EVALUATION OF WETLANDS ON THE SOUTHERN SWAN COASTAL PLAIN

Report to:
Waters & Rivers Commission
Hyatt Centre
3 Plain St
Perth, W. A., 6000

Report from:
V & C Semeniuk Research Group
21 Glenmere Rd
Warwick, W. A., 6024

JUNE 1998

EVALUATION OF WETLANDS ON THE SOUTHERN SWAN COASTAL PLAIN

Introduction

The Waters & Rivers Commission (WRC) commissioned the V& C Semeniuk Research Group (VCSRG) to provide an evaluation of wetlands in the region of the southern Swan Coastal Plain between Mandurah and Dunsborough, using the recommended changes to EPA Bulletin 374 (1990, 1993), outlined in Hill et al (1996), to assign them to various management categories. This document is a response to that invitation. As such, this document outlines the philosophy of approach, the rationale, and the procedures adopted, generally, to evaluate the wetlands in this area and to assign them to various management categories. It also identifies wetlands of outstanding environmental significance in this region.

The report is structured as follows:

- Study Objectives
- Consanguinity of wetlands: the concept, the practicality, the criteria, the resultant wetland suites
- The evaluation process: methodology, the criteria, the categories
- General results of the evaluation process
- Wetlands of outstanding environmental significance

Study objectives

The Waters and Rivers Commission outlined two objectives for this project. The first one was to establish and apply a set of criteria for evaluating the natural environmental values and status of all wetlands within the southern coastal plain region. The second objective was to identify wetlands of outstanding natural environmental significance and to document these values.

Figures Required
1. Suites
2. Management categories
3. Outstanding wetlands

Some issues need to be considered to ensure that these objectives are achieved. Primarily, there is a need to address the full range of wetland types which would be encountered. In this area, there are estuaries, rivers, creeks, floodplains, palusplains, paluslopes, lakes, sumplands and damplands. Recognition of such a range and diversity are important for two reasons:

1) their effect on the content and scope of evaluation criteria, and

2) the effect of that diversity in determining a basis for comparative analysis.

Given the range and diversity of wetland types, it can be seen that the content and scope of any set of evaluation criteria to be designed, should be broadscale and encompassing. This is necessary to ensure that a wide range of wetland values is covered.

Additionally, in order to avoid the mistakes inherent in comparing different systems, it is important to evaluate wetlands on a comparable basis. In this study, that basis is the approach using consanguineous suites. The rationale underlying this approach is that wetlands are fundamentally related through geomorphic and hydrological setting and processes. Wetlands in similar geomorphic/hydrological settings, and with similar wetland processes, are identified, and separated into suites or groups. Wetlands within those suites are then evaluated. As the wetlands in the Coastal Plain area south of Bunbury, had not been previously assigned to suites, this necessitated extension of the work of Semeniuk (1988) into the Busselton region, prior to commencement of evaluation.

Consanguinity

The concept and its usefulness

Consanguineous wetlands are inter-related wetlands. As defined by Semeniuk (1988), they may have a similarity because they occur in the same geomorphic, geologic, and hydrologic setting, or because they have been formed by the same underlying process. The notion of consanguineous suites essentially recognises that there are different types of wetlands residing in different settings. Recognition of these differences is important for comparative, for management, and for representative conservation purposes. Thus the identification of consanguineous suites is a powerful first step to comparing similar or "like" wetlands for evaluation and assessment procedures

The criteria

In general, seven criteria used to establish wetland consanguinity (Semeniuk 1988):

1. *Wetlands should occur in reasonable proximity*
2. *Wetlands should be similar in size and shape*
3. *A recurring pattern of similar wetland forms or a spectral range of inter-related wetland forms resulting from a dynamic process*
4. *Wetlands should have a similar stratigraphy*
5. *Wetlands should have similar water salinity regimes*
6. *Wetlands should have similar hydrological dynamics*
7. *Wetlands should have similar origin*

Limited data was obtained from in-house drill core data and field investigations. However, in this project, due to constraints of time and budget, information obtained from the literature was used to apply some of the criteria, in lieu of more extensive field investigations. One of the criteria, pertaining to water salinity, was not applied, because of the incomplete data set.

The extent to which the criteria were applied, and the sources of data, are explained below.

1. *Wetlands should occur in reasonable proximity*
   Fully applied.

2. *Wetlands should be similar in size and shape*
   Fully applied.

3. *There should be a recurring pattern of similar wetland forms or a spectral range of inter-related wetland forms resulting from a dynamic process*
   Fully applied. Information was obtained from geomorphic setting.

4. *Wetlands should have a similar stratigraphy*
   Information was obtained from the following sources: published geology and soils maps, some in-house data, and field investigations.

5. *Wetlands should have similar water salinity regimes*
   No information was accessed for application.

6. *Wetlands should have similar hydrological dynamics*
   Limited data was obtained from geomorphic setting, field investigations of selected wetlands and in-house data.

7. *Wetlands should have similar origin*
   Limited data was obtained from in-house drill core data and field investigations.

The resultant wetland suites

As a result of applying the above criteria to the wetland patterns of the region between Bunbury and Bussleton, twenty-seven suites were identified in the previously unclassified southern portion of the study area. Twenty-three of these wetland suites are new and are related to the different geomorphology occurring in this area. They are:

1. Vasse-Wonnerup Suite
2. Geographe Bay Suite
3. Big Swamp Suite
4. Minninup Suite
5. Ludlow Suite
6. Yunderup Suite
7. Mialla Suite
8. Ngamburnup Suite
9. Mewett Rd Suite
10. Mallocup Suite
11. Cokelup Suite
12. Capel Suite
13. Ambergate Suite
14. Ruabon Suite
15. Anniebrook Suite
16. Tutunup Suite
17. Yoganup Suite
18. Brunswick River Suite
19. Capel River Suite
20. Sabina River Suite
21. Carbunup River Suite
22. Blackwood Plateau Suite
23. Wicher Plateau Suite

The wetland suites are briefly described and located in the Table below.

Coding of the Busselton region Consanguineous Wetland Maps

Suite	map_symbol
Ruabon	P.2
Anniebrook	P.3
Vasse-Wonnerup	E.5
Capel River	R.5
Sabina River	R.6
Carbunup	R.7
Jandakot	B.3
Mialla	S.7
Big Swamp	Qu.6
Minninup	Qu.7
Cokelup	B/P.7
Capel	B/P.8
Ludlow	S.5
Mallocup	B/P.6
Ngamburnup	S.8
Yunderup	S.6
Ambergate	B/P.9
Yoganup	W.2
Wicher Plateau	W.1
Geographe Bay	Qu.5
Blackwood Plateau	Bl.1
Tutunup	Bl.2
Ridge Hill Shelf	D.7

Consanguineous wetland suites on the coastal plain south of Bunbury.

Name	Location	Geomorphic Setting	Primary Wetlands	Description	Stratigraphy
Vasse-Wonnerup Suite	1930 IV SE 1930 I SW SE NE 2030 IV NW	Holocene Vasse Estuarine Flat	Estuarine basins, flats, deltas, abandoned channels and tidal channels	Impounding of fluvial discharge by Holocene coastal dune barrier, as well as estuarine and fluvial inundation and channelling in shore parallel interdune swale.	Fine quartz sand and muddy sand with estuarine shells
Geographe Bay Suite	1930 IV SE 1930 I SW	Holocene Dunes	Linear leptoscale freshwater damplands	Groundwater intersecting swales within a low dune/swale complex	Calcareous sand
Big Swamp Suite	2031 III NE, SE, SW	Holocene alluvium	Mesoscale freshwater sumplands and damplands and palusplain	Basins with ancestral fluvial and possibly estuarine phases, and flats resulting from fluvial and estuarine processes	Peaty sand and quartz sand
Minninup Suite	2031 III SW	Contact between Holocene Dunes and Pleistocene Dunes	Macroscale sumpland	Formerly an estuarine basin now subject to groundwater hydrology and perching of direct precipitation	Friable ferricrete and peat overlying muddy sand (peat & clay) and estuarine
Ludlow Suite	1930 I SW, NE	Pleistocene limestone plain	Leptoscale linear damplands	Interdune depressions between low limestone ridges intersected by groundwater; some perched precipitation	Peaty sand and Pleistocene limestone
Yunderup Suite	1930 I SW, SE	Contact between Pleistocene limestone and Pleistocene quartz sand	Leptoscale linear damplands	Interdune depressions intersected by groundwater	Peaty sand

Mialla Suite	2031 IV SE 2031 III NE	Pleistocene Eaton Sand Ridge	Macroscale to microscale rounded to irregular sumplands and damplands	Wetlands occur in depressions between hills	Quartz sand
Ngamburnup Suite	1930 I SW, SE 1930 IV SE	Pleistocene quartz sand flat	Leptoscale to mesoscale linear damplands and irregular shaped sumplands	Interdune depressions intersected by groundwater	Quartz sand
Mewett Rd Suite	1930 IV SE	Pleistocene quartz sand dunes	Leptoscale rounded sumplands	Interdune depressions intersected by groundwater	Quartz sand
Mallocup Suite	2030 IV NW 1930 I SE, NE	Estuarine flat developed along the boundary of the alluvial plain underlain by Guildford Formation and the Bassendean Dunes	Mesoscale irregularly elongated sumplands	Unconformity contact	Quartz sand overlying Pleistocene estuarine limestone
Cokelup Suite	2031 III SW	Contact between Pleistocene Dunes and the alluvial plain underlain by Guildford Formation	Macroscale sumpland	Located along unconformitybetween dunes of quartz sand but underlain by alluvial sediments.	Black clay

Capel Suite	1930 I SE, NE, SW 2030 IV NW, SE	Alluvial plain underlain by Guildford Fmtn	Palusplain with minor areas of floodplain	Fluvial deposits	Mottled and iron stained sandy, silty clay
Ambergate Suite	1930 I SE, SW	Contact between alluvial plain underlain by Guildford Formation and Bassendean Dunes	Macroscale linear sumplands	Unconformity contact	
Jandakot Suite	1930 I SW, SE, NE 1930 IV SE 2030 IV NW, NE,	Bassendean Dunes	Microscale to macroscale sumplands and damplands	Groundwater surfacing or near surface in depressions to develop water table basins	Peat, peaty sand or humic sand overlying quartz sand
Bennett Brook Suite	2031 III SE, NE, SW 2030 IV NW	Bassendean Dune with microscale creeks	Macroscale irregular damplands, chains of irregular/linear microscale to mesoscale sumplands and damplands, microscale creeks and palusplain	Depressions which intersect the water table. Precipitation is ponded by clay lenses in the subsurface. Palusplains are situated between creeks and drainage lines	Quartz sands or clay overlying quartz sand
Ruabon Suite	1930 I SW, SE, 2030 IV SW,	Plain underlain by Bassendean Sand	Palusplain, drainage lines, and microscale basins	Groundwater surfacing or near surface under flats and some perching of precipitation	Quartz sand and ferricrete
Keysbrook Suite	2031 III SE, 2030 IV NE, NW 2031 II NW	Alluvial fans & creeks of the Pinjarra Plain	Palusplain, creeks and microscale basins	Sediment discharge to develop alluvial fans; surface runoff and ponding of precipitation	Clay overlying lateritic clay and sand

Anniebrook Suite	1930 IV SE	Busselton Plain underlain by Guildford Formation and Bassendean Sand	Palusplain, and microscale sumplands	Small scale rivers & sheet wash deposit sand to produce the planar surface	Quartz sands and muddy fine sands
Tutunup Suite	2030 IV SW, NE 1930 I SE, 2031 III SE	Contact between Blackwood Plateau and plain underlain by Bassendean Sand	Macroscale sumplands and floodplains	Seepage from the Mesozoic sediments underlying the Blackwood Plateau at its contact with the plain, produce sumplands and floodplains on the low lying areas between the alluvial fans	Fine quartz sand with iron impregnations, ferricrete, and sandstone boulders
Yoganup Suite	1930 IV SE	Contact between Wicher Plateau, Yoganup alluvial fans and Busselton Plain	Mesoscale valley shaped sumplands	Discharge depressions for surface runoff from alluvial fans	Fine to very coarse grained quartz sand
Swan River Suite	Preston River	Traversing the Swan Coastal Plain	River, floodplain	Incised channel with terraces	Alluvium of quartz sand and clay
BrunswickRiver Suite	Brunswick River Collie River	Traversing the Swan Coastal Plain	River and well-developed floodplain within valley tract	Channels with relatively short coastal plain segments, traversing flat terrain of generally lower relief than the Swan River Suite	Mud and sands

Capel River Suite	Capel River	Traversing the plain underlain by Bassendean Sand	River, terraces, some narrow development of floodplain, abandoned channels and billabongs	River channel through Bassendean Dune terrain	
Sabina River Suite	Sabina River Abba River Vasse River	Traversing the plain underlain by Bassendean Sand	River with narrow but continuous floodplains within the valley tract, and macroscale areas of floodplain in the interfluves	Inundation of lowland areas within the plain and lateral migration of channels interacting with dunes	
Carbunup Suite	Carbunup River Annie Brook Mary Brook Station Gully Brook Buayanup River	Traversing the Busselton Plain	Creeks, narrow palusplains or floodplains	Short seasonal microscale channels from the Whicher Plateau	Fine iron impregnated quartz sand
Blackwood Plateau Suite	2031 II SW 2030 IV NE, SW	Blackwood Plateau	Rivers, creeks, sumplands and occasional narrow palusplains	Fluvial incision; surface runoff & ponded precipitation in areas with more gentle slopes or shallow depressions	Laterite detritus or quartz sand & gravel overlying Precambrian rocks
Wicher Plateau Suite	1930 IV SE	Wicher Plateau	Microscale linear sumplands along valley tracts	Perching of surface water along valley floors	Quartz sand and possibly laterite

The evaluation process: the methodology, the categories & the criteria

Methodology

There were three general methods used in this study: aerial photographic assessment, review of published information and field site inspection. More specific details on methodology in relationship to delineation of consanguineous suites and for implementing the criteria for evaluation are described in appropriate later sections.

The photographic analysis of a given wetland included:

1. assessment of the presence and amount of natural vegetation
2. assessment of the presence and type of a buffer zone
3. assessment of the geomorphic integrity of the wetland
4. investigation of unusual geomorphic features or setting
5. assessment of the nature of local catchment
6. analysis of hydrological linkages, and
7. analysis of possible wetland hydrological functions
8. analysis of ecological linkages

The literature and database searches were undertaken to derive information on specific functions of wetlands such as faunal usage or habitat attributes. The following databases were accessed:

- CALM database on rare and endangered and priority flora
- CALM database on rare and endangered and priority fauna
- Birds Australia database on waterfowl use of wetlands

Literature and published maps were used to access information on unusual geological, landform or soil formations, pollen sites and fossil sites. Publications were also a supplementary source of information on values of specific wetlands e.g., National Directory of Important wetlands 1997 .

A variety of wetlands determined as important or potentially important from analysis of aerial photographs, or determined as important from the CALM and Birds Australia Database, or determined as important from the literature, were site-inspected and assessed in the field. The on-site inspections/assessments of wetlands included the following procedure:

1. an assessment of wetland vegetation status
2. recognition of wetland vegetation diversity (e.g., structural diversity, presence of restricted community types)
3. recognition of unusual vegetation physiognomy (potential indicators of changes to wetland hydrology)
4. recognition of dynamic biological responses as an indicator of habitat alteration (evident in floral community changes)
5. selected site investigation of stratigraphy
6. investigation of possible recharge and discharge mechanisms and their anthropogenic alteration

Note should be taken that some wetlands would be of Conservation status, or assessed as being capable of Resource Enhancement (i.e., rehabilitation) even if they were somewhat weed-infested, or partly anthropogenically degraded, particularly if they supported significant breeding bird numbers, were a stopover for migratory water birds, supported rare, endangered or unusual plants, or had geoheritage significance.

The procedure outlined above, was used for a general evaluation of wetlands in the study area in response to the primary objective. As noted earlier, there was a second objective to this study, i.e., the identification of wetlands of *outstanding environmental significance*. This translated to identification of wetlands with values that are recognised as being of Statewide, National or International significance. The following criteria were used to select wetlands in this class:

- wetlands that have outstanding values as a faunal habitat or refuge,
- wetlands that have value as a habitat for significant flora,
- wetlands that have high habitat diversity,
- wetlands that have value as a rare wetland type,
- wetlands that are an outstanding example of a particular type of wetland and wetland processes
- wetlands that have value as a scientific resource

The wetlands in this category of outstanding environmental significance generally satisfied more than one criterion.

Note again should be taken that some wetlands would be of high conservation status, even if they were somewhat weed-infested, or partly anthropogenically degraded for the reasons outlined above. Generally, however, wetlands need to be of high geoheritage significance to be outstanding wetlands if they are partly degraded.

The categories

The Waters & Rivers Commission requested that evaluation of wetlands be categorised into three management classes to supplement previous work done by the Commission in this field (Hill et al 1997). The classes were:

1. Conservation
2. Resource Enhancement
3. Multiple Use

The conservation category was understood to mean that the priority would be to manage the wetland as a reserve and to protect the attributes and functions which were of high value. Alteration to the wetland would be strongly discouraged and mechanisms would be put in place to protect the wetland from any man-induced deterioration.

The resource enhancement category was understood to mean that the priority would be to maintain the wetland, its attributes and functions, and wherever possible enhance the ecological status of the wetland by such activities as improving water quality or re-vegetating cleared areas with endemic site-appropriate species

The multiple use category was understood to mean that the priority would be to maintain multiple uses of the wetland including ecological functions. This would necessitate maintaining the geomorphic integrity of the wetland. It **excludes** destruction of the wetland through processes such as infilling, excavation, mining, or erection of urban structures.

The criteria

Although evaluation of wetlands has taken place in other regions, much debate and confusion surrounds the issue. Therefore, a major aspect of this study was to present clear and comprehensive criteria for each of the above management categories with respect to natural or ecological attributes. The study did not call for values of wetlands important to human functions to be incorporated.

Prior to commencement of the task, Waters & Rivers Commission were approached to organise a meeting with interested professional parties and stakeholders to discuss appropriate evaluation criteria. As this workshop did not eventuate, and given the short term and urgency for completion, the only option was to proceed with the study and design the evaluation criteria within the Semeniuk Research Group.

Evaluation demands a logical and systematic approach to exhaustively capture all recognised **natural** wetland values, therefore, criteria were designed to assess the following attributes of wetlands.

- wetland type
- wetland processes maintaining the system
- wetland habitats
- wetland functions
- biodiversity
- scientific value

Conservation categories

Criteria are listed below for the category of ***Conservation***. The list is organised in the same sequence as the list of wetland attributes above. This order does not imply priority. The evaluation criteria aim to be comprehensive.

Wetland type: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. it is an anthropogenically unaltered wetland type (i.e., river, creek, paluslope, palusplain, floodplain, lake, sumpland, dampland)
2. it is a scarce wetland type
3. it is a representative wetland type (i.e., representative of its consanguineous suite)

Wetland processes: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. the wetland is subject to anthropogenically unaltered wetland processes (i.e., recharge and discharge mechanisms, hydroperiod, sedimentary processes,)
2. the wetland exhibits unusual wetland processes

3. the wetland exhibits representative wetland processes (i.e., representative of its consanguineous suite and geomorphic setting)

Wetland habitats: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. the wetland is a habitat for rare & endangered fauna
2. the wetland is a habitat for rare & endangered flora
3. the wetland exhibits a high diversity of habitats

Wetland functions: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. the wetland is necessary for maintenance of large faunal populations
2. the wetland is a refuge for resident fauna
3. the wetland is an important breeding, feeding or watering site for migratory populations (local and international)
4. the wetland is a significant regional component of the hydrological cycle (has an important hydrological storage, recharge or discharge function; or an hydrochemical function)

Biodiversity: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. the wetland exhibits unaltered wetland vegetation and fauna
2. the wetland has a scarce vegetation association or faunal association
3. the wetland has a highly diverse wetland flora or fauna

Scientific value: *A wetland may be classed as* Conservation *if it satisfies one or more of the following criteria*

1. the wetland contains scientifically significant pollen records
2. the wetland is underlain by unusual wetland sediments (indicators of wetland history)
3. the wetland has unusual geomorphology (i.e., it is situated in an unusual geomorphic setting or contains unusual geomorphic features within it)

Resource Enhancement categories

Criteria are listed below for the category of ***Resource Enhancement***. The list is organised in the same sequence as the list of wetland attributes above. This order does not imply priority. The evaluation criteria aim to be comprehensive.

Wetland type: *A wetland may be classed as* Resource Enhancement *if it satisfies the following criterion*

1. it is an anthropogenically altered wetland type (i.e., river, creek, paluslope, palusplain, floodplain, lake, sumpland, dampland) but retains its natural geomorphology and natural, if modified, hydrological mechanisms.

Wetland processes: *A wetland may be classed as* Resource Enhancement *if it satisfies the following criterion*

1. the wetland is subject to anthropogenically altered wetland processes (i.e., recharge and discharge mechanisms, hydroperiod, sedimentary processes) to the degree that habitats can still be identified and rehabilitated

Wetland habitats: *A wetland may be classed as* Resource Enhancement *if it satisfies the following criterion*

1. the wetland habitats are disturbed but the wetland is a habitat for rare & endangered fauna or flora, or the wetland exhibits a high diversity of habitats and for these reasons should be re-habilitated (i.e., water quality addressed, water levels naturalised, re-vegetation of communities undertaken, and re-establishment of ecological links with surrounding areas via corridors and/or buffer zones)

Wetland functions: *A wetland may be classed as* Resource Enhancement *if it satisfies one or more of the following criteria*

1. the wetland is necessary for maintenance of specific faunal populations
2. the wetland is a breeding, feeding or watering site for migratory faunal populations (local)

3. the wetland is a fauna refuge but is degraded and requires re-vegetation or improvement of water quality
4. the wetland is a significant local component of the hydrological cycle (has an hydrological storage, recharge or discharge function; or an hydrochemical function)
5. the wetland is a regionally important hydrological or ecological link in a system
6. portion of extended wetlands is vegetated and therefore functions as an ecological corridor

Biodiversity: *A wetland may be classed as* Resource Enhancement *if it satisfies the following criterion*

1. the wetland exhibits some unaltered wetland vegetation and fauna which may be extended through re-vegetation programmes

Multiple Use category:
Criteria are listed below for the category of ***Multiple Use***. The list is organised in the same sequence as the list of wetland attributes above. This order does not imply priority. The evaluation criteria aim to be comprehensive.

Wetland type: *A wetland may be classed as* Multiple Use *if it satisfies the following criterion*

1. it is an anthropogenically altered wetland type and retains its natural geomorphology but has highly modified, hydrological mechanisms.

Wetland processes: *A wetland may be classed as* Multiple Use *if it satisfies the following criterion*

1. the wetland is subject to anthropogenically altered wetland processes (i.e., recharge and discharge mechanisms, hydroperiod, sedimentary processes) to the degree that habitats can no longer be identified and rehabilitated

Wetland habitats: *A wetland may be classed as* Multiple Use *if it satisfies the following criterion*

1. the wetland habitats are disturbed such that re-vegetation is possible but not re-habilitation (i.e., sediments, water quality and water levels, are altered so that re-establishment of original flora and fauna communities is not possible)

Wetland functions: *A wetland may be classed as* Multiple Use *if it satisfies one or more of the following criteria*

1. the wetland is necessary for maintenance of low numbers of faunal populations
2. the wetland is a feeding or watering site for local migratory faunal populations (usually in association with a number of other wetlands as no single wetland is sufficient to maintain species)
3. the wetland is a component of the hydrological cycle and therefore to catchment management (has an hydrological storage, recharge or discharge function; or an hydrochemical function, albeit a minor function)

Biodiversity: *A wetland may be classed as* Multiple Use *if it satisfies the following criterion*

1. the wetland has minor biodiversity, but does have ecosystem diversity and landscape diversity

General results of the evaluation process

From the aerial photographic analysis, a preliminary assessment of the nature of a given wetland was carried out. Following this, supplementary data from the field inspection, the databases from CALM and Birds Australia, and the review of literature, as outlined in the methods section, was used to assign each wetland to one of the three management categories.

The results of the evaluation process in this project are presented in three ways:

- on maps at the scale of 1:25,000 showing wetland management categories for every wetland;
- in a Table describing the attributes of the regionally important wetlands presented below within a context of each of the different wetland suites, and
- in a description of outstanding wetlands and wetland regions also listed below.

Wetlands of regional significance

Wetland Name	Wetland Suite	Map Sheet	Attributes
Harvey Estuary	Peel-Harvey Estuary Suite	2032 III NE 2032 IV SE 2032 I SW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. High avifauna diversity and use 4. Aquatic fauna habitat 5. International migratory waterfowl site 6. Breeding site 7. Restricted flora 8. Rare fauna 9. Geomorphic diversity 10. Unusual geomorphic features
Leschenault Inlet	Leschenault Inlet Suite	2031 III NE 2031 IV SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. High avifauna use and diversity 4. International migratory waterfowl site 5. Breeding site 6. Aquatic fauna habitat

			7. Geomorphic evolution
Vasse/Wonnerup Estuary, Broadwater and Deadwater	Vasse-Wannerup Suite	1930 IV SE 1930 I SE, SW, NE 2031 III SW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Avifauna diversity and use 4. Outstanding site for several species of waterfowl 5. International migratory waterfowl site 6. Breeding site 7. Coastal geomorphic evolution - progradation and erosion
D70	Geographe Bay Suite	1930 IV SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. S103 represents the only vegetated remnant 4. Coastal evolution
Big Swamp	Big Swamp Suite	2031 III NE, SE, SW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Avifauna use

Bussel Hwy palusplain	Bunbury Suite	2031 III NE,	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat
Lake Preston S5 and sumpland crossing Myalup Beach Rd	Lake Preston Suite	2031 IV NE 2032 III SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat 4. Outstanding site for several species of waterfowl 5. International migratory waterfowl site 6. Coastal evolution
	Koallup Suite	2031 IV NE	Wetlands all cleared
Minninup Swamp	Minninup Suite	2031 III SW	1. Only wetland in the suite 2. Wetland processes representative of patterns within the suite 3. Coastal evolution 4. Avifauna use
Damplands along Ludlow Rd	Ludlow Suite	1930 I SW, NE	1. Representative of wetland type within a suite

			2. Wetland processes representative of patterns within the suite 3. Represents the only vegetated remnant
			4.
Lake Clifton Duck Pond Boundary Lake Lake Pollard Martins Tank Lake Hayward Lake Newnham Lake Yalgorup D35 northern section	Clifton Suite	2032 III NE, SE 2032 IV SE	5. Representative of wetland type within a suite 6. Wetland processes representative of patterns within the suite 7. High avifauna diversity 8. International migratory waterfowl site 9. Outstanding site for several species of waterfowl 10. Coastal evolution 11. Rare organo-sedimentary features 12. Wetland habitat 13. Wetland evolution
22D	Yunderup Suite	1930 I SW, SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Represents the only vegetated remnant

S93 S41 S45 S38 S39	Mialla Suite	2031 II NE 2031 IV SE	1. Outstanding example of this wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat
	Ngamburnup Suite	1930 I SW, SE 1930 IV SE	All wetlands cleared
S9	Mewett Rd Suite	1930 IV SE	1. Representative of wetland type within a suite Wetland processes representative of patterns within the suite
S103 Ceared delta shaped area around Capel River	Mallocup Suite	2030 IV NW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. S103 represents the only vegetated remnant 4. Coastal evolution 5. Riverine processes
Cokelup Swamp	Cokelup Suite	2031 III SW	1. The only wetland in the suite 2. Unusual vegetation communities 3. Unusual sediments

			4. Diverse habitats
P18	Capel Suite	1930 I NE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Represents the only vegetated remnant 4. Priority flora
Lake Mealup Lake McClarty S12 S34 D21 D16	Bibra Suite	2032 IV SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. High avifauna diversity 4. International migratory waterfowl sites 5. Outstanding sites for several species of waterfowl 6. Breeding sites

S42, S40, S14, S19, S9, S12, S21 and palusplain S18, S47, S45, D34, S54, D42, S60, S35, S85, S46 and palusplain	Hamden Suite	2032 III SE 2032 II SW	1. Outstanding examples of this wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat 4. Unusual vegetation communities 5. Linked ecological system 6. Linked with upland 7. Faunal refuge
	Ambergate Suite	1930 I SE, SW	All wetlands cleared
S18, D66, D74, D25, D151, S116, D93, D79, D120, S78, D157, D36, S55, D10, D76, D88, S170, S99, D5, S130, D57, D58, D65, D107, D68, D92, S110, S64, S67, S90, D27, D59 S61, S101, S71 D10, S29, D9, D22, D30, D4	Jandakot Suite	2031 I SW, NW	1. Outstanding examples of this wetland type 2. Wetland processes representative of patterns within the suite 3. Wetland habitat 4. Linked ecological system 5. Linked hydrological system 6. Priority flora S202 & D277

S202, D277 (Wellard Nature Reserve)			
S35, S54, S65, S56,S44, S52, S45, S39 S72, S70, S63, S64, S67, and palusplain S123, S211, S100, S105, S106, S110 S96, S259, S252, S148, S156, S138, S154, S159 S205, D293, S283, D200, D189, D183 D253 S264 S211 S318, D342, S353, S323, S352, S324, S319, and palusplain	Riverdale Suite	2031 I NW 2032 II SW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitats 4. Linked wetland system 5. Geomorphic features of system-linear wetland chains 6. Unusual wetland sediments S323

Clifton Road wetland S14 Centeniary Road palusplain S104, S108, S146, S182, S149 and palusplain S3, S7	Bennett Brook Suite	2032 III NE 2031 III SE 2032 II SW	1. Wetland processes representative of patterns within the suite 2. Outstanding example of this wetland type within a suite 3. S14 international migratory waterfowl site 4. S14 outstanding site for one species of waterfowl 5. Linked wetland system 6. Linked with upland
S131 S143 S154 S138 S85 S129 S232 part S136 L145 S135,S131, S133, S141, and lakes near Herron Point Rd	Mungala Suite	2032 II NW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitats 4. Linked wetland system 5. Linked with upland 6. Outstanding site for one species of waterfowl

Benger Swamp	Benger Swamp Suite	2031 I SW	1. Unusual wetland geomorphology 2. Wetland processes representative of patterns within the suite 3. Avifauna use and diversity 4. Outstanding site for several species of waterfowl 5. Important breeding site 6. Site for endangered fauna 7. International migratory waterfowl
Yoongarillup Rd palusplain Acton Park Rd palusplain S46 Road verge to Tutunup Road	Ruabon Suite	1930 I SW, SE, 2030 IV SW,	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Unusual vegetation communities 4. Scarce wetland habitat 5. Priority flora
Hill Rd Palusplain Palusplain south of Herron Point Rd S79 S68 Palusplain south of Williamson Rd	Keysbrook Suite	2032 III NE, 2032 II NW, NE 2032 I SW	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Unusual vegetation communities 4. Rare & restricted flora 5. Leptoscale basins are indicators of unusual wetland and sedimentary processes

Leptoscale basins north of Benger Swamp Palusplain Parkhills Rd D562, D570, D505, D515, D581 S144 S477 Palusplain on Southwestern Hwy			
Remnant palusplain vegetation near Radford park west of Buayanup River	Anniebrook Suite	1930 IV SE	1. Represents the only vegetated remnant
Portion S58 Portion F62 and F63 Portion S17 Portion F94	Tutunup Suite	2030 IV SW 1930 I SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Unusual vegetation communities 4. Unusual setting 5. Represents the only vegetated remnants 6. Priority flora

S17	Yoganup Suite	1930 IV SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Unusual vegetation communities 4. Unusual setting 5. Represents the only vegetated remnant
Portion of Wellesley River floodplain Portion of Murray River floodplain Portion of Harvey River floodplain	Swan River Suite	Preston River Capel River Wellesley River Harvey River	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Scarce habitat 4. Linked wetland system
Brunswick River	BrunswickRiver Suite	Brunswick River Collie River Sabina River Abba River Vasse River	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat type
Carbunup River	Carbunup Suite	Carbunup River Annie Brook Mary Brook Station Gully Brook Buayanup River	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat type

S 23 PS 10 PS 29 PS 31 P34 F25 PS1x, PS2x, PS3x, PS4x, PS5x, PS6x, PS7x, PS8x PS9x, PS10x, PS11x, PS12x PS102, PS101, PS109, PS95, S107 F136, PS132 P52, PS49, PS44, F63 P47 P59, D64, PS54, PS60, PS53	Little Dardanup Suite	2031 I SE,NE 2032 II NE,SE 2032 I SE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat type 4. Linked wetland system 5. Unusual vegetation assemblages

FP1x, FP2x, FP3x, FP4x, FP5x, P110, P112, P117, PS106, PS116, PS115, S104	Walyungup Suite	2031 I NE 2032 IISE	1. Representative of wetland type within a suite 2. Wetland processes representative of patterns within the suite 3. Wetland habitat type 4. Linked wetland system 5. Unusual vegetation assemblages
S1x S2x L98	Nalyerin Suite	2031 I NE	1. Rare wetland types in this setting 2. Wetland processes representative of patterns within the suite 3. Wetland habitat
	Blackwood Plateau Suite		All wetlands are cleared
S20	Wicher Plateau	1930 IV SE	1. Representative of wetland type within a suite Wetland processes representative of patterns within the suite

One of the very noticeable features of the study area is the disproportion of wetlands categorised as Multiple Use. This category dominates the region, with the exception of Yalgorup National Park and the Kemerton district. In Bunbury, the regional centre, the destruction of estuarine wetlands is particularly to be decried. In Bunbury urban region, remaining wetlands require the most urgent action for protection, as their importance seems largely to be underestimated.

Wetlands of outstanding environmental significance

Wetlands have many attributes, some of which may be ranked as Regionally significant and some of which may be ranked as of Statewide to International significance. Therefore a brief description is presented herein of outstanding wetlands on the southern Swan Coastal Plain. The attributes that determine whether a wetalnd is of outstanding significance are:

- avifauna usage
- vegetation attributes
- geoheritage values
- well preserved example of a consanguineous suite

The data on waterbirds was compiled from several sources: a current analysis of Birds Australia data bases on waterbirds (1987-1997) and the findings of Raines *et al.* (unpub.), information from Lane *et al.* (1996), Watkins (1993) and Garnett (1992). Ninety eight sites were analysed from this region and compared with 693 other wetland sites in southern Western Australia. Wetlands recognised under the Convention of Wetlands of International Importance (Ramsar Convention) are particularly noted. The report compiled by J Raines is included in its entirety in Appendix 1.

A caution is advised in over interpreting these findings as some wetlands have not been sampled thoroughly, and relatively little effort has been made to assess breeding at many wetlands compared to other parameters. Many wetlands require considerably more survey work over a range of seasons to fully assess their values, particularly with respect to breeding.

This analysis does not include any non-waterbird species. A waterbird is defined as being a species which is dependent on wetlands for its survival and includes waterfowl, shorebirds and certain species of harrier, eagle and warbler as defined by Jaensch *et al.* (1988).

Data on flora was obtained from CALM database on priority species and restricted communities.

Information on geoheritage values were obtained from the literature, and inhouse R&D data of VCSRG.

The outstanding wetlands in this region are as follows:

1) Harvey Estuary
2) Robert Bay
3) Leshenault Inlet and outlying wetlands
4) Vasse-Wonnerup Estuary
5) Clifton Road Swamp S14
6) Lake Preston and surrounds
7) Lake Clifton and surrounding lakes (Martins Tank Lake, Lake Pollard, Lake Yalgorup)
8) Riverdale Suite
9) Hamden Suite wetlands
10) Kemerton wetlands
11) Ruabon Suite
12) Cokelup Swamp

These wetlands are described in detail below.

1) Harvey Estuary- is in the top 5% of sampled wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is in the top 1% for numbers of Darter. It is in the top 4.4% for variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is also significant for the number of waterbirds which are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992), particularly the Freckled Duck. Finally the Harvey Estuary is recognised as a wetland of International importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

In terms of geoheritage, the Harvey Estuary provides a range of shore types that are significant (cf Semeniuk & Semeniuk 1990, 1991). With the array of beachridges and the small fluvial delta, it presents a unique well preserved shore system that now is poorly represented, or not at all represented, in the region of the southern Swan Coastal Plain.

2) Robert Bay- is in the top 5% of sampled wetlands for numbers of individual waterbirds and the top 10% for median numbers of individual waterbirds. It is in the top 1% of sampled wetlands for Red-necked Avocet.

3) Leshenault Inlet and outlying wetlands - (including those immediately east of Cathedral Avenue)- is in the top 5% of sampled wetlands for median numbers of individual waterbirds, for variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements and in the top 7.9% for species richness. It is in the top 1% of sampled wetlands for numbers of Caspian Tern which is listed on the Japan Australia and China Australia Migratory Bird Agreements. Additional data collected by Ninox Wildlife Consulting, and re-analysed in the present study, indicates the wetland complex is in the top 5% for variety of breeding species. It also suggests that Leshenault Inlet is significant for numbers of individual waterbirds, for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and in the top 5% for ten other waterbird species including three species listed on both migratory bird agreements.
Alexander Island- ranks in the top 1% of sampled wetlands for numbers of Darter.

In terms of geoheritage, Leschenault Inlet represents an assemblage of estuarine environments developed behind a barrier dune complex (Semeniuk 1985, 1998). It is a globally distinct system, and is at the least of Statewide significance in terms of geoheritage. However, parts of Leschenault Inlet are anthropogenically modified and destroyed. Those parts that are remaining are of geoheritage significance, especially the mangroves in the Preston River delta area, the remainder of the Collie delta, the supratidal samphire flats to the north, the stranded supratidal flats to the north, the crenulate west shore of the barrier, and the samphire-vegetated tidal flatforms (Pen et al 1998; Semeniuk 1998).

4) Vasse-Wonnerup Estuary- is in the top 5% of sampled wetlands for numbers of individual waterbirds, for median numbers of individual waterbirds, for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and for the variety of these species present. It is also in the top 5% of wetlands for species richness and for variety of breeding species. The estuary is considered internationally significant for the Red-necked Avocet, Black-winged Stilt, Curlew Sandpiper, Sharp-tailed Sandpiper, Wood Sandpiper and Greenshank (Watkins 1993). The estuary is in the top 1% for these species as well as the Australasian Grebe, Australian Pelican, Pied Cormorant, White-faced Heron, Great Egret, Yellow-billed Spoonbill, Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal, Lesser Golden Plover, Black-tailed Godwit, Pectoral Sandpiper, Red-necked Stint, Silver Gull, Whiskered Tern and White-winged Tern. Nine out of these 23 species are listed on migratory bird agreements. It is also notable for the Fairy Tern which breeds there in large colonies (Lane *et al.* 1996). Finally the Vasse-Wonnerup Estuary is recognised as a wetland of international importance and listed under the Ramsar Convention.

The Broadwater in this system is in the top 5% of sampled wetlands for numbers of individual waterbirds and for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is in the top 1% of sites for the Australasian Shoveler and in the top 7.9% for species richness. The Broadwater is in the top 10% for variety of breeding species.

In terms of geoheritage, the Wonnerup-Vasse system also represents an assemblage of estuarine environments developed behind a low relief barrier dune complex, but one where there is ongoing dynamic interaction between the barrier and the fluvial environment (Searle & Semeniuk 1985). There are gradations from barred lagoons with active channels, to active estuarine channel breaching of the barrier, to abandoned lagoons. The system is unique from Statewide perspective, and is at the least of Statewide significance in terms of geoheritage.

5) Clifton Road Swamp S14- is in the top 1% of sampled wetlands for the Australian White Ibis and in the top 10% of wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements.

6) Lake Preston and surrounds -
These wetlands are 1) a megascale linear saline lake (Lake Preston), 2) a sub-rounded sumpland (Lake Josephine), 3) portion of a linear freshwater sumpland. They represent wetlands which were former lagoons behind a Quindalup Dune barrier. The lagoon has been segmented at the southerly end, and the resulting wetlands are much less saline than Lake Preston. The margins are vegetated by herbland (*Samphires*), sedgeland (*Baumea articulata, Baumea juncea, Typha orientalis,* and *Gahnia trifida*), and forest (*Melaleuca cuticularis, M. rhaphiophylla, E. gomphocephala,* and *Agonis flexuosa*).

The wetlands have conservation value as examples of wetland type, examples of evolution of lagoons on a prograding coast, and as avifaunal habitats. Lake Preston is regionally significant for median numbers of individual waterbirds and for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is particularly important to Australian Shelduck and Musk Duck. Lake Preston is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Preston represents an elongate isolated water body that was formerly connected to Leschenault Inlet (Semeniuk 1996). It records a change from estuarine conditions to barred saline/brackish conditions, with concomitant changes in sediments and biota. As such it represents a system of Statewide to National geoheritage.

7) Lake Clifton and surrounding lakes - These wetlands are 1) a megascale linear saline lake (Lake Clifton), 2) sub-rounded to linear lakes (Lake Pollard, Boundary Lake, Martins Tank Lake, Lake Yalgorup, Lake Newnham), 3) sub-rounded sumplands and 4) sub-rounded to linear damplands. They represent wetlands in a linear inter-ridge depression along an unconformity interface. The margins are vegetated by sedgeland (*Baumea juncea,* and *Gahnia trifida*), and open heath to open shrub (*Melaleuca cuticularis*). The southern part of Lake Clifton is vegetated by shrub (*M. cuticularis, M. rhaphiophylla* and *Banksia littoralis*) and closed heath (*Melaleuca viminea, M. polygaloides, M. teretifolia, M. leptoclada, Acacia saligna, Kunzea ericifolia, Gahnia trifida).*

The wetlands have conservation value as examples of wetland types, and as avifaunal habitats. **Lake Clifton** is regionally significant for species richness and for variety of species listed under either the Japan Australia or China Australia Migratory Bird Agreements. The lake is considered to be internationally significant to the Red-necked Avocet (Watkins 1993). It is ranked in the top 1% of wetlands that are important to the Great Crested Grebe, Pied Cormorant, Little Black Cormorant, Little Pied Cormorant, Australian Shelduck, Pacific Black Duck, Musk Duck, Fairy Tern and Red-necked Avocet. It is also highly important for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention. **Martins Tank Lake** is regionally significant for numbers of individuals listed on either the Japan Australia or China Australia Migratory Bird Agreements and for variety of these species. It is also highly important for numbers of individuals that are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). **Lake Pollard** is regionally significant for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is also important for numbers of individual waterbirds listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). **Lake Yalgorup** is regionally significant for numbers of waterbirds that are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). It is important for the variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements and for numbers of individuals of these species.

Lake Clifton, Duck Pond, Boundary Lake, Lake Hayward, Lake Newnham- (North and South), Martins Tank Lake, Lake Pollard and Lake Yalgorup are recognised as a wetlands of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Clifton is important as a scientific site because of the stromatolites and unusual aquatic fauna present. Stromatolites are organo-sedimentary deposits which only form under very specific conditions and are used as indicators of climatic and salinity regimes.

From a perspective of geoheritage, this system represents a significant area. The wetlands are located along unconformity interfaces developed along the various limestone bodies formed in a complex shore history (Semeniuk 1995). Lake Clifton itself represents an elongate isolated water body developed along the unconformable contact between the Tims

Thicket Limestone and the Myalup Sand (Semeniuk 1996). The other wetlands have formed between the Myalup Sand and the Kooalup Limestone. From a geoheritage perspective, the system of wetlands is of Statewide to National significance.

8) Riverdale Suite - Wetlands in this suite form linear chains which are remnants of the meandering and lateral migration of the Harvey River. For this reason, they are important scientific features. Conservation of the wetlands should include wetland geometry. The wetlands are ecologically linked and provide habitats for a range of fauna including amphibia, long-necked tortoises and *Cherax*. There is considerable habitat diversity from permanently inundated basins to seasonally waterlogged basins and upland. Vegetation assemblages range from sedgelands to heaths to scrub to low forest. The wetlands are hydrologically linked but interesting local pedogenic processes occur e.g., in wetland S323 iron impregnation and cementation has resulted in a steep sided wetland with an impermeable base.

9) Hamden Suite wetlands - These wetlands are outstanding examples of this suite. They are ecologically connected to each other and the surrounding upland. They are habitats for amphibia, reptiles and invertebrates, and therefore, nodes for food and water for local migratory fauna. They are floristically diverse, and represent a variety of vegetation assemblages such as low forest, scrub, and several low heaths. They also include a variety of habitats from seasonally inundated basins, seasonally waterlogged basins and flats, to dry upland areas.

10) Kemerton wetlands - These wetlands are outstanding because they represent the only well developed and intact wetland system outside of theYalgorup National Park in the whole study area. The wetlands are hydrologically linked as they are expressions of the groundwater table. They are ecologically connected to the surrounding upland, being nodes for water and food for fauna. They represent a variety of vegetation assemblages from low forest to scrub to low heath, and a variety of habitats from seasonally inundated areas to seasonally waterlogged to dry upland areas. The area would make an outstanding wetland park.

11) Ruabon Suite - These wetlands are in a very unusual setting. It is a plain underlain by Bassendean Sand. Only microscale remnants of vegetation remain but these are in good condition. The vegetation in each of the remnant patches is dissimilar. Plant communities are unusual and it is likely that with further investigation priority flora will be identified in these areas. The remnant vegetation is indicative of the floral diversity which once was present.

12) Cokelup Swamp - This wetland is in an unusual setting i.e., between two arms of the Pleistocene Dunes and on a basement of mud and muddy sand of the Guildford Formation. The wetland is a sumpland and lies adjacent to palusplain. The whole wetland complex supports a variety of habitats and vegetation associations. The vegetation ranges from closed forest to low closed heath. The forest is inundated making it ideal avifauna habitat, and the closed heath is seasonally waterlogged making it suitable habitat for small marsupials and reptiles.

References

Burbidge, A.H. and Craig, M. (1996). Lake McClarty: an important Ramsar wetland. Western Australian Bird Notes No. 78.

Garnett, S. (1992). Threatened and extinct birds of Australia. Royal Australasian Ornithologists Union Report Number 82. Pp. 212. Royal Australasian Ornithologists Union, Melbourne.

Geological Survey of Western Australia (1981) 1:50,000 Urban Geology Series. Bunbury - Burekup Sheet 2031 III - 2031 II

Geological Survey of Western Australia (1987) 1:50,000 Environmental Geology Series. Busselton Sheet 1930 I, Capel Sheet 2030 IV

Geological Survey of Western Australia (1991) 1:50,000 Environmental Geology Series. Yallingup Sheet 1930 IV and part sheet 1830 I

Hamilton, N. T. M. and Collins, L. B. (1997) Morphostratigraphy and evolution of a Holocene composite barrier at Minninup, southwestern Australia. Austr. Jour. Earth Sciences **44**, 113-124

Hill, A. L., Semeniuk, C. A., Semeniuk, V and Del Marco, A. (1996) Wetland Mapping, Classification and Evaluation. Wetlands of the Swan Coastal Plain Vol. 2A Waters & Rivers Commission and Dept. Environmental Protection

Jaensch, R. P., Vervest, R.M. and Hewish, M.J. (1988). Waterbirds in nature reserves of south-western Australia 1981-1985: Reserve accounts. Royal Australasian Ornithologists Union Report Number 30. Pp. 290. Royal Australasian Ornithologists Union, Melbourne.

Lane, J., Jaensch, R. and Lynch, R. (1996). Western Australia, pp. 762-943 in R. Blackley, Usback, S. and Langford, K. (eds). A Directory of Important Wetlands in Australia, Second Edition. Pp. 968. Australian Nature Conservation Agency, Canberra.

Ninox Wildlife Consulting. (unpub.). The significance of mosquito breeding areas to the waterbirds of Leschenault Estuary, Western Australia. Unpublished report prepared for Mosquito Control Review Committee, Waterways Commission (1989).

Pen, L., Semeniuk V, & Semeniuk CA (1998). Peripheral wetlands of Leschenault Inlet Jour. Roy. Soc. W.A.

Raines, J.A., Yung, F.H. and Burbidge, A.H. (unpub.). Wetlands of outstanding ornithological importance for the Register of the National Estate in south-west Western Australia: Report to the Australian Heritage Commission. Royal Australasian Ornithologists Union, Melbourne (1995).

Searle, D. J. & Semeniuk, V (1985) The natural sectors of the inner Rottnest Shelf adjoining the Swan Coastal Plain. Jour. Roy. Soc. W.A. **67**, 116-136

Semeniuk, C. A. (1988) Consanguineous wetlands and their distribution in the Darling System southwestern Australia. Jour. Roy. Soc. W. A. **71**, 69-87

Semeniuk, C. A. & Semeniuk, V. (1990) The coastal landforms and peripheral wetlands of the Peel-Harvey estuarine system. Jour. Roy. Soc. W. A. **73**,(1) 9-21

Semeniuk, V. (1985) Age structure of a Holocene Barrier dune system and its implications for sea level history reconstructions in south west Australia. Marine Geology **67**, 197-212

Semeniuk, V. (1995) Yalgorup Plain palaeogeography J Coastal Research

Semeniuk, V. (1996) Quaternary stratigraphy Yalgorup Plain RSWA

Semeniuk, V. (1998) Sedimentology of Leschenault

Semeniuk, V. & Semeniuk, C. A. (1991) Radiocarbon ages of some coastal landforms in the Peel-Harvey Estuary, south-western Australia. Jour. Roy. Soc. W. A. **73**,(3) 61-71

Watkins, D. (1993). A national plan for shorebird conservation in Australia. R.A.O.U. Report Series, No. 90. Royal Australasian Ornithologists Union, Melbourne.

APPENDIX 1

Outstanding Ornithological Values for Wetlands on the Swan Coastal Plain South of the Peel Estuary.

Compiled by Australasian Ecological Services for the
V & C Semeniuk Research Group.

This compilation comprises a current analysis of Birds Australia data bases on waterbirds (1987-1997) and the findings of Raines *et al.* (unpub.), with additional information from Lane *et al.* (1996), Watkins (1993) and Garnett (1992). Ninety eight sites were analysed from this region and compared with 693 other wetland sites in southern Western Australia. Twenty seven wetlands raking in the top 5% (top 39) and/or top 10% (top 78) of sites of importance for various forms of waterbird usage are described in this report. Wetlands recognised under the Convention of Wetlands of International Importance (Ramsar Convention) are also noted. Notably, some wetlands have not been sampled thoroughly and relatively little effort has been made to assess breeding at many wetlands compared to other parameters. Many wetlands therefore require considerably more survey work over a range of seasons to fully assess their values, particularly with respect to breeding. This analysis does not include any non-waterbird species. A waterbird is defined as being a species which is dependent on wetlands for its survival and includes waterfowl, shorebirds and certain species of harrier, eagle and warbler as defined by Jaensch *et al.* (1988).

Alexander Island- ranks in the top 1% of sampled wetlands for numbers of Darter.

Benger Swamp- ranks in the top 1% of sampled wetlands for numbers of White-necked Heron, White-faced Heron, Australian White Ibis, Hardhead, Spotless Crake, Purple Swamphen, Clamorous Reed Warbler and Little Grassbird. It is also in the top 5% of sampled wetlands for variety of breeding species, for species richness and in the top 4.4% for variety of species that are listed on either the Japan Australia or China Australia Migratory Bird Agreements. It ranks in the top 5% for variety of species listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). It is particularly notable for numbers of Australasian Bittern (top 5%) and because this species breeds there.

It also ranks in the top 10% of sampled wetlands for numbers of individual waterbirds, for numbers of individual waterbirds that are listed under Japan Australia and China Australia Migratory Bird Agreements and for median numbers of individual waterbirds. It is notable for the number of individual waterbirds listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). The Australasian Bittern which has been regularly detected at the swamp probably breeds there and the Freckled Duck has occurred in small numbers but bred and moulted there (Lane *et al.* 1996).

Blackwatch Swamp-is in the top 10% of sampled wetlands for numbers of Great Cormorant.

Boundary Lake- is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

The Broadwater- Is in the top 5% of sampled wetlands for numbers of individual waterbirds and for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is in the top 1% of sites for the Australasian Shoveler and in the top 7.9% for species richness. The Broadwater is in the top 10% for variety of breeding species.

Caris Park Swamp- is in the top 1% of sampled wetlands for numbers of Nankeen Night Heron.

Carraburmup Swamp- is in the top 5% of sampled wetlands for median numbers of waterbirds and for variety of breeding species. It is in the top 1% for numbers of Little Black Cormorant and Little Pied Cormorant. It is in the top 7.9% for species diversity and in the top 10% for numbers of individual waterbirds and for median numbers of individual waterbirds.

Lake Clifton- is in the top 5% of sampled wetlands for species richness and for variety of species listed under either the Japan Australia or China Australia Migratory Bird Agreements. The lake is considered to be internationally significant to the Red-necked Avocet (Watkins 1993). It is ranked in the top 1% of wetlands for Great Crested Grebe, Pied Cormorant, Little Black Cormorant, Little Pied Cormorant, Australian Shelduck, Pacific Black Duck, Musk Duck, Fairy Tern and Red-necked Avocet. It is also in the top 10% for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. Finally Lake Clifton is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Clifton Road Swamp- is in the top 1% of sampled wetlands for the Australian White Ibis and in the top 10% of wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements.

Duck Pond- is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Goodale Sanctuary- is in the top 1% of sampled wetlands for the Darter..

Grey Road Swamp-is in the top 10% of sampled wetlands for median numbers of individual waterbirds.

Harvey Estuary- is in the top 5% of sampled wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is in the top 1% for numbers of Darter. It is in the top 4.4% for variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is also significant for the number of waterbirds which are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992), particularly the Freckled Duck. Finally the Harvey Estuary is recognised as a wetland of international

importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Hayward- is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Leshenault Inlet and outlying wetlands (including those immediately east of Cathedral Avenue)- is in the top 5% of sampled wetlands for median numbers of individual waterbirds, for variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements and in the top 7.9% for species richness. It is in the top 1% of sampled wetlands for numbers of Caspian Tern which is listed on the Japan Australia and China Australia Migratory Bird Agreements. Additional data collected by Ninox Wildlife Consulting, and re-analysed in the present study, indicates the wetland complex is in the top 5% for variety of breeding species. It also suggests that Leshenault Inlet is significant for numbers of individual waterbirds, for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and in the top 5% for ten other waterbird species including three species listed on both migratory bird agreements.

Martins Tank Lake- is in the top 5% of sampled wetlands for numbers of individuals listed on either the Japan Australia or China Australia Migratory Bird Agreements and in the top 4.4% for variety of these species. It is also in the top 5% of wetlands for numbers of individuals that are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). Martin's Tank Lake is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

McCarly's Swamp (also known as Ludlow Swamp)- is in the top 1% of sampled wetlands for numbers of Nankeen Night Heron, Australian White Ibis, Straw-necked Ibis and Maned Duck. It is in the top 10% for variety of breeding species. The wetland is particularly notable for colonial breeding species of waterbird such as Great Egret, Straw-necked Ibis, Australian White Ibis and Nankeen Night Heron (Lane *et al.* 1996).

Lake McClarty- is in the top 5% of sampled wetlands for numbers of individual waterbirds, for median numbers of individual waterbirds, for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and for the variety in these species. It is also in the top 5% for species richness and for the variety in species listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). At least seven species breed at Lake McClarty (Burbidge and Craig 1996), placing it in the top 10% for variety of breeding species. Lake McClarty is also considered to be of international importance to the Red-necked Avocet, Curlew Sandpiper and the Wood Sandpiper (Watkins 1993). It ranks in the top 1% of wetlands for these species as well as the Hoary-headed Grebe, Darter, White-faced Heron, Great Egret, Glossy Ibis, Yellow-billed Spoonbill, Australian Spotted Crake, Black-winged Stilt, Marsh Sandpiper, Black-tailed Godwit, Sharp-tailed Sandpiper, Pectoral Sandpiper, Long-toed Stint and Ruff. Nine of these 17 species are listed under migratory bird agreements. Finally Lake McClarty is recognised as a wetland of

international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Mealup- is in the top 5% of sampled wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and for the variety of these species using this site. It is also in the top 5% for species richness. The lake ranks in the top 1% for numbers of Yellow-billed Spoonbill, Australian Crake, Red-kneed Dotterel, Wood Sandpiper and Pectoral Sandpiper, the later two of which are listed on migratory bird agreements. Lake Mealup is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Newnham- (North and South)- is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Pollard- is in the top 5% of sampled wetlands for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is also in the top 5% for numbers of individual waterbirds listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). Lake Pollard is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Lake Preston- is in the top 5% of sampled wetlands for median numbers of individual waterbirds and for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements. It is in the top 1% for Australian Shelduck and Musk Duck. Lake Preston is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

Robert Bay- is in the top 5% of sampled wetlands for numbers of individual waterbirds and the top 10% for median numbers of individual waterbirds. It is in the top 1% of sampled wetlands for Red-necked Avocet.

Rosamel Swamp-is in the top 1% of sampled wetlands for the Little Pied Cormorant.

Vasse-Wonnerup Estuary- is in the top 5% of sampled wetlands for numbers of individual waterbirds, for median numbers of individual waterbirds, for numbers of individual waterbirds listed on either the Japan Australia or China Australia Migratory Bird Agreements and for the variety of these species present. It is also in the top 5% of wetlands for species richness and for variety of breeding species. The estuary is considered internationally significant for the Red-necked Avocet, Black-winged Stilt, Curlew Sandpiper, Sharp-tailed Sandpiper, Wood Sandpiper and Greenshank (Watkins 1993). The estuary is in the top 1% for these species as well as the Australasian Grebe, Australian Pelican, Pied Cormorant, White-faced Heron, Great Egret, Yellow-billed Spoonbill, Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal, Lesser Golden Plover, Black-tailed Godwit, Pectoral Sandpiper, Red-necked Stint, Silver Gull, Whiskered Tern and White-winged Tern. Nine out of these 23 species are listed on migratory bird agreements. It is also notable for the Fairy Tern which breeds

there in large colonies (Lane *et al.* 1996). Finally the Vasse-Wonnerup Estuary is recognised as a wetland of international importance and listed under the Ramsar Convention.

Waneragup Lake- is in the top 1% of sampled wetlands for the Maned Duck.

Lake Yalgorup- is in the top 5% of sampled wetlands for numbers of waterbirds that are listed under the *Wildlife Conservation Act 1950* or by Garnett (1992). It is in the top 4.4% of sampled wetlands for variety of species listed on either the Japan Australia or China Australia Migratory Bird Agreements and is in the top 10% for numbers of individuals of these species. Lake Yalgorup is recognised as a wetland of international importance as part of the Peel-Yalgorup Wetland System listed under the Ramsar Convention.

References

Burbidge, A.H. and Craig, M. (1996). Lake McClarty: an important Ramsar wetland. Western Australian Bird Notes No. 78.

Garnett, S. (1992). Threatened and extinct birds of Australia. Royal Australasian Ornithologists Union Report Number 82. Pp. 212. Royal Australasian Ornithologists Union, Melbourne.

Jaensch, R. P., Vervest, R.M. and Hewish, M.J. (1988). Waterbirds in nature reserves of south-western Australia 1981-1985: Reserve accounts. Royal Australasian Ornithologists Union Report Number 30. Pp. 290. Royal Australasian Ornithologists Union, Melbourne.

Lane, J., Jaensch, R. and Lynch, R. (1996). Western Australia, pp. 762-943 in R. Blackley, Usback, S. and Langford, K. (eds). A Directory of Important Wetlands in Australia, Second Edition. Pp. 968. Australian Nature Conservation Agency, Canberra.

Ninox Wildlife Consulting. (unpub.). The significance of mosquito breeding areas to the waterbirds of Leschenault Estuary, Western Australia. Unpublished report prepared for Mosquito Control Review Committee, Waterways Commission (1989).

Raines, J.A., Yung, F.H. and Burbidge, A.H. (unpub.). Wetlands of outstanding ornithological importance for the Register of the National Estate in south-west Western Australia: Report to the Australian Heritage Commission. Royal Australasian Ornithologists Union, Melbourne (1995).

Watkins, D. (1993). A national plan for shorebird conservation in Australia. R.A.O.U. Report Series, No. 90. Royal Australasian Ornithologists Union, Melbourne.