GOVERNMENT OF WESTERN AUSTRALIA

Mapping and Classification of Wetlands from Augusta to Walpole in the South West of Western Australia

Water Resource Technical Series

Water and Rivers Commission Report WRT 12

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Water and Rivers Commission

WATER AND RIVERS COMMISSION

HYATT CENTRE
3 PLAIN STREET
EAST PERTH
WESTERN AUSTRALIA 6004

TELEPHONE (08) 9278 0300
FACSIMILE (08) 9278 0301

Cover Photograph:
The outstanding and natural basin and flat wetlands of the Scott Coastal Plain in the Scott National Park (looking north from Scott River Road). Photograph by Alan Hill, January 1997.

MAPPING AND CLASSIFICATION OF WETLANDS FROM AUGUSTA TO WALPOLE IN THE SOUTH WEST OF WESTERN AUSTRALIA

Report to the Water and Rivers Commission

by the
V. & C. Semeniuk Research Group

Water and Rivers Commission
Policy and Planning Division

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For more information contact:

Water and Rivers Commission
Policy and Planning Division
Hyatt Centre
3 Plain Street
EAST PERTH WA 6004

Telephone (08) 9278 0300

This report contributes to a series of documents published for the purposes of water allocation planning in the Busselton to Walpole Region. Other publications focus on the following topics:

- An Investigation into the Aboriginal Significance of Wetlands and Rivers in the Busselton-Walpole Region
- Educational and Scientific Use of Wetlands and Rivers in the Busselton-Walpole region
- Recreational Use of Water Bodies in the Busselton-Walpole Region
- A Systematic Overview of the Environmental Significance of Wetlands, Rivers and Estuaries in the Busselton-Walpole Region
- The distribution of freshwater fish in the south western corner of Western Australia
- Historical Significance of Wetlands and Rivers in the Busselton-Walpole Region
- Divertible Water Resource Inventory
- An Investigation of a Hierarchical Approach to Describing Wetland Resources: The Busselton-Walpole Water Resource Region and the Lake Muir Lowland Wetland Region
- A Description of the Hydrology of the Lake Muir Lowland Wetland Region and Implications for Management
- Preliminary Allocation Discussion Paper and Review of Public Submissions
- Busselton-Walpole Region Water Resources Allocation Plan

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Foreword

The vision of the Water and Rivers Commission is to excel at water resource management by ensuring waters and rivers are used wisely by the community. The Commission has made a commitment to manage the water resources of Western Australia for the benefit of present and future generations in partnership with the community.

The Commission is currently undertaking a series of studies aimed at developing a water resources allocation strategy for the Busselton-Walpole Region. Allocation is to be based on the ecological, cultural and water supply values and needs of the community.

Currently, the Commission is working in the Busselton-Walpole Region of the South West Drainage Division. It is the second region covered and follows a study of the Perth-Bunbury Region carried out between 1985 and 1991. As part of the Busselton-Walpole work, consultants V & C Semeniuk Research Group were engaged to map and classify wetlands in four selected parts of the Region.

This report presents the results of the wetland mapping and classification work in three areas between Augusta and Walpole. It is being published to make publicly available the detailed wetland mapping and other new information on wetland grouping which has resulted from these studies.

Mapping and classification of wetlands in the three areas between Augusta and Walpole has shown how extensive and interconnected the Region's wetland resources are. They include approximately 35% of total area mapped. The description of extent and type of the predominantly natural wetlands, valued for their biologically diverse floristics and fauna, between Augusta and Walpole provides information which should be used to protect wetland values and to support sustainable development in appropriate areas.

Some of the work carried out on the coastal plain area of the Busselton-Walpole Region, between Bunbury and Dunsborough, has already been published as part of a study on the wetlands of the Swan Coastal Plain (Hill et al 1996).

Together with the other reports, by the V & C Semeniuk Research Group and others, being made available as part of the regional study, it is hoped that this report will encourage preservation, management and wise use of wetlands and also inform community debate on how the community may wish to more effectively protect and sustainably use the region's water resources. The Commission welcomes comments on this report from any interested person or organization.

Tim McAuliffe

Tim McAuliffe
Director, Policy and Planning Division
Water and Rivers Commission

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Summary

The Water and Rivers Commission is currently working on the Busselton-Walpole Regional Allocation Study in order to guide current and future management of water resources for their effective protection and sustainable use. As part of the Busselton-Walpole Study the V & C Semeniuk Research group were engaged as consultants to map and classify wetlands in three selected parts of the Region. This report presents three consultant reports to the Commission. The report is being published to make the detailed wetland mapping and classification, and other new information on wetland grouping, available to the public.

This report presents wetland mapping and classification for a large part of the south coast from Augusta to Walpole and an inland area including Lakes Muir and Unicup and reaches of the Deep River. This region has been divided into three study areas: the Augusta to Donnelly River area, the Meerup to Walpole area and the Muir-Unicup area.

All wetlands within the three study areas have been mapped at a scale of 1:25 000 and classified as one of the nine basic wetland types using the geomorphic classification system of C A Semeniuk. In addition to forming in basins, flats and channel landforms, wetlands have also been identified and mapped on hillslopes, especially in the lower Deep River catchment. Thirty eight maps were produced at a scale of 1:25 000 to present geomorphic wetland mapping for the Augusta to Walpole area. These maps are available in digital and hardcopy form from the Water and Rivers Commission.

Mapping and classification of wetlands in the three areas between Augusta and Walpole has shown that the total area of wetland is very high, about 35% of the mapped area, and confirms the extensive, diverse and inter-connected nature of the Region's predominantly natural wetlands. This reports describes wetland extent and type between Augusta and Walpole and provides information which should be used to protect wetland values and to support sustainable development in appropriate areas.

After being classified on a site specific basis, wetlands were amalgamated into regional groups using the concept of, and criteria for, consanguineous suites. Due to the large number of wetlands, the remoteness of many of the wetlands and the difficulty of access it was not possible to address all of the selection criteria within time and budget constraints. Hence, only a preliminary identification and mapping of consanguineous suites is presented in this report.

A total of forty-three preliminary consanguineous suites were identified within report's study area. The small area between Northcliffe and Windy Harbour is regionally significant for wetland diversity since it contains ten consanguineous suites. The large number of suites in the small area indicates a richness in diversity of wetland type.

A preliminary identification of outstanding wetlands was also carried out during wetland mapping and classification work. Much of the wetland resource in this area is relatively undisturbed and in natural condition and so many of the wetlands are of outstanding value.

The results of this study provide new information that is to be used, along with existing and other recently commissioned studies, in a broad-scale evaluation of wetlands across the Busselton-Walpole Region.

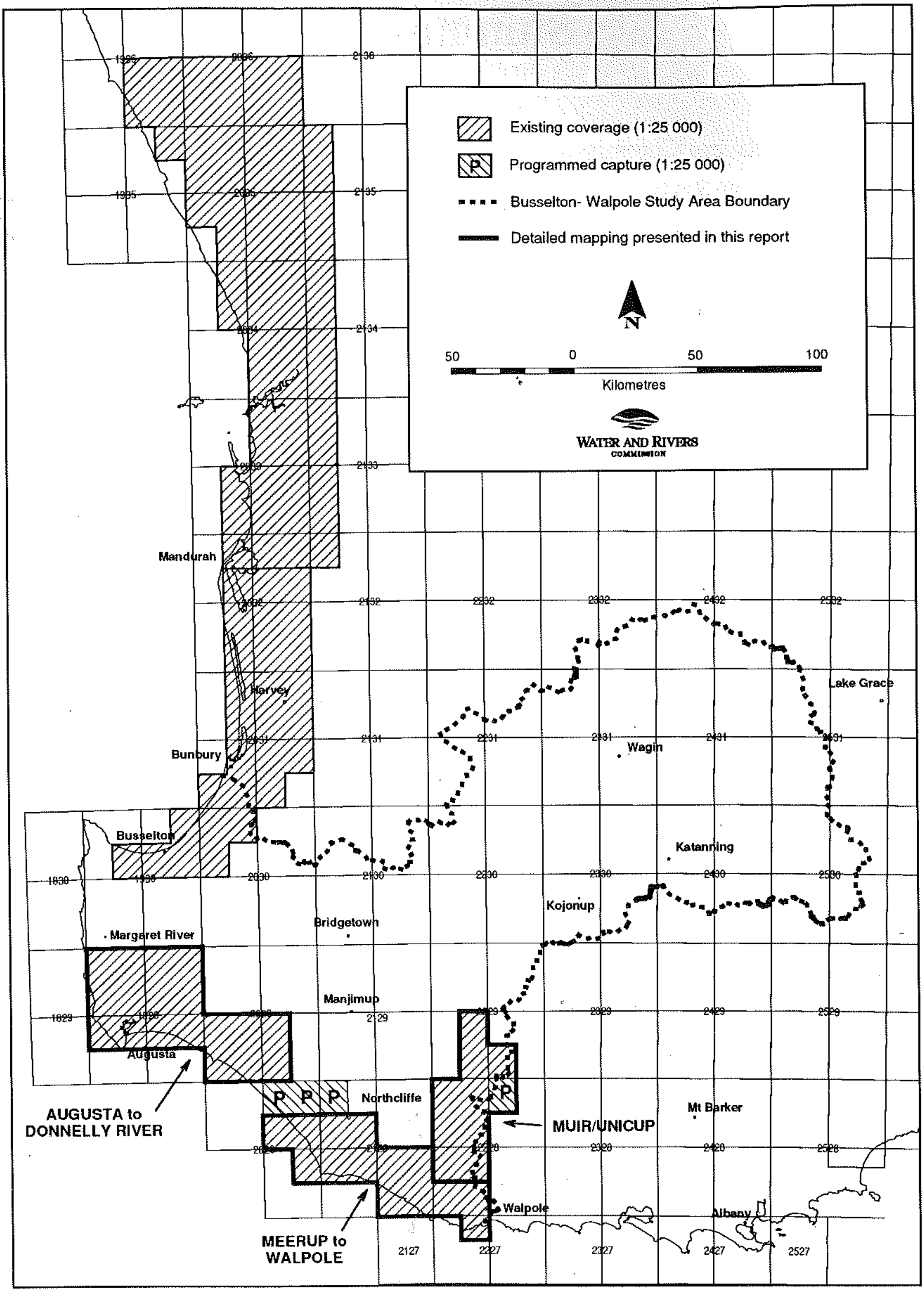


Figure 1: Geomorphic wetland mapping in the Busselton-Walpole region and the location of the three study areas

PART A: Wetland Mapping and Classification

1. Wetland mapping and classification

1.1 Introduction

This report presents wetland mapping and classification for three wetland rich areas of the lower south west of Western Australia. Two of the areas cover coastal wetlands from Augusta to Walpole, including many of the wetlands of the D'Entrecasteaux National Park. The third area covers wetlands in an inland setting, including Lakes Muir and Unicup, numerous other wetlands and the upper reaches of the Deep River.

For each of the three areas, wetlands have been mapped, classified and grouped to identify basic differences and similarities in the resources. A preliminary identification of outstanding wetlands was also carried out during mapping and classification.

These investigations have been initiated as part of the Commission's Busselton-Walpole Regional Allocation Study. The Allocation Study is to investigate, and present for public comment, what is known about the region's water resource values to assist management for sustainable use. Water resource values which are being investigated include maintenance of river and wetland ecosystems, the recreational and cultural values of these resources and their potential for water supply.

The three areas have been selected for detailed mapping to provide information on the large areas of wetlands they contain, the potential high value of the wetlands and the potential for future development to impact on these values. Whilst the information gathered is of immediate use to regional water planning, detailed mapping is also important for ongoing management and protection, and would assist any planning and design of buffers around wetlands and rivers.

1.2 The Busselton-Walpole Region

The Busselton-Walpole Region incorporates a large part of the south west of Western Australia and is based on the catchments of the Deep, Shannon, Warren, Donnelly and Blackwood Rivers and the rivers of the Busselton Coast including the Capel, Ludlow, Sabina and Margaret Rivers (Figure 1).

The wetlands of the region are many and diverse, and the values they provide have been impacted on by a variety of activities. Whilst there has been some investigation of individual wetlands, comparatively little region-wide assessment of wetlands has occurred. Wetland mapping and classification has been carried out in the coastal plain area of the Busselton-Walpole Region, between Bunbury and Dunsborough, and published in a report on the wetlands of the Swan Coastal Plain (Hill *et al* 1996) (see Figure 1). This detailed wetland mapping has also been presented on a broadsheet showing the coastal wetlands from Pinjarra to Dunsborough (Del Marco and Hill 1995). The Busselton-Walpole Allocation Study includes a broad-scale evaluation of wetlands across the region using this work and additional work, such as the wetland descriptions presented in this report.

1.3 Wetland definition

For the purposes of this study, wetlands are *"areas of seasonally, intermittently or permanently waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, e.g. waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries"* (Wetlands Advisory Committee 1977). This definition was agreed upon by the Wetlands Advisory Committee in and is often used by the scientific community in Western Australia.

In practice, wetland terrains may be distinguished from upland by the occurrence of water, or waterlogged soils, or vegetation typical of water conditions (eg., swamp trees, reed beds), or hydric soils (ie., formed in response to prevailing water inundation or waterlogging, and including peats, peaty sands, carbonate muds, etc).

Rivers and creeks are, by definition, wetlands. However, they are often treated in isolation from the floodplains, damplands, sumplands and palusplains that surround them. While this can sometimes be a useful distinction, it is important that rivers, creeks, artificial channels are recognised as wetlands which are intimately connected to other wetland types. Use of the phrase 'channel wetlands' to describe rivers, creeks and artificial channels is useful and to be encouraged in building the linkage between these and other wetland types. In this report, all wetland types are presented in the mapping and classification.

1.4 An overview of wetland mapping, classification and evaluation

Mapping, classification and evaluation are important parts of water resource management and wetland protection, and provide basic information for management. Mapping wetlands defines the edge of seasonally waterlogged land and often uses vegetation and presence of hydric soils as indicators. Classification places a wetland into a group defined by one of more of the wetland's attributes, such landform or water longetivity. Classification is a necessary and important part of compiling a national or regional inventory, assessing the natural variability of natural resources and selecting representative areas for heritage or conservation (Semeniuk 1996).

Wetland evaluation is a separate process which uses the results of mapping and classification along with other information to identify and describe a wetland's existing and potential values. It can be used to focus wetland protection and management resources. Seasonal wetlands in south-western Australia have been shown to be extremely valuable, rating comparitively with the highest areas of biodiversity in the world (see Appendix A). Unfortunately, these seasonal wetlands are being rapidly cleared. This report presents information on wetland extent and type that may be used in the planning and management decision making processes, to protect wetland values in future. Evaluation work carried out in this study reflects a preliminary identification of wetlands with outstanding values, undertaken during the mapping and classification work.

1.5 Geomorphic classification of wetlands

Wetlands in each of the three project areas have been classified using the geomorphic classification system. By grouping wetlands according to the landform in which they are located and their permanency of water, this system highlights fundamental differences or similarities between wetlands. The system differentiates five landform types which can be host to wetlands and four categories of water longevity. These are shown in Table 1 below with the thirteen resultant types of wetland.

Not all wetland types will be present in a given locality. This classification system has been designed for world-wide use and so incorporates landform and water regimes for different climatic settings.

If further differentiation is required between wetlands of the same basic type, then the classification can be augmented by describing the wetland's vegetation, its shape, water salinity or other characteristics. Numerous wetland descriptors have been developed for use with the geomorphic classification system. One of the most useful descriptors is for wetland vegetation community cover and organization. These and other wetland descriptors, such as for wetland size, shape and water salinity, are shown in Appendix B.

Table 1: Wetland types defined within the global geomorphic classification system

	LANDFORM				
WATER LONGETIVITY	BASIN	CHANNEL	FLAT	SLOPE	HIGHLAND
permanent inundation	lake	river	-	-	-
seasonal inundation	sumpland	creek	floodplain	-	-
intermittent inundation	playa	wadi	barlkarra	-	-
seasonal waterlogging	dampland	trough	palusplain	paluslope	palusmont

As examples of the classification system, a flat which is seasonally inundated is classified as a floodplain, a wetland which is a seasonally waterlogged basin is classified as a dampland.

1.6 Consanguinity and Consanguineous suites

A consanguineous suite contains wetlands which are related to each other because they have similar geomorphic, stratigraphic and hydrologic features, and similar processes of formation and maintenance. Consequently, within a given suite, similar wetland types may have similar geometry, similar history, similar recharge and discharge mechanisms, similar water salinity, or similar sediments specific to basins, flats or channels.

There are a range of criteria which determine wetland consanguinity (see Table 2) (Semeniuk 1988), and ideally, all of these criteria should be satisfied prior to allocation of a wetland to a given consanguineous suite, and hence its regional classification. However, in this study it was not possible given the remoteness of many of the wetlands, the difficulty of access, and the large number of wetlands, within the time or budget constraints, to address all of the criteria. Hence, only a preliminary identification and mapping of consanguineous suites is presented here.

Table 2: Criteria to identify natural wetland groups (Semeniuk 1988)

The criteria are applied in sequence as in a dichotomous key
1. Occurrence of wetlands in reasonable proximity to each other, although proximity alone may be no indication of wetland relationship as other factors such as geomorphic processes and hydrologic regime may become significant
2. A similarity in wetland size and shape
3a. Recurring pattern of similar wetland forms, ie. a single wetland type predominates, or an assemblage of wetland types predominate or 3b. A heterogeneous pattern representing a spectral range of inter-related wetland forms, or an association of dissimilar but genetically related wetlands; these could result where there are similar underlying causative factors e.g. fluvial or hydrological processes
4. Similar stratigraphy and hence similar developmental history;
5. Similarity of water salinity and its dynamics;
6. Similarity of hydrological dynamics (eg whether wetlands are recharged and maintained by ponding, seepage, surface run-off, groundwater rise
7. Similar origin (eg karstification)

From work carried out on the Swan Coastal Plain, it is clear that there is a very strong correlation between geomorphology and wetland consanguinity. Wetland geometry, stratigraphy, origin, hydrological mechanisms and prevailing processes are related to the geomorphic setting. As a consequence of this relationship, the preliminary delineation of wetland suites on the southern coastal plain (Areas I and II) is based initially on the geological/geomorphological units. The geological subdivisions, both in terms of age and composition form the underlying framework on which to apply the other criteria for establishing regional wetland suites.

The scope of this study is based on a limited number of field surveys and an aerial flight, and supplemented by a desk study of maps, photographs, and review of research publications on natural aspects of wetlands in this region.

1.7 Wetland evaluation and the preliminary identification of outstanding wetlands during the mapping and classification process

Given the scope of the three mapped areas, a description of the Augusta to Walpole Area's wetlands and a preliminary identification of outstanding wetlands has been carried out. The evaluation will contribute to the regional evaluation of wetlands of outstanding environmental significance (Pen 1997). Comprehensive evaluation of a wetland is a process which requires 1) an understanding of the particular wetland (through field data inventory and monitoring), 2) an understanding of its context in a regional setting, and 3) an understanding of the range of wetland functions, uses and attributes.

Wetland evaluation is the process used to describe and weigh a wetlands existing and potential values. Wetland evaluation can also be used to focus planning, management and protection processes. In describing wetland values it is helpful to use precise nomenclature. Claridge (1991) uses the terms characteristics, functions, uses and attributes to describe wetland value (see Appendix A). Vegetated seasonal wetlands in south-western Australia, particularly on the coastal plains, have outstanding value including recognition that they are among the most biologically diverse areas in the world (see Appendix A). Wetland functions (such as ground water recharge, flood control, sediment retention, habitat for wildlife, etc.) need to be better recognised and protected in planning and management decision making processes. Use of this mapping is critical for maintaining and augmenting the multiplicity of environmental services (or wetland functions) provided by the remaining natural wetlands of the Busselton-Walpole Region.

The preliminary identification of outstanding wetlands in the Augusta to Walpole area has been applied to each consanguineous suite in turn using the criteria listed in Table 3. Due to the scope of the study of the Augusta to Donnelly River area, outstanding wetlands were described generally for part of the study area and not to the level of consanguineous suite.

1.8 Scope of this report

This report covers three study areas in the Busselton-Walpole Region. Discussion of results for each area have been presented separately in Sections 3-5 to maintain the integrity of each project and the information gathered. Whilst there has been similarity in basic approach to mapping and classification in each study area, there are some differences in the level of detail.

In the Augusta to Donnelly River area wetland mapping and classification has been carried out at a scale of 1: 25 000 as part of this study. Identification and mapping of consanguineous suites has occurred for eastern portion of the study area only and is based on 1: 250 000 base map information.

In the Meerup to Walpole area wetland mapping and classification has been carried out as part of this study at a scale of 1: 25 000 and identification and mapping of consanguineous suites is based on 1: 250 000 base maps. Preliminary identification of outstanding wetlands has occurred to the level of consanguineous suite, with discussion of some individual wetlands.

In the Muir-Unicup area wetland mapping and classification has been carried out at a scale of 1: 25 000 as part of this study. Identification and mapping of consanguineous suites has been based on the more detailed scale of the 1: 25 000 wetland mapping. Preliminary identification of outstanding wetlands has occurred to the level of consanguineous suite, with discussion of some individual wetlands.

1.9 Wetland mapping and classification

Geomorphic wetland mapping and classification within the Busselton-Walpole Region is detailed in Figure 1. The northern coastal plain area of the Region, between Bunbury and Dunsborough, was mapped and classified as part of the Busselton-Walpole study and previously published by Water and Rivers Commission and the Department of Environmental Protection (Hill et. al. 1996). Wetland mapping and classification for the Augusta to Walpole area is presented for the first time in this report, see Figures 2 to 5. Geomorphic wetland mapping and classification for the Augusta to Walpole area produced 38 x 1: 25 000 maps which are available in digital or hardcopy form from the Water and Rivers Commission. An example of the detail contained in this mapping is shown in Figure 2.

Table 3: Criteria used to identify wetland values

CRITERION	DESCRIPTION
condition of wetland	Condition of wetland includes assessment of the landform and stratigraphy, hydrology such as hydroperiod, water levels, water quality, and maintenance mechanisms, and vegetation in the wetland and the buffer zone.
representativeness	Representativeness is assessed on the range of wetland types present in each suite as well as the characteristics of each suite.
scarcity of wetland type	Scarcity relates to the size, distribution and duplication of wetland suites.
habitat diversity	Habitat diversity refers to the variability present in each suite as well as the presence/absence of restricted habitat types.
geomorphic/landscape values	specific features present in the wetlands
faunal values	Documented use of wetlands by specific fauna, and the importance of the wetland in maintaining populations.
linkage of systems	Linkage of systems refers to hydrological links such as creeks flowing into or from basins, creeks on flats, palusmonts grading into paluslopes and palusplains in valley systems; and to ecological links such as a series of basins ranging from permanent open water to seasonally waterlogged vegetated damplands surrounded by upland.

In each of the three areas, basin, flat and slope wetlands have been mapped by consultants V. & C. Semeniuk Research Group for the Water and Rivers Commission between 1993 and 1996. The complimentary mapping of channel wetlands (rivers and creeks) is based on existing 1: 25 000 topographic maps produced by the Department of Land Administration. All perennial watercourses have been reclassified to rivers, all non-perennial watercourses to creeks.

The wetlands of the Augusta to Walpole area have been grouped into preliminary consanguineous suites and are summarised in Table 4. The consanguineous suites for the three areas are described in more detail in Part C of this report. The outstanding wetlands which have been identified in this study during mapping and classification for the Augusta to Walpole area are summarised in Table 5.

1.10 Discussion

The wetland mapping and classification presented in this report represents some of the first application of the expanded geomorphic classification system in Western Australia. This expanded geomorphic classification system has been developed to encompass wetlands worldwide.

Since 1987, an earlier version of the geomorphic system has been used to successfully map and classify wetlands in the Darling System, the area for which it was specifically developed. The Darling System is a mostly humid to subhumid region encompassing coastal plain and plateau settings. This classification recognised seven basic wetland types.

As work extended northwards and southwards of the Darling System it became apparent that in changing climatic zones there would be additional wetland types. For example, in a more humid climate there would be additional landforms that would host wetlands, and in more arid climates the periodicity of water availability would alter.

Hence the expanded classification was developed and trialed to include wetlands present on hillslopes and hilltops and wetlands which are intermittently inundated. This expanded concept continues to identify the basic, common features that are present in all wetlands (their landform setting and hydroperiod). It also incorporates the use of descriptors of wetland shape, size, soils, vegetation and water salinity to further describe the wetlands systematically and hierarchically.

Use of the geomorphic approach in these areas has also been used as an opportunity to test the system in different geomorphic and climatic settings from those in the Perth-Bunbury region. It has shown that in addition to the seven wetland types that occur in the Perth-Bunbury region, the southwest also supports wetlands which have formed on the slopes and tops of hills (paluslopes and palusmonts).

The Muir/Unicup area differs in two important ways from the coastal plain regions of southwestern Australia. Firstly, the region is located in the Ravensthorpe Ramp geomorphic area and secondly, the Muir/Unicup area has a history of aridity. As a result of their physiographic and climatic setting and the Cenozoic history, these wetlands have undergone a complex history and present today a complex hydrology. For example, freshwater and saline wetlands occur adjacent to each other in the Muir-Unicup area and paleo-drainage and current drainage also exist in close proximity in both areas. However, at a descriptive level, at which level classification is applied, the wetland classification was successfully used to categorize wetland in both regions.

However, there are some issues in this area which require further comment, particularly in regard to altered regimes in wetlands, and to gradation between wetland types.

Many wetlands throughout the state have ceased to function according to their natural hydroperiod in that their water regime may be fully maintained/managed by use of drains, pumps or dykes. Such wetlands still function biologically but may be difficult to define in terms of hydroperiod in that their water regime should be considered as artificial. In this context, it is stressed that the geomorphic classification system deals mainly with natural wetlands, or with wetlands in which the hydroperiod dynamics are predominantly natural despite some modification.

The task of mapping wetlands has also shown that many of the wetlands form gradational, linked systems, i.e. they grade laterally or upslope into each other. In these instances, the external wetland boundaries may be located accurately using aerial photo mosaics verified by field checking. However, some internal boundaries, such as the contact between paluslopes and palusplains, are difficult to discern because of the gradational nature of the land surface. A satisfactory solution, in most instances, has been to continue the line of the flat such that it forms the base of the slope. For all management and practical purposes, a system such as paluslopes grading to palusplains should be regarded as linked and holistic, and treated in this way.

Table 4: Preliminary list of wetland suites in the Augusta to Walpole and Muir-Unicup Areas identified during wetland mapping and classification.

Note: The consanguineous wetland suites have been only preliminary identified. Sections of the table left blank indicate that the information is not yet known or the data is not presently available.

The Augusta to Donnelly River area (Note: Investigation limited to eastern third of this area)

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
AD1. Donnelly River and Floodplain suite	Holocene alluvial flats	Leptoscale meandering river with floodplain	Underlain by alluvium comprising River and clay, sand and loam	
AD2. Bolghinup Lake suite	Pleistocene limestone dunes	One microscale linear sumpland	Underlain by calcrete	
AD3. Balgamup suite*	Pleistocene quartz sand dunes, overlying Tertiary Estuarine sediments.	Microscale to mesoscale sumplands and damplands in the blowout areas of the coastal dunes	Underlain by quartz sand.	
AD4. Pneumonia Road suite	Pleistocene alluvial flats	Numerous leptoscale circular sumplands close together in a palusplain; vegetation maculiform	Sumplands underlain by clay. Palusplains underlain by alluvial deposits of sands, muddy sands and laterite	
AD5. Cleave Road suite	Pleistocene alluvial flats	Microscale rounded sumplands located on a floodplain and palusplain	Underlain by muddy sands and laterite	Associated with Barley Brook
AD6. Double Creek suite*	Pleistocene colluvial flats and slopes	Leptoscale creeks and associated microscale flats and slopes; sumplands	Underlain by colluvium and laterite	The wetlands are located in the superficial valley-fill deposits and are underlain by colluvium and laterite.
AD7. Lake Jasper suite	Contact of Pleistocene limestone/Pleistocene quartz sand dunes/ Tertiary estuarine flats	Macroscale to microscale ovoid to linear lakes and sumplands; vegetation bacataform	Underlain by quartz sand	
AD8. Donnelly River Estuary	Contact of Pleistocene limestone dunes/ cretaceous rock head	Meandering linear estuary; vegetation peripheral		Estuary is barred at the mouth by wave re-worked quartzo-calcarous sand. Its geometry is constrained to a narrow channel by the surrounding basalt and limestone outcrops, except in its upper reaches, where it widens out onto what appears to be a former floodplain.
AD9. D'Entre-casteaux suite*	Tertiary estuarine flats	Extensive palusplain, macroscale to leptoscale irregular and sometimes coalescing sumplands and damplands and linear dunes; vegetation maculiform	Underlain by estuarine sediments,fine/medium and very coarse sands and ferricrete.	
AD10. Alamein suite	Tertiary estuarine flats	Macroscale to mesoscale damplands.	Underlain by estuarine sediments.	
AD11. Fly Brook suite*	Tertiary alluvial/lacustrine flats	Slopes associated with creeks	Underlying alluvial sediments are strongly laterised.	Waterlogged valley slopes and headwaters.

* Several suites occur in more than one study area — see Section 2.3.

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
AD12. Storry Road suite	Tertiary sandy alluvial flats	Paluslopes; freshwater	Underlain by quartz sand	Wetlands located on the slopes of linear dunes at the base of the scarp of the Darling Plateau
AD13. Jack and Jill suite	Tertiary complex association of laterite, pisolithic gravel, sand, alluvial and colluvial flats, slopes and ridges	Macroscale to leptoscale irregular sumplands and damplands	Underlain by quartz sands and gravelly and sandy muds	

The Meerup to Walpole area

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
MW1. Windy Harbour Ridge suite	Holocene calcareous sand dunes, ridges and chaots	Microscale elongate damplands; vegetation maculiform	Underlain by fine sand	Wetlands formed in inter-ridge depressions; maintained mainly by groundwater rise
MW2. Meerup suite	Holocene calcareous sand dunes, ridges and chaots	Mesoscale to leptoscale irregular basins; some vegetated, some not	Underlain by sand (calcareous) with a superficial peat layer	Wetlands in the interdune hollows of the backshore, some maintained by groundwater rise
MW3. Gardner River estuary	Holocene calcareous sand dunes, ridges and chaots	Estuary, narrow shore-normal with narrow fringing latiform flats		Wave dominated estuary
MW4. Malimup suite	Pleistocene sand dunes	Microscale to mesoscale damplands and slopes	Underlain by sand and limestone	Wetlands within the bowls of the parabolic dunes, formed by deflation to the water table
MW5. Windy Harbour suite	Contact of Pleistocene limestone dunes/Tertiary estuarine flats	Mesoscale irregular damplands and shallow sumplands; vegetation zoniform to maculiform; water fresh to subhaline	Black humic sand overlying slightly humic medium and fine quartz sand	Wetlands formed at the base of limestone ridges and the Tertiary estuarine unit, maintained by groundwater rise and seepage from the base of the dunes and limestone ridge.
MW6. Sand Peak suite*	Contact of Pleistocene sand dunes/Tertiary estuarine flats, where coastal dunes have encroached over the Tertiary basement	Microscale to mesoscale, irregular linear sumplands and damplands; vegetation maculiform	Underlain by sand sheets that rest on estuarine or lagoonal deposits	Localised deflation has created wetlands within the bowls of the parabolic dunes
MW7. Coastal track suite*	Contact of Pleistocene sand dunes, and the estuarine, lagoonal and lacustrine Tertiary basement	Irregular leptoscale to microscale discrete damplands, sumplands and lakes; freshwater; vegetation ranges from zoniform to heteroform to maculiform	Humic quartz sand overlying incipient coffee rock over dark grey quartz sand	
MW8. Lake Maringup suite	Contact of Pleistocene sand dunes/Tertiary estuarine flats/ Precambrian rock plateau	Macroscale shallow basins within a floodplain; vegetation heteroform	Underlain by peats and peaty sands and grey quartz sands	Former estuary
MW9. Broke Inlet/ Nornalup-Walpole Estuary suite	Contact of Pleistocene sand dunes/Tertiary estuarine flats/ Precambrian rock plateau	Macroscale to megascale "T" shaped estuaries bordered by narrow fringing flats	Flats are quartz sand dominated, which may overlie either coffee rock or ferricrete at groundwater level. Deltas are underlain by shelly sand overlying black mud	Estuaries barred from the ocean or another inlet by limestone, lateritic and gneiss barriers

* Several suites occur in more than one study area — see Section 2.3.

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
MW10. Crystal Lake suite	Contact of Pleistocene limestone dunes/ Precambrian rock plateau	Microscale freshwater lakes and steep sided karst features; lakes range from sub-rounded to linearly irregular; vegetation bacataform		Karst features fed by freshwater channel wetlands
MW11. Walpole River suite*	Tertiary colluvium flats and slopes	Paluslopes, sometimes associated with microscale creeks; vegetation maculiform; groundwater fresh	Slopes underlain by quartz sand which overlies coffee rock, over sandy mud and silt, or by a sequence of black peat over peaty sand over sand. Creeks underlain by peaty sand overlying layers of black to brown muddy sand and black terrestrial clay, over quartz sand	Some soil horizons create a perched aquifer above the regional water table
MW12. Linear dunes — palusplain suite	Tertiary estuarine flats	Palusplain, vegetation maculiform	Underlain by fine/medium and very coarse sands over-lying slightly muddy sand with iron staining and cementation	Land slightly undulating overlain by parabolic dunes, maintained by groundwater rise
MW13. Floodplain suite	Tertiary estuarine flats	Floodplains, palusplain and leptoscale creeks and some lakes and sumplands; vegetation maculiform or paniform; freshwater to hyposaline	Humic or peaty sand overlying muddy sand	Wetlands formed through erosion by channels draining the estuarine flats
MW14. Valley suite	Tertiary estuarine flats	Slopes, palusplain and leptoscale channels; vegetation maculiform	Underlain by a thin layer of peat overlying grey fine sand.	Wetlands occur in valleys of Tertiary deposits between granite gneiss outcrops and are impeded and oriented by small-scale dune ridges
MW15. Inlet River suite	Tertiary estuarine flats	Palusplain, transected by leptoscale meandering creeks	Quartz sand in the creeks is interlayered with ferricrete gravel and ferricrete sheets; Palusplain composed of quartz sand (over-printed with iron mottling and staining) overlying muddy sand	Palusplain underlain by estuarine sediments, transected by creeks and interrupted by granite outcrops from which seepage occurs
MW16. Gardner River suite	Tertiary estuarine flats	Leptoscale to microscale creeks and rivers and leptoscale associated floodplains and palusplain	Channels cut into granite of ferruginous pisolitic soil with a superficial overlay of sand and muddy sand	
MW17. Doggerup circular basin suite	Tertiary alluvium flats	Circular microscale to mesoscale freshwater lakes, sumplands and damplands on a palusplain	Wetlands underlain by alluvium (sand and muddy sand), peat, and lenses of limestone. Peat horizons may be 0.5 – 2 m thick	Wetlands formed in depressions on undulating palusplain maintained by groundwater rise. Many basins have been deepened by burning of peat fill

* Several suites occur in more than one study area — see Section 2.3.

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
MW18. Doggerup creek suite	Tertiary alluvium flats	Leptoscale creek with many tributaries from headwaters (paluslopes)	Underlain by quartz sand	
MW19. Sandy Peak Creek suite	Tertiary alluvium flats	Paluslopes, adjacent palusplain, floodplain, creeks; vegetation mainly latiform	Peaty or humic sand overlying fine quartz sand	Complex discharge area for fresh groundwater and surface water
MW20. Chudulup suite	Tertiary alluvium flats	Palusplain dissected by leptoscale meandering creeks; vegetation maculiform; fresh groundwater	Substrate is grey quartz sand with a thin layer of peat at the surface.	Palusplain underlain by alluvial sediments, transected by numerous dendritic creeks and interrupted by granite outcrops from which seepage occurs.
MW21. Pallinup suite	Tertiary siltstone flat	Palusplains and basins; groundwater is fresh	Suite is underlain by the Pallinup Shale overprinted by colluvial materials which range from muddy sand and silt to a white fine quartz sand, with over-printing of iron staining and cementation	Wetlands occur in valleys which were probably Tertiary wetlands and which retain palaeo-geographic features such as former watercourses. Some perching occurs above the shallow iron indurated layer.
MW22. Pingerup Lakes suite	Tertiary siltstone flat	Lakes and sumplands; fresh groundwater; vegetation maculiform	Peaty sand overlying a muddy sand layer as wetland fill	Wetlands probably windows to the water table
MW23. Weld River suite	Precambrian rock plateau	Rivers, leptoscale entrenched channels; water	Channels occur through a layer of sedimentary fill sequence of is subhaline quartz sand on muddy sand on ferruginised muddy (kaolin) sand on mudstone on granite	
MW24. Deep River/ Shannon River Delta	Precambrian rock plateau	River delta; groundwater ranges from hyposaline to mesosaline	Delta underlain by shelly and humic sand overlying black sand overlying white river sand	Cuspate wave dominated delta

The Muir-Unicup area

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
MU1. Muir suite	Tertiary alluvial flats (Young Basin, isolated excavation structure in Old Basin)	Megascale sumpland (Lake Muir), sumplands, seasonal freshwater leptoscale to microscale creeks; vegetation bacataform	Suite is underlain by a range of substrates. The eastern and northern sides of Lake Muir sumpland are underlain by cream medium sand over-lying mottled grey/ green sandy mud overlying mottled orange/yellow/grey mud overlying buff sand overlying green muddy sand to a depth of 1 m. The sumpland margin on the western side is composed of grey clay underlain by	Lake Muir is a basin formed by geomorphic processes belonging to a former arid period. At the time of its initial formation, undulation in the plateau terrain in the area intersected the regional saline water table, forming a wetland depression. This basin was enlarged by salt weathering of the margins, combined with aeolian deflation. The contact zone of the large basin with the older plateau surface underwent rill and creek erosion, resulting in drainage lines oriented normal to the slope. Today the basin continues to be a window to the water table

continued . . .

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
. . . continued			a layer of white coarse sand (quartz) to a depth of 1.5 m. The sediments underlying wetlands of the dune/swale sequence are alternately quartz sand and gravelly quartz sand with grains of $CaCO_3$. Creeks are underlain by a layer of humic sand overlying mottled orange/grey muddy sand overlying mottled sand with ferricrete nodules	
MU2. Byenup suite	Tertiary plateau and flat (Old Plateau and Old Basin)	Lakes, sumplands, damplands, flats, and several small scale creeks. Microscale to macroscale wetland basins which are rounded, sub-rounded and ovoid, freshwater to hyposaline; vegetation varies from complete to patchy to peripheral cover. Freshwater floodplains; vegetation maculiform	Basins are underlain by peat or peaty sand over sand, or underlain by peat over black mud (clay) over sand, or underlain by peat or peaty sand over cream/orange mottled muddy sand (saprolite) with nodules of laterite. Floodplains underlain by either white sand over laterite or saprolite over laterite	Many of the basins are surrounded by beach ridges indicating a period of aridity in the history of the wetlands
MU3. Unicup suite	Tertiary plateau (Old Plateau)	Lakes, sumplands, floodplains, palusplains and creeks.	Basins underlain by peat over grey sand over laterite, or peat over black mud over laterite, or shelly mud over clay over muddy sand. Wetland fill overlies a shallow sand layer on saprolite. Creeks and flats are underlain by quartz sand on laterite overlying the regional saprolite lithosome.	The range of wetlands is associated with a former drainage pattern which has been modified by changing climatic/geomorphic/hydrologic patterns from the Tertiary to the present. Wetlands exhibit gradation from creeks, to broad valley flats and slopes, to basins. This probably represents an evolutionary sequence where creeks continue to geomorphically degrade to become broad valley flats and slopes which in turn eventually clog to form irregular shaped basins such as Noobijup Lake. During intermittent cycles of inundation and in conditions of variable winds, sedimentary processes result in the basins becoming excavated, ringed by beach ridges, and finally circular. Thus the wetlands display a history of evolutionary formative processes from the Tertiary to the present
MU4. Weld River suite	Precambrian rock plateau	Rivers, leptoscale entrenched channels; water is subhaline	Channels occur through a layer of sedimentary fill sequence of quartz sand on muddy sand on ferruginised muddy (kaolin) sand on mudstone on granite	
MU5. Deep River suite	Tertiary plateau, Young Rivers	Microscale straight and meandering rivers and creeks, microscale to mesoscale basins which are	Creeks are underlain by medium, fine, coarse quartz sand or peaty sand, overlying mottled	

continued . . .

SUITE	Geologic/geomorphic framework	Description of Wetlands	Stratigraphy	Origin of Wetlands
. . . continued		the tributary headwaters, and mesoscale floodplains and palusplains associated with the Deep River itself. Vegetation: creeks maculiform and bacataform, floodplains maculiform	orange, grey, cream muddy sand. Floodplains are underlain by humic, medium muddy sand overlying layers of coarse to very coarse quartz sand, overlying mottled orange/cream sandy mud. Palusplains are underlain by slightly humic muddy sand, or sand, overlying mottled orange/cream muddy sand with ferricrete.	
MU6. Walpole River suite	Tertiary plateau	Paluslope wetlands sometimes associated with creeks or palusplain; vegetation maculiform; surface and groundwater fresh	Paluslopes underlain by peaty sand over grey quartz sand	
MU7. Pallinup suite	Tertiary plateau	Palusplain with microscale sumplands; fresh groundwater; vegetation maculiform	Wetlands underlain by sands, silts and muddy sands overlying a shallow iron-indurated layer	
MU8. Jack and Jill suite	Tertiary plateau	Mesoscale to leptoscale irregular paluslopes, sumplands and damplands.	Underlain by quartz sands with a pedogenic overprint of mottling beige/red/yellow gravelly sandy muds overlying granite	

Table 5: Outstanding wetlands in the Augusta to Walpole and Muir-Unicup areas identified during wetland mapping and classification.

Note: Outstanding values of wetlands have been preliminary identified using information available to date. In many suites the full value of the wetlands has not yet been determined and hence the results should be viewed as preliminary.

SUITE		Outstanding Wetland Values *	Notes
	The Augusta to Donnelly River area (Note: Investigation limited to eastern third of this area)		
AD1.	Donnelly River and Floodplain suite	C, H, G, R, L	Outstanding ecological values due to habitat diversity.
AD2.	Bolghinup Lake suite	C, G, R, S	Exhibits significant geomorphical features — wetland underlain by calcrete.
AD3.	Balgamup suite	C, F, R, H	
AD4.	Pneumonia Road suite	C, G, R	Exhibits significant geomorphical features — small closely spaced circular claypans in a flat.
AD5.	Cleave Road suite	C, H, R, L	Outstanding ecological values due to habitat diversity.
AD6.	Double Creek suite	C, R	
AD7.	Lake Jasper suite	C, H, F, R	Outstanding ecological values due to habitat diversity.
AD8.	Donnelly River Estuary	C, G, R, F, S	Exhibits significant geomorphical features — channel and estuarine flats.
AD9.	D'Entrecasteaux suite	C, H, R	Outstanding ecological values due to habitat diversity.
AD10.	Alamein suite	C, H, R	Outstanding ecological values due to habitat diversity.
AD11.	Fly Brook suite	C, R	
AD12.	Storry Rd suite	C, R	
AD13.	Jack and Jill suite	C, R	
	The Meerup to Walpole area		
MW1.	Windy Harbour Ridge suite	C, R, H, S	Undisturbed, represent a type uncommon on the southcoast and restricted to Windy Harbour.
MW2.	Meerup suite	S, H, G, C, R	Unusual habitat, probably young and undergoing rapid change making them excellent examples of wetland processes and evolution.
MW3.	Gardner River estuary	C, R, G	Reasonably inaccessible and relatively undisturbed. Gardner River represents this type of estuary along the southern coast.
MW4.	Malimup suite	C, R, H, F	Representative of this suite, its processes and vegetation types. Important source of freshwater to fauna, contrasting habitat to surroundings.
MW5.	Windy Harbour suite	C, R, H	Relatively few in number, appear to have undergone less frequent burning as other Tertiary flat basins; supports less disturbed and better zoned vegetation
MW6.	Sand Peak suite	C, R, H, F	Similar attributes as Malimup Suite.
MW7.	Coastal track suite	C, R, H, F	Represent a range of wetland types and habitats.
MW8.	Lake Maringup suite	C, R, S, F, L	Unique wetland type — probably a former estuarine system. Important fauna habitat for fish, frogs and avifauna. Habitat for two species of fish with restricted or sparse distribution, and for Declared Rare Fauna, the Black Bittern (Jaensch 1992b).
MW9.	Broke Inlet/Nornalup-Walpole Estuary suite	C, R, S, H, G, L, F	Largely undisturbed with very high habitat value due to the diversity of the systems.
MW10.	Crystal Lake suite	C, S, G, R	Unique in study area and landscape.

SUITE	Outstanding Wetland Values *	Notes
MW11. Walpole River suit	C, R, F, L	Northcliffe area wetlands provide habitat for endemic and new species of invertebrates (Horwitz 1994), a new species of freshwater crayfish, and habitat for a frog which is extremely restricted in its occurrence (Wardell-Johnson and Roberts 1991).
MW12. Linear dunes - palusplain suite	C, R	Undisturbed and represents a wetland type and habitat resulting from a relatively simple stratigraphic and hydrological system.
MW13. Floodplain suite	C, R, S, H, G, F, L	Largely undisturbed, diverse habitat areas; only occurs in one location in the study area
MW14. Valley suite	C, R, S, G	Undisturbed, only one location in study area makes this suite regionally significant. The combination of processes which operate in this suite makes it scientifically interesting from a geomorphic/hydrological point of view.
MW15. Inlet River suite	C, R, F	Suite is widespread in the region and largely undisturbed, best represented by Inlet River.
MW16. Gardner River suite	C, R, L	These wetlands recur throughout the study area but Gardner River is the type example of this wetland.
MW17. Doggerup circular basin suite	C, R, H, G, F	Many undisturbed wetlands, some significantly altered by fire damage. Diverse range of habitats and a high density of wetlands. L. Samuel, L. Florence and Doggerup L. provide habitat for 7 species of fish (1 restricted distribution and 2 rare), frogs, marron, tortoises and invertebrates.
MW18. Doggerup creek suite	C, R, S	Relatively undisturbed and does not recur in study area, but does occur in areas further north.
MW19. Sandy Peak Creek suite	C, R, S, L, G	Wetland complex forms a complete integrated system. Unusual geometry, arrangement of wetlands and setting.
MW20. Chudulup suite	C, R, F, L	Wetlands near Mt Chudulup are significant for invertebrate families of Cladocera and Insecta (Pusey and Edwards 1990b), rare fish *Lepidogalaxias salamandroides* (Allan & Berran 1990, Pusey 1990, Bayly 1992) and the amphibian *Geocrinia rosea* (Wardell-Johnson and Roberts 1993).
MW21. Pallinup suite	C, R, G, F	Wetlands are undisturbed, invertebrate studies indicate unusual and diverse populations present in the wetlands. Development history and hydrology is little understood and so of interest to scientists.
MW22. Pingerup Lakes suite	C, R, S, H, F	Relatively undisturbed, diverse number of habitats; suite not replicated elsewhere in study area.
MW23. Weld River suite	C, R, F, L	Includes Deep River, Shannon River, the upper reaches of Gardner River, and Frankland River.
MW24. Deep River/Shannon River Delta	C, R, S, H, G, F, L	Relatively scarce wetland types, undisturbed, diverse habitats.

continued . . .

* Outstanding wetlands were identified during expert mapping against the following criteria:

C Condition of wetland: includes assessment of the landform and stratigraphy, hydrology such as hydroperiod, water levels, water quality, and maintenance mechanisms, and vegetation in the wetland and the buffer zone.

R Representativeness: is assessed on the range of wetland types present in each suite as well as the characteristics of each suite.

S Scarcity of wetland type: relates to the size, distribution and duplication of wetland suites.

H Habitat diversity: refers to the variability present in each suite as well as the presence/absence of restricted habitat types.

G Geomorphic/landscape values: specific features present in the wetlands

F Faunal values: Documented use of wetlands by specific fauna, and the importance of the wetland in maintaining populations.

L Linkage of systems: refers to hydrological links such as creeks flowing into or from basins, creeks on flats, palusmonts grading into paluslopes and palusplains in valley systems; and to ecological links such as a series of basins ranging from permanent open water to seasonally waterlogged vegetated damplands surrounded by upland.

. . . continued

SUITE		Outstanding Wetland Values *	Notes
			The Muir-Unicup Area
MU1.	Muir suite	G, F, R, S	Lake Muir is scientifically important in that it is the only wetland of its type with features indicating its derivation/formation within earlier phases of aridity. The suites wetlands contain diverse habitats and are important for avifauna. The suite contains three rare and endangered plant species and one restricted plant species.
MU2.	Byenup suite	G, F, R, H, L	Large area of wetlands; extensive peat swamps with predominantly fresh surface water. Some lakes in this suite are outstanding and /or regionally significant with respect to avifauna. Also support diverse invertebrate populations, freshwater crayfish and the Oblong tortoise. Two declared rare orchids also occur in this suite.
MU3.	Unicup suite	H, G, F, L, R	This suite is scientifically important as it provides evidence for wetland developmental processes and hydrological history in the Muir-Unicup area. The suite is also important for avifauna use.
MU4.	Weld River suite	C, R, F, L	Includes Deep River, Shannon River, the upper reaches of Gardner River, and Frankland River.
MU5.	Deep River suite	C, R, H, L	The suite is important as an example of a fluvial wetland system in a humid environment. Little survey data on vegetation or fauna to date.
MU6.	Walpole River suite	C, L, F, R	Many wetlands are undisturbed and part of linked systems. Northcliffe area especially ecologically important for fauna.
MU7.	Pallinup suite	G, F, R	This suite contains wetlands which have retained paleo features of the Tertiary and is of interest to a variety of scientists. Preliminary findings of invertebrate studies indicate unusual and diverse populations.
MU8.	Jack and Jill suite	C, R	The suite is largely unexplored but represents a wetland type which is unusual in the plateau regions: wetlands underlain by granitic basement. These areas are undisturbed.

* Outstanding wetlands were identified during expert mapping against the following criteria:

C Condition of wetland: includes assessment of the landform and stratigraphy, hydrology such as hydroperiod, water levels, water quality, and maintenance mechanisms, and vegetation in the wetland and the buffer zone.

R Representativeness: is assessed on the range of wetland types present in each suite as well as the characteristics of each suite.

S Scarcity of wetland type: relates to the size, distribution and duplication of wetland suites.

H Habitat diversity: refers to the variability present in each suite as well as the presence/absence of restricted habitat types.

G Geomorphic/landscape values: specific features present in the wetlands

F Faunal values: Documented use of wetlands by specific fauna, and the importance of the wetland in maintaining populations.

L Linkage of systems: refers to hydrological links such as creeks flowing into or from basins, creeks on flats, palusmonts grading into paluslopes and palusplains in valley systems; and to ecological links such as a series of basins ranging from permanent open water to seasonally waterlogged vegetated damplands surrounded by upland.

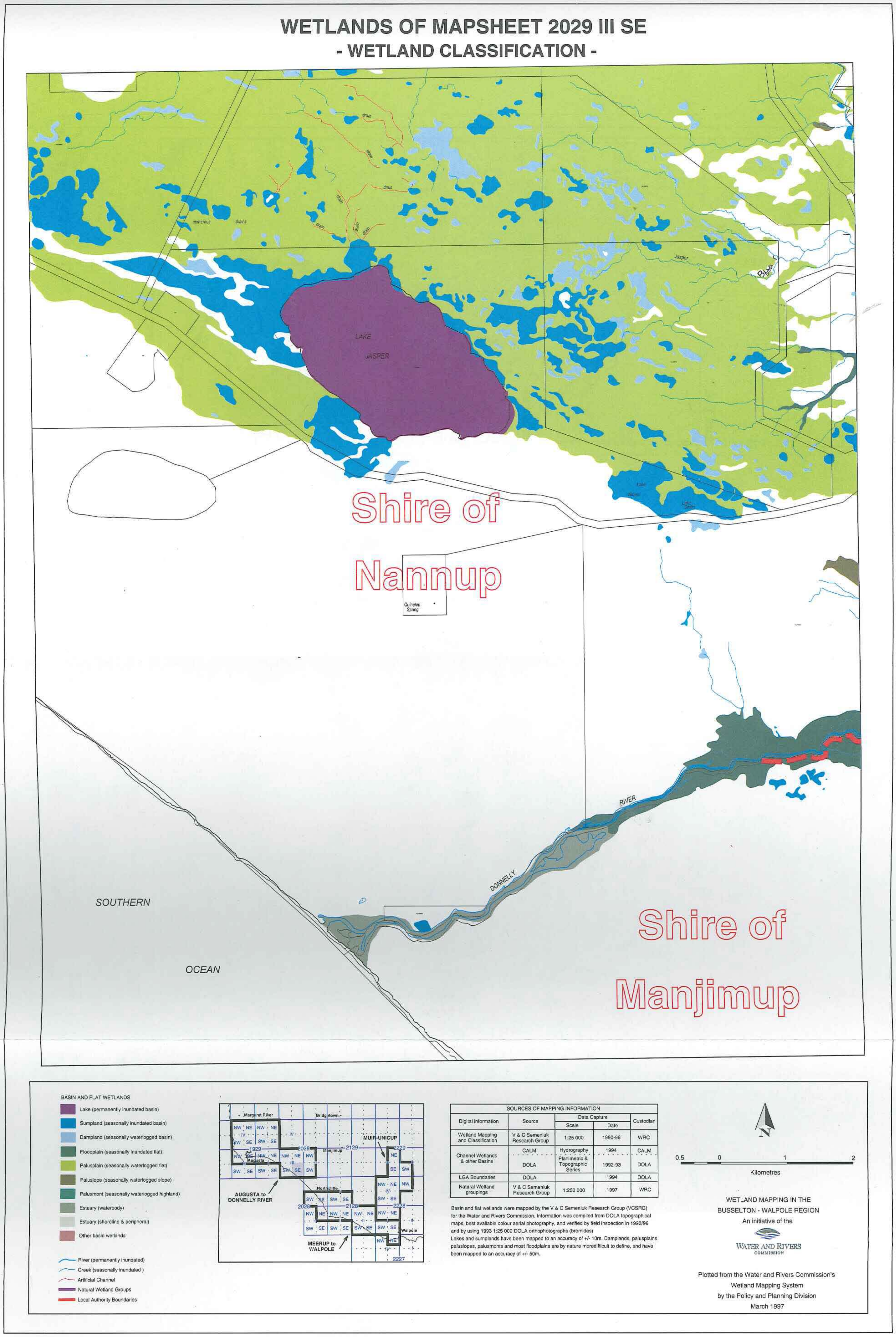


Figure 2: An example of Detailed Wetland Mapping

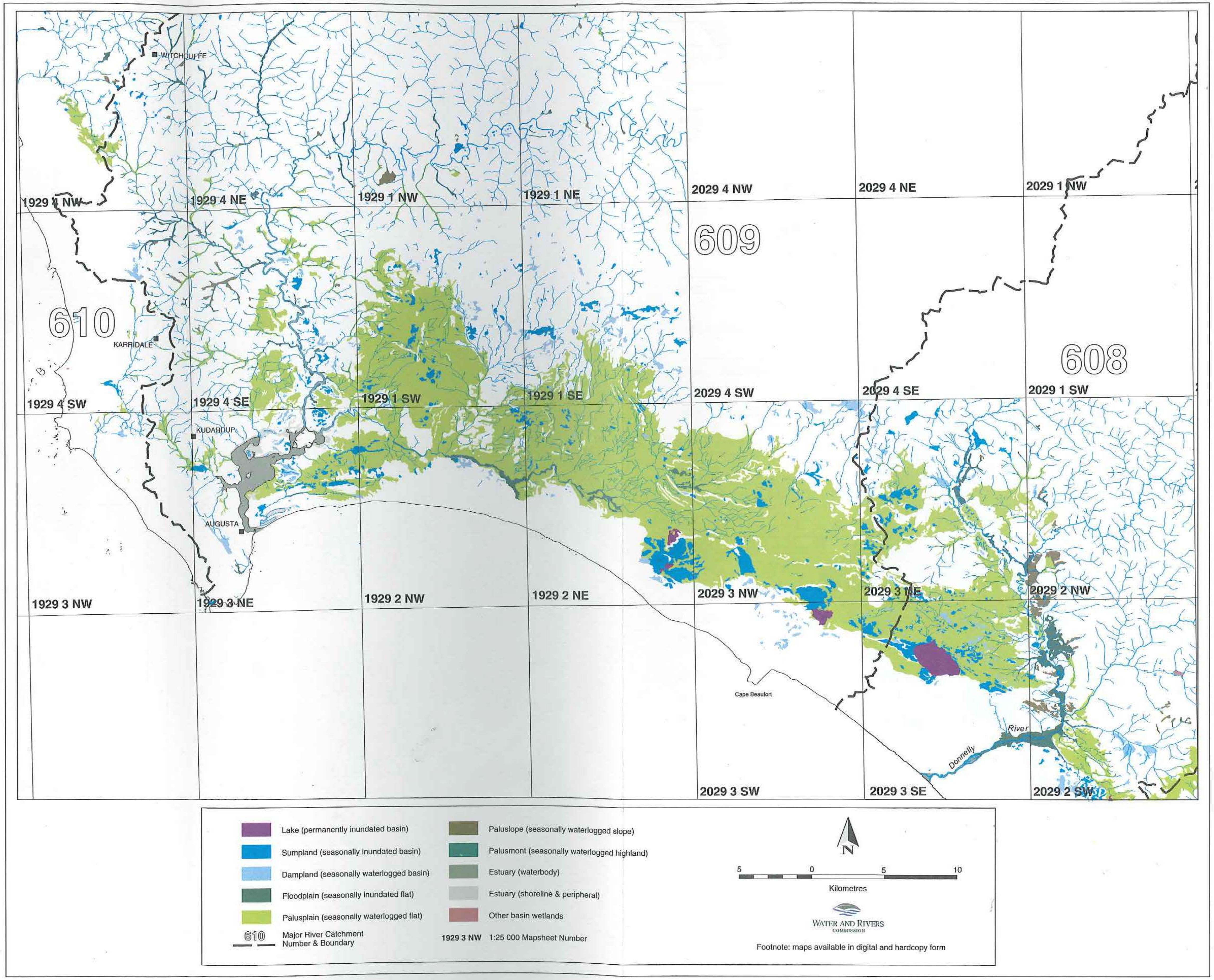


Figure 3: Wetlands of the Augusta to Donnelly River Area

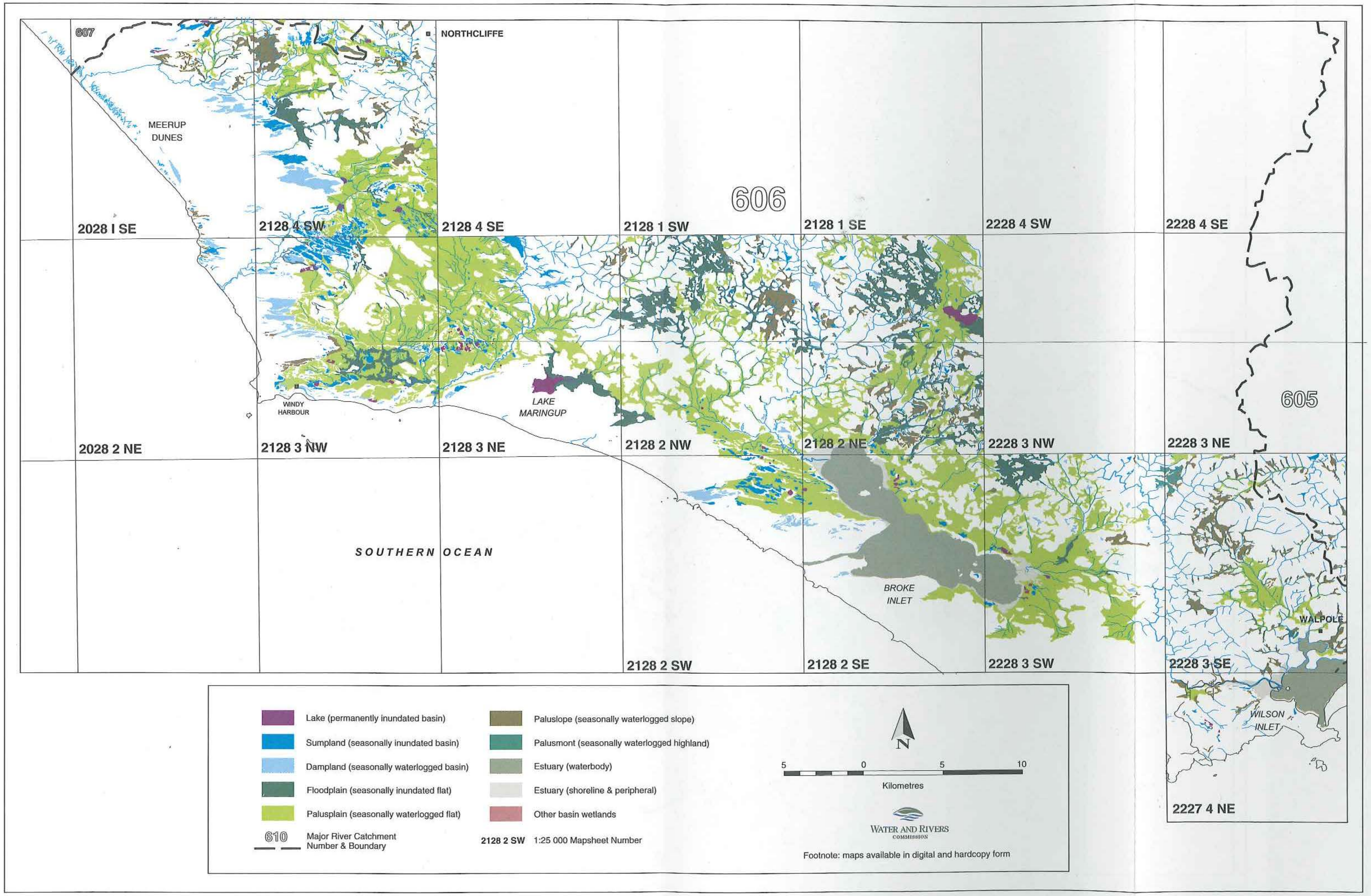


Figure 4: Wetlands of the Meerup to Walpole Area

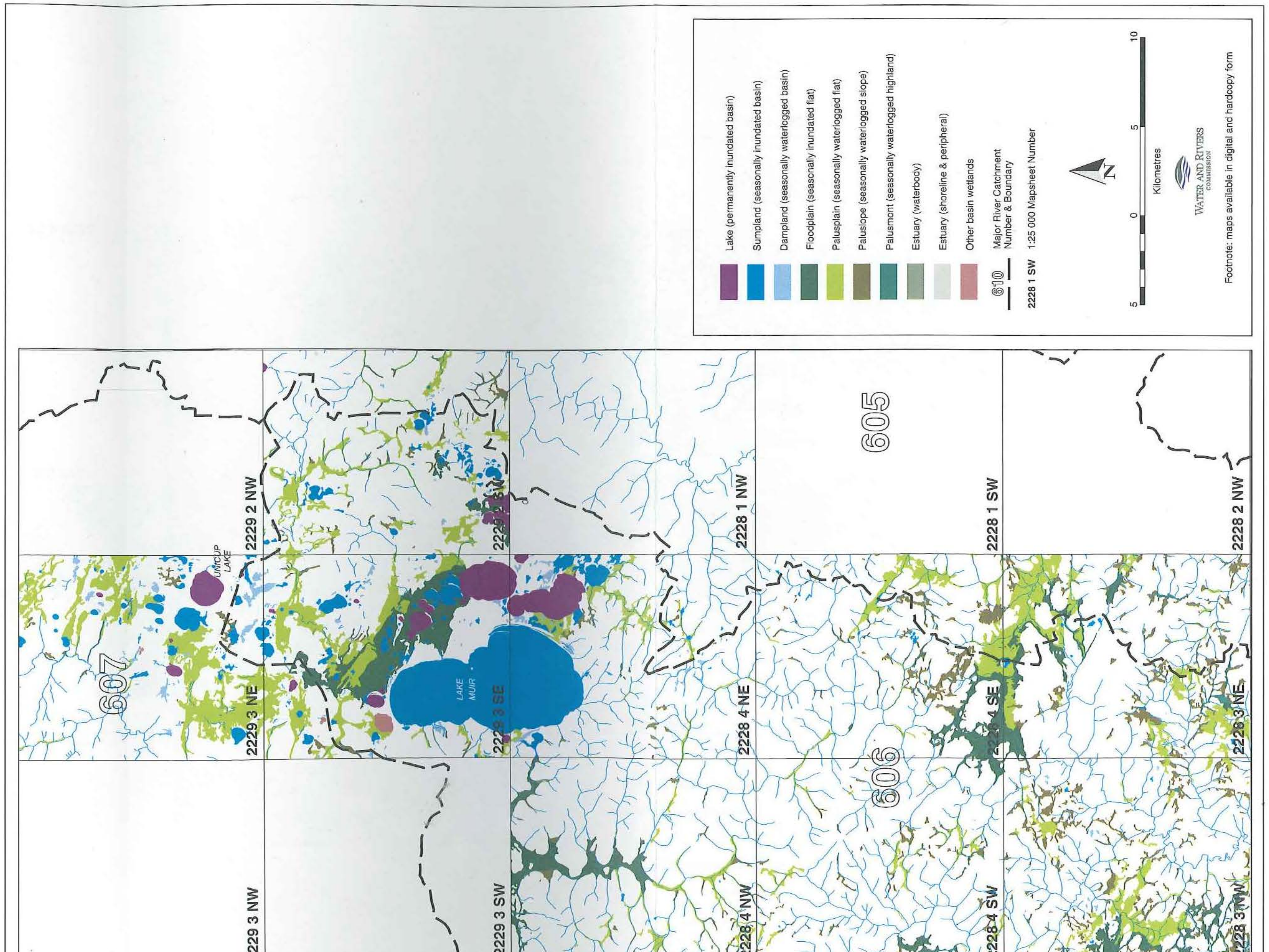


Figure 5: Wetlands of the Muir-Unicup Area

PART B:
Consanguineous Suites and Preliminary Identification of Outstanding Wetlands

2. The Augusta to Donnelly River area

2.1 Study area and scope

The Augusta to Donnelly River area extends from the town of Witchcliffe, north of Cape Leeuwin, to the mouth of the Donnelly River on the south coast and encompasses a large part of the Scott Coastal Plain. The study area is defined by eighteen 1: 25 000 map sheets as shown in Figure 3. All wetlands in this area have been mapped and classified at 1: 25 000.

Investigation of consanguineous wetlands suites has been limited to the six easternmost sheets of the study area, and should be viewed as an appendix to the work presented in the following chapter, Section 3. These six sheets cover part of the D'Entrecasteaux National Park near Gingilup Swamps to north west of the Donnelly River.

2.2 The consanguineous suites of the Augusta to Donnelly River area

The area's consanguineous suites are described systematically using the modified geological framework of Wilde and Walker (1984). This has been structured as follows:

- Holocene alluvial flats.
- Pleistocene limestone dunes.
- Pleistocene quartz sand dunes.
- Pleistocene alluvial flats.
- Pleistocene colluvial flats and slopes.
- Contact of Pleistocene quartz sand dunes/Tertiary estuarine flats.
- Contact of Pleistocene limestone dunes/Cretaceous rock headland.
- Tertiary estuarine flats.
- Tertiary alluvial/lacustrine flats.
- Tertiary sandy alluvial flats.
- Tertiary complex association of laterite, pisolitic gravel, sand, colluvial and alluvial flats, slopes, and ridges

All suites have been numbered and named after a local landmark and their location is shown on Figure 6. A representative area of each suite is presented in Figure 7 to illustrate the types, scale, and geometry of wetlands in each suite.

Holocene Alluvial Flats

AD1 — Donnelly River and Floodplain Suite

The Donnelly River is a leptoscale meandering river with floodplain underlain by alluvium comprising clay, sand and loam.

Pleistocene Limestone Dunes

AD2 — Bolghinup Lake Suite

This suite contains one wetland which is a sumpland near Black Point in the coastal limestone. It is a microscale linear sumpland underlain by calcrete which occurs approximately 0.3 metres below the surface. A shallow layer of peaty sand overlies the calcrete. The vegetation is maculiform.

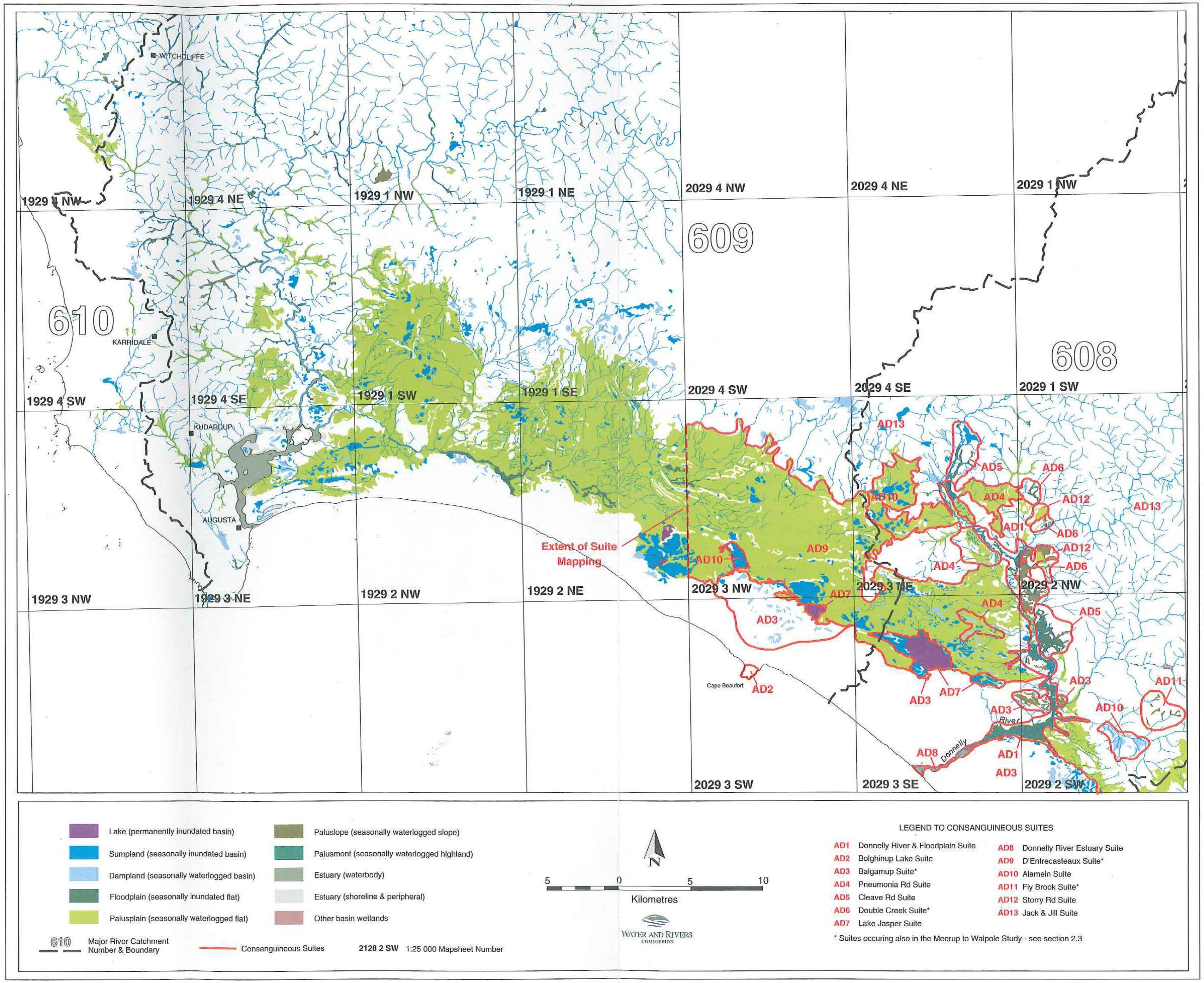


Figure 6: Preliminary Description of the Consanguineous Wetland Suites in Domains throughout the Augusta to Donnelly River Area

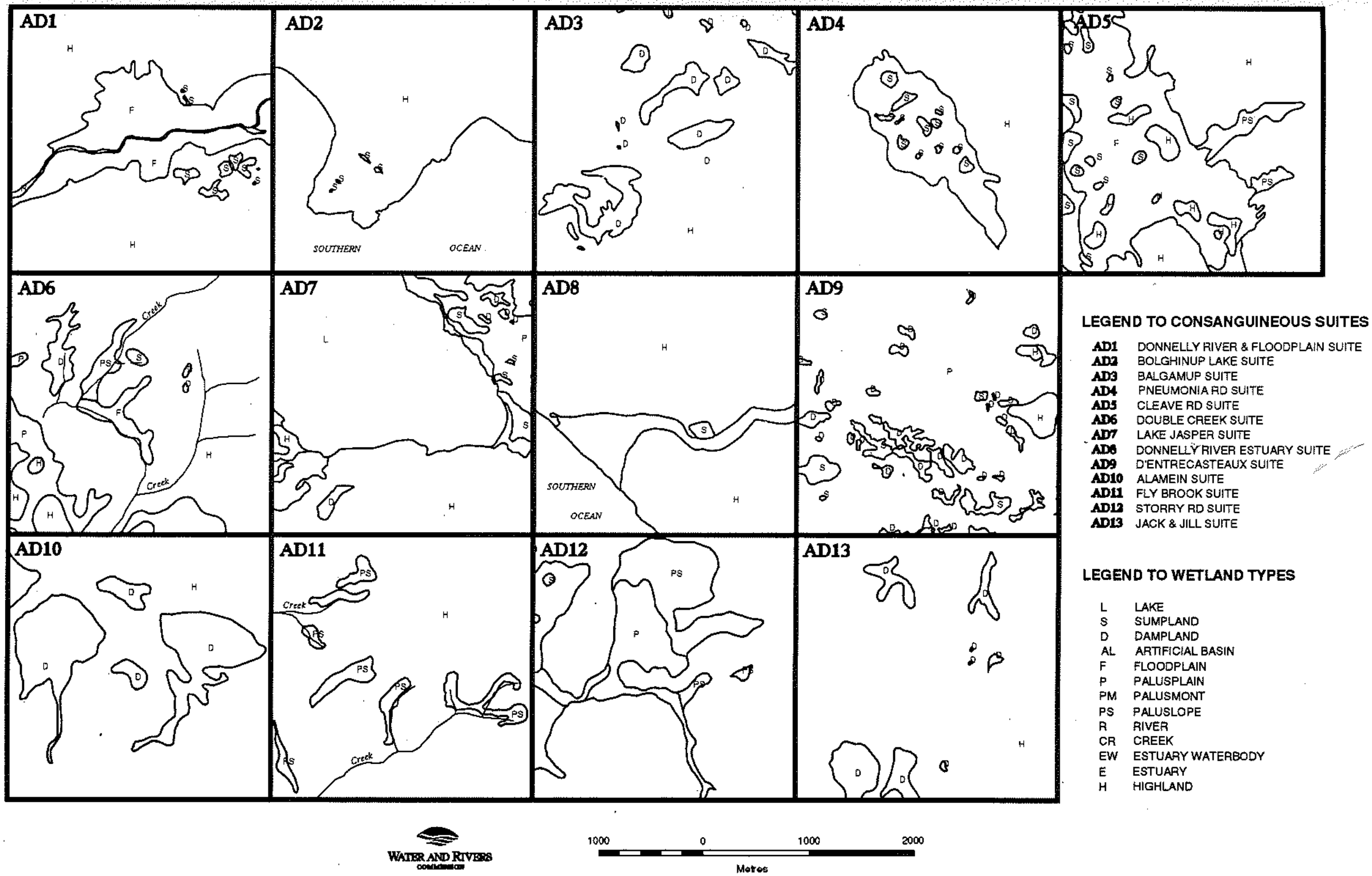


Figure 7: Representative example of consanguineous wetland suites in the Augusta to Donnelly River area

Pleistocene Quartz Sand Dunes

AD3 — Balgamup Suite

There are several locations in the study area where this suite occurs. The suite contains microscale to mesoscale sumplands and damplands in the blowout areas of the coastal dunes. They are underlain by quartz sand, the wetter basins contain a surface layer of peat. The vegetation is often maciluform, comprising herblands, sedgelands, heath and shrublands.

Pleistocene Alluvial Flats

AD4 — Pneumonia Road Suite

This suite contains numerous leptoscale circular basins close together in a palusplain. The basins are sumplands which are underlain by clay, the palusplain is underlain by alluvial deposits of sands, muddy sands and laterite. The water table fluctuates between approximately +0.3 m to -0.4 m. The vegetation cover of the basins is forest of *Melaleuca preissiana* and sedgelands. Vegetation of the palusplain comprises maculiform sedgelands and low heaths typical of other parts of the palusplain areas.

AD5 — Cleave Road Suite

This is a suite of basins and flats underlain by alluvial deposits. The basins are microscale rounded sumplands located on a floodplain and palusplain. There are two locations in the study area.

Pleistocene Colluvial Flats and Slopes

AD6 — Double Creek Suite

This suite contains localised areas of microscale flats, slopes, basins and leptoscale channels. The flats (floodplains and palusplains), and slopes are often associated with the creeks but the basins (sumplands) are separate. The wetlands are located in the superficial valley fill deposits and are underlain by colluvium and laterite.

Contact of Pleistocene Quartz Sand Dunes/Tertiary Estuarine Flats

AD7 — Lake Jasper Suite

This is a suite of basins located at the base of the Pleistocene quartz dunes on the Tertiary estuarine flat. They comprise macroscale to microscale ovoid to linear lakes and sumplands. They are underlain by quartz sand. The wetlands are freshwater, (84-192 mg/L), acidic (pH 4.4 – pH 6.3), and meso-eutrophic (N = 0.46 - 0.7 mg/L and P = 0.01 - 0.02 mg/L) (Jaensch 1992a and b, Edward *et al*; 1994). Vegetation is bacataform and comprises sedgelands of *Baumea articulata* and *B. juncea*, and shrublands to forests of *Melaleuca rhaphiophylla*.

Contact of Pleistocene Limestone Dunes/Cretaceous Rock Head

AD8 — Donnelly River Estuary

This is a meandering linear estuary, barred at the mouth by wave re-worked quartzo-calcareous sand. It's geometry is constrained to a narrow channel by the surrounding basalt and limestone outcrops, except in its upper reaches, where it widens out onto what appears to be a former floodplain. There are no associated estuarine flats and vegetation is peripheral.

Tertiary Estuarine Flats

AD9 — D'Entrecasteaux Suite

This suite contains extensive palusplain, macroscale to leptoscale irregular and sometimes coalescing sumplands and damplands, and linear dunes. They are underlain by estuarine sediments. The vegetation cover is maculiform, and largely comprises forests, sedgelands and heaths. The forests are *Melaleuca preissiana*; the sedgelands contain species of *Baumea, Evandra, Mesomelaena, Restio*, and *Leptocarpus*; and the heaths contain species of *Acacia, Agonis, Adenanthos, Anarthria, Calothamnus, Hakea, Pericalymma*, and *Xanthorrhoea*.

AD10 — Alamein Suite

This suite contains macroscale to mesoscale damplands. They are underlain by estuarine sediments. The vegetation cover is maculiform and comprises forests, sedgelands and heaths.

Tertiary Alluvial/Lacustrine Flats

AD11 — Fly Brook Suite

This suite contains slopes associated with creeks. These are sometimes headwaters of the creeks and sometimes valley slopes. The underlying alluvial sediments are strongly laterised.

Tertiary Sandy Alluvial Flats

AD12 — Storry Road Suite

This suite of wetlands is located on the slopes of linear dunes at the base of the scarp of the Darling Plateau. They are underlain by quartz sand.

Tertiary Complex Associatiion of Laterite, Pisolitic Gravel, Sand, Colluvial and Alluvial Flats, Slopes and Ridges

AD13 — Jack and Jill Suite

This suite contains macroscale to leptoscale irregular sumplands and damplands. They are underlain by quartz sands with pedogenic overprinting of a sequence of beige, red, and yellow gravelly and sandy muds.

2.3 Correlation between described wetland suites of the Augusta to Donnelly River area and wetland suites of the Meerup to Walpole area

There are several suites which occur in the Augusta to Donnelly River area which do not occur to the east in the Meerup to Walpole area. They are:

- Donnelly River suite
- Bolghinup Lake suite
- Pneumonia Road suite
- Cleave Road suite
- Donnelly River Estuary suite
- Lake Jasper suite
- Alamein suite
- Storry Road suite
- Jack and Jill suite

There are several suites which occur in both study areas they are listed below under both names for correlation:

Meerup to Walpole area	Augusta to Donnelly River area
Sand Peak (MW6)	Balgamup suite (AD3)
Coastal Track (MW7)	D'Entrecasteaux suite (AD9)
Walpole River* (MW11)	Fly Brook suite (AD11)
Walpole River* (MW11)	Double Creek suite (AD6)

It should be noted that wetland suites with an asterisk show marked similarities at this level of delineation, however, with further investigation it is probable that they will either be further sub-divided or amalgamated. On current information, correlation between these suites must remain tentative.

2.4 Preliminary identification of outstanding wetlands

Preliminary identification of outstanding wetlands of the Augusta to Donnelly River area is presented in the form of a general summary. Overall, each suite of wetlands can be represented by type examples of wetlands with features characteristic of the suite. The majority of wetlands are located in a largely undisturbed catchment and are therefore operating with natural hydrological processes. Ecologically, many areas are undisturbed and retain their natural functions.

There are several suites which have outstanding ecological values as determined by habitat diversity. These are:

- Lake Jasper suite;
- D'Entrecasteaux suite;
- Donnelly River and floodplain;
- Cleave Road suite, and
- Alamein suite.

There are several suites which exhibit significant geomorphological features. These are:

- Bolghinup Lake suite — wetland underlain by calcrete;
- Pneumonia Road suite — small closely spaced circular claypans in a flat; and
- Donnelly River Estuary — channel and estuarine flats.

Although faunal surveys have been very restricted in both areal extent and in the selection of habitat in this area, the available information to date, suggests that there are several wetlands which have important functions related to maintenance of faunal populations. These are:

- Lake Jasper Suite,
- Donnelly River and floodplain; and
- Donnelly River Estuary.

The Lake Jasper Suite is known to contain the following species of fish: *Bostockia porosa, Edelia vittata, Nannatherina balstoni, Galaxias occidentalis, Tandanus bostocki, Pseudogobius olorum* and *Favonogobius suppositus* (Jaensch 1992a). Other aquatic species include tortoises and marron. The area is also rich in amphibians. *Litoria adelaidensis, Crinia glauerti, Limnodynastes dorsalis, Geocrinea leai* and *Crinea georgiana* (Jaensch 1993) have been found here. Avifauna occur in high numbers, and species richness is also high. On and around the lakes breeding is significant (Jaensch 1992b).

The Donnelly River Estuary supports local populations of several waterbird species. The most important are: Little Black Cormorant, Pacific Black Duck and Eurasian Coot. Eight commercial fish species are present in the estuary.

Although the vegetation of palusplain, paluslopes, and damplands appears to be similar at first inspection, it should be noted that this is not the reality, except where frequency of fires has reduced the natural diversity of the wetland flora. As a result of tolerance to minor stratigraphic and hydrologic variability, or in response to dynamic changes such as water levels, firing, and land clearance, or as part of a longer term adaption to rainfall variability, some species have shown a wide tolerance to variable landscape conditions adapting to a range of abiotic factors, while others have become restricted by very specific requirements. As a result, assemblages from the palusplain areas show a) several species which are ubiquitous throughout the area, b) species which only occur in some communities, and c) species which have become very restricted in geographic distribution, some of which are regarded as rare and endangered. Below are listed samples of communities to illustrate the variability of composition and also the apparent randomness and unpredictability of occurrence of restricted species within them. These communities are informal groups based on species occurrence descriptions drawn from the literature (Lewis Environmental Consultants 1990). A botanical list of species in Table 6 is included in Appendix D.

Table 6: Composition of four wetland vegetation communities occurring in the Augusta to Donnelly River area

	COMMUNITY 1	COMMUNITY 2	COMMUNITY 3	COMMUNITY 4
TREE SPECIES	*M. preissiana*	*M. preissiana* *N. floribunda*	*M. preissiana* *B. littoralis* *E. marginata* *E. patens*	*M. preissiana* *N. floribunda* *E. marginata* *B. ilicifolia*
UNDERSTOREY	*A. hastulata* *A. uliginosa* *A. obovatus* *A. parviceps* *A. scabra* *A. aff. fascicularis* *B. sparsa* *B. spathulata* *C. lateralis* *H. ceratophylla* *J. lupulina* *P. ellipticum* *R. ustulatus* *X. preissei*	*A. myrtifolia* *A. cunninghami* *A. obovatus* *A. detmoldii* *A. prolifera* *B. spathulata* *C. crassus* *C. caeruleum* *Darwinia sp* *D. nivea* *G. manglesioides* *H. ceratophylla,* *H. sulcata* *H. varia, H. stellaris* *K. recurva* *P. ellipticum* *R. serialis* *S. rodwayanus* *V. trinerius* *V. juncea* *X. preissei*	*A. extensa* *A. myrtifolia* *A. linearifolia* *A. parviceps* *A. scabra* *E. epacridiodes* *H. aff cordifolium* *J. pallidus* *P. hispida* *X. preissei*	*A. myrtifolia* *A. uliginosa* *A. obovatus* *A. prolifera* *A. scabra* *B. sparsa* *H. sulcata* *H. firmum* *H. ericifolium* *H. strictum* *L. scariosus* *L. barbata* *P. ellipticum* *R. ustulatus* *S. curvifolius*
RARE OR RESTRICTED COMMUNITIES	*A. carinata,* *H. cordifolium* *L. alternifolium* *R. ustulatus* *V. lasiosperma*	*Darwinia sp* *L. orbifolia*	*A. carinata* *H. cordifolium* *S. verticellatum* *H. stricta*	*Darwinia sp* *Boronia sp* *V. lehmannii*

3. The Meerup to Walpole area

3.1 Study area location

The Meerup to Walpole area encompasses the southern coastal plain and coastal edge of the Yilgarn Plateau between Meerup and Walpole on the south coast of Western Australia (Figure 4). It includes the area known as the southern acid peat flats surrounding Mt Chudulup, part of D'Entrecasteaux National Park, Walpole-Nornalup National Park, the Pingerup Plains, the estuaries, Broke Inlet and Nornalup/Walpole Inlets, and the major rivers, Donnelly River, Gardner River, Shannon River, Deep River and Walpole River.

3.2 Regional setting

3.2.1 Climate Setting and Wetland Types

The Meerup to Walpole area lies in the subtropical climatic belt of Western Australian, an area which is characterised by a seasonal rainfall of between 1000 mm and 1200 mm per annum. This amount of rainfall is sufficient to influence a wide range of landforms to act as hosts to inland wetlands. These include tops of plateaux, slopes of valleys, basins and flats, and a number of major channels which terminate in estuaries behind coastal barriers. Because of the range of wetland types, their variation in scale, geometry, and geomorphology, the regional classification of these wetlands into consanguineous suites provides a framework for aggregation and comparison of wetlands, and an approach for recognising fundamental diversity.

3.2.2 Geology and geomorphology

Regionally, the area was divided into four geomorphic units by (Wilde and Walker 1984) based on underlying geological materials (Figure 8):

- the Coastal Belt,
- the Estuarine deposits,
- the Tertiary alluvial flats,
- the Precambrian bedrock.

However for this study, these units have been aggregated into three geomorphic units based on geological materials and their ages:

- the Quaternary Coastal Dune Belt
- the Tertiary Flats
- the Precambrian hinterland

To some extent, these geological materials control and have controlled development of large scale landform, so that these geological subdivisions also correlate with the major land units in the region. A brief description of each unit and their relevant wetlands is outlined below:

The Quaternary Coastal Dune Belt

The Quaternary Coastal Dune Belt forms a distinct unit in this region. It extends along the length of the coastline of the study area, but varies in width from ca. 500 m east of Point D'Entrecasteaux to ca. 5 km near Mount Clare. The Quaternary Coastal Dune Belt consists predominantly of Holocene and Pleistocene dunes. The Holocene dunes are composed of calcareous sand, and form long attenuated parabolic dunes, oriented southwest to northeast, with smaller parabolics within.

Some dunes are mobile, (but these are not restricted to the present shoreline) and some are vegetated. The Holocene parabolic dunes contain no wetlands in the study region. In local areas such as seaward of the Meerup Dunes, there are chaots (Semeniuk *et al.* 1989) and at Windy Harbour there is an area of linear shore parallel beach ridges. In both of these local areas, wetlands occur in the interdune/inter-ridge depressions.

The Pleistocene dunes are composed of two types of material; a) unconsolidated quartz sand and b) limestone. Thus, essentially the dunes are unconsolidated and lithified, respectively. The unconsolidated quartz sand underlies parabolic dunes that transgress inland. The limestone generally occurs along the coast forming a coastal barrier which is variously lithified. In many areas the parabolic dunes have encroached inland over the limestone, but Precambrian bedrock, and Tertiary lagoonal, lacustrine, and estuarine deposits have become exposed in deflated areas in the wake of the dunes' movement inland. It is in these deflation hollows and superimposed on this basement that the wetlands occur.

The Tertiary Flats

Inland from the Quaternary Coastal Dune Belt are Tertiary estuarine, lagoonal, and lacustrine deposits underlying

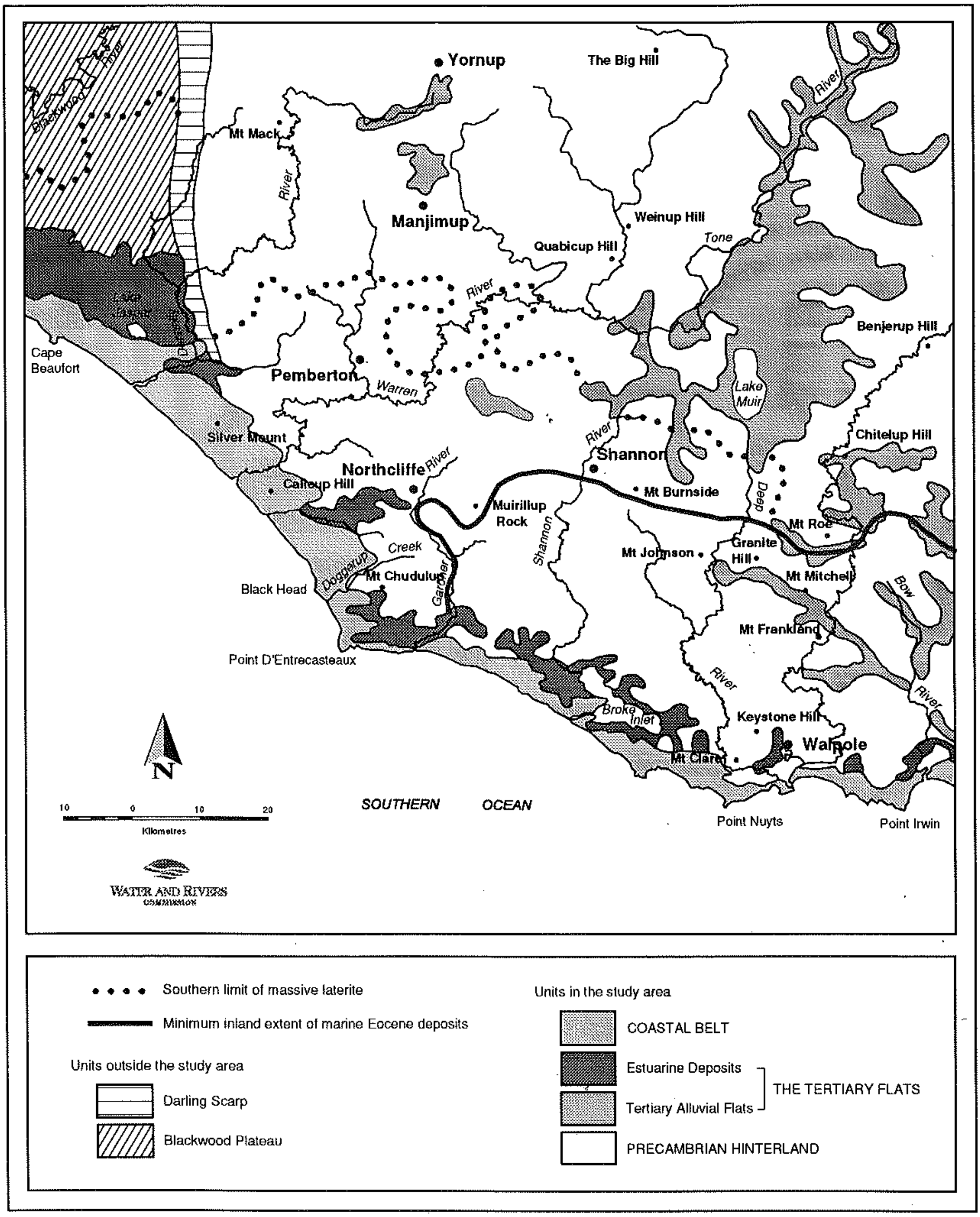


Figure 8: The modified geologic/geomorphic framework of Wilde and Walker (1984)

an extensive plain, and occurring in the incised valley systems or on drainage divides of the Yilgarn Plateau. Tertiary sediments also underlie local flats in the region. The Tertiary Flats are subdivided by Wilde and Walker (1984) into four types:

- estuarine, lagoonal, and lacustrine deposits,
- alluvial deposits,
- siltstone (referable to the Pallinup Siltstone)
- unassigned deposits

The Tertiary Flats nearest the coast are underlain by estuarine, lagoonal, and lacustrine deposits. Locally, these are overlain by linear small scale dunes. These Tertiary sediments have been deposited over the Precambrian rock which crops out as knolls throughout the system. In addition, there are small scale linear dunes of reworked aeolian sand originating from basin floors of the numerous small wetlands which occur in the area.

Further away from the coast, the development of Tertiary deposits has been controlled by geomorphic processes, especially lateritization and fluvial erosion, transport and deposition of sedimentary materials, and hence, deposits of conglomerate, quartz grit, sand and clay, mainly of alluvial or lacustrine origin, and strongly lateritized in part, are extensively developed over the Precambrian shield in the valleys forming wetland flats and slopes.

Locally, Tertiary flats are underlain by the Pallinup Siltstone Formation (Wilde and Walker 1984), which hosts wetlands. This formation is a grey/brown siltstone. It overlies the Precambrian rocks and controls the development of wetland flats. An example of this association occurs at Mount Chudulup.

Further unassigned Tertiary Units underlying Tertiary flats mark former courses of the Tertiary drainage systems in the region. The deposits are variously dissected by the present drainage, resulting in valley slopes and flats which are host to wetlands. These types of Tertiary flats are underlain by various colluvial materials such as white sand and sandy alluvium.

The Pre-Cambrian Hinterland

Precambrian rocks and lateritic rocks underlie the dissected plateau of the Yilgarn Block which is composed of a suite of granitic rocks ranging from granite to adamellite to granodiorite. Much of the bedrock is covered by colluvial deposits, aeolian deposits and laterite.

3.2.3 Hydrology

General hydrologic setting and mechanisms

The area can be subdivided into two major hydrological regions:

- the coastal plain zone
- the dissected plateau zone

On the coastal plain, hydrological processes are largely governed by the range of geomorphic settings, soil types and diagenetic and pedologic processes, and their interactions, e.g., the occurrence of low lying flats; diagenetic overprints therein; transgressing dune fields; unconformities; granite outcrops; modern channels and estuaries. These features and their hydrologic implications are discussed below.

Much of the Meerup to Walpole area is a system of low lying flats. In some areas, under these flats, diagenesis has resulted in a layer of ferricrete precipitated at the water table under the flat. This ferricrete layer, by retarding vertical drainage, results in an alteration of the hydroperiod, and hence extends the residency time of surface water. The features of the shallow hydrology relevant to wetlands in these settings are:

1. there is a simple groundwater rise with the onset of precipitation;
2. much of the area has a shallow water table; and
3. some of the terrain exhibits perched shallow groundwater due to the ferricrete.

The hydrologic processes associated with the dune fields as they relate to wetlands, are as follows: 1) there is some surface water flow in leptoscale creeks; 2) there is surface water flow down dune slopes; and 3) water flows from underground through the underlying limestone and from the base of dunes. Dune fields which have migrated over older sediments as parabolic forms have bowls (internal deflation areas) which become wetlands; these wetlands are either windows to the water table, or surface water, ponded by exposed impervious materials in the deflation bowl.

Unconformities between the regional geomorphic/ geologic units, such as the Pleistocene dunes and the Tertiary flats, often provide conduits for groundwater flow and/or seepage.

On the coastal plain granite outcrops effect hydrology in three ways:

1. by acting as aquatards for groundwater flow along unconformities between the granite and superimposed sediments;
2. by providing conduits for groundwater flow along fracture zones or joints; and
3. by providing an impermeable surface for runoff which then discharges as surface flow onto the surrounding flats.

Estuaries are common along the coastal plain and exhibit a recurring pattern in shape and style of sedimentary fill. They are elongate basins behind a coastal barrier located at the boundary of the Quaternary Coastal Dune Belt and the Estuarine deposits, or in the case of Nornalup/Walpole Inlet, between the Precambrian bedrock and the Quaternary Coastal Dune Belt. Two of the estuaries are connected to the Southern Ocean through a narrow outlet channel while the third, Lake Maringup, is now isolated from marine influences by the coastal barrier. The surrounding palusplains are drained by small to medium scale channels which discharge into these barred estuaries, forming cuspate deltas which are reworked into peripheral narrow flats by wind waves generated within the estuary.

On the Precambrian hinterland, hydrologic processes are more complicated, and only a preliminary account is given here. Watercourses dissect the plateau of the hinterland and these include both rivers and creeks. Associated with these channels are groundwater flows often from the surrounding granite outcrops, or from the surface of surrounding lateritized or pisolitic layers. However, in the sub-surface, there are independent conduits and discharge zones as developed along dyke systems, unconformities, and palaeo-surfaces and channels. In addition, linear dunes on the plateau produce local basins, and valley floor and valley slope deposits act as local aquifers.

Water depth measurements were obtained from literature surveys and field measurements during this study. Information from literature was often restricted to surface water in lakes and sumplands, except in the work by Horwitz (1994) where maximum and minimum groundwater levels were also recorded. Horwitz (1994) shows a regional fluctuation in water levels of approximately 0.70 m in the basins and 1.70 m on the flats.

Water Quality

Information on water quality can be useful as a lower level criterion in defining wetland suites. The information on water quality in this area is derived from three sources: a) the Water Authority of Western Australia, b) selected research publications, (Bayly 1992, Jaensch 1992a and b, Edward *et al.* 1994, Horwitz 1994), and c) fieldwork conducted for this study. A brief description of water quality is provided below, but most of the information is used in the description of the appropriate suites, where relevant.

The data on water quality from the Water Authority pertain to stream salinity, and will be discussed only within the context of individual suites, where appropriate.

The data from research publications cover a diverse and often single sampling event for parameters such as pH, total dissolved solids (TDS), phosphorous and nitrogen. The information from the literature could be related to the following suites (the suites are defined/described in Section 3.3): Windy Harbour Suite, Coastal Track Suite, Doggerup Basin Suite, Deep River Suite, Chudulup Suite, Inlet River Suite, Pallinup Suite, Walpole River Suite, Floodplain Suite and Lake Maringup Suite. As such, the relevant information is noted within the description of these suites.

Measurements of pH documented in the literature generally range between 3.2 – 4.0 for winter sampling and 5.0 – 7.0 for autumn sampling, with little variation between suites. TDS determined by conductivity generally ranged from (K18) 100 – 200 uS/cm, although some sites showed higher values up to c.550 uS/cm. TDS calculated as mg/L for most suites ranged between 100 – 200 mg/L. Walpole River Suite, Inlet River Suite, Deep River Suite and Doggerup Basin Suite tend to lie at the lower end of the spectrum, while Windy Harbour Suite and Coastal Track Suite, although fresh, were slightly higher (K20) 553 uS/cm. Most of the waters sampled for phosphorous and nitrogen were surface waters which ranged from meso-trophic to eutrophic (Wetzel 1975): e.g., 0.01 mg/L P to 0.19 mg/L P and 0.30 mg/L N to 1.0 mg/L N. Lake Maringup registered the lowest concentration of phosphorous, i.e., <0.01 mg/L P.

Field sampling for this study also was often a single measurement during either January 1995 or May 1995, and was restricted to water salinity (TDS) only.

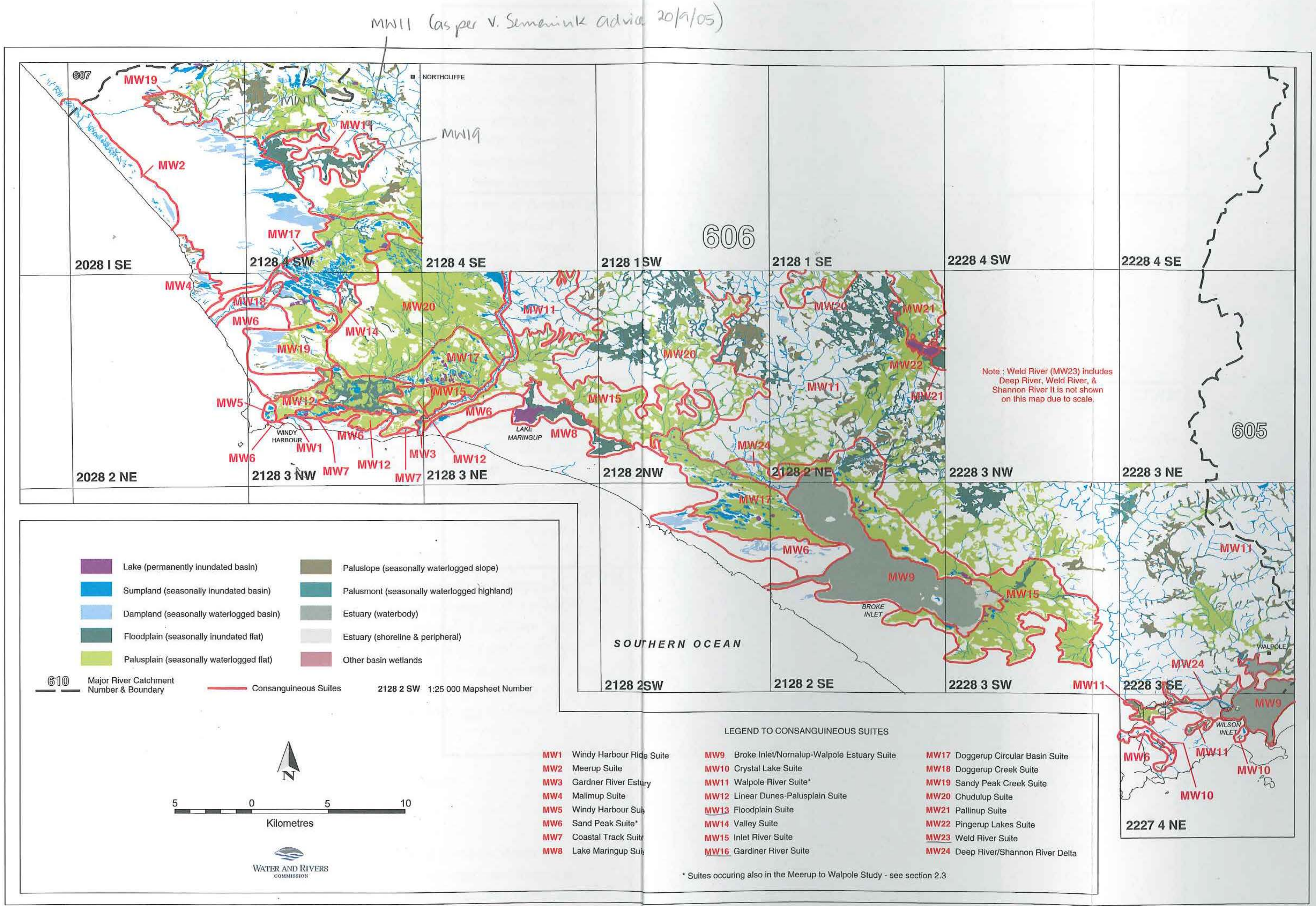
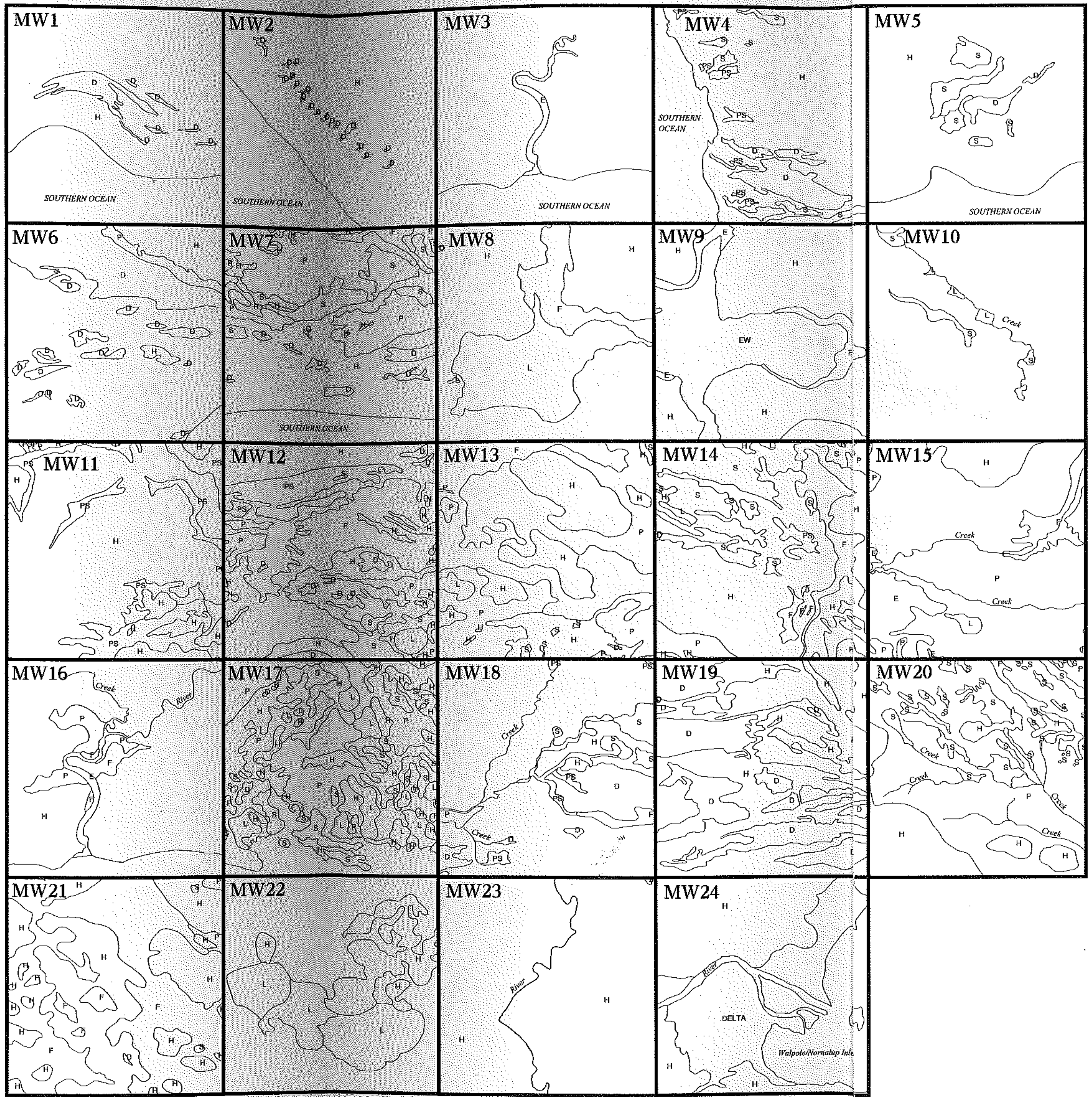


Figure 9: Preliminary Description of Consanguineous Wetland Suites in Domains throughout the Meerup to Walpole Area



LEGEND TO CONSANGUINEOUS SUITES

MW1	WINDY HARBOUR RIDGE SUITE
MW2	MEERUP SUITE
MW3	GARDNER RIVER ESTUARY
MW4	MALIMUP SUITE
MW5	WINDY HARBOUR SUITE
MW6	SAND PEAK SUITE
MW7	COASTAL TRACK SUITE
MW8	LAKE MARINGUP SUITE
MW9	BROKE INLET/NORNALUP-WALPOLE ESTUARY SUITE
MW10	CRYSTAL LAKE SUITE
MW11	WALPOLE RIVER SUITE
MW12	LINEAR DUNES-PALUSPLAIN SUITE
MW13	FLOODPLAIN SUITE
MW14	VALLEY SUITE
MW15	INLET RIVER SUITE
MW16	GARDNER RIVER SUITE
MW17	DOGGERUP CIRCULAR BASIN SUITE
MW18	DOGGERUP CREEK SUITE
MW19	SANDY PEAK CREEK SUITE
MW20	CHUDULUP SUITE
MW21	PALLINUP SUITE
MW22	PINGERUP LAKES SUITE
MW23	DEEP RIVER SUITE
MW24	DEEP RIVER/SHANNON RIVER DELTA

LEGEND TO WETLAND TYPES

L	LAKE
S	SUMPLAND
D	DAMPLAND
AL	ARTIFICIAL BASIN
F	FLOODPLAIN
P	PALUSPLAIN
PM	PALUSMONT
PS	PALUSLOPE
R	RIVER
CR	CREEK
EW	ESTUARY WATERBODY
E	ESTUARY PERIPHERAL
H	HIGHLAND

1000 0 1000 2000

Metres

WATER AND RIVERS COMMISSION

Figure 10: Representative example of consanguineous wetland suites in the Meerup to Walpole area

3.3 Consanguineous wetland suites

As the occurrence of consanguineous suites is determined by geomorphic/geologic units, and/or the contacts between them, they are described systematically within the modified geologic/geomorphic framework of Wilde and Walker (1984). This has been structured as follows:

1. Holocene calcareous sand dunes, ridges, and chaots
2. Pleistocene limestone dunes
3. Contact of Pleistocene limestone dunes/Tertiary estuarine flats
4. Contact of Pleistocene quartz sand dunes/Tertiary estuarine flats
5. Triple contact of Pleistocene quartz sand dunes/ Tertiary estuarine flats/Precambrian rock knolls
6. Contact of Pleistocene limestone/Precambrian rock knolls
7. Contact of Tertiary estuarine flats/Precambrian rock knolls
8. Tertiary colluvium flats and slopes
9. Tertiary estuarine flats
10. Tertiary alluvial/lacustrine flats
11. Tertiary siltstone flats
12. Precambrian granitic rock plateau

It should be noted that more than one suite can occur within any of the above settings.

All suites have been numbered and named after a local landmark and their location is shown on Figure 9. A representative area of each suite is presented in Figure 10 to illustrate the types, scale, and geometry of wetlands in each suite.

The description of each suite is structured in the following way:

- small scale geomorphology and geomorphic processes
- wetland types
- water parameters — levels, quality, hydrological mechanisms
- stratigraphy
- vegetation — pattern, structure, composition

Discrepancies from this format are due to information deficits as a result of the scope of the project.

Holocene Calcareous Sand Dunes, Ridges and Chaots

MW1 — Windy Harbour Ridge Suite

This is a suite of shore parallel beach ridges with wetlands in the inter-ridge depressions. The wetlands are microscale, elongate damplands constrained by the dimensions and orientation of the swale. They are underlain by fine sand, and maintained mainly by groundwater rise. The groundwater is fresh. Vegetation is maculiform and comprises low woodland of *Banksia littoralis* with an understorey of sedgeland of *Lepidosperma gladiatum*. In one location along a former creek line dissected by the dune ridges the sediments are peat overlying slightly muddy sand and the vegetation comprises forest of *Agonis juniperina*.

MW2 — Meerup Suite

This is a suite of mesoscale to leptoscale irregular basins in the interdune hollows of the backshore. The wetlands are underlain by calcareous sand with a superficial peat layer, and are maintained by groundwater rise. Some are vegetated, some are not. They are an unusual feature and some are possibly ephemeral as a result of encroachment by mobile dunes.

MW3 — Gardner River Estuary.

This estuary is narrow, shore-normal, and bordered by high coastal dunes. The suite is composed of peripheral wetland flats formed by reworking of sediments from the delta of the Gardner River by waves and wind. The flats are sand dominated and latiform supporting a sedgeland of *Isolepis nodosa*. At the time of sampling in summer (Jan. 1995), the water body was hyposaline.

Pleistocene Limestone Dunes

MW4 — Malimup Suite

This is a suite within the coastal parabolic dunes. As a result of deflation irregular shaped areas have formed as incipient microscale to mesoscale damplands within the bowls of the parabolic dunes. The process occurs by lowering the land surface in relation to the water table which maintains the wetland basin. The wetlands are underlain by sand and limestone, and the groundwater is freshwater.

Contact of Pleistocene Limestone Dunes/ Tertiary Estuarine Flats

MW5 — Windy Harbour Suite.

This is a suite of basin wetlands situated at the base of limestone ridges and the Tertiary estuarine/lagoonal unit. They are mesoscale, irregular damplands and shallow sumplands probably maintained by groundwater rise and seepage from the base of the dunes and the limestone ridge. Water table fluctuations are probably in the order of 1.2m, although in January the wetland soil was wet to within 20 cm of the surface. Water is fresh to subhaline. The stratigraphy is black humic sand overlying slightly humic medium and fine quartz sand. The wetland vegetation varies from zoniform to maculiform and includes sedgelands, heaths, and shrublands comprising species of *Oxylobium, Agonis, Melaleuca, Astartea, Baumea and Leptocarpus.*

Contact of Pleistocene Sand Dunes/ Tertiary Estuarine Flats

MW6 — Sand Peak Suite.

This is a suite where the coastal dunes have encroached over the Tertiary basement. Localised deflation has created irregular linear shaped areas which have become microscale to mesoscale sumplands and damplands within the bowls of the parabolic dunes. They are underlain by sand sheets that rest on estuarine or lagoonal deposits. Commonly the vegetation is maculiform composed of sedgelands (*B. articulata, J. kraussii, I. nodosa, Schoenus spp.*) and heaths (*M. incana, H. firnum, A. juniperina*) and shrublands (*B. littoralis*).

MW7 — Coastal Track Suite

This suite lies along the contact of the quartz/calcareous dunes which overlie Pleistocene limestone, and the estuarine, lagoonal and lacustrine Tertiary deposits. It is a suite of irregular leptoscale to microscale discrete and coalescing wetland basins forming damplands, sumplands and lakes, separated by linear dune ridges. The water salinity is fresh and water levels fluctuate approximately 1m as a result of seasonal groundwater rise and fall. The stratigraphy is humic quartz sand overlying incipient coffee rock which in turn overlies dark grey quartz sand. The vegetation ranges from zoniform, to heteroform to maculiform, and comprises low open woodland, open to closed heaths, and sedgelands. Common genera include *Melaleuca, Astartea, Eutaxia, and Leptocarpus.*

Contact of Pleistocene Sand Dunes/Tertiary Estuarine Flats/Precambrian Rock Plateau

MW8 — Lake Maringup Suite

Along the contact between the Pleistocene dunes, the Tertiary estuarine flats, and the Precambrian granite occurs a wetland complex of macroscale shallow basins within a floodplain. These include Lake Maringup. The wetlands are underlain by peats and peaty sands, and grey quartz sands and water sampled in January 1995 was fresh. The wetland vegetation is heteroform composed of sedgelands, low forest, and scrub containing species of *Baumea, Melaleuca, Agonis, Banksia, Lepidosperma.*

MW9 — Broke Inlet/Nornalup-Walpole Estuary Suite

Broke, Walpole and Nornalup Inlets are macroscale to megascale T-shaped estuaries barred from the Southern Ocean or another inlet by limestone, lateritic, and gneiss barriers, but retaining narrow tidal channels. They are bordered by narrow fringing flats and cuspate wave-dominated deltas with islands, shoals, and multiple channel pathways at the mouth. They are receiving basins for several rivers and creeks. The flats are quartz sand dominated. This may overlie either coffee rock or ferricrete at groundwater level, and mud below this. The deltas are underlain by shelly and humic sand overlying humic mud overlying black sand overlying white river sand and the groundwater ranges from hyposaline to meso-saline. The flats support shrublands to low open woodlands of *Melaleuca cuticularis* over a sedgeland of *Juncus kraussii, Baumea juncea, Acacia spp., M. viminua, Agonis spp.,* and *Astartea aff. fascicularis.* The vegetation on the deltas is typified by sedgeland (*Juncus kraussii, Gahnia trifida, and Isolepis nodosa*), and open low shrubland (*Melaleuca cuticularis, M. viminua, A. juniperina).*

Contact of Pleistocene Limestone Dunes/ Precambrian Rock Plateau

MW10 — Crystal Lake Suite

The wetland suite lies along the contact between the dunes overlying limestone and the Precambrian granite located around Nornalup Inlet. The wetlands are microscale lakes which range from sub-rounded to linearly irregular and have steep sided karst features. They wetlands are freshwater and fed by streams.

The wetland vegetation is bacataform and comprises low forest, heath, and sedgeland.

Tertiary Colluvium Flats and Slopes

MW11 — Walpole River Suite

This is a suite of paluslope wetlands on colluvial sand. The wetland slopes are sometimes associated with microscale creeks such as in the Walpole River location, but may also occur independently. The wetland slopes are underlain by quartz sand which overlies coffee rock which overlies sandy mud and silt, or by a sequence of black peat overlying peaty sand overlying sand. These horizons create a perched aquifer above the regional water table. The creeks are underlain by peaty sand overlying layers of black to brown muddy sand and black terrestrial clay, overlying quartz sand. The groundwater was fresh and in January 1995 about 130 cm below the surface. The wetland vegetation is maculiform, and comprises patches of scrub of Agonis juniperina with an understorey of low heath, grassland, or sedgeland, comprising species of Kangaroo Paw, *Homalospermum, Beaufortia, Calothamnus, Agonis, Astartea, Adenanthos, Evandra, Anarthria, Leptocarpus.*

Tertiary Estuarine Flats

MW12 — Linear Dunes-Palusplain Suite

This is a suite of slightly undulating palusplain overlain by disrupted parabolic dunes enclosing irregular leptoscale to microscale areas. The palusplain is underlain by grey sand overlying slightly muddy sand with iron staining and incipient cementation. The groundwater level was 130 cm below the surface when sampled in May/June and the water was subhaline. The wetland vegetation is maculiform heath and shrubland comprising the following genera: *Melaleuca, Hakea, Homalospermum, Nuytsia, Calothamnus, Evandra,* and *Baumea.*

MW13 — Floodplain Suite

This is a suite formed through erosion by leptoscale creeks which drain fresh water from the estuarine flats, and also act as conduits for backflow from the Gardner River. This creates floodplain areas which are easily discernible as distinct wetland ecosystems and local enlarged pools within the channel and billabongs which are mesoscale lakes and sumplands. The water level is never very far from the surface and ranges from freshwater to hyposaline. The stratigraphy is humic or peaty sand overlying muddy sand. The wetland vegetation is maculiform or paniform and comprises forest, shrubland, and sedgeland of species such as *Melaleuca rhaphiophylla, M. lateritia, M. polygaloides, M. incana, M. leptoclada, Pericalymma* species, and *Leptocarpus* species.

MW14 — Valley Suite

This suite is located in valleys of Tertiary deposits between granite gneiss outcrops. Wetlands include some slopes, valley floors (palusplains) and leptoscale channels which are impeded and orientated by small-scale dune ridges. These are underlain by a thin layer of peat overlying grey fine sand, and support a maculiform heath assemblage of species of *Agonis, Homalospermum, Banksia, Gompholobium, Beaufortia.*

MW15 — Inlet River Suite

This is a suite of palusplain underlain by estuarine sediments, transected by creeks, and interrupted by granite outcrops from which seepage occurs. The creeks are leptoscale and meandering. Quartz sand in the creeks is interlayered with ferricrete gravel and ferricrete sheets, while the palusplain is composed of quartz sand (overprinted with iron mottling and staining) overlying muddy sand. The riparian vegetation is shrubland. The palusplain supports a low heath of *Beaufortia, Acerosa, Hakea, Adenanthos, Homalospermum, Lepidosperma* species. The creek was mesosaline when sampled in January 1995, and the groundwater under the palusplain was fresh.

MW16 — Gardner River Suite

This suite of wetlands typically contains leptoscale to microscale creeks and rivers (Gardner River, Inlet River and Forth River) and leptoscale associated flats (floodplain and palusplain), near the channel's estuary. The channels are cut into granite or ferruginous pisolitic soil with a superficial overlay of sand and muddy sand. The channels are fringed with narrow bands of vegetation of *Melaleuca* and *Agonis* species forming tall shrublands, and patches of sedgeland of *Lepidosperma tetraquetrum.*

Tertiary Alluvium Flats

MW17 — Doggerup Circular Basin Suite

This is a suite of circular basins on a palusplain, interspersed among randomly oriented linear dune ridges. The basins are microscale to mesoscale freshwater lakes, sumplands, and damplands in the swales. The wetlands are underlain by alluvium (sand and muddy sand), peat, and lenses of limestone. Peat horizons 0.5 – 2 m thick have developed in the wetlands, but have been reduced through fire. Although the vegetation assemblages are naturally diverse in this area and include forests, heaths, grasslands, scrub, and sedgelands, disturbance species colonising the fire effected substrates have become widespread. The vegetation surrounding lakes with a severe fire history is periform or latiform with low forest of *Agonis juniperina.*

MW18 — Doggerup Creek Suite

This suite is a leptoscale creek with many tributaries and its headwaters (paluslopes).

MW19 — Sandy Peak Creek Suite

This is a suite which incorporates a drainage system of paluslopes (on the coastal dunes), adjacent palusplain, floodplain, creeks and drainage lines of surface water and groundwater flow. This is overprinted by linear dune ridges and outlying arms of the coastal parabolic dunes. The arms of the dunes segment areas of paluslope into separate entities, but the system is integrated through the dominant drainage flow pattern which is to the southeast towards the Gardner River. The area seems to be a discharge area for fresh groundwater and surface water flow from the western coastal dunes.Although sedgelands and shrublands line the channels, the dominant vegetation is latiform heath comprising species of *Agonis, Homalospermum, and Astartea.* The substrate is peaty or humic sand overlying fine quartz sand.

MW20 — Chudulup Suite

This is a suite of palusplain underlain by alluvial sediments, transected by numerous dendritic creeks, and interrupted by granite outcrops from which seepage occurs. The creeks are leptoscale and meandering. The groundwater is always close to the surface (50 cm below) and is freshwater. The substrate is grey quartz sand with a thin layer of peat at the surface. The vegetation is maculiform and comprises low heaths, grasslands, and shrublands.

Tertiary Siltstone Flat

MW21 — Pallinup Suite

This suite is composed of valleys which were probably Tertiary wetlands and which retain palaeogeographic features such as former watercourses which still operate to preferentially direct water flow even though the present fluvial system may be discordant. The suite is underlain by the Pallinup Shale overprinted by colluvial materials which range from muddy sand and silt to a white fine quartz sand, with overprinting of iron staining and cementation. The wetlands are palusplains, and basins. Some perching occurs above the shallow (0.9 m – 1.2 m) iron indurated layer. The groundwater is fresh. The vegetation comprises sedgeland and shrubland of *Anarthria, Leptocarpus, Evandra, Restio, Kunzea, Acacia, Hakea, Calothamnus, Pericalymma, Agonis, Homalospermum* and *Astartea.*

MW22 — Pingerup Lakes Suite

This suite is composed of lakes and sumplands with a peaty sand overlying a muddy sand layer as wetland fill. The minimum water table level is very close to the surface and the wetland soils are permanently saturated. The wetlands are probably windows to the water table. The groundwater is fresh. The wetland vegetation is maculiform, and comprises forest of Melaleuca preissiana, sedgeland of *Baumea articulata, Leptocarpus scariosus, Mesomelaena tetragona,* heath of *Agonis hypericifolia,* mixed heath, and herbland of *Villarsia parnassifolia.*

Precambrian Rock Plateau

MW23 — Weld River Suite

This suite of wetlands includes Deep River, Weld River, and Shannon River. They are leptoscale entrenched channels through a layered sedimentary fill sequence of quartz sand on muddy sand on ferruginised muddy (kaolin) sand on mudstone on granite. The water is subhaline and supports a patchy fringing vegetation of shrubland or forest of *Agonis juniperina.*

MW24 — Deep River/Shannon River Delta

This suite is composed of a cuspate wave-dominated delta with islands, shoals, and multiple channel pathways at the mouth. The delta is underlain by shelly and humic sand overlying humic mud overlying black sand overlying white river sand. The vegetation comprises sedgeland (*Juncus kraussii, Gahnia trifida,* and *Isolepis nodosa*), and low open shrubland (*Melaleuca cuticularis, M. viminua, Agonis juniperina*). The groundwater ranges from hyposaline to mesosaline.

3.4 Preliminary identification of outstanding wetlands

As described in Section 1.7, the scope of the project and the paucity of available information have meant that only a preliminary identification of the area's outstanding wetlands has been carried out, based on the seven criteria listed in Section 1.7.

Information used in the analysis of the wetland suites in the study area, was derived from publications and selected field visits. Published information on fauna was drawn from the following sources:

Amphibia	Wardell-Johnson and Roberts (1991,1993); Jaensch(1993)
Fish	Christensen (1982);Allen and Berra (1989); Pusey (1990); Bayly (1992); Jaensch (1992a)
Invertebrates	Pusey and Edward (1990b); Edward *et al.* (1994); Horwitz (1994);
Waterbirds	Jaensch (1992a);

Information relating to amphibia (frogs) includes some locations cited in respective studies listed above, but overall, the surveys of amphibia have not been long term or comprehensive, and so definitive statements of their occurrence with respect to consanguineous suites cannot be made. Moreover, frog population numbers seem to be generally low. Some patterns did emerge, however, and these pertained to endemism. The frog species *Crinea glauerti* and *Litoria adelaidensis* were fairly widespread, while the species in the *Geocrinea rosea* complex are very site specific (Wardell-Johnson and Roberts 1991). *Geocrinea rosea* is located around the Pemberton area and *G. lutea* is restricted to the Walpole area according to current surveys. At this stage results from surveys do not permit rigorous assessment of whether species are related or restricted to consanguineous suites.

Similarly, some fish distributions are widespread and some are restricted (Christensen 1982, Pusey 1990, Jaensch 1992a). *Bostockia porosa* and *Edelia vittata* are widespread whereas other species such as *Galaxiella munda, G. nigrostriata, Galaxias maculatus, Lepidogalaxias salamandroides, Nannatherina balstoni* and *Tandanus bostockii* are restricted in distribution. For example, *Galaxiella nigrostriata* occurs between Northcliffe and Denmark. *Nannatherina balstoni* occurs in two geographic areas: between Lake Quitjup and Lake Smith, on the Scott Coastal Plain, and between Northcliffe and Broke Inlet. *Tandanus bostockii* appears to be restricted to the locations of habitats comprising sedgelands of *Leptocarpus* species. Where it has been possible to deduce precise locations for species of fish, this information has been incorporated into the framework of the consanguineous suites. However, from the present data, it is still indeterminate whether the presence of fish species correlates with types of consanguineous wetland suites, or simply with water quality and periodicity. For instance, *Galaxias occidentalis* prefers neutral waters, *L. salamandroides* prefers more acidic waters, *E. vittata, B. porosa, G. munda* and *G. occidentalis* tolerate some salinity (Christensen 1982).

Invertebrates that are of widespread distribution include micro-crustacean fauna, e.g., Cladocera, Copepoda, and Ostracoda (Pusey and Edward 1990b) and Insecta e.g., Chironomidae. Micro-crustacean cies endemic to south-western Australia include the copepod *Calamoecia attenuata*. Invertebrates endemic to specific regions of the south-west include *Daphnia occidentalis*; copepods *Calamoecia elongata, C. attenuata, Boeckella geniculata, Hemiboeckella andersonae, Paracyclops sp. nov.* in the Northcliffe region; and microcrustaceans *Biapertura imitatoria*, a Cladoceran species, copepods *Calamoecia elongata*, and *Hemiboeckella andersonae* (Bayly 1992) which appear restricted to the Doggerup Basin, Walpole River and Chudulup suites.

In the study by Horwitz (1994), a number of sites selected for invertebrate sampling coincide with the following consanguineous suites: Windy Harbour, Coastal Track, Doggerup Basin, Deep River, Chudulup, Inlet River, Walpole River and Pallinup suites. Many species were found to be either locally endemic or endemic to the south-west. In the first category are oligochaetes, acarinas, and the decapod *Engaewa subcoerulea*. This local endemism may not necessarily correlate with a particular consanguineous suite, but rather with locality, or specific habitats in a given physiographic/hydrologic region. This aspect needs to be further investigated. In the second category are oligochaetes, acarinas, isopods, diptera and decapods. The most important sites for invertebrates appear to be in the Doggerup Basin suite, the Chudulup suite and the Walpole River suite, in that these suites contain species-rich assemblages. Data on invertebrates are presented where appropriate in the descriptions of the consanguineous suites.

Information on avifauna, although not exhaustive, appears to shcw opportunistic use of wetlands as drought refuges, feeding and loafing sites (Jaensch 1992b). For instance, individual wetlands appear to support high numbers of avifauna, e.g. Lake Florence and Lake Maringup, while other wetlands with similar characteristics do not.

Information on habitat diversity and geomorphic/ landscape values were obtained from field surveys conducted during this study. Traverses and field sites pertaining to this study area are shown in Appendix C to illustrate the extent of the data base. In many suites the information available is depauperate and should in no way be considered a true representation of the value of the wetland suite. This information is only an informal indication of wetland value. Each of the suites are assessed below, and the criteria important to their assessment, are listed at the beginning of each description.

MW1 — Windy Harbour Ridge Suite

condition of wetland
representativeness
habitat diversity

This is a suite of shore parallel beach ridges with wetlands in the inter-ridge depressions. The wetlands are undisturbed and remain in contact with their dune surroundings, even though there are tracks through the area. They represent a type of wetland and setting which is uncommon on the southern coast and restricted to Windy Harbour. There are sumplands and damplands which provide different vegetation assemblages, both of which contrast with the surrounding dune vegetation, thus increasing the habitat and vegetation diversity.

MW2 — Meerup Suite

scarcity of wetland type
habitat diversity
geomorphic/landscape values

These wetland basins occur in the hollows between chaots on the beach shore, and are underlain by calcareous sand. Both of these characteristics create an unusual habitat. The nearest comparative wetland type in this area would be the Gardner River Estuary Suite, however these latter wetlands are probably freshwater, although their hydroperiods and water levels would be affected by tidal fluctuations. Located in such a dynamic environment, they are likely to be of very recent age and undergoing rapid change, therefore they are excellent examples of wetland processes and evolution.

MW3 — Gardner River Estuary

condition of wetland
representativeness
geomorphic/landscape values

Gardner River estuary is reasonably inaccessible, and has come under very little people pressure. There are recreation sites surrounding the estuary but no obvious structures or alteration to banks or bars which form the estuary itself. Therefore, it remains relatively undisturbed and the operation of its natural fluvial, aeolian, and oceanic processes unaltered. It represents a type of estuary along the southern coast where wave processes dominate the evolution of shoreline features.

MW4 — Malimup Suite

condition of wetland
representativeness
habitat diversity
faunal values

This is a suite of microscale to mesoscale damplands within the coastal parabolic dunes. There are three locations in the study area: east of Windy Harbour, east of Gardner River Estuary, and Malimup. The wetlands are inaccessible and are therefore undisturbed and unaltered hydrologically. They retain their natural contact with the surrounding dunes. As such they are representative of this suite, its processes, and its vegetation types. The wetlands provide a contrasting habitat to their surrounds, and also, importantly, freshwater to fauna in the region.

MW5 — Windy Harbour Suite

condition of wetland
representativeness
habitat diversity

This is a suite of basin wetlands situated at the base of limestone ridges at its contact with the Tertiary estuarine flat at Windy Harbour. They are relatively few in number and represent a quite distinctive discrete wetland within the larger wetland flat, which creates a mosaic of habitats. The wetlands appear not to have undergone such frequent burning as other basins within the Tertiary flats and support a less disturbed and better zoned vegetation cover.

MW6 — Sand Peak Suite

condition of wetland
representativeness
habitat diversity
faunal values

This is a suite formed where the coastal dunes have encroached over the Tertiary basement. Although the habitats will vary as a result of the substrate, the wetland attributes will be similar to the Malimup Suite. The wetlands are inaccessible and are therefore undisturbed and unaltered hydrologically; they retain their natural contact with the surrounding dunes. They provide a contrasting habitat to their surrounds, and also, importantly, freshwater to fauna in the region. They are representative of this type of wetland, its processes, and its vegetation types.

MW7 — Coastal Track Suite

condition of wetland
representativeness
habitat diversity
faunal values

This is a suite of discrete and coalescing damplands, sumplands and lakes, along the contact of the quartz/calcareous dunes which overlie Pleistocene limestone, and the estuarine Tertiary deposits. The wetlands and uplands are relatively undisturbed. They represent a range of wetland types and habitats, and therefore create aquatic and terrestrial habitats for fauna, particularly invertebrate species (Horwitz 1994).

MW8 — Lake Maringup Suite

condition of wetland
representativeness
scarcity of wetland type
faunal values
linked systems

The Lake Maringup Suite is unique in the study area as a wetland type. It was probably a former estuarine system and still retains elements of that former environment. This is a wetland complex of macroscale shallow basins within a floodplain. Lake Maringup, itself, is used for recreation, and therefore, there are local areas of impact such as roadways and other forms of physical disturbance. However there is no evidence of disturbance to the hydrologic or sedimentologic systems.

The wetlands of this suite are an important habitat for fauna (Jaensch 1992a). There are six species of fish: *Galaxias occidentalis, Bostockia porosa, Edelia vittata, Nannatherina balstoni, Atherinosoma wallacei* and *Pseudogobius olorum.* Two species are worthy of further mention. *N. balstoni* at present survey has a sparse distribution and *P. olorum* has not been found between Lake Jasper and Lake Maringup. Frog species are also important in the area. The two dominant species (*Crinia glauerti* and *Litoria adelaidensis*) inhabit the sedgelands with interspersed shrubs and trees. *Litoria moorei* also occurs in the area. Avifauna are also important wetland users. Large numbers of species use the lake and two species breed in the area. Relevant species include Grey Teal, Pacific Black Duck, and Eurasian Coot. Lake Maringup also provides the habitat for Declared Rare Fauna, the Black Bittern (Jaensch 1992b).

MW9 — Broke Inlet/Nornalup-Walpole Estuary Suite

condition of wetland
representativeness
scarcity of wetland type
habitat diversity
geomorphic/landscape values
linked systems
faunal values

Broke, Walpole and Nornalup Inlets are macroscale to megascale estuaries barred from the Southern Ocean or another inlet by barriers, but retaining narrow tidal exchange channels. They are bordered by narrow fringing flats and cuspate wave-dominated deltas. The wetlands are largely undisturbed except for local incursions into the flats for recreation and accommodation. The surrounding upland areas are also largely undisturbed which results in stability of the aeolian and freshwater hydrology aspects of the system and relative stability of the vegetation assemblages. Estuaries themselves are an uncommon wetland type, but each may be subdivided internally, into a further range of wetland types such as: the permanent open water basin, the marginal flats, the deltas of the major channels, and the slopes, flats and microscale channels discharging freshwater into the basin. The size of the estuaries, and the range of freshwater, brackish and saline water habitats further illustrate the diversity of the system. Deltas, which are active provide a wide range of information e.g., sedimentological and shoreline processes, erosion, deposition, information through sediment analysis and water quantity and quality measurements, on provinces drained by the river creating the delta. Estuaries are a linked hydrological, sedimentological and ecological system, linking the upland and lowland hinterland and the marine system via river channels, deltas, tidal channels and the receiving basin itself.

Broke Inlet is ranked in the top 5% of wetlands in the region for its importance to waterbirds, including numbers of species nominated under international treaties. Although not fully surveyed for use by fauna, deltaic environments in general support a range of fauna, exemplified by the occurrence of seventeen commercial fish species, species of Foraminifera, and the range of invertebrate fauna recorded in surveys by Wallace (Hodgkin and Clark 1989).

MW10 — Crystal Lake Suite

condition of wetland
scarcity of wetland type
geomorphic/landscape values

These wetlands lie along the contact between the dunes overlying limestone and the Precambrian granite located around Nornalup Inlet. The wetlands are microscale lakes and steep sided karst features. As such, the suite is unique in the study area and in the landscape. It is scientifically important to investigate the interplay of the groundwater, the aquifers, the formation of the wetlands and their characteristics.

MW11 — Walpole River Suite

condition of wetland
representativeness
faunal values
linked systems

This is a suite of paluslope wetlands dispersed throughout the study region and occurring in disparate areas. These wetland slopes are sometimes associated with microscale creeks. Many of these types of wetlands have been cleared for rural activities. As these wetlands are restricted to the extreme south coast of Western Australia because of the combination of precipitation/evaporation conditions, they signal an important climatic difference between the Swan Coastal Plain and the southern coastal plain of between Augusta and Walpole.

Some information on faunal use is available for specific wetlands in this suite, but given the dispersal of the wetlands, this information cannot be readily transposed from one region to another. The information used in this report relates to wetlands in the area west and south east of Northcliffe and should not be extrapolated for areas near Walpole River. In the Northcliffe area, researchers have identified endemic and new species of invertebrates (Horwitz 1994). For instance, Northcliffe has become the type locality for *Daphnia occidentalis; Calamoecia elongata* is a species endemic to this region; and three new species have been discovered; a new species of copepod, *Paracyclops sp. nov.*, a new species of janirid isopod, and a new species of freshwater crayfish, *Engaewa sp. nov.* The Northcliffe area also contains the habitat for the frog *Geocrinea lutea* which is extremely restricted in occurrence (Wardell-Johnson and Roberts 1991).

Wetland slopes also form part of a linked geomorphic/hydrologic system between the Precambrian uplands and the Tertiary flats, i.e., between valley slopes, channels and palusplain or floodplain.

MW12 — Linear Dunes -Palusplain Suite

condition of wetland
representativeness

This is a suite of slightly undulating palusplain overlain by disrupted parabolic dunes enclosing irregular leptoscale to microscale areas. It is undisturbed and represents a wetland type and habitat resulting from a relatively simple stratigraphic and hydrological system.

MW13 — Floodplain Suite

condition of wetland
representativeness
scarcity of wetland type
habitat diversity
geomorphic/landscape values
faunal values
linked systems

A suite resulting from erosion by leptoscale creeks which also act as conduits for backflow from the Gardner River. This creates floodplain areas, local enlarged pools within the channel and billabongs (which are mesoscale lakes and sumplands). The wetlands are undisturbed except for Gardner River Road which intersects the suite. The suite occurs only in one location in the study area, but, because it is quite extensive, it contains a large number of diverse habitats ranging from permanent open water, to forests underlain by peat, to heathlands underlain by clay to sedgelands underlain by sand and ferricrete.

As an erosional feature located within the palusplain, it is part of an ecological linked system. It is also part of an hydrological system linking the Valley and Creek Suites with the Gardner River. As such it has both landscape and faunal values. Pusey and Edward (1990b) found it to be significant for Trichoptera, Diptera, and Chironomids. It also provides habitats for freshwater crustaceans, mussels, tortoise and fish: *Galaxiella sp.*, *Bostockia porosa*, *Edelia vittata* and *Nannatherina balstoni*. The presence of species of *Galaxiella* and *Nannatherina*, are significant because they are normally restricted or sparsely distributed. Frog surveys indicate that the habitat vegetated by low forest of *Agonis juniperina* in this area supports high numbers of the frog *Crinea glauerti*. The limited work done on avifauna (Jaensch 1992b) indicates that the area supports significant numbers of birds as well as some unusual species such as Yellow-billed Spoonbill and Spotless Crake, and is the breeding site for two known species — the Black Cormorant and the Clamorous Reed-warbler.

MW14 — Valley Suite

condition of wetland
representativeness
scarcity of wetland type
geomorphic/landscape values

Valleys of Tertiary deposits between granite gneiss outcrops host wetlands which include some slopes, valley floors (palusplains) and leptoscale channels which are impeded and orientated by small-scale dune ridges. The wetlands are undisturbed. The combination of fluvial, groundwater, and aeolian processes which operate in this suite make it scientifically interesting from a geomorphic/hydrologic point of view. The suite occurs only in one location in the study area, and as it is mesoscale, the occurrence is regionally significant.

MW15 — Inlet River Suite

condition of wetland
representativeness
faunal values

This is a suite of palusplain underlain by estuarine sediments, transected by creeks, and interrupted by granite outcrops. The wetland area is undisturbed except for minor roads and local development of recreational residences. Neither of these at their present level of development have significantly impacted on the system. Although the suite is widespread in this region, it is best represented at Inlet River.

Research on fauna has been carried out in selected wetlands in this suite. Five species of fish have been collected: *Galaxiella nigrostriata*, *Galaxias occidentalis*, *Bostockia porosa*, *Edelia vittata* and *Nannatherina balstoni*. Koonacs and tortoises are also present. Limited avifauna surveys have been carried out, and the Great Cormorant, herons, and crakes have been noted. Ostracods, insects, and beetles (Coleoptera) have been recorded (Pusey and Edward 1990b) and new species of janirid isopods and the crustacean *Engaewa subcoerulea* have been documented by Horwitz (1994).

MW16 — Gardner River Suite

condition of wetland
representativeness
linked systems

This suite of wetlands typically contains leptoscale to microscale creeks and rivers and leptoscale associated flats (floodplain and palusplain). The wetlands are undisturbed. They recur throughout the study area, but Gardner River is the type example of this wetland. The Gardner River suite adjoins the Floodplain suite, the Gardner River Estuarine suite, and the Inlet River suite.

MW17 — Doggerup Circular Basin Suite

condition of wetland
representativeness
habitat diversity
geomorphic/landscape values
faunal values

This is a suite of circular basins on a palusplain, interspersed among randomly oriented linear dune ridges. Although many of the wetlands are undisturbed, there are a number which have been significantly altered through fire damage. Up to 0.5 m of peat has been lost unevenly from the basins, producing multi-level water depths and a range of vegetation responses to systems in disequilibrium. The suite represents a range of wetlands from lakes to damplands and from mesoscale to leptoscale. As a result, the number of habitats present in this suite is large and ranges from open water to herbland to grassland, heaths,scrub and forests. The density of wetlands in this suite is also high.

Most of the faunal surveys have been concentrated in this suite. Surveys of Lake Samuel, Lake Florence and Doggerup Lake have documented seven fish species: *Galaxiella nigrostriata, Galaxiella munda, Bostockia porosa, Edelia vittata, Galaxias occidentalis, Lepidogalaxias salamandroides* and *Nannatherina balstoni. G. munda* is restricted in distribution and *L. salamandroides* and G. *occidentalis* are rare. The frogs *Litoria adelaidensis, Crinea glauerti* and *Geocrinia leai* are recorded in this area (Wardell-Johnson and Roberts 1991). *G. leai* is considered rare and restricted in distribution. The wetlands also provide habitats for marron and tortoise. It was found that the highest mean richness for invertebrates occurred in this suite (Edward *et al.* 1994, Horwitz 1994).

MW18 — Doggerup Creek Suite

condition of wetland
representativeness
scarcity of wetland type

This suite comprises a leptoscale creek with many tributaries and paluslopes at its headwaters. The wetlands although not recurring in the study area, do occur in areas further to the north. In contrast to most of the creeks in the coastal zone which are single channels, this creek has tributaries and headwater slopes located in the Quaternary dunes. The wetland system is relatively undisturbed.

MW19 — Sandy Peak Creek Suite

condition of wetland
representativeness
scarcity of wetland type
linked systems
geomorphic/landscape values

This is a suite of paluslopes, palusplain, floodplain, creeks and drainage lines of surface water and groundwater flow. The wetland complex forms a complete integrated system and as such is assessed. It is unusual both in the geometry and arrangement of wetlands and in its setting. It is not replicated elsewhere in the Scott coastal plain or in the study area. The surface and ground water from this complex flow southeast towards Gardner River flushing the palusplain areas between, and thus can be viewed as part of a linked system.

MW20 — Chudulup Suite

condition of wetland
representativeness
faunal values
linked systems

This is a suite of palusplain, underlain by alluvial sediments, transected by numerous dendritic creeks, and interrupted by granite outcrops from which seepage occurs, thus linking several wetland types through fluvial processes. The wetlands extend eastwards from the Mt Chudulup area. The wetlands around Mt Chudulup are significant for invertebrate families of Cladocera and Insecta (Pusey and Edward 1990b), the rare fish *Lepidogalaxias salamandroides* (Allen and Berra 1989, Pusey 1990, Bayly 1992) and the amphibian *Geocrinia rosea* (Wardell-Johnson and Roberts 1993). The suite is relatively undisturbed.

MW21 — Pallinup Suite

condition of wetland
representativeness
geomorphic/landscape values
faunal values

This suite contains valleys with paluslopes, palusplains, floodplains and occasional basins, which were probably Tertiary wetlands and which retain palaeo features such as watercourses. The wetlands are undisturbed. At present, they are little understood in terms of development history and hydrology, and are therefore of scientific interest to wetland scientists and geomorphologists.

Primary findings in the field of invertebrate studies indicate unusual and diverse populations present in these wetlands, particularly in families of Cladocera, Insecta, Diptera, Chironominae (Pusey and Edward 1990b) and mites (Horwitz 1994). Surveys for other fauna may yield equally interesting results.

MW22 — Pingerup Lakes Suite

condition of wetland
representativeness
scarcity of wetland type

habitat diversity
faunal values

This suite contains lakes and sumplands which are relatively undisturbed. This suite is not replicated elsewhere in the study area. In a surrounding of seasonally waterlogged flats, the suite of three basins (mesoscale areas providing areas of permanent to seasonal surface water), should be considered as a group. They incorporate a diverse number of habitats ranging from sedgelands to heaths to forests.

MW23 — Weld River Suite

condition of wetland
representativeness
faunal values
linked systems

This suite of wetlands includes Deep River, Shannon River, the upper reaches of Gardner River, and Frankland River. Data from the Water Authority on water quality show the total dissolved solid measurements for each river to be <1000 mg/L i.e., freshwater, and as the catchments are largely uncleared, other water quality parameters may also be uncontaminated. If this is the case, then these channel wetlands are regionally significant in the Southwest region. Some limited surveys have been carried out on the fish present in the Frankland and Shannon Rivers. *Gambusia affinis* and *Edelia vittata* were recorded in the Frankland River (Christensen 1982); *Galaxias occidentalis* was recorded in the Shannon River. Insecta, Diptera, and Orthocladiniiae have been noted in some channels (Pusey and Edward 1990b).

MW24 — Deep River, Shannon River Deltas

condition of wetland
representativeness
scarcity of wetland type
habitat diversity
geomorphic/landscape values
faunal values
linked systems

These wetlands are cuspate wave-dominated deltas with islands, shoals, and multiple channel pathways at the mouth. They are relatively scarce wetland types and both deltas provide excellent and undisturbed examples of this type of delta. There are many habitats associated with deltas, ranging from brackish to saline and from islands to channels to floodplains to levees. Deltas, which are active provide a wide range of information e.g. sedimentological and shoreline processes, erosion, deposition, information through sediment analysis and water quantity and quality measurements, on provinces drained by the rivercreating the delta. Deltas are part of a linked hydrological and ecological system incorporating the river channel and the estuary. Although not surveyed for use by fauna, deltaic environments in general support a range of fauna.

3.5 Summary

While there are a total of twenty-three suites between Meerup to Walpole, within a small area between Northcliffe and Windy Harbour there are twelve consanguineous suites indicating a richness in diversity of wetland type:

- Windy Harbour Ridge suite
- Windy Harbour suite
- Linear dune -palusplain suite
- Coastal Track suite
- Floodplain suite
- Sandy Peak Creek suite
- Valley suite
- Chudulup suite
- Doggerup circular wetland suite
- Inlet River suite
- Sand Peak suite
- Doggerup Creek

Such a large number of suites in close proximity to each other makes this area regionally significant for wetland diversity. Many of the suites do not occur elsewhere in the study area. Preliminary results from faunal surveys (Pusey and Edward 1990a and b, Jaensch 1992b, Wardell-Johnson and Roberts 1991, 1993, Horwitz 1994) have reinforced the importance of this wetland region for endemic fauna, fauna restricted in distribution, rare fauna and fauna indicative or representative of fluvial and lake environments.

4. The Muir-Unicup area

4.1 Study area and scope

The Muir-Unicup area, is located on the Ravensthorpe Ramp between Tone River to the west and Frankland River to the east. It encompasses the area around Lakes Muir and Unicup and extends south into the catchment of the Deep River and provides the opportunity to map and study the wetlands of an inland setting situated in a humid to sub-humid climatic belt. The area is of interest not only for the significant wetlands in the north (Lake Muir, Lake Unicup and the Toordit-Byenup Lagoon System) but also the extensive flat wetlands which envelop the rivers and creeks to the south in the intermediate rainfall zone (900 – 1100 mm).

Mapping and classification of wetlands in this area is presented in Figure 5.

Wetlands were classified on a site specific basis and then amalgamated into regional groups using the concept of, and criteria for, consanguineous suites. The section firstly summarises aspects of the regional setting of the study area as background to the wetlands, and then, describes the regional wetland suites and their values and/or functions as understood to date.

4.2 Regional setting

This discussion of regional setting addresses the five systems which to a large extent determine the styles and types of wetlands developed in the region: climate, geology, geomorphology, hydrology and botanical provinces. The focus has been placed on the Muir-Unicup area and its immediate surrounds. A detailed description of the regional processes associated with the development of wetlands in the Lake Muir Lowland region has been prepared by the V. & C. Semeniuk Research Group (1997a). The hydrology of the Lake Muir Lowland, together with implications for management, has been detailed by the V. & C. Semeniuk Research Group (1997b).

4.2.1 Climate

The study area is located in a Mediterranean Climate, with winter rainfall and summer drought. It is classed as Csb climate (= Subtropical Dry Summer, with long mild summer) by Koppen (1936), and a winter-wet southwest region by Gentilli (1972). The area experiences a strong gradient in rainfall variation from south to north, with 900 mm annual rainfall occurring to the south of Lake Muir, and 700 mm annual rainfall occurring to the north of Lake Unicup. The annual evaporation is circa 1600 mm, with a less marked south to north gradient than rainfall. In terms of climate, the southern parts of the Study Area may be classed as humid, while the northern parts are subhumid, gradational into semiarid climates further north.

Rainfall is an important factor in the development and maintenance of wetlands for several reasons. Excess rainfall over evaporation results in increasingly wet habitats, the flushing out of salt in the groundwater and soil water, and in the growth of luxuriant vegetation and (hence) peat. Evaporation, equally, is an important factor in the development and maintenance of wetlands in that for exposed bodies of water it results in elevating the salinity.

The combined effects of abundant rainfall, the south-north gradient of decreasing rainfall, and the degree of evaporation in the Lakes Muir/Unicup area are as follows:

- generally, wetlands will be freshwater systems, since they are largely located within a humid to subhumid climate;
- large water bodies perched above relatively impermeable layers are subject to evaporation and hence increase in salinity to become point sources of saline water;
- the gradient in decreasing rainfall from south to north results in a general increase of salt in groundwater regionally;
- the gradient in increase of salt in groundwater regionally means that river headwaters in the region are draining saltier terrains and groundwaters as they incise further and further to the north.

4.2.2 Geology

The geology of the region is described within a framework of two main units:

- the Precambrian rocks which underlie all the area; and
- the Cenozoic regolith materials.

The Western Australian Precambrian Shield in this part of Australia is comprised of the ancient Archaean Yilgarn Craton (formerly the Yilgarn Block), composed mainly of granitic rocks and gneisses, and 3340 – 2420 millions years in age, and the relatively younger Proterozoic rocks of the Albany-Fraser Province, composed of a variety of metamorphic rocks, granites, and gneisses, and circa 2200 – 1800 million years in age. The boundary between the two is located on the Manjimup Lineament to the west, and the Pemberton Lineament to the east. Consequently, the Lakes Muir and Unicup area are wholly located within the terrain of the Albany-Fraser Province.

The regional variation in geology, in terms of rock types and formational structural trends such as fold trends, shears, attitudes of layering, and trends of dykes, however, has little influence on the development of terrain, geomorphology, drainage, and wetlands.

There are two aspects of the Precambrian geology that have direct and indirect influence on the geomorphology and hydrology of the area:

- the deep weathering of Precambrian rock to yield saprolite that acts to perch water; and
- the Manjimup and Pemberton Lineaments; these may have influenced the development and location of the upwarp flexure termed the Jarrahwood Axis, formed when Australia rifted from Antarctica.

Cenozoic materials are Tertiary, Pleistocene and Holocene in age, and constitute the regolith (weathered materials, and sedimentary cover over the Precambrian bedrock). The Cenozoic materials include:

1. Tertiary fluvial deposits within former (ancient) valley tracts;
2. Tertiary fluvial deposits now cemented by sesquioxides of iron;
3. Tertiary aeolian deposits now cemented by sesquioxides of iron;
4. Tertiary to Pleistocene aeolian quartz sand deposits;
5. Pleistocene wetland basin-fill and wetland basin margin deposits;
6. Pleistocene wetland valley-fill deposits;
7. Holocene fluvial deposits;
8. Holocene wetland deposits.

The sesquioxides of iron that indurate the aeolian and fluvial sediments are 1 – 2 m thick "laterite" formations that overlie weathered bedrock (= saprolite).

The Cenozoic deposits commonly form a sequence as follows:

- Holocene wetland deposits, e.g. peat
- Pleistocene wetland deposits, e.g. beachridge sand
- Tertiary to Plesitocene sand
- Laterite, e.g. iron sesquioxide indurated aeolian or fluvial sand
- Saprolite = deeply weathered (chemically rotted) Precambrian bedrock

The most important materials that help control the disposition of landforms and wetlands are laterite, which forms a hill-capping resistant sheet of hard duricrust, and saprolite, which as mentioned above, is instrumental in the local perching of groundwater in the region. All other Cenozoic materials are generally of a passive-fill nature, and lie low in the landscape.

4.2.3 Geomorphology

At a regional scale, the Study area has been subdivided into two main geomorphic units (Wilde and Walker, 1984; Fairbridge and Finkl 1978):

- the Darling Plateau, a region of relatively high plateau mainly more than 300 m above MSL, and underlain by the Archaean Yilgarn Craton; and
- the Ravensthorpe Ramp, a region of terrain inclination towards the coast, where the terrain is 200 m or less in height, and underlain by the rocks of the Proterozoic Albany-Fraser Province.

Within this context, the study area is set wholly within the Ravensthorpe Ramp.

In more detail, at finer scales, the area of the Lakes Muir and Unicup region has a fairly simple geomorphology, and the account that follows is partly descriptive, and partly interpretative; i.e, the geomorphology is described, then an interpretation of origin/development follows. The geomorphology is presented at the large scale, and within a framework of relative age of units. Details of the geomorphology at the smaller scales is presented in another study (V. & C. Research Group 1997a).

The main regional geomorphic units in the study area are (Figure 11):

- the Old Plateau;
- the Old Basin;
- the Young Basin;
- the Young Rivers.

The Old Plateau is the undulating landscape, with internal relative low relief of circa 20 m, composed of plains, shallow drainage lines, interconnected basins and drainage lines, and scattered round wetlands (Figure 11). Note that the term "Old Plateau" is not to be confused with, or made synonymous with the term Old Plateau as used by Jutson in his description of the evolution of terrains from youthful to peneplain. In the study area, the term "Old Plateau" refers to the plateau situated at >200 m, which forms the oldest land surface in the region. In this study area, the Old Plateau is underlain by saprolite, or a sheet of laterite, or yellow aeolian sand. The Old Plateau has formed by the long term, prolonged fluvial erosion, where the terrain has become subdued, the watersheds vague, and the fluvial courses shallow and broad. Slow drainage rates and local ponding results in the development of basin wetlands within the broad/ shallow valley tract, and under former arid to semi-arid climatic conditions, results in the formation of isolated, round, beachridge-ringed wetlands.

The Old Basin is the older excavation basin of two such excavation structures. In plan, the Old Basin is irregular to vaguely triangular, with its margins strongly modified by consequent drainage. The location and form of the Old Basin corresponds to the Tertiary Alluvial Flats of Wilde and Walker (1984). The Old Basin is located at circa 180 – 200 m AHD, and is bordered peripherally by the Old Plateau. The terrain of the Old Basin is relatively flat, though there are local hills of bedrock protruding with 20m relative local relief. The terrain is underlain mainly by saprolite, and some quartz sand reworked from the excavation margins. The margins of the Old Basin are incised by consequent streams that cut back into the Old Plateau. Lines of wetlands are disposed along these older consequent drainage lines.

The Old Basin has formed by Tertiary age arid zone aeolian and salt-flat-weathering driven by near-watertable conditions, leading to the excavation of a basin into the Old Plateau. Once the basin was excavated, its margins have undergone consequent stream erosion (incising into the Old Plateau), and later partial fill by aeolian and fluvial sediment from the margins. As for the Old Plateau, slow surface drainage rates and local ponding within the Old Basin and its marginal consequent stream suite results in the development of smaller basin wetlands within the shallow consequent stream valley tract, and under former arid to semi-arid climatic conditions, resulted in the formation of isolated, round, beachridge-ringed wetlands.

The Young Basin is the younger excavation basin of two such excavation structures. In plan, the Young Basin is oval with its margins moderately modified on its southern shore by consequent drainage. The location and form of the Young Basin corresponds to Lake Muir. The Young Basin is located at circa 160m AHD, and is bordered peripherally to the west by the Old Plateau, and on all other sides by the Old Basin. The floor of the Young Basin is flat. Its margins are commonly cliffed, with cliffs cut into bedrock, saprolite and laterite. The southern margin of the Young Basin is incised by consequent streams that cut back into the Old Plateau.

The Young Basin also has formed by Quaternary age arid zone aeolian and salt-flat-weathering driven by near-watertable conditions, leading to the excavation of a basin into the Old Basin and the Old Plateau. Since the Young Basin is a relatively recent excavation, its margins have not undergone extensive consequent stream erosion, nor fill by aeolian and fluvial sediment.

The Young Rivers are the incised drainage lines that are cutting into all the above units. The Young Rivers have weakly meandering to straight main channels with dendritic tributary channels. The main channels are incised into the Old Plateau, with incisions of 3-6m relief, exposing bedrock, saprolite, laterite, and other Cenozoic materials. The sediments within the main channel are sands and muds. The tributaries are broad and shallow, varying to steeply incised channels that cut into a variety of materials at their headwaters. The sediments within the tributaries are veneers of sand and mud. While the down-stream parts of the main channels may predate, equate, or postdate the formation of the Old Basin, the headwater regions clearly postdate the formation of the Old Basin. The Young Rivers are drainage lines cut into the Ravensthorpe Ramp, and formed subsequent to the formation of the Ramp. The ongoing headwater erosion of these rivers has cut and is cutting into the terrain of the Old Plateau, Old Basin, and Young Basin.

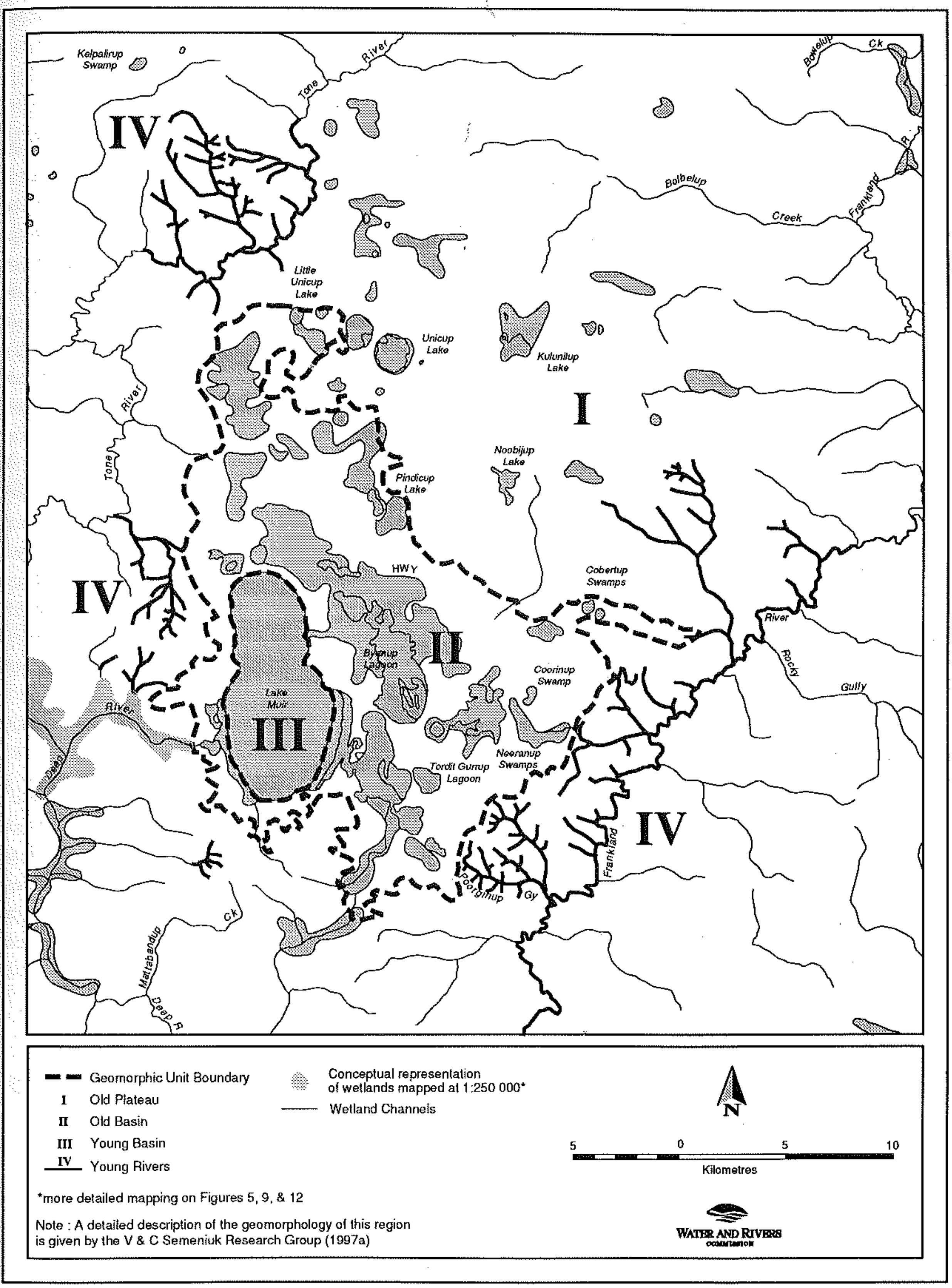


Figure 11: Main Regional Geomorphic Units of the Muir-Unicup Area

4.2.4 Hydrology

The hydrology is described in this area from three aspects: the main groundwater, the perched groundwater, and the surface drainage waters.

Groundwater in the study area occurs at circa 180 m AHD in the southern part of the area, and circa 220 m in the northern parts of the area, i.e., there is a regional groundwater table gradient rising from south to north. Lakes Muir and Unicup are largely windows to this regionally inclined water table. The aquifer within which this groundwater resides is largely fractured Precambrian bedrock and weathered rock, but locally, dependent on stratigraphy, it may be Tertiary aeolian sand, or fluvial sand. The salinity of the main groundwater system varies: it is saline to brackish where it is near evaporative discharge zones; it is also brackish to saline where recharge into the groundwater system is via creeks and rivers that are draining saline land upslope; its salinity is fresh where the water table is deep and/or distant from any evaporative discharge zone. There also is a weak gradient in the groundwater from south to north, reflecting the climatic gradient, and the increase in saline sources upslope.

Perched groundwater in the study area occurs at various levels, depending on the perching mechanism. Some perching is due to the relatively impermeable nature of saprolite, hence local irregularities in the sheet of saprolite result in local subsurface ponding (perching) of meteoric water. Other perching is due to laterite, or due to ferricrete in wetlands, the latter resulting in perching of water to create local wetlands. Other perching is due to wetland fill deposits, such as peat or clay, again resulting in the local development of, or prolonging of wetland conditions. Salinity of perched groundwater is variable, depending on stratigraphic situations and proximity to the surface: water residing in aeolian sand, but perched on saprolite several metres below the surface may be fresh, while that perched on saprolite but near the surface may be brackish to saline. Similar to the pattern outlined for the main groundwater body, there also is a general and weak gradient of salinity increase for perched water from south to north, regionally, in response to the climate gradient.

Surface drainage water is that meteoric water or emerging spring water which is run-off and channelled in the creeks and rivers of the area. The salinity of the water is variable, depending on the source of the water, and the type of terrain where the run-off was sourced. The general pattern is that creeks and rivers draining saline lands or brackish to saline wetlands themselves become brackish.

4.2.5 Vegetation

The vegetation in the region belongs to the Darling Botanical District, Menzies Subdistrict, of Beard (1981). This is a region of jarrah-marri forest on the uplands, termed the Bridgetown System, composed of jarrah-marri, and wandoo becoming common in the east of the System. Valleys and channel wetlands are lined with paperbark, swamp gum, tee-trees, and reeds. The lowlands that contain wetlands of the lakes Muir-Unicup area are part of the Kwornicup System, which is a mosaic with jarrah-marri forest in the uplands as the dominant member, enclosing numerous patches of jarrah low forest, paperbark low-forest and reed swamps (Beard 1981). Owing to the swampy nature of the terrain, the jarrah-marri forests are often mixed with yate, swamp yate and wandoo. *Eucalyptus occidentalis* and the salt water paperbark are common on clay floored swamps, and reeds, the common paperbark and the saltwater paperbark are common on sand-floored swamps. River courses are lined with paperbark, swamp gum, and locally, tea-trees.

4.3 Types of wetlands

The wetlands in the area include basins, flats, slopes and channels. The basins range from macroscale to microscale and are predominantly rounded or elliptical, though some are irregular. The flats are mesoscale to macroscale and occur either separately or in association with wetland basins. The slopes are microscale and are either associated with flats or channels. Channels are microscale and are straight or meandering.

4.4 Consanguineous Wetland Suites

For administrative purposes, this study region has been subdivided into two areas:

- Muir/Unicup system
- Deep River system.

This subdivision also parallels the natural distribution of wetland suites. Thus the Muir/Unicup system is the restricted area containing basin and flat wetlands and some channels. The Deep River system is the more extensive area containing the elements of the Deep River drainage. Each of these systems contain a number of different consanguineous wetland suites. All suites have been numbered and named after a local landmark and their location is shown on Figure 12. A representative area of each suite is presented in Figure 13 to illustrate the types, scale, and geometry of wetlands in each suite.

The Muir/Unicup area contains three consanguineous wetland suites, while the Deep River system contains four suites. The consanguineous suites in the Muir/Unicup system at this stage of the study, appear not to be duplicated elsewhere in southwestern Australia, although there could be some overlap with the Pallinup suite further south. However, consanguineous suites in the Deep River system in this area are replicated in other fluvial systems in the plateau, and more examples will become evident as the study proceeds.

The suites in the Muir/Unicup system are:

- MU1 — Muir Suite
- MU2 — Byenup Suite
- MU3 — Unicup Suite

The suites in the Deep River system are:

- MU4 — Weld River suite
- MU5 — Deep River suite
- MU6 — Walpole River suite
- MU7 — Pallinup suite
- MU8 — Jack and Jill suite

Each of these suites will be described below in terms of wetlands types in the suite, the origin of the wetland types if known, hydrologic framework and water characteristics, stratigraphy and soils, and vegetation.

4.4.1 Suites in the Muir-Unicup system

MU1 — Muir Suite

The first suite is the Muir Suite and contains Lake Muir itself, and several small scale associated creeks to the south and west which flow into Lake Muir. One of the important factors in recognising the Muir suite as a distinct unit is its origin, and hence a description is provided below as a preamble to describing the suite in more detail. The origin of the suite will explain the occurrence of the main basin, which is the core of the system, as well as the associated smaller scale elements such as consequent creeks and the peripheral beachridges.

Lake Muir is a basin formed by geomorphic processes belonging to a former arid period, initiated probably in the late Tertiary and continuing into the late Quaternary. At the time of its initial formation, undulations in the plateau terrain in the area intersected the regional saline water table, forming a wetland depression. Salt weathering of the margins, combined with aeolian deflation, enlarged the area of the wetland to form a large flat-floored basin. Thus, the basin is an isolated excavation structure cut into the area of the old plateau. Today, this basin continues to be a window to the regional water table.

After its formation, the contact zone of the large basin with the older plateau surface, (a zone comprised of a relatively steeper sloping surface compared to the surrounding plateau and the flat-floored basin), underwent rill and then creek erosion, i.e., channelled erosion. This resulted in the formation of consequent drainage lines oriented normal to the slope. Thus the margins of the large basin today are bordered and modified by several leptoscale to microscale consequent creeks. The best examples of these creeks are to be found north of Myalgelup Road.

Later in its history, the Lake Muir system developed a beachridge complex on its eastern margin. This resulted in the development of ridge-swale wetland basins.

Lake Muir is classified as a sumpland because that is currently its prevailing condition, however, it is known to remain inundated in years of higher rainfall or in years when unusual extended seasonal precipitation occurs. The surface water is poikilohaline and ranges from subhaline to hyposaline as a result of evaporation (2 – 4 ppt). The surface water registered a pH = 7.6 in September but ranges from pH 6.2 – 9.7 (Jaensch and Lane 1993). Sampling of the groundwater shows that a freshwater lens overlies the saline groundwater, with the latter exhibiting a higher concentration of salts (10 – 96 ppt).

The periphery of Lake Muir is composed of a variety of shore types which include: parallel sand ridges, cuspate forelands, low cliffs of laterite, and headlands and cliffs of gneissic rock. The beach ridge system is located on the southeast margin of Lake Muir. It is composed of a shore-parallel system of low ridges and swales. The beach ridge system exhibits a complicated hydrology, for two reasons: there are at least two environmental gradients, and each is associated with different natural geomorphic/hydrologic processes. There is a gradient from saline to fresh groundwater which is in direct relationship with distance from Lake Muir; and there is a difference in vadose zone evaporation which is in direct relationship to depth to groundwater. This latter factor is complicated by the dune/swale nature of the landform. The wetlands in the swales of the beach ridges therefore exhibit a range of salinities depending on the aquifer which was intercepted at the time of sampling and on the dominant hydrologic process operating at the sampling site. Generally, also, the groundwater varies in salinity depending on stratigraphic setting within the beachridge complex: The sand aquifers under the beachridges themselves tend to contain freshwater, while and the carbonate muddy sands that immediately underlie the swales tend to contain hyposaline water. The pH of the groundwaters tend to become more acidic further away from Lake Muir. During the September 1995 sampling, groundwater adjacent to the sumpland registered pH = 8.0, while groundwaters in the older swales registered pH = 5.5.

On the eastern and northern side, the Lake Muir sumpland is underlain by cream medium sand overlying mottled grey/green sandy mud overlying mottled orange/yellow/ grey mud overlying buff sand overlying green muddy sand to depth of 1 m. Some Calcium carbonate ($CaCO_3$) grains and shell occur in the surface layers. On the western side, the sumpland margin is composed of a grey clay underlain by a layer of white muddy coarse sand (quartz) to a depth of 1.5 m. The sediments underlying the wetlands of the dune/swale sequence are alternately quartz sand and gravelly quartz sand with grains of CaCO3. These layers overlie grey muddy sand in swales nearest Lake Muir, green muddy sand or calcareous mud in swales furthest from Lake Muir, depending on the height of the swale.

The vegetation of Lake Muir is peripheral (bacataform) with low forest of *Melaleuca cuticularis* with an understorey of *Gahnia trifida*, scrub of *M. viminua*, sedgeland of *Juncus kraussii*, and herbland of *Halosarcia*. The vegetation of wetlands in the dune/swale sequence ranges from herbland (*Halosarcia lepidosperma, Wilsonia backhousei*) nearest Lake Muir to sedgeland (*Gahnia trifida, Lepidosperma effusum*) to shrubland (*M. cuticularis* u/s *Baumea juncea*), to forest (*M. rhaphiophylla* u/s *Lepidosperma gracile*) and (*M.preissiana/Eucalyptus rudis*).

The consequent creeks discharging into the Lake Muir sumpland are seasonal and freshwater. The creeks are underlain by humic sand overlying mottled orange/grey muddy sand which in turn overlies mottled sandy mud with ferricrete nodules. The creeks support a variety of vegetation in bacata form; they comprise scrub of *Agonis* spp, *Acacia* spp, *Melaleuca* spp, *Hakea* spp and sedgelands of *Lepidosperma* spp and *Baumea* spp.

MU2 — Byenup Suite

The second suite is the Byenup suite and contains lakes (such as Byenup Lagoon, Tordit-Gurrup Lagoon), sumplands (such as Pindicup Lake, Neeranup Swamp, and Red Lake), damplands, flats, and several small scale creeks in the vicinity of Muir Highway and Unicup Road. The wetlands occur in a dune terrain overlying a Tertiary flat.

Wetland basins in this suite are rounded, sub-rounded and ovoid and range in size from microscale to macroscale. Many of the basins are surrounded by beach ridges indicating a period of aridity in the history of the wetlands (beach ridges form around wetlands in times of aridity). The surface water of wetland basins within this suite ranges from fresh to hyposaline (up to 10 ppt). The surface waters of wetland basins registered pH = 6.0 in September 1995, although the range is pH = 6.0 – 9.3 (Jaensch 1992a), with the most acidic readings coming from wetlands with peat substrates such as Poorginup Swamp. Groundwater salinities of wetland basins in this suite lie in the range of hyposaline to hypersaline (42.2 ppt, Jaensch and Lane 1993). The sedimentary fill within the wetland basins to a depth of 2 m can be characterised as one of three types:

- those underlain by peat or peaty sand over sand;
- those underlain by peat over black mud (clay) over sand, and
- those underlain by peat or peaty sand over cream/ orange mottled muddy sand (saprolite) with nodules of laterite.

The wetland flats in this suite are mainly floodplains. They are underlain by either white sand over laterite or saprolite over laterite. The laterite is located very near the surface, depth ranging from 20 – 130 cm, but most commonly in the top 30 cm. At the time of sampling in in September 1995, the surface of the flats was covered in fresh water. By January 1996, the surface water had either flowed off or had evaporated, and the main groundwater table lay at depths greater than 1.5 m below the layer of laterite.

The vegetation of the wetland basins varies from complete to patchy to peripheral cover but consists mostly of forest and sedgeland. The most typical arrangement of vegetation is concentriform with a centre of sedgeland of *Baumea articulata/B. juncea* and a margin of forest of *Melaleuca rhaphiophylla* or a mix of *M.preissiana/ Banksia littoralis*. In addition, there are assemblages of open shrubland *M. cuticularis*; sedgelands of *Baumea juncea, B. vaginalis, B.articulata, Schoenus brevifolius, Leptocarpus scariosus; Gahnia drummondii or G. trifida*; and heaths containing *M. lateritia, M. diosmifolia, Astartea aff. fascicularis, Pericalymma ellipticum, M. viminua*.

There are two types of vegetation on the floodplain. Both are maculiform. The first comprises an open woodland or shrubland of *M. cuticularis*, scrub of *M. viminua*, scrub of *M. leptospermoides, M. leptoclada* open shrub *M. rhaphiophylla* and sedgeland *Leptocarpus scariosus*. *Melaleuca viminua* is the dominant species. The second type comprises woodlands of *M. preissiana* with an understorey of heath of *M. diosmifolia, M. lateritia, H. varia, Calothamnus lateralis, Baeckea sp, L. scariosus, B. vaginalis*. Palusplains are vegetated by a woodland of *M. preissiana/B. littoralis* with an understorey of heath of *Pericalymma ellipticum* and some *Actinostrobus pyramidalis*.

MU3 — Unicup Suite

The third suite is the Unicup suite and contains lakes such as Unicup Lake, sumplands such as Tolkerlup Swamp, Little Unicup Lake, Moorinup Lake, floodplains, palusplains and creeks. The Unicup suite is located within the Tertiary plateau. The range of wetlands is associated with a former drainage pattern which has been modified by changing climatic/geomorphic/hydrologic patterns from the Tertiary to the present. Wetlands exhibit gradation from creeks, to broad valley flats and slopes, to basins. This probably represents an evolutionary sequence where creeks continue to geomorphically degrade to become broad valley flats and slopes which in turn eventually clog to form irregular shaped basins such as Noobijup Lake. During intermittent cycles of inundation and in conditions of variable winds, sedimentary processes result in the basins becoming excavated, ringed by beach ridges, and finally circular. Thus the wetlands display a history of evolutionary formative processes from the Tertiary to the present.

The surface waters of the wetland basins in this suite range from fresh to hyposaline (< 1000 ppm – 10 000 ppm). The surface waters registered a range of pH readings (pH = 5.8 – 9.7) in September 1995. The wetland basins are underlain by peat over grey sand over laterite, or peat over black mud over laterite, or shelly mud over clay over muddy sand. The wetland fill overlies a shallow sand layer on saprolite.

Creeks and flats that are in natural vegetated situations had fresh surface water in winter. In January 1996, the wetlands were dry, and the water table was below the layer of laterite. Creeks and flats are underlain by quartz sand on laterite which in turn overlies the regional saprolite lithosome.

The vegetation of the lakes and sumplands in this suite varies from patchy to peripheral cover while damplands are usually completely vegetated. Several examples are described below to illustrate vegetation pattern.

Moorinup Lake is heteroform and consists of forest (*Melaleuca preissiana/B. littoralis*), forest (*M. cuticularis* u/s heath-*Pericalymma ellipticum*, sedgeland — *L. gracile*), scrub (*M. viminua*), sedgeland (*B. articulata*), and sedgeland (*B. juncea*).

Little Unicup Lake is bacataform. It is composed of forest (*M. preissiana/Banksia littoralis*), forest (*M. cuticularis*), scrub (*M. cuticularis u/s Gahnia trifida*), heath (*M. diosmifolia*), and herbland (*Halosarcia and Wilsonia*).

Lake Unicup is also bacataform and is composed of forest (*M. preissiana/Banksia littoralis*), sedgelands (*Baumea juncea, B. articulata*), and heaths (*M. rhaphiophylla, M. diosmifolia, M. lateritia and M. cuticularis*).

Vegetation on the flats is maculiform and consists of similar assemblages to those described above with the addition of heath (*Viminaria juncea, Acacia saligna*), heath (*Hypocalymma angustifolium*), and herbland (*Cotula coronopifolia*). The majority of the creeks are cleared, but where they are vegetated, the assemblage is most often shrubland of *M. rhaphiophylla*.

4.4.2 Suites in the Deep River System

MU4 — Weld River Suite

This suite of wetlands includes Deep River, Weld River, and Shannon River. They are leptoscale entrenched channels through a layered sedimentary fill sequence of quartz sand on muddy sand on ferruginised muddy (kaolin) sand on mudstone on granite. The water is subhaline and supports a patchy fringing vegetation of shrubland or forest of *Agonis juniperina*.

MU5 — Deep River Suite

The Deep River suite contains microscale straight and meandering rivers, creeks, microscale to mesoscale basins which are the headwaters of tributaries, and mesoscale floodplains and palusplains associated with Deep River itself. The surface water and groundwater of the channels sampled in September 1995 was fresh. The groundwater also was fresh and acidic (pH = 5.1 – 6.8). The creeks are underlain by medium, fine, coarse quartz sand or peaty sand, overlying mottled orange, grey, cream muddy sand. Creek vegetation is maculiform and bacataform, consisting of shrubland (peaflowers and acacias, kangaroo paw and *A. flexuosa, A. juniperina*), heath *(Homalospermum firmum, Beaufortia squarrosa, Adenanthos obovatus*) and sedgeland *(Lepidosperma tetraquetum)*.

The mesoscale floodplains and palusplains associated with the Deep River were surveyed in September 1995. Although the surface water and groundwater were fresh when sampled, the surface water registered a pH of 7.6 while the corresponding pH of the groundwater was 5.8. The floodplains are underlain by humic, medium, muddy sand overlying layers of coarse to very coarse quartz sand which in turn were overlying mottled orange/cream sandy mud. Vegetation is maculiform and consists of open woodland (*Melaleuca preissiana*), open woodland (*M. cuticularis*), scrub (*M. viminua*), shrubland (*Agonis linearifolia, M. viminua*), shrubland (*M. rhaphiophylla, M. spathulata)*, heath (*A. aff. fascicularis*), heath (*Melaleuca sp*), heath (mixed; < 30 cm), heath (*M. diosmifolia)* and sedgelands *(L. gracile)*, *(G. trifida)*, and *(B. articulata)*. The palusplains are underlain by slightly humic muddy sand or sand, overlying mottled orange/ cream muddy sand with ferricrete, and are vegetated by a very open woodland with an understorey of mixed heath < 30 cm.

MU6 — Walpole River Suite

The second suite in the Deep River System is the Walpole River Suite. This is a suite of paluslope wetlands sometimes associated with creeks and sometimes asociated with palusplain. Both the surface water and groundwater are fresh. The paluslopes are underlain by peaty sand over grey quartz sand, and support a maculiphytic vegetation typical of this suite near its type locality of Walpole (i.e., woodland (*M. preissiana*), heath (*A. juniperina, A. linearifolia, Beaufortia squarrosa, Homalospermum firmum, Adenanthos obovatus*) heath (*M. diosmifolia*), heath (*M. lateritia*), heath (*A. aff. fascicularis*) and sedgeland.

MU7 — Pallinup Suite

The third suite is the Pallinup Suite which contains palusplain with microscale sumplands. The groundwater is fresh. The stratigraphy under the wetland is composed of sands, silts and muddy sands overlying a shallow iron-indurated layer, and supports a maculiform sedgeland and shrubland of the following taxa; *Anarthria, Leptocarpus, Evandra, Restio, Kunzea, Acacia, Hakea, Calothamnus, Pericalymma, Agonis, Homalospermum*, and *Astartea*.

MU8 — Jack and Jill Suite

The fourth suite is the Jack and Jill Suite. This suite contains mesoscale to leptoscale irregular paluslopes, sumplands and damplands. The wetlands are underlain by quartz sands with a pedogenic overprint of mottling which results in a sequence of beige, red, and yellow gravelly, sandy muds overlying granite.

4.5 Preliminary identification of outstanding wetlands

Outstanding wetlands for the Muir-Unicup to Deep River suites have been described in the context of the seven criteria listed in Section 1.7. Information used in assessment of the wetland suites in the study area was dependent on published information and limited field visits. Traverses and field sites are located in Appendix C to illustrate the extent of the data base. Of the information required to fully assess and evaluate a wetland — geomorphic features, representative vegetation assemblages, rare and endangered flora and fauna, surveys of amphibia, fish, crustacea, invertebrates, reptiles, and avifauna — only the first and last categories have been used in this study. In many suites the full value of the wetlands has not yet been determined, and the results of this study should be viewed as preliminary results. These remarks apply also to avifauna information. The wetlands surveyed for avifauna use are listed below. Sometimes many surveys were undertaken and sometimes only one survey was undertaken for a particular wetland The focus of the surveys was waterbird usage, and breeding was recorded incidentally.

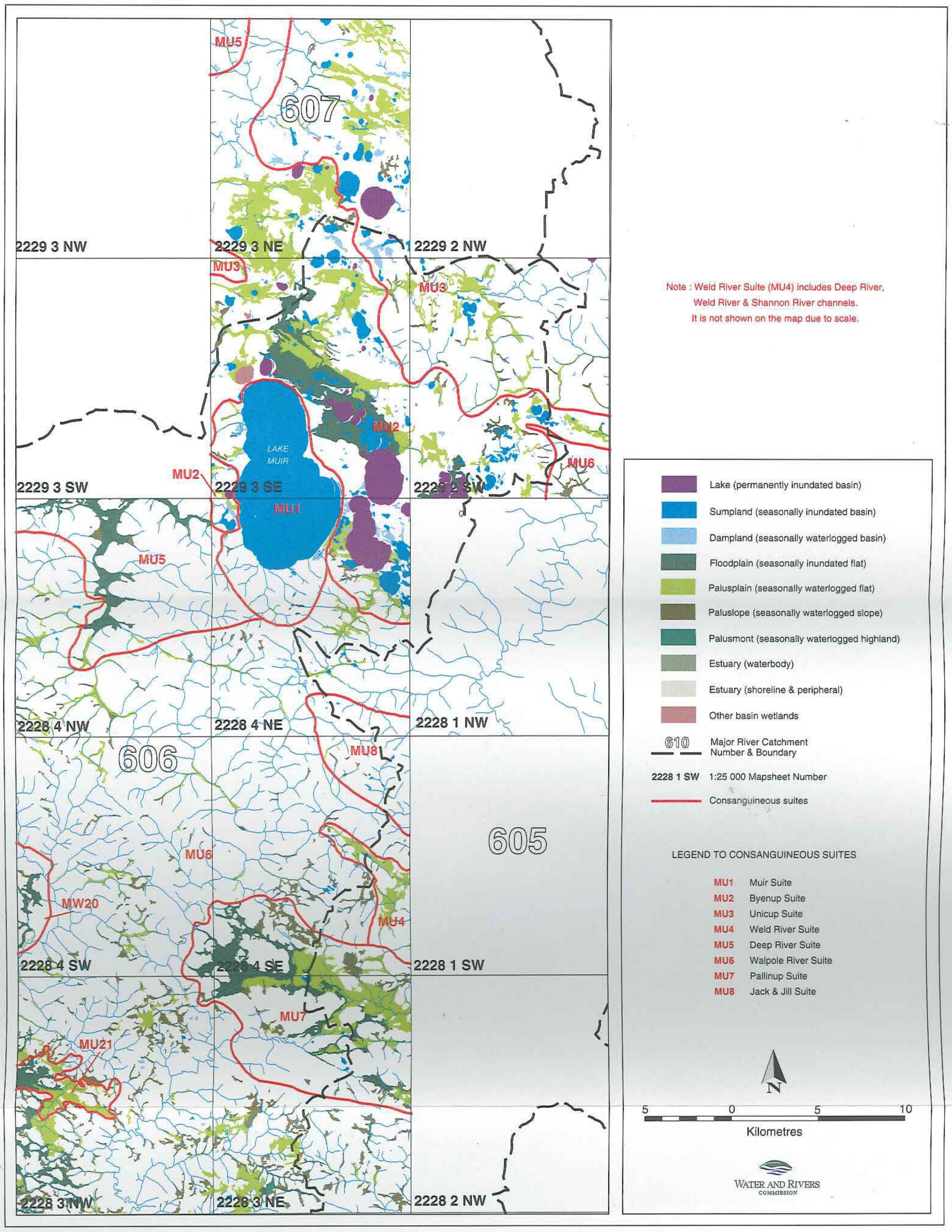
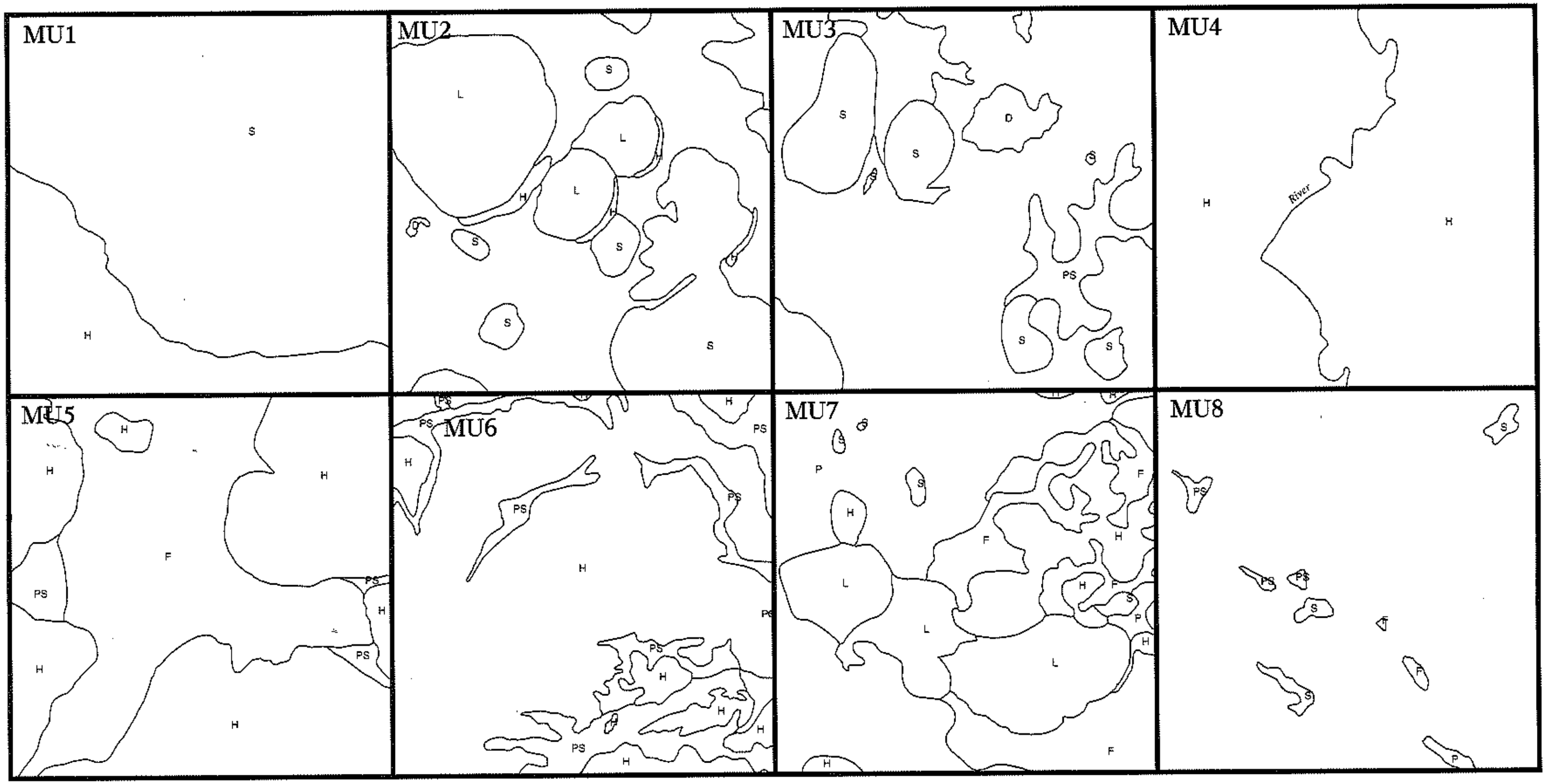


Figure 12: Preliminary Description of Consanguineous Wetland Suites in Domains throughout the Muir-Unicup Area

Figure 13: Representative example of consanguineous wetland suites in the Muir-Unicup Area



LEGEND TO CONSANGUINEOUS SUITES

- MU1 MUIR SUITE
- MU2 BYENUP SUITE
- MU3 UNICUP SUITE
- MU4 WELD RIVER SUITE
- MU5 DEEP RIVER SUITE
- MU6 WALPOLE RIVER SUITE
- MU7 PALLINUP SUITE
- MU8 JACK AND JILL SUITE

1000 0 1000 2000

Metres

WATER AND RIVERS COMMISSION

LEGEND TO WETLAND TYPES

L	LAKE	R	RIVER
S	SUMPLAND	CR	CREEK
D	DAMPLAND	EW	ESTUARY WATERBODY
AL	ARTIFICIAL BASIN	E	ESTUARY
F	FLOODPLAIN	H	HIGHLAND
P	PALUSPLAIN		
PM	PALUSMONT		
PS	PALUSLOPE		

MU1 — Muir Suite

The most important wetland in this suite is Lake Muir itself. As will be discussed later, the beach ridge complexes are also important.

Lake Muir is a megascale wetland approximately 4 600 hectares in size and contains brackish surface water for nine months of the year. It is scientifically important in that it is the only wetland of its type with features indicating its derivation/formation within earlier phases of aridity:

1. its margins show salt weathering evident in the cliffs, indicating the way in which it was excavated and the manner in which it expanded laterally; and
2. its substrate comprises layers of finely laminated sedimentary fill which indicate the history of sedimentation and chemical precipitation, which, when linked to climatic conditions, unveil a history of wetland evolution with respect to climate change and concomitant hydrological developments.

This history is also integral to the geomorphic/hydrologic function of the wetland in the present in that it determines the present hydrology, i.e., a naturally saline system within a humid/subhumid climatic setting. Lake Muir therefore represents a unique wetland suite.

Lake Muir is ecologically important in that it is a major moulting area for Australian Shelduck, and periodically is a major drought refuge for waterfowl. Twenty three species of waterfowl have been recorded in the wetlands, five of which have been nominated in international treaties. Two species have been recorded breeding (Jaensch and Lane 1993). Five species of migrant shorebird occur. The highest numbers of birds recorded have been for the following species; Pacific Black Duck, Black Swan, Grey Teal, Eurasian Coot, and Australian Shelduck. Regionally the wetland ranks as the most important wetland site for Pacific Black Duck and Black Swan when compared to 602 other wetland sites (Raines *et al.* In Prep.).

In addition to the main sumpland itself, the suite contains a series of wetlands in the swales of the marginal beach ridges. These wetlands demonstrate changes to hydrological conditions over time and over spatial gradients, and have formed a series of habitats which illustrate the principles of wetland soil development and vegetation succession in such marginal beach ridge settings. The range of habitats also become significant in terms of diversity and in terms of avifaunal use.

Known rare and endangered plants in the suite include *Caladenia christinae, C.harringtoniae and Diuris drummondii*. Geographically restricted species include *Leptocarpus ceramophalis*.

MU2 — Byenup Suite

This suite contains a large area of wetlands. Byenup Lagoon itself covers 570 hectares, Tordit-Garrup Lagoon 690 hectares; and there are approximately 1500 hectares of flats. The wetlands are extensive peat swamps with predominantly fresh surface water. The wetlands are part of a linked freshwater system which is largely undisturbed. Local salinised areas do exist but these are probably the result of adjacent land clearing.

The peat-floored wetlands are scientifically important in that they stratigraphically, isochronologically, and probably palynologically record a transition from more arid conditions earlier in the Holocene to relatively more humid (peat-forming) conditions of today.

The following wetlands in the suite have been surveyed for avifauna (Jaensch *et al.* 1988):

Byenup Lagoon
Cobertup Swamp
Kodjinup Swamp
Neeranup East Swamp
Pinticup Swamp
Poorginup Swamp
Red Lake
Tordit-Gurrup Lagoon

Wetlands with more than 29 species of avifauna are classified as outstanding with respect to avifaunal use. Forty six waterbird species are recorded in the Byenup system (41 at Byenup Lagoon itself), including 5 species listed under international treaties, and 4 migrant shore-birds. Highest numbers of waterbirds were recorded in Tordit-Garrup Lagoon. The lakes in the suite are the centre of population of the Australasian Bittern, and major breeding sites for Little Bittern, Australiasian Bittern and Spotless Crake, especially Byenup Lagoon. The wetlands are a major moulting area for Australian Shelduck particularly when Lake Muir is too shallow. The wetlands in the suite are regionally important sites for the following species: Australian Shelduck, Pacific Black Duck, Hardhead, and Darter (Jaensch *et al.* 1988).

Wetlands are of local importance in that they regularly support small numbers of several waterbird species, e.g. Spotless Crake, Clamorous Reed-Warbler, Pacific Black Duck, Purple Swamphen, White necked heron, Great Egret and Swamp Harrier.

Diverse populations of invertebrate taxa have been found in the suite, e.g., Tordit-Garrup (52 species), Byenup (43 species), Poorginup (39 species), including Coleoptera, Diptera and water mites. These wetlands are the only known habitat of some species of water mite (Hydracarina). Of the 11 species of *Hydracarina* found in the area, 6 species also have restricted distributions. Crustacea *Cherax preissii* and *C. quinquecarinatus*, and the Oblong tortoise *Chelodina oblonga* also occur in these wetlands.

Two declared rare orchids occur: *Diuris drummondii* and *Caladenia harringtoniae*. Large natural sedgeland regions occur, including the substantial sedgeland of *Eliocharis sphacelata* at Kulunilup Lake which is restricted in distribution in the region.

MU3 — Unicup Suite

The wetlands in this suite are variable in that they range from fresh surface water to hyposaline, and from closed discrete systems such as Little Unicup Lake to linked systems such as Kulunilup Lake and flats. But while the suite contains a range of wetland types, they are responding to similar underlying hydrological mechanisms.. The corollary is that these wetland types not only illustrate diversity but also stand as scientifically important examples of wetland history from creek to flat to irregular wetland to rounded wetland in response to evolutionary geomorphic processes. Thus this suite is scientifically important in that it provides evidence for wetland developmental processes and hydrological history in the Muir-Unicup area.

The suite is also important for avifauna use. The following wetlands have been surveyed (Jaensch *et al.* 1988):

Bokarup Swamp
Kulunilup Swamp
Noobijup Lake
Unicup Lake
Unicup South Lake
Little Unicup Lake
Yarnup Swamp

These wetlands are significant sites for Australasian Bittern and Little Bittern especially Kulunilup Swamp, Yarnup Lagoon and Bokarup Swamp. The first two wetlands are also important breeding areas for these two species. In total, 28 waterbird species have been recorded at Unicup lake, 15 at Yarnup Swamp, 12 at Kulunicup, and 11 at Bokarup Swamp. Some of these species are related to freshwater habitats such as Dusky Moorhen and Clamorous Reed Warbler and some species are related to brackish (hyposaline) habitats such as Red-capped Plover and Banded Stilt. This is reasonable diversity of waterbird species. In addition, high numbers of waterbirds, specifically Australian Shelduck and Grey Teal, have been recorded at Little Unicup Lake (Jaensch *et al.* 1988).

A number of wetlands in this suite are important locally in that they regularly support small populations of specific waterbird species such as Pacific Black duck, Australian Wood Duck, Musk Duck, Spotless Crake, White-faced Heron, Dusky Moorhen, Little Grassbird, and Purple Swamphen, and are feeding areas for species other than waterbirds, such as Squaretailed kite, and White-tailed black cockatoo (Wilson 1995).

MU4 — Weld River Suite

This suite also occurs in the Meerup to Walpole study area. The outanding wetlands in this suite are preliminary identified in Section 3.4, MW11 — Walpole River Suite.

MU5 — Deep River Suite

The Deep River suite is important because it includes the range of wetland types associated with fluvial systems: river, creek, paluslope, floodplain, and paluspIain. The suite is an example of a fluvial wetland system in a humid environment. The wetlands are relatively undisturbed, but to date, there is very little survey data on vegetation or fauna. Given the variety of habitats the ecological functions of the wetlands are likely to be significant.

MU6 — Walpole River Suite

The Walpole River suite occurs throughout the plateau regions along the South Coast. Most of the wetlands are undisturbed. The paluslopes of this suite are often part of a linked system with either creeks or palusplains or floodplains. Sometimes they link headwater depressions with the valley floor wetlands within the plateau, sometimes they border large areas of palusplain or floodplain. However, there are also examples of paluslopes which occur within the granitic or lateritic uplands which are discrete wetlands. As part of a linked system, they are important hydrologically as a direct recharge or discharge mechanism for other wetland types; independently they have been found to be ecologically important to fauna such as amphibia, crustacea, copepoda, and isopoda (Wardell-Johnson and Roberts 1991, Horwitz 1994). However, surveys have been concentrated in the Northcliffe area and the paluslopes in this region remain scientifically unexplored.

MU7 — Pallinup Suite

This suite contains wetlands which have retained palaeo features of the Tertiary and as such there may be repositories of fossils/pollen which may be important in unravelling the series of events in geological history which determined the present geological structures and hydrological processes. This is of interest to wetland scientists, hydrologists, geomorphologists and geologists.

Preliminary findings in the field of invertebrate studies indicate unusual and diverse populations present in these wetlands.

MU8 — Jack and Jill Suite

This suite is largely unexplored, however it represents a wetland type which is unusual in the plateau regions: smallscale sumplands and damplands underlain by granitic basement. These areas are undisturbed. It is likely that they are important water sources for mammals and other vertebrates.

References

Allen, G.R. and Berra, T.M. 1989, Life history aspects of the West Australian Salamanderfish, *Lepidogalaxias salamandroides Mees., Rec West Aust Mus*, 14 (3): 253-267.

Balla, S.A. and Davis, J.A. 1993, *Wetlands of the Swan Coastal Plain, Volume 5: Managing Perth's wetlands to conserve the aquatic fauna*, Water Authority of Western Australia. S. Balla (ed.)

Bayly, I.A.E. 1992, The micro-Crustacea and physico-chemical features of temporary ponds near Northcliffe, Western Australia, *Journal of the Royal Society of Western Australia*, 75: 99 – 106.

Beard, J.S. 1981, *Vegetation Survey of Western Australia*, 1: 1 000 000 series Sheet 7: Swan, Univeristy of Western Australia Press.

Christensen, P. 1982, The distribution of Lepidogalaxias salamandroides and other small freshwater fishes in the lower south-west of Western Australia, *Journal of the Royal Society of Western Australia*, 65(4): 99 – 106.

Claridge, G. 1991, *An overview of wetland "values": A necessary preliminary to wise use*, Paper presented to the wetlands conservation and management workshop, Newcastle, Australia, 11 – 15 February 1991.

Cowardin, L.M., Carter, V., Golet, F.C. and LaRoe, E.T. 1979, *Classification of wetlands and deepwater habitats of the United States*, U.S. Dept. of the Interior, Fish and Wildlife Service Dec.

Davis, S.N. and De Wiest, R.J. 1966, *Hydrogeology*, John Wiley and Sons Inc.

Dell, J. and How, R. 1988, Mammals of the Darling Scarp, *Western Australian Naturalist*, 17: 86 – 93.

Del Marco, A. and Hill, A. 1995, *Wetlands of the Southern Swan Coastal Plain: Coastal wetlands from Pinjarra to Dunsborough* (broadsheet), Water Authority of Western Australia, Perth.

Drever, J.I. 1982, *The geochemistry of natural water*, Prentice-Hall, Inc.

Dugan, P.J. (ed.) 1990, *Wetland conservation: A review of current issues and required action*, International Union for Conservation of Nature and Natural Resources, Switzerland.

Edward, D.H.D., Gazey, P., and Davies, P.M. 1994, Invertebrate community structure related to physico-chemical parameters of permanent lakes of south coast of Western Australia, *Journal of the Royal Society of Western Australia*, 77: 51 – 63.

Environmental Protection Authority (EPA). 1990, *A guide to wetland management in Perth*, Western Australia. EPA Bulletin 374.

Environmental Protection Authority (EPA). 1993, *A guide to wetland management in the Perth and near Perth Swan Coastal Plain area*, Perth, Western Australia, EPA Bulletin 686.

Fairbridge, R.W. and Finkl, C.W. 1979, Palaeogeographic evolution of a rifted cratonic margin: SW Australia, *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol. 26, pp 221 – 252.

Gentilli, J. 1972. *Australian climatic patterns*, Nelson.

Hammer, U.T. 1986, *Saline lake ecosystems of the world*, Dr. W. Junk Publishers.

Hill, A.L., Semeniuk, C.A., Semeniuk, V. and Del Marco, A. 1996 *Wetlands of the Swan Coastal Plain Volume 2: Wetland Mapping Classification and Evaluation*, Water and Rivers Commission and the Department of Environmental Protection, Perth.

Hodgkin, E.P. and Clark, R. 1989, *Broke Inlet and Other Estuaries of the Shire of Manjimup: An inventory of information on the estuaries and coastal lagoons of south Western Australia*, Estuarine Studies Series No. 6, EPA, Perth.

Horwitz, P. 1994, *Patterns of endemism in the freshwater fauna of the far southern peatlands and shrublands of Southwestern Australia*, Report to Australian Heritage Commission and the Heritage Council of Western Australia.

How, R. and Dell, J. 1993, 'Vertebrate fauna of the Perth Metropolitan Region: Consequences of a modified environment' in *Urban Bush Management*, Proceedings of a seminar by Australian Institute of Urban Studies, June, 1992, Perth.

Hutchinson, G.E. 1957, *A treatise on limnology. Volume 1*, Wiley and sons.

Jaensch, R.P. 1992a, *Fishes in wetlands on the south coast of Western Australia*, CALM, Woodvale.

Jaensch, R.P. 1992b, *Waterbirds in wetlands on the south coast of Western Australia Summer 1991 – 2*, CALM, Woodvale.

Jaensch, R.P. 1993, *A survey of frogs in wetlands on the south coast of Western Australia*, CALM, Woodvale.

Jaensch, R.P. and Lane, J. 1993, 'A directory of important wetlands in Australia-Western Australia' in *A directory of important wetlands in Australia*, eds S. Usback and R. James, ANCA.

Jaensch, R.P., Vervest, R.M. and Hewish, M.J. 1988, *Waterbirds in nature reserves of south-western Australia 1981 – 1985: Reserve accounts*, Royal Australian Ornothologists Union (RAOU), Report 30.

Keighery, G.J. 1991, *Flora of lots 65/66 and reserve 32926, Anstey Road, Forrestdale*, Perth.

Keighery, G.J. and Keighery, B.J. 1991, *Floristics of reserves and bushland areas of the Perth region*, Wildflower Society of Western Australia, Perth.

Koppen, W. 1936, 'Das Geographifche System de Klimate' in *Handbuch der Kleimaologie, eds.* W. Koppen and R. Geiger, Berlin.

Lewis Environmental Consultants. 1990, *Heavy Minerals Mine — Beenup. E.R.M.P*, Prepared for BHP-UTAH Minerals International.

Paijmans, K., Galloway, R., Faith, D., Fleming, P., Haantjens, H., Heyligers, P., Kalma, J. and Loffler, E. 1985, *Aspects of Australian wetlands*, CSIRO, Australian Division Water and Land Resources Technical Paper No. 44 pp. 1 – 71.

Payne, J. 1993a, *Wetlands in the City of Gosnells*, Water Authority of Western Australia and Environmental Protection Authority, Perth.

Payne, J. 1993b, *Wetlands in the City of Armadale*, Water Authority of Western Australia and Environmental Protection Authority, Perth.

Pusey, B.J. 1990, Seasonality, aestivation and the life history of the salamanderfish Lepidogalaxias salamandroides (Pisces: Lepidogalaxiidae), *Environmental Biology of Fishes*, 29: 15 – 26, Kluwer Academic Publ. Netherlands.

Pusey, B.J. and Edward, D.H.D. 1990a, Structure of fish assemblages in waters of the southern acid peat flats, South-western Australia, *Australian Journal of Marine and Freshwater Research*, 41: 721 – 734.

Pusey, B.J. and Edward, D.H.D. 1990b, Limnology of the southern acid peat flats, South-western Australia, *Journal of the Royal Society of Western Australia*, 73(2): 29 – 46.

Raines, J.A., Yung, S.H. and Burbidge, A.H. In Prep. *Wetlands of outstanding ornithological importance for the register of the National Estate in southwest Western Australia.*

Semeniuk, C.A. 1988, Consanguineous wetlands and their distribution in the Darling System, south western Australia, *Journal of the Royal Society of Western Australia*, 70: 69 – 87.

Semeniuk, C.A. 1996, Correspondence with Water and Rivers Commission, 11 April 1996.

Semeniuk, V., Cresswell, I.D. and Wurm, P.A.F. 1989, The Quindalup Dunes: The regional system, physical framework and vegetation habitats, *Journal of the Royal Society of Western Australia*, 71: 23 – 47.

Semeniuk, C.A., Semeniuk, V., Cresswell, D. and Marchant, N.G. 1990, Wetlands of the Darling System, south western Australia: a descriptive classification using vegetation pattern and form, *Journal of the Royal Society of Western Australia*, 72(4): 109 – 121.

Storey, A.W., Vervest, R.M., Pearson, G.B., and Halse, S.A. 1993, *Wetlands of the Swan Coastal Plain Volume 7: An assessment of the different types of wetlands for waterbirds*, Water Authority of Western Australia and Environmental Protection Authority, S. Balla (ed.).

V. & C. Semeniuk Research Group 1997a (In Prep.) *Investigation of a Hierarchical Approach to Wetland Evaluation: The Busselton-Walpole Region and the Lake Muir Lowland Wetland Region*, A report to the Water and Rivers Commission.

V. & C. Semeniuk Research Group 1997b (In Prep.) *Description of the Hydrology of the Lake Muir Lowland Wetland Region and Implications for Management*, A report to the Water and Rivers Commission.

Wardell-Johnson, G. and Roberts, J.D. 1991, 'The survival status of the *Geocrinea rosea* (Anura: Myobatrachidae) complex in riparian corridors: biogeographical implications' in *Nature Conservation 2: The role of corridors,* eds D.A. Saunders and R.J. Hobbs, Beatty and Sons, Chipping Norton, pp. 167 – 175.

Wardell-Johnson, G. and Roberts, J.D. 1993, Biogeographic barriers in a subdued landscape: the distribution of the *Geocrinea rosea* (Anura: Myobatrachidae) complex in south-western Australia, *Journal of Biogeography,* 20: 95 – 108.

Weston, A. 1989, *Vegetation and significance of flora of Lots 65 and 66 Anstey Road, Forrestdale, City of Armadale,* (unpubl.) Report prepared for G.R Crimp & Partners.

Wetlands Advisory Committee. 1977, *The status of reserves in System Six,* Report of the Wetlands Advisory Committee to the Environmental Protection Authority, Perth, Western Australia.

Wetzel, R.G. 1975, *Limnology*, Saunders, Philadelphia.

Wilde, S.A. and Walker, I.W. 1984, *Pemberton-Irwin Inlet Western Australia*, 1: 250 000 Geological Series — Explanatory Notes, Geol. Survey of West. Aust.

Wilson, I. 1995, Interim Management Guidelines Avifauna Management — Manjimup District, CALM.

APPENDICES

Appendix A: Wetland values (after Hill *et al.* 1996)

A nomenclature to describe wetland values (Claridge 1991)

It is helpful to be precise in the description of values of a given wetland so that they may be more readily understood, communicated and protected.

The VALUE of a wetland benefit (function, use or attribute) may be defined as a measure or expression of the worth placed by society on that particular function, use or attribute (Claridge 1991), where:

CHARACTERISTICS are those properties of a wetland which describe the area in the simplest and most objective possible terms. e.g. wetland size, species present, soils and water quality.

Characteristics, singly or in combination, give rise to benefits (existing or future) which may be functions, uses or attributes of a wetland.

A FUNCTION is some aspect of a wetland that, potentially or actually, supports or protects a human activity or human property without being used directly.

A USE is some direct utilization of one or more of the characteristics of a wetland.

An ATTRIBUTE of a wetland is some characteristic or combination of characteristics which is valued by a group within society, but which does not necessarily provide a function or support a use (Claridge 1991).

Dugan (1990) similarly uses the terms 'functions', 'products' and 'attributes' to help describe wetland values for the International Union for the Conservation of Nature.

Some of the characteristics, functions, uses and attributes derived from Perth's wetlands are listed below (Dugan 1990; Claridge 1991).

Characteristics

- size;
- shape;
- species present;
- abundance of species vegetation structure;
- extent of vegetation;
- pattern of vegetation distribution, soils;
- geology;
- geomorphology;
- processes occurring (Physical and biological);
- nature and location of water entry;
- nature and location of water exit;
- climate;
- location in respect of human settlement and activities;
- location in respect of other elements in the environment;
- water flow/turnover rates;
- water depth;
- water quality;
- altitude;
- slope fertility;
- nutrient cycles;
- biomass production/export
- habitat present;
- area of habitat;
- habitat interspersion;
- drainage pattern;
- area of open water;
- recent evident of human usage;
- historic or prehistoric evidence of human usage;
- pH;
- dissolved oxygen;
- suspended solids;
- evaporation/precipitation balance;
- tidal range/regime;
- characteristics of the catchment;
- characteristics of other wetlands in the region.

Functions

- Groundwater recharge;
- Flood control;
- Shoreline stabilization/erosion control;
- Sediment retention;
- Nutrient/pollutant absorption;
- Export of nutrient;
- Storm protection/windbreak;
- Microclimate stabilization;
- Flow regulation/maintenance;
- Nursery/breeding area;
- Habitat for fish;
- Habitat for wildlife;
- Contribution to the maintenance of existing processes or natural systems;
- Wildlife corridor;

Uses

- Extraction of naturally occurring plant products;
- Extraction of naturally occurring animal products;
- Extraction of mineral products;
- Water supply/storage;
- Production of plant products;
- Production of animal products;
- Recreation/tourism;
- Water transport;
- Research site;
- Monitoring site;
- Education site;
- Waste disposal/water treatment.

Attributes

- Richness or diversity of flora or fauna;
- Landscape/aesthetic qualities;
- Valued as a cultural, symbolic or spiritual place by a defined group within the community;
- Presence or rare, endangered or uncommon flora, fauna, communities, ecosystems, natural landscapes, processes or wetland types;
- Site of historically significant research or other historically significant event;
- Wilderness;
- Type locality of a taxon;
- Constitutes a significant gene pool;
- Contains evidence of products of past processes important in the evolution of flora, fauna, landscapes, wetland systems or climate;
- Contains evidence demonstrating, or contributing to the maintenance of, existing processes or natural systems at the local, regional or national level;
- Source of information which has lead to a better understanding of evolutionary processes, existing natural systems or processes or the history of human occupation;
- Presence of a distinctive way of life , custom, process, land use, function or design in danger of being lost;
- Demonstrates the principal characteristics of one or more of the range of types of wetlands, or landscapes;
- Demonstrates the principal characteristics of the range of human activities in the wetland environment.

Use of the above terminology improves the framework for identifying and categorising the values of wetlands such as the economic aspects of wetland use and significantly enhances the schedule of 'wetland functions' which have been listed by the Department of Environmental Protection in Bulletins 374 and 686 (EPA 1990; 1993).

An aspect of wetland value is discussed further below because of its relevance to south-western Australia: the value of seasonal wetlands.

Special features and requirements of seasonal wetlands in south-western Australia

Studies have shown that damplands and palusplains support high genetic diversity (Weston 1989; Keighery 1991), waterbird breeding habitat (Storey *et al* 1993) and the presence of rare species (Payne 1993a,b; Keighery 1991). Seasonally waterlogged wetlands often also envelope channel wetland systems in south-western Australia and so play an important part in maintaining wetland function, such as maintaining and enhancing the condition and water quality of rivers, creeks, artificial channels and estuarine systems. Protection of such wetlands is considered by the USA EPA to be a vital part of pollution protection in the United States (Dugan 1990).

Vegetated seasonal wetlands are often more botanically rich than other wetland types and have a higher animal species richness than permanent wetlands (Balla and Davis 1993). This follows the Australia-wide trend that the most botanically diverse wetlands are those which are only subject to temporary water excess (Paijmans *et al.* 1985). In south-western Australia, the floristic diversity of the seasonally waterlogged wetlands is well supported by studies of Perth's Brixton Street area in Kenwick (Keighery and Keighery 1991) and the Anstey/Keane Road Dampland in Forrestdale (Weston 1989).

The Anstey/Keane Road wetland has been described as the **richest vegetation remnant on the Swan Coastal Plain** following the identification of 293 species on the 150 ha site. This is estimated to represent 80% of the site's plant species diversity which further underlies its value when compared with much larger areas such as Kings Park (400 ha — 275 species) or Bold Park (321 ha — 226 species) (Keighery 1991).

South-western Australia's damplands also provides important habitat for fauna. For example the Quenda is known to show a marked preference for dense wetland vegetation (How and Dell 1993) and is able to sustain a higher population density in the productive dampland and palusplain environments than is possible in other, drier habitats. However, these populations are precariously placed as their habitat is lost and fragmented by clearing and bushland degradation and predation. Regular movements of individuals over 250 – 800 m have been recorded (Dell and How 1988).

Seasonally waterlogged areas are also recognized as prime breeding areas for waterbirds. Much of south-western Australia's waterlogged pastures are used by nomadic avifauna and other waterbirds for breeding and feeding during the winter months. Scopewest, a study of the waterbird usage of wetlands on the Swan Coastal Plain, found that for Grey Teal, 55% of individuals and 86% of breeding activity occurred on damplands and floodplains (Storey *et al.* 1993). For the Pacific Black Duck, 60% of individuals and 55% of breeding activity occurred on these wetland types.

Specific reptiles and invertebrates also extensively inhabit damplands and palusplains. Damplands and palusplains are therefore an important part of the spectrum of wetland types in south-western Australia. With sumplands, damplands probably support more aquatic flora and fauna than lakes (Balla and Davis 1993).

However seasonally waterlogged wetlands are being lost at a faster rate than other wetland types due to their less conspicuous wetland profile and the traditional approach to land development. While Perth has experienced the loss or degradation of approximately 70% of its wetlands, it has probably lost 80 – 90% of its seasonally waterlogged areas. Protection of seasonally waterlogged areas in the South West should be a community and state priority.

Appendix B: Descriptors of wetland landform, water and vegetation

Water, landform and vegetation descriptors are used to augment the 13 basic wetland types. For example, large oval lakes that remain fresh throughout the year can be termed macroscale, ovoid, freshwater, stasohaline lakes.

The full range of descriptors is presented in Figures a, b and c below. Soil type has not been incorporated at this stage as a descriptor into the classification, however, use of terms such as peaty, calcareous, gypseous, diatomaceous, or quartzose (sandy) could readily be added to the system if necessary.

Descriptors of water

Water in a wetland may be further described in terms of its salinity, the consistency of salinity, other chemical features of its water quality, and its source. In the proposed classification, water in wetlands is further described in terms of salinity and consistency of salinity. Other descriptors can be added if necessary, depending on the need and the type of study.

Salinity may be subdivided into categories of: fresh, brackish (or mixosaline), saline and hypersaline. In the literature, definitions vary for categories such as brackish, saline, hypersaline (Davis and Dewiest 1966, Drever 1982, Cowardin *et al.*, 1979; Hammer 1986). The category terms and boundaries adopted in the proposed classification are after Hammer (1986).

Wetlands that are seasonally variable in salinity are categorised by the salinity state in which the wetland

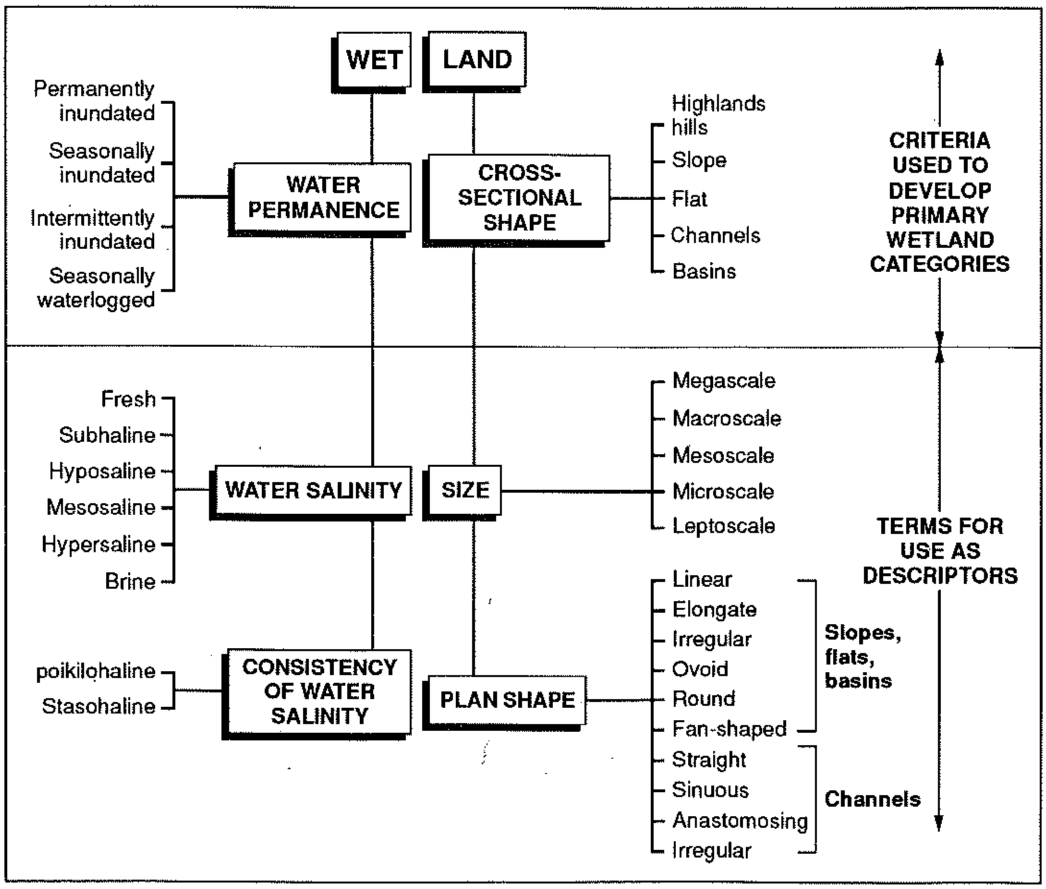


Figure a: Wetland components for use in classification

exists for the major part of each year. For example, a wetland that ranges from freshwater for most of the year, to brackish during the season of reduced water supply, would be classified as freshwater. However, a term is introduced to denote whether salinity is constant or variable. Water salinity that is consistent throughout the year (ie. it remains totally within a given salinity field) is termed stasohaline; water quality that markedly fluctuates throughout the year is termed poikilohaline.

Descriptors of landform

The cross sectional geometry was initially used to subdivide a wetland into hills/highlands, slopes, flats, channels and basins. The landform host to a wetland, however, can be further categorised on the basis of plan geometry and size. In plan, encompassing the limnetic and littoral zones (Hutchinson 1957; Cowardin *et al.*, 1979), wetland shapes may be described as linear, elongate, irregular, fan-shaped, ovoid or round, for basins, slopes and hills/highlands; and straight, sinuous, anastomosing, or irregular for channels.

Wetlands may be further categorised according to scale. For hills/highlands, slopes, basins and flats the categories of geomorphic scale for wetlands developed therein are:

- Megascale: Very large scale wetlands larger than a frame of reference of 10 km × 10 km
- Macroscale: Large scale wetlands encompassed by a frame of reference of 1000 m × 1000 m to 10 km × 10 km
- Mesoscale: Medium scale wetlands encompassed by a frame of reference of 500 m × 500 m to 1000 m × 1000 m
- Microscale: Small scale wetlands encompassed by a frame of reference of 100 m× 100 m to 500 m × 500 m
- Leptoscale: Very small scale wetlands encompassed by a frame of reference of less than 100 m × 100 m

Thus all basins that are permanently inundated are lakes; those that are smaller than 100 m × 100 m are leptoscale lakes, those that fit in a frame of 1 km × 1 km are mesoscale lakes, and those that are of a size greater than 10 km × 10 km are megascale lakes.

In the case of channels, a definitive width to length relationship is used to separate size of channel wetlands:

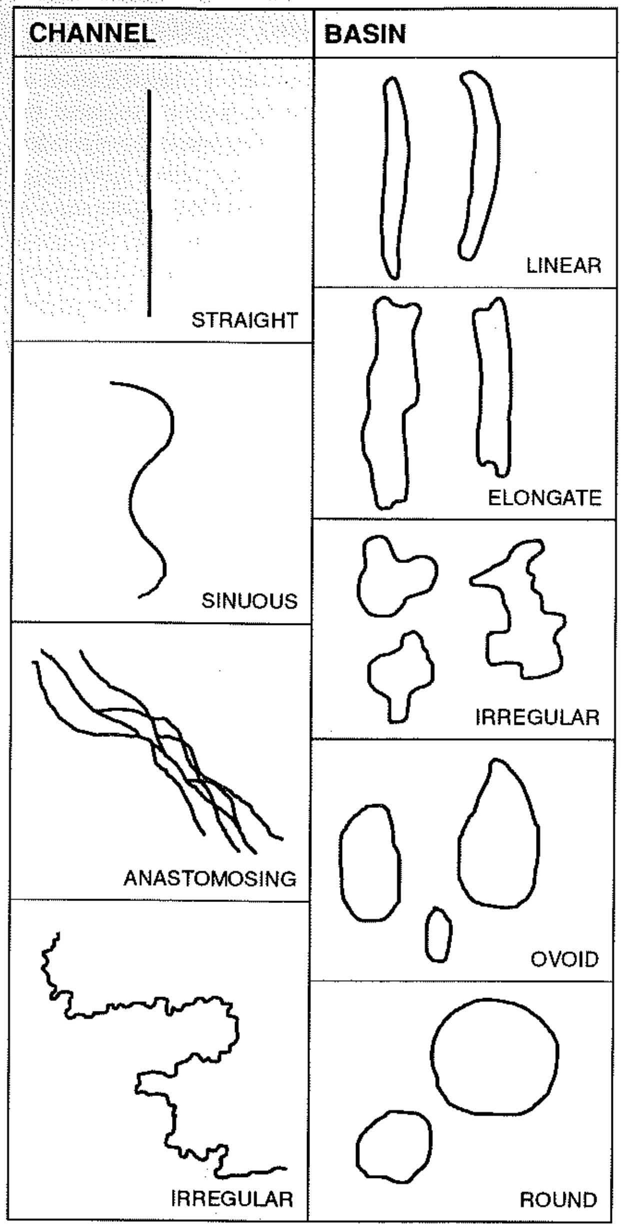


Figure b: Descriptors for plan geometry of wetlands

- Macroscale: Large scale channels 1 km and greater wide, by several to tens of kilometres long.
- Mesoscale: Medium scale channels hundreds of metres wide, by thousands of metres long.
- Microscale: Small scale wetlands tens of metres wide, hundreds of metres long.
- Leptoscale: Fine scale channels several metres wide, tens of metres long.

Thus, all channels that are seasonally inundated are creeks, but those that are less than several metres wide are leptoscale creeks, and those that are of a size greater than 1 km wide as macroscale creeks.

Descriptors of wetland vegetation

Semeniuk *et al.* (1990) proposed a classification of wetland vegetation which can be used to augment the basic geomorphic wetland types. The proposed vegetation classification system is based on the extent and pattern of wetland vegetation cover, the internal organisation of that vegetation in plan, the range of structural vegetation types in zones and the details of floristics. Vegetation cover is divided into 3 intergradational classes: peripheral, mosaic and complete and complexity of wetland vegetation is divided into 3 classes: homogeneous, zoned and heterogeneous. The combination of cover and internal organisation results in 9 basic wetland vegetation categories: periform, paniform, latiform, zoniform, gradiform, concentriform, bacataform, heteroform and maculiform (Figure c).

To augment the basic geomorphic wetland types, the 9 vegetation categories are modified to adjectival form, with the substitution for "... form" in the nomenclature by "... phytic". Thus a sumpland with gradiform heath/sedgeland and a dampland with zoniform forest/heath/sedgeland could be termed gradiphytic sumpland and zoniphytic dampland. In these cases the emphasis is on the classification of the wetland type, and the vegetation adjectival qualifier simply augments the nomenclature of the wetland.

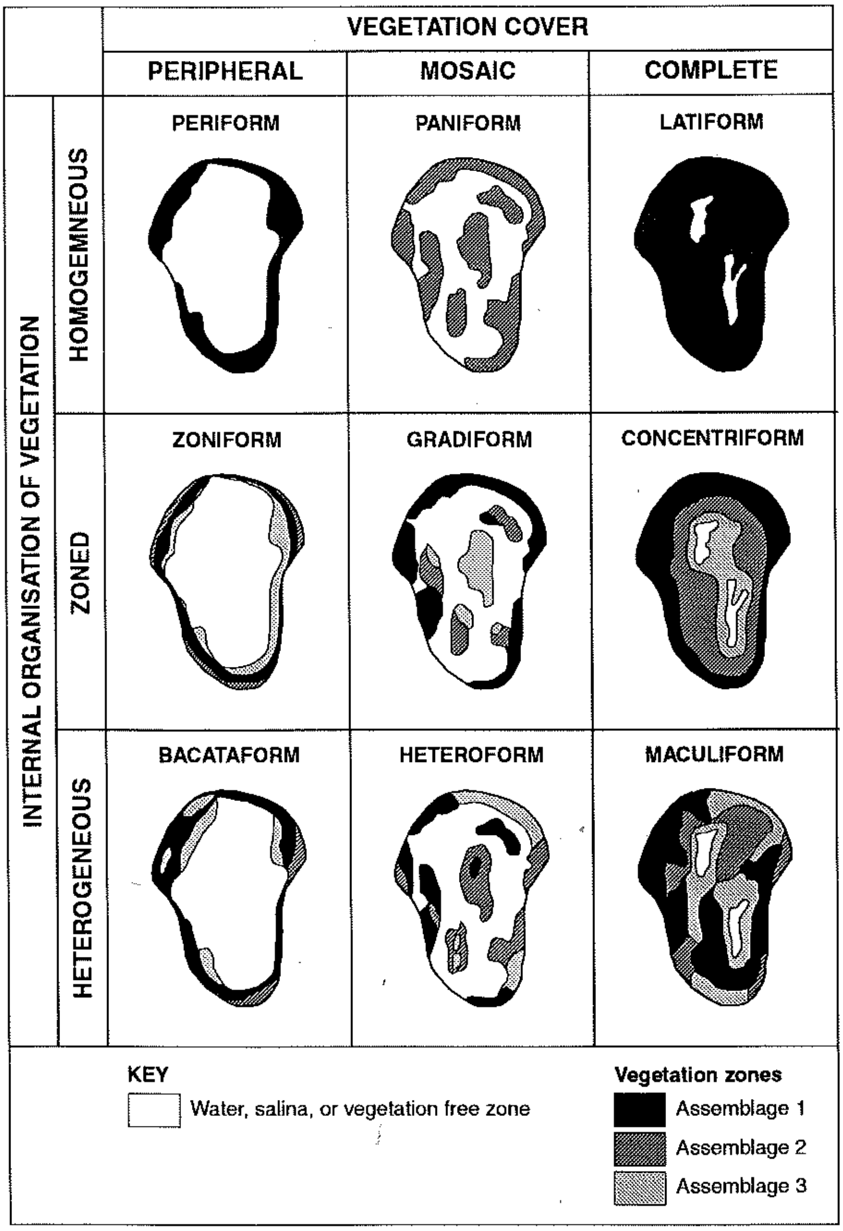
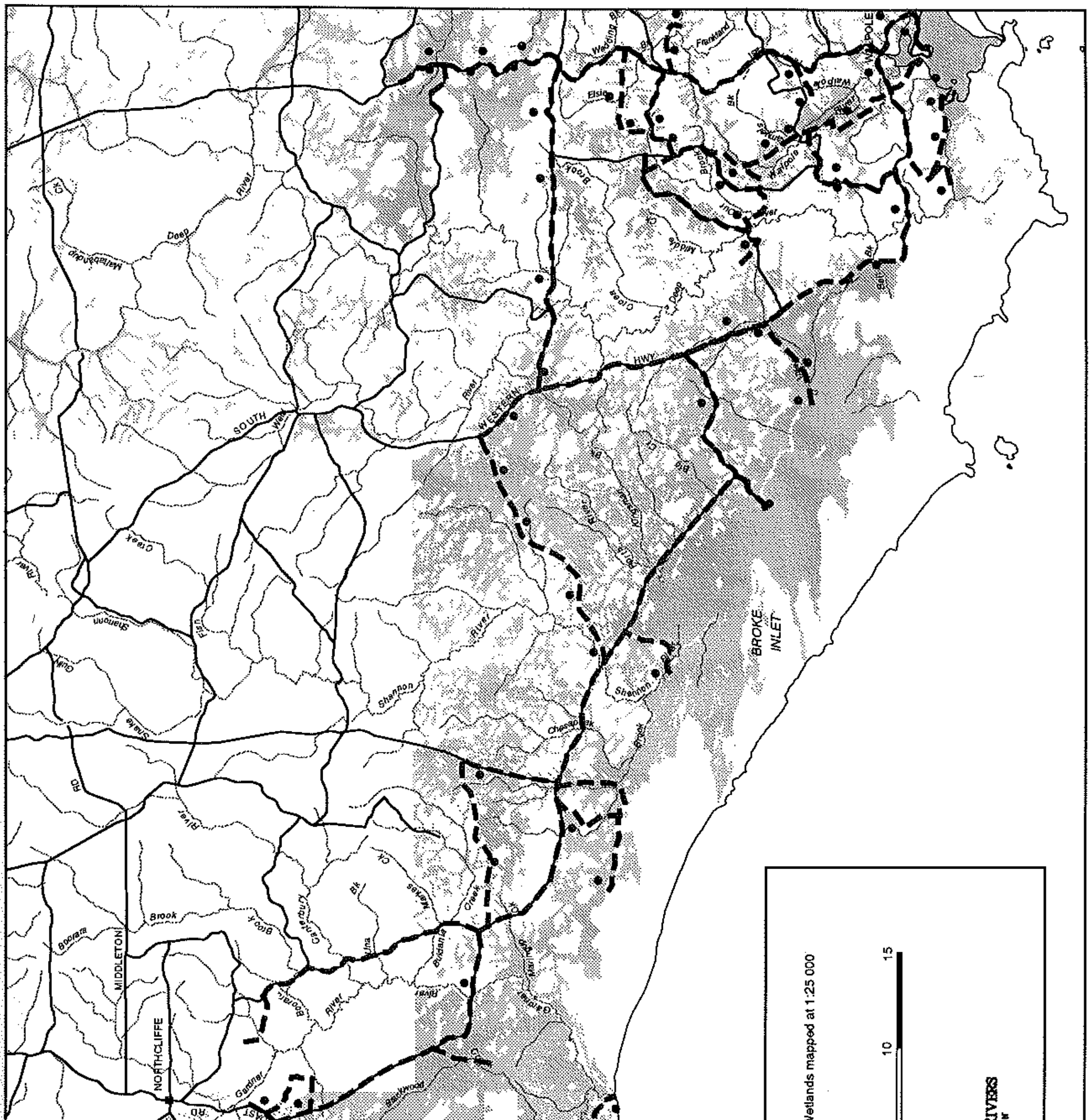


Figure c: Classification of wetland vegetation based on vegetation cover and form (Semeniuk *et al.* 1990)

Appendix C:



Traverses and field sites used to assist determination of suites in the Meerup to Walpole area

Appendix D:

Botanical list of species in Table 6, covering four wetland vegetation communities in the Augusta to Donnelly River area

Acacia myrtifolia
Acacia uliginosa
Adenanthos detmoldii
Agonis linearifolia
Anarthria prolifera
Astartea aff. fascicularis
Boronia spathulata
Calothamnus lateralis
Darwinia sp.
Eutaxia epacridoides
Hakea sulcata
Hibbertia stellaris
Hovea stricta
Hypocalymma ericifolium
Johnsonia lupulina
Kunzea recurva
Leptocarpus scariosus
Lyginia barbata
Pimelia hispida
Restio serialis
Schoenus curvifolius
Velleia trinervis
Villarsia lasiosperma
Xanthorrhoea preisseii

Aotus carinata
Actinodium cunninghamii
Adenanthos obovatus
Agonis parviceps
Anathria scabra
Beaufortea sparsa
Calothamnus crassus
Conospermum caeruleum
Dryandra nivea
Grevillea manglesioides
Hakea ceratophylla
Hakea varia
Homalospermum firmum
Hypocalymma cordifolium
Hypocalymma strictum
Juncus pallidus
Lambertia orbifolia
Leucopogon alternifolius
Pericalymma ellipticum
Restio ustulatus
Schoenus rodwayanus
Stylidium verticellatum
Verticordia lehmannii
Viminaria juncea

Water and Rivers Commission

Hyatt Centre
3 Plain Street
East Perth Western Australia 6004

Telephone (08) 9278 0300
Facsimile (08) 9278 0301