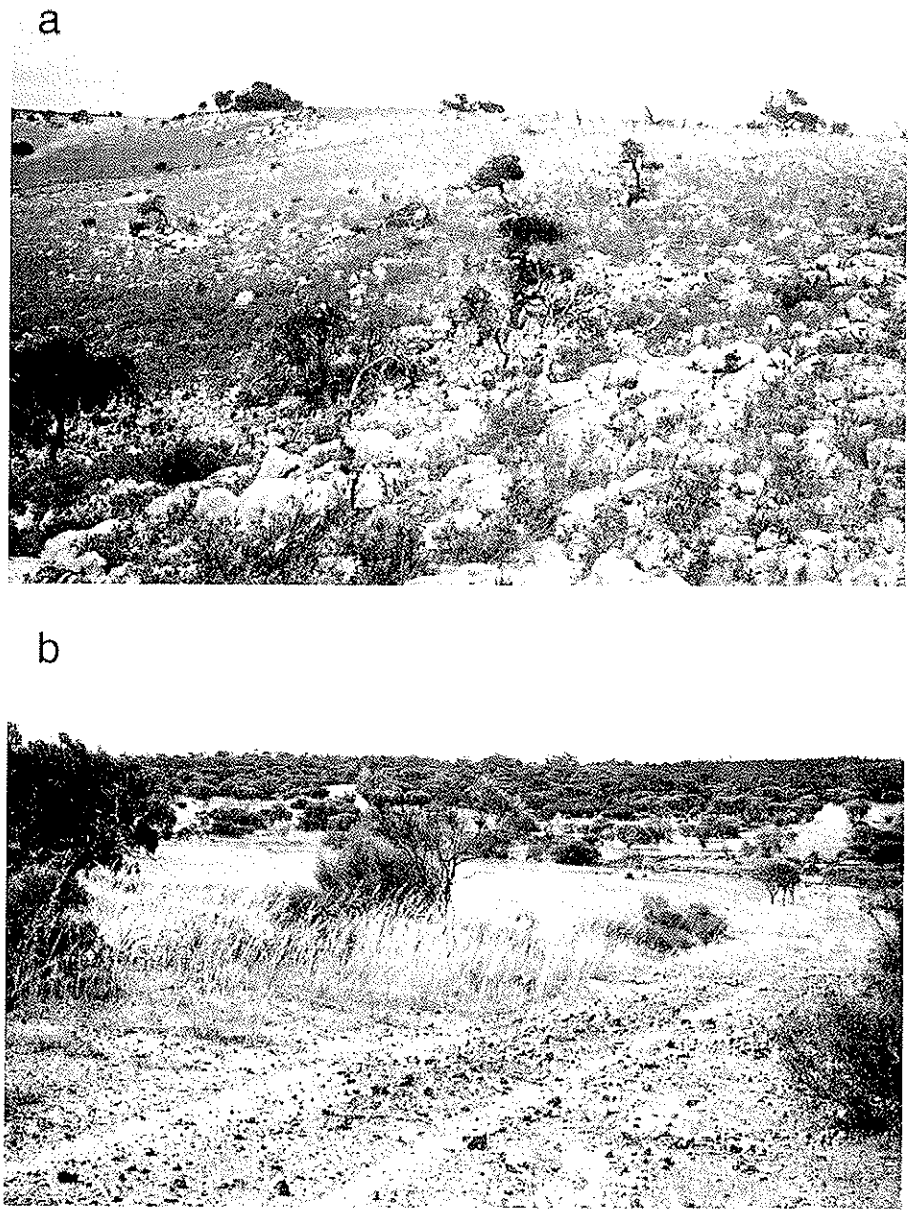

Figure 4 Landscapes where sandplain is absent. (a) The Toolonga Calcilutite at Kalbarri, which is argillaceous limestone, demonstrates a complete absence of sandplain (114°11'E, 27°35'S). (b) Red loamy soils developed on Precambrian metamorphic and igneous rocks of the Northampton Block (114°38'E, 28°23'S).

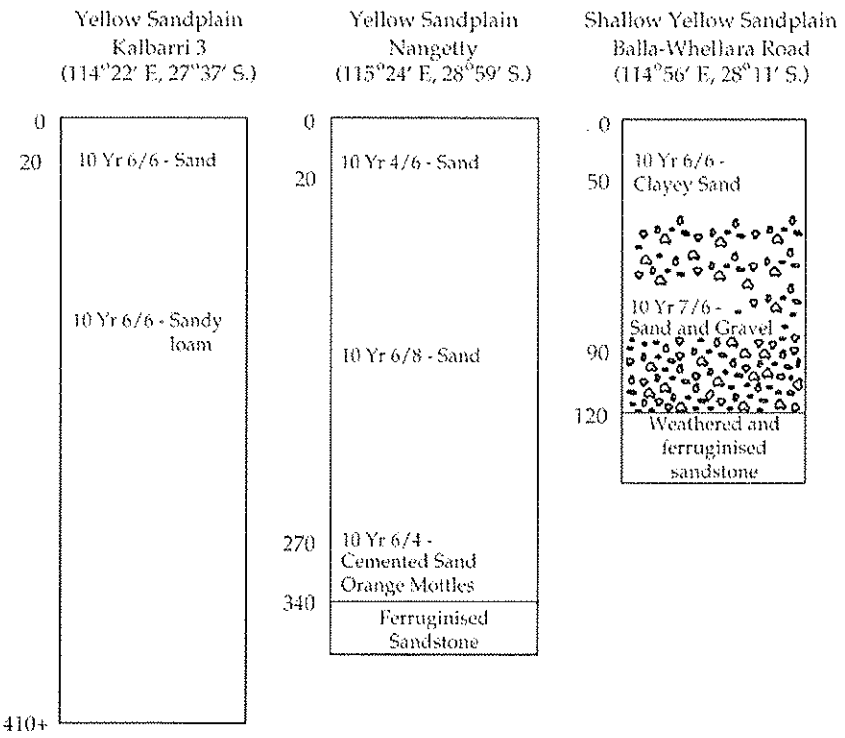

Figure 5 Examples of massive and poorly differentiated sands with no internal sedimentary structures.

sandstone capping. Isolated sand sheets occur on the summits of some of these mesas where they overlie highly altered sandstone, which in turn overlies highly weathered and eroded shale.

The sands throughout the study area do not contain sedimentary structures such as bedding planes, which could indicate a fluvial or aeolian origin. Dunal features are, however, widespread on the Victoria Plateau. The distribution of sand dunes and their orientation can be seen from aerial photography. The expression of dune form ranges from ill-defined sand ridges and hummocks to linear dune forms with well-preserved dune crests. Some dunes are circular in shape while others are Y-shaped features. Dune mapping by Wyrwoll and King (1984) in the Geraldton area shows that the dunes have a mixture of west–east and north–south trends. The lack of a more distinct dune orientation pattern is thought to be due to the erosion and degradation of the original dunefield pattern.

Grainsize characteristics

Grainsize analysis shows that the sandplain profiles can be readily distinguished from one another according to the relative proportions of coarse, medium and fine sand and relative clay contents (Table 1). Moreover, for two of these sites, their grainsize measurements revealed a striking similarity in gross particle size characteristics between sand and underlying rock.

Higher coarse-sand values in association with a correspondingly lower fine-sand content are evident in the surficial sands of the Nangetty profile. Similarly, the occurrence of medium sand at a higher percentage at the surface in association with reduced levels of fine sand occurring at Kalbarri 3 and Nangetty is most likely to be indicative of surficial reworking of the sandplain. Finer, more aeolian susceptible components have thus been mobilised from the surface of the sandplain leaving a higher percentage of medium and coarse sand as a surface deflation lag. At the same time the finer sand components have accumulated locally as sand dunes. This would have occurred during the Quaternary arid phases such as reported by Wyrwoll and Milton (1976) and Wyrwoll (1979, 1993). This relationship and the grainsize characteristics of known aeolian materials on the Victoria Plateau are considered later.

The calculation of whole-profile sand moment values (surface sands excluded) revealed a mean size of 1.49–1.84 ϕ and sorting values of 0.75–0.87 ϕ at Kalbarri 3. These can be compared with a mean size range of 1.90–2.00 ϕ and sorting values of 0.92–1.01 ϕ at Nangetty. All of the above grainsize parameters show fundamentally different sandplain profiles. The data also demonstrate the importance of whole-profile analysis because of the potential disrupting effects of surficial reworking. Prior to this investigation, studies of sandplain genesis in Western Australia have largely focused on the top metre or so of sand.

A comparison of the sandplain data with that from Tenindewa (Table 1), a fixed sand dune and known aeolian deposit, shows a dominance of fine sand with very little clay and coarse sand. The mean size range is 2.42–2.49 ϕ and the sand is moderately to well sorted at 0.51–0.56 ϕ. These particle size characteristics contrast strongly with those of the sandplain profiles.

Quartz grain microtextures

Scanning electron microscope (SEM) analysis did not find any mechanically induced microtextures but instead features more typical of diagenetic alteration and source rock inheritance, such as precipitation forms and etch features (Figure 6a), grain angularity (Figure 6b), adhering particles (Figure 6c) and grain contact faces (Figure 6d). The analysis of quartz grain microtextures did not support a sedimentary origin for the sandplain but instead favoured an *in situ* origin for the sands (Newsome & Ladd 1999).

Mineral magnetic analysis

Newsome (1998) investigated 14 deep sandplain profiles for their mineral magnetic properties. Figure 7 shows data for six sandplain profiles from the Victoria Plateau. A scatter plot of magnetic susceptibility against saturation isothermal remanent magnetisation (Walden *et al* 1999) shows inter-site variability. Coolcalalaya 2 demonstrates a clear separation from the other sites. In the field, Coolcalalaya 2 and 3, which are undifferentiated red sands, lie relatively close to one another but are distinguishable according to their mineral magnetic signals. Furthermore, although Kalbarri 2 and 3 are close to each other in the field they also show different mineral magnetic signals. Kalbarri 3 and Coolcalalaya 4, however, demonstrate tighter within-profile groupings than the other sites. The data therefore show the Victoria Plateau sandplain to be a heterogeneous body of sand. Such inter-site variability is more consistent

Table 1 Comparison of the grainsize characteristics (% composition) of three sandplain sites and a fixed sand dune (total fine <2 mm fraction).

Depth (cm)	Clay	Silt	Fine sand	Medium sand	Coarse sand
Kalbarri 3					
0–20	2.92	2.33	8.40	71.17	15.17
100–120	8.74	2.16	13.00	59.94	16.16
190–210	9.12	2.87	22.71	52.95	12.35
290–310	9.25	3.42	20.94	51.44	14.95
390–410	8.72	4.72	25.67	51.29	9.60
Balla-Whellara Road					
0–50	19.69	10.30	32.02	36.22	1.77
80–100	18.63	17.69	28.10	32.76	2.82
Rock	15.24	14.54	39.68	27.20	3.30
Adjacent dune	3.27	0.23	48.96	48.09	0.67
Nangetty					
0–20	2.12	4.96	14.90	46.55	31.47
100–120	4.47	5.16	32.17	44.93	13.27
250–270	7.16	2.97	36.56	40.91	12.40
320–340	4.69	7.99	38.79	34.68	13.85
Rock	5.03	8.31	33.97	36.21	16.19
Tenindewa Dune					
0–20	0.23	2.36	56.73	39.87	0.81
180–200	1.89	0.1	53.65	43.94	0.38
580–600	0.73	2.31	59.32	37.38	0.27
680–700	0.83	1.58	56.13	40.85	0.61
780–800	1.04	1.39	59.13	38.08	0.36

Data source Newsome (1998).

Table 2 Heavy minerals (% composition) of sandplain (subsurface sands) and underlying sandstone.

Site	Ilmenite	Leucoxene	Rutile	Magnetite	Zircon	Tourmaline	Garnet	Staurolite	Sillimanite	Kyanite	Andalusite	Epidote	Monazite	Amphibole	Spinel	Unidentified
Balla-Whellara Road	15	14	4	<1	52	9	<1	<1	4	–	–	<1	<1	–	–	<1
Balla-Whellara Road Dune	13	15	2	<1	48	15	<1	1	3	<1	–	<1	<1	<1	–	<1
Balla-Whellara Road Rock	4	13	<1	<1	55	6	–	<1	4	–	–	<1	–	2	–	–
Kalbarri 3	18	54	3	<1	10	3	–	3	4	4	–	–	–	–	–	<1
Nangetty	11	31	4	1	47	2	tr	<1	–	2	–	tr	<1	–	tr	<1
Nangetty Rock	8	21	7	tr	52	2	–	2	tr	4	–	3	–	1	–	tr

Data source Newsome (1998).

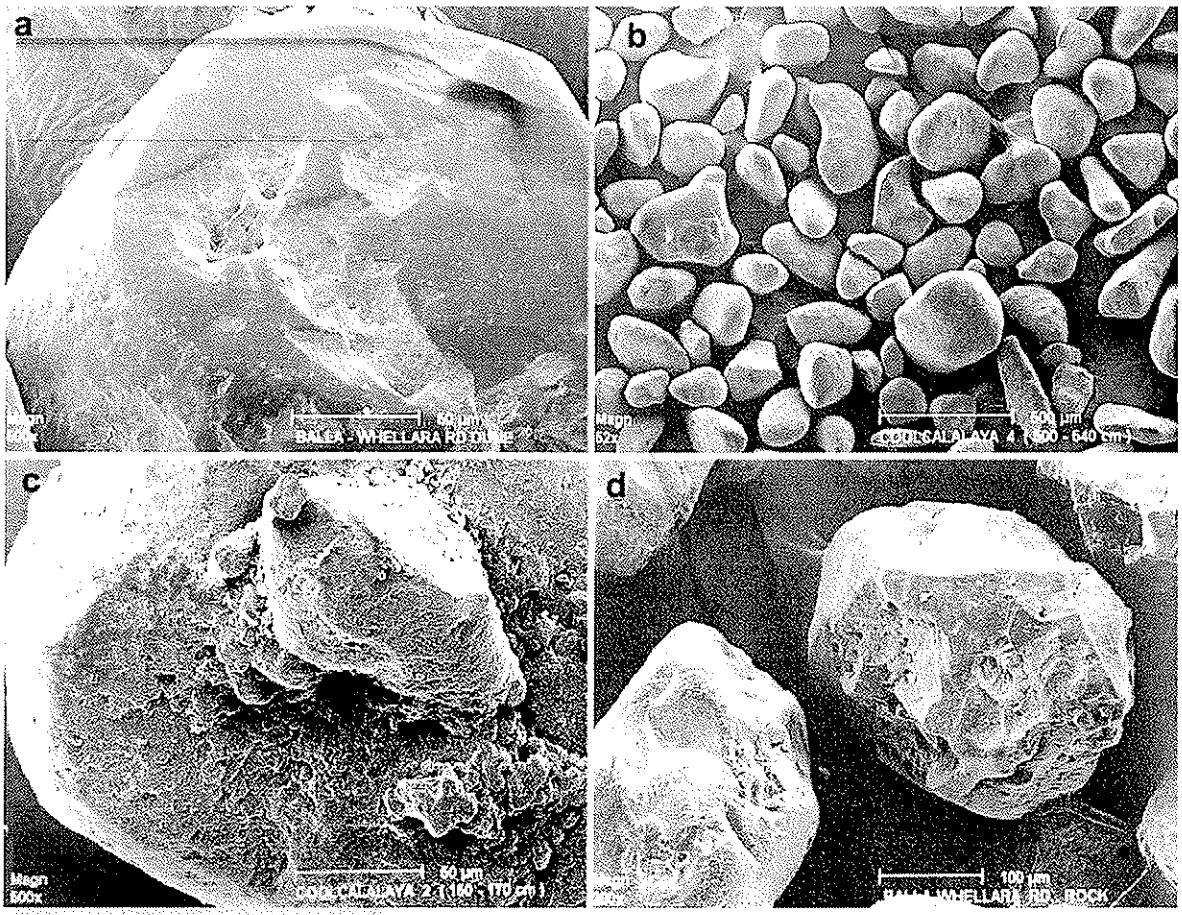

Figure 6 Quartz grain features of the Victoria Plateau sands. (a) Balla-Whellara Road dune, showing smooth silica veneer and etch features. Note the absence of any mechanically induced microtextures. (b) Coolcalalaya 4. Sand contains both rounded and irregularly shaped grains. (c) Coolcalalaya 2. Adhering particles, which are most likely the remnants of sandstone matrix, survive pretreatment to disaggregate the sands. (d) Balla-Whellara Road. Sheet-like grain contact faces occur both in rock samples and overlying sands.

with *in situ* development from underlying rocks than long-distance transport.

Heavy minerals

Differences between the sandplain profiles are further confirmed by the differing heavy mineral spectra of three selected profiles from the Victoria plateau (Table 2). While Kalbarri 3 has a low zircon content the Balla-Whellara Road group of sites have high zircon levels. The latter sites are also characterised by a relatively high tourmaline content but low levels of leucoxene. The Nangetty profile differs again with high zircon but moderate amounts of leucoxene.

A relationship between sand and underlying rock can also be demonstrated in the Balla-Whellara Road and Nangetty profiles. Table 2 shows both the Balla-Whellara Road sand and rock to have very similar proportions of leucoxene, zircon and tourmaline. The rock and underlying sandplain at Nangetty have similar relative proportions of ilmenite, leucoxene and zircon. Besides, if the rock were not a source of overlying sand there is likely to be significant and noticeable differences in these rock–sand mineral assemblages. Such heterogeneity of mineral assemblages in the Victoria Plateau sandplain is also not consistent with a long-range transport origin for the Victoria Plateau sands.

The mineralogy of the Balla-Whellara Road group of sites further substantiates the evidence for a local origin for the sands. These sites are characterised by relatively low levels of ilmenite and leucoxene, high zircon and a significant presence of tourmaline. A very similar mineralogy can be traced from the rock into nearby sands and a local sand dune (Table 2). The mineralogical correspondence between the sandplain and the dune at Balla-Whellara Road is well-defined. Tourmaline is especially important in establishing this relationship with 15% occurring in the dune sand as compared with a content of 9% in nearby sands and 6% in the Balla-Whellara Road rock sample.

The Balla-Whellara Road group of sites is particularly important in three ways. First there is its distinctive mineralogy, typified by tourmaline. This makes the sandplain different from other sites in the same locality and demonstrates the heterogeneity of the Victoria Plateau sandplain. Second, there is also a connection between local sands and

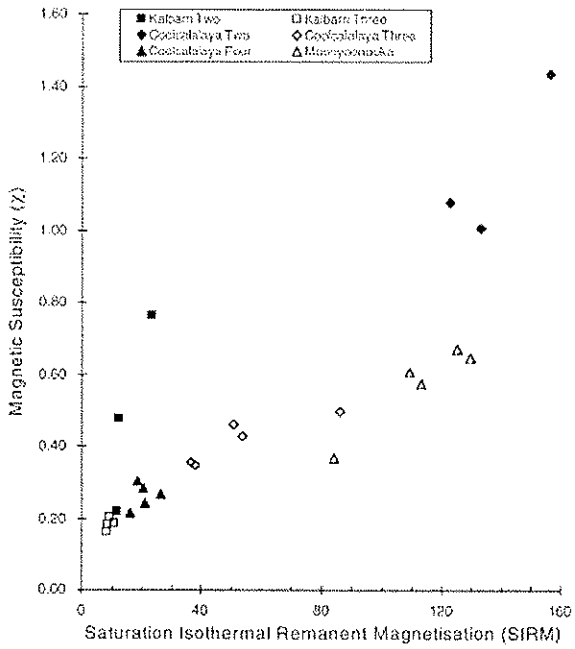

Figure 7 Mineral magnetic properties of selected deep sandplain profiles (surface sand excluded).

underlying rock, and third, the data illustrate that a local sand dune is related to this site.

An examination of the mineralogical evidence presented here therefore also provides supporting evidence in favour of an *in situ* origin. It provides confirmation that the reworked surface of the sandplain at this site has been transported only at the local scale.

INTERPRETATION AND CONCLUSIONS ON SANDPLAIN GENESIS IN WESTERN AUSTRALIA

For the reliable recognition of aeolian sands and in defining regolith, it is important to use as many features and methods as possible (Lancaster 1995; Ollier & Pain 1996). Newsome (1998) and Newsome and Ladd (1999) have found the sandplains on the Victoria Plateau exhibit the following features: (i) a total absence of internal sedimentary structures; (ii) clear local bedrock provenance; (iii) a close correspondence of sand with sandstone in upland positions; (iv) the absence of sand from non-sandstone lithologies in similar and juxtaposed topographic situations; (v) profiles with differing and sometimes a relatively high clay content; (vi) a lack of field and SEM evidence for long distance and widespread sand transport; (vii) heterogeneous grainsize, mineralogy and mineral magnetic characteristics, that are uncharacteristic of widespread long-distance sand transport; (viii) a demonstrated link between sandplain and underlying rocks as provided by grainsize, SEM and heavy-mineral data; and (ix) the grainsize characteristics of a known aeolian bedform contrasting strongly with those of adjacent and local sandplains.

This evidence supports a mostly *in situ* origin, with only localised aeolian mobilisation in some areas, for the sandplains as previously suggested for the Victoria Plateau area by Wyrwoll and King (1984). This work is also in agreement with the *in situ* model for the origin of sandplains on the Yilgarn Craton that was originally proposed by Carrol (1939) and Prider (1966).

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CHAPTER 16—Human impacts on geoheritage features of the Swan Coastal Plain and coastal zone, southwestern Australia

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In southwestern Australia, a rapidly expanding human population has impacted on the natural history and the geoheritage of the Swan Coastal Plain and its coastal zone. To date, there have been losses of significant sites of geoheritage through re-landscaping of natural landforms, reclamation, urbanisation, alteration of soils, diverting of river channels, vegetation clearing, nutrient enrichment of waterways and groundwater, and groundwater abstraction, amongst others. The reasons for these impacts are complex and varied. For instance, at one level, environmental managers, government agency decision makers and politicians, frequently have not fully appreciated the significance of geologic processes and products, or the significance of geoheritage. At another level, there is a perception that within a technological culture, science, technology and engineering can fix all, without appreciating that systems can be irrevocably destroyed; and at a third level, decision makers are anthropocentric, placing development and wealth above all natural features. Many geoheritage features on the Swan Coastal Plain are of global to national significance. Examples include: (i) the suite of coastal forms showing the connection between tectonic setting, coastal processes and sedimentation in a basin-wide context, exemplified by the interrelationship of cuspate forelands along the northern coast and the dune barrier along the southern coast; (ii) the diversity and array of wetlands, illustrating a variety of geomorphology, hydrologic mechanisms and origins; and (iii) the occurrence and internal structures of star dunes, with their buried soils, cross-stratification and unconformities providing insight into Quaternary glacial/interglacial desert history and evolution of dune forms. This chapter provides an overview of the geoheritage features on the Swan Coastal Plain in order to alert the scientific community and land-use managers and decision makers to the important features therein and some of the developmental processes that have either degraded or destroyed them. An understanding of the significance of features of geoheritage in this region, and the history of their degradation or destruction will ensure that past errors in judgement may be averted in the future.

KEY WORDS: anthropogenic factor, conservation, dunes, environmental geology, geoheritage, Quaternary, Swan Coastal Plain, wetlands.

INTRODUCTION

Since European settlement of the Swan Coastal Plain, commencing over 170 years ago, centred initially on Perth on the shore of the Swan River, southwestern Australia (Figure 16.1), there has been an inexorable population increase (~1.5 million), bringing with it various types of impacts on the environment (Bolton & Hutchison 1973; Jarvis 1986). Many of these impacts have reduced the floral and faunal biodiversity of the region, resulting in local extinctions, and have contributed to the pollution, contamination, or lowering of the natural quality of water bodies, atmosphere and soil. These impacts occur within a region of southwestern Australia considered to be botanically one of the richest in the world (Marchant 1973).

Much of the historical environmental perturbations, however, took place within a context of ignorance, culturalcentricity, anthropocentricity, an ethos of 'taming and developing a wild land', and a presumption of human dominance over the landscape, prior to the general raising of environmental consciousness witnessed over the past two decades. In those times, there was generally not the information to appreciate the significance of the natural history environment nor the type of understanding of environmental issues as held today.

In more recent times, spanning several decades, there has been an enormous increase in knowledge about the natural history of the Swan Coastal Plain, a better appreciation of its significance, and an awakening of an environmental consciousness to the extent that conservation of the natural environment is slowly becoming a more prominent part of the cultural ethos. However, population expansion and its concomitant exploitation of the natural environment continues (Ministry for Planning 1995a; Nagle 1998). Perth, for instance, is considered globally as a centre of hyperurbanisation. While acquisition of increased information on natural history is contributing both to more rational land-use planning, and to an informed public taking direct action on environmental issues, town planners, public service decision-makers, various government agencies and

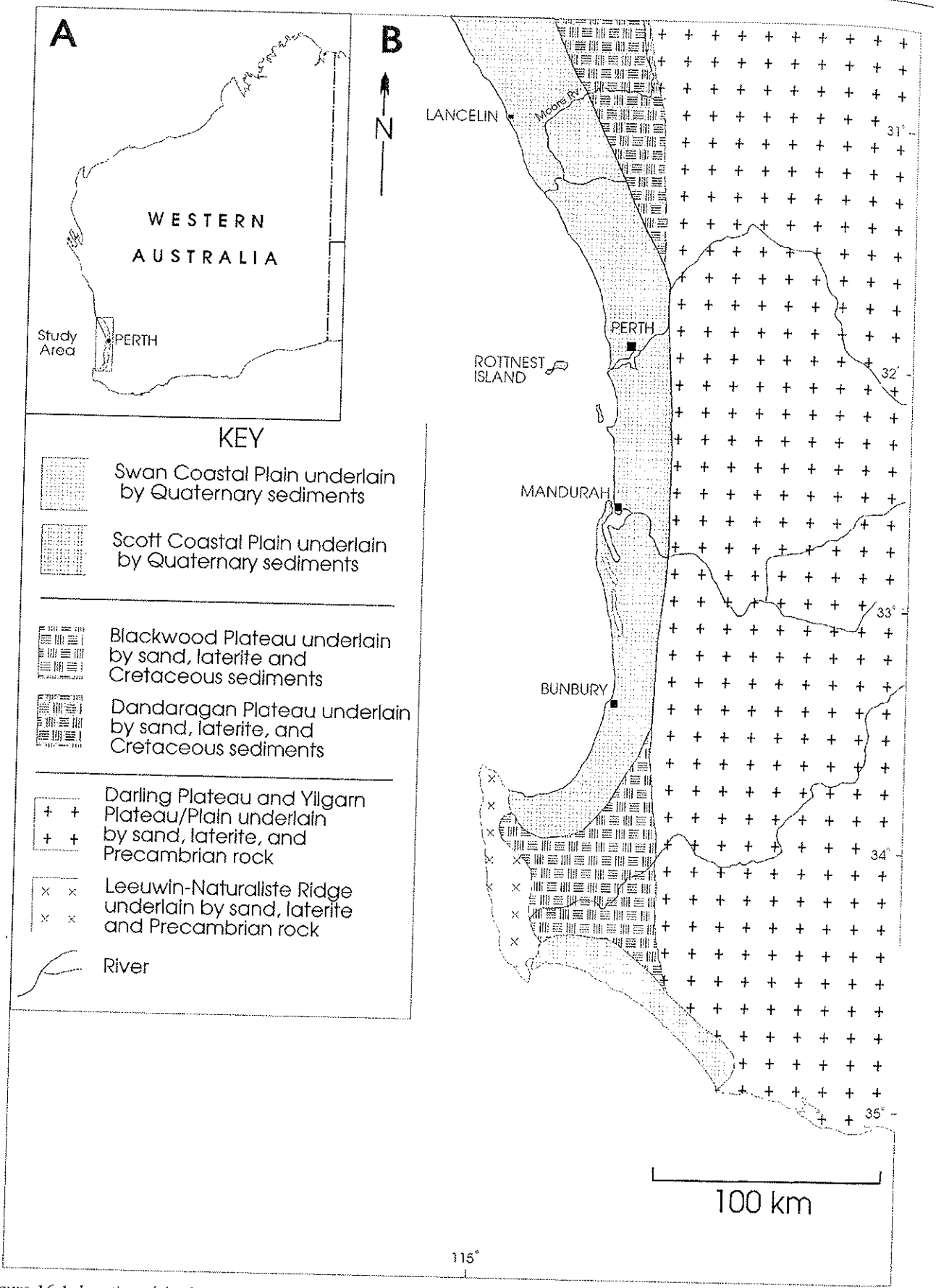


Figure 16.1 Location of the Swan Coastal Plain in relationship to geological setting. Note that the northern third of the Swan Coastal Plain between Moore River and Dongara is not included in this map.

politicians appear still trapped in what may be termed the 'settler's ethos'. For example, between 1960 and 1980, studies of landform and vegetation on the Swan Coastal Plain generally took place within an agenda of land capability for silviculture, agriculture or urbanisation (Havel 1968; McArthur & Bettenay 1960; McArthur & Bartle 1980a, b). As recently as 1996, against a backdrop of global concern about increasing population and local concern that Perth has limited resources to sustain even its extant population without impacts on biodiversity, water resources and air quality, the Ministry for Planning (a government agency concerned with town planning) pursued a management philosophy that reflected a perception that there was a general lack of community support for any measures to restrict Perth's population growth (Ministry for Planning 1995a, b, 1996).

Conservation is now an emerging paradigm with the establishment, for instance, of nature reserves at the local scale and the recognition of world-heritage sites at the global scale. These precepts have been applied to Western Australia, with the vesting of local Conservation Reserves, listing of sites on the Register of the National Estate by the Australian Heritage Commission, and recognition of some areas for World Heritage nomination (e.g. the Shark Bay region). To date, however, emphases on conservation have been in the sphere of biodiversity, with the conservation of natural history features associated with geology and geoprocesses not adequately addressed. In this context, this chapter attempts to deal with this problem by outlining some of the philosophy behind geoheritage, focusing on some of the features of the geoheritage of the Swan Coastal Plain, placing the significance of the region in a global, national to regional perspective, and documenting some of the destruction that has occurred over the past three decades.

CONCEPT OF GEOHERITAGE

Conservation globally, to date, has been concerned with preservation of biota, in particular, rare and endangered species, and more recently, preservation of communities (Wyatt & Moss 1990; Blandin 1992; Withers & Horwitz 1996). Hence, the recognition of diversity (or biodiversity) as a basis to conservation (IUCN 1992; Ledec & Gooland 1988; Wyatt & Moss 1990) has become a relatively powerful focusing force in the conservation arena. Conservation, however, should be concerned with more than preservation of biodiversity, encompassing a range of natural history features. It should include: (i) purely biological phenomena of scientific and heritage value, from rare and endangered species, to representative communities (Soule & Wilcox, 1980), to biodiversity (McNeely *et al.* 1990); (ii) features combining biota and geology, geomorphology, pedology and hydrology, essentially linking biodiversity with geoheritage (Hopkins 1994); and (iii) purely physical (i.e. non-biological) aspects of scientific and heritage value, such as unusual or representative rock and landscape formations, many of which may be subsumed under the term 'geoconservation' (Duff 1994; Creaser 1994; Markovics 1994).

Where landscapes, geological formations or physical features are of outstanding importance, their conservation is viewed as axiomatic. At the national level, examples are The Breadknife (The Warrambungals, New South Wales), Uluru (central Australia), the Twelve Apostles (coastal Victoria), or classic exposures of dinosaur footprints (Broome, Western Australia). Not so clear to the general public and decision-making non-scientists, is the case for geoheritage. Conservation of geoheritage sites generally has been made more acceptable where unusual geological features or a unique geological setting is coincident with or results in the occurrence of unusual or rare biota (Hopkins 1994) and caves as reservoirs of unusual or rare species (Osborne 1991; Humphrey 1993).

The term geology, often used synonymously with earth sciences, is diverse and encompassing. This scientific discipline has related subsidiary disciplines of geomorphology, pedology, hydrology, and surface processes such as sedimentology. The latter have become more specific endeavours within the science. Additionally, the science of geology encompasses a diversity of interests. On the physical side, it includes at macro-regional scales, studies of global tectonics, mountain building and landscape evolution, at medium scales, studies of earth surface processes such as weathering, erosion and sedimentation, involving water, wind and ice, and at microscale, studies of crystal defects and deformation. On the chemical side, it involves studies of precipitation, cementation, solution and alteration at all scales. This broad definition and scope of geology becomes important when different types and expression of national or state-wide significant sites of geoheritage are discussed, and when the term geoheritage is used to encompass a wide variety of geological features.

The term geology, in the context of geoheritage, encompasses, amongst others, the following: features of igneous, metamorphic and sedimentary rocks, and their relationships at all scales; features of craton/basin relationships; mineral locations; fossil locations; pollen locations; type stratigraphic locations; type igneous, metamorphic or pedogenic locations. It includes sites of importance in understanding geological processes; sites of importance for geomorphology, sedimentology, stratigraphy, pedology, and hydrology; as well as sites of profound aesthetic geological importance, or of intrinsic geological value.

The term geoconservation is used here in the following sense: 'conservation, or preservation of earth science features (geologic, geomorphologic, pedologic, and hydrologic) of sufficient significance to warrant protection for purposes of heritage, science, or education'. The term geoheritage is used here as follows: 'global to national to state-wide important features of geology, including igneous, metamorphic, sedimentary, structural, geochemical, palaeontological, geomorphic, pedologic, and hydrologic attributes, that offer important information or insights into the formation or evolution of the continent; or that can be used for research, teaching, or reference sites'.

From these perspectives, many features on the Swan Coastal Plain have geoheritage significance. They include textbook examples of geoprocesses, such as development of coastal cuspate forelands, occurrences of relict desert-formed star dunes, and the geomorphology, stratigraphy, and hydrological functioning of wetland basins.

Note should be taken that just as biologic systems are diverse, geological systems are also diverse. For instance,

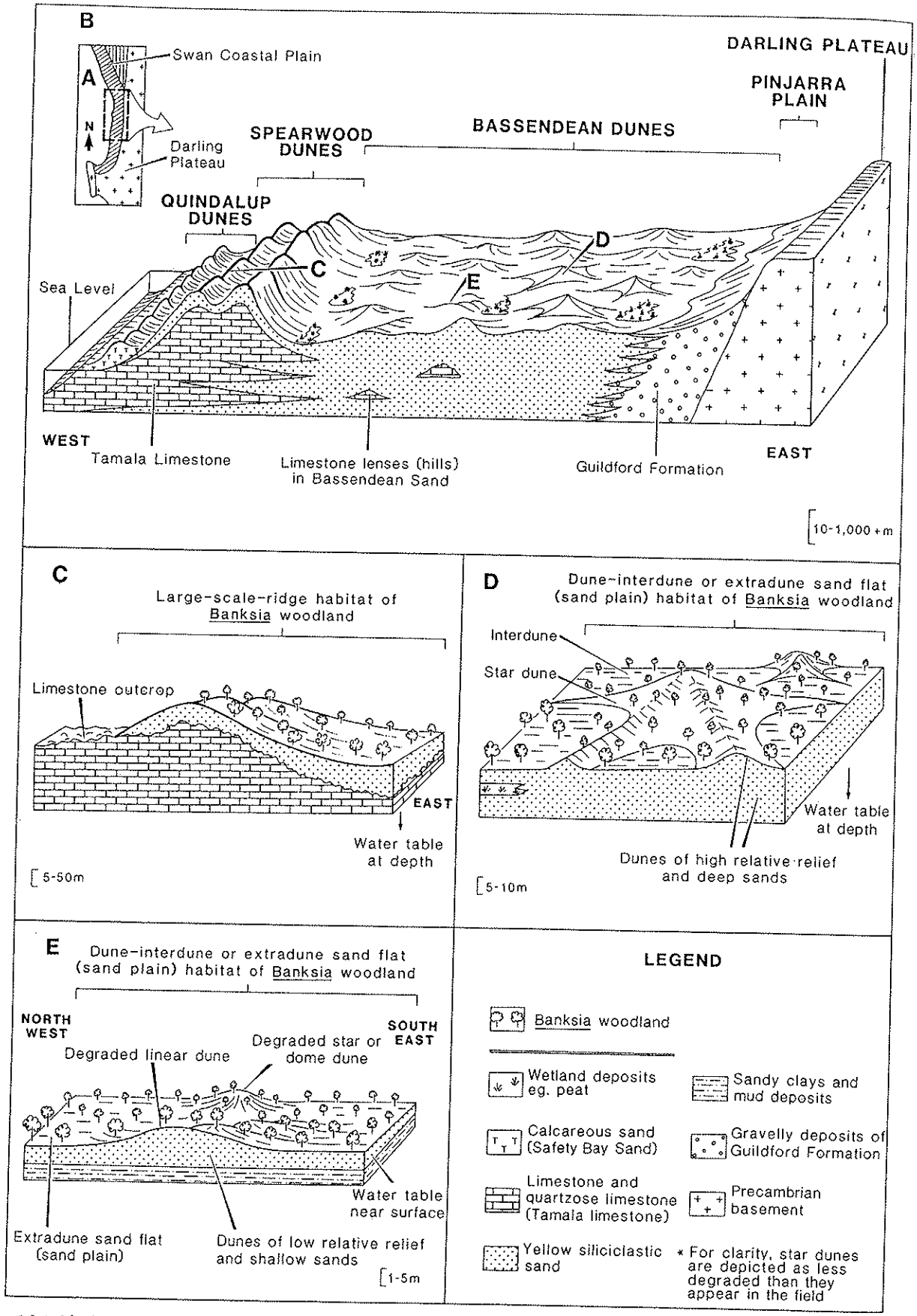


Figure 16.3 Idealised block diagrams showing geomorphic units of the Swan Coastal Plain, their shore-parallel distribution, gross surface features, and stratigraphy, with details of landscape and vegetation habitats (from Semeniuk & Glassford 1989).

the terms wetland and dune carry implications of a large array of wetland types and dune forms. Thus, wetlands may be lakes, sumplands, damplands, paluslopes, palusmonts (Semeniuk & Semeniuk 1997), or in the terminology of the Ramsar Convention Bureau (1991), fens, marshes, ponds, oases, etc. Dunes may be linear, parabolic, hairpin, star or barchan, amongst others. Similar to the objective of nature conservation, to conserve the vast diversity of life forms, an objective of the conservation of sites of geoheritage value should be the conservation of the variety of geologic forms on the Earth. In this context, the conservation of a single lake as an example of a wetland system, or a single parabolic dune form in one area as representative of the full variety of dune types globally is insufficient. If wetlands, for instance, exhibit a large diversity of geometric and hydrologic types, stratigraphic fills and origins, then at the least their conservation should encompass an example of each of the types extant. Similarly, various types of dunes need to be conserved to capture the full range of shapes, types and origins that are possible as an example of the geoheritage of the Earth.

GLOBAL SETTING OF THE SWAN COASTAL PLAIN

In the first instance, it is necessary to place the Swan Coastal Plain in a global to national perspective in order to appreciate some of the geological features occurring there and in this context the general pattern of coasts and near-coastal plains are briefly reviewed. The case will be made that the Swan Coastal Plain, viewed globally, stands unique, whereas many of the coasts and coastal plains worldwide conform to recurring patterns of coastal and near-coastal landforms, with two or more examples representing the coastal form (Johnson 1919; Davies 1980; Bird & Schwartz 1985; Davis 1994).

Coastal form and immediately inland coastal plains and uplands often can be related to their geologic and geomorphic setting within a global tectonic framework in terms of plate tectonics (Uyeda 1978). Examples are island-arc coasts (such as the Indonesian Archipelago), leading-plate-edge coasts (the Andes–Rocky Mountains chain), trailing-plate coasts (North American east coast), collision coasts (the northern Mediterranean coast). The Swan Coastal Plain, in this context, is a Quaternary surface developed on a subsiding linear basin developed along a passive-trailing-plate margin.

Globally, coastal forms, in generalised patterns, include: (i) erosional coasts cut into igneous, metamorphic, or sedimentary bedrock, or Quaternary aeolianites, resulting in cliffs and rocky shores, and where there is sediment supply, associated pocket beaches, local sandy bays, mud-lined embayments, spits, cuspate forelands, tombolos, and narrow alluvial plains, related to laterally equivalent rocky shores, such that cliff coasts grade to more diffuse coasts of alternating headlands and depositional pockets; (ii) ria coasts grading to archipelagos, where the post-glacial transgression has inundated fluvially dissected terrains, and within which sedimentation ranges from negligible to embayment-filling; (iii) inlet and estuary-dominated coasts, grading to deltaic coasts; (iv) low-gradient prograding coasts and their inland adjoining low coastal plains (these coasts may be carbonate or terrigenous depositional systems); (v) sandy beach and dune coasts, often backed by prograded beach ridge plains; (vi) barrier island and barrier dune systems, and their adjoining leeward lagoons; and (vii) coral-reef coasts. The coastal zone of the Swan Coastal Plain varies from south to north, reflecting a climate gradient and the increasing effect of tectonic uplift. Coastal form changes from barriers-and-estuaries, to barrier dunes, to limestone rocky shores with intermittent cuspate forelands and pocket beaches (Searle & Semeniuk 1985).

Western Australia exhibits a range of megascale basin- and craton-related coastal and near-coastal landforms, crossing a variety of climate types (Woods 1980; Woods *et al.*, 1985; Semeniuk 1993, 1995a, b): the Kimberley ria/archipelago coast, the Canning Coast, the Pilbara Coast, the Carnarvon Coast, and the Perth Basin Coast. The latter coast is the context for the Swan Coastal Plain.

DESCRIPTION OF THE SWAN COASTAL PLAIN AND ITS COASTAL ZONE

The Swan Coastal Plain and its coastal zone (Gentilli & Fairbridge 1952; Gentilli 1979; Searle & Semeniuk 1985) has a number of features that set it apart from the pattern of other coastal types in Western Australia and worldwide.

(1) The Swan Coastal Plain, with elevations from near sea-level to 90 m above sea-level, is the Quaternary surface of the north–south linear Perth Basin (Figures 16.1, 16.2 on Plates 8 & 9, 16.3), a Phanerozoic basin that borders the linear north-oriented and extensive Darling Fault (Playford *et al.* 1976; Geological Survey of Western Australia 1990). Sediments filling this basin range from Permian to Quaternary, although the Pliocene, Pleistocene and Holocene history has had the major role in determining the form of the coastal plain and coastal zone.

(2) The coastal plain is bordered to the east by the retreating Darling Fault scarp, that defines the margin of an extensive plateau (Figures 16.2 on Plates 8 & 9, 16.3), situated some 300–600 m above sea-level. The northern part of the plain is bordered by the Dandaragan Plateau. Today the plain is located in a semi-arid climate, though at times during the Pleistocene it was in an arid climate (Glassford 1980; Glassford & Semeniuk 1995).

(3) The Swan Coastal Plain Quaternary sediments form north–south-oriented belts parallel to the Darling Fault and to the coast. They are the product of the interplay of fluvial and alluvial-fan input, and alternating desert conditions and marine transgressions building a system of quartz-rich desert sands to the east and coastal limestone ridges to the west (Figure 16.3).

(4) The onshore and nearshore coastal zone comprises shore-parallel limestone ridges forming ridge and wetland chains onshore, and chains of islands, rocky reefs and promontories in the marine nearshore.

These aspects underpin why the coastal zone has developed its geomorphic character with the Swan Coastal Plain comprising generally north–south-oriented megascale geomorphic systems. In order from west to east, from marine environments to inland, these are: offshore chains of shore-parallel rocky reefs and islands, onshore limestone ridges, cuspate forelands, sandy beaches and dunes, beach ridge

Table 16.1 Summary of features of the various geomorphic units of the Swan Coastal Plain (all units are Quaternary in age).

Geomorphic unit	Formation and description
Pinjarra Plain: mainly eastern part of the Swan Coastal Plain, comprising alluvial fans and fluvial deposits.	Guildford Formation: muddy and sandy deposits.
Bassendean Dunes: the eastern third of the Swan Coastal Plain, comprising low undulating sand hills, high sand hills, relict dune forms, and star dune.	Bassendean Sand: mainly quartz sand.
Spearwood Dunes: the western third of the Swan Coastal Plain, in its central to northern parts, comprising shore-parallel ridges.	Yellow sand overlying Tamala Limestone, i.e., quartz sand overlying calcarenite.
Mandurah–Eaton Ridge: long and moderately high limestone and sand ridge in the southern part of the Swan Coastal Plain, in its southern part.	Yellow to white quartz sand and limestone lenses.
Yalgorup Plain: the western third of the Swan Coastal Plain, in its southern part, comprising limestone plains, former cuspate forelands, and shore-parallel ridges.	Yellow to white quartz sand overlying Tims Thicket Limestone, Kooallup Limestone, and Myalup Sand, i.e., quartz sand overlying calcarenite.
Quindalup Dunes: coastal dunes of variable landforms.	Quartz/carbonate sand.

plains, and limestone rocky shores. Then there is a belt of limestone ridge and wetland chains, a belt of quartz sand hills and relict dunes, with associated wetland networks, and a zone of fluvial sediments and alluvial fans (Figures 16.2 on Plates 8 & 9, 16.3) (McArthur & Bettenay 1960; Searle & Semeniuk 1985; Semeniuk & Searle 1986a, b; Semeniuk 1985, 1997; Semeniuk *et al.* 1988, 1989; C. A. Semeniuk 1988). The system of shore-parallel landform units have been formally named (Table 16.1) as Quindalup Dunes (Holocene coastal dunes), Spearwood Dunes (limestone ridge belt), Bassendean Dunes (quartz sand hills) and Pinjarra Plain (alluvial fan and fluvial terrain adjoining the scarp).

The megascale landforms have developed soils and vegetation habitats specific to the geomorphic setting (Speck *in* Seddon 1972; Heddle *et al.* 1980; Cresswell & Bridgewater 1985). For instance, the major soil associations overlie the following various fundamentally different parent materials (Figure 16.3): calcareous and quartz coastal dunes, limestone ridges, yellow quartz sand hills; white quartz sand hills, fluvial muddy sand and sand flats and plains; and ironstone and clay associations on slopes. At the local scale, these megascale settings for soil associations, in response to terrain aspect, slope, soil processes, depth to water table, and time, result in a plethora of small-scale mosaics of soils and vegetation habitats, each exemplifying a close landform–soil–vegetation relationship. The range of wetland types developed within a given geomorphic system and the vegetation habitats developed in coastal dune systems, as described by C A Semeniuk (1988) and Semeniuk *et al.* (1989), well illustrate these patterns.

Groundwaters and wetlands

Unconfined to locally confined, mainly fresh groundwater underlies the coastal plain system, and its configuration, dynamics and hydrochemistry is determined by its geomorphic and stratigraphic setting. Over much of the coastal plain, the water-table is shallow, or perched, even if the terrain is relatively high and the groundwater mounded. Hence, there are numerous wetlands formed where water-tables or perched groundwaters intersect or are close to the land surface. The variety of geomorphic/stratigraphic settings of these wetlands, and the range of different hydrologic settings in the various geomorphic/stratigraphic contexts has resulted in a wide range of wetland types, varying in size, shape, network patterns, hydrologic maintenance, stratigraphy, soils and origin (Figure 16.4). There are a variety of origins for the wetlands. Some are windows to the water-table formed as a rising post-glacial sea-level caused continental water-tables to rise, thus flooding ridge-and-basin systems, or basins within an undulating terrain (e.g. those in the Bassendean Dunes and some in the Spearwood Dunes). Some are perched, formed by sedimentary accumulation of muddy sediment which then acted as a perching layer (e.g. in Bassendean Dunes). Others are hydrologically coalesced basins (e.g. in Bassendean Dunes). Some are developed as karst solution features between two stratigraphic formations (e.g. contact between the Spearwood Dunes and the Bassendean Dunes), while others are expressions of karst within a formation (e.g. within the Spearwood Dunes). Some are deflation surfaces excavated by wind to the water-table (e.g. in the Quindalup Dunes) and some are interdune and beach ridge swales (also in the Quindalup Dunes). These wetlands, depending on setting, are filled with a variety of sediments.

Coastal zone and major coastal sectors

The coastal zone presents an interesting relationship between the existing oceanographic and coastal processes, megascale geologic setting, ancestral geomorphic systems,

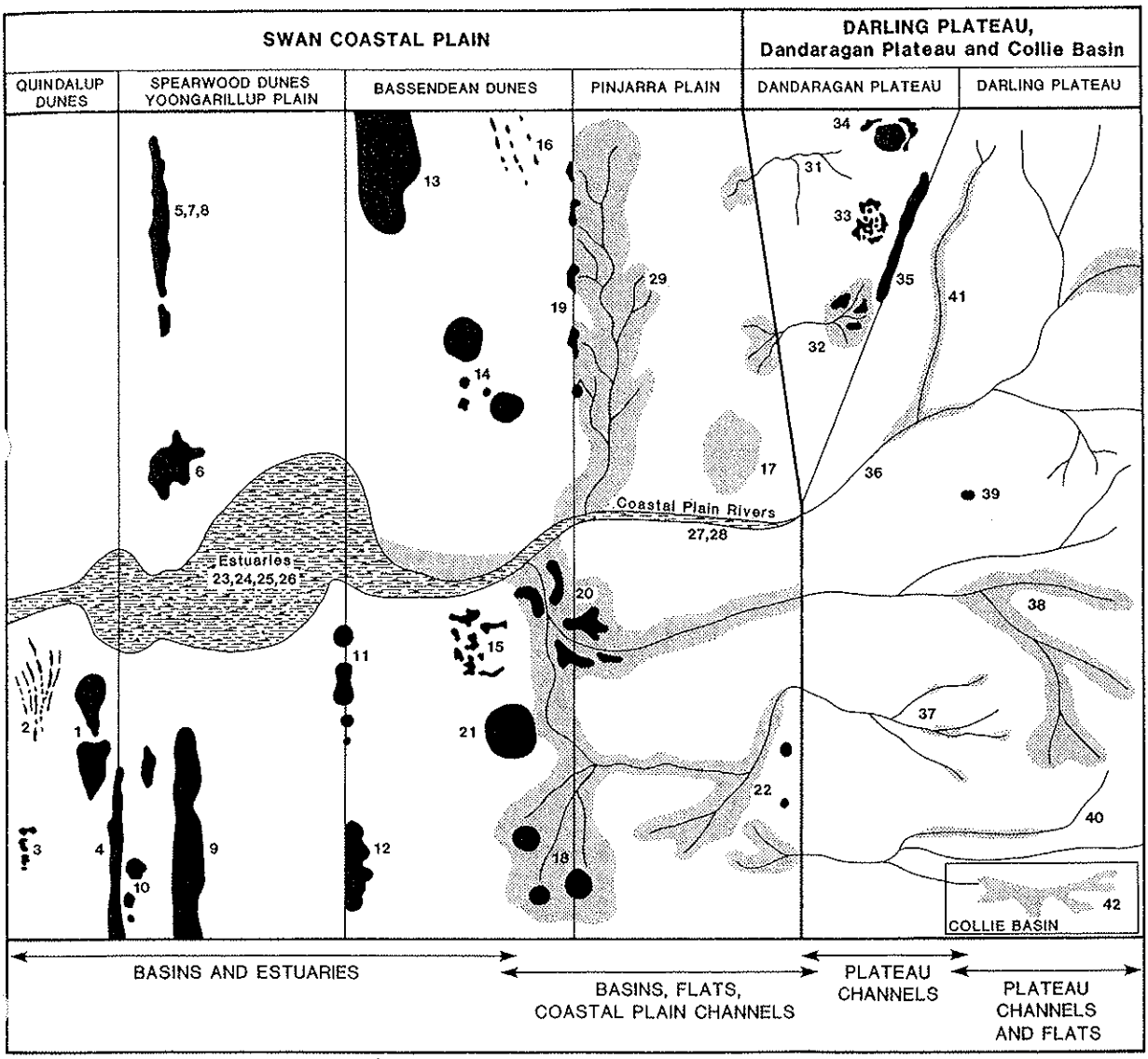


Figure 16.4 Idealised map showing the variety and distribution of the consanguineous wetlands, i.e. the natural wetland groupings or suites in the Darling Plateau and Swan Coastal Plain region centred on the Moore River to Bunbury region. In this region there are 42 such groups each related to geomorphic setting or interfaces between geomorphic units. Details of the suites are presented in C. A. Semeniuk 1988.

the source and availability of sediment, their sites of accumulation, and the resulting coastal and marine geomorphology. Swell from the Indian Ocean and that refracted from the Southern Ocean impinge on the shore from the southwest (Silvester 1963; Steedman & Craig 1983; Searle & Semeniuk 1985). Summer is characterised by a strong seabreeze/landbreeze system that generates local wind-waves and onshore sand-mobilising winds. These derive from the west, to southwest, to north, in southern to middle to northern parts of the coast, respectively. As a result, the coastal zone experiences combined swell and wind-waves largely from southwest to south, and wind from similar directions, all of which shape and affect the coast profoundly (Searle & Semeniuk 1985). Southwesterly swell and wind waves impel a net northwards shoreline transport of sand, which locally is trapped behind energy shadows of rocky reefs and islands to develop cuspate forelands and tombolos (Semeniuk *et al.* 1988).

Within a general tectonic setting in the Perth Basin of uplift to the north and subsidence to the south (expressed as the uplifted inliers and higher relief faulted splinters to the north, and the Bunbury Trough to the south), and long-term megascale protection from the Indian Ocean by a Precambrian inlier (the Leeuwin–Naturaliste Ridge), there is a dominance of limestone ridges, barriers and rocky reefs to the north of the Leschenault–Preston Sector, a general absence of such structures to the south, and a relatively low-energy coast to the far south (Figure 16.5). Consequently, the middle to northern part of the coast adjoining the Swan Coastal Plain is a bathymetrically complex, with cuspate forelands and local tombolos formed behind energy shadows developed leeward of the chains of

Table 16.2 Coastal sectors, their generalised form and origin (from Searle & Semeniuk 1985).

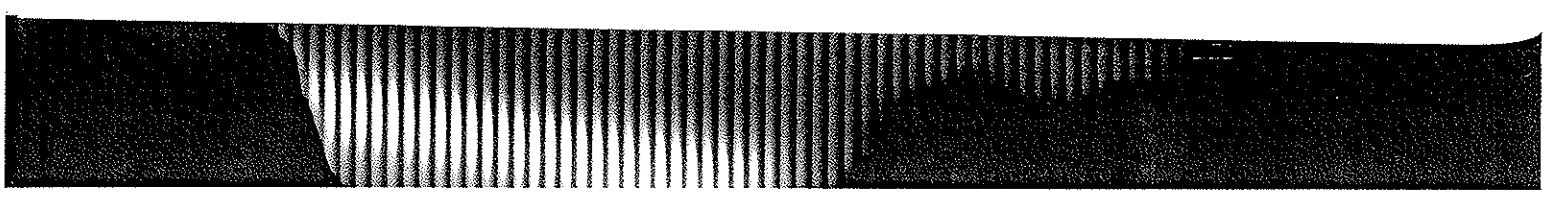
Coastal sector	Generalised form and origin
Wedge Island to Dongara Sector (northernmost sector)	High energy, semi-protected coast, with cuspate forelands and tombolos developed behind the offshore chains of rock reefs and islands, and limestone cliff coasts developed along the more exposed parts of the coast; since the wind-wave regime has intensified, the wind waves erode the coast to develop a limestone rocky shore dominated coast.
Whitfords–Lancelin Sector	High energy, semi-protected coast, with cuspate forelands and tombolos developed behind the offshore chains of rock reefs and islands, and limestone cliff coasts developed along the more exposed parts of the coast; northwards of this zone, cuspate forelands are generally small and localised.
Cape Bouvard – Trigg Island Sector	High energy, semi-protected coast, with cuspate forelands and tombolos developed behind the offshore chains of rock reefs and islands, and limestone cliff coasts developed along the more exposed parts of the coast; the largest accumulation of sand occurs in the Rockingham-Becher cuspate foreland, which is developed as a result of sand transported from the eroding dune barrier to the south meeting the first major zone of shelter.
Leschenault–Preston Sector	High energy, unprotected coast, with development of dune barrier, barring a shore-parallel linear lagoon and estuary; dune barrier rapidly retrograding and eroding, supplying sand by northwards net shoreline transport to more northerly sectors.
Geographe Bay Sector (southernmost sector)	Relatively protected, prograding low barrier generating beach ridge plain, with dune swale wetlands; interaction with numerous short creeks and rivers; discharge to sea develops dynamic shore-parallel elongate estuarine complexes.

offshore barriers of limestone rocky reefs and islands (Searle & Semeniuk 1985). The southern third of the coast, free of offshore barriers, is relatively simple, with development of a barrier dune system (Semeniuk 1985, 1995c) and the southernmost part is a dynamic complex of low barriers and shore-parallel estuaries. In this context, the coastal zones can be divided into five broad sectors (Table 16.2). Key features from these sectors are described below.

Within the Geographe Bay Sector, incorporating the onshore plain, the Vasse–Wonnerup estuary, and the shore, the system of Holocene to Pleistocene shore-parallel elongate estuarine complexes stands unique in Western Australia, because the semi-sheltered nature of the coast where beach-ridge barriers are forming and interacting dynamically with fluvial outlets. In the Leschenault–Preston Sector, characterised by an extensive shore-parallel barrier dune, there is a distinctive and important submarine geomorphic system: submerged beachrock bands and low ridges, marking the style of coastal retreat (Figure 16.6) (Semeniuk & Searle 1987). These beachrock bands/ridges have formed as a result of ongoing long-term coastal erosion (Semeniuk 1985), temporally marked by rapid coastal retreat induced by episodic storms, within a setting where beachrock is forming in the coastal zone, and in a context of more pronounced coastal erosion occurring to the south.

Within the Cape Bouvard to Trigg Island Sector, predominantly south of Perth, there is the Rockingham–Becher Cuspate Foreland, a large accumulation of sand derived from the eroding Leschenault–Preston barrier to the south. The area is the location where the first series of offshore limestone barriers act to shelter the mainland shore, and hence there has been a massive buildup of sediment over 7000 years to develop the largest (double) cuspate foreland system in Western Australia. Deriving from this situation are a range of landforms and wetlands that are nationally unique. This sedimentary accumulation is the largest, most continuous, and internally variable repository of Holocene archival material on Holocene coastal evolution, soil development, wetland development and stratigraphic evolution, climate changes (Semenuik 1986), and Holocene coastal process history in Western Australia.

The next coastal sector, immediately north of Perth, contains a series of smaller, more discrete cuspate forelands, and there is a significant story in the development and natural destruction of these coastal landforms (Figure 16.7). The localised barriers of rocky reefs and small islands that helped form, shelter and sustain cuspate forelands, in time geomorphologically degrade and erode through biological, chemical and wave processes (Semeniuk & Johnson 1985). Additionally, cuspate forelands, formed initially behind a given offshore barrier or rocky reef, were in dynamic equilibrium under specific formative conditions of swell, wind strength and direction, and wind-waves. With changing net direction of coastal wind over the Holocene, and hence changing wind-wave and swell directions, the cuspate forelands were subject to progressively different oceanographic and wind conditions, and progressed to a state of disequilibrium. As a result, depending on their orientation relative to their protective barriers, cuspate forelands are in various stages of natural erosion. These stages represent important lessons of national significance in the story of coastal development.



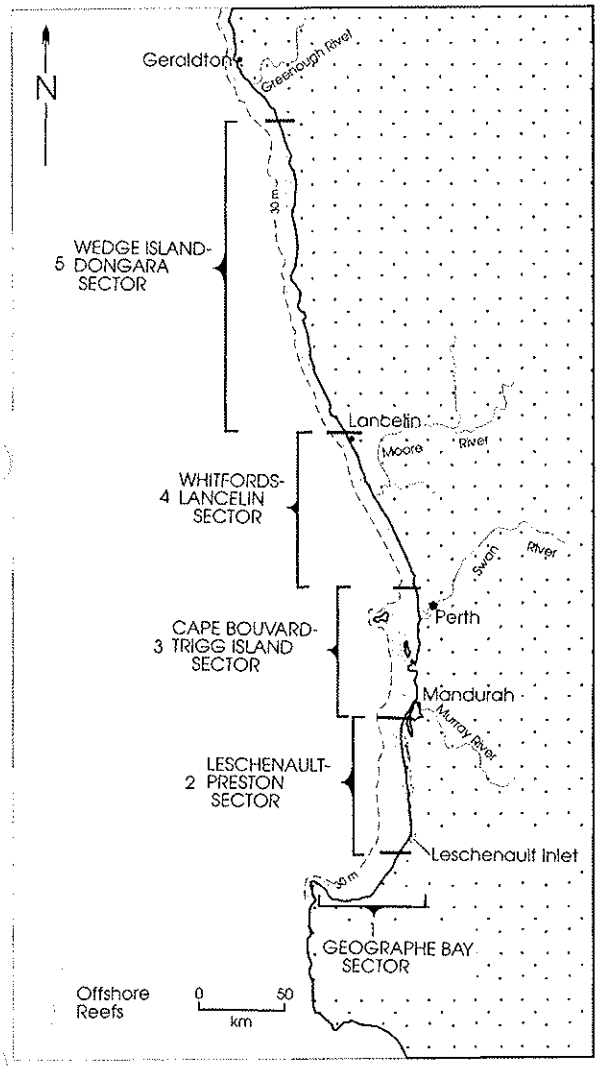


Figure 16.5 Distribution of the five coastal sectors along the Western Australian coast adjoining the Swan Coastal Plain (after Searle & Semeniuk 1985). Note that the nearshore coastal zone becomes more bathymetrically complex from the southern part of the Cape Bouvard – Trigg Island Sector, northwards, as shown by the occurrence of offshore islands and reefs (stippled).

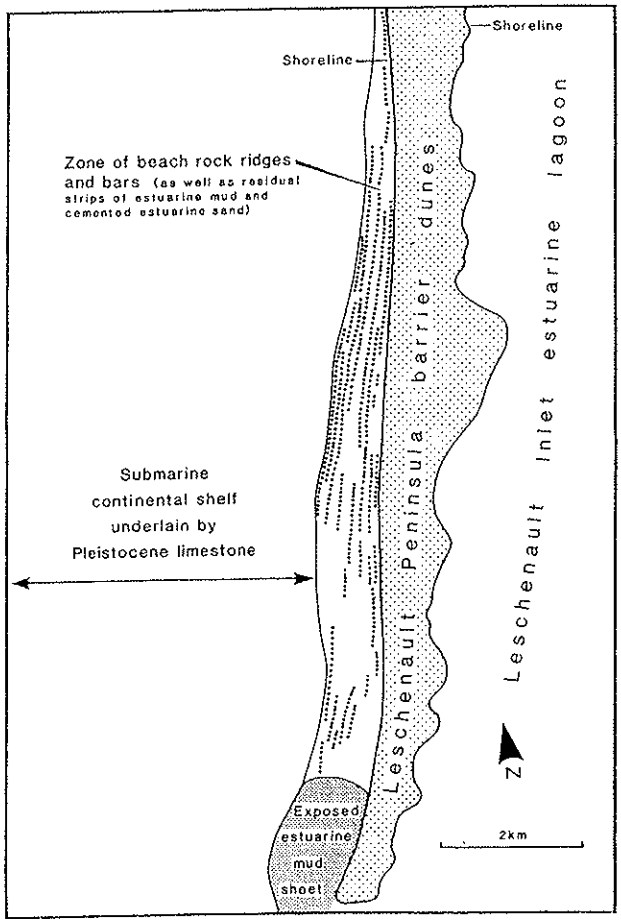


Figure 16.6 Occurrence and patterns of distribution of beachrock bands and ridges in the submarine nearshore of the Leschenault Peninsula (Semeniuk & Searle 1987). The bands and ridges record successive phases of coastal retreat. See Figure 16.5 for location.

From south to north, regionally, coastal wind changes in net direction and strength strongly influence the development of coastal dune form and orientation. Short parabolic dunes with axes oriented easterly progressively change to northeasterly inland ingressing, more attenuated parabolic dunes and fretted parabolic dunes, to northerly inland ingressing, highly attenuated parabolic (hairpin) dunes (Figure 16.8). Winds also influence the development of shore types along inland wetland margins (beach ridges, and lunettes).

Variety of estuaries

Estuaries along the coast of the Swan Coastal Plain exhibit a regional variation, each with a distinct form related to their coastal setting (Hesp 1984): from north to south, the climate and the drainage catchment becomes more humid, the rivers interact with varying ancestral coastal types, and the Holocene sea-level history has been different (Semeniuk & Searle 1986a). The main estuaries are: the Moore River estuary, the Swan–Canning River estuary, the Peel–Harvey estuary, the Leschenault Inlet estuary, and the Vasse–Wonnerup estuary.

The Moore River estuary is a small estuary interacting with a mobile, dynamic dune barrier which at the coast has diverted the generally westerly course of the river. The Swan and Canning River estuary is a Pleistocene to Holocene shore-normal inundated river valley that traverses a range of Swan Coastal Plain geomorphic belts (the pre-Holocene age of the Swan River valley was documented by Churchill 1959). The Peel–Harvey estuary is a Pleistocene to Holocene, geomorphically compound and complex estuary (Semeniuk & Semeniuk 1990, 1991), formed in part by post-glacial inundation of both an area of confluence between three rivers (to form Peel Inlet), and the linear inter-ridge swale formed at the junction between the belt of limestone ridge and quartz sand hills (to form Harvey estuary). Deltas bordering the Peel–Harvey estuary, formed where the various rivers enter the relatively protected waters of the estuary, have responded to the environmental setting in relation to fetch, and dominant and prevailing wind directions to develop wave-dominated

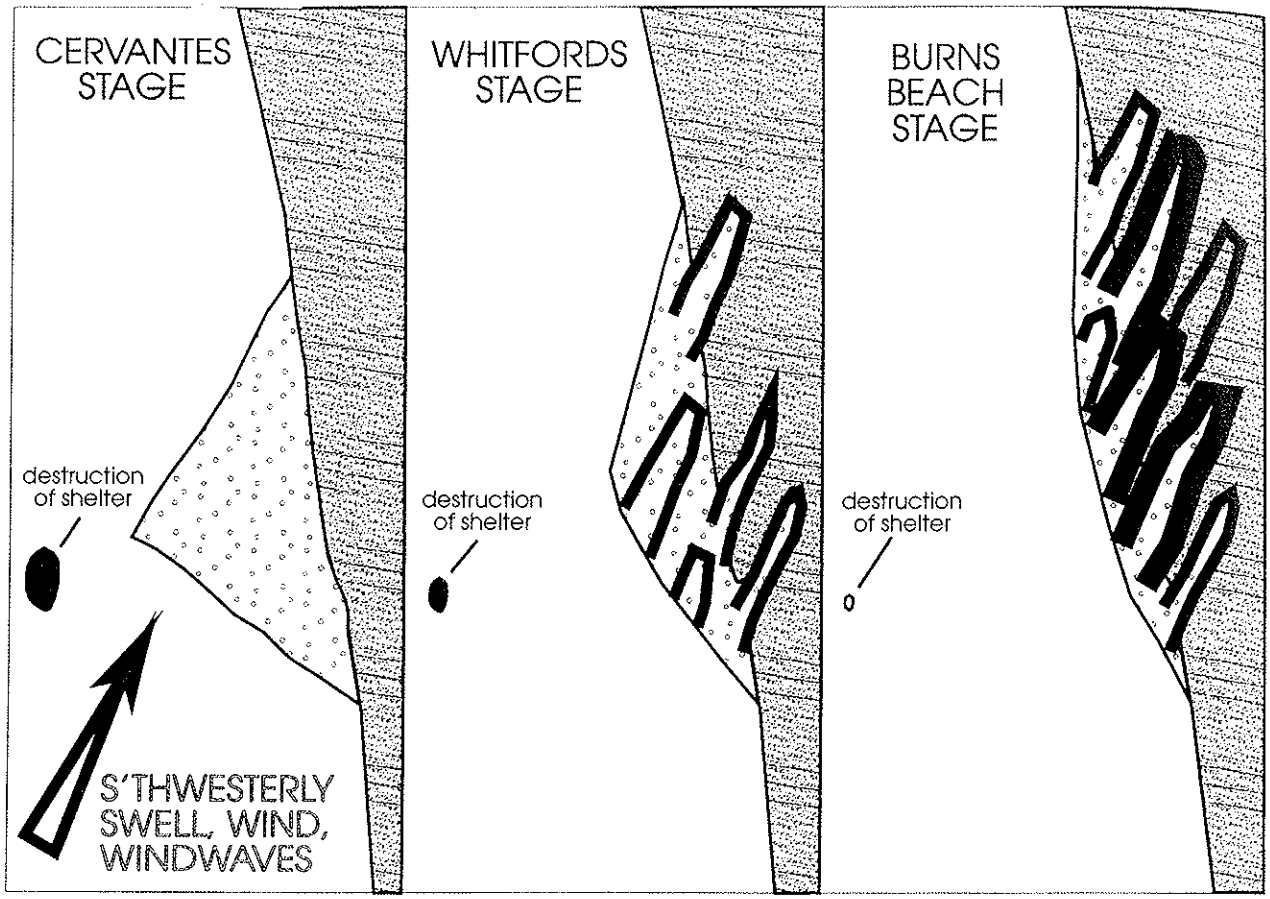


Figure 16.7 Long-term dynamics of cuspate forelands showing the three main stages related to the progressive loss of the shelter effect of the offshore rocky reefs. The first stage, exemplified by the Cervantes cuspate foreland, is the prograded fully developed cuspate foreland developed behind a large offshore rocky reef; the cuspate foreland has built out from a limestone cliff-line. The second stage, exemplified by the Whitfords Cusp (Semeniuk & Searle 1986b), following diminution of the offshore rocky reef shelter, is an eroding cuspate foreland, and through coastal retreat there is developed a series of inland ingressing parabolic dunes cross-cutting the primary geomorphology of the cuspate foreland. The third stage, exemplified by the Burns Beach system, is a nearly fully eroded cuspate foreland with an abundance of retrograded parabolic dunes; the coast is almost cut back to the buried limestone cliff-line.

deltas and fluvially dominated deltas (Semeniuk & Semeniuk 1990). Specific shores along the Peel–Harvey estuary, comprising spits, narrow beach-ridge plains, and bar-and-lagoons, are variably important from a geoheritage perspective in that they contain a record of Holocene estuarine geomorphic coastal history, and sea-level history. The tidal delta leeward of the oceanic entrance to Peel Inlet is a large, complex accumulation of sediment. The deposit resulted from shoreline sand drift, *en route* from the eroding Leschenault–Preston Barrier to the Rockingham–Becher Cuspate Foreland, being entrained by tides to form a flood-tidal delta. The importance of the resulting tidal delta lies in its large size, complex history related to shifting centres of accumulation, and developmental history under conditions of a variable sea-level (Semeniuk & Semeniuk 1991).

The Vasse–Wonnerup estuary system, located along the Geographe Bay coast, as noted earlier, is a dynamic complex resulting from the interactions of creeks/rivers and low coastal dune barriers. There is no defined delta, with most of the sediment accumulating under laterally migrating and meandering channel and point-bar systems, with local temporary outlets of the fluvial channel being periodically blocked by the low barrier dunes. Inland there are Pleistocene equivalents of this system, with low limestone ridges (former low barriers) alternating with ribbons of estuarine sediment and fluvial mud, that provide textbook examples, illustrating the interrelationship of landforms, stratigraphy, soil types, groundwater and vegetation. They also provide Quaternary models of low dune barriers and estuarine sedimentation useful for interpreting the geologic record.

In contrast to the estuaries above, the Leschenault Inlet estuary, formed behind a high dune barrier, is wholly Holocene in age (Semeniuk 1985). It once consisted of a narrow, elongate lagoon some 80 km long, similar to The Coorong in South Australia, with deltas to the south. Around 4.5 ka BP, the lagoon was segmented by parabolic dune encroachment, forming the now isolated Lake Preston lagoon to the north, and the Leschenault Inlet estuary to the south. The Leschenault Inlet estuary has a number of features that combine to make it significant: sedimentologically and stratigraphically it is simple at the large scale, but complex in detail because it formed under conditions of a variable sea-level (Semeniuk 1985, 2000) and parabolic dunes encroach on its western shore to form bar-and-lagoon complexes. Two contrasting deltas occur in its

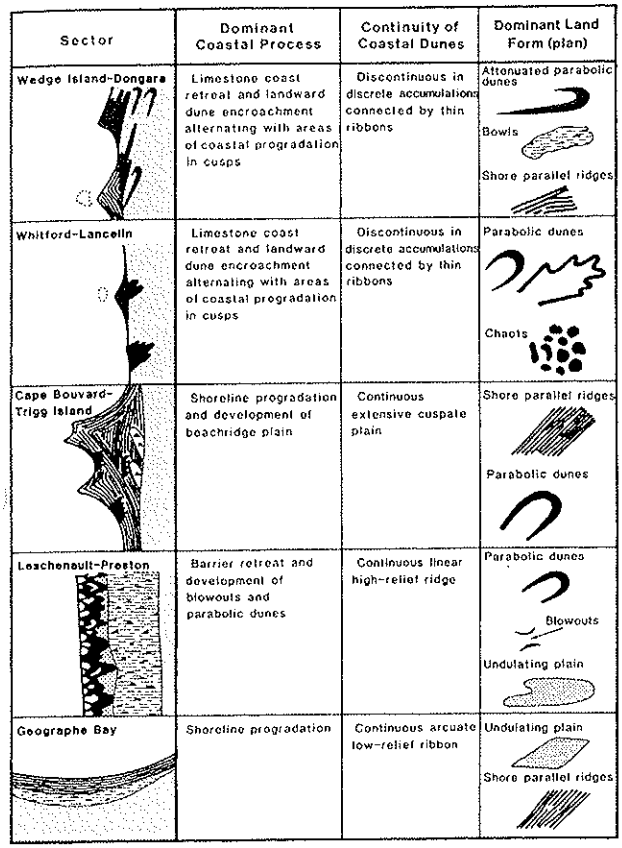


Figure 16.8 The changes in morphology and dune types of the coastal dunes south to north along the various coastal sectors (after Semeniuk *et al.* 1989). The illustration shows the changes in dominant coastal processes, the continuity of coastal dunes, and the idealised dominant dunal land form for each sector.

southern part, and it supports, as a population outlier, the most southern occurrence of the white mangrove, *Avicennia marina*, in Western Australia (Semeniuk 2000). These deltas are especially interesting in that one formerly was tide-dominated, with the delta outlet located where tidal processes dominated, and the other combines elements of wave-dominated and fluvial-dominated aspects within the same delta; both deltas are important estuarine deltaic features in Western Australia (Figure 16.9).

Sea-level history

Along the southwestern Australian coast, there is also an important sedimentary archive and geomorphic record of a variable Holocene sea-level that Playford (1977, 1988), Semeniuk and Searle (1986a), Semeniuk and Semeniuk (1991), and Semeniuk (2000) related to Holocene tectonism. The sea-level history resides in the local sedimentary accumulations (coastal deposits and estuarine deposits), and limestone rocky shores, respectively (Fairbridge 1960; Playford 1977, 1988; Semeniuk 1985, Searle *et al.* 1988, Semeniuk & Semeniuk 1991; Hamilton & Collins 1997). The variable sea-level history of this coast is a globally significant feature yet to be fully explored in terms of Quaternary tectonics and eustasy, coastal and continental shelf rheology in response to loading, the response of coastal dynamics to the variable relative sea-levels, sedimentary accumulations, sediment budgets, and groundwater responses.

Limestone terrains

Inland, in the Mandurah to Bunbury area, there is a limestone belt called the Yalgorup Plain [Semeniuk 1997: formerly referred to as the Spearwood Dunes (McArthur & Bettenay 1960) and Yoongarillup Plain (McArthur & Bartle 1980b)] that exhibits landforms and stratigraphy of former cuspate foreland, and quartz-sand-ribbon depositional systems. This system contains globally important Quaternary examples of Pleistocene beach ridge patterns, cuspate foreland geometry, classic seagrass bank to beach to dune shoaling stratigraphy, and wetlands intimately related to the post-depositional geomorphic modification of the plain.

Relict desert dunes and relationship to coastal dune deposits

In the central to northern inland parts of the Swan Coastal Plain, the quartz-sand hills (Bassendean Dunes) exhibit features of star-dune morphology and complex linear megadune morphology (Figure 16.10) (Glassford 1980; Semeniuk & Glassford 1987). These are relict from earlier, more arid climates. Today, these dune forms are in a humid climate and vegetated mostly by a *Banksia* association. In addition, the western margin of the quartz-sand hills exhibits a complex stratigraphic relationship of intercalations of limestone and quartz sand, resulting in limestone lenses embedded in quartz-sand formations (Semeniuk & Glassford 1989), a feature of geological interest illustrating a type of geological contact between continental and coastal deposits.

GLOBALLY TO REGIONALLY SIGNIFICANT NATURAL HISTORY RESOURCES

It is evident, from the above descriptions, that there is a range of features on the Swan Coastal Plain that are of geoheritage significance. The level of significance needs to be addressed. It should be noted that global or national significance can only be appreciated by people who value knowledge and heritage, and by those who know about, or can compare, similar overseas features.

In this chapter, the notion of global significance applies to geologic features and areas that satisfy one or more of a number of criteria. First, they are not represented elsewhere globally (e.g. the linear wetlands formed by karst). Second, they exhibit features that illustrate to the geologic scientific community, important and exemplary processes and principles (e.g. Pleistocene cuspate foreland geomorphology, and seagrass to beach to dune stratigraphy therein; wetland development and processes in beach ridge swales in the Rockingham–Becher area). Third, they exhibit a gradation of forms that illustrate the principle behind their development (e.g. geomorphic types of cuspate forelands in the Whitfords–Lancelin Sector). Next, they represent globally the first description of a geologic principle or pattern (e.g. beachrock bands/ridge in the Leschenault Peninsula area).

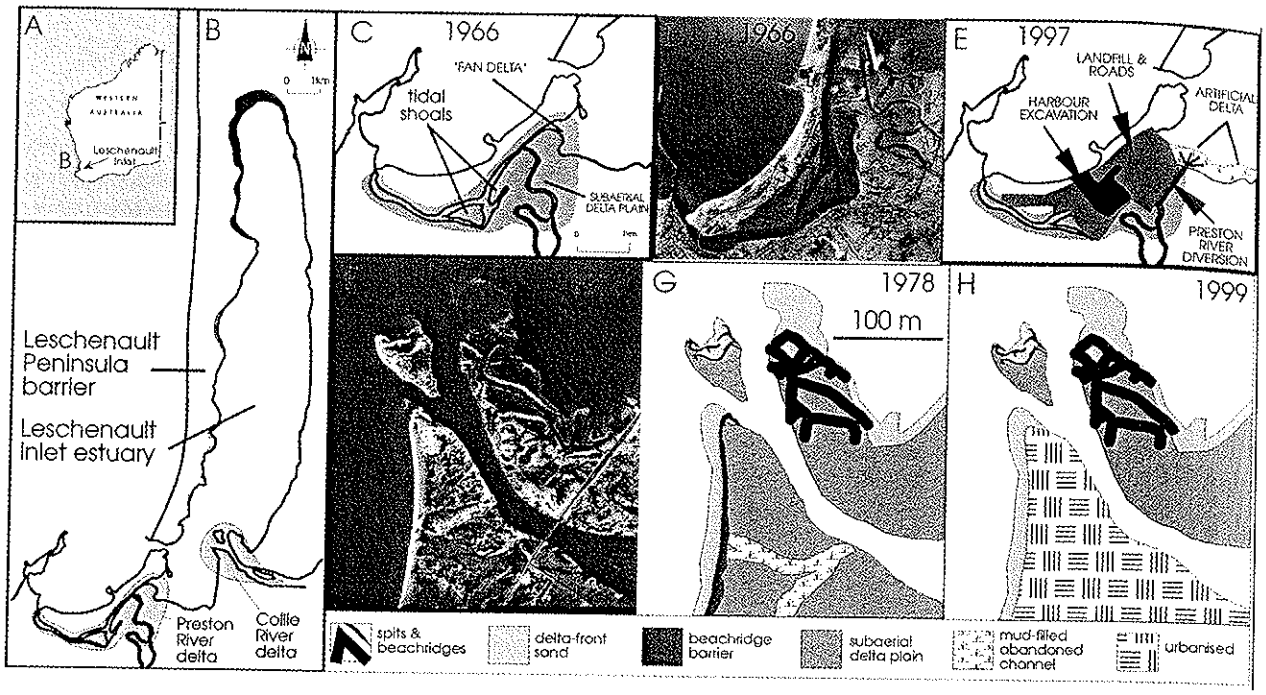


Figure 16.9 The estuarine deltas in the Leschenault Inlet estuary (Semeniuk 2000). (a) Location map. (b) Location of the Preston River delta and the Collie River delta in southern Leschenault Inlet. (c) More detailed map of the Preston River delta in 1966 showing the subaerial delta plain, meandering river channels, tidal shoals, and the fan delta. (d) Aerial photograph centred on the delta in 1966, showing tidal shoals, fan delta, and meandering channels on the subaerial plain. (e) Same area shown in (c), but with four types of anthropogenic impacts (landfill and roads, harbour excavation, channel diversion, and redirected deltaic sedimentation) largely destroying the integrity of the delta by 1997. (f) Aerial photograph of the Collie River delta in 1978 showing main channel, mid-channel island, cheniers on the northeastern part of the delta, subaerial plain and abandoned distributary channels on the southern part of the delta. (g) Map of the Collie River delta in 1978, based on the aerial photograph shown in (f) showing the geomorphic components of the delta. (h) Map of the Collie River delta in 1999, showing the destruction of the southern part of the Collie River delta through urbanisation.

Finally, they contain important archival information in relation to geologic, biologic or climatic history that supplements the general picture that may be emerging globally. For example, the climate history recorded in the sediments of wetlands provides information on the functioning of climate during the Holocene in this part of the world, or that preserved in star dunes that provides information on Quaternary climate changes in relation to glacial and interglacial periods.

In many situations, a feature of the Swan Coastal Plain provides information or a geological insight not represented elsewhere globally. Three examples are provided here. The first is the relationship of tectonic setting, coastal processes and sedimentation in a basin-wide context, as exemplified by the relationship of cuspate forelands along the northern coast and the barrier dune system along the southern coast. The second is the diversity and array of wetland types on the Swan Coastal Plain, illustrating a variety of geomorphology, hydrologic mechanisms and origins. The third is the internal structures of star dunes, with their buried soils, cross-stratification and unconformities related to former dune surfaces. The information from the star dunes provides insight into Quaternary glacial/interglacial desert history, and evolution of star-dune forms, as preserved on the Swan Coastal Plain. Such features, well preserved here, have not been explored in modern star-dune environments elsewhere globally because of logistic constraints, hence the Swan Coastal Plain star dunes serve as an international model for understanding the development and evolution of such dune forms.

National significance and state-wide significance apply to geologic features, essentially similar to those above, but important to the understanding of the geologic history of Australia and Western Australia, respectively, and representing perhaps the Australian examples of features present elsewhere globally. These features are important for research, education, illustrating principles, and natural outdoor museums. More detailed criteria for national significance are presented in Australian Heritage Commission (1990). Regional significance applies to features, similar to those outlined above, that may be present elsewhere globally and nationally, but that are well-developed in a given area to be of importance to local universities, schools and natural history students. For example, a well-exposed limestone cliff illustrating exceptionally well preserved aeolian cross-layering and buried soil sheets, though well represented elsewhere in Australia, may be important for education and research to the regional population.

With these criteria, thirteen key areas and/or features of the Swan Coastal Plain and coastal zone that are of geo-

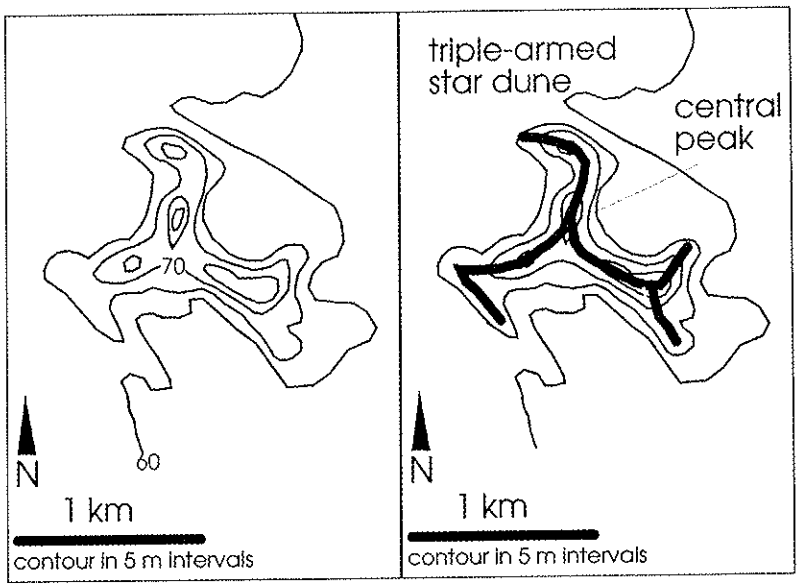


Figure 16.10 Star dune in the Ellenbrook area (see Figure 16.11 for location) showing trple-armed form of the dune, and the cuspid nature of the some of the arms. Left illustration shows the topographic contours above MSL, and right illustration shows interpretation of the star-dune form.

heritage significance are listed and described briefly below (Figure 16.11).

(1) The Becher Cuspate foreland (Searle *et al.* 1988): the most southerly and part of the the largest (double) cuspate foreland in Western Australia, with its suite of wetlands (the Becher Wetland Suite: C. A. Semeniuk 1988). This is a globally significant beach-ridge plain and associated Holocene wetlands that store information on climate change, Holocene sea-level history, former coastal processes, wetland evolution, wetland hydrochemical processes (the latter especially is of international significance).

(2) Cuspate forelands in the Whitfords–Lancelin Sector (Searle & Semeniuk 1985; Semeniuk & Searle 1986b): a range of cuspate forelands of varying sizes and in different stages of natural geomorphic destruction that illustrate the principles of construction and natural destruction of such coastal landforms. The ensemble of these coastal forms is of global significance.

(3) Yalgorup Plain (Semeniuk 1997): Pleistocene cuspate forelands showing a history of transgression and regression, Pleistocene climate and sea-temperature changes, beach-ridge history, and the relationship of the cusp axes to offshore barriers; also illustrates the development of wetlands along unconformity contacts, and the karst control of marine water recharge. This area is globally significant.

(4) Swan Coastal Plain wetlands (excluding those formed within the Holocene beach ridges and dunes): the variety of geomorphically diverse wetland suites encompassing systems in the Bassendean Dunes, the Spearwood Dunes and Pinjarra Plain (C. A. Semeniuk 1988). The wetlands display a diversity of shape, size, association, stratigraphy, history, and margin types (e.g. lunettes that border them locally). These wetland ensembles, lying in parallel belts in the Swan Coastal Plain, in contrast to wetland types and assemblages in North and South America, Canada, Europe, Asia and Africa, are globally unique systems.

(5) Leschenault Peninsula beach rock bands/ridges (Semeniuk & Searle 1987): comprising low bands and ridges of submerged beachrock, formed where the coast retreated episodically; as the most southern beachrock location along an eroding coast that records extent and periodicity of coastal retreat. This feature is of national significance.

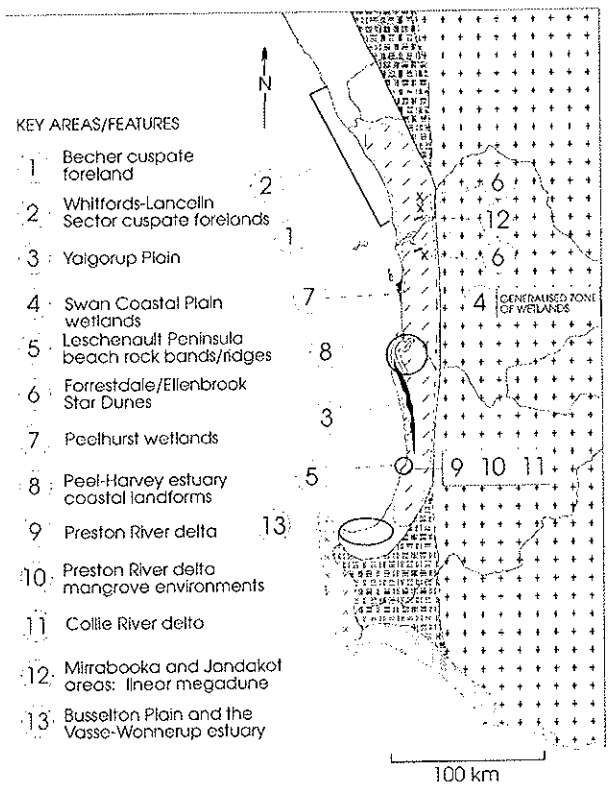


Figure 16.11 Location of 13 sites of geoheritage significance on the Swan Coastal Plain.

Table 16.3 Types of human impacts on the environment, Swan Coastal Plain.

Human impact	Description with examples
Urbanisation	Extensive areas cleared for human habitation with levelling of coastal dunes and/or star dunes, filling of wetlands, excavation of peat from wetlands, nutrient enrichment of waterways and groundwater; alteration of groundwater regimes.
Marina and harbour construction, and general coastal modification	Excavation and landscape modification of coastal dunes, and peripheral estuarine landforms such as deltas; emplacement of breaker groynes and seawalls that fundamentally alter the wave character of the coast.
Clearing for industrial or recreational development (e.g., industry/golf), or for pasture, horticulture, forestry	Extensive areas cleared for development and exploitative landuse with levelling of coastal dunes and/or star dunes, filling of wetlands, nutrient enrichment of waterways and groundwater; alteration of groundwater regimes.
Mining and quarrying	Exploitation of carbonate sand from seagrass banks, mining of peat and diatomaceous earth from wetlands; quarrying of yellow sand for building purposes; mining/quarrying of mineral sands and use of the overburden as spoil dumps; quarrying of silica sand for glass-making.
Refuse disposal	Excavation and filling of dunes; filling of wetlands; nutrient enrichment of waterways and groundwater.
Reclamation	Filling of wetlands; filling of estuarine deltas.
Groundwater contamination	Disposal of effluents that irrevocably modify the material of the natural environment; where groundwater contamination is of a nature that is not irrevocable (e.g., nutrient enrichment), in the medium term, it may be flushed by meteoric recharge.
Groundwater Abstraction	Alteration of groundwater regimes, and often extreme modification and destruction of wetlands.
Road Construction	Alteration of landscape and of groundwater regimes; fragmentation of landscapes; often modification and destruction of wetlands by infilling and peat excavation.

(6) Star Dunes in the Forrestdale/Ellenbrook area (Semeniuk & Glassford 1989): multi-arrayed to cuspate medium-sized star dunes and star-dune complexes, formed under conditions of a former arid climate. These features are of state-wide to national significance.

(7) Peelhurst Wetlands (C. A. Semeniuk 1988): the wetland suite that was developed as dune slack systems along a line of natural blowouts on the southern coast of Becher Cuspate Foreland some 1000 years ago. This area represented a young example of a style of wetland development showing relation of wetland to dune-blowout history, and evolution of wetlands soils from *ca* 1000 a B.P. to present. When extant, the system was one of a kind in Western Australia, and was of state-wide significance.

(8) Peel–Harvey estuary coastal landforms (Semeniuk & Semeniuk 1990): stranded channel shoal complexes, relict tidal delta system, modern tidal delta, spit-and-lagoon complexes, and beach-ridge ribbons. This area illustrates the development of estuarine peripheral coastal landforms, their soils and vegetation under conditions of a variable sea-level, changing climate, oceanic littoral sand drift, and coastal aspect. In terms of geoheritage, this system is of state-wide significance

(9) Preston River delta, that occurred in the southern part of the Leschenault Inlet estuary (Semeniuk 2000): the combined fluvial and tidal dominated delta. This area is of state-wide significance.

(10) Mangrove environments of the Preston River delta (Semeniuk *et al.* in press): essentially mangrove fringed tidally oriented shoals. This feature is of state-wide significance.

(11) Collie River delta, that occurred in the southern part of the Leschenault Inlet estuary (Semeniuk in press): the combined fluvial dominated and storm-wave influenced delta. This area is of state-wide significance.

(12) Linear megadune, Mirrabooka area and Jandakot area (Glassford 1980): two related linear sand-dune complexes formed under conditions of a former arid climate. This feature is of state-wide to national significance.

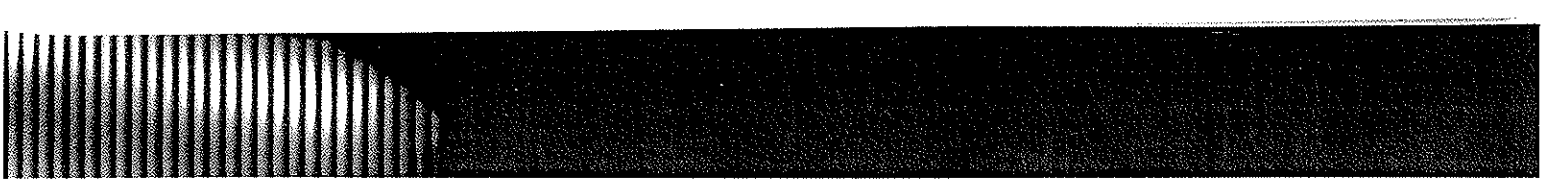
(13) Busselton Plain and the Vasse–Wonnerup estuary: the low plain inland from Geographe Bay, comprising alluvial plains, geomorphically degraded dunes, fluvial courses, wetland complexes, and Pleistocene to Holocene estuarine complexes developed as a barrier and linear estuary complex. This area is of state-wide significance.

TYPES OF HUMAN IMPACTS

With population growth, there has been a concomitant impact on the natural history features of the Swan Coastal Plain and coastal zone. In this region, as elsewhere globally, expanding human populations, through exploitation and modification of the environment, have contributed to a general lowering of the quality of the natural environment. This has occurred through deforestation, general vegetation clearing, alteration of soils, nutrient enrichment of waterways and groundwater, water abstraction, reclamation, diverting of river channels, and re-landscaping of natural landforms, amongst others. It is not implied here that these activities are wholly unacceptable, but rather that they

Table 16.4 Key sites of geoheritage significance, Swan Coastal Plain and coastal zone, their destruction or modifications to date by human development.

Key geoheritage area	Anthropogenic impacts
Becher Cuspate Foreland (i.e. remaining southern part of the double cuspate foreland: the Rockingham-Becher Cuspate Foreland)	Urbanisation, industrial development, and golf course development to the extent that only 30% remains in Conservation Reserve Estate; urban and recreational development proceeded in the 1990s along the cusp axis, the most important part where wetlands were preferentially developed; in 1991 the Australian Heritage Commission recognised the geoheritage importance of the area, but this did not arrest its destruction and modification (Binnie & Partners 1988; Bowman Bishaw Gorham 1994; Environmental Protection Authority 1989, 1992a; Department of Planning and Urban Development 1993).
Cuspate forelands in Whitfords-Lancelin Sector	Urbanisation during the 1970s to the 1990s has destroyed a number of these coastal landforms (LeProvost Environmental Consultants 1990; Department of Planning and Urban Development 1992a).
Yalgorup Plain	Though a portion of this system resides in the Yalgorup National Park, the majority was cleared for pasture in the past, and in the 1990s partly cleared for forestry; there has been urbanisation in the 1990s of large tracts of this plain.
Swan Coastal Plain wetlands (excluding those formed within the Quindalup Dunes	Urbanisation and road construction, clearing, infilling, and peat excavation, have largely destroyed wetlands of the Gnangara Suite and the Gwelup Suite, and wetlands in the type location of the Jandakot Suite (Department of Planning and Urban Development 1992b; Ministry for Planning 1995b); forestry and agriculture has largely destroyed wetlands of the Riverdale Suite and wholly destroyed wetlands of the Kooallup Suite.
Leschenault Peninsula beach rock bands/ridges	Disposal of acidic and iron-rich effluent on the Leschenault Peninsula during the 1970s and 1980s, resulted in seepage seawards, destroying this feature through gypsification and dissolution.
Star Dunes Forrestdale/ Ellenbrook	Urbanisation and development of golf courses in the Forrestdale and Ellenbrook area in the 1990s have resulted in the wholesale clearing and levelling of many such dunes (Department of Planning and Urban Development 1992b,1994, 1996; Ministry for Planning 1995b).
Peelhurst Wetlands	Urbanisation and golf course development proceeded in the 1990s and fully destroyed this wetland suite. In 1991 the Australian Heritage Commission recognised the geoheritage importance of the area, but this did not arrest its destruction (Environmental Protection Authority 1992; Tingay & Associates 1992; Tingay & Associates and Warren F Johnson & Co 1992), Department Planning and Urban Development 1993).
Peel-Harvey estuary coastal landforms	Reclamation and marina development during the 1980s to 1990s destroyed many areas along the estuary shore, including the stranded shoal complex, the relict tidal delta, and locally the spit-and-lagoon complexes (BSD Consultants Pty Ltd 1992; Environmental Protection Authority 1992b); the last destruction was under way in 1999 with another urban/marina complex being developed on the remainder of the relict tidal delta complex, in spite of the fact that it was on the Register of the National Estate (Australian Heritage Commission), and that it adjoins and is part of a site nominated for conservation under the Ramsar Convention (Ramsar Convention Bureau 1991; Lane et al. 1996).
Preston River delta	Reclamation and harbour development, and diversion of the Preston River; these modifications took place in the late 1970s, and irrevocably altered the nature of the delta.
Mangroves of the Preston River delta	Though part of the Preston River delta, the mangrove habitats within the delta are singled out because of their State-wide significance; impacts derive from reclamation and harbour development, and road construction during the 1970s.
Collie River delta	Urbanisation of the southern subaerial plain in the late 1990s (LeProvost Environmental Consultants 1991) involving clearing, excavations, levelling; drainage of the northern subaerial plain along cheniers in the 1940s.
Linear megadune, Mirrabooka area and Jandakot area	Sand quarrying and adjoining urbanisation in the 1960s has resulted in the destruction and local modification through levelling, respectively, of this twin dune form.
Busselton Plain and the Vasse-Wonnerup estuary	Mineral sand mining from the 1960s to the 1990s has destroyed wetlands and landscapes of this region, and largely erased a unique and important stratigraphic record; coastal marina development has canalised the Holocene estuary system.



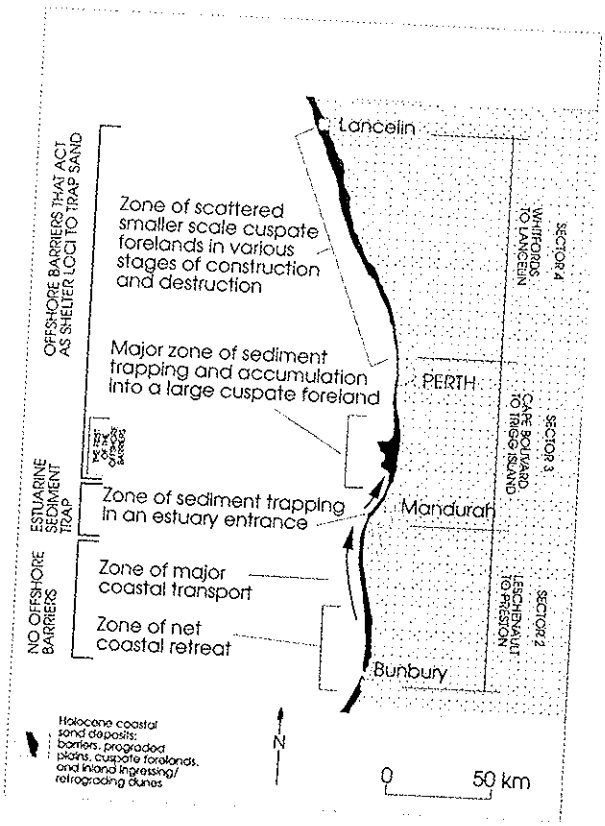


Figure 16.12 Regional processes and dynamics between Leschenault – Preston Sector and Whitfords – Lancelin Sector showing interrelationship of coastal types.

should be undertaken in a rational manner, encompassing the issues of biodiversity, geoheritage, pollution/contamination, and wise environmental management. The notion is presented that, for example, urbanisation, quarrying, marina construction or mining, should not be undertaken in areas that are assessed as having high to moderate geoheritage significance.

The types of human impacts on the natural environment that affect sites of geoheritage significance are described, with examples given in Table 16.3. The many and extensive areas impacted by human populations, but that are only of local to regional geoheritage significance (e.g. the Swan River estuary, the limestone rocky shores of Perth, the undulating sand hills of the Bassendean Dunes, and the catchment of the Brunswick and Collie Rivers) are excluded from consideration in this chapter.

On the Swan Coastal plain, there already has been much destruction of areas of importance as geoheritage sites following activities listed above. Generally in Western Australia, in the past, and continuing to a large extent into the present, these modifications of the natural environment took place without any perception of geoheritage. Today, with the environmental controls imposed through the Environmental Protection Authority Act (1986) and some policies emplaced through the Department of Environment that attempt to protect wetlands and landforms (Department of Environment 1993), landform systems that were impacted decades ago would be critically examined and assessed as to their significance. Probably today they would not be so indiscriminately modified or destroyed. Indeed there has been a raising of consciousness in this matter (Carter 1987; Lemmon *et al.* 1979; Joyce 1995): the concept of geoheritage is now embedded in the Australian conservation literature, criteria exist for Nomination for Selection for the Register of the National Estate by the Australian Heritage Commission (1990), and the Geological Society of Australia commissioned a study into the design of selection criteria for sites of geoheritage and geoconservation (Joyce 1995).

DISCUSSION

Some of the areas on the Swan Coastal Plain that were of high geoheritage significance have been modified or destroyed. Key areas of geoheritage significance that were destroyed or modified are listed and described in Table 16.4. Some of these impacts occurred years before concepts such as geoheritage were conceived or in a context of ignorance (e.g. the Preston River delta of the Leschenault Inlet estuary). Some occurred in spite of the information about the geoheritage significance being readily available and that the information was part of an assessment process (e.g. the southern part of the Collie River delta of the Leschenault Inlet estuary; the Peelhurst Wetlands; the cuspate foreland of Point Becher with its wetlands arrayed along the cusp axis; see discussion below).

Current perceptions about conservation and geoheritage now generally held by scientists and the general community, probably would not have been acceptable two hundred years ago at the time of the European settlement of Australia, and even 50 years ago, immediately after World War II—a factor indicating the changes in community attitudes to environmental and conservation issues that have occurred over the past few decades. Projecting this pattern into the future, with increasing awareness of environmental issues, education and personal wealth, one may hope that there will be a greater consciousness of the significance of geoheritage issues and a more concerted effort to preserve features of geoheritage significance. Future land managers and decision makers cannot plead naivety given increasing numbers of publications dealing with geoheritage issues, the documentation of the destruction of globally significant sites to date, and the focus on issues of geoheritage.

An important issue in geoheritage in Western Australia is the notion of interconnectedness or linkage. Sites of significance can be viewed as site-specific, such as a stratigraphic type section, or a specific wetland, but in fact there is a regional interconnectedness of many features of the Western Australian geologic systems, especially in the Quaternary, and it is the integrated system that stands as a globally significant model. For instance, consider the coastal zone between Geographe Bay and Lancelin (Figure 16.12): there is a south to north interrelated pattern in sediment transport, sedimentary accumulations, and geomorphic evolution of the coast related to the regional system of tectonics (resulting in a submergence of the offshore barrier limestone chains and the south to north changes in tectonic response as reflected in a variable sea-level history), the gradient in climate during the Holocene (resulting in a change in resultant wind direction), the prevailing net northward littoral sand drifts, style of biological, chemical

and physical erosion of the limestone reefs, and the changes in maintenance of coastal form due to changes in wind patterns (resulting from Holocene climate changes). The total integrated picture is a model of global significance, and preservation of sites of geoheritage must address the integrated whole picture and not deal only with site-specific areas in a piecemeal fashion.

To date, there have been significant losses of sites of geoheritage in Western Australia. This may be related to a range of complex issues. Environmental managers, government agency decision makers and politicians, despite being in positions of adjudication, frequently have not fully appreciated the significance of geologic processes and products, or the significance of geoheritage, i.e. natural-geoscience information. In fact, they frequently do not understand the significance of heritage outside the realm of cultural heritage. There is also an unsubstantiated opinion that in a technological culture, science, technology and engineering can fix all, without appreciating that systems can be irrevocably destroyed. Examples here include star dunes with their stratigraphy and buried soils, for instance, that contain irreplaceable and valuable geohistorical information, which have taken hundreds of thousands of years to develop, or wetland systems that have taken ten thousand years to develop, and that are still very poorly understood in terms of their functioning, and indeed cannot be restored or reconstructed.

This chapter has provided an overview of the significance of the Swan Coastal Plain, southwestern Australia, from a view of geoheritage and outlined some of the human impacts on globally, nationally and regionally significant sites. From this perspective, the objective of this chapter is to alert the scientific community and land-use managers and decisions makers to the important features of the Swan Coastal Plain, and to the destruction of the Australian geoheritage that has occurred to date, so that an understanding of such history will ensure that past errors in judgement are not repeated.

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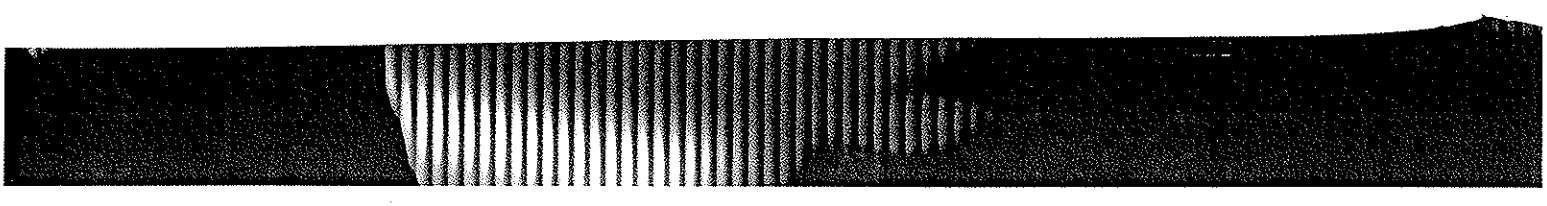

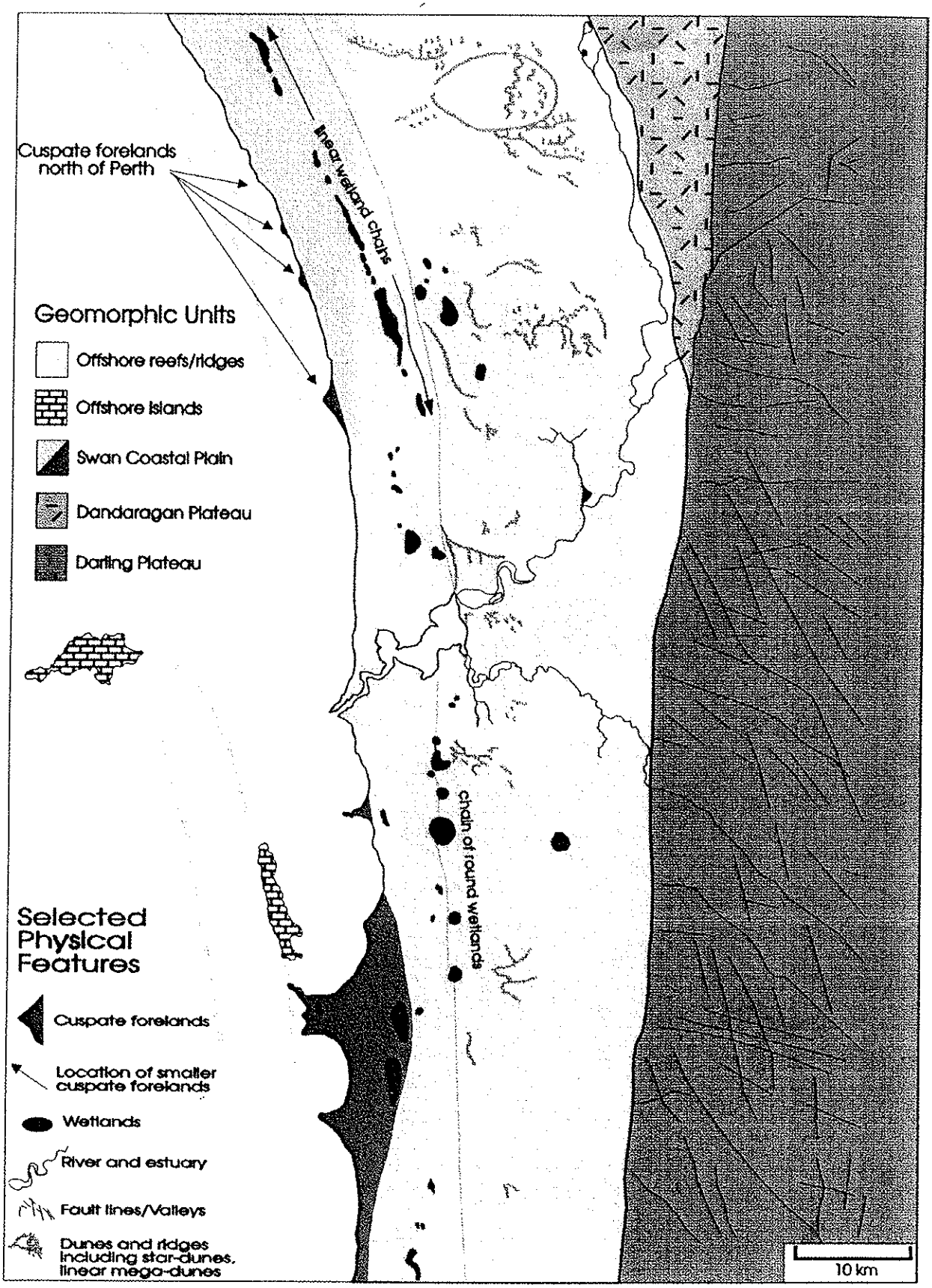
Cuspate forelands north of Perth
linear wetland chains
Geomorphic Units
Offshore reefs/ridges
Offshore islands
Swan Coastal Plain
Dandaragan Plateau
Darling Plateau
chain of round wetlands
Selected Physical Features
Cuspate forelands
Location of smaller cuspate forelands
Wetlands
River and estuary
Fault lines/Valleys
Dunes and ridges including star-dunes, linear mega-dunes
10 km

Figure 16.2

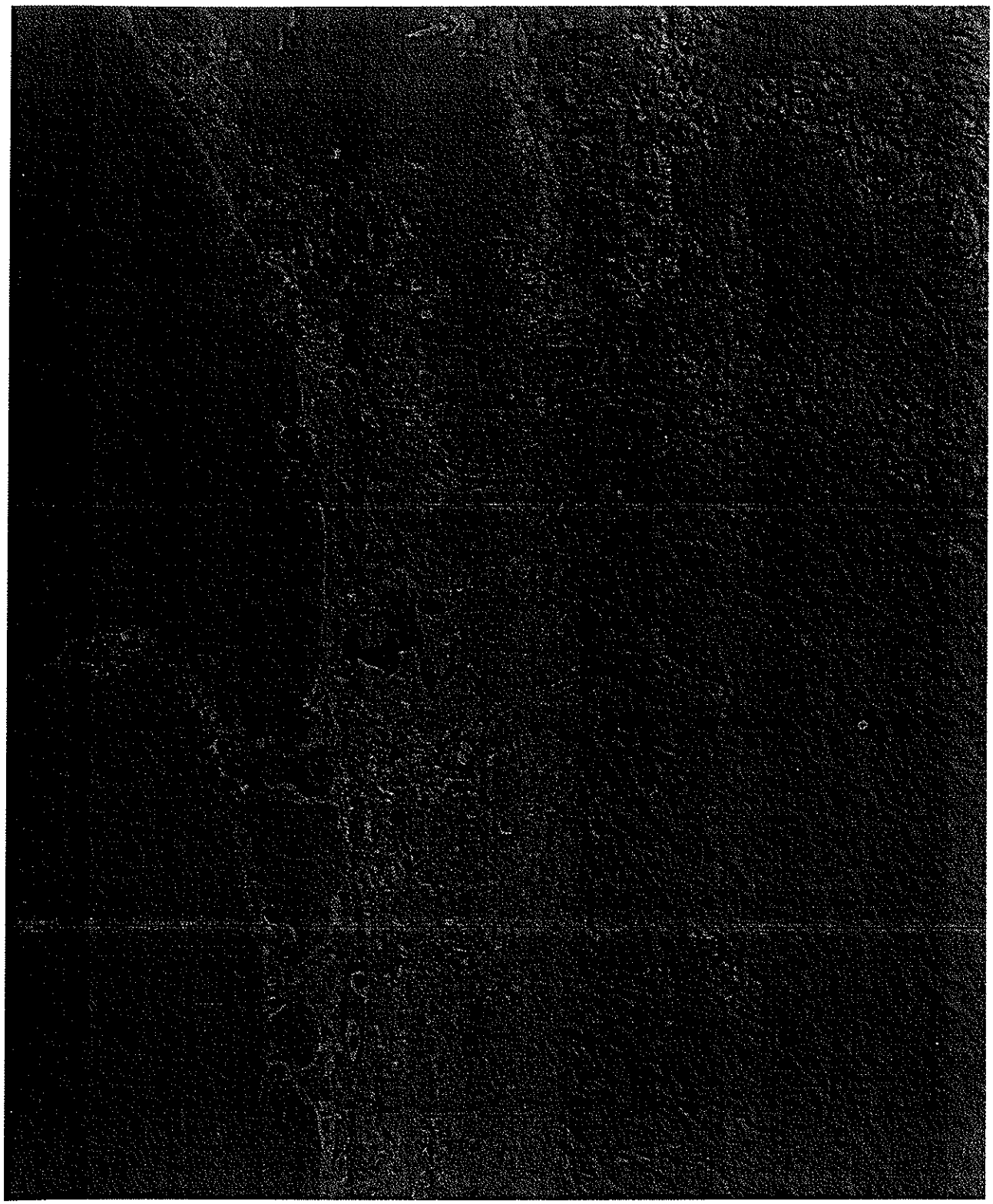

Figure 16.2 Line diagram and coloured satellite image centred on Perth and the Swan River, showing natural features of interest on the Swan Coastal Plain. To the east is the fractured Precambrian rock terrain of the Yilgarn Craton that, with associated laterite and sand, comprises the Darling Plateau. Features marked on the map are the large double cuspate foreland of the Becher Point area, the small cuspate forelands north of Perth, offshore ridges and reefs, chains of linear wetlands and of round wetlands, the more conspicuous various other large wetlands, the various linear and star-dune forms and star-dune networks. The extent of urbanisation in the region is evident on the image but is not shown in the line drawing.

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Name: Assessment of Bushland Patches in the Karrakatta – Centeral and South Vegetation Complex
Date: 17/05/2006
Capture Author: Thomas Leong

Comments:
Polygon
Created to match documented study area with low level of accuracy

Accuracy Levels:

- High = Document contained visual and or described spatial references easily copied, resulting in little or no polygon boundary errors
- Acceptable = Document contained visual and or described spatial references with complex boundaries, resulting in minor boundary errors
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Report Info – Captured without problems
Custodial/Contact – Captured without problems
Content – Captured without problems

ASSESSMENT OF BUSHLAND PATCHES

IN THE

KARRAKATTA - CENTRAL AND SOUTH

VEGETATION COMPLEX

Prepared by: Mattiske Consulting Pty Ltd

Prepared for: Ministry for Planning

May 1996

MFP001/211/96

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APPENDICES

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1. SUMMARY

Mattiske Consulting Pty Ltd was commissioned to survey nominated bushland patches in the Karrakatta Complex Central and South, to assess their condition and to compare the results obtained by this method with the condition classification developed by the Ministry for Planning. The results reflected differences in many of the condition ratings of the bushland patches using the two methods.

Some of the bushland patches when surveyed were found to be fully developed as housing estates, others had only parts of the patches developed with varying areas of remnant bushland remaining. In areas where residential or industrial development has been long established, the perimeters of the bushland patches were generally badly degraded with weeds, but in areas where such development has been recent, some of the bushland patches were less weed affected.

The majority (94.5%) of the bushland patches supported vegetation associations which could be considered to be subsets of the Karrakatta Complex - Central and South as defined by Heddle *et al.* (1980), namely an Open Forest of *Eucalyptus gomphocephala* - *Eucalyptus marginata* - *Eucalyptus calophylla* and a Woodland of *Eucalyptus marginata* - *Banksia* spp. The range of vegetation associations defined for the respective bushland patches reflected the greater degree of resolution on the respective areas. The localised swamp communities (River Gum Woodland - *Eucalyptus rudis* and Paperbark - *Melaleuca* spp.) again reflect the degree of assessment and level of the differentiation feasible within a regional mapping exercise such as the System 6 vegetation mapping (Heddle *et al.* 1980). Similarly, the shrubland and limestone heath associations reflect the level of mapping, although the bushland areas supporting these latter two associations also supported the forests and woodlands that are more typical of the Karrakatta Complex Central and South.

The vegetation associations in each of the bushland patches was recorded and five associations were found to occur in only one area. Although these may be important to conserve, the overall condition of the patch must be considered as rehabilitation of a badly degraded site is very consuming in terms of time and money. One bushland patch recorded the presence of four vegetation associations, and five bushland patches the presence of three vegetation associations. These were correlated to the vegetation complexes of Heddle et al. (1980) and the community types of Gibson *et al.*(1994).

At each bushland patch the major weeds and their total percentage of the understorey were recorded. The weeds common to all bushland patches were the perennial veldt grass (*Ehrharta calycina*) and a mixture of annual grasses and daisies. Most of those identified were readily controlled with selective sprays or by hand pulling.

In future, it has been suggested that to accurately record the condition of a bushland patch it is essential to do survey work on the ground not only for the specific patches but also for the adjacent remnants and protected areas.

2. INTRODUCTION

Mattiske Consulting Pty Ltd was commissioned by the Ministry for Planning to undertake a survey of nominated bushland patches within the Karrakatta Complex Central and South. An analysis of the selected areas (patches) which had previously been undertaken was provided by the Ministry for Planning and a comparison was made between the data obtained from both sources.

The botanists from Mattiske Consulting Pty Ltd assessed each of the nominated patches for soil, special features, previous and current use, competing land use, and compatible uses of the land resulting in an assessment of the overall condition. In addition the vegetation associations were listed together with the major species, including weeds, plus the total percentage of weeds present in the patch.

The bushland patches were surveyed either by 4-wheel drive vehicles along firebreaks, other tracks or formal streets, or by walking through the area. A total of 8 days was spent locating and surveying all the bushland patches.

3. OBJECTIVES

The objectives of the study were:

- to assess the condition, presence and boundaries of selected bushland patches,
- to determine if the original method used by the Ministry for Planning to assess the bushland patches was accurate (in terms of condition rating) and up to date in terms of presence,
- to make recommendations for future assessments, and
- to link vegetation associations observed on the bushland patches with the vegetation complexes as defined by Heddle *et al.* (1980) and with the vegetation types as defined by Gibson *et al.* (1994).

4. METHODS

Prior to undertaking the field work, all the bushland patches nominated on the overview map were accurately located using a metropolitan road directory. Bushland patches to be surveyed were grouped during planning to reduce the travelling distance.

After the assessment form was prepared, a field day was spent determining if the format was satisfactory. For the remaining field days the form adopted was utilised and some 8-10 bushland patches were assessed on each day during this development phase. Some of the bushland patches were fenced making access impossible so these were perimeter walked. A four-wheel drive vehicle was used to survey some of the larger bushland patches, particularly those where there appeared to be no road access around or through the bushland patch. Those bushland patches readily accessible by conventional vehicle were assessed by walking through the area from as many different access points as possible.

At each bushland patch the vegetation association(s) and the percentage of weeds present were recorded. Once the survey of the bushland patch had been completed a decision was reached on the overall condition of the area. However, sometimes during the assessment of each vegetation association, a portion of the bushland patch was recorded as very good but another portion would be recorded as poor but the overall assessment for the area would be recorded as moderate.

With some bushland patches it was often difficult to determine if the unfenced land in a developed area was privately owned or vacant crown land. In future, if additional assessments are to be undertaken, it is important to consult the local councils for any bushland areas intended for development or recently opened up. In addition recent aerial photographs may enable some of this information to be assessed.

5. RESULTS

A total of seventy-three areas were assessed for their bushland condition. The assessment was made on the intactness of each area (percentage of weeds) and the variety of vegetation associations present. Weed invasion is a major consideration when determining if a patch should be set aside for consideration in the Urban Bushland Strategy Plan as a bushland area, as rehabilitation from a site with little or no understorey is very costly in terms of money and time. Often rehabilitation of such land requires a dedicated team to undertake much of the work.

5.1 Overall Condition of the Nominated Bushland Patches

The comparison between the assessment of the nominated bushland patches by the Ministry for Planning and the field work undertaken by Mattiske Consulting Pty Ltd

is given in Table 1. It can be seen from Table 1 that the nominated bushland areas were classified differently by Mattiske Consulting Pty Ltd when compared with the assessments provided by the Ministry for Planning. Mattiske Consulting Pty Ltd had 5 basic classifications, very good, good, moderate, poor and very poor which did allow some overlap, thus the classification of very good - good, whereas the Ministry for Planning used their EASY index which allowed ratings of very good, good and poor.

Table 1: The Condition of the nominated Bushland Areas and the Number of Bushland Areas within Each Condition Classification as determined by Mattiske Consulting Pty Ltd (MCPL) and as summarised by the Ministry for Planning (MFP)

MPCL Condition Classification	Number of Bushland Areas	MFP Condition Classification	Number of Bushland Areas
Very Good	14	Very Good	6
Very Good - Good	1		
Very Good - Moderate	1		
Good	20	Good	53
Good - Moderate	4		
Moderate	11		
Moderate - Poor	2		
Poor	9	Poor	14
Very Poor	5		
Developed for Housing etc	6		
TOTAL NUMBER	73		73

By making this combination (Tables 1 and 2) the assessment undertaken by both groups differed slightly for the different condition classification levels. At the very good classification Mattiske Consulting Pty Ltd (15) assessed 9 patches more than the Ministry for Planning (6) at this level. At the good classification Mattiske Consulting Pty Ltd assessed 15 less at the various combinations of good and moderate levels (38 compared with 53). However if the very good and good categories are combined then the results for these two categories are similar (53 by Mattiske Consulting Pty Ltd versus 59 by the Ministry for Planning - Table 2). The total numbers of poor or very poor were equivalent (14 by Mattiske Consulting Pty Ltd and 14 by Ministry for Planning).

Table 2: Mattiske Consulting Pty Ltd (MCPL) and Ministry for Planning (MFP) Classification Categories condensed into four Major Condition Classification Levels

Condition Classification	MCPL	MFP
Very Good	15	6
Good	38	53
Poor	14	14
Developed	6	0
TOTAL	73	73

However by referring to Appendix A and comparing those classified by the Ministry for Planning with those classified by Mattiske Consulting Pty Ltd there were differences in the assessments (Table 3). One bushland area assessed by the Ministry for Planning as Good was developed when surveyed by Mattiske Consulting Pty Ltd. The latter supports the need to verify the information with ground truthing.

5.2 Vegetation Associations and Karrakatta Complex Central and South

There were seventeen different vegetation associations found within the nominated bushland areas (Appendix A). These are listed in Table 4 together with the number of bushland areas in which these were found. The Jarrah - Banksia *(Eucalyptus marginata - Banksia* spp.) woodland is the most common association found within the nominated bushland patches (Table 4). This is followed by the mixed Banksia woodland and the Tuart woodland (*Banksia* spp. - *Eucalyptus gomphocephala*). Five of the listed vegetation associations were only recorded from one site.

The majority (94.5%) of the bushland patches supported vegetation associations which could be considered to be subsets of the Karrakatta Complex - Central and South as defined by Heddle *et al.* (1980), namely an Open Forest of *Eucalyptus gomphocephala - Eucalyptus marginata - Eucalyptus calophylla* and a Woodland of *Eucalyptus marginata - Banksia* spp. (Reference Numbers 1, 2, 6, 7, 8, 8a, 8b, 9, 11, 15, 16 in Table 4 and Appendix A). The range of vegetation associations defined for the respective bushland patches reflected the greater degree of resolution on the respective areas. The localised swamp communities (River Gum Woodland - *Eucalyptus rudis* and Paperbark - *Melaleuca* spp.; Reference Numbers 5, 12 and 13 in Table 4 and Appendix A) and the other Woodlands (Reference Numbers 3, 4, and 10 in Table 4 and Appendix A) again reflect the degree of assessment and level of the differentiation feasible within a regional mapping exercise such as the System 6 vegetation mapping (Heddle *et al.* 1980). Similarly, the shrubland and limestone heath associations

(Reference Numbers 14 and 17 in Table 4 and Appendix A) reflect the level of mapping, although the bushland patches supporting these latter two associations also supported the forests and woodlands that typify the Karrakatta Complex Central and South.

Table 3: Comparison of the Condition Classification of the Ministry for Planning (MFP) and the Condition Classification of Mattiske Consulting Pty Ltd (MCPL)

MFP Condition Classification	MCPL Condition Classification	Number of Bushland Areas
Very Good	Very Good	1
Very Good	Good	1
Very Good	Moderate	2
Very Good	Poor	2
Good	Very Good	14
Good	Very Good - Good	1
Good	Very Good - Moderate	1
Good	Good	17
Good	Good - Moderate	2
Good	Moderate	7
Good	Moderate - Poor	2
Good	Poor	3
Good	Very Poor	2
Good	Developed	4
Poor	Good - Moderate	2
Poor	Good	2
Poor	Moderate	1
Poor	Poor	4
Poor	Very Poor	3
Poor	Developed	2
	TOTAL	73

Table 4: **Vegetation Associations recorded from the nominated Bushland Areas, their reference number (Appendix A), the number of Bushland Patches recording each Vegetation Association and a comparison with the Gibson *et al.* (1994) Vegetation Type.**

Vegetation Association	Reference Number	Number of Patches	Gibson *et al.* Vegetation Type No.
Tuart woodland	1	10	24
Jarrah Tuart woodland	2	1	24
Marri woodland	3	2	3b
Jarrah - Marri woodland	4	6	3b
River Gum woodland	5	2	11
Mixed Banksia woodland	6	15	23a,23b,22
Tuart - Banksia woodland	7	3	24
Jarrah - Banksia woodland	8	41	21a,28
Occasional Tuart	8a	8	21a, 28
Occasional Marri	8b	1	21a, 28
Marri - Banksia woodland	9	3	28
Eucalyptus todtiana - Banksia woodland	10	2	-
Jarrah - Banksia - Woody Pear woodland	11	4	20b
River Gum - *Melaleuca preissiana* association	12	1	11
River Gum - *Melaleuca rhaphiophylla* swamp	13	3	11,17
Shrubland	14	2	24
Tuart - Marri woodland	15	2	-
Jarrah woodland	16	1	-
Limestone association	17	1	26a

It may be tempting to target the five vegetation associations with only one representative for consideration and reservation but often these were found to occur in highly degraded, small portions of the total area. The limestone association occurred as a small patch on the edge of a degraded Jarrah - *Banksia* woodland and therefore not worthy of conservation. However patch 1653 with the River Gum - *Melaleuca preissiana* association, although small in areas with an understorey of grass weeds, supported a *Eucalyptus todtiana* - *Banksia* woodland and Jarrah - Banksia woodland and therefore is very important for conservation. The three River Gum - *Melaleuca rhaphiophylla* associations all edged wetlands and should therefore all be conserved. All were classified as Good by Mattiske Consulting Pty Ltd mainly on their wetland value rather than their vegetation diversity or intactness.

However of the Banksia associations found there could have been one or a combination of five major Banksia species. These were *Banksia attenuata, Banksia menziesii, Banksia ilicifolia, Banksia grandis* and *Banksia prionotes*. In Appendix B these Banksia species are listed against the patches in which they occur. *Banksia prionotes* was only recorded from 5 areas and at patch 3156 was the only Banksia species recorded, but this patch was classified as poor whereas patch 1167, which included *Banksia prionotes, Banksia attenuata* and *Banksia menziesii* was classified as good, making the latter patch important for reservation.

5.3 Number of Different Vegetation Associations in each Patch

By referring to Appendix A it can be seen that patch 10296 recorded four major vegetation associations within the area, and that one of these associations the Jarrah-Banksia woodland, had two sub-associations, with occasional Marri and occasional Tuart. This patch was given an overall rating of Good - Moderate, so would be worthy of consideration for inclusion in the Urban Bushland Strategic Plan (UBSP), for the variety of vegetation associations present and its condition.

Five of the patches recorded three different vegetation associations. Of these one patch 2781, with the vegetation associations of Tuart woodland, Jarrah - Banksia woodland and Shrubland was assessed as very good and so would be worthy of consideration for inclusion in the Urban Bushland Strategic Plan (UBSP). Two were given an overall classification of good. These were Patch 2590, discussed in the section above and patch 798 with a River Gum woodland, Mixed Banksia woodland and Jarrah - Banksia woodland. Both of these are again very important and so would be worthy of consideration for inclusion in the Urban Bushland Strategic Plan (UBSP).

Two other patches with three vegetation associations, patch 1763 and patch 910, were recorded as moderate. Patch 1763 had vegetation associations Mixed Banksia woodland, Jarrah - Banksia woodland and *Eucalyptus todtiana* - Banksia woodland. The *Eucalyptus todtiana* - Banksia woodland only being recorded from two patches makes this patch important for consideration. Patch 910 with Jarrah Banksia woodland, Marri - Banksia woodland and Jarrah woodland is important for

consideration as this was the only patch recording Jarrah woodland.

The remaining patch with three vegetation associations was patch 8723 which included the limestone area with a rating of poor. This is discussed in Section 5.2 where it is listed as not worthy of consideration.

Although time was not allocated to searching for Rare and Endangered or Priority species, one priority species, *Jacksonia sericea* (Priority 3) was recorded for the following patches, 1526, 1615, 1685, 1770, 1929, 2215, 2982, 3156, 3260 and 5120.

5.4 Comparison between the Vegetation Types of Gibson *et al.* (1994) and the Vegetation Associations of Mattiske Consulting Pty Ltd

Gibson *et al.* (1994) list 10 major Vegetation Types as occurring within the Karrakatta Vegetation Complex. However generally, the typical tree species listed by them for each Vegetation Type is too limited when compared to the findings of Mattiske Consulting Pty Ltd.

Contrary to the Vegetation Types 21a and 21b of Gibson *et al.* (1994), Mattiske Consulting Pty Ltd never found *Banksia attenuata* to occur as the dominant tree species but was always associated with another *Banksia* species, predominantly *Banksia menziesii* (Appendix B). Similarly Gibson *et al.* (1994) Vegetation Type 22 lists *Banksia ilicifolia* as occurring with *Banksia attenuata*, whereas Mattiske Consulting Pty Ltd had *Banksia ilicifolia* occurring with *Banksia attenuata* and *Banksia menziesii*, with one exception, and then *Banksia ilicifolia* occurred associated with *Banksia menziesii*.

Gibson *et al.* (1994) recorded the following Vegetation Types from the Karrakatta Vegetation Complex: Vegetation Types 9, 11, 17, 20(a), 21(a &b&c) 23(b), 24, 25, 26(a&b), 28. The comparison with these Vegetation Types and the Vegetation Associations of Mattiske Consulting Pty Ltd is given in Table 4. This comparison was not easy as the surveying undertaken by Mattiske Consulting Pty Ltd was more detailed than that of Gibson *et al.* (1994), with the possible exception of the *Banksia* woodland. However with the information collected by Mattiske Consulting Pty Ltd the mixed Banksia shrubland is readily further divided into *Banksia attenuata* - *Banksia menziesii* woodland; *Banksia attenuata* - *Banksia ilicifolia* - *Banksia menziesii* woodland; *Banksia attenuata* and/or *Banksia menziesii* - *Banksia prionotes* woodland and *Banksia prionotes* woodland (Appendix C). There is no *Banksia prionotes* woodland listed in Gibson *et al.* (1994).

Within most of the vegetation patches surveyed by Mattiske Consulting Pty Ltd there were two or more vegetation associations present which in some instances, does relate to two or more Vegetation Types of Gibson *et al.*(1994). However it is also apparent by referring to Table 4, where Mattiske Consulting Pty Ltd had separate Associations, in particular the *Eucalyptus* species - *Banksia* woodlands, these were lumped in the

Gibson *et al.* (1994) classification. In addition Mattiske Consulting Pty Ltd found Gibson *et al.* (1994) Vegetation Types 3b and 20b which they recorded as occurring in the Pinjarra Plain Vegetation Complex.

It would therefore be advisable if additional surveying of patches is to occur to list the vegetation associations at each patch and to cross reference these to Gibson *et al.*, (1994) rather than giving the "best fit" Vegetation Type. This will ensure that all vegetation associations are noted especially where diversification occurs within a patch.

5.5 Weeds

For each association within the bushland patch an estimation of the percentage of weeds present was made. There were four categories $<20\%$, 20-40%, 40-80% and $>80\%$. Where the weeds were confined to the margins of the bushland patch and along roadsides the value given was $<20\%$. If the weeds had penetrated into the bushland but the understorey was still in relatively good condition the percentage of weeds was 20-40%. If the whole of the area was covered in weeds but there were still a few of the understorey plants visible the rating was 40-80% and where the whole of the area was covered in weeds, occasionally with scattered to non-existent understorey species it was categorised as $>80\%$.

Occasionally an assessment was made for the whole of the bushland patch, especially where there was only one vegetation association, but this was uncommon, as often it was found that some areas of the bushland patch were relatively weed free whereas others had weeds as the dominant species. The most commonly encountered weeds were: Perennial Veldt grass (*Ehrharta calycina*), Wild Gladiolus (*Gladiolus caryophyllaceus*), African Love Grass (*Eragrostis curvulum*), Lupins (*Lupinus consentinii*), Wild Radish (*Raphanus raphanistrum*), Rose Pelargonium (*Pelargonium capitatum*), Pigface (*Carpobrotus edulis*), Flat Weed (*Hypochoeris glabra*), Couch (*Cynodon dactylon*) and a mixture of annual grasses and daisies. The annual species were only just commencing to germinate but the common annual grasses observes were Blowfly Grass (*Briza maxima*), Hare's Tail Grass (*Lagurus ovatus*), Annual Veldt Grass (*Ehrharta longiflora*), Wild Oats (*Avena fatua* and *Avena barbata*). At Patch 8723 Geraldton Carnation Weed (*Euphorbia terracina*) was common where the limestone was outcropping but was not recorded from any other bushland patches.

5.6 Human Disturbance

With increasing human populations in the area the disturbance by man will continue to increase. In some of the bushland patches 4-wheel drive vehicles had created tracks leading to the destruction of some of the vegetation. In some of the southern areas where horses were kept the tracks through the bushland areas were used as bridle trails. This use of the bushland tracks should be discouraged if the area is to be conserved.

In some of the bushland patches local residents had dumped their garden clippings, some of which had the potential to develop into environmental weeds. One bushland patch adjoining factories in Gnangara Road had a large quantity of plastic dumped on the ground. Old cars were found in many bushland areas as well as general household rubbish.

Five of the bushland patches, 2982, 7879, 8881, 9578, 10296 were already declared reserves. One was under the control of the Department of Conservation and Land Management, the others under the local council but two of these was maintained by the Naturalist Club in the area.

5.7 Surrounding Land Use Pressures

Some of the bushland patches in the northern suburbs were surrounded by large blocks of privately owned land in which a lot of the natural bush had been conserved. It would be advisable to encourage local councils when subdividing land into large blocks to ensure that much of the natural vegetation is retained. This together with a nearby bushland patches will act as corridors for wildlife.

Some of the designated bushland patches adjoined a buffer zone beside a lake. Unfortunately the bushland patch adjoining one such lake has already been released for housing, so the extra buffer zone cannot be added. In future all local councils should be encouraged, where possible, to add extra land to bushland areas around lakes and swamps. Market gardens had been established in several areas surrounding bushland, resulting in the remaining bushland being placed under water stress and competition from the introduction of weeds. Also one bushland area opposite a market garden had been used to dump some excess cucumbers and pumpkins.

Where a bushland area occurs opposite or beside a school the children should be encouraged to become involved in maintenance of the area. Teachers should be encouraged to use the bushland area for educational purposes, not just biology or nature study, but mathematics (tree measurements etc), english (stories about plants, animals etc), social studies (how this bush differs from one in another suburb etc), art and craft (drawing etc) and physical education (orienteering, provided the students are instructed to stay on the tracks).

5.8 Patches Worthy of Consideration in the UBSP

A total of 40 bushland areas may be suitable for consideration, see Appendix C where each of the 73 patches is summarised. A further 3 bushland areas could be suitable for consideration provided money and time can be allocated for their rehabilitation. All the above factors were taken into account when the final recommendations was listed.

6. MANAGEMENT CONSIDERATIONS

If the bushland patches are to be managed for conservation of the biological values a range of management strategies need to be in place. These management strategies should be decided and their organisation and implementation commenced before the patch or bushland area is vested and managed for conservation. Below are listed some of the problems encountered when undertaking the survey.

- Bushland in some of the established areas was degraded yet bushland adjoining new developments was often in a very good condition. To maintain bushland in good condition it must be well managed. It is important to educate the residents of the area, especially those adjoining the bushland, in the importance of maintaining the bushland structure for aesthetic reasons, the improvement of the local ecosystem, as a buffer to heavy traffic noise and not as a haven for snakes, spiders etc. and a fire risk.

- To maintain a good bushland patch the local residents must not use the area for dumping of garden and household rubbish and when walking through the area to stay on paths or tracks.

- The local council should be encouraged to spray a selective weedicide to control the weeds on the bushland verges and those along gazetted tracks within the bushland patch.

- If possible community groups, including schools, should be encouraged to become interested in their bushland patch and to assist with its policing and rehabilitation. An excellent example of this was the Cardup Reserve where the local Naturalist Club was involved with its maintenance.

- Any excessive or non-formal tracks within a bushland patch should be closed and rehabilitated. If the bushland is in good condition, rehabilitation will take place naturally.

- Firebreaks must be maintained by the local council and the community educated in the problems of fires. It should be emphasised that regular fires in a bushland area will allow weeds to invade which in themselves become more of a fire hazard than the natural bush. By developing local community groups responsible for bushland patches they can then report any outbreak of fires.

- Bushland areas should be prominently labelled giving the name of the patch or reserve and the "rules", eg. no dogs, walk trail etc.

The important underlying aspect of all this is the need:

- to educate the community, local councils and especially those personnel responsible for bushland maintenance and schools in the importance of their local areas, and

- to encourage them to use the bushland areas for their recreation and education and to make them responsible for its continued maintenance.

7. RECOMMENDATIONS

Very few bushland patches remain in well established suburbs so it is important that local councils and the Ministry for Planning include reasonable size bushland areas in any new development. The area of the bushland patches must be of several hectares to ensure the preservation of its environmental integrity and provide a habitat large enough for animals, including kangaroos.

In determining which bushland areas should be considered in the Urban Bushland Strategy Plan for conservation a range of factors need to be considered. These include representation of the vegetation complexes and vegetation associations on a local and regional basis, the percentage of weeds and their distribution within the area, the amount of human disturbance already recorded in the bushland patch and the surrounding land use.

An on the ground survey is necessary before an area can be assessed for its biological values. The integrity of the area, the vegetation associations present and any significant plants and animals in the area should be included in the assessment. The necessity for an on the ground assessment has been indicated in this current assessment of the Karrakatta Complex - Central and South.

8. LIST OF PARTICIPANTS

The following personnel assisted in various stages of the project:

Principal Plant Ecologist and Study Coordinator:
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Principal Botanist:
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APPENDIX A: PATCH NUMBER, CONDITION CLASSIFICATION ASSESSED BY MATTISKE CONSULTING PTY LTD (MCPL) AND MINISTRY FOR PLANNING (MFP) AND VEGETATION

Occurrence Id No	Patch Id No	MFP Condition Classification	MCPL Condition Classification	Major Vegetation Association	System 6 Vegetation Complex
486	781	Good	V Good	6,8	K
589	972	V Good	V Good	8	K
634	1167	V Good	Good	8,3	K
798	1272	Good	Good	5,6,8	K
910	1440	Good	Moderate	8,9,16	K
977	1526	Good	Good - Moderate	8,15	K
1012	1566	Good	Moderate	4,8	K
1014	1615	Good	V Good	8	K
1093	1685	Good	Poor	1	K
1140	1770	Good	Good	7,8	K
1142	1772	Good	V Good	4,8	K
1153	1786	Good	Moderate - Good	6,14	K
1243	1929	Good	V Good - Good	8	K
1254	1945	Good	V Good	7,8	K
1273	1974	Good	V Good	6,8	K
1277	1978	Good	V Good	8	K
1286	1995	Good	Good	8	K
1296	2013	Good	Good	6,8	K
1339	2085	Good	Moderate - Poor	8	K
1354	2107	Good	Housing	N/A	K
1358	2115	Poor	Good - Moderate	8	K
1371	2139	Good	Housing	N/A	K
1388	2167	Good	Good	8	K
1419	2215	Good	Good	6,8	K
1503	2379	Good	Moderate	6	K
1622	2536	V Good	Poor	1,6	K
1653	2590	Good	Good	8,10,12	K
1728	2707	V Good	Poor	4	K
1763	2768	Good	Moderate	6,8,10	K
1774	2781	Good	V Good	1,8,14	K
1865	2919	Good	Developed	N/A	K
1886	2948	Good	Developed	N/A	K
1908	2982	Good	V Good	2	K
1971	3081	Good	Good	8	K
1974	3084	Good	V Good	8	K
1975	3085	Good	V Good	8	K

APPENDIX A: PATCH NUMBER, CONDITION CLASSIFICATION ASSESSED BY MATTISKE CONSULTING PTY LTD (MCPL) AND MINISTRY FOR PLANNING (MFP) AND VEGETATION

Occurrence Id No	Patch Id No	MFP Condition Classification	MCPL Condition Classification	Major Vegetation Association	System 6 Vegetation Complex
2023	3156	Poor	Poor	6	K
2033	3175	Good	V Good	6,8	K
2083	3259	Poor	V Poor	8	K
2084	3260	Good	V Good	6,8a	K
2374	3724	Poor	Poor	6	K
2418	3785	Poor	V Poor	4	K
2475	3864	Good	Moderate	3 (+ plantings)	K
2549	3976	Good	V Good	8	K
2685	4209	Good	Good	6	K
3201	5120	Good	Poor	8,8a	K
4189	6887	Good	Good	8,11	K
4287	7100	Good	Good	4,8	K
4385	7221	Good	Good	8	K
4548	7480	V Good	Moderate	8a	K
4738	7879	V Good	Moderate	8,8a	K
4937	8093	Good	Good	8,11	K
4979	8162	Good	Moderate	8	K
4976	8180	Good	V Poor	8	K
5091	8384	Good	Moderate	8	K
5170	8515	Good	V Good	6	K
5170	8723	Good	Poor	1,8,17	K
5342	8801	Good	V Poor	7,9	K
5356	8881	Good	Good	4	K
5711	9578	Good	V Good - Moderate	8,9	K
6040	10016	Poor	Poor	9	K
6065	10072	Poor	V Poor	1	K
6095	10143	Poor	Poor	2	K
6106	10163	Poor	Housing	N/A	K
6135	10222	Poor	Good	8,8a	K
6152	10252	Poor	Housing	N/A	K
6173	10296	Poor	Good-Moderate	1,8a,8b,11,15	K
6194	10328	Good	Good	1,13	K
6270	10458	Poor	Good	8a,13	K
6194	10488	Good	Good	8a,13	K
6325	10553	Good	Moderate - Poor	1	K
6428	10726	Poor	Moderate	1,11	K
6487	10838	Good	Good	1,5	K

APPENDIX B: BANKSIA SPECIES AND THE VEGETATION ASSOCIATIONS IN WHICH THEY OCCUR RELATED TO PATCH NUMBER

Patch Id No	*Banksia attenuata*	*Banksia grandis*	*Banksia ilicifolia*	*Banksia menziesii*	*Banksia prionotes*	Vegetation Associations					
						6	7	8	9	10	11
781	x			x		x		x			
972	x		x	x				x			
1167	x			x	x				x		
1272	x		x	x		x		x			
1440	x		x	x				x	x		
1526	x		x	x				x			
1566	x			x				x			
1615	x		x	x				x			
1770	x			x			x	x			
1772	x	x		x				x			
1786	x		x	x		x					
1929	x			x				x			
1945	x			x			x	x			
1974	x		x	x		x		x			
1978	x		x	x				x			
1995	x			x				x			
2013	x		x	x		x		x			
2085	x	x						x			
2115	x	x		x				x			
2167	x			x				x			
2215	x				x	x		x			
2379	x			x		x					
2536	x					x					
2590	x		x	x				x		x	
2768	x		x	x		x		x		x	
2781	x			x				x			
3081	x			x				x			
3084	x			x				x			
3085	x			x				x			
3156					x	x					
3175	x			x		x		x			
3259	x			x				x			
3260	x		x	x		x		x			

APPENDIX B: BANKSIA SPECIES AND THE VEGETATION ASSOCIATIONS IN WHICH THEY OCCUR RELATED TO PATCH NUMBER

Patch Id No	*Banksia attenuata*	*Banksia grandis*	*Banksia ilicifolia*	*Banksia menziesii*	*Banksia prionotes*	Vegetation Associations					
						6	7	8	9	10	11
3724	x			x	x	x					
3864	x	x			x			x			
3976	x			x				x			
4209	x			x		x					
5120	x	x	x	x				x			
6173	x			x				x			
6887	x			x				x			x
7100	x			x				x			
7221	x			x				x			
7484	x			x				x			
7879	x	x		x				x			
8093	x			x				x			x
8162	x	x		x				x			
8180	x		x	x				x			
8384	x		x	x				x			
8515	x			x		x					
8723	x	x						x			
8801	x	x		x			x		x		
9578	x		x	x				x	x		x
10016			x	x					x		
10222	x	x		x				x			
10296	x	x		x				x			x
10458	x			x				x			
10726	x			x							x

URBAN BUSHLAND ADVISORY GROUP
ANALYSIS OF VEGETATION COMPLEX
URBAN BUSHLAND STRATEGIC PLAN (UBSP)

NAME OF COMPLEX: KARRAKATTA COMPLEX CENTRAL AND SOUTH

SUMMARY INFORMATION

COMPLEX NO: 49

AREA IN SECURE TENURE: 2138 ha

ADDITIONAL AREA REQUIRED FOR SECURE TENURE: 1322 ha

AREA AVAILABLE: 5116 ha

6.1% of the complex is in secure tenure, with 20.9% remaining in the PMR

COMPLEX DESCRIPTION:

SWAN COASTAL PLAIN - AEOLIAN DEPOSITS Predominantly low open forest of *E. gomphocephala - E. marginata - E. calophylla* and woodland of *E. marginata - Banksia* spp.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

2. Patch 634.1167 Adjacent to Neerabup National Park
Total area of bushland 34.1 ha

Zoning: Rural (34.1 ha of bush)

No of Lots: There are 8 lots involved which vary in size from 1.3 to 140.2 ha. The area of vegetation on each lot ranges in size from 0.1 to 8.9 ha.

Ownership: Private Persons (5 lots) State Government (3 lots)

Conclusion: At the present time, this patch is a good candidate for UBAG to include in the Urban Bushland Strategic Plan.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Portion along Burns beach Road lost to road extension.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Marri Woodland	~~3b~~ 28	20-40%
Jarrah - Banksia woodland	28	<20%

Important species: *Banksia prionotes*

Adjacent land use: Strawberry farm, horse hire, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

3. Patch 4548.7480 Yangebup and Success (Adjacent to Thomsons Lake) Total area of bushland 128.7 ha

The patch has: another vegetation complex adjacent, is adjacent to secure tenure (Thomsons Lake), adjacent to protected area, has DRF within 500m.

Zoning: Urban (124.5 ha of bush) Urban Deferred (2.3 ha of bush) Rural (1.9 ha of bush)

No of Lots: Some of Urban area has been subdivided for residential and has many lots (> 100). 4 Rural lots, 2 Urban Deferred. Lots range in size from ~ 500m square to 2 ha.

Ownership: Urban area is being developed by Homeswest. Part of this area has been subdivided and sold to private persons. The other land owners include: State Government (4 lots), private persons (2 lots).

Conclusion: Parts of this area may be suitable for inclusion in UBSP. The provision of bushland POS in urban development needs to be investigated. Urban area is already committed.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate, due to human disturbance. Housing development on north and south side of Beeliar Road. Corner of Spearwood Avenue and Beeliar Road cleared for road works.

Recommendation: Not suitable for consideration in UBSP due to size and bushland condition.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland, occasional Tuart	21a	20-40%

Adjoining land use: Residential.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

4. Patch 1728.2707 Woodvale
Total area of bushland: 28.2 ha

The patch has: no abutting vegetation complexes

Zoning: Urban. Almost complete area has been subdivided for residential development

No of Lots: ~300 lots of residential size

Ownership: Mostly Private Persons

Conclusion: This area has already been developed.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Poor
Extends onto a recreation area.

Recommendation: Not suitable for consideration as UBSP due to degradation of the bushland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Marri woodland	~~3b~~ 2.8	80%

Adjacent land use: Houses, oval, tennis court

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

5. Patch 4738.7879 Wattleup
Total area of bushland 26.3 ha

This patch has: Another vegetation complex abutting, adjacent to secure tenure and protected area. DRF within 500m.

Zoning: Rural (26.3 ha of bush)

No of Lots: Rural (22 lots ranging from 1 ha to 2 ha)

Ownership: Private Persons (21 lots) Crown Land (1 lot)

Conclusion: The lots in this patch of bush are small special rural lots. This area is not a good candidate for the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate
Includes Holdsworth Reserve; vegetation poor in remaining bushland. Private property along Pearce Road, McLeod Rd and north side of Dalison Rd.

Recommendation: Holdsworth Reserve could be considered suitable for possible inclusion in UBSP provided rehabilitated.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland, occasional Tuart	21a	40-80%
Jarrah - Banksia woodland	21a	20-40%

Adjoining land use: Residential, horse properties.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

6. Patch 1622.2536 Craigie/Padbury
Total area of bushland: 22 ha

The patch has: adjacent area in secure tenure, also policy and protected areas nearby.

Zoning: Public Purposes - Water (13.5 ha of bush) Road Reserve (7.3 ha of bush) Urban (1.2 ha of bush)

No of Lots: Public Purposes (1 lot, 82 ha) Road Reserves (2 areas, 7.3 ha) Urban 840.7ha)

Ownership: All Crown Land

Conclusion: Liaison should be held with Water Authority Corporation regarding intention for Public Purpose reserve. Other areas have limited potential for inclusion in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Poor
Water Authority Corporation land which includes a Waste Treatment Plant.

Recommendation: Not suitable for consideration in UBSP due to its bushland condition.

Vegetation Associations	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart woodland	24	40-80% +
Banksia woodland	23a	40-80%

Adjoining land use: Freeway, residential

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

7. Patch 589.1123 Neerabup
Total area of bushland: 7.9 ha

The patch has: Another vegetation complex abutting, adjacent to secure tenure and policy area.

Zoning: Rural (6.6 ha of bush) Unidentified (1.3 ha of bush)

No of Lots: Rural (8 lots ranging from 1 to 1.5 ha)

Ownership: Private persons

Conclusion: This area is not a good candidate for inclusion in UBSP due to small lot sizes.

8. Patch 4548.7717 Success
Total area of bushland: 3.9 ha

The patch has: Another vegetation complex abutting, adjacent to secure tenure, policy and protected area. DRF within 500m.

Zoning: Rural (3.9 ha of bush)

No of Lots: Rural (3 lots ranging from 1.8 to 1.9 ha)

Ownership: Private persons

Conclusion: This area has been subdivided for Special Rural and is not suitable for inclusion in UBSP.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Very Good condition and top 5% of EASY Index

9. Patch 4738.7828 Success
Total area of bushland: 2.8 ha

The patch has: Another vegetation complex abutting, is adjacent to policy and protected areas. DRF is within 500m.

Zoning: Rural (2.5 ha of bush)

No of Lots: Rural (5 lots ranging from 0.8 to 1.4 ha)

Ownership: Private Persons

Conclusion: This area has been divided for Special Rural and is not suitable for inclusion in the UBSP.

10. Patch 4738.7862
Total area of bushland: 2.6 ha

The patch has: Another vegetation complex abutting

Zoning: Rural (2.5 ha of bush)

No of Lots: Rural (5 lots ranging from 0.3 to 1.4 ha)

Ownership: Private Persons

Conclusion: This area has been subdivided for Special Rural and is not suitable for inclusion in the UBSP.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

(NOT on MAP)

11. Patch 486.781 North of Flynn Dr, Neerabup
Total area of bushland 200.7 ha

The patch has: another vegetation complex abutting, adjacent to secure tenure, adjacent to policy area.

Zoning: Industrial (194.5 ha of bush) Public Purposes -Water Authority (6.2 ha of bush)

No of Lots: Industrial (5 lots ranging from 48 ha to 100 ha) Public Purposes

Ownership: Private Persons (3 lots) Local Government (2 lots) State Government (1 lot plus 3 P&R lots)

Conclusion: Several of the Industrial lots are large with Vegetation in good condition. This area should be considered for the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good
Quarry established on north side of Flynn Rd.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%
Banksia woodland	23a	<20%

Adjoining land use: Industry

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

12. Patch: 1388.2167 Gnangara
Total area of bushland 388.7 ha

The patch has: Another vegetation complex abutting, is adjacent to secure tenure and policy areas.

Zoning: Rural (~199 ha of bush) Industrial (170.4 ha of bush) Road Reserve (4.0 ha of bush)

No of Lots: Rural (137 lots ranging in size from 0.1 to 25.1 ha) Industrial (85 lots ranging from 3.6 ha to 105 ha)

Ownership: Commercial Organisation (18 lots) State Government (30 lots)

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
About 50% of the original area now developed for housing or industry, however a reasonably large area remains.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%
Adjoining Badgebup Lake		40-80%

Adjoining land use: Residential, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

13. Patch: 1653.2590 Gnangara
Total area of bushland: 41 ha

The patch has: Another vegetation complex abutting, adjacent to policy, secure and protected areas.

Zoning: Rural (25.7 ha of bush) Urban Deferred (4.5 ha of bush) Industrial (4.0 ha of bush) Important Regional Road (6.3 ha of bush)

No of Lots: Rural (17 lots ranging in size from 0.1 ha to 20.3 ha. Areas of bush on these lots ranges from 0.1 to 5.8 ha) Urban Deferred (1 lot of 4.7 ha) Industrial (2 lots ranging from 0.1 ha to 105 ha) Important Regional Road (1 lot of 6.4 ha)

Ownership: Commercial Organisation (3 lots) Private Person (13 lots) State Government (3 lots) Crown Land (2 lots)

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good. Houses on portion of eastern edge.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%
River Gum - *Melaleuca preissiana* woodland	no equivalent 14	40-80%
Eucalyptus todtiana - Banksia woodland	11	<20%

Adjoining land use: Residential, industrial, golf course, Gnangara Aboriginal Community

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

14. Patch 1763.2768 Landsdale
Total area of bushland: 143.5 ha

The patch has: Another vegetation complex abutting.

Zoning: Urban deferred (6.7 ha of bush) Urban (109 ha of bush) Industrial (23.5 ha of bush)

No of Lots: Urban Deferred (2 lots ranging in size from 2.1 to 39.5 ha) Urban area (~200 residential sized lots, Larger lots - 6 ranging from 4 ha to 48 ha). Industrial (2 lots ranging from 6.8 ha to 33.5 ha)

Ownership: Private Persons, Commercial Organisations

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate
Proposed housing development.

Recommendation: Could be considered for inclusion in UBSP due to presence of interesting vegetation associations, but could be further degradation due to encroaching land use.

Vegetation Associations	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	22	<20%
Eucalyptus todtiana Banksia woodland	no equivalent	<20%
Jarrah Banksia woodland	28	<20%

Important species: *Banksia prionotes* and *Banksia ilicifolia*

Adjoining properties: Housing, market gardening, floriculture

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

15. Patch 1774.2781 Pinnaroo Memorial Park, Padbury
Total area of bushland 116.6 ha

The patch has: Another vegetation complex abutting, adjacent to secure tenure, adjacent to protected area

Zoning: Public Purposes (106.1 ha of bush). Urban (10 ha of bush)

No of Lots: Public purposes (11 lots ranging in size from 2.8 ha to 25.9 ha. Bushland in the lots ranges from 0.1 ha to 25.8 ha) Urban (residential lots and 3 larger lots ranging from 0.7 to 3 ha.

Ownership: State Government (11 lots, 116.3 ha)

Conclusion: This area of bushland warrants further investigation and may be included in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very Good

Recommendation: Consider for inclusion in UBSP

Vegetation Associations	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah Banksia woodland	28	<20%
Tuart woodland	24	40-80%
Shrubland with emergent Tuart	24	20-40%

Important species: *Banksia grandis* and *Banksia prionotes* (2). *Melaleuca huegelii* (3).

Adjoining properties: Residential, freeway, parkland, joins Hepburn Heights conservation area.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

16. Patch 4189.6887 Bibra Lake
Total area of bushland: 35 ha of bush

The patch has: Another vegetation complex abutting, adjacent to secure tenure and policy area.

Zoning: Urban (7 ha of bushland) Road Reserves (28 ha of bush)

No of Lots: Urban (8 lots ranging from 0.3 ha to 2 ha)

Ownership: Commercial Organisations

Conclusion: This area is not a good candidate for inclusion in the UBSP due to commitment of reserves for roads. Urban portion has only small area of this complex.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Large areas developed for housing along Forrest Rd, Phoenix Rd and Sudlow Rd.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	20-40%
Jarrah - Banksia - Woody Pear woodland	20b	20-40%

Important species: *Xylomelum occidentale*, Woody Pear.

Adjoining land use: Residential, main roads

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

17. **Patch 4976.8180 Mandogalup, The Spectacles, Postans, Hope Valley**
Total area of bushland: 162.4 ha

The patch has: Other vegetation complex abutting, adjacent to secure tenure , policy and protected areas.

Zoning: Rural (142.8 ha of bush) Road Reserves (~20 ha)

No of Lots: Rural (10 lots)

Ownership: Private Persons (1 lot, 49.9 ha total size) Crown Land (8 lots, 0.2 - 121.9 ha total size.

Conclusion: This area of bushland warrants further investigation for inclusion in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very poor
Includes quarry and shire dump

Recommendation: Not suitable for consideration in UBSP due to condition.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	40-80%

Adjoining land use: Quarry, Alcoa of Australia Limited, rural, disturbed bushland

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

18. **Patch 5170.8515 Orelia**
Total area of bushland: 80.4 ha

The patch has: Another vegetation complex abutting. Secure, policy and protected areas are adjacent. DRF is within 500m.

Zoning: Crown - Public Purposes Water (21.8 ha of bush) Urban (59 ha of bush)

No of Lots: Crown - Public Purposes Water (2 lots from 11.9 ha to 30.2 ha) Urban 8 lots ranging from 1.6 ha to 14.7 ha)

Ownership: Crown Land vested in Water Authority Corporation, State Government.

Conclusion: Liaison should be held with Water Authority Corporation to find out intentions for this area. Urban area is already committed.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good
Perimeter only bushland. Remainder developed as housing.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	23a	<20-80%.

Adjoining land use: Residential.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

19. **Patch 5170.8723 Parmelia**
Total area of bushland: 21.6 ha

The patch has: Other vegetation complexes abutting. It is adjacent to secure tenure, policy and protected areas. DRF is within 500m.

Zoning: Public Purposes - High school (7.6 ha of bush) Urban (13 ha of bush)

No of Lots: Public Purposes - High School (1 lot, 12.1 ha) Urban (1 lot, 91 ha)

Ownership: Public Purposes - High School - Crown Land, Urban State Government

Conclusion: This area of bushland warrants further investigation for inclusion in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Poor
Most of the area currently being developed for housing with building lots advertised for sale, roads under construction and enhancement with rose beds.

Recommendation: Not suitable for consideration in UBSP due to large housing development of the area.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Marri woodland	21a	40-80%
Tuart woodland	24	40-80%
Limestone outcrop	26a	40-80%

Interesting species: The limestone formation was not seen in any of the other patches assessed.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

20. Patch 5356.8881 Leda
Total area of bushland: 74.5 ha

The patch has: Another vegetation complex abutting, secure tenure and policy areas adjacent

Zoning: Urban (74.5 ha of bush)

No of Lots: Urban (Residential size and 2 larger lots)

Ownership: State Government

Conclusion: This area warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Includes Department of Conservation and Land Management managed Leda Reserve. Houses are developed along the streets and the bushland is behind the houses.

Recommendation: Could be considered for inclusion as UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Marri woodland with Tuart	3b	<20% - 80%

Surrounding land use: Residential

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

21. Patch 6194.10328 Baldivis
Total area of bushland: 57.4

The patch has: Another vegetation complex abutting.

Zoning: Rural (51.1 ha of bushland)

No of Lots: Rural (17 lots, ranging from 3.9 ha to 27.3 ha)

Ownership: Private Persons (16 lots) Commercial Organisation (1 lot)

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Housing along east and west sides of Jarvis Rd. Bushland area is behind private property.

Recommendation: Consider for inclusion in UBSP as a wetland is considered in this vegetation patch.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart woodland	24	40-80%
Melaleuca rhaphiophylla swamp	11	<20%

Adjoining land use: Nursery, grazing, residential.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

22. Patch 6194.10488 Baldivis
Total area of bushland: 38.6 ha

The patch has: Another vegetation complex abutting.

Zoning: Rural (38.5 ha of bushland) Urban Deferred (0.1 ha of bushland)

No of Lots: Rural (11 lots ranging from 8.1 ha to 15 ha) Urban Deferred (1 lot, 25.3 ha)

Ownership: Rural - Private Persons 9 lots, Commercial Organisation 1 lot. Urban Deferred 1 lot.

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Site not visited as surrounded by private property.

Recommendation: Consider for inclusion in UBSP as includes wetland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland occasional Tuart	21a	Unknown.
Melaleuca rhaphiophylla swamp	11	Unknown

Adjoining land use: Market garden, private property

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

23. Patch 6325.10553 Karnup
Total area of bushland: 120.1 ha

The patch has: Another Vegetation complex abutting. Adjacent to secure tenure and policy area.

Zoning: Rural (91.3 ha of bushland) Urban Deferred (24.7 ha)

No of Lots: Rural (15 lots ranging from 3 ha to 33 ha) Urban Deferred (5 lots ranging from 4 ha to 25.3 ha)

Ownership: Private Ownership (19 lots) Commercial Organisation (1 lot)

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate - poor
Most of the area developed for housing.

Recommendation: Not suitable for consideration in UBSP due to large development of the area.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart woodland	24	80%

Adjoining land use: Private property

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

24. Patch 6487.10838 Karnup
Total area of bushland: 36.9 ha

The patch has: Another vegetation complex abutting. Adjacent to secure tenure and policy areas.

Zoning: Rural (14.9 ha of bush) Road Reserves (22 ha of bush)

No of Lots: Rural (4 lots ranging from 3.9 ha to 26.2 ha)

Ownership: Private Persons (4 lots)

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Northern section of original area only not developed but will act as a wildlife corridor for Pagononi Swamp.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
River Gum woodland	11	<20%
Tuart woodland	24	20-40%

Adjoining land use: Residential, grazing, tree plantation.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and Top 5% in EASY Index

25. Patch 4979.8162 Hope Valley, The Spectacles
Total area of bushland: 99.2 ha

The patch has: No other vegetation complex adjacent

Zoning: Rural (98.6 ha of bush)

No of Lots: Rural (9 lots, ranging from 6.6 ha to 35.8 ha)

Ownership: Private Persons (5 lots) State Government (2 lots) Crown Land (1 lot) Commercial Organisation (1 lot)

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate
Tree storey good but understorey very degraded.

Recommendation: Not suitable for consideration in UBSP due to degradation of understorey species.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	40-80%

Adjoining land use: Alcoa of Australia Limited red mud lakes, quarry

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

26. Patch 798.1272 Wanneroo
Total area of bushland: 71.9 ha

The patch has: No other adjacent vegetation complexes.

Zoning: Urban (71.9 ha of bush)

No of Lots: Urban (5 lots ranging from 5 ha to 352 ha)

Ownership: Private Persons, Commercial Organisations and Unidentified

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	Unknown.
River Gum woodland with *Kunzea ericifolia*	11	40-80%
Banksia woodland	22	<20%

Adjoining land use: Industrial, residential

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

27. Patch 1142.1772 Wanneroo
Total area of bushland: 62.6

The patch has: No other vegetation complex abutting.

Zoning: Urban Deferred (44.5 ha of bush) Rural (5.2 ha of bush) Urban (12 ha of bush)

No of Lots: Urban Deferred (2 lots, ranging from 35.9 to 40.1 ha) Rural (5 lots, ranging from 1.6 to 2 ha) Urban (4 lots, 1 ha to 9.3 ha)

Ownership: Private Person (5 lots) Commercial Organisation (7 lots)

Conclusion: This area of bushland warrants further investigation and may be included in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good
Chicken farm developed in northern area; special rural housing and market garden on eastern edge of Griffiths Rd.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%
Marri - Jarrah woodland	~~3b~~	40-80%

Adjacent land use: Chicken farm, school, Department of Conservation and Land Management land.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

28. Patch 1277.1978 Wanneroo
Total area of bushland: 49.1 ha

The patch has: No other vegetation complex abutting.

Zoning: Rural (48.2 ha of bushland)

No of Lots: Rural (21 lots ranging from 1 ha to 4.4 ha)

Ownership: Commercial Organisation (2 lots) Private Persons (18 lots) Crown Land (1 lot)

Conclusion: This area of bushland warrants further investigation and may be included in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good
Only a small area of bushland remains. Housing blocks are large and have retained large amounts of the bushland.

Recommendation: Consider for inclusion in UBSP although remaining bushland is considerably reduced.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%

Adjoining land use: Residential, market garden

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

29. Patch 1354.2107 Wanneroo
Total area of bushland: 51 ha

The patch has: secure tenure and protected areas adjacent.

Zoning:	Rural (38.1 ha of bush)
No of Lots:	Rural (118 lots, ranging from 0.2 to 2.8 ha
Ownership:	Commercial Organisation (11 lots) State Government (2 lots) Crown Land (1 lot) Private Persons (114 lots)
Conclusion:	This patch is made up of very small lots with many land owners. Therefore, opportunities for inclusion in UBSP are limited.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Developed as residential housing.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

30. Patch 2033.3175 Landsdale
Total area of bushland: 52 ha

The patch has: no other vegetation complexes abutting

Zoning: Urban Deferred (19.6 ha of bush) Urban (21 ha of bush Note: some of this area has been cleared) Road Reserve (8.5 ha of bush)

No of Lots: Urban Deferred (10 lots ranging from 0.8 to 16.1 ha)

Ownership: Crown Land (2 lots, one of which is the Landsdale Threatened Community. This area will be zoned P&R in the NW Corridor Omnibus Amendment) State Government (1 lot) Private Persons (7 lots)

Conclusion: This area has had 15.1 ha reserved for P&R. Most of the rest of the area is zoned Urban or for a road reserve. Therefore it is not likely that more of the area can be included in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very Good
Buddist Monastry on Evandale Rd and housing on Landsdale rd.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson et al. (1994) Classification	% Weeds Present
Jarrah Banksia woodland	23a	<20%
Banksia woodland	28	<20%

Adjoining properties: Residential, floriculture, market garden, conservation park in good condition.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

31. Patch 2549.3976 Dianella
Total area of bushland: 92.9 ha (Some of which has already been cleared for residential development)

The patch has: Another vegetation complex abutting.

Zoning: Urban (~62 ha of bush remaining)

No of Lots: Urban (5 lots ranging from 10 ha to 31 ha

Ownership: Local Authority, State Government

Conclusion: Most of this area has been committed for development. Officers will find out if any of this area has been set aside for bushland public open space.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	20-40%

Adjoining land use: Residential, main road.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

32. Patch 3201.5120 Shenton Park
Total area of bushland: 53.1 ha

The patch has: no other vegetation complexes abutting

Zoning: Public Purposes - Hospital (1.6 ha of bush) Public Purposes - Water (3.8 ha of bush) Urban (49 ha of bush)

No of Lots: Public Purposes - Hospital (4 lots ranging from 0.4 ha to 15.6 ha Public Purposes - Water (5 lots ranging from 0.3 - 11 ha) Urban (7 lots)

Ownership: Crown Land (5 lots) Commercial Organisation (11 lots)

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Poor
Patch includes University of Western Australia research station. However it is one of the few remaining bush areas in this old established suburb.

Recommendation: Should be considered for inclusion in UBSP as it is one of the few remaining areas of bushland in this suburb but would required a considerable amount of rehabilitation.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	40-80%

Important species: *Jacksonia sericea* (Priority 3)

Adjoining land use: Hospital, University of Western Australia, Water Authority Corporation, Agriculture Western Australia.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

33. Patch 4287.7100 Bibra Lake
Total area of bushland: 61.2

The patch has: Another vegetation complex abutting, secure, policy area and DRF.

Zoning: Industrial (~60 ha of bush) Road Reserve (~2 ha of bush)

No of Lots: Industrial (3 lots ranging from ha to 128 ha)

Ownership: Unidentified (1 lot), Commercial Organisations (2 lots)

Conclusion: This area warrants further consideration in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Surrounded by barbed wire fence.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	<20%
Marri - Jarrah woodland	3b	40-80%

Adjoining land use: Factory, quarry, main roads.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

34. Patch 4937.8093 Hope Valley
Total area of bushland: 48.2 ha

The patch has: Another vegetation complex abutting.

Zoning: Rural (47.6 ha of bush)

No of Lots: Rural (21 lots, ranging from 0.6 and 20.3 ha)

Ownership: Private Persons (19 lots) Commercial Organisation (1 lot) State Government (1 lot)

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Large are developed for housing.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson et al. (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	40-80%
Jarrah - Banksia - Woody Pear woodland	20b	20-40%

Important species: *Xylomelum occidentale.* There is very little of this association in reservation.

Adjoining land use: Residential, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good condition and top 6 - 10% of EASY Index

35. Patch 5091.8384 Postans, The Spectacles
Total area of bushland: 57.8 ha

The patch has: another vegetation Complex adjacent

Zoning: Rural (29.8 ha of bush) Public Purposes - Special (26.8 ha of bush)

No of Lots: Rural (6 lots ranging from 0.5 - 66 ha) Public Purposes - Special (2 lots ranging from 10.7 - 57 ha)

Ownership: Crown Land (5 lots) State Government (2 lots) Commercial Organisation (1 lot)

Conclusion: This area of bushland warrants further investigation for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate
Large block on corner of McLaughlin Rd and Thomas Rd developed as Emu farm. Includes Water Authority Corporation land.

Recommendation: Not suitable for consideration in UBSP due to insufficient land remaining.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	20-80%

Adjoining land use: Part of the original patch now an emu farm, part owned by Water Authority Corporation, remainder residential.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

36. Patch 910.1440 Wanneroo
Total area of bushland: 38.9 ha

The patch has: no vegetation complex abutting.

Zoning: Urban (8 ha of bush) Urban Deferred (30.6 ha of bush)

No of Lots: Urban (5 lots ranging from 0.4 - 11.3 ha) Urban Deferred (12 lots ranging from 1.6 ha to 21.6 ha)

Ownership: Private Persons and State Government

Conclusion: The Urban Deferred area warrants consideration for inclusion in UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate.
Area south of Ashley Rd developed as market garden. Some areas are very good, others degraded.

Recommendation: Could be considered for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart - Marri woodland	24	<20%
Marri - Banksia woodland	28	40-80%
Jarrah - Banksia woodland	28	<20%

Adjacent land use: Market gardens, floriculture, Shire depot

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

37. Patch 1865.2919 Landsdale
Total area of bushland: 35.6 ha

The patch has: no other vegetation complex abutting.

Zoning: Urban Deferred (32.5 ha of bush) Industrial (1.9 ha of bush) Road Reserve (1.1 ha of bush)

No of Lots: Urban Deferred (8 lots ranging from 1.3 ha to 40.6 ha) Industrial (1 lot, 4.4 ha) Road Reserve (1 area, 4.5 ha)

Ownership: Commercial Organisation, Private Persons, Local Government

Conclusion: The bushland on the largest Urban Deferred lot warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Developed.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

38. Patch 2084.3260 Alexander Heights/Marangaroo
Total area of bushland: 31.3 ha

The patch has: no other vegetation complex abutting.

Zoning: Urban (22.7 ha of bush) Public Purposes - High School (8.6 ha of bush)

No of Lots: Urban (27 lots ranging from 0.1 ha to 5.6 ha) Public Purposes - High School (1 lot, 10 ha)

Ownership: Private Persons, State Government, Crown Land, Commercial Organisations

Conclusion: This area comprises small lots (Check to see how much has been cleared for residential development. Officers to check SP to see if any of the area will be reserved as bushland public open space.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good.
Area of disturbance running north-south from near Crabtree Road.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	22	<20%
Banksia woodland with emergent Jarrah and Tuart	28	<20%

Important species: *Jacksonia sericea* (Priority 3)

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

39. Patch 1419.2215 Wanneroo
Total area of bushland: 31 ha

The patch has: No other vegetation complex abutting.

Zoning: Urban (31 ha of bush)

No of Lots: Urban (8 lots ranging from 2..4 - 8.7 ha)

Ownership: Private Persons, Commercial Organisations

Conclusion: This area warrants further consideration for inclusion in the UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Portion burnt in 1995-1996 summer

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	20-40%
Banksia woodland - *Banksia prionotes* and *B. grandis*	No equivalent	20-40%

Important species: *Banksia prionotes* and *Banksia grandis*. *Jacksonia sericea* (Priority 3)

Adjoining land use: Residential, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

40. Patch 4385.7221
Total area of bushland: 28.4 ha

The patch has: Another vegetation complex adjacent

Zoning: Railway Reserve (3.6 ha of bush) Industrial (24 ha of bush)

No of Lots: Railway reserve (lots ranging from 1.5 to 5.6 ha) Industrial (lots ranging from 0.3 to 16 ha

Ownership: State Government, Commercial Organisations, Local Government, Private Persons

Conclusion: The 16 ha lot and most suitable surrounding lots warrant consideration for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good
Quarry developed along railway line.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	<20%

Adjoining land use: Quarry, railway line, main roads

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

41. Patch 1153.1786
Total area of bushland: 27.5 ha

The patch has: no other vegetation complexes abutting

Zoning: Rural (2.1 ha of bush) Urban (19.5 ha of bush) Public Purposes - Water (2.9 ha of bush)

No of Lots: Rural (9 lots ranging from 0.1 to 3.9 ha) Urban - Many (~ 150) small lots Public Purposes (1 lot, 31.5 ha)

Ownership: State Government, Private Persons, Commercial Organisations

Conclusion: The bushland in this area has been subdivided into small lots and is not a good candidate for inclusion in The UBSP. Liaison should be held with The Water Authority Corporation regarding their intentions for The bushland on the Public Purposes lot.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good - moderate.
Private property between Dundebar Rd and Belgrade Rd; portion of property on Belgrade Rd fenced.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	22	20 - 40%
Shrubland	24	40-80%

Adjacent land use: Market gardens, houses, water reservoir.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

42. Patch 1286.1995 Wanneroo
Total area of bushland: 26.6 ha

The patch has: No other vegetation complex abutting.

Zoning: Public Purposes High School (0.1 ha of bush) Rural (22.7 ha of bush) Urban (3.3 ha of bush)

No of Lots: Public Purposes (1 lot, 12.9 ha) Rural (20 lots ranging from 0.5 to 1.8 ha) Urban (1 lot, 4.5 ha)

Ownership: Private Persons, Crown Land

Conclusion: The Rural areas have been subdivided into Special Rural Lots. This area is not a good candidate for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good.
Semi-rural housing along Aquanita Pl, Chicquita Pl and High Rd

Recommendation: If not all the gazetted as semi-rural could be considered for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	20-40%

Adjoining land use: Semi-rural

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

43. Patch 1093.1685 Wanneroo
Total area of bushland: 26.3 ha

The patch has: No other vegetation complexes abutting

Zoning: Urban Deferred (26.3 ha of bush)

No of Lots: Urban Deferred (10 lots ranging from 1.6 to 40.1 ha)

Ownership: Commercial Organisations, Private Persons

Conclusion: This area warrants further investigation for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Poor
Only remaining bushland is the fenced area which includes water tank. Remainder is housing.

Recommendation: Not suitable for consideration in UBSP due to poor condition of the bushland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart woodland	24	40-80%

Adjacent land use: Nursery, housing.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

44. Patch 977.1526 Mariginiup/Wanneroo
Total area of bushland: 22.8 ha

The patch has: Another vegetation complex abutting

Zoning: Rural (17.1 ha of bush) Urban Deferred (3.9 ha of bush)

No of Lots: Rural (7 lots ranging from 3.6 to 10.6 ha) Urban Deferred (3 lots ranging from 3.1 to 4.2 ha)

Ownership: Private Persons, Crown Land

Conclusion: The largest lot zoned Rural is Crown Land. This area warrants further consideration for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Good - moderate. Signs prohibiting horses and vehicles. Portion south of Caporn Rd residential.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart - Marri woodland	no equivalent	20-40%
Jarrah - Banksia woodland	28	<20%

Important species: *Jacksonia sericea* (Priority 3)

Adjoining land use: Residential, disused quarry.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

45. Patch 5711.9578 Baldivis
Total area of bushland: 22.5 ha

The patch has: Another vegetation complex abutting

Zoning: Urban (21.9 ha of bush) Urban Deferred (0.6 ha of bush)

No of Lots: 6 lots ranging from 4 ha to 21.1 ha)

Ownership: Commercial Organisations, Private Persons, Crown Land

Conclusion: This area warrants further consideration for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good Includes the Baldivis Nature Reserve.

Recommendation: Should be considered for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	<20%
Marri - Banksia woodland	28	40-80%

Adjoining land use: School, rural.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

46.	**Patch 2034.3176 Marangaroo/ Landsdale** **Total area of bushland:** 22.1 ha The patch has: no other vegetation complex abutting	
Zoning:	Urban	
No of Lots:	This area has already been subdivided into ~200 residential sized lots	
Ownership:	Mostly Private Persons	
Conclusion:	This area is not suitable for inclusion in The UBSP.	

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

47. Patch 1014.1615 Wanneroo
Total area of bushland: 21.4 ha

The patch has: Another vegetation complex abutting

Zoning: Rural - Special Rural

No of Lots: 21 lots

Ownership: Private Persons

Conclusion: This area has been subdivided into Special Rural lots and is not suitable for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good.
Casuarina Way developed as housing. Bushland adjoins Garden Park.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%

Important species: *Jacksonia sericea* (Priority 3)

Adjacent land use: Parkland, special rural housing.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

48. Patch: 1254.1945 Wanneroo
Total area of bushland: 21 ha

The patch has: no other vegetation complex abutting

Zoning: Public Purposes - Water (11.5 ha of bush) Rural (9.5 ha of bush)

No of Lots: Public Purposes - Water (1 lot, 31.5 ha) Rural (8 lots ranging from 0.1 to 2 ha)

Ownership: Private Persons, State Government, Commercial Organisations, Crown and

Conclusion: Liaison should be held with the Water Authority Corporation regarding their intentions for The Public Purposes Reserve. The rest of the area is not a good candidate for inclusion in The UBSP due to Special Rural subdivision.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Very good
Corner of Anna Rd and High Rd, High Rd and Lenore Rd and length of Lenore Rd developed as semi-rural housing. Water Authority Corporation land fenced.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart - Banksia woodland	24	20-40%
Jarrah - Banksia woodland	28	<20%

Adjoining land use: Residential, reservoir.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland in Good Condition, Top 11- 20 % of EASY Index

49. Patch 1339.2085
Total area of bushland: 19.2 ha

The patch has: No other vegetation complex abutting

Zoning: Rural (19.2 ha of bush)

No of Lots: 10 lots ranging from 1.9 to 4.4 ha

Ownership: Private Persons, Commercial Organisations

Conclusion: This area warrants further consideration for inclusion in The UBSP.

Mattiske Consulting Pty Ltd Assessment - May 1996

Condition: Moderate - poor
South eastern portion privately owned.

Recommendation: Not suitable for consideration UBSP due to area remaining being too small.

Vegetation Association	% Weeds Present
Jarrah - Banksia woodland	20-40%

Adjoining land use: Residential, market garden

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

CONCLUSION:
KARRAKATTA COMPLEX CENTRAL AND SOUTH

The areas listed below have been included in the summary as warranting further consideration for inclusion in the UBSP.

RURAL	886.8 ha
URBAN	978.4 ha
URBAN DEFERRED	176.7 ha
INDUSTRIAL	478.3 ha
PUBLIC PURPOSES	201.8 ha
TOTAL	2722.0 ha

1322 ha of this complex is required for inclusion in the UBSP to meet the 10% criteria set by UBAG. This summary presents ~ 2722.0 ha of bushland in 35 patches to choose from.

This type of assessment gives no consideration to the design of these areas

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **1167**

Condition: Good
Portion along Burns Beach Rd lost to road extension

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Marri Woodland	3b	20-40%
Jarrah -Banksia woodland	28	<20%

Important species: *Banksia prionotes*

Adjacent land use: Strawberry farm, horse hire, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **1566**

Condition: Moderate
Private property along Wanneroo Rd and Pinjar Rd reducing the size of the vegetation patch.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	<20%
Marri - Jarrah woodland	3b	20-40%

Adjoining land use: Market gardens.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **1770**

Condition: Good
Although reduced in size does act as buffer zone for Lake Jandebup. Area north east of Belgrade Rd on Lenore Rd developed as semi-rural housing.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart - Banksia woodland	24	20-40%
Jarrah - Banksia woodland	28	<20%

Important species: *Jacksonia sericea* (Priority 3)

Adjacent land use: Horticulture, semi-rural housing.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **1929**

Condition: Very Good - Good

Recommendation: Large area developed for housing.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	20-40%.

Important species: *Jacksonia sericea* (Priority 3)

Adjoining land use: Residential, market garden, horses

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **1974**

Condition: Very Good
Verge along Ashby St planted with exotics. Residential area on Badgebup Rd.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	40-80%
Banksia woodland	22	<20%

Adjoining land use: Residential, market garden.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered to warrant further consideration for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **2013**

Condition: Good

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson et al. (1994) Classification	% Weeds Present
Banksia woodland	22	40-80%
Jarrah - Banksia woodland	28	<20-40%

Adjoining land use: Residential, paddocks

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **2115**

Condition: Good - Moderate

Recommendation: Has the potential to be considered for inclusion in UBSP.

Vegetation Association	Gibson et al. (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	28	20-40%

Adjoining land use: Residential, horse, parkland.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: 2139

Condition: Develop as housing.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **2379**

Condition: Moderate
Water Authority Corporation land

Recommendation: Not suitable for consideration in UBSP due to poor quality of the bushland.

Vegetation Associations	Gibson et *al.* (1994) Classification	% Weeds Present
Banksia woodland with emergent Tuarts	23a	20-40%, up to 80%

Adjoining land use: Freeway, Water Authority Corporation operations

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **2982**

Condition: Very Good
Shepherd's Bush Reserve.

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah Tuart woodland	24	<5%

Important species: This reserve contains Jarrah and Tuart trees of very large size.
Jacksonia sericea (Priority 3)

Adjoining land use: Residential.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **3081**

Condition: Good
Condition of area likely to be reduced due to encroaching land use of market gardens and housing. Housing developed along Kingsway.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	28	2-5%

Adjoining land use: Market gardening

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **3084**

Condition: Very Good
Patch on Kingsway developed as semi-rural housing.

Recommendation: Consider for inclusion in UBSP

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	28	2-5%

Adjoining properties: Semi-rural, market gardens.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: 3085

Condition: Very Good
House built on block in Kingsway Rd

Recommendation: Develop as Vegetation

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	B28	2-5%

Important species: *Banksia ilicifolia*

Adjoining properties: Market gardens, residential

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **3156**

Condition: Poor

Recommendation: Do not consider for inclusion in UBSP due to poor quality of the bushland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	28	80%

Important species: *Jacksonia sericea* (Priority 3)

Adjoining land use: Shopping centre, recreation park. Large amount of rubbish scattered through the bushland.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **3259**

Condition: Very poor
Most of the area developed for housing.

Recommendation: Do not consider for inclusion in UBSP due to insufficient bushland remaining.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	23a	>80%

Adjoining land use: Residential, playground.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **3724**

Condition: Poor
Area fenced

Recommendation: Not suitable for consideration in UBSP due to poor quality of the bushland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	23a	Varies between 20% and 80%

Important species: *Banksia prionotes*

Adjoining land use: Residential, highway

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: 3785

Condition: Very Poor
Some large Tuarts and Marri on the patch

Recommendation: Not considered suitable for inclusion in the UBSP, due to the understorey.

Vegetation Association	Gibson *et al.* (!994) Classification	% Weeds Present
Jarrah - Marri woodland	3b	> 80%

Adjoining land use: Residential, main road

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number:	**3864**
Condition:	Moderate Several exotic species have been planted
Recommendation:	Do not consider for inclusion in UBSP as too many exotic species have been planted.
Vegetation Association:	Marri jarrah woodland.
Adjoining land use:	Residential, part of the Karrinyup Country Club

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **4209**

Condition: Good
Area fenced with a sign "Private Property Keep Out".

Recommendation: Consider for inclusion in UBSP. Adjoins a high school.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Banksia woodland	23a	<20% - 80%

Adjoining land use: TV Channel 7 & 9, residential, high school.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **8801**

Condition: Very Poor
Housing development on Bertram Rd and Wellard Rd to corner with Homestead Rd.

Recommendation: Not suitable for consideration in UBSP due to quality of the bushland.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart - Banksia woodland	24	>80%
Marri - Banksia woodland	28	>80%

Adjoining land use: Residential, bushland

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10016**

Condition: Poor
Includes Archery park.

Recommendation: Do not consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Marri - Banksia woodland	28	40-80%.

Adjoining land use: Rural

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10072**

Condition: Very Poor

Recommendation: Do not consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Tuart woodland	24	>80%

Adjoining land use: Rural, horses

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10143**

Condition: Poor
Included some very large Tuarts. Several vehicle tracks.

Recommendation: Do not consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland occasional Tuart	24	40-80%

Adjoining land use: Rural, pine plantation

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10222**

Condition: Good
South east section developed as a market garden

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland	21a	<20 - 80%
Jarrah - Banksia woodland occasional Tuart	21a	20-40%

Adjoining land use: Residential, quarry, market garden

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10296**

Condition: Good - Moderate
Includes Karnup Reserve.
Large area now privately owned.

Recommendation: Consider for inclusion in UBSP except for Eighty Road, as patch includes Karnup Reserve.

Vegetation Association	**Gibson *et al.* (1994) Classification**	**% Weeds Present**
Banksia woodland with occasional Woody Pear.	20b	<20%
Tuart woodland	24	>80%
Jarrah Banksia woodland with occasional Marri	21a	<20%
Jarrah - Banksia woodland occasional Tuart	21a	40-80%.
Tuart - Marri woodland	No equivalent	40-80%

Adjoining land use: Residential, market garden, pine plantation

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10458**

Condition: Good
South west corner privately owned

Recommendation: Consider for inclusion in UBSP.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia woodland occasional Tuart	21a	20-40%.
Melaleuca rhaphiophylla swamp bordered by River Gum.	17	20-40%

Adjoining land use: Market garden, pine plantation.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10726**

Condition: Moderate
Corner of Amarilo Rd and Mallee Drive only remaining bushland

Recommendation: Could be considered for inclusion in UBSP due to the two vegetation associations recorded.

Vegetation Association	Gibson *et al.* (1994) Classification	% Weeds Present
Jarrah - Banksia - Woody Pear woodland	20b	40 - 80%
Tuart woodland	24	40-80%

Adjoining land use: Residential, grazing, horses.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: 10252

Condition: Privately owned.

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **10163**

Condition: All privately owned

KARRAKATTA COMPLEX CENTRAL AND SOUTH : ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: **2919**

Condition: Developed.

KARRAKATTA COMPLEX CENTRAL AND SOUTH :
ANALYSIS OF REMNANTS

Areas of Bushland considered for inclusion in the UBSP

Mattiske Consulting Pty Ltd Assessment - May 1996

Patch Number: 2948

Condition: Land allocated for other than conservation

APPENDIX D : PHOTOGRAPHIC RECORD OF CONDITION OF SELECTED PATCHES

Photo 1: Patch 3260 Shepherd's Bush. Classified by Ministry for Planning as Good 20% and by Mattiske Consulting Pty Ltd as Very Good.

Photo 2: Patch 4209 classified by Ministry for Planning as Good 50% and by Mattiske Consulting Pty Ltd as Good.

APPENDIX D : PHOTOGRAPHIC RECORD OF CONDITION OF SELECTED PATCHES

Photo 3: Patch 8162 classified by Ministry for Planning as Good 5% and by Mattiske Consulting Pty Ltd as Moderate.

Photo 4: Patch 3864, Karrinyup Country Club. Classified by Ministry for Planning as Good 20% and by Mattiske Consulting Pty Ltd as Moderate. Due to plantings of exotic species this patch is not recommended for bushland reservation.

APPENDIX D : PHOTOGRAPHIC RECORD OF CONDITION OF SELECTED PATCHES

Photo 5: Patch 2536 classified by Ministry for Planning as Very Good and by Mattiske Consulting Pty Ltd as Poor.

Photo 6: Patch 2919 classified by Ministry for Planning as Good 20% but found to be developed by Mattiske Consulting Pty Ltd.