2000

Identification of wetland plant hydrotypes on the Swan Coastal Plain Western Australia

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Identification of Wetland Plant Hydrotypes on the Swan Coastal Plain Western Australia

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A Thesis Submitted in Partial Fulfillment of the

Requirements for the Award of

Bachelor of Science (Honours) Environmental Management

Edith Cowan University

Submission Date – 17 / 11 / 2000

USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

The hydrology of 19 Swan Coastal Plain wetlands was described in relation to its influence on the composition and structure of wetland vegetation. Sixty species were identified as 'wetland' plants. The water depth ranges, or hydrological envelopes, of these species were determined and species grouped together based on the water regimes they experienced.

Descriptions of wetland hydrology suggested that the surface and groundwater levels of the majority of study wetlands had declined in both the short (3-5 years) and long-term (20-50 years). Wetlands belonging to the Bibra Suite did not follow this trend as surface water levels either increased or remained relatively constant in the long term.

Ordinations and TWINSPAN analysis illustrated that wetlands with similar physical characteristics generally shared similar species composition. Species richness and the number of exotics, wetland species and perennial shrubs were also important in determining similarities and differences between wetlands.

The hydrological envelopes established in the study were compared to the literature. Water depth ranges for all study trees and the majority of perennial shrubs and emergent macrophytes were generally supported by previous studies.

Seven perennial and two annual hydrotype groups were established. Species from four of the perennial groups experienced a similar depth of inundation, but the depth to groundwater at the dry end of their range varied. Species from the other three hydrotypes did not tolerate inundation and also experienced differences at the dry end of

their ranges. Of the two annual hydrotypes, one group tolerated inundation while the other did not.

Comparisons with the literature and the low occurrence rate of some species resulted in modifications to the hydrotype groupings. Twenty-three perennials and five annual species representing the nine hydrotypes remained in the final hydrotype scheme. A test case was presented as an example of how hydrotypes could be used to predict the impact of altered hydrology on wetland vegetation composition and structure.

The results from this study indicated that the hydrology of Swan Coastal Plain wetlands was changing and that, by grouping wetland species into hydrotypes based on water depth ranges they experience, the effects of these changes on vegetation structure and composition could be predicted.

I certify that this thesis does not, to the best of knowledge and belief:

(1) incorporate without acknowledgement and material previously submitted for a degree or diploma in any institution of higher education;

(2) contain any material previously published or written by another person except where due reference is made in the text;

(3) contain any defamatory material.

Signature..RC Coombs

Date..31.1.2001.........

ACKNOWLEDGMENTS

I would first like to thank Dr Ray Froend, my supervisor, for his advice and for brewing up such a challenging and interesting project.

I would also like to thank my husband, Richard Loomes, for going above and beyond the call of duty in the form of cooking, cleaning, washing and ironing during the past few months. To my non-university friends, thanks for understanding that, although I wasn't sick or dying, I couldn't keep up the usual round of social obligations this year.

I would also like to thank the following people:

Eddie van Etten and Phillip Groom for their patience in answering my endless silly questions about Ordinations and other statistical anomalies.

Neil Pettit and Gary Ogden for their help with field work and also for answering inane questions.

Natasha Hyde from the Water and Rivers Commission for patiently deciphering my cryptic emails and providing reams of water monitoring data.

Finally, many thanks to my fellow honours sufferers, Kelli O'Neill, Tara Reid and Hayley Valentine for keeping me sane this year.

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INTRODUCTION

AIMS AND SIGNIFICANCE OF THE STUDY

Wetlands are highly productive, complex ecosystems (Balla, 1994), estimated to cover up to 6% of the Earth's surface (Mitsch and Gosselink, 1993). Despite this, humankind has only recently begun to understand and appreciate the vital ecological functions they provide (Mitsch and Gosselink, 1993). Wetland vegetation is central to these processes (Ponting, 1991). Intact, healthy wetland vegetation provides complex habitat for native fauna, it stabilizes sediments (Balla, 1994), filters pollutants from surface run-off (Upton and Kinnear, 1997) and provides primary production for wetland ecosystems (Froend et al.,1993).

In south-western Australia 9600 wetlands are found across an area known as the Swan Coastal Plain. These wetlands generally form either from the ponding of rainwater on impermeable surfaces or as an expression of the groundwater table (Balla, 1994). The surrounding vegetation therefore experiences periods of wetting and drying in response to seasonal rainfall (Brock, 1991). Many wetland species of this region have developed mechanisms to survive these sometimes unpredictable water regimes (Neilsen and Chick, 1997).

Reproductive adaptations include the vegetative growth of rhizomes by emergent species during periods of prolonged inundation or seed germination following a drying episode (Brock and Casanova, 1997). Growth responses to water regimes range from large macrophytes maintaining sufficient biomass above water to allow continued photosynthesis, to lengthening of leaf stems by smaller species, allowing leaves to float on the rising water surface (Neilsen and Chick, 1997). Annual species, intolerant of flooding, germinate from seed banks when water levels recede, completing their life-cycles before the following wet season (ter Heerdt and Drost, 1994). Aquatic annuals and perennials only survive during flood periods (Tiner, 1991).

There are a number of components of the water regime that influence wetland vegetation (Roberts et al., 1999). The time of year of flooding determines the climatic variables, such as day length and temperature that persist during inundation (Roberts et al., 1999). The combination of climatic variables and water availability a species requires will determine when it grows and reproduces (Roberts et al., 1999). The rate at which water rises is important as a rapid increase in depth will not allow emergent species to grow quickly enough to stay above the water (Brock and Casanova, 1994). The frequency of flooding and the interval between flood episodes are also important for growth and reproduction. For example, the seeds of some species may become unviable if dry for too long a period, while other species may require lengthy dry periods to germinate and establish (Roberts et al., 1999).

The most important components of the water regime, however, are the depth of inundation and the duration of the flood event (Roberts et al., 1999). The impact of depth is dependent on the size and growth form of a species. As discussed above large species can grow above the water, however, smaller plants will drown (Roberts et al., 1999). The duration of inundation, or the time that surface water is present, will determine whether some species produce sexually or vegetatively, or whether others, tolerant of short periods of inundation only, will survive at all (Roberts et al., 1999). These two water regime components are also the most significant as they have a greater impact on a wider range of species than other factors. For example, inundation will kill many intolerant species regardless of the season of flooding and rate of rise (Mountford and Chapman, 1993).

A strong relationship therefore exists between the distribution, growth and reproduction of wetland vegetation and the depth and duration of seasonal flooding (Mountford and Chapman, 1993; Froend and McComb, 1994; Brownlow et al., 1994; Neilsen and Chick, 1997). This relationship is especially obvious where vegetation forms bands around a wetland and each successive band is less tolerant of inundation (Wheeler, 1999).

Altered water regimes also demonstrate the importance of water levels to wetland vegetation (Wheeler, 1999). As each species is adapted to a specific water level range, or hydrological envelope, any change in water levels can ultimately affect its distribution. Long-term persistent changes can cause a shift in community composition and structure as species better adapted to the new conditions become established (Harding, 1993). Lowering water tables can result in the loss of species intolerant of drying and their gradual replacement by terrestrial species with drier hydrological envelopes (Keddy and Reznicek, 1986; Moore and Keddy, 1988). Changed climatic patterns and human activities such as groundwater abstraction are the main causes of declining water levels in Australia (Froend et al. 1993; Balla, 1994).

Due to their larger size, longer life-span and more expansive root systems, wetland trees are often more tolerant and respond more slowly to changes in water levels than other species (Jenik, 1990; Balla, 1994). Muir (1983) found evidence of this in a study of vegetation of sandplain wetlands, in which a young band of trees was found growing inside a band of an older species known to be more tolerant of inundation. This suggests that, although conditions had dried enough to allow the new species to establish, the other wetland tree persisted.

Emergent macrophytes, that is sedges and rushes with vegetative parts emerging from seasonal fresh water (Semeniuk et al., 1990), respond much quicker to altered water regimes than trees and many other perennial wetland species (Froend, et al. 1993). Not only are they lost to declining water tables, like many species they are also affected by rising levels (McComb and Lake, 1990; ter Heerdt and Drost, 1994). Increased groundwater levels can result from climatic changes as well as increased runoff from urban areas and the removal of native vegetation (Balla, 1994).

Emergent macrophytes generally respond to increasing water depths in two ways (van der Valk, 1994). Firstly, if levels rise quickly, they may be lost due to drowning if they do not have enough leaf area above the water surface to allow respiration (van der Valk, 1994). Secondly, if the water rises more gradually they may respond by migrating upslope to more suitable depths (Froend and McComb, 1994; van der Valk, 1994). Migration downslope will occur in response to lower water levels (Froend and McComb, 1994; ter Heerdt and Drost, 1994).

The distribution and composition of perennial wetland shrubs, herbs and ferns are also influenced by water level gradients (Harding, 1999). These species generally tolerate lower depths of inundation for shorter periods than trees and emergent macrophytes and are often more prominent as fringing species (Keddy and Reznicek, 1986). However, changed water regimes will affect these species in a similar fashion to the emergent macrophytes as they are either lost or migrate to more suitable water levels (Keddy and Reznicek, 1986).

In Western Australia the association between vegetation and water regimes is used to help determine ecological water requirements, which is the part of the water budget allocated to ecological components of the environment considered to be valuable or beneficial (Water and Rivers Commission, 1997). This formal identification of environmental requirements is essential to establish environmental water provisions, which ensure water allocations between industry, society, urban developments and the environment are equitable (Roberts et al., 1999).

Currently there is little detailed knowledge of the relationships between plant community composition and water regimes (Brock, 1991; Froend and McComb, 1994). Instead ecological water requirements are based on the measured requirements of key species as determined by a small group of expert plant ecologists (Water Authority, 1995). For example the requirements set for a group of Swan Coastal Plain wetlands under the East Gnangara Environmental Water Provisions Plan (Water and Rivers Commission, 1997) were based largely on work by Froend et al. (1993) on the hydrological envelope of the emergent macrophyte *Baumea articulata.* The study established life history traits and growth responses to altered water regimes under experimental conditions (Froend et al. 1993).

The greater the number of species for which this type of detailed information regarding water requirements were known, the more accurate and efficient the process of establishing ecological water requirements would become (Froend and McComb, 1994). However, in the absence of such data it should be possible to determine the basic water requirements for a number of species based on their hydrological envelopes and period of inundation that they tolerate. This broader, less detailed list of species requirements could also be used by a larger group of people to describe ecological water requirements, as botanists would no longer need a background in hydrology.

Once established, hydrological envelopes could also be used to group species together into functional types or hydrotypes based on the water regime they experience. As with other functional classifications, hydrotypes could be used to simplify the description of complex ecosystems (Boutin and Keddy, 1993). This would allow community composition and function to be described by examining groups of wetland plants rather than individual species (Boutin and Keddy, 1994; Mountford and Chapman, 1993; Brock and Casanova, 1994).

The grouping of plants into functional types is a long established practice. Traditionally they have been grouped based on the similarities in their reproductive or morphological responses to environmental conditions (Diaz and Marcelo, 1997). An early example of this is the life-form approach developed by Raunkiaer in 1934 (Lund and Hindmarsh, 1997) to group plants adapted to different climates (Kleyer, 1999). In recent years the use of functional groups has increased as their value in summarizing the complexity of species and populations into a few recurrent patterns has gained greater acceptance (Barradas et al., 1999).

A number of functional classifications have been established for wetland plants. Boutin and Keddy (1993) grouped 43 North American species by 27 traits related to nutrient uptake, stress tolerance, dispersal ability and life history characteristics. Keddy et al. (1994) used competitive ability functional traits to group 20 plants, also from

North America. Functional traits similar to those mentioned here have also been used to develop simulation models to predict the impact of altered wetland hydrology (van der Valk, 1981; Ellison and Bedford, 1995).

Brock and Casanova (1994) developed the only widely known Australian functional classification scheme, in which 60 species from two wetlands in NSW were grouped based on reproductive traits and tolerance/avoidance mechanisms. The species used in this study were predominately submerged and amphibious with little emphasis on fringing terrestrial species.

It has already been noted that the detailed information required to allocate species into functional groups in these types of classification schemes is not available for many plants of the Swan Coastal Plain wetlands. It has also been suggested that in the absence of this information it should be possible to group these species into hydrotypes, based solely on their hydrological envelopes. Halse et al. (1993) used a similar system as part of a baseline study for the long term monitoring of vegetation in nature reserves in the south-west of Western Australia. Although not intended as a scheme to group species together, this study used four littoral zones to describe the position of plants in a wetland relative to the low and high water mark (Halse et al., 1993).

Despite the work by Halse et al. (1993) on southwestern Australian species and by Brock and Casanova (1994) on aquatic plants of NSW, no classification scheme unique to the fringing species of the Swan Coastal Plain wetlands has been developed.

The overall objective of this study therefore was to describe the hydrological envelopes of wetland species of the Swan Coastal Plain, and to use this information to group species into hydrotypes. To achieve this, the vegetation and hydrology of selected wetlands will also need to be described.

Specific objectives are:

1. To describe the hydrology of Swan Coastal Plain wetlands with reference to the wetland vegetation they support.

2. To determine the hydrological envelopes and duration of flooding experienced by wetland vegetation of the Swan Coastal Plain.

3. To group wetland species with similar hydrological envelopes into hydrotypes for use as a tool to predict the impact of changed water regimes.

SWAN COASTAL PLAIN WETLANDS

The wetlands selected for inclusion in this study all occur on the Swan Coastal Plain, which runs parallel to the coast in the Perth region of Western Australia (Davidson, 1995). The Swan Coastal Plain is 23km wide in the south, 34 km wide in the north and is bounded to the east by the Darling and Gingin Scarps (Davidson, 1995). The climate experienced in this region is Mediterranean with mild, wet winters and hot dry summers (Allen, 1979).

Four main geomorphic units constitute the Swan Coastal Plain (Seddon, 1972). The Pinjarra Plain, at the foot of the Darling Scarp, is up to 8km wide and formed from alluvium (Balla, 1994). The oldest system, the Bassendean Dunes, lies to the west of the Pinjarra Plain forming an undulating plain of deep, heavily leached sands (Davidson, 1995). West of the Bassendean system is the Spearwood Dune System, which is higher, younger and less leached (Seddon, 1972) and formed from the weathering of the underlying limestone (Davidson, 1995). The most westerly formation is the Quindalup Dune System consisting of wind-blown quartz beach sand and lime (Davidson, 1995).

Wetlands usually occur in depressions between the dunes with more than 9600 found across this area covering 362 000ha of land (Balla, 1994). These wetlands include 200 lakes, which contain permanent water, 4879 sumplands that hold water only during winter and spring and 3924 seasonally waterlogged areas, or damplands (Balla, 1994).

The majority of Swan Coastal Plain lakes are shallow expressions of the groundwater table which fill following winter rainfall and dry during summer as groundwater levels fall, rainfall decreases and surface evaporation increases (Davidson, 1995). Sumplands and damplands can form from water perching over impermeable soils or as expressions of underlying groundwater (Davidson, 1995). It is generally accepted that rainfall, both direct and from catchment runoff, has the greatest impact on groundwater and wetland depth under natural conditions (Balla, 1994).

Long term records indicate a rising trend in Perth rainfall to the 1930s during which time water levels would have been higher in many wetlands than during the low rainfall years of the 1970s and 1980s (Balla, 1994; Davidson, 1995). Good rainfall in the winter of 1991 (Water Authority, 1995) followed by high summer rainfall in 1992 (Valentine, 2000) resulted in very high wetland surface water levels over the following two years.

Due to the differences in the underlying landforms, soil types and hydrology, Swan Coastal Plain wetlands vary in character (Balla, 1994). However, as groups of wetlands do share similar characteristics, they have been drawn together into consanguineous suites (Semenuik, 1988).

The Jandakot Mound is a shallow, unconfined groundwater aquifer that occurs in the sedimentary deposits under the Swan Coastal Plain (Water Authority, 1991). It is bounded by the Indian Ocean to the west, the Swan and Canning Rivers to the north, Southern River to the east and Rockingham to the south (Water Authority, 1991).

The shallow groundwater table, directly recharged from rainfall (Water Authority, 1991), has resulted in much of the area being covered by small lakes and sumplands interconnected by damplands (Balla, 1994). Clearing of native vegetation for housing developments in the region have resulted in this groundwater table rising (Balla, 1994).

However, the mound has also been managed as an important source of groundwater since 1975, resulting in ongoing groundwater abstraction (Water Authority, 1991).

The vegetation of remnant wetlands and the surrounding *Banksia* woodlands of the Jandakot Mound support a diverse range of fauna (Water Authority, 1991). Two wetlands, Thomsons and Forrestdale Lakes, are listed as wetlands of international importance for waterbirds, or RAMSAR wetlands (Water Authority, 1991).

The Gnangara Mound is also an unconfined groundwater aquifer formed in sedimentary deposits, which although described as shallow, is much deeper than the Jandakot Mound (Balla, 1994). Moore River and Gingin Brook mark its boundaries to the north, Ellen Brook to the east, the Swan River to the south and the Indian Ocean to the west (Water Authority, 1995).

Gnangara Mound wetlands are often isolated with well-defined boundaries (Balla, 1994). They occur in low-lying areas where the water table is close to or above ground level for much of the year (Water Authority, 1995). Soils characteristic of saturated areas have formed around these wetlands and support vegetation associations dependent on groundwater (Water Authority, 1995).

As a major water source for the Perth region, the Gnangara Mound is also subject to groundwater abstraction (Water Authority, 1995). Other impacts on wetlands include water uptake by pine plantations and clearing of vegetation for urban and rural development (Water Authority, 1995).

The remnant vegetation of the area is chiefly comprised of *Banksia* woodland important as habitat for flora and fauna (Balla, 1994). The list of fauna species known to be found over the Gnangara Mound includes 12 native mammals, 13 fish, 75 amphibians and reptiles and 233 birds, 70 of which are waterbirds (Water Authority, 1995).

SECTION 1: HYDROLOGY AND VEGETATION OF THE SWAN COASTAL PLAIN WETLANDS

1.1 METHODS

1.1.1 STUDY DESIGN

It was beyond the scale of the project to study the vegetation of all Swan Coastal Plain wetlands. As a result a smaller group of 21 wetlands was selected, based on their inclusion in an existing vegetation monitoring program, and the availability of four years of monitoring data. Nine of these wetlands were located on the Jandakot Groundwater Mound and 12 on the Gnangara Groundwater Mound (Figure 1.1). A total of 29 permanent monitoring transects made up of three to five individual plots had been established across the 21 wetlands.

To describe the hydrology of these wetlands and to identify changes in water levels over time, surface and groundwater data were required. The Water and Rivers Commission, the Water Corporation and preceded State Government authorities collect this data monthly for all Swan Coastal Plain wetlands for water level monitoring purposes.

Surface water data were used to describe the water regimes components previously identified as important to the composition and structure of wetland vegetation. This was done initially for each wetland and for of each plot within a transect. As plant species lists were recorded for each plot, water regimes experienced by all species at each transect could then be established and a distinction made between wetland and non-wetland species.

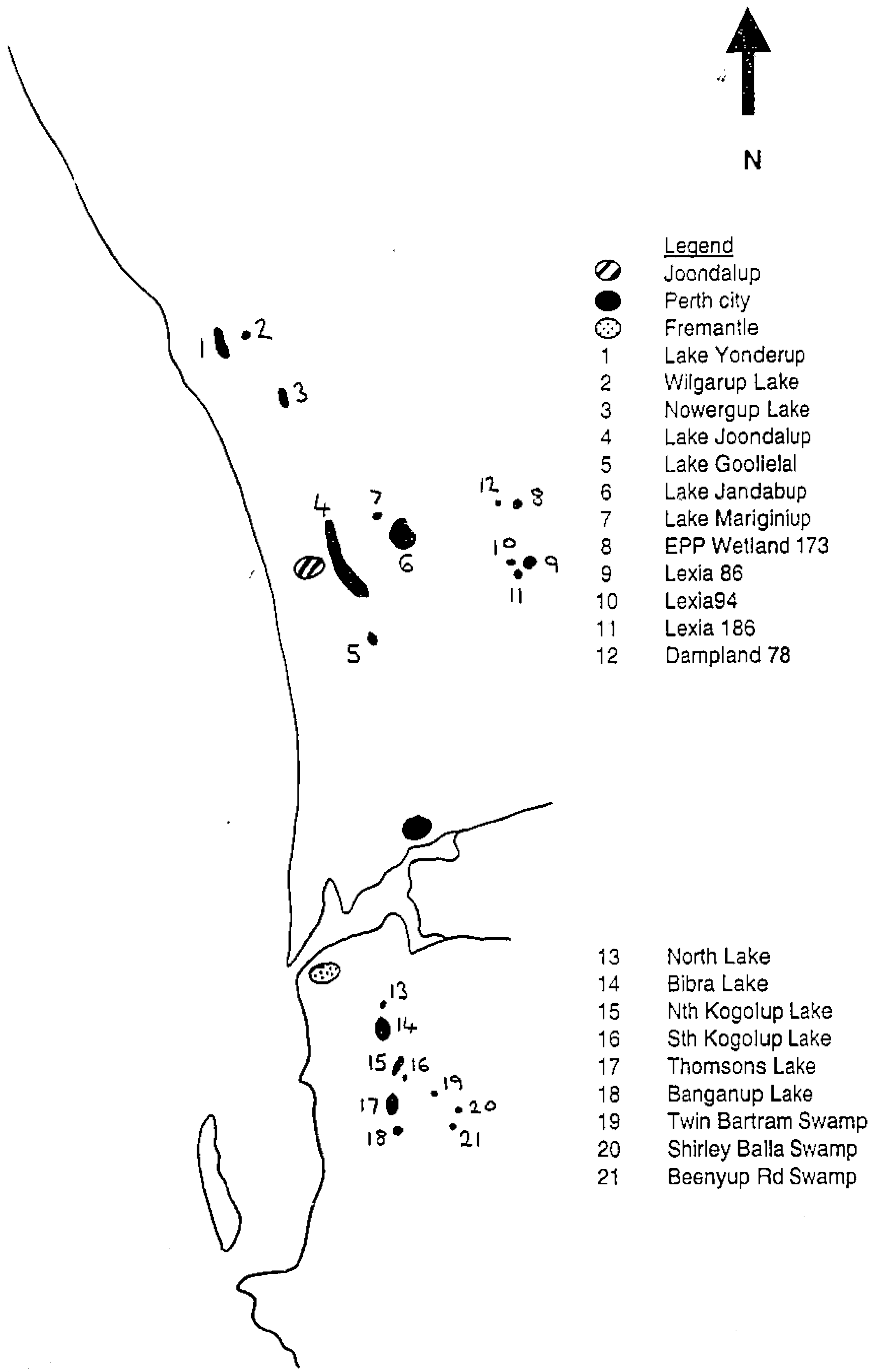


Figure 1.1
Location of study wetlands on Swan Coastal Plain
(Source: Froend et al., 1993, p.8)

At this stage it was realised that surface water data were unavailable for two of the wetlands included in the vegetation monitoring program as they were only seasonally waterlogged not inundated. These wetlands, Lexia Wetland 94 and Melaleuca Park Dampland 78, were therefore not included in the study, reducing the number of transects to 27.

1.1.2 DATA COLLECTION AND COLLATION

Hydrological data

The majority of hydrological data collected from groundwater monitoring bores and wetland staff gauges (surface water) were sourced from the State Water Resource Information System (SWRIS) database presented by the Water and Rivers Commission of Western Australia. Surface water data for North and South Kogolup Lakes and Thomsons Lake were obtained from the Water Corporation, now responsible for monitoring these wetlands.

Individual maps showing the location of each groundwater bore and staff gauge were sourced from the Water and Rivers Commission. In the case of a wetland being serviced by more than three bores, these were used to ensure the bores selected were spaced as evenly as possible around the perimeter. A map of each wetland was then compiled to provide an overall picture of its size and the location of bores, staff gauges and vegetation transects (Appendix 1). Details of the bores and staff gauges are presented in Appendix 2.

The physical characteristics of study lakes, including lake bed elevation, size, type, vegetation form and wetland suite, were obtained from the literature (Arnold, 1990; Hill et al., 1996; Water Authority of Western Australia, 1995; Water and Rivers Commission, 1997).

Vegetation data

Vegetation data were sourced from the Water and Rivers Commission annual reports (1997-1999) on ongoing monitoring of fringing wetland vegetation health and species composition of selected wetlands. Gnangara wetland data were collected from 10m wide transects consisting of 4-5 plots each of which was 10-20m long (Pettit and Froend, 2000). Plots were named A through to D or E with plot A located at the wetland end of each transect. The elevation at the start and end of each plot was also recorded. More than one transect was established at larger wetlands to ensure all vegetation communities were sampled (Pettit and Froend, 2000).

Within each plot the position, density, diameter and health of each tree was recorded as were the presence of seedlings, saplings or resprouters. All other species were identified and the cover estimated using the Domin scale of cover and abundance (Kent and Coker, 1992).

The forms of data collected in the Jandakot wetlands (Ladd, 1999) were generally the same as that from Gnangara. However the transects were 40-120m long and 10m wide and divided into 3-4 plots. Domin values were calculated for 3 randomly placed 1m^2 quadrats in each plot and for non-tree species only.

As the ongoing health of wetland trees was beyond the scope of this study only data pertaining to the presence or absence of species within each plot and their Domin cover values in both the Jandakot and Gnangara wetlands were considered.

1.1.3 DATA ANALYSES

Hydrological data

Description of the hydrological regimes of study wetland

All data were reformatted for use in Excel. Monthly bore and staff gauge data were graphed for each wetland to illustrate trends in ground and surface water (mAHD) over time.

To standardize the data set across sites all water depths were converted from mAHD to meters. To achieve this bathymetry data were used to establish the lowest elevation of each wetland (mAHD) and these values subtracted from surface water levels and plot elevations (mAHD). For example, the lake-bed of Lake Banganup was 12.7 mAHD, the elevation at the start of plot A was 12.9 mAHD and the water depth was 12.95 mAHD. Following the appropriate calculations it can be seen that plot A was 0.2m above lakebed level and was 0.05m underwater.

All following hydrological analyses were also based on seasonal (June-May) means to encapsulate entire winter wetting and summer drying seasons. Parameters were calculated over 20, 10 and 5 year periods to provide data relevant to vegetation of different life spans. Shorter data sets were considered over periods of 8, 5 or 3 years.

Mean, mean minimum and mean maximum surface water levels were calculated from staff gauge data to establish the mean range in water levels across each wetland. Although groundwater data was available for most wetlands, bores were generally too far from the vegetation transects to allow accurate extrapolation of groundwater depths. Groundwater levels were therefore determined as the depth from the elevation of a transect to the mean, minimum and maximum surface water levels. This data was presented in profile diagrams, which also illustrated plot size and elevations.

The mean number of months per year each wetland was completely dry or below mean minimum levels was also calculated as was the amplitude between seasonal minimum and maximum water levels.

To establish the rate of surface water rise across wetlands during flooding episodes, the number of months between annual minimum and maximum levels were counted and means calculated. Seasonal amplitudes were then divided by the number of months of flooding and converted to cm/month. The months at which the peak levels occurred were also recorded.

Description of the hydrological regimes of individual study plots

Elevations recorded at the start and end of each plot were used in a process similar to that described above to determine which plots were inundated. The depth of inundation, the mean number of months each flooded plot was underwater and the rate at which water levels rose across the transects were also calculated.

Mean minimum and maximum surface and groundwater levels were used to allocate each plot to a hydrological zone based on a classification scheme adapted from Halse et al (1993) (Table 1.1). Due to changing elevations across many plots, classifications were based on the hydrological conditions experienced across the majority of the plot. Plots in which plants grew between high and low watermarks were classified as littoral. Plots located around the high watermark were described as littoral/supralittoral, while those situated on low-lying ground, which became wet during winter were deemed seasonally water logged. Plots that remained dry throughout the year were classified as supralittoral if the groundwater table was less then 2m below the surface, and terrestrial if the depth to groundwater was more than 2m.

Table 1.1
Description of hydrological zone classification based on location of vegetation

Zone	Description
Littoral	Plants between low and high water mark
Littoral/supralittoral	Plants around high water mark.
Seasonally waterlogged	Plants in winter wet depressions
Supralittoral	Plants above highwater mark where groundwater <2m below the surface
Terrestrial	Plants above highwater mark where groundwater >2m below the surface

(Adapted from Halse et. al, 1993, p.6)

Vegetation data

Species lists

Vegetation data from the 1997, 1998 and 1999 monitoring reports were combined to form a master species list (Appendix 3) and the literature used to detail the form (shrub, tree, annual, perennial etc), height, growth conditions (sand, winter wet depressions etc) and flowering season of each species (Burbidge, 1984; Marchant et al., 1987; Bennett, 1988). Using the combined data sets, the occurrence of individual species in each plot was recorded and this data presented in tabular form to provide a visual representation of species presence or absence across each transect.

Community classification and description

Prior to further vegetation data analysis it was noted that the Domin scales of cover and abundance differed between the Jandakot (Ladd, 1997-1999; Ladd and Schnulberger, 2000)) and Gnangara (Pettit and Froend, 1997-2000) vegetation reports. To allow comparisons of data sets, the scales were altered, as illustrated in Table 1.2. All values for tree species and large shrubs (>3m) were considered, while smaller species were judged important if values were 5 (11-25% cover) or above, or if combined values of species from the same structural group, sedges for example, were 5 or above.

Table 1.2
Domin scales of plant cover and abundances used in Ladd (1997-2000) and Pettit and Froend (1997-2000) (from Kent and Coker, 1992) and converted scale used in current report.

Ladd (1997, p. 5)			Pettit and Froend			Converted scale	
Old value	New value	Cover/density	Old value	New value	Cover/density	Value	Cover/density
1	1	1-2 plants	+	1	1 plant		
2	2	3-5 plants	1	1	1-2 plants	1	1-2 plants
3	3	6-10 plants	2	2	>1 plant <1% cover	2	<1% cover
4	4	11-30 plants	3	3	1-4% cover	3	1-4% cover
5	4	31-100 plants	4	4	4-10% cover	4	4-10% cover
6	4	5-10%	5	5	11-25% cover	5	11-25% cover
7	5	11-25%	6	6	26-33% cover	6	26-33% cover
8	6	26-33%	7	7	34-50% cover	7	34-50% cover
9	7	34-50%	8	8	51-75% cover	8	51-75% cover
10	8	51-75%	9	9	76-90% cover	9	76-90% cover
11	9 & 10	76-100	10	10	91-100% cover	10	91-100% cover

Due to the nature of the sampling technique used at the Jandakot wetlands, descriptions of species composition of individual plots given in Ladd (1997-2000) were also considered to ensure important species had not been overlooked in the 1 x 1m quadrats. At this point transect 1 at Thomsons Lake was discarded as no description was provided.

The converted scale was applied to structural formation classes developed by Walker and Hopkins (1984, p. 46-47) (Table 1.3) to identify important or dominant overstorey and understorey species in all monitored plots along the permanent transects. The final community classifications were then based on the dominant overstorey.

Table 1.3
Vegetation community types defined by growth form and Domin cover and abundance values

Crown separation	D closed or dense	M Mid-dense	S Sparse	V very sparse	I Isolated plants	L Isolated clumps
Domin value	9,10	7,8	5,6	3,4	1,2	
Growth form						
T- Tree	Closed forest	Open forest	Woodland	Open woodland	Isolated trees	Isolated clump of trees
S- Shrub	Closed shrubland	Shrubland	Open shrubland	Sparse shrubland	Isolated shrubs	Isolated clump of shrubs
G- Grassland	Closed grassland	Grassland	Open grassland	Sparse grassland	Isolated grass	Isolated clump grass
V- Sedge	Closed sedgeland	Sedgeland	Open sedgeland	Sparse sedgeland	Isolated sedges	Isolated clump of sedges
H- Herb	Closed herbland	Herbland	Open herbland	Sparse herbland	Isolated herbs	Isolated clump of herbs

(from Walker and Hopkins, 1984, p. 46-47)

T - woody plant >2m tall with a single stem or branches well above the base.
S - woody plant multistemmed at the base (or within 200mm from ground level) or, stemmed, <2m tall.
G - forms discrete but open tussocks usually with distinct individual shoots, or if not, th if single-forming a hummock
V- herbaceous, usually perennial, erect plant generally with a tufted habit and of the families Cyperaceae or Restionaceae
H - herbaceous or slightly woody, annual or sometimes perennial plant; not a grass.

(from Walker and Hopkins, 1984, p. 49-50)

1.1.4 CLASSIFICATION AND ORDINATION

The statistical package PCOrd was used to perform the classification technique Two-way indicator species analysis (TWINSPAN) and the ordination procedure Detrended Correspondence Analysis (DCA).

DCA provided a multidimensional spatial arrangement of the species data so those plots close together in the ordination space shared similar species composition (Rigg et al., 1998). To achieve this, DCA generates scaled axes on which units simulate the mean rate of species turnover (Rigg et al., 1998). Generally, a complete turnover of species composition in the samples is represented by an axis length of 400 (Kent and Cocker, 1992). DCA also allowed gradients of change in species composition to be identified (Rigg et al., 1998).

This ordination technique has been criticised by some authors due to problems arising from rescaling and detrending (Kent and Cocker, 1992; Rigg et al., 1998). However, it is still regarded as a powerful and effective method of indirect ordination of ecological data, displaying a high level of robustness (Kent and Cocker, 1992; Rigg et al., 1998).

TWINSPAN and DCA were initially performed on the presence and absence data of all species (244) across all plots (105), as Domin values were incomplete. To identify hydrological and floristic gradients across the ordination, correlations (Pearson' product moment correlation coefficient) were performed between axis 1, 2 and 3 values and species richness, percentage of exotics and percentage of wetland species in each plot and mean maximum surface water depth and duration of flooding. Other hydrological parameters, minimum and maximum water depth, rate of water rise and season of flooding were not considered. Following the ordination and correlations, results of a TWINSPAN classification were used to establish the grouping patterns of the plots.

The second DCA ordination was performed on the 60 wetland species, however, only 100 plots were analysed as five contained terrestrial species only. Domin cover and abundance values replaced presence and absence. Correlations between axes values and mean maximum surface water depth, duration of flooding and species richness were performed along with cover values for species from each life-form class. Prior to these correlations values for individual species within each lifeform were combined to establish one value for each lifeform present in each plot. Values greater than 10 (85-100% cover) were treated as 10. Plot groupings were again determined by TWINSPAN.

1.2 RESULTS

1.2.1 HYDROLOGY OF STUDY WETLANDS

Wetland characteristics

Nine of the 19 study wetlands had permanently inundated basins and were therefore classified as lakes (Table 1.4). These wetlands were generally larger than other types, ranging in area from the 24.6ha North Lake to Lake Joondalup at 611.5ha (Hill et al., 1996a; Hill et al., 1996b). The Gnangara lakes occurred either as groundwater fed depressions in the Spearwood dunes of the Yanchep Suite, or as drainage impeded groundwater wetlands in the Bassendean dunes of the Gnangara Suite. Jandakot lakes occurred where groundwater was impounded between the Spearwood and Bassendean dunes of the Bibra Suite. Vegetation forms varied between these wetlands (Hill et al., 1996a; Hill et al., 1996b).

Banganup, Beenyup Rd., Twin Bartram and Shirley Balla Swamps were all classified as sumplands as their basins were only seasonally inundated, as were those of Lexia Wetlands 86 and 186, Melaleuca Park Wetland 173, and Kogolup and Wilgarup Lakes (Hill et al., 1996a; Hill et al., 1996b). Lexia 186 was the smallest of these wetlands at 0.7ha while the combined areas of North and South Kogolup Lakes was 72.4ha. Wetland 173 was the only one occurring in the Muchea Suite as a result of groundwater and rainwater ponding over impermeable sediments at the transition between the Bassendean dunes and the Pinjarra Plain. Beenyup Rd., Twin Bartram and Shirley Balla Swamps and Lexia Wetlands 86 and 186 resulted as groundwater surfaced or rose close to the surface of depressions located in the Bassendean dunes of the Jandakot Suite. Other sumplands occurred in the previously described Bibra and Yanchep suites. Vegetation forms also varied between sumplands (Hill et al., 1996a; Hill et al., 1996b).

Table 1.4

Table showing the area of individual study wetlands and the wetland type, suite and vegetation form ascribed to each wetland by Hill et al., (1996a,b)

Wetland	Area (ha)	Wetland type	Suite	Vegetation form
Banganup Lake	37.6	Sumpland	S/B.1	Bacataform
Beenyup Rd. Swamp	31.6	Sumpland	B.3	Maculifrom
Bibra Lake	188.7	Lake	S/B.1	Heterofrom
Lake Goollelal	73.8	Lake	S.1	Gradiform
Lake Jandabup	430.5	Lake	B.2	Bacataform
Lake Joondalup	611.5	Lake	S.1	Heteroform
Kogolup Lake	72.4	Sumpland	S/B.1	Bacataform
Lexia 86	1.2	Sumpland	B.3	Concentriform
Lexia 186	0.7	Sumpland	B.3	Maculiform
Lake Mariginiup	145.1	Lake	B.2	Bacataform
Melaleuca Park - Epp Wetland 173	14.5	Sumpland	B/P.3	Heteroform
North Lake	24.6	Lake	S/B.1	Bacataform
Lake Nowergup	46.1	Lake	S.1	Zoniform
Shirley Balla Swamp	19.4	Sumpland	B.3	Bacataform
Thomsons Lake	244.3	Lake	S/B.1	Bacataform
Twin Bartram Swamp	30	Sumpland	B.3	Maculiform
Wilgarup Lake	15.6	Sumpland	S.1	Maculiform
Lake Yonderup	30	Lake	S.1	Maculiform

Wetland type
Lake - permanently inundated basin
Sumpland - seasonally inundated basin

Wetland suite
S/B.1 - Bibra suite. Spearwood dunes and Bassendean dunes. Contact depressions with groundwater impounded against Spearwood dune ridge.
B.3 - Jandakot suite. Bassendean dunes. Groundwater surfacing or near to surface in depressions.
S.1 - Yanchep suite. Spearwood dunes. Occur in depressions between ridges fed by discharge from limestone and groundwater table rise.
B.2 - Gnangara suite. Bassendean dunes. Groudwater wetlands. Drainage impeded by thin clay, diatom mud or ferricrete layers.
B/P.3 - Muchea suite. Transition between Bassendean dunes and Pinjarra Plain. Discharge of groundwater into basins. Ponding of rainwater and groundwater occurs over impereable sediments.

Vegetation form
Bacataform - peripheral cover composed of a patch work of associations.
Maculiform - vegetation that completely covers a wetland, but composed of mosiacs of associations.
Heteroform - mosiac cover composed of a patchwork of associations.
Gradiform - vegetation which occurs in patches, or in mosiacs, or as islands, but which is overall zoned.
Concentriform - vegetation which entirely covers the wetland and is concentrically zoned in structure and/or composition; zonation may be symmetric or asymmetric.
Zoniform - vegetation which is peripheral and concentrically zoned; zonation may be symmetric or asymmetric.

Hydrology of individual wetlands

Monthly surface and groundwater data were used to describe the hydrological regime of each of the study wetlands and to identify changes over 20, 10 and 5 year periods. Hydrological parameters described included mean minimum and mean maximum water depths, mean seasonal amplitude between minimum and maximum levels, the mean number of months per year a wetland was completely dry and the season of peak water levels. These parameters were chosen as they have previously been identified as the most relevant to the composition and structure of wetland vegetation communities (Roberts et al., 1999).

Lake Banganup

Staff gauge data for Lake Banganup (Figure 1.2) indicated that water levels have fluctuated widely since records commenced in 1963, however, the long-term trend was for constant levels. Table 1.5 presented seasonal (May-June) mean surface water levels for 20, 10 and five year periods. This data suggested that levels were higher over last five years than during the other two time periods. Despite rising water levels, seasonal amplitudes have decreased, the rate at which surface water levels rise (cm/month) has halved and the mean number of months per year Lake Banganup is completely dry has increased from 8.1 to 8.6.

Groundwater data was only available from 1992 and reflected the high water levels of that year (Figure 1.3). Seasonal decreases in water depths, amplitudes, rate of water level rise and a later season of flooding (September to October) (Table 1.6) were shown.

Table 1.5

Surface water parameters calculated from staff gauge data. Each parameter is presented for the 19 study wetlands for 20, 10 and 5 year periods. Minimum elevation represents the elevations of lake beds which were required to calculate mean, minimum and maximum surface water depths. Amplitude represents the variation in seasonal water depth.

					Hydrological Parameter					
Wetland/ time period (years)	Minimum elevation (mAHD)	mean surface water(cm)	mean min. surface water (cm)	mean max. surface water (cm)	amplitude surface water (cm)	mean no. months > mean min.	mean no. months dry	months min- max	rate water rise (cm/month)	season of peak level
Lake Banganup	12.7									
20		-15	-52	30	82	4.38	8.1	5.2	16	Aug-Sep
10		11	2	40	38	5.4	7	4.6	8	Sep-Oct
5		9	0	31	31	4	8.6	4.3	7	Sep-Oct
Beenyup Rd Swamp	24.63									
8		29	0	69	69	6.125	5.88	4.62	15	Sep-Oct
5		13	0	35	35	4.2	7.8	4.6	8	Sep-Oct
Bibra Lake	13.1									
20		172	125	208	83	9.05	0	6.6	13	Sep-Oct
10		195	147	204	84	9.9	0	6.6	13	Sep-Oct
5		161	111	200	89	10.8	0	6.4	14	Sep-Oct
Lake Goollelal	25.3									
20		173	134	211	77	10.43	0	6.25	12	Sep-Oct
10		184	149	223	74	10.7	0	6	12	Sep-Oct
5		185	146	222	76	10.2	0	6	13	Sep-Oct
Lake Jandabup	44.11									
20		52	0.8	90	82	10.76	0.71	6.16	13	Aug-Oct
10		51	10	89	79	10.3	0.9	6.28	13	Sep-Oct
5		39	1	80	79	9.8	1.8	6.6	15	Sep-Oct
Lake Joondalup	15.4									
20		155	109	195	86	10.81	0	6.25	14	Sep-Oct
10		154	104	196	92	10.1	0	6	15	Sep-Oct
5		134	81	178	97	10.6	0	5.87	16	Sep-Oct
North Kogolup Lake	14.6									
5		36	-4	71	75	10.5	2.75	5.2	14	Sep
South Kogolup Lake	13.8									
20		88	27	141	114	9.71	1.19	6.1	18	Sep-Oct
10		117	58	163	105	10	0.7	6	18	Sep-Oct
5		92	37	145	108	5	1.4	5.4	20	Sep-Oct
Lexia 86	48.31									
3		9	0	30	30	4.3	7.7	4.3	7	Sep-Oct
Lexia 186	48.33									
3		2	0	23	23	1	11	1.33	17	Sep
Lake Mariginiup	41.3									
20		49	-1	91	92	10	0.4	6.05	15	Sep-Oct
10		51	11	85	74	9.9	0	5.9	12	Sep-Oct
5		35	-10	68	78	12	0	5.6	14	Sep-Oct
Epp Wetland 173	50.1									
3		59	10	102	92	1	10	4.67	2	Aug-Oct
North Lake	12.38									
20		175	110	223	113	9.76	0.14	5.7	20	Sep-Oct
10		156	98	203	105	9.4	0.3	6.1	17	Sep-Oct
5		111	55	159	104	10	0.6	6.43	16	Sep-Oct
Lake Nowergup	13.11									
20		360	324	395	71	11	0	7.2	10	Sep-Oct
10		353	314	389	75	10.9	0	7.3	10	Sep-Oct
5		345	299	385	86	10.8	0	7.6	11	Sep-Oct
Shirley Balla Swamp	25									
5		28	-3	58	61	11.6	5.6	4.8	13	Sep-Oct
Thomsons Lake	11.8									
20		57	6	102	96	10.48	2.1	5.05	19	July-Aug
10		74	38	115	77	8.2	0.5	4.8	16	July-Aug
5		45	16	84	68	9.4	0	4.4	15	July-Aug
Twin Bartram Swamp	23									
8		52	7	100	93	8.62	3.4	5	19	Sep-Oct
5		39	0	84	84	7.8	4.2	5	17	Sep-Oct
Wilgarup Lake	6									
5		17	0	48	48	3.8	8.2	3.2	15	Sep-Oct
Lake Yonderup	5.91									
20		-1	-19	11	29	10.05	3.71	5.6	5	July-Sep
10		6	5	10	5	8.2	0	6	1	Aug-Sep
5		5	3	8	5	8.8	0	6	1	Aug-Sep

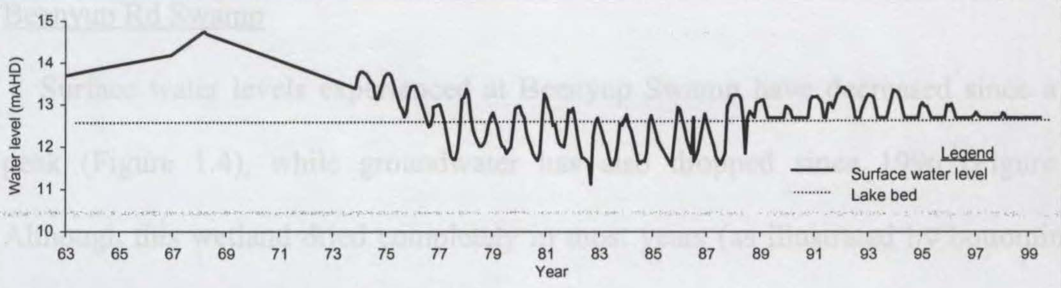


Figure 1.2: Lake Banganup monthly surface water levels (1963-2000)

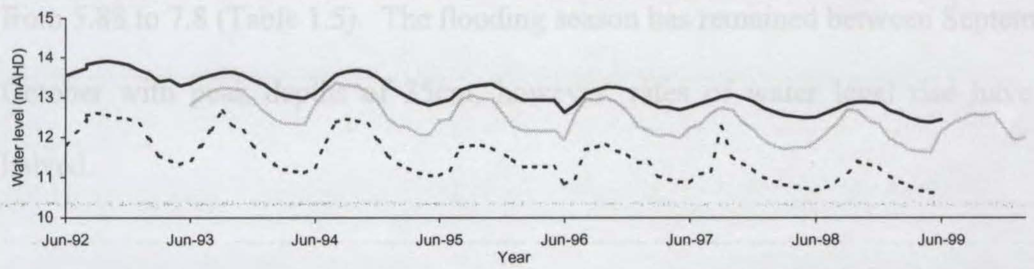


Figure 1.3: Lake Banganup groundwater levels (1992-2000)

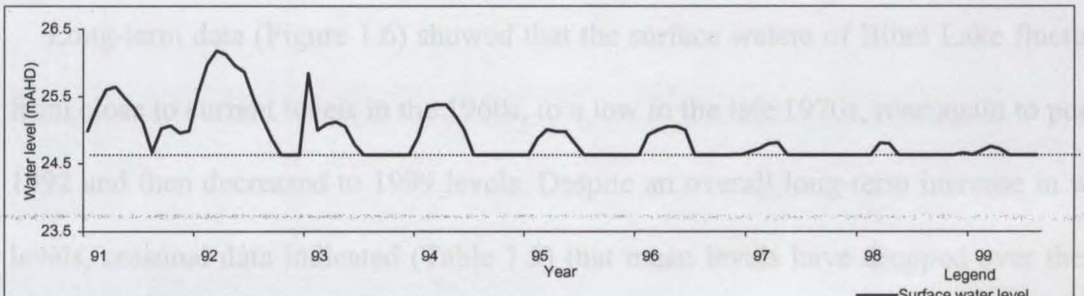


Figure 1.4: Beenyup Rd.Swamp monthly surface water levels (1991-2000)

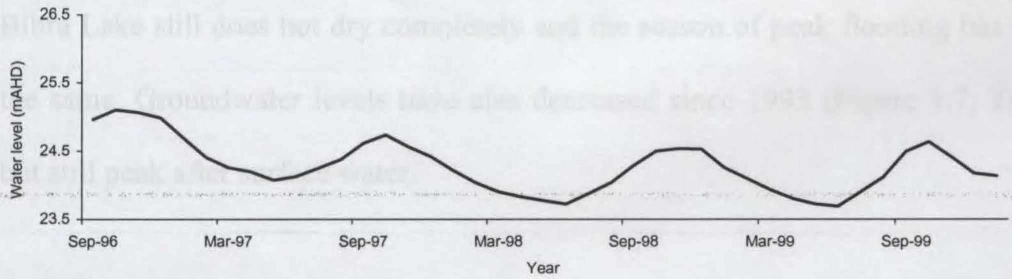


Figure 1.5: Beenyup Rd Swamp groundwater levels (1996-2000)

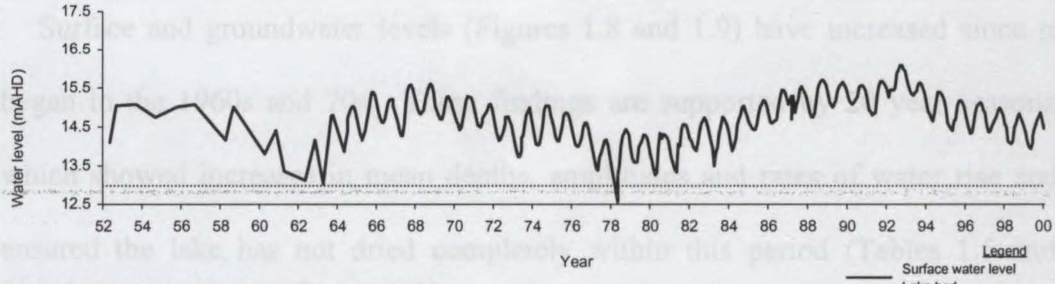


Figure 1.6 : Bibra Lake monthly surface water levels (1952-2000)

Beenyup Rd Swamp

Surface water levels experienced at Beenyup Swamp have decreased since a 1992 peak (Figure 1.4), while groundwater has also dropped since 1996 (Figure 1.5). Although this wetland dried completely in most years (as illustrated by bottoming-out of data points in Figure 1.4) the mean number of months it remains dry has increased from 5.88 to 7.8 (Table 1.5). The flooding season has remained between September and October with peak depths of 35cm, however, rates of water level rise have almost halved.

Bibra Lake

Long-term data (Figure 1.6) showed that the surface waters of Bibra Lake fluctuated from close to current levels in the 1960s, to a low in the late 1970s, rose again to peak in 1992 and then decreased to 1999 levels. Despite an overall long-term increase in water levels, seasonal data indicated (Table 1.5) that mean levels have dropped over the last 20 years. Seasonal amplitudes and rate of water rise have increased over that time. Bibra Lake still does not dry completely and the season of peak flooding has remained the same. Groundwater levels have also decreased since 1993 (Figure 1.7, Table 1.6), but still peak after surface water.

Lake Goollelal

Surface and groundwater levels (Figures 1.8 and 1.9) have increased since records began in the 1960s and 70s. These findings are supported by 20 year seasonal data which showed increases in mean depths, amplitudes and rates of water rise and have ensured the lake has not dried completely within this period (Tables 1.5 and 1.6). September and October remained the months of peak water levels, which reached depths in excess of 2m.

Table 1.6

Groundwater bore parameters for 19 study wetlands. Bore codes are presented for wetlands where data for more than 1 bore was available.

Wetland bore and transect	Time period (years)	Mean min. seasonal water level (m)	Mean max. seasonal water level (m)	Seasonal amplitude (m)	No. months min-max	Rate water level rise (cm/month)	Season of peak levels
Lake Banganup LB2	7	0.08	0.7	0.62	5.57	11.13	Sep-Oct
	3	-0.21	0.38	0.59	5.37	10.99	Oct
Beenyup Rd Swamp	3	-0.78	0.16	0.94	6	15.67	Oct-Nov
Bibra Lake BM5A	5	3.3	4.06	0.76	6.4	11.88	Oct
Lake Goollelal	20	1.12	1.9	0.78	6.33	12.32	Aug-Oct
	10	1.26	2	0.74	5.8	12.76	Sep-Oct
	5	1.24	2.05	0.81	5.6	14.46	Sep-Oct
Lake Jandabup JB12A	20	0.86	1.8	0.94	5.74	16.38	Sep
	10	0.71	1.61	0.9	5.89	15.28	Sep-Oct
	5	0.49	1.41	0.92	5.6	16.43	Sep-Oct
Lake Joondalup 8281	20	2.78	3.6	0.82	6	13.67	Sep-Oct
South	10	2.75	3.61	0.86	6.11	14.08	Sep-Oct
	5	2.46	3.37	0.91	6.4	14.22	Sep-Nov
Lake Joondalup JP 20C	10	1.51	2.13	0.62	6.7	9.25	Oct
East	5	1.24	1.97	0.73	6.2	11.77	Oct
Lake Joondalup JP 18C	10	-3.55	-2.81	0.74	5.7	12.98	Sep-Nov
North	5	-3.68	-2.91	0.77	5.2	14.81	Sep-Oct
North Kogolup Lake	5	1.65	2.94	1.29	5.2	24.81	Oct
South Kogolup Lake	no bore						
Lexia 86 GNM16	4	-0.66	0.42	1.08	5.5	19.64	Sep-Oct
Lexia 186 GNM15	4	-1.11	-0.13	0.98	5.75	17.04	Sep-Oct
Lake Mariginiup MS10	20	-0.24	0.65	0.89	6.1	14.59	Sep-Oct
	10	-0.32	0.56	0.88	6.3	13.97	Sep-Oct
	5	-0.51	0.36	0.87	5.8	15	Sep-Oct
Wetland 173 GNM14	4	-0.9	0.8	0.7	5	14	Aug-Oct
North Lake	3	-0.14	0.85	0.99	6.43	15.4	Oct-Nov
Lake Nowergup LN 2/89	10	2.22	3.47	1.25	6.6	18.94	Aug-Nov
North	5	1.93	3.51	1.58	7.2	21.94	Oct-Nov
Lake Nowergup LN 6/89	10	1.1	2.83	1.73	5.5	31.45	Aug-Nov
South	5	0.88	2.8	1.92	5.4	35.56	Oct-Nov
Shirley Balla Swamp	3	-0.59	0.58	1.17	6	19.5	Oct
Thomsons Lake TM 4C	10	0.24	1.21	0.97	4.7	20.64	Aug-Oct
Transect 2	5	-0.02	1.03	1.05	4.33	24.25	Aug-Oct
Thomsons Lake TM 9C	10	-0.28	0.76	1.04	5	20.8	Aug-Oct
Transects 3&4	5	-0.46	0.42	0.88	5	17.6	Sep-Oct
Twin Bartram Swamp	3	-0.06	0.86	0.92	5.67	16.23	Oct
Wilgarup Lake	3	-1.04	-0.14	0.9	6.67	13.49	Oct
Yonderup Lake	10	1.93	2.25	0.32	5.88	5.44	Aug-Sep
	5	1.86	2.21	0.35	6	5.83	Aug-Sep

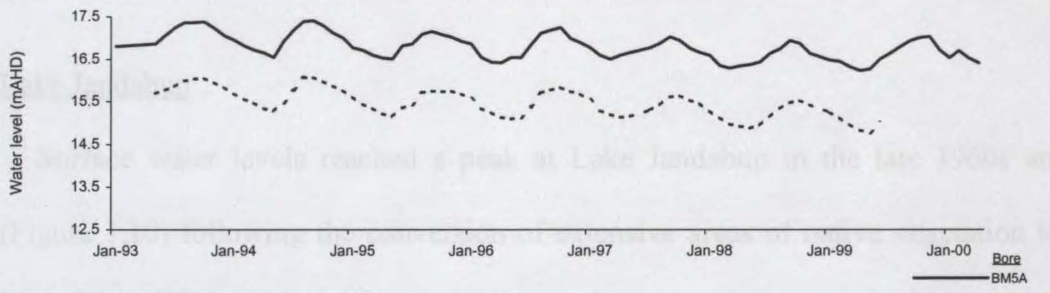


Figure 1.7: Bibra Lake groundwater levels (1993-2000)

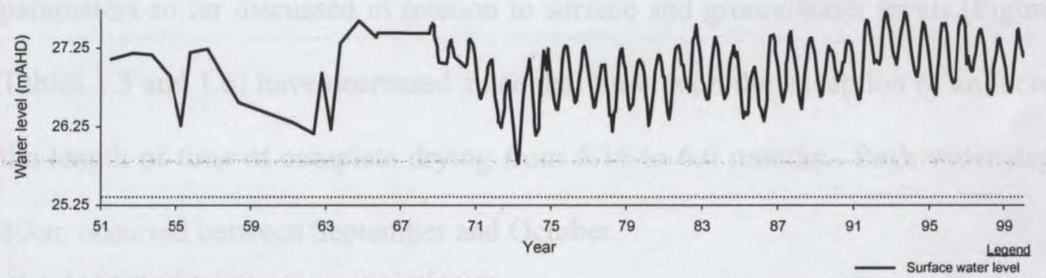


Figure 1.8: Lake Goollelal monthly surface water levels (1951-2000)

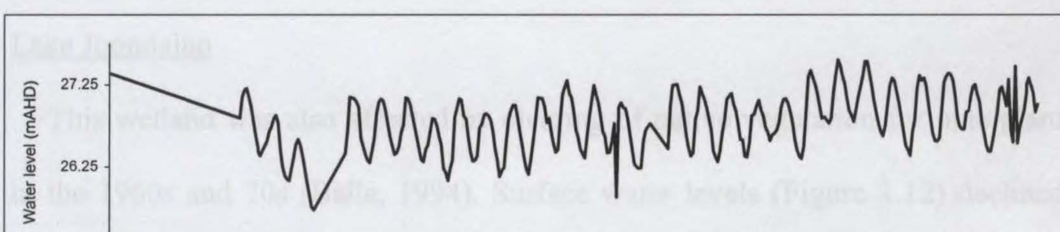


Figure 1.9: Lake Goollelal monthly groundwater water levels (1965-2000)

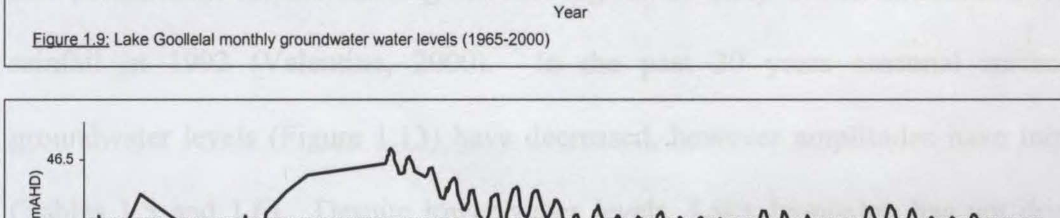


Figure 1.10: Lake Jandabup monthly surface water levels (1954-2000)

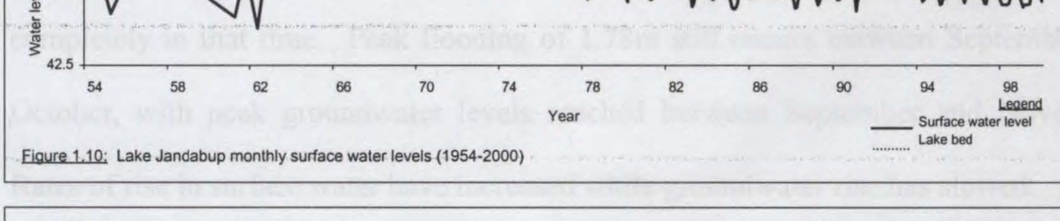


Figure 1.11: Lake Jandabup groundwater levels (1977-2000)

Lake Jandabup

Surface water levels reached a peak at Lake Jandabup in the late 1960s and 70s (Figure 1.10) following the conversion of extensive areas of native vegetation to pine plantations (Balla, 1994) coupled with wetter than average years. All of the hydrological parameters so far discussed in relation to surface and groundwater levels (Figure 1.11, Tables 1.5 and 1.6) have decreased since that time, with the exception of an increase in the length of time of complete drying from 6.16 to 6.6 months. Peak water depths of 80cm occurred between September and October.

Lake Joondalup

This wetland was also affected by clearing of native vegetation for pine plantations in the 1960s and 70s (Balla, 1994). Surface water levels (Figure 1.12) declined from that period until further clearing for housing in the early 1990s coincided with high rainfall in 1992 (Valentine, 2000). In the past 20 years seasonal surface and groundwater levels (Figure 1.13) have decreased, however amplitudes have increased (Tables 1.5 and 1.6). Despite lower water levels, Lake Joondalup has not dried out completely in that time. Peak flooding of 1.78m still occurs between September and October, with peak groundwater levels reached between September and November. Rates of rise in surface water have increased while groundwater rise has slowed.

North Kogolup Lake

Water data for North Kogolup was only available from 1993. Figures 1.14 and 1.15 illustrated that ground and surface water levels declined over this time. On average this wetland is dry for 2.75 months of the year with peak surface water depths

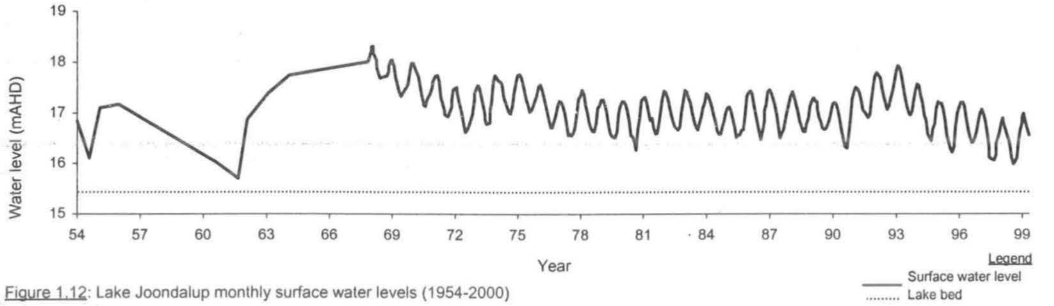


Figure 1.12: Lake Joondalup monthly surface water levels (1954-2000)

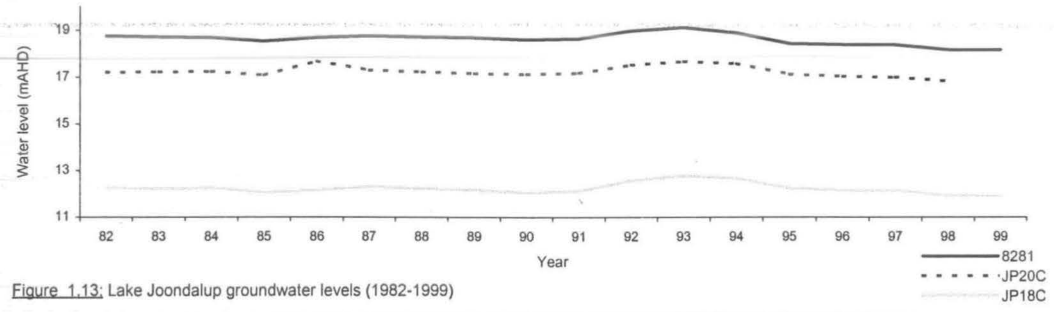


Figure 1.13: Lake Joondalup groundwater levels (1982-1999)

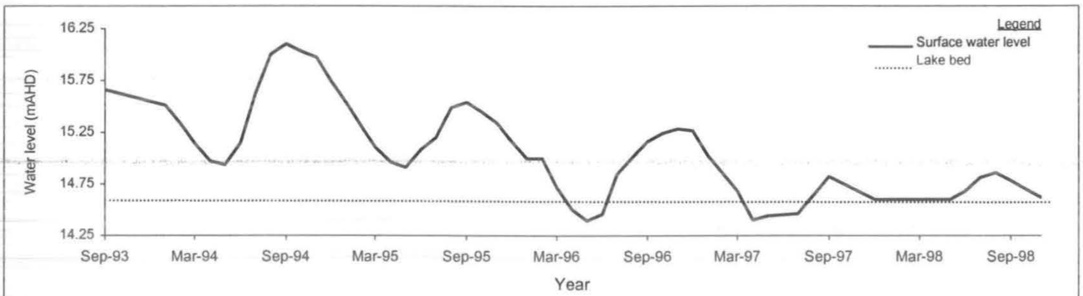


Figure 1.14: Nth Kogolup Lake monthly surface water levels (1993-1998)

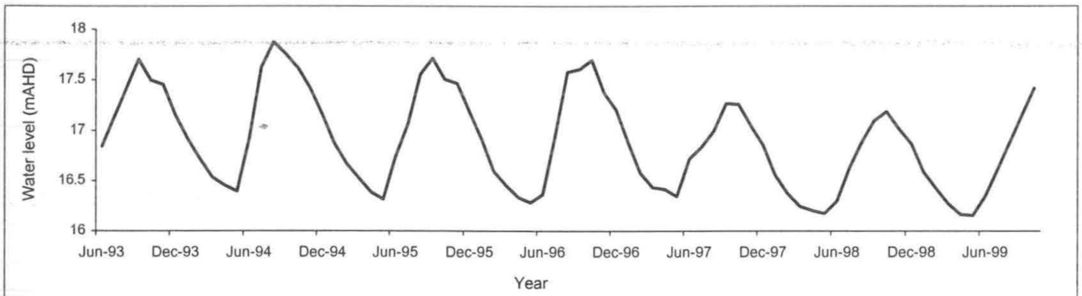


Figure 1.15: North Kogolup Lake groundwater levels (1993-1999)

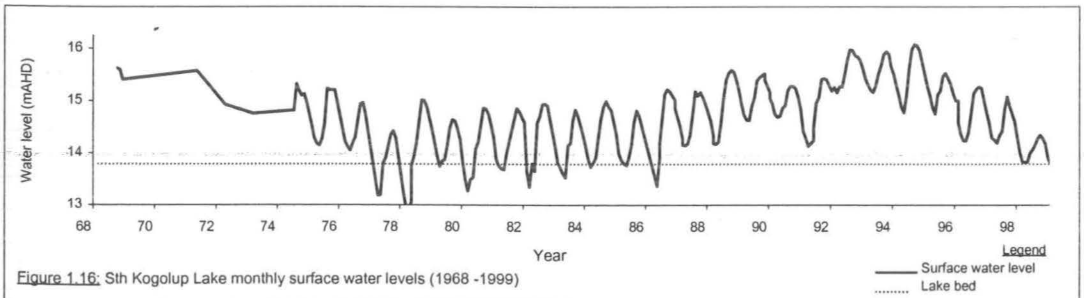


Figure 1.16: Sth Kogolup Lake monthly surface water levels (1968 -1999)

of 71cm reached in September and highest groundwater levels in October (Tables 1.5 and 1.6). North Kogolups close proximity to South Kogolup suggests that both wetlands have experienced similar patterns of drying.

South Kogolup Lake

Although surface water levels over the last five years match the decline experienced in North Kogolup, long-term monthly data indicates that levels have fluctuated by more than three meters since the late 1960s (Figure 1.16). Lowest levels occurred in the late 1970s and a peak was reached in 1992. Seasonal data reflected this fluctuation, with minimums and maximums peaking at a ten year mean while still increasing between 20 and five year means (Table 1.5). The mean number of months the wetland was completely dry has increased and the rate of water rise followed a similar pattern. Peak surface water depths of 78cm were recorded in September and October. No groundwater data was available for this wetland.

Lexia 86

The three years of surface water data available for this wetland indicated that it dried completely every year for a period of approximately 7.7 months (Table 1.5). Surface water levels have remained fairly constant during this time while groundwater has declined (Figures 1.17 and 1.18). Seasonal groundwater amplitudes (Table 1.6) are greater than surface water variations as is the rate of water level rise. This shallow wetland reached a depth of only 30cm during September and October, the same period during which peak groundwater levels were recorded.

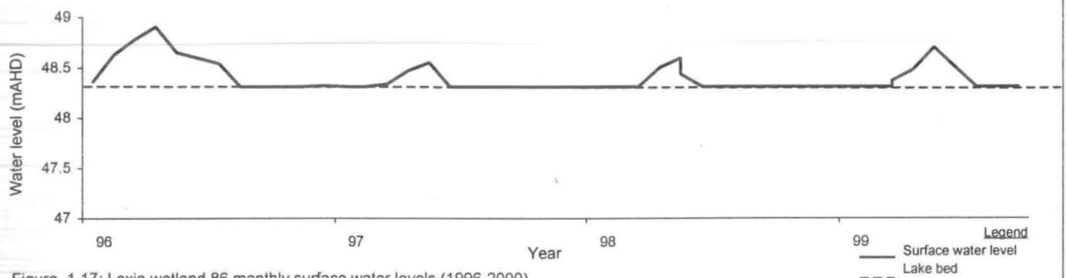


Figure 1.17: Lexia wetland 86 monthly surface water levels (1996-2000)

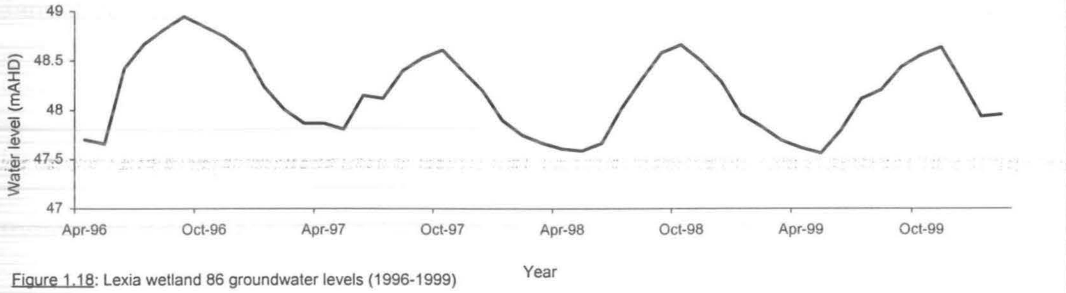


Figure 1.18: Lexia wetland 86 groundwater levels (1996-1999)

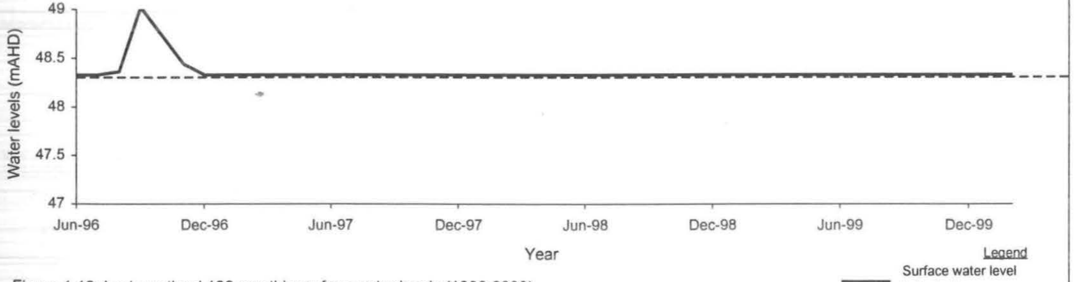


Figure 1.19: Lexia wetland 186 monthly surface water levels (1996-2000)

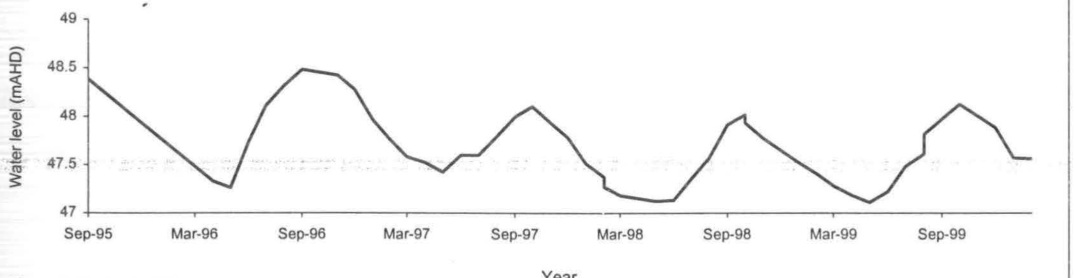


Figure 1.20 : Lexia 186 groundwater levels (1995-1999)

Lexia 186

Lexia 186 has also experienced drying over the last five years, however, both surface and groundwater have only declined slightly (Figures 1.19 and 1.20). The wetland was dry for 11 months of each of the past three years, reaching a mean depth of 23cm during September (Table 1.5). Rates of ground and surface water rises were similar (Tables 1.5 and 1.6).

Lake Mariginiup

Long-term surface water data for Lake Mariginiup showed a pattern similar to Lakes Jandabup and Joondalup with peak levels reached in the late 1960s following land clearing (Figure 1.21). Surface and groundwater levels have declined since that time (Figures 1.21 and 1.22). Seasonal data (Tables 1.5 and 1.6) supported these findings, indicating that all parameters have decreased over the past 20 years. The lake, however, remains wet throughout the year, peaking between September and October at a mean depth of 68cm.

Melaleuca Park Wetland 173

Figures 1.23 and 1.24 indicated that water levels have declined in this wetland over the past four years. Surface water occurred for only two months of year, September and October, reaching depths between 10cm and 102cm (Table 1.5). Groundwater levels also peaked during this time (Table 1.6).

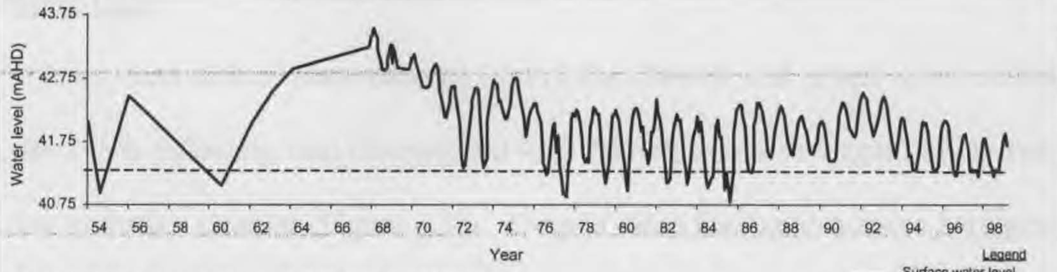


Figure 1.21: Lake Mariginiup monthly surface water levels (1954-2000)

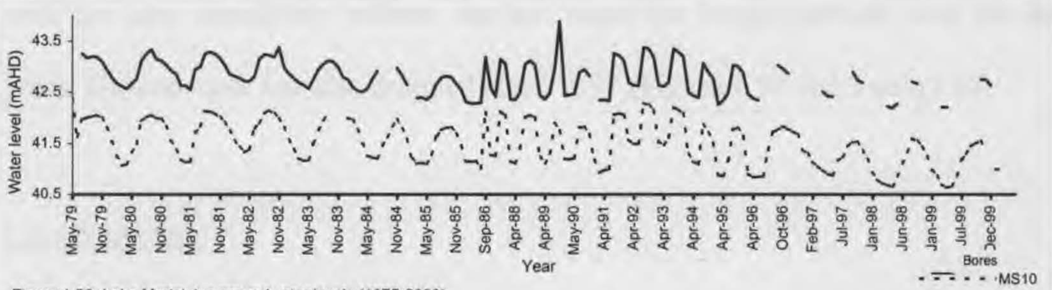


Figure 1.22: Lake Mariginiup groundwater levels (1975-2000)

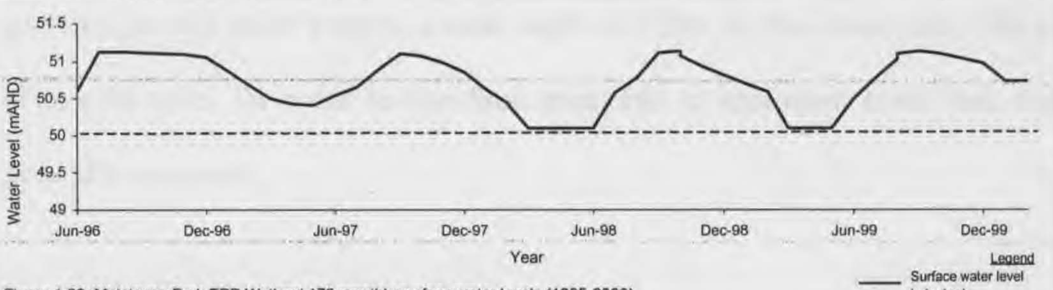


Figure 1.23: Melaleuca Park EPP Wetland 173 monthly surface water levels (1995-2000)

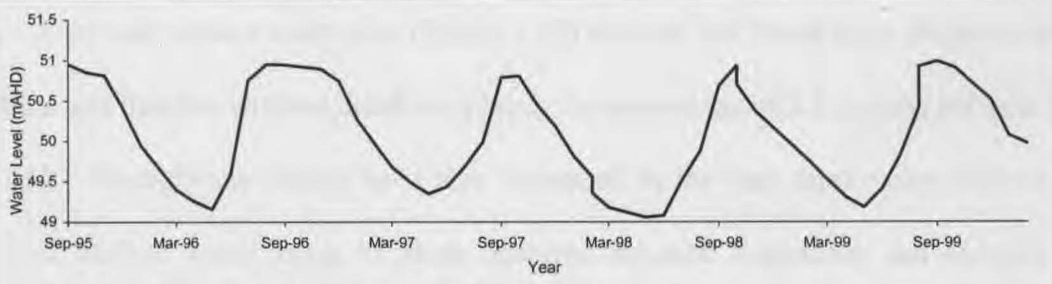


Figure 1.24 : Meleleuca Park EPP Wetland 173 groundwater levels (1995-2000)

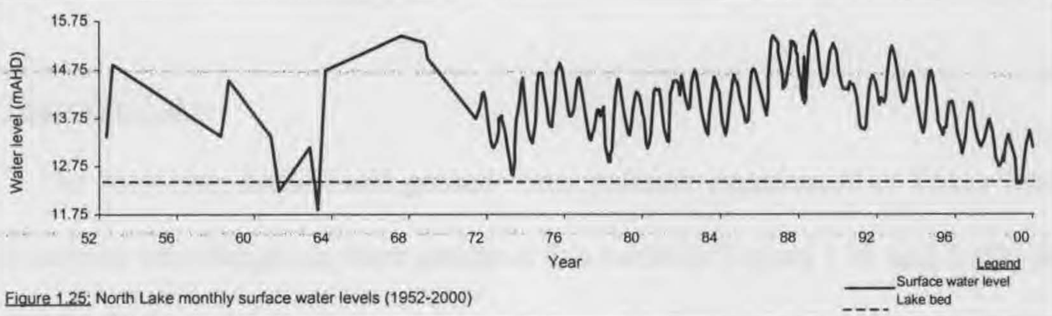


Figure 1.25: North Lake monthly surface water levels (1952-2000)

North Lake

Long-term surface water data for North Lake showed peak levels were reached in the late 1960s following land clearing and high rainfall events and again in the late 1980s due to further clearing (Figure 1.25). Despite these fluctuations and a long-term trend of constant water levels, Table 1.5 indicated that drying occurred over the last 20 years with the lake completely without surface water for longer periods over the last five years. Groundwater has also dropped since 1997 (Figure 1.26 and Table 1.6).

Lake Nowergup

This wetland has also dried over the last 20 years (Figures 1.27 and 1.28, Tables 1.5 and 1.6), but still holds water to a mean depth of 2.99m for the entire year. The number of months taken for water to rise from minimum to maximum levels has, however, generally increased.

Shirley Balla Swamp

Five year surface water data (Figure 1.29) showed that levels have dropped over that time and that this wetland dried completely for an average of 5.6 months per year (Table 1.5). Groundwater depths have also decreased in the past three years (Figure 1.30). Peak surface water levels of 58cm occurred between September and October while groundwater peaked during October (Tables 1.5 and 1.6).

Thomsons Lake

The long-term surface and ground water patterns experienced at Lakes Jandabup, Joondalup and Mariginiup were similar at this wetland (Figures 1.31 and 1.32). Surface and groundwater levels showed peaks around 1992, following heavy rainfall periods. Seasonal water levels have declined over the past 20 years to a mean depth of

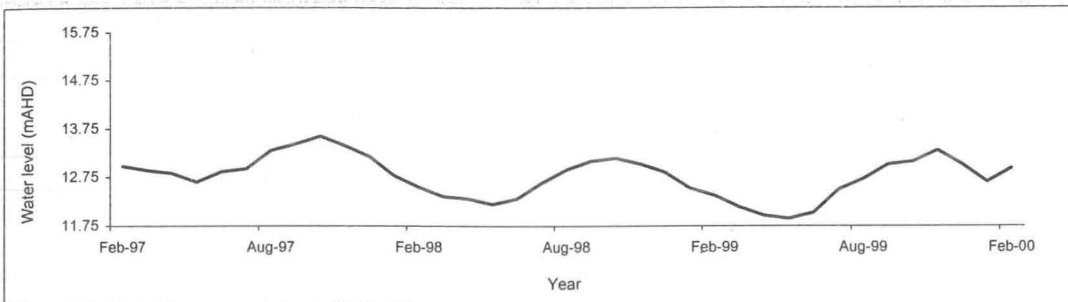


Figure 1.26: North Lake groundwater levels (1997-2000)

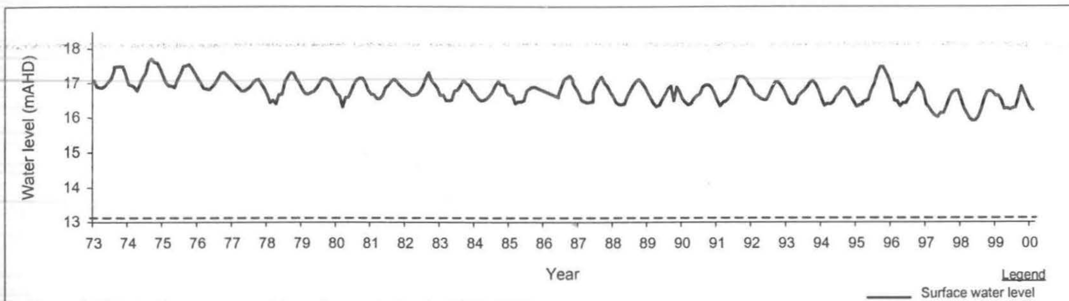


Figure 1.27: Lake Nowergup monthly surface water levels (1973-2000)

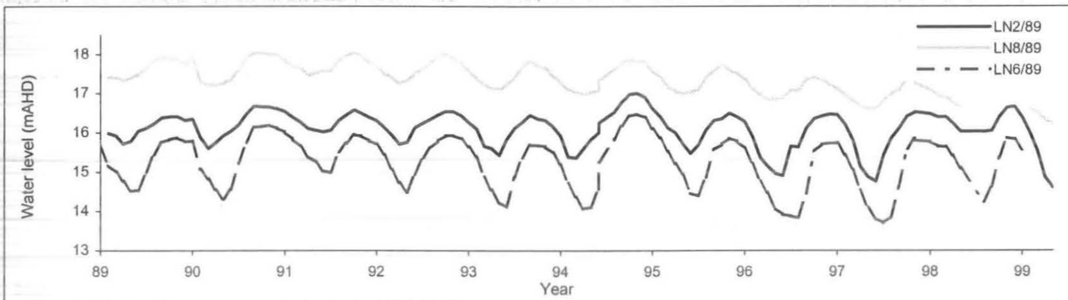


Figure 1.28: Lake Nowergup groundwater levels (1989-1999)

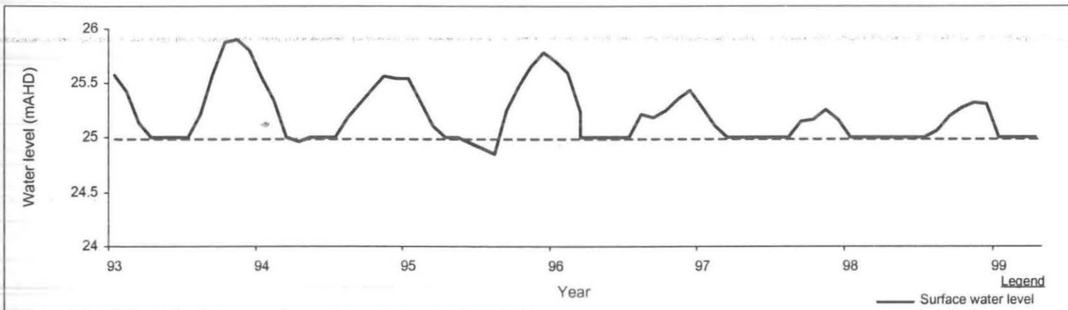


Figure 1.29: Shirley Balla Swamp monthly surface water levels (1993-2000)

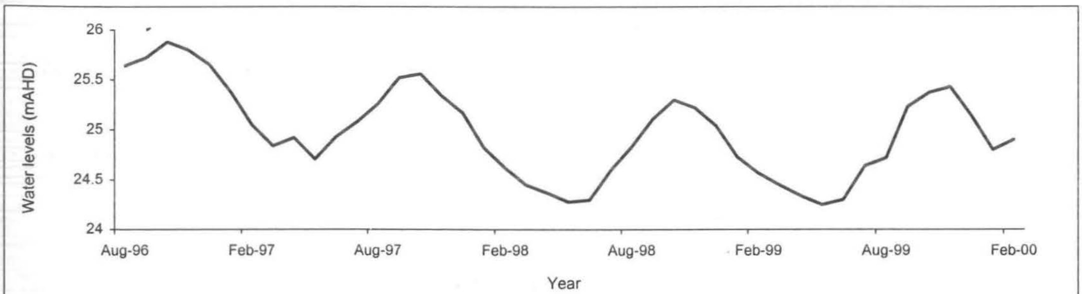


Figure 1.30: Shirley Balla Swamp groundwater levels (1996-2000)

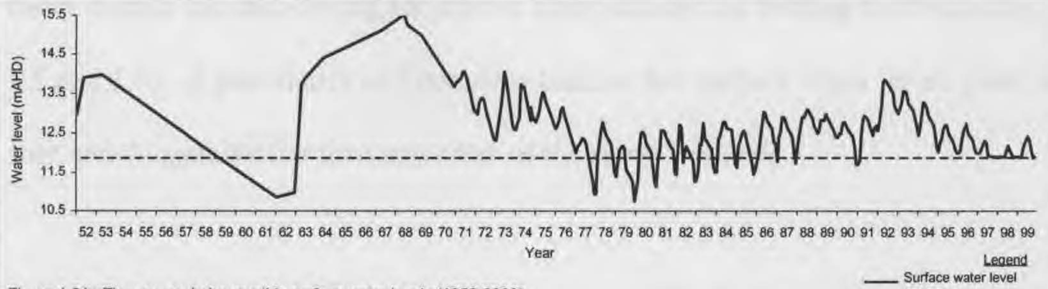


Figure 1.31: Thompsons Lake monthly surface water levels (1952-2000)

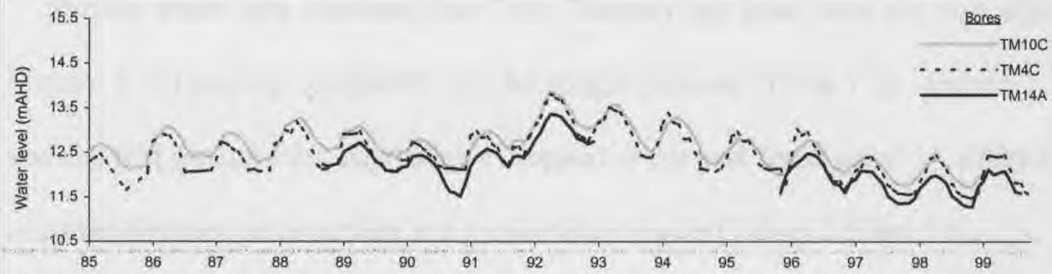


Figure 1.32 : Thompsons Lake groundwater levels (1985-2000) Year

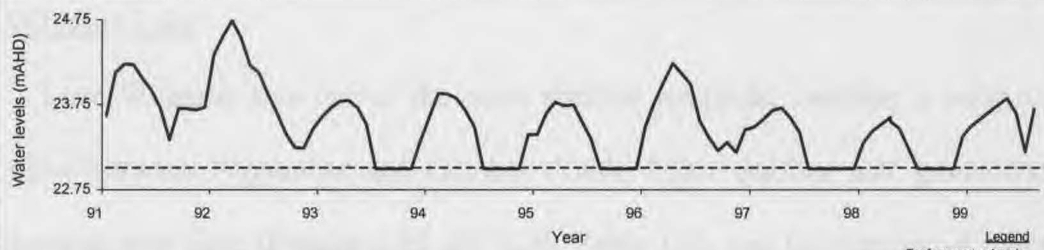


Figure 1.33: Twin Bartram Swamp monthly surface water levels (1991-2000)

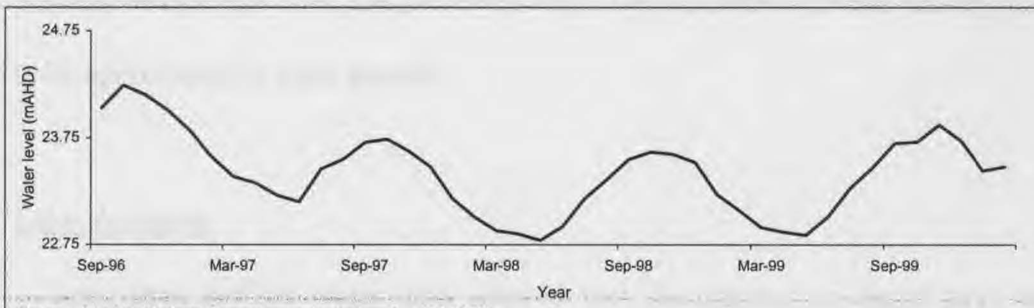


Figure 1.34: Twin Bartram Swamp groundwater levels (1996-2000)

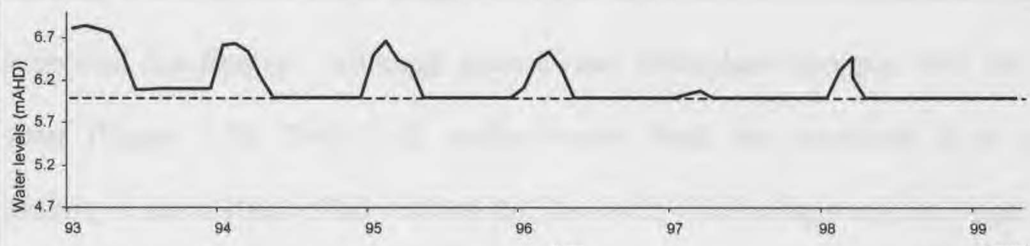


Figure 1.35: Lake Wilgarup monthly surface water levels (1993-1999)

84cm despite the lake drying for shorter time periods and wetting more quickly (Tables 1.5 and 1.6). A peculiarity of Thomsons Lake is that surface water levels peak between July and August, earlier than any other of the study wetlands.

Twin Bartram Swamp

Surface water data indicated that Twin Bartram has dried over the past eight years (Figure 1.33) staying completely dry for longer periods (Table 1.5). Figure 1.34 also showed that groundwater depths have dropped in the past three years. A slight time lag occurred between peak surface and groundwater levels (Tables 1.5 and 1.6).

Wilgarup Lake

Lake Wilgarup was one of the more shallow wetlands, reaching a mean depth of 48cm between September and October (Table 1.5). Surface and groundwater had dropped over time (Figures 1.35 and 1.36, Table 1.6), and the number of months this wetland completely dried has increased since 1993. Seasonal means showed this period to be approximately eight months.

Lake Yonderup

Long-term surface water data showed that fluctuations in depth have decreased markedly since the late 1980s (Figure 1.37). Declines in seasonal amplitudes (Table 1.5) supported this finding. Although groundwater levels have dropped over the past 20 years (Figure 1.38, Table 1.6), surface water depth has remained fairly constant, peaking at about 10cm. This wetland had, however, dried completely for longer periods in recent times. Surface and groundwater levels peaked between August and September at this site, which was earlier than all other sites with the exception of Thomsons Lake.

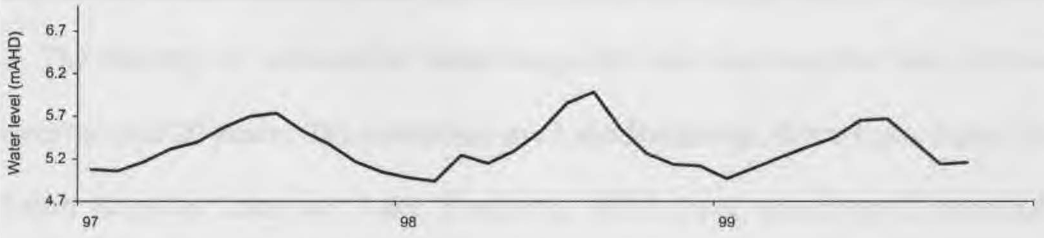


Figure 1.36: Lake Wilgarup groundwater levels (1997-1999)

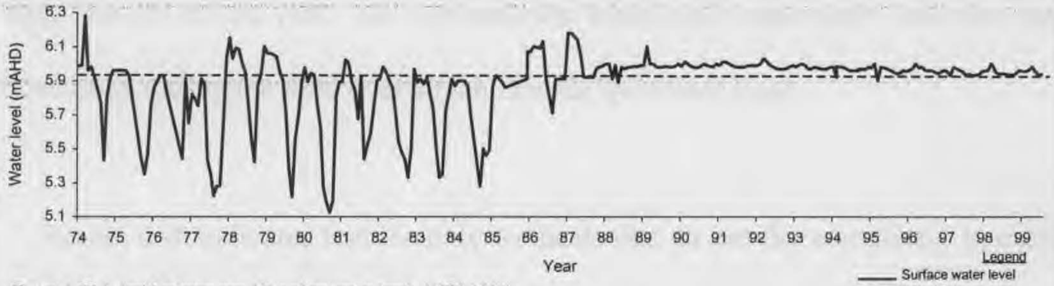


Figure 1.37: Lake Yonderup monthly surface water levels (1974-2000)

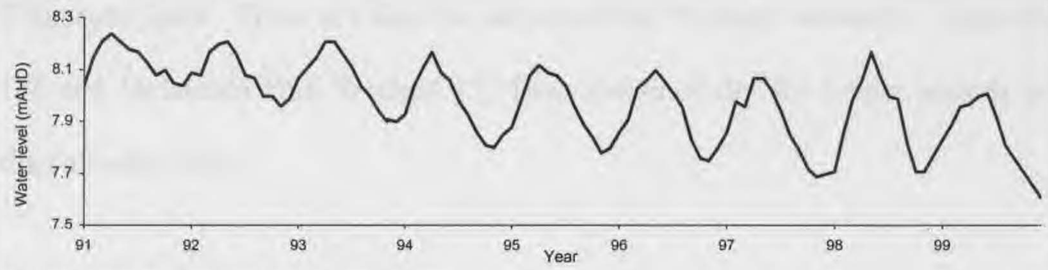


Figure 1.38 : Lake Yonderup groyndwater levels (1991-2000)

Summary of similarities and differences in hydrological regimes of study wetlands

The majority of wetlands for which long term data was available have become drier over the past 20 years. The exceptions are Lake Banganup, Bibra Lake, Lake Goollelal, South Kogolup Lake and Lake Yonderup, which have experienced increased mean water depths. All of these lakes other than Lake Goollelal still continue to dry for up to eight months of the year. All wetlands for which only short-term data was available have dried during the time over which records have been kept.

Recent data indicated that the only wetlands that do not dry completely in most years are Bibra Lake, Lake Goollelal, Lake Joondalup, Lake Mariginiup, Lake Nowergup and Thomsons Lake. These are also the largest of the 19 study wetlands. Lexia Wetland 186 and Melaleuca Park Wetland 173 have remained dry for longer periods per year than all other sites.

Hydrology and hydrological zone classification of individual plots

The elevation at the start and end of each of the 105 individual study plots was used to determine surface water depths and then to allocate each plot to a hydrological zone. Groundwater bore data were not used to establish groundwater depths as many of the bores were too far from the vegetation transects to allow accurate extrapolation of depths. Groundwater levels were therefore determined as the depth from the elevation of a transect to surface water as illustrated in Figure 1.39.

Banganup Lake

Despite lowering water levels, the hydrological zones found along this transect have remained the same over the past 20 years. Plot A was generally inundated for less than one month during spring to a depth no greater than 10cm (Table 1.7). Due to its location around the high water mark (Figure 1.39) it was placed into the littoral/supralittoral zone.

Although the elevational gradient rises sharply across plot B (Figure 1.39), the lower portion occurred in an area that was influenced by groundwater during winter rather than by surface water. The entire plot was therefore described as seasonally waterlogged. Plot C also remained dry, and as the mean maximum groundwater table was more than 2m below the surface, it was appointed to the terrestrial zone (Table 1.7).

Beenyup Rd Swamp

The hydrological zones of this transect also remained unchanged with time despite lowering water levels. Plot A flooded for one to two months during most winter seasons to a depth of 10-50cm (Table 1.7). As it was located below the high water mark (Figure 1.40) it fell into the grouping of littoral zone. The majority of plot B was also

Table 1.7

Surface water levels, duration of flooding and rate of rise or groundwater levels for monitored wetland plots over 20, 10 and 5 year periods. A-start represents the beginning of monitoring plot A. A-end represents the A and the beginning of plot B. The same technique is used to describe subsequent plots.

Transect	Period (years)	Plot A-start Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	A-end Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	B-end Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	C-end Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	D-end Mean mnth of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	E-end Mean mnth of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)
Banganup	20	0.35	-35	-72	10	0.2	-85	-122	-40	0	-265	-302	-220	0	-305	-342	-260								
	10	0.7	9	0	20	0.2	-59	-68	-30	0	-239	-248	-230	0	-279	-288	-250								
	5	0.4	-11	-20	11	0.1	-61	-70	-41	0	-241	-250	-219	0	-281	-290	-259								
Beenyup	8	3.38	-8	-37	32	3.38	-8	-37	32	0	-68	-97	-28	0	-188	-217	-148								
	5	1.6	-20	-37	-2	1.6	-20	-37	-2	0	-84	-97	-62	0	-204	-217	-182								
Bibra Lake	20	6.35	2	-35	48	5.4	-8	-45	38	2.8	-48	-55	28	0.4	-88	-95	-12								
	10	7.8	25	-13	44	7.2	15	-23	34	4.2	-5	-33	24	0.7	-65	-73	-16								
	5	4.4	-9	-49	40	4	1	-59	30	0.6	-59	-69	20	0	-99	-109	-2								
Goollelal	20	10.8	43	-16	61	9.85	23	-18	59	9.1	18	-21	59	7.95	13	-31	46	6.75	3	-31	36				
	10	11.8	54	-1	73	11.2	34	-3	71	10.7	29	-6	68	9.9	24	-16	58	8.2	14	-26	48				
	5	12	55	-4	72	11	35	-6	70	10.2	30	-9	67	9.4	25	-19	57	7.6	15	-29	47				
Jandabup	20	0	-151	-202	-113	0	-186	-237	-148	0	-298	-349	-260	0	-335	-386	-297	0	-348	-399	-310				
	10	0	-152	-193	-114	0	-187	-228	-149	0	-299	-340	-261	0	-336	-377	-298	0	-349	-390	-311				
	5	0	-164	-202	-123	0	-199	-237	-158	0	-311	-349	-270	0	-348	-386	-386	0	-361	-399	-320				
Joondalup East	20	4.55	-15	-63	25	0	-155	-201	-115	0	-105	-151	-65	0	-85	-131	-45	0	-225	-271	-185				
	10	4.8	-16	-66	26	0	-156	-206	-116	0	-106	-156	-64	0	-86	-136	-44	0	-226	-276	-184				
	5	2.8	-36	-89	8	0	-176	-229	-132	0	-136	-179	-82	0	-106	-159	-62	0	-246	-299	-202				
Joondalup North	20	0.55	25	-21	65	0	-155	-201	-115	0	-255	-301	-215	0	-295	-341	-255	0	-655	-701	-615				
	10	1.1	24	-26	66	0	-156	-206	-114	0	-256	-306	-214	0	-296	-346	-254	0	-656	-706	-614				
	5	0.4	4	-49	48	0	-176	-229	-132	0	-276	-329	-232	0	-306	-369	-272	0	-676	-729	-632				
Joondalup South	20	5.6	15	-31	55	1.25	-25	-71	15	0.1	-81	-122	-39	0	-152	-191	-105	0	-425	-471	-385				
	10	5.7	14	-36	56	1.9	-26	-76	16	0.2	-82	-125	-40	0	-153	-196	-104	0	-426	-476	-384				
	5	3.4	-6	-59	38	0.6	-46	-99	-2	0	-102	-154	-62	0	-173	-219	-122	0	-446	-499	-402				
Nth Kogolup 1	5	0	-264	-304	-229	0	-464	-504	-429	0	-644	-684	-609	0	-764	-804	-729	0	-864	-904	-829				
Nth Kogolup 2	5	0	-204	-244	-169	0	-284	-324	-249	0	-424	-464	-389	0	-604	-644	-569	0	-764	-804	-729				
Sth Kogolup	20	2.7	-32	-93	21	2.7	-32	-93	21	2	-52	-113	1	1.65	-72	-133	-19	1.65	-92	-133	-19				
	10	4.8	-3	-62	46	4.8	-3	-62	43	3.5	-23	-82	23	1.5	-43	-102	3	1.5	-63	-102	3				
	5	3	-28	-83	25	3	-28	-83	25	2.2	-48	-102	5	2	-68	-123	-15	2	-88	-123	-15				
Lexia 86	3	0.6	-9	0	30	0	-67	-76	-46	0	-95	-104	-74	0	-101	-110	-80	0	-85	-94	-64				
Lexia 186	3	0	-148	-150	-127	0	-198	-200	-177	0	-192	-194	-171	0	-208	-210	-187	0	-229	-231	-208				
Mariginiup	20	6.55	29	-21	71	4.1	-14	-64	28	2.1	-51	-101	-9	0	-69	-111	-19	0	-61	-121	-29	0	-71	-131	-39
	10	3.2	31	-9	65	3.8	-12	-52	22	1.7	-49	-89	-15	0	-67	-99	-25	0	-59	-109	-35	0	-69	-119	-45
	5	2.6	15	-30	48	1.8	-28	-73	5	1	-65	-110	-32	0	-83	-120	-42	0	-75	-130	-52	0	-85	-140	-62
Wetland 173	3	2	-10	-85	8	0	-61	-110	-18	0	-84	-133	-41	0	-87	-136	-44	0	-88	-137	-45				
North Lake 1	20	4.1	13	-52	61	2.75	-27	-92	21	1.15	-67	-132	-19	0.08	-107	-152	-39								
	10	3.3	-6	-64	41	2.5	-46	-104	1	2.1	-86	-144	-39	1.6	-126	-164	-59								
	5	0.8	-51	-107	-3	0.4	-91	-147	-43	0	-131	-87	-183	0	-171	-227	-123								

Table1.7 continued

Transect	Period (years)	Plot			A-start			A-end				B-end				C-end				D-end	
		Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	Mean mnths of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)	Mean mnth of flood	Mean depth (cm)	Mean min depth (cm)	Mean max depth (cm)
North Lake 2	20	5.15	33	-32	81	2.75	-27	-92	21	1.15	-107	-172	-59	0	-187	-252	-139	0	-247	-312	-199
	10	4.4	14	-44	61	2.5	-46	-104	1	0.7	-126	-184	-79	0	-206	-264	-159	0	-266	-324	-219
	5	1	-31	-87	103	0.4	-91	-147	-43	0	-171	-227	-123	0	-251	-307	-203	0	-311	-367	-263
Nowergup North	20	0	-79	-115	-44	0	-199	-235	-164	0	-269	-305	-234	0	-419	-455	-384	0	-519	-555	-484
	10	0	-86	-125	-50	0	-206	-245	-170	0	-276	-315	-240	0	-426	-465	-390	0	-526	-565	-490
	5	0	-94	-140	-54	0	-214	-260	-174	0	-284	-330	-244	0	-434	-480	-394	0	-534	-580	-494
Nowergup South	20	0.02	31	-57	66	0	-179	-215	-144	0	-469	-505	-434	0	-669	-705	-634	0	-899	-935	-864
	10	0.3	24	-67	60	0	-186	-225	-150	0	-476	-515	-440	0	-676	-715	-640	0	-906	-945	-870
	5	0.6	16	-82	56	0	-194	-240	-154	0	-484	-530	-444	0	-684	-730	-644	0	-914	-960	-874
Shirley Balla 1	5	0	-82	-113	-52	0	-82	-113	-52	0	-142	-173	-112	0	-212	-243	-182	0	-292	-323	-262
Shirley Balla 2	5	0.4	-52	-83	-22	0	-72	-103	-42	0	-72	-103	-42	0	-92	-123	-62	0	-112	-143	-82
Thomsons 2	20	0.4	-113	-169	-73	0	-123	-174	-78	0	-203	-254	-158	0	-183	-234	-138	0	-163	-214	-118
	10	0.8	-96	-137	-60	0	-106	-142	-65	0	-186	-222	-145	0	-166	-202	-125	0	-146	-182	-105
	5	0	-125	-159	-91	0	-135	-164	-96	0	-215	-244	-176	0	-195	-224	-156	0	-175	-204	-136
Thomsons 3	20	0.2	-113	-174	-78	0	-133	-184	-88	0	-243	-294	-198	0	-593	-644	-548	0	-683	-734	-638
	10	0.4	-96	-142	-65	0	-116	-152	-75	0	-226	-262	-185	0	-576	-612	-535	0	-666	-702	-625
	5	0	-125	-164	-96	0	-145	-174	-106	0	-255	-284	-216	0	-605	-634	-566	0	-695	-724	-656
Thomsons 4	20	1.3	-23	-76	22	0.5	-83	-134	-38	0	-183	-234	-138	0	-403	-454	-358	0	-623	-674	-578
	10	2.1	-6	-42	35	1.2	-66	-102	-25	0	-166	-202	-125	0	-386	-422	-345	0	-606	-642	-565
	5	1	-35	-64	4	0.4	-95	-124	-124	0	-195	-224	-156	0	-415	-444	-376	0	-635	-664	-596
Twin Bartram	8	6.7	12	-33	60	4.88	-8	-53	40	1.62	-48	-93	0	0	-108	-153	-60	0	-188	-233	-140
	5	4.2	-1	-40	44	3.4	-21	-60	24	0.6	-61	-100	-16	0	-121	-160	-76	0	-201	-240	-156
Wilgarup	5	3.8	14	-3	45	2.8	-6	-23	25	0.6	-42	-59	-11	0	-68	-85	-37	0	-100	-117	-69
Yonderup	20	0	-170	-188	-158	0	-163	-181	-151	0	-154	-172	-142	0	-152	-170	-140	0	-166	-184	-154
	10	0	-163	-164	-159	0	-156	-157	-152	0	-147	-148	-143	0	-145	-146	-141	0	-159	-160	-155
	5	0	-64	-166	-161	0	-157	-159	-154	0	-148	-150	-145	0	-146	-148	-143	0	-160	-162	-157

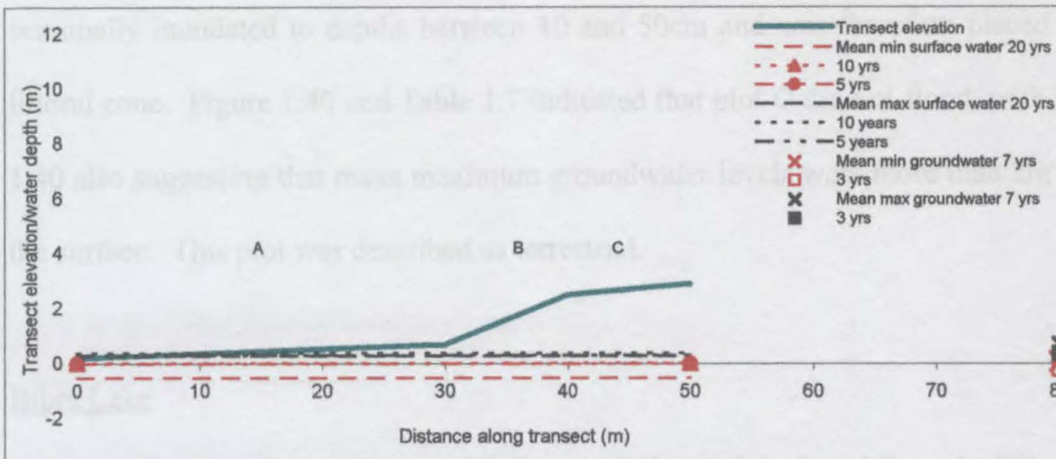


Figure 1.39: Hydrological regime experienced across the Lake Banganup vegetation monitoring plots over a 20 year period.

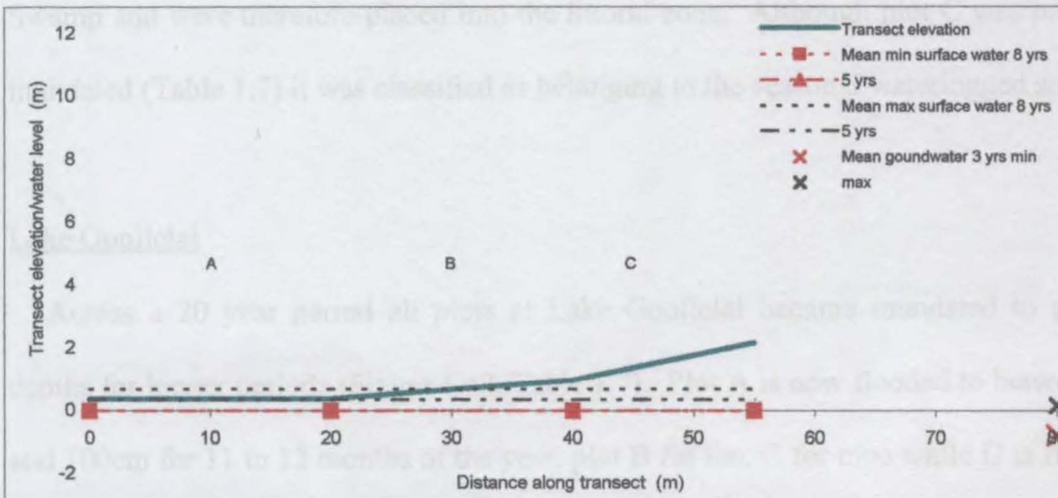


Figure 1.40: Hydrological regime experienced across the Beenyup Rd Swamp vegetation monitoring plots over a 20 year period.

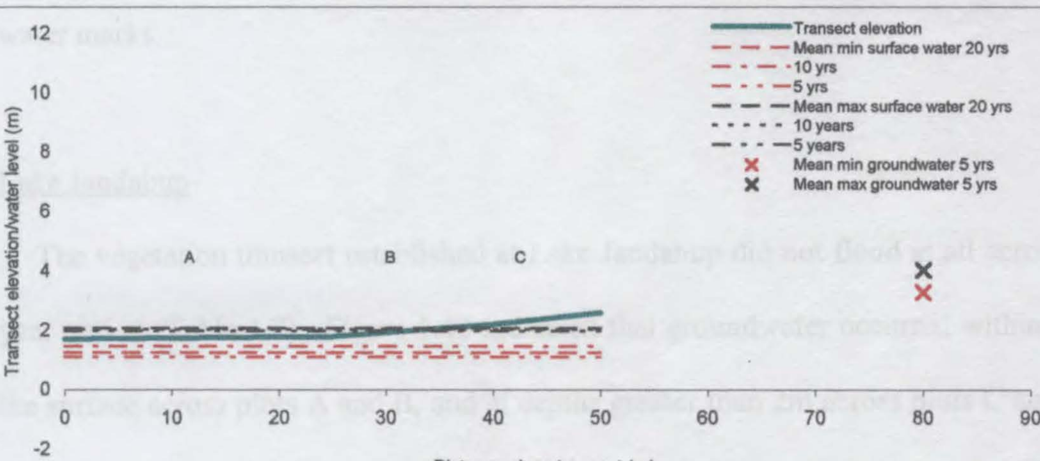


Figure 1.41: Hydrological regime experienced across the Bibra Lake vegetation monitoring plots over a 10 year peiod.

seasonally inundated to depths between 10 and 50cm and was therefore placed in the littoral zone. Figure 1.40 and Table 1.7 indicated that plot C did not flood, with Figure 1.40 also suggesting that mean maximum groundwater levels were more than 2m below the surface. This plot was described as terrestrial.

Bibra Lake

Although only inundated to depths of around 10cm, plots A and B on the Bibra Lake transect (Figure 1.41) experienced similar flooding patterns to plots A and B at Beenyup Swamp and were therefore placed into the littoral zone. Although plot C was partially inundated (Table 1.7) it was classified as belonging to the seasonal waterlogged zone.

Lake Goollelal

Across a 20 year period all plots at Lake Goollelal became inundated to greater depths for longer periods (Figure 1.42, Table 1.7). Plot A is now flooded to between 50 and 100cm for 11 to 12 months of the year, plot B for ten, C for nine while D is flooded to 10-50cm for seven to eight months. Despite this, all plots were classified as littoral as short periods of drying still resulted in them occurring between the low and high water marks.

Lake Jandabup

The vegetation transect established at Lake Jandabup did not flood at all across a 20 year period (Table 1.7). Figure 1.43 indicated that groundwater occurred within 2m of the surface across plots A and B, and at depths greater than 2m across plots C and D. A and B were therefore classified as supralittoral while C and D were described as terrestrial.

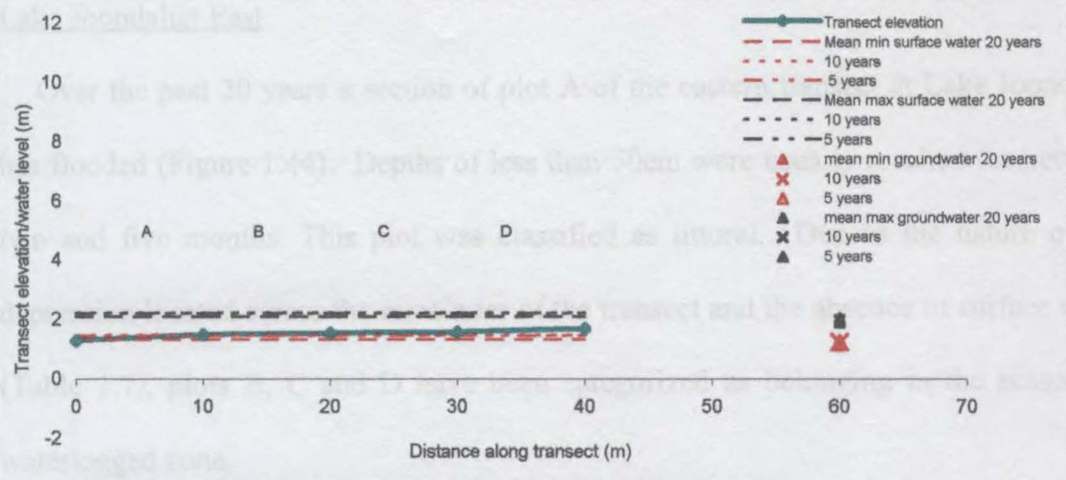


Figure 1.42: Hydrological regime experienced across the Lake Goollelal vegetation monitoring plots over a 20 year period.

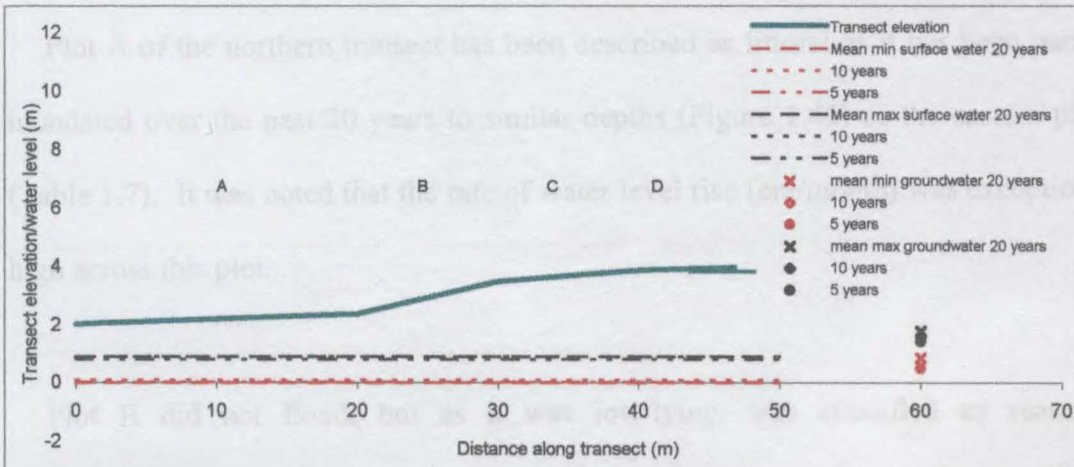


Figure 1.43: Hydrological regime experienced across the Lake Jandabup vegetation monitoring plots over a 20 year period.

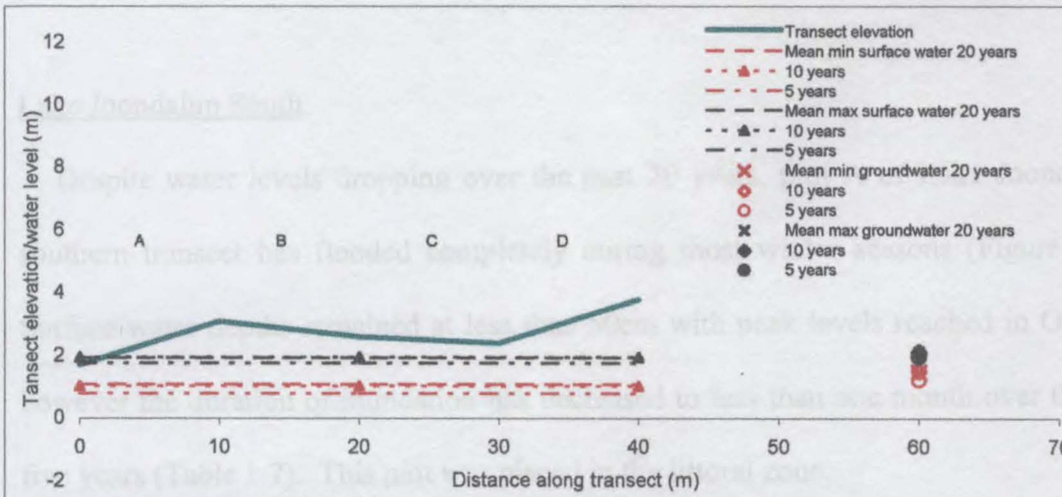


Figure 1.44: Hydrological regime experienced across the Lake Joondalup east vegetation monitoring plots over a 20 year period.

Lake Joondalup East

Over the past 20 years a section of plot A of the eastern transect at Lake Joondalup has flooded (Figure 1.44). Depths of less than 50cm were usually reached for between two and five months. This plot was classified as littoral. Due to the nature of the depression located across the remainder of the transect and the absence of surface water (Table 1.7), plots B, C and D have been categorized as belonging in the seasonally waterlogged zone.

Lake Joondalup North

Plot A of the northern transect has been described as littoral as it has been partially inundated over the past 20 years to similar depths (Figure 1.45) as the eastern plot A (Table 1.7). It was noted that the rate of water level rise (cm/month) was exceptionally high across this plot.

Plot B did not flood, but as it was low-lying, was classified as seasonally waterlogged. Plots C and D were described as terrestrial as groundwater levels were greater than 2m deep (Figure 1.45).

Lake Joondalup South

Despite water levels dropping over the past 20 years, plot A of Lake Joondalup's southern transect has flooded completely during most winter seasons (Figure 1.46). Surface water depths remained at less than 50cm with peak levels reached in October, however the duration of inundation has decreased to less than one month over the past five years (Table 1.7). This plot was placed in the littoral zone.

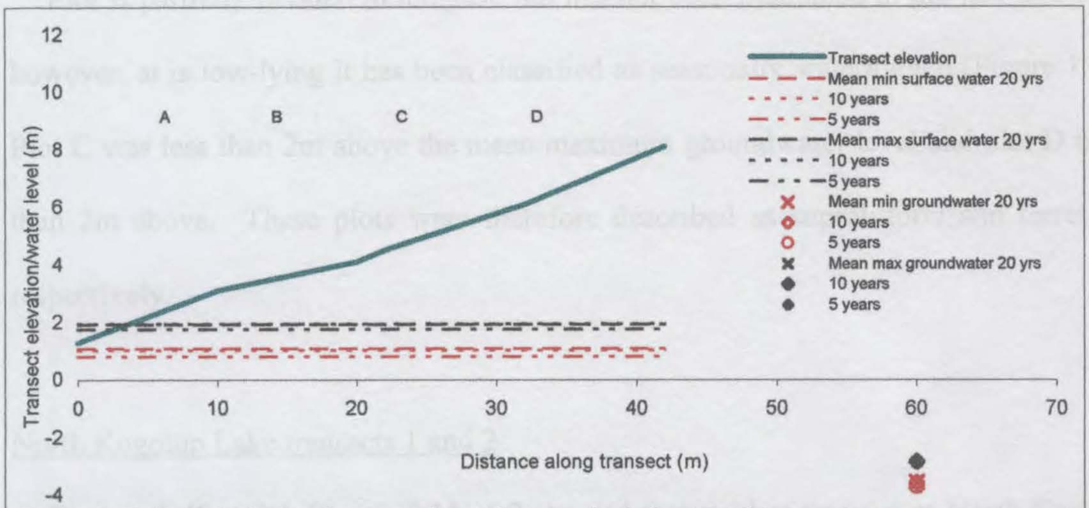


Figure 1.45: Hydrological regime experienced across the Lake Joondalup north vegetation monitoring plots over a 20 year period.

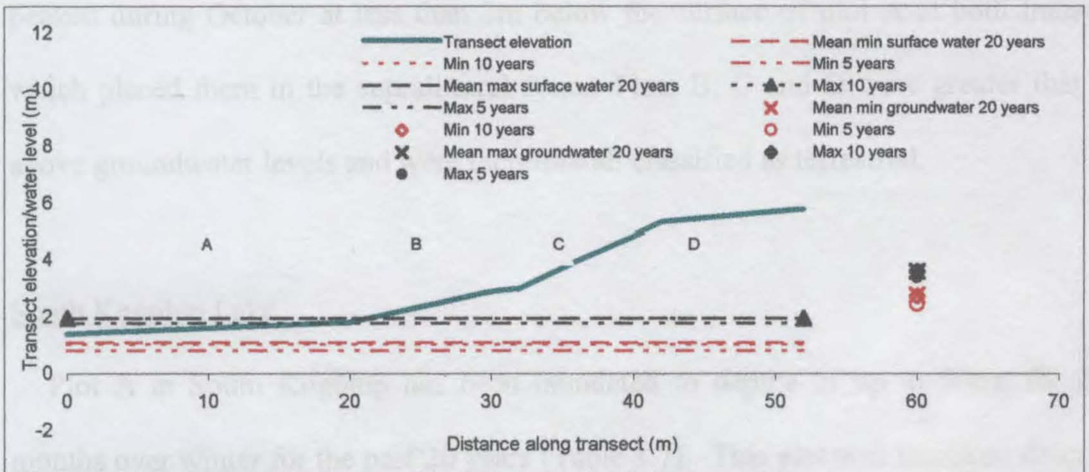


Figure 1.46: Hydrological regime experienced across the Lake Joondalup south vegetation monitoring plots over a 20 year period.

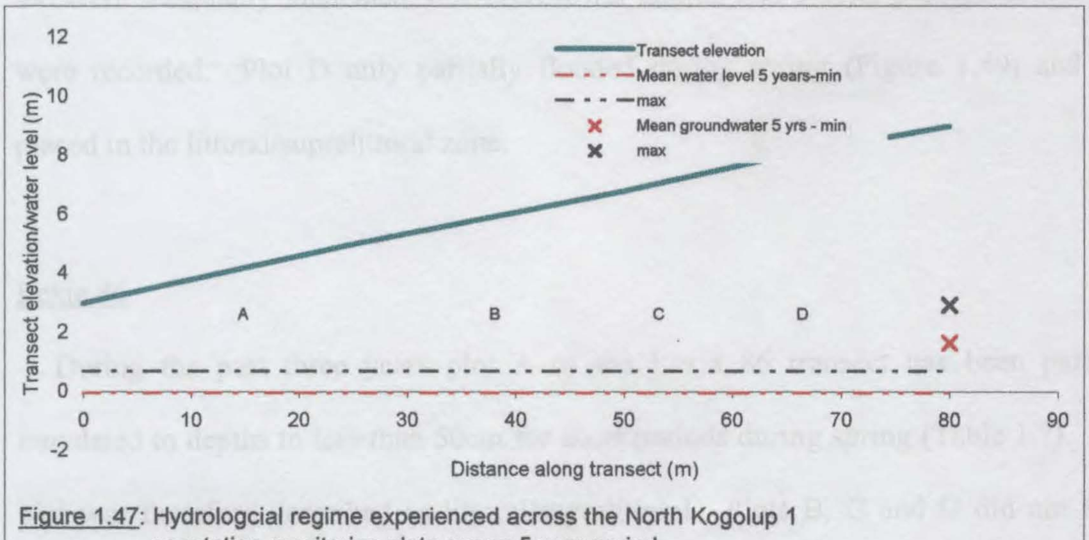


Figure 1.47: Hydrologcial regime experienced across the North Kogolup 1 vegetation monitoring plots over a 5 year period.

Plot B partially flooded in the past, but has not been inundated in the last five years however, at is low-lying it has been classified as seasonally waterlogged (Figure 1.46). Plot C was less than 2m above the mean maximum groundwater level and plot D more than 2m above. These plots were therefore described as supralittoral and terrestrial respectively.

North Kogolup Lake transects 1 and 2

Figures 1.47 and 1.48 and Table 1.7 showed that neither transect at North Kogolup Lake were inundated during the past five years. Mean maximum groundwater levels peaked during October at less than 2m below the surface of plot A at both transects, which placed them in the supralittoral zone. Plots B, C and D were greater than 2m above groundwater levels and were therefore all classified as terrestrial.

South Kogolup Lake

Plot A at South Kogolup has been inundated to depths of up to 50cm for 2-3.5 months over winter for the past 20 years (Table 1.7). This plot was therefore described as falling within the littoral zone. Plots B and C were also classified as littoral as they too were seasonally inundated, however, lower depths and shorter periods of flooding were recorded. Plot D only partially flooded during spring (Figure 1.49) and was placed in the littoral/supralittoral zone.

Lexia 86

During the past three years plot A of the Lexia 86 transect has been partially inundated to depths to less than 50cm for short periods during spring (Table 1.7). This plot was therefore described as littoral/supralittoral. Plots B, C and D did not flood (Figure 1.50) and were classified as seasonally waterlogged.

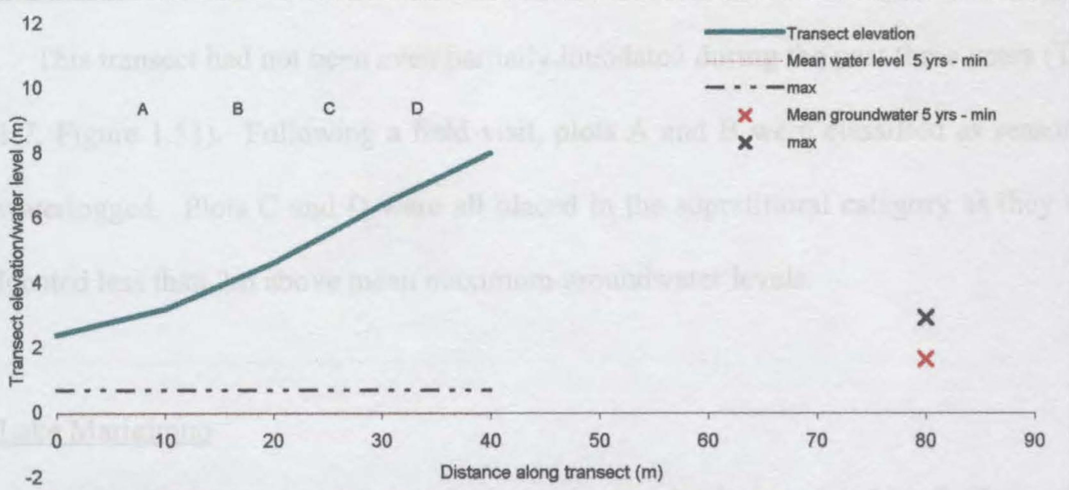


Figure 1.48: Hydrological regime experienced across the North Kogolup 2 vegetation monitoring plots over a 5 year period.

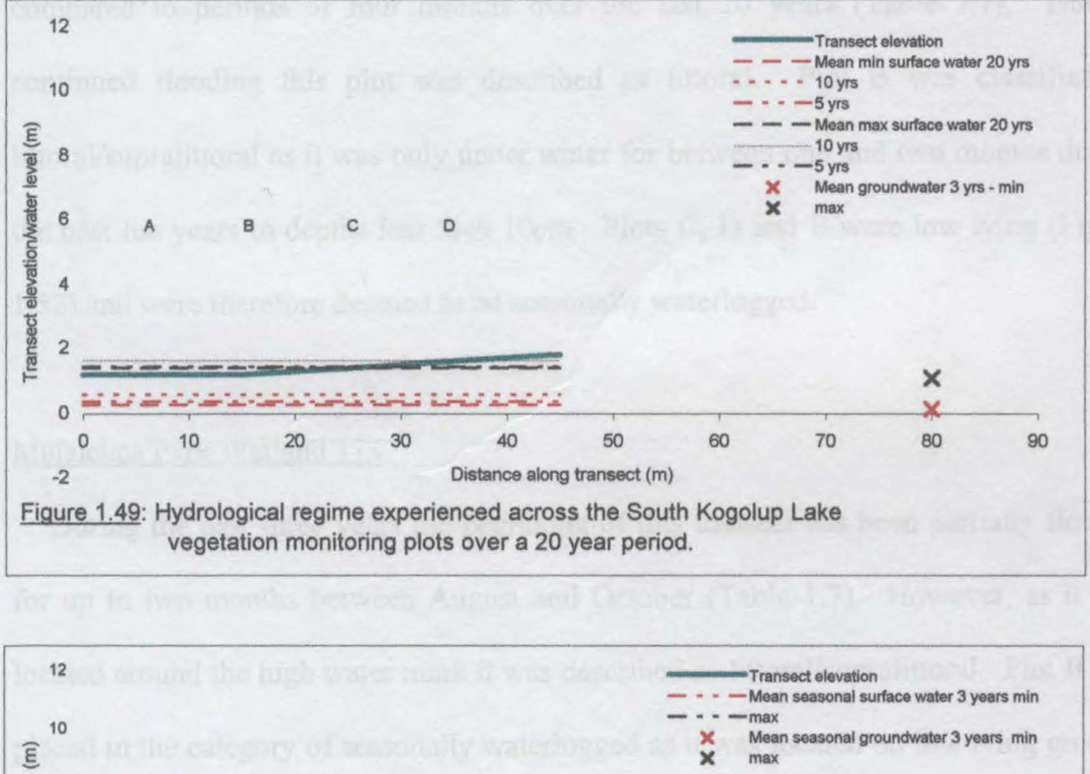


Figure 1.49: Hydrological regime experienced across the South Kogolup Lake vegetation monitoring plots over a 20 year period.

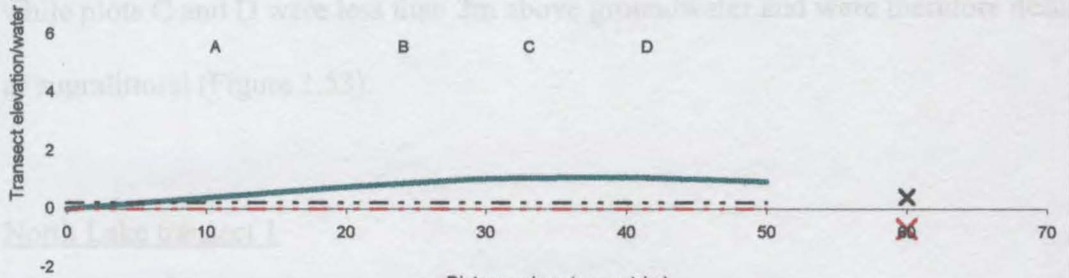


Figure 1.50: Hydrological regime experienced across the Lexia Wetland 86 vegetation monitoring plots aover a 3 year period.

Lexia 186

This transect had not been even partially inundated during the past three years (Table 1.7, Figure 1.51). Following a field visit, plots A and B were classified as seasonally waterlogged. Plots C and D were all placed in the supralittoral category as they were located less than 2m above mean maximum groundwater levels.

Lake Mariginiup

Plot A of the Lake Mariginiup transect was completely inundated by shallow surface water (<50cm) for almost two months during the winters of the past five years compared to periods of four months over the last 20 years (Table 1.7). Due to continued flooding this plot was described as littoral. Plot B was classified as littoral/supralittoral as it was only under water for between one and two months during the past ten years to depths less than 10cm. Plots C, D and E were low lying (Figure 1.52) and were therefore deemed to be seasonally waterlogged.

Melaleuca Park Wetland 173

During the past three years the beginning of this transect has been partially flooded for up to two months between August and October (Table 1.7). However, as it was located around the high water mark it was described as littoral/supralittoral. Plot B was placed in the category of seasonally waterlogged as it was located on low lying ground, while plots C and D were less than 2m above groundwater and were therefore described as supralittoral (Figure 1.53).

North Lake transect 1

Plot A of this transect has been flooded for most seasons over the past 20 years, however depth and duration of inundation has decreased (Figure 1.54 and Table 1.7)

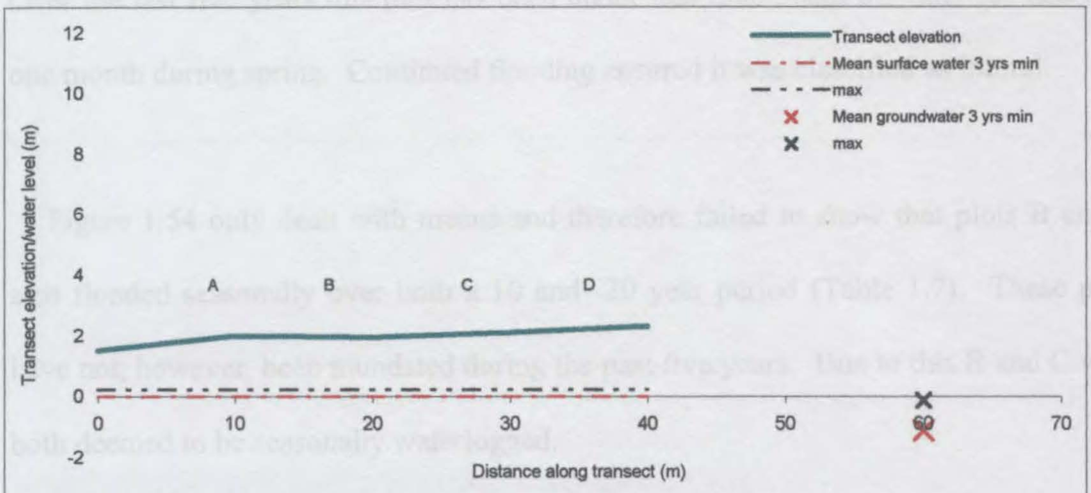


Figure 1.51: Hydrologcial regime experienced across the Lexia Wetland 186 vegetation monitoring plots over a 3 year period.

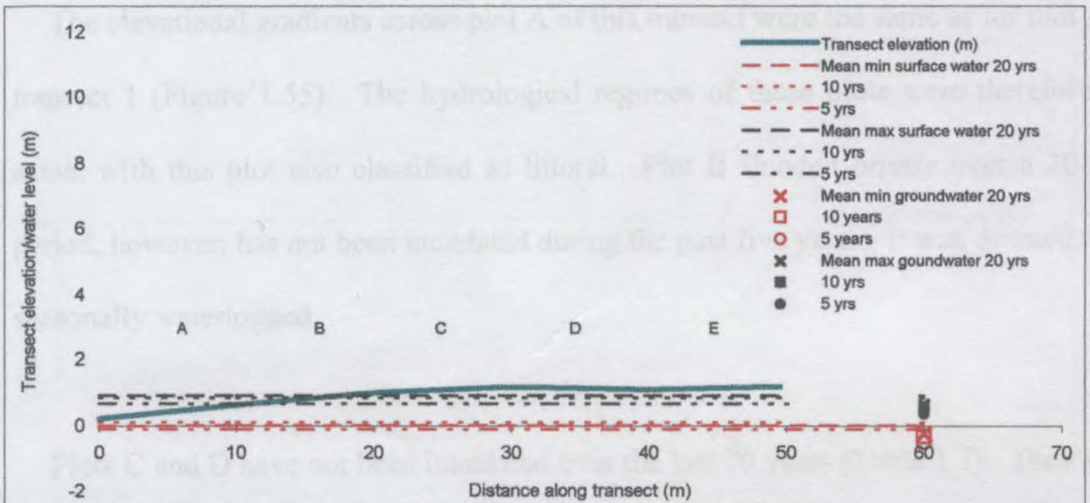


Figure 1.52: Hydrological regimes experienced across the Lake Mariginiup vegetation monitoring plots over a 20 year period.

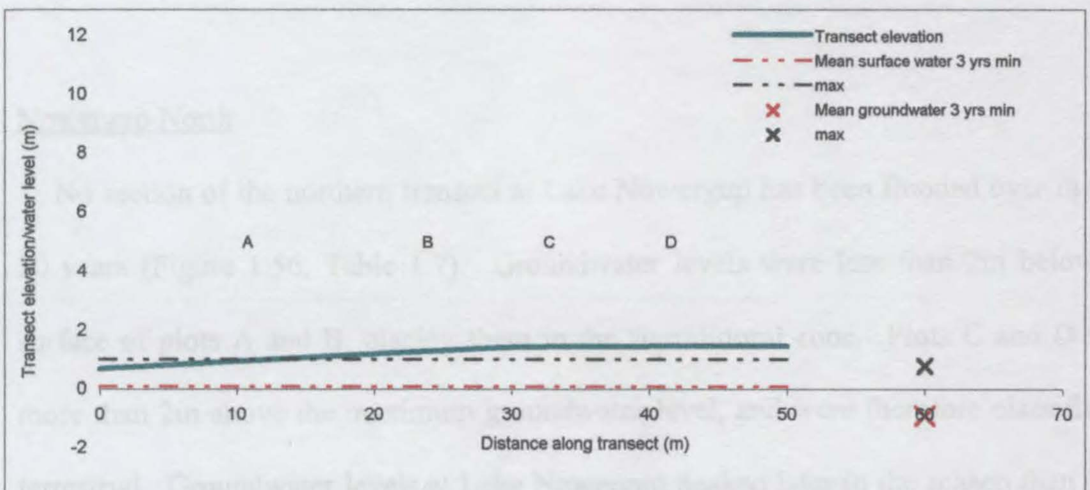


Figure 1.53: Hydrological regime experienced across the Melalueca Park EPP 173 Wetland vegetation monitoring plot over a 3 year period.

Over the last five years this plot has been under less than 50cm of water for less than one month during spring. Continued flooding ensured it was classified as littoral.

Figure 1.54 only dealt with means and therefore failed to show that plots B and C also flooded seasonally over both a 10 and 20 year period (Table 1.7). These plots have not, however, been inundated during the past five years. Due to this B and C were both deemed to be seasonally waterlogged.

North Lake transect 2

The elevational gradients across plot A of this transect were the same as for plot A of transect 1 (Figure 1.55). The hydrological regimes of these plots were therefore the same, with this plot also classified as littoral. Plot B flooded briefly over a 20-year period, however, has not been inundated during the past five years. It was deemed to be seasonally waterlogged.

Plots C and D have not been inundated over the last 20 years (Table 1.7). They were therefore classified as supralittoral and terrestrial respectively, with groundwater depths of less than 2m and greater than 2m (Figure 1.55).

Nowergup North

No section of the northern transect at Lake Nowergup has been flooded over the last 20 years (Figure 1.56, Table 1.7). Groundwater levels were less than 2m below the surface of plots A and B, placing them in the supralittoral zone. Plots C and D were more than 2m above the maximum groundwater level, and were therefore classified as terrestrial. Groundwater levels at Lake Nowergup peaked later in the season than other wetlands.

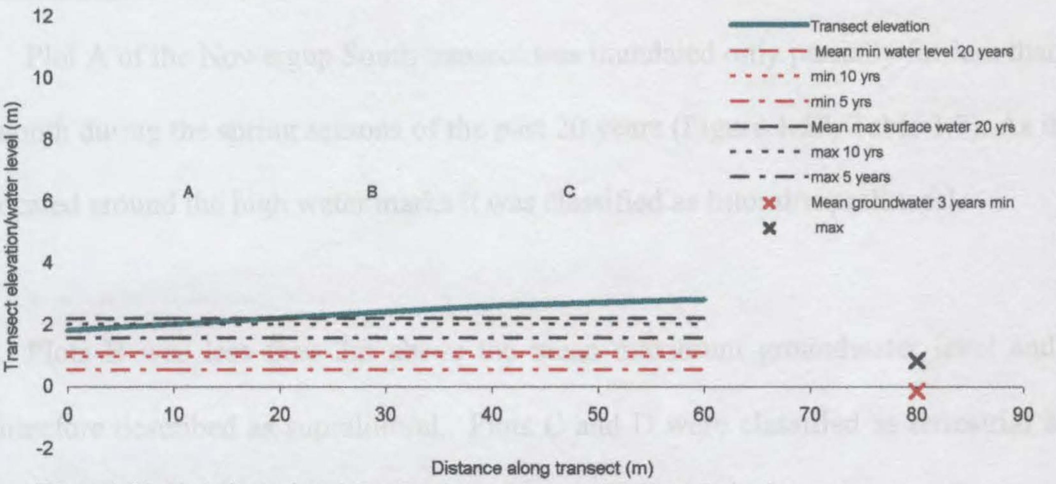


Figure 1.54: Hydrological regime experienced across the North Lake 1 vegetation monitoring plots over a 20 year period.

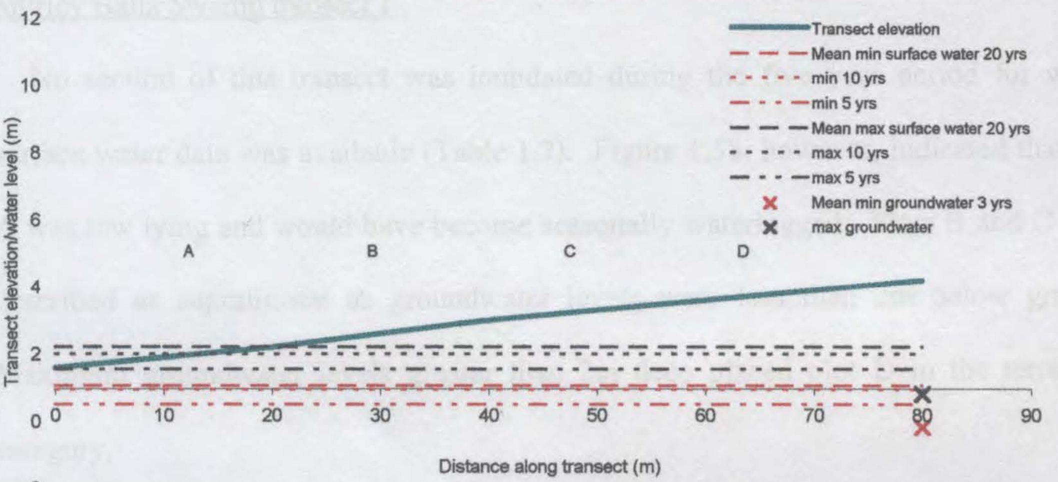


Figure 1.55: Hydrological regime experienced across the North Lake 2 vegetation monitoring plots over a 20 year period.

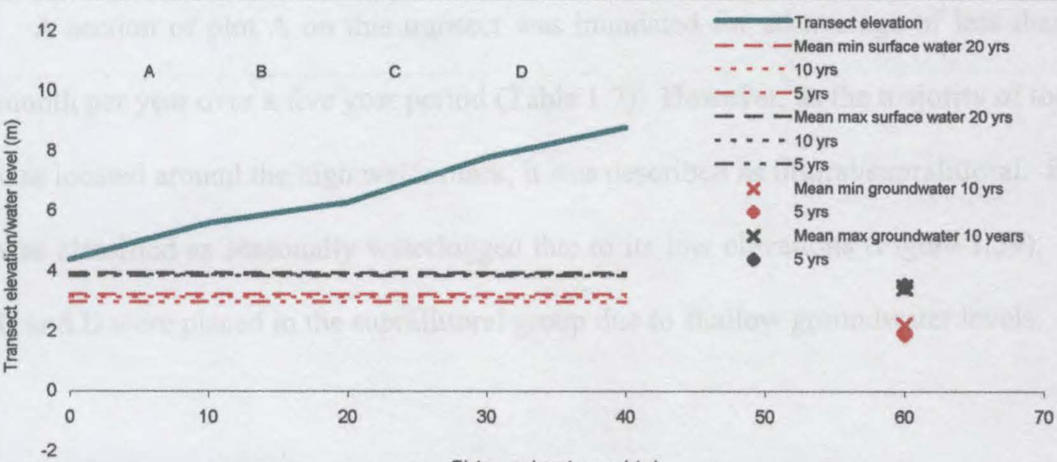


Figure 1.56: Hydrological regime experienced across the Nowergup Lake north vegetation monitoring plots over a 20 year period.

Nowergup South

Plot A of the Nowergup South transect was inundated only partially for less than one month during the spring seasons of the past 20 years (Figure 1.57, Table 1.7). As it was located around the high water marks it was classified as littoral/supralittoral.

Plots B was less than 2m above the mean maximum groundwater level and was therefore described as supralittoral. Plots C and D were classified as terrestrial as the groundwater was more than 2m below the surface.

Shirley Balla Swamp transect 1

No section of this transect was inundated during the five year period for which surface water data was available (Table 1.7). Figure 1.58, however, indicated that plot A was low lying and would have become seasonally waterlogged. Plots B and C were described as supralittoral as groundwater levels were less than 2m below ground. Maximum groundwater levels greater than 2m deep placed plot D in the terrestrial category.

Shirley Balla Swamp transect 2

A section of plot A on this transect was inundated for an average of less than one month per year over a five year period (Table 1.7). However, as the majority of the plot was located around the high water mark, it was described as littoral/supralittoral. Plot B was classified as seasonally waterlogged due to its low elevations (Figure 1.59). Plots C and D were placed in the supralittoral group due to shallow groundwater levels.

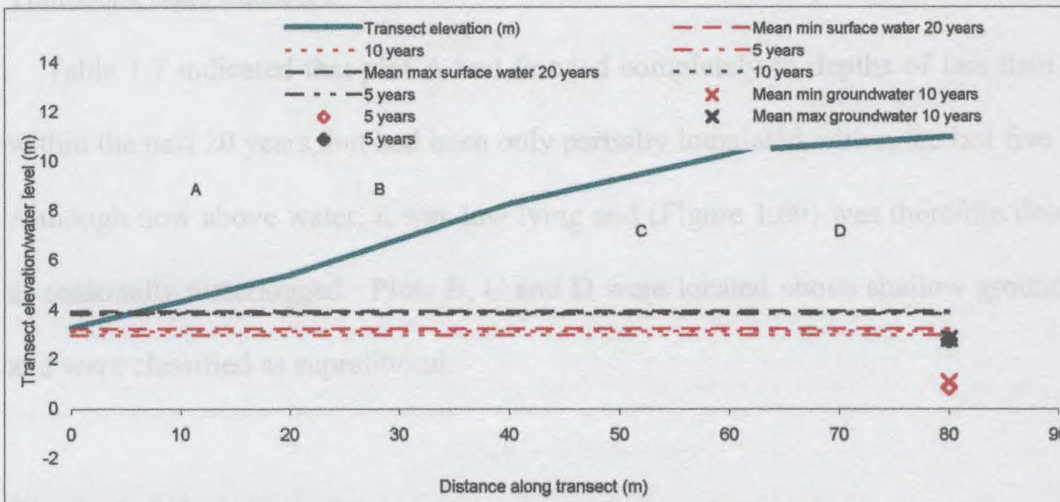


Figure 1.57: Hydrological regime experienced across the Nowergup Lake south vegetation montoring plot over a 20 year period.

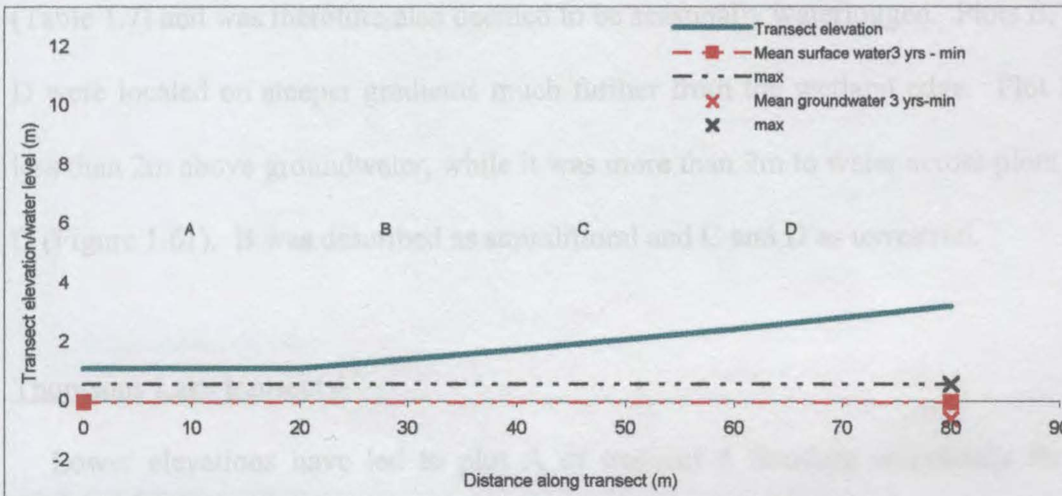


Figure 1.58 : Hydrological regime experienced across the Shirley Balla Swamp transect 1 vegetation monitoring plots over a 20 year period.

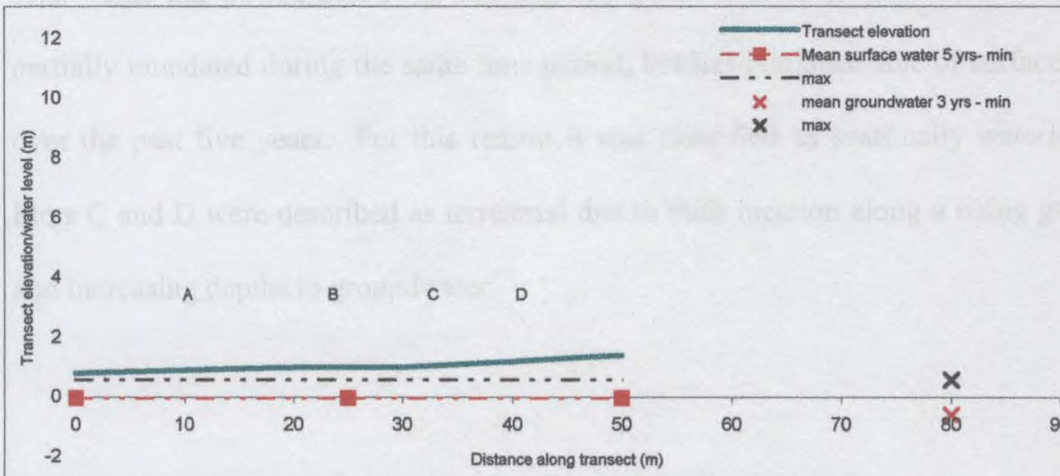


Figure 1.59: Hydrological regime experienced across the Shirley Balla Swamp 2 vegetation monitoring plots over a 20 year period.

Thomsons Lake transect 2

Table 1.7 indicated that plot A had flooded completely to depths of less than 50cm within the past 20 years, but had been only partially inundated within the last five years. Although now above water, it was low lying and (Figure 1.60) was therefore described as seasonally waterlogged. Plots B, C and D were located above shallow groundwater and were classified as supralittoral.

Thomsons Lake transect 3

Plots A of this transect experienced similar hydrological regimes to that of transect 1 (Table 1.7) and was therefore also deemed to be seasonally waterlogged. Plots B, C and D were located on steeper gradients much further from the wetland edge. Plot B was less than 2m above groundwater, while it was more than 2m to water across plots C and D (Figure 1.61). B was described as supralittoral and C and D as terrestrial.

Thomsons Lake transect 4

Lower elevations have led to plot A of transect 4 flooding completely for most winter seasons of the past 20 years to maximum depths of 50cm (Figure 1.62, Table 1.7). This has placed plot A in the littoral/supralittoral category. Plot B had been partially inundated during the same time period, but has remained free of surface water over the past five years. For this reason it was classified as seasonally waterlogged. Plots C and D were described as terrestrial due to their location along a rising gradient and increasing depths to groundwater.

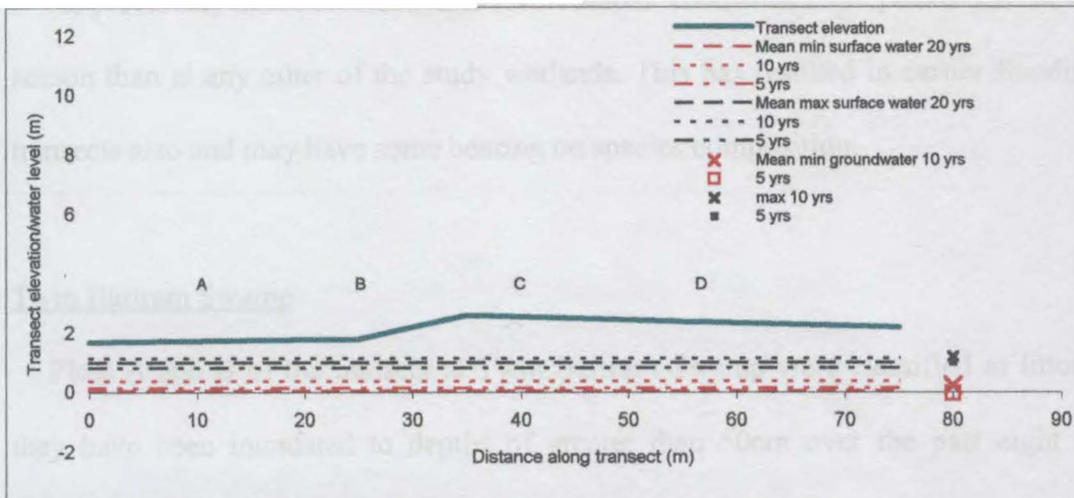


Figure 1.60 : Hydrological regime experienced across the Thomsons Lake 2 vegetation monitoring plots over a 20 year period.

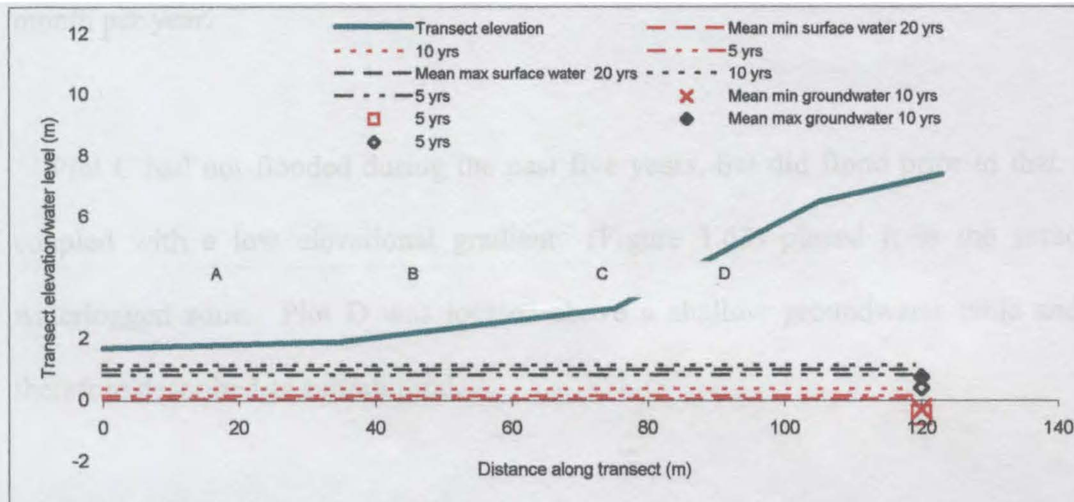


Figure 1.61: Hydrological regime experienced across the Thomsons Lake 3 vegetation monitoring plots over a 20 year period.

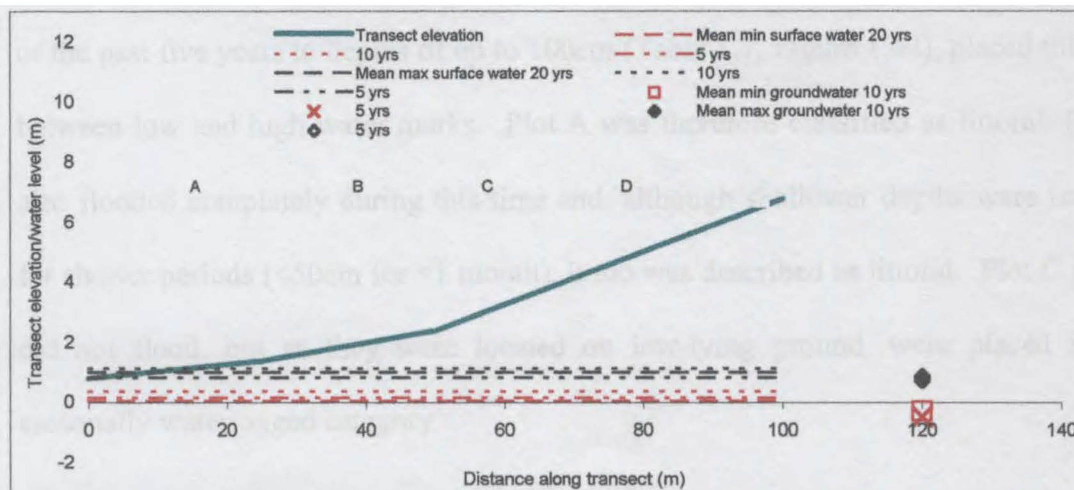


Figure 1.62: Hydrological regime experienced across the Thomsons Lake 4 vegetation monitoring plots over a 20 year period.

As previously noted surface water levels across Thomsons Lake peaked earlier in the season than at any other of the study wetlands. This has resulted in earlier flooding of transects also and may have some bearing on species composition.

Twin Bartram Swamp

Plots A and B of the transect at Twin Bartram Swamp were classified as littoral as they have been inundated to depths of greater than 50cm over the past eight years (Table 1.7). Plot A was completely flooded for an average of more than three months per season during the last five years, while plot B was under water for less than one month per year.

Plot C had not flooded during the past five years, but did flood prior to that. This coupled with a low elevational gradient (Figure 1.63) placed it in the seasonally waterlogged zone. Plot D was located above a shallow groundwater table and was therefore described as supralittoral.

Lake Wilgarup

Complete inundation of plot A for an average of 2.8 months during winter and spring of the past five years to depths of up to 100cm (Table 1.7, Figure 1.64), placed this plot between low and high water marks. Plot A was therefore classified as littoral. Plot B also flooded completely during this time and, although shallower depths were reached for shorter periods (<50cm for <1 month), it too was described as littoral. Plot C and D did not flood, but as they were located on low-lying ground, were placed in the seasonally waterlogged category.

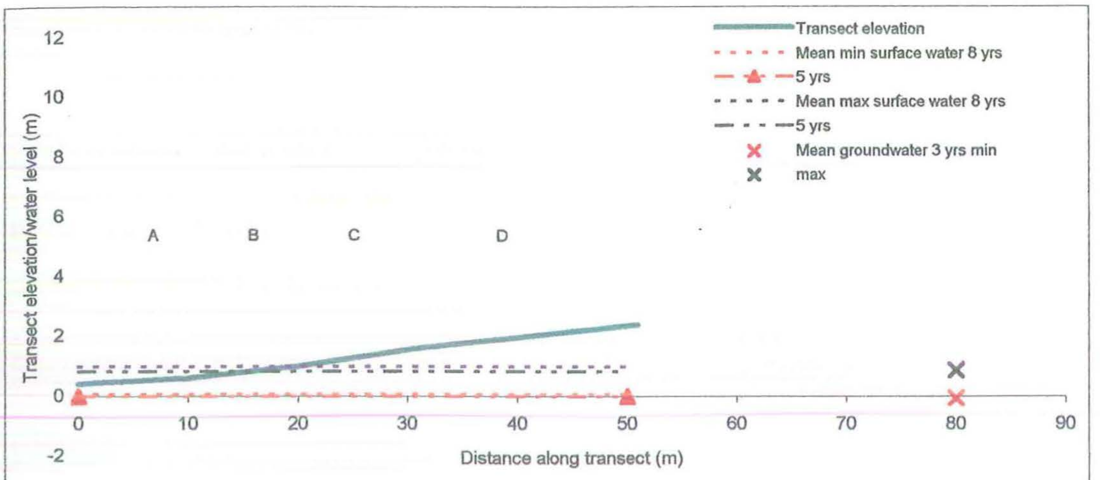


Figure 1.63: Hydrological regime experienced across the Twin Bartram Swamp vegetation monitoring plots over a 5 year period.

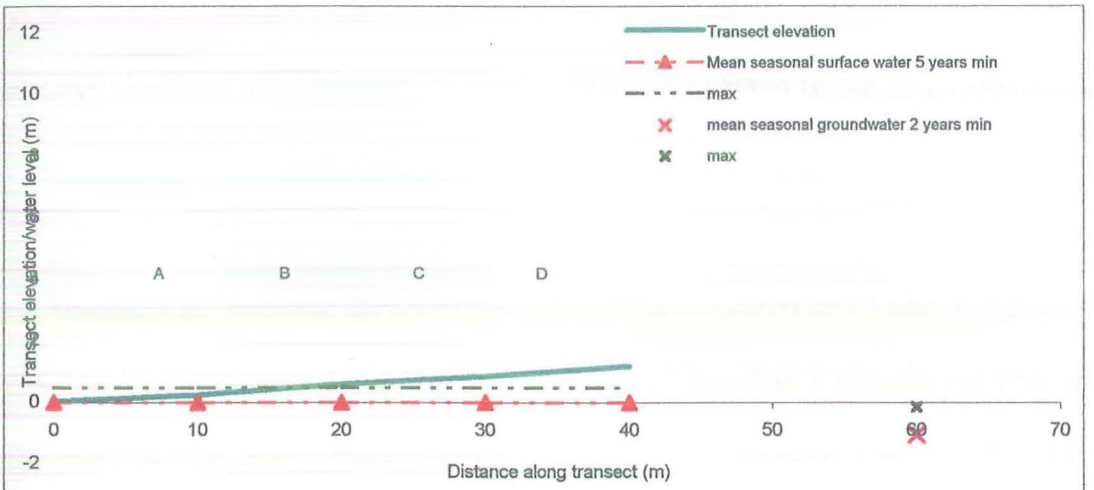


Figure 1.64: Hydrogical regimes experienced across the Lake Wilgarup vegetation monitoring plots over a 5 year period.

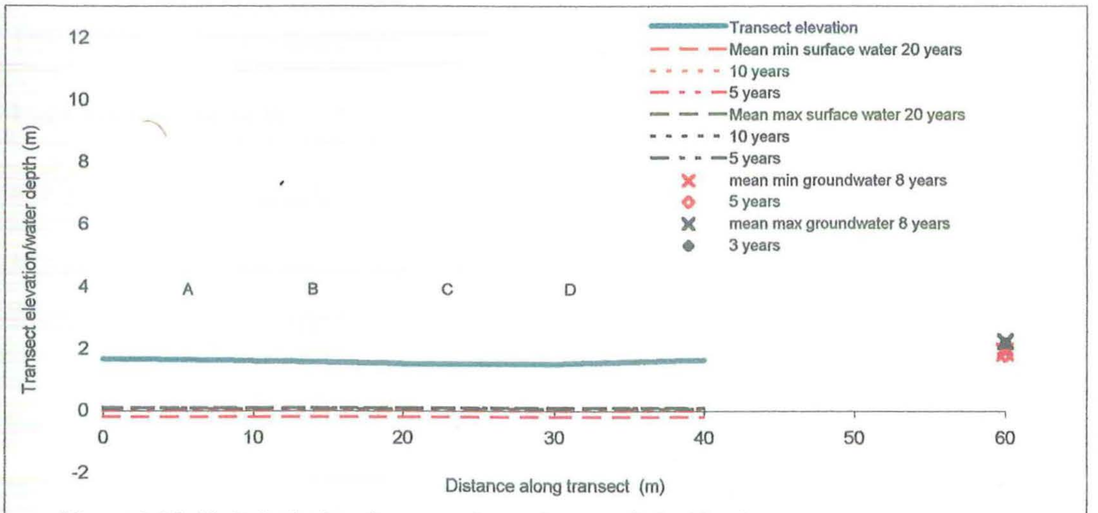


Figure 1.65: Hydrological regime experienced across Lake Yonderup vegetation monitoring plots over a 20 year period.

Yonderup Lake

The transect established at Yonderup Lake had not been inundated during the past 20 years (Figure 1.65, Table 1.7). All plots were described as supralittoral due to a shallow groundwater table.

Summary of differences in hydrological regimes experienced at individual study transects

The vegetation monitoring transects at South Kogolup Lake, Bibra Lake and Lake Goollelal were the only ones shown to have flooded entirely within the past twenty years. All of these transects have experienced rising water levels over that time. Plot A at Lake Goollelal was inundated to depths greater than 50cm for up to 12 months of the year for the last five years making this the wettest of all study plots.

Transects at Beenyup Rd Swamp, Twin Bartram Swamp and Lake Wilgarup were flooded for up to half of their length for periods of less than 4 months per year within the previous five years. Plots A of Lake Mariginiup, Joondalup Lake South and North Lake transects 1 and 2 were completely inundated for less than two months of the year for the past five years. In comparison, plots A at Lake Joondalup East and North, Lexia 186, Wetland 173, Nowergup South, Shirley Balla Swamp transect 2 and Thomsons Lake transect 4 were only partially inundated over the same time period. All other study transects have not flooded within the past five years, however, Thomsons Lake transects 2 and 3 have been inundated within the past 10 years.

1.2.2 VEGETATION OF THE STUDY WETLANDS

Species belonging to each hydrological zone

A list of all species that were found to occur in each of the five hydrological zones was compiled (Appendix 3). The focus of the study was wetland vegetation, therefore the species found in the wettest categories, littoral, littoral/supralittoral and seasonally waterlogged, were compared to the literature to develop a list of 60 species (Table 1.8), that were to be regarded as wetland species throughout the remainder of the study.

A total of 244 species, 168 native and 74 exotic (Appendix 3) were divided into the five hydrological zones (Appendix 4). The only native perennials found to occur across all zones were the trees, *Eucalyptus rudis* and *Melaleuca rhaphiophylla,* and the large shrub, *Astartea fascicularis.* All of the remaining 12 widespread species were exotics.

Banksia littoralis and *Melaleuca teretifolia* were also fairly common native trees, however, they were not found in the driest zone (Appendix 4). The native sedges, *Baumea articulata* and *Lepidosperma longitudinalee*, two native grasses, *Agrostis avenacea* and *Centella asiatica* and two exotic species, *Polypogon monspeliensis* and *Lotus angustissimus* also occurred across these zones. Other species common to both wet and dry zones include *Melaleuca preissiana,* a native tree, *Pultenaea reticulata, Pericalymma ellipticum, Hypocalymma angustifolium* and *Rhagodia baccata,* woody native shrubs, and sedges and rushes such as *Baumea juncea, Typha orientalis* and *Leptocarpus scariosus* (Appendix 3, Appendix 4).

Despite these species occurring in most hydrological zones, all of them are known to be associated with wetlands (Appendix 3). Numerous other species found in the seasonally waterlogged zone and the drier areas were also identified as wetland

Table 1.8

60 Wetland species as identified from the literature or by their occurrence in littoral, littoral/supralittoral or seasonally waterlogged hydrological zones in the study wetlands. Species are listed by lifeform.

Lifeform	Species name	Lifeform	Species name
Trees		Emergent macrophytes	
	Banksia ilicifolia		Baumea arthrophylla
	Banksia littoralis		Baumea articulata
	Eucalyptus rudis		Baumea juncea
	Melaleuca preissiana		Baumea vaginalis
	Melaleuca rhaphiophylla		Carex fascicularis
	Melaleuca teretifolia		Isolepis marginata
Perennial shrubs			Isolepis producta
	Adriana quadripartita		Isolepis prolifera*
	Aotus sp.		Juncus pallidus
	Astartea fascicularis		Lepidosperma elatius
	Beaufortia elegans		Lepidosperma longitudinal
	Calothamnus lateralis		Leptocarpus scariosus
	Exocarpus sparteus		Typha orientalis
	Hypocalymma angustifolium	Annuals	
	Kunzea ericifolia		Chenopodium glaucum
	Myoporum capraroides		Chenopodium pallidum*
	Pericalymma ellipticum		Conyza albida*
	Pultenaea ochreata		Cotula coronopifolia
	Pultenaea reticulata		Gnaphalium sphaericum
	Rhagodia baccata		Homalosciadium homolcarpum
	Solanum symonii		Isolepis cernua
	Viminaria juncea		Lemna sp.
Perennnial herbs			Polypogon monspeliensis*
	Azolla sp.		Schoenus pennisetis
	Centella asiatica		Triglochin sp.
	Centella cordifolia		Villarsia capitata
	Gratiola peruviana		
	Halogaris brownii		
	Hemarthria uncinata		
	Laxmania ramosa		
	Lepyrodia glauca		
	Lepyrodia muirii		
	Lyginia barbata		
	Phyla nodiflora*		
	Pteridium esculentum		
	Schoenus rodwayanus		
	Sporobolus virginicus		

plants (Appendix 4). These include the fringing tree *Banksia ilicifolia,* perennial shrubs such as *Adriana quadripartita, Beaufortia elegans, Calothamnus lateralis, Exocarpos sparteus, Kunzea ericifolia* and others.

Numerous small perennial herbs, ferns and grasses, both native and exotic were also identified as wetland associates (Appendix 3, Appendix 4). These included the herbs *Phyla nodiflora, Centella cordifolia* and *Hemarthia uncinata, Pteridium esculentum,* a fern and the sedge species *Lepyrodia glauca* and *Lepyrodia muirii.*

Only 23 species were found to occur exclusively in the wettest areas or zone 1 (Appendix 4). Four species, were identified as aquatic or semi-aquatic herbs, with *Azolla* sp.and *Haloragis brownii,* found to be perennial and *Lemna* sp., *Triglochin* sp. and *Villarsia capitata,* annuals (Appendix 3). The remaining plants were small perennials, annuals and emergent macrophytes.

Species composition and community structure

Data from three years of vegetation monitoring plots were combined to provide an overall species list for each plot within each transect. Domin values were then used to describe the dominant understorey and overstorey community of each study plot to allow comparisons between water regime and species composition and structure.

Lake Banganup

The three plots across the 50m transect at Lake Banganup had a total of 37 plant species, 14, or 38%, of which were exotic (Table 1.9). The native species were made up of five perennial shrubs, one emergent macrophyte and six trees, with the remainder consisting of herbs and annuals. *E. rudis* was one of two species that occurred across the entire transect, the other was the exotic, *Hypochoeris glabra.*

Plot A was classified as littoral as it belonged to the wettest hydrological zone (Table 1.10) *Baumea articulata* was recorded only in this plot and further into the wetland. It dominated the understorey of plot A above a closed forest of *E. rudis, M. preissiana* and *M. teretifolia* (Table 1.11). A band of young *M. preissiana* was observed in this area during a field visit. *E. rudis* and *M. preissiana* also formed the overstorey in the seasonally waterlogged plot B along with a third wetland tree, *B. littoralis.* The open shrubland, which formed the understorey, consisted chiefly of *A. fascicularis* and *A. quadripartita.*

Dryland species dominated the open shrubland understorey of plot C, which had not been inundated during the past years. The overstorey was a mixed woodland of *E. rudis, B. ilicifolia* and the dryland tree species *Banksia attenuata.*

Table 1.9

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Banganup monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-11	0.4	littoral/supralittoral
B	-61	0.1	seasonally waterlogged
C	-241	0	terrestrial

Table 1.10

Species presence/absence across Lake Banganup vegetation monitoring transect

Plot and location along transect (m); shaded cells (presence) shown as "x".

Species	A 0-30	B 30-40	C 40-50
Eucalyptus rudis	x	x	x
*Hypochoeris glabra**	x	x	x
Baumea articulata	x		
Deyeuxia quadriseta	x		
Melaleuca teretifolia	x		
*Circium vulgare**	x		
*Cynodon dactylon**	x		
Astartea fascicularis	x	x	
Melaleuca preissiana	x	x	
Microlaena stipiodes	x		x
*Aira caryophyllea**	x		x
*Solanum nigrum**		x	
Adriana quadripartita		x	
Banksia littoralis		x	
Centella asiatica		x	
*Sonchus oleareaceus**		x	
*Stellaria media**		x	
*Briza maxima**		x	x
*Bromus diandrus**		x	x
*Cerastium glomeratum**		x	x
*Ehrharta longiflora**		x	x
Isolepis nodosus		x	x
*Vulpia myuros**		x	x
Banksia attenuata			x
Banksia ilicifolia			x
Cotula australis			x
Dichopogon capillipes			x
Homalosciadium homalocarpum			x
Jacksonia sternbergiana			x
Macrozamia riedlei			x
Trachymene pilosa			x
Wahlenbergia priessii			x
Xanthorrhoea preissii			x

Table 1.11

Dominant vegetation communities along Lake Banganup monitoring transect

Plot	Community
A	Mixed *E. rudis, M. preissiana, M. terertifolia* closed forest Closed *B. articulata* sedgeland
B	Mixed *E.rudis, M. preissiana, B. littoralis* closed forest Open *A. fascicularis, A. quadripatita* shrubland
C	Mixed *E. rudis, B.attenuata, B. ilicifolia* woodland Open mixed shrubland

Beenyup Rd Swamp

Beenyup Rd Swamp also consisted of three plots, however it was slightly longer than the Banganup transect at 55m (Table 1.13). Of the 37 species recorded at this site 18 or 48% were introduced, three of these were found in all plots.

The native species included two wetland trees, *M. rhaphiophylla* and *M. preissiana*, and one dryland species, along with three perennial native shrubs and three emergent macrophytes. The remaining native species were predominately herbs (Table 1.13).

Plots A and B were both classified as littoral (Table 1.12) and contained the greatest number of wetland species. A band of very broad, bushy *M. rhaphiophylla* formed a closed forest in these plots, with a clump of *B. articulata* and some grass species dominated the open understorey of the first plot, and *B. articulata* and *L. elatius* forming a sparse sedgeland in plot B (Table 1.14).

Plot C, in which an isolated *M. preissiana* and *Eucalyptus marginata* grew above an open shrubland of non-wetland species (Table 1.14), had not been inundated in recent years (Table 1.12).

Bibra Lake

Despite the presence of six wetland species, the Bibra Lake site was species poor, with seven exotics being the only other species recorded (Table 1.16).

Plots A and B of this transect had been inundated within the past five years (Table 1.15) and were dominated by an open forest of *M. preissiana* (Table 1.17). *M. teretifolia* also occurred in plot B. The emergent macrophytes, *J. pallidus* and *C.*

Table 1.12

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Beenyup Rd Swamp monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-20	1.6	littoral
B	-20	1.6	littoral
C	-84	0	terrestrial

Table 1.13

Species presence/absence across Beenyup Rd Swamp vegetation monitoring transect

Species	Plot and location along transect (m) A 0-20	B 20-40	C 40-55
Isolepis marginata	■	■	■
*Hypochoeris glabra**	■	■	■
*Briza maxima**	■	■	■
*Briza minor**	■	■	■
Baumea articulata	■		
*Cotula coronopifolia**	■		
*Polypogon monsplesiensis**	■		
*Sonchus asper**	■		
*Stellaria media**	■		
Gnaphalium sphaericum	■	■	
Melaleuca rhaphiophylla	■	■	
Agrostis avenacea	■	■	
*Solanum nigrum**	■	■	
*Sonchus oleareacea**	■	■	
Lepidosperma elatius		■	
Lobelia alata		■	
*Lotus angustissimus**		■	
Trachymene pilosa		■	
*Ehrharta calycina**		■	■
*Trifolium campestre**		■	■
Burchardia umbellata			■
Drosera erythroriza			■
Eucalyptus marginata			■
Homalosciadium homalocarpum			■
Lyperanthus nigricans			■
Macrozamia riedlei			■
Melaleuca preissiana			■
Microleana stipiodes			■
Poranthera microphylla			■
Xanthorrhoea gracilis			■
Xanthorrhoea preissii			■
*Anagallis arvensis**			■
*Ehrharta longiflora**			■
*Romulea rosea**			■
*Ursinia anthemoides**			■
*Wahlenbergia capensis**			■
*Zantedeschia aethiopica**			■

Table 1.14

Dominant vegetation communites across Beenyup Rd Swamp monitoring transect

Plot	Community
A	Closed *M. rhaphiophylla* forest
	Clump of *B. articulata*
B	Closed *M.rhaphiophylla* forest
	Sparse *B. articulata* sedgeland
C	Isolated *M. preissiana* and *E. marginata* trees
	Open mixed shrubland

Table 1.15

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Bibra Lake monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	9	4.4	littoral
B	1	4	littoral
C	-59	0.6	seasonally waterlogged

Table 1.16

Species presence/absence across Bibra Lake vegetation monitoring transect

	Plot and location along transect		
	A	B	C
Species	0-25	25-40	40-50
Melaleuca preissiana	x	x	x
Centella asiatica	x	x	x
*Cynodon dactylon**	x	x	x
Juncus pallidus	x		
Carex fascicularis	x		
*Circium vulgare**	x		
*Solanum nigrum**	x		
Melaleuca teretifolia		x	
*Bromus diandra**		x	
*Vicia sativa**		x	
*Lotus angustissimus**		x	
*Sonchus oleraeacea**		x	
*Sonchus asper**		x	
Eucalyptus rudis		x	x

Table 1.17

Dominant vegetation communities along Bibra Lake monitoring transect

Plot	Community
A	Open *M. preissiana* forest
	Open *C. fascicularis, J. pallidus* sedgeland
B	Open *M. preissiana, M. teretifolia* forest
	Closed mixed herb and grassland
C	Closed *M. preissiana, E. rudis* forest
	Closed mixed herb and grassland

fascicularis, along with herb and grass species, formed the understorey of the first plot, while the grasses dominated across plot B.

A closed *M. preissiana*, *E. rudis* forest dominated the overstorey of the seasonally waterlogged plot C, with grasses and herbs again forming the understorey.

Lake Goollelal

This transect consisted of four 10 x 10 m plots all of which had been flooded for longer than half of each of the last five years (Table 1.18). More than 65% of 29 species recorded were exotic including the wetland species, *P. nodifolia*, which occurred across all four plots and two emergent macrophytes, *T. orientalis* and *Isolepis prolifera*.

Exotics and emergent macrophytes dominated the understorey. The emergents *B. articulata*, *L. longitudinalee* and *T. orientalis* occurred in plot A only, while *J. pallidus* and *I. prolifera* were found in plot B, C and D (Table 1.19).

The overstorey along this transect was found to be fairly open, with *M. preissiana* and *E. rudis* forming an open woodland and open forest in plots A and B respectively, and an open woodland of M. *preissiana* in plot C (Table 1.20). *Eucalyptus rudis* and *M. rhaphiophylla* combined in plot D to form woodland.

Table 1.18

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Goollelal monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	55	12	littoral
B	35	11	littoral
C	30	10.2	littoral
D	25	9.4	littoral

Table 1.19

Species presence/absence across Lake Goollelal vegetation monitoring transect

Species	Plot and location along transect: A 0-10	B 10.-20	C 20-30	D 30-40
*Phyla nodiflora**	x	x	x	x
*Cynodon dactylon**	x	x	x	x
Centella cordifolia	x	x	x	x
Melaleuca priessiana	x	x	x	
Eucalyptus rudis	x	x		x
Baumea articulata	x			
*Typha orientalis**	x			
Lepidosperma longitudinale	x			
Acacia saligna		x	x	
Juncus pallidus		x	x	x
*Isolepsis prolifera**		x	x	x
*Paspalum distichum**		x	x	x
*Zantedeschia aethiopica**			x	
*Conyza bonariensis**			x	
Agrostis avenacea			x	x
*Sonchus oleraceus**			x	x
*Rumex crispus**			x	x
*Aster subulatus**			x	x
*Lactuca serriola**			x	x
*Solanum nigrum**			x	x
*Pelargonium capitatum**			x	x
*Vicia sativa**			x	x
*Solanum laciniatum**				x
Melaleuca rhaphiophylla				x
*Anagallis arvensis**				x
*Hypochaeris glabra**				x
*Lotus suaveolens**				x
*Briza maxima**				x
*Lolium rigidium**				x

Table 1.20

Dominant vegetation communites across Lake Goollelal vegetation monitoring transect

Plot	Community
A	Mixed *M. preissiana, E. rudis* open woodland
	Sparse *B. articulata, L. longitudinal, T orientalis** sedgeland
B	Mixed *M. preissiana, E. rudis* open forest
	Closed grassland
C	*M. preissiana* open woodland
	Closed grassland
D	Mixed *E. rudis, M. rhaphiophylla* woodland
	Closed grassland

Lake Jandabup

All four plots along the 50m transect at Lake Jandabup were found to have remained dry over recent years, plots C and D were dry enough to be classified as terrestrial (Table 1.21). All plots recorded similar species richness, with a total of 47 species identified, of which, only six were exotics (Table 1.22).

Although not located on the transect, two emergent macrophytes, *B. articulata* and *L. scariosus,* were recorded beyond plot A during a field visit. Perennial native shrubs dominated the understorey of plots A and B (Table 1.22). These included the wetland species *A. fascicularis, B. elegans* and *H. angustifolium.* Terrestrial species dominated the understorey of plots C and D.

Melaleuca preissiana formed an open woodland overstorey in plot A, combined with dryland Banksia species in plot B as a mixed woodland and in plot C to form an open forest (Table 1.23). *Melaleuca preissiana, M. rhaphiophylla* and *B. ilicifolia* dominated plot D as an open forest.

Lake Joondalup East

Twenty-two species, 14 native and eight exotic, were found along this 40m transect (Table 1.25). The natives included two wetland trees, five perennial shrubs and three emergent macrophytes. The remaining species were predominantly perennial herbs. Species richness of plots A and B in this transect was more than double that in plots C and D.

Plot A of this transect had been partially flooded in recent years (Table 1.24) and was the only plot in which *B. articulata* was recorded. This emergent macrophyte

Table 1.21

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Jandabup monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-164	0	supralittoral
B	-199	0	supralittoral
C	-311	0	terrestrial
D	-348	0	terrestrial

Table 1.22

Species presence/absence across Lake Jandabup vegetation monitoring transect

	Plot and location along transect			
	A	B	C	D
Species	0-20	20-30	30-40	40-50
Melaleuca priessiana	X	X	X	X
Hibbertia subvaginata	X	X	X	X
*Ehrharta calycina**	X	X	X	X
*Briza maxima**	X	X	X	X
*Gladiolus caryophyllaceus**	X	X	X	X
*Carpobrotus edulis**	X			
*Pentaschistis airoides**	X			
Beaufortia elegans	X	X		
Dianella revoluta	X	X		
Lyginia barbata	X	X		
Jacksonia furcellata	X		X	X
Alexgeorgia nitens	X			X
Ursinia anthemoidies	X			X
Adenanthos cygornum	X	X	X	
Hypocalyma angustifolium	X	X	X	
Acacia pulchella	X	X	X	
Astartea fascicularis	X	X	X	
Hypolaena exsulca	X	X	X	
Allocasuarina fraseriana		X		
Euchilopsis linearis		X		
Microtis alba		X		
Banksia attenuata		X	X	X
Stylidium repens		X	X	X
Lechenaultia floribunda		X	X	X
Dampiera linearis		X	X	X
Gompholobium tomentoseum		X	X	X
Loxocarya flexuosa		X	X	X
Dianella divaricata		X	X	X
*Pinus pinaster**			X	
Lomandra haemaphrodita			X	
Trachymene pilosa			X	X
Acacia huegelii			X	X
Banksia menziesii			X	X
Lomandra priessii			X	X
Xanthorrhoea priessii			X	X
Corynotheca micrantha			X	X
Banksia ilicifolia				X
Melaleuca rhaphiophylla				X
Eucalyptus rudis				X
Calytrix fraserii				X

Table continued over

Table 1.22 Lake Jandabup

Species	A	B	C	D
Lepidosperma tenue				
*Hypochaeris glabra**				
Burchardia umbelata				
Thysanotus patersonii				
Patersonia occidentalis				
Lagenifera huegelii				
Lobelia rhombifolia				

Table 1.23

Dominant vegetation communites across Lake Jandabup vegetation monitoring transect

Plot	Community
A	Open *M. priessiana* woodland
	Closed mixed *A. fascicularis, H. angustifolium, B. elegans* shrubland
B	Mixed *M. priessiana, B. attenuata* woodland
	Closed mixed *A. fascicularis, H. angustifolium, B. elegans* shrubland
C	Open *M. preissiana, B. attenauta, B. menzeisii* forest
	Mixed shrubland
D	Open *M. preissiana, M. rhaphiophylla, B. attenauta, B. menzeisii B. ilicifolia* forest
	Mixed shrubland

Table 1.24

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Joondalup East monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	36	2.8	littoral
B	-176	0	seasonally waterlogged
C	-136	0	seasonally waterlogged
D	-106	0	seasonally waterlogged

Table 1.25

Species presence/absence across Lake Joondalup East vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-10	10.-20	20-30	30-40
Melaleuca rhaphiophylla	■	■	■	■
Banksia littoralis	■	■	■	■
Lepidosperma longitudinale	■	■	■	■
Baumea juncea	■	■	■	■
Exocarpus sparteus	■			
Opercularia hispida	■			
Baumea articulata	■			
Lobelia alata	■			
*Avena barbata**	■			
Jacksonia furcellata	■	■		
*Ehrharta calycina**	■	■		
Dianella divaricata	■	■		
*Briza maxima**	■	■		
*Avena fatua**	■	■		
*Ehrharta longifolia**	■	■		
Acacia saligna	■			■
*Gladiolus caryophyllaceus**		■		
*Orobanche minor**		■		
Eucalyptus rudis		■	■	■
Centella cordifolia		■	■	■
*Cynodon dactylon**		■	■	■
Pterostylis vitata				■

Table 1.26

Dominant Vegetation communities across Lake Joondalup East vegetation monitoring transect

Plot	Community
A	Open *M. rhaphiophylla, B. littoralis* woodland
	Closed *B. articulata, L. longitudinal, B. juncea* sedgeland
B	Open *M. rhaphiophylla, B. littoralis* woodland
	B. juncea, L. longitudinal sedgeland
C	Open *M. rhaphiophylla, B. littoralis, E. rudis* woodland
	Closed *L. longitudianl, B. juncea* sedgeland
D	*M. rhaphiophylla, B. littoralis, E. rudis* woodland
	Closed *L. longitudianl, B. juncea* sedgeland

dominated the plot with *L. longitudinalee* and *B juncea* under an overstorey of open *M. rhaphiophylla* and *B. littoralis* woodland (Table 1.25; Table 1.26).

Plots B, C and D were only waterlogged during wet seasons (Table 1.24). *M. rhaphiophylla* and *B. littoralis* formed an open woodland in plot B and combined with *E. rudis* across plots C and D (Table 1.26). The understorey of these plots was dominated by a sedgeland of *B. juncea* and *L. longitudinale.*

Lake Joondalup North

Species richness increased along the 45m northern transect at Lake Joondalup, from plot A with eight species to plot D with 23 (Table 1.28). Thirty-eight species were recorded in total, 15 of which were introduced. Species composition was similar to that of the eastern transect, with the same emergent macrophytes and similar herbs, grasses and exotic species. Other native species included four trees and eight shrubs.

Plot A was classified as littoral (Table 1.27) and was dominated by wetland species with seven of the eight species recorded belonging to this group (Table 1.28). Two of these species, *H. brownii* and *Triglochin* sp., were identified as aquatic plants. A closed *B. articulata, B. juncea, L. longitudinale* sedgeland dominated under M. *rhaphiophylla* woodland (Table 1.29).

Baumea articulata and *L. longitudinale* also formed the understorey (Table 1.29) across the seasonally waterlogged plot B (Table 1.27), under *M. rhaphiophylla* and *A. saligna* woodland. Plots C and D, both classified as terrestrial, were dominated by dryland *Banksia* species and shrubs.

Table 1.27

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Joondalup North monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	4	0.4	littoral
B	-176	0	seasonally waterlogged
C	-276	0	terrestrial
D	-306	0	terrestrial

Table 1.28

Species presence/absence across Lake Joondalup North vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-10	10.-20	20-30	33-43
Triglochin sp	x			
Haloragis brownii	x			
Melaleuca rhaphiophylla	x	x		
Baumea articulata	x	x		
Baumea juncea	x	x		
Lepidosperma longitudinale	x	x		
*Ehrharta longifolia**	x		x	x
Myoporum capraroides	x		x	x
Acacia cyclops		x		
*Bromus diandrus**		x		
*Fumaria officinalis**		x		
Stipa compressa		x	x	
*Pelagonium capitatum**		x	x	
Acacia saligna		x	x	x
*Ehrharta calycina**		x	x	x
Ptilotus stirlingii			x	
Conostylis candicans			x	
*Gladiolus caryophyllaceus**			x	
Pimelea argentea			died	
Sowerbea laxifolis			x	
Anagallis a arvensis			x	
Jacksonia furcellata			x	x
Arthropodium capillipes			x	x
*Romulea rosea**			x	x
*Euphorbia peplus**			x	x
Macrozamia riedlei			x	x
Banksia prionotes			x	x
Banksia attenuata				x
Eucalyptus calophylla				x
*Briza maxima**				x
Microlena stiipoides				x
*Avena fatua**				x
Dianella divaricata				x
*Solanum nigrum**				x
*Cynodon dactylon**				x
*Sonchus asper**				x
Lactuca erriola				x
Chenopodium glaucum				x
*Solanum linneanum**				x
Corynotheca micrantha				x

Table 1.29

Dominant vegetation communities across Lake Joondalup North vegetation monitoring transect

Plot	Community
A	*M. rhaphiophylla* woodland
	Closed *B. articulata, L. longitudinal, B. juncea* sedgeland
B	Mixed *M. rhaphiophylla, A. saligna* woodland
	Open *B. articulata, L. longitudinal* sedgeland
C	*B. prionotes* woodland
	Sparse *J. furcellata* shrubland
D	Mixed *B. prionotes, B. attenuata, E. calophylla* woodland
	Sparse J. furcellata shrubland

Lake Joondalup South

Plot C had the lowest species richness of all plots along this 53m transect with less than 25% of the total of 44 species recorded (Table 1.31). Four trees, only one of which was a wetland species, six shrubs and two emergent macrophytes plus a number of herbs and grasses, made up the 23 native species found at this site. The only species that occurred across all sites was an exotic shrub, *Pelargonium capitatum*.

Overstorey density decreased with distance from the waters edge (Table 1.32). A closed forest of *M. rhaphiophylla* dominated the seasonally inundated plot A (Table 1.30 and Table 1.32) above an isolated clump of *B. articulata* and a number of herb species. Open shrubland occurred under thinning *M. rhaphiophylla* woodland across the seasonally waterlogged plot B.

Melaleuca rhaphiophylla thinned further in plot C where it mixed with *A. saligna* in open woodland above grassland. The overstorey of plot D was dominated by an open *B. prionotes* and *B. attenuata* woodland, while *J. furcellata* and other dryland shrubs and grass species formed the understorey (Table 1.32). Both of these plots had remained dry during the past five years (Table 1.30).

Table 1.30

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Joondalup South monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-6	3.4	littoral
B	-46	0.6	seasonally waterlogged
C	-102	0	supralittoral
D	-173	0	terrestrial

Table 1.31

Species presence/absence across Lake Joondalup South vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-30	33-43	43-53
*Pelargonium capitatum**	■	■	■	■
*Phyla nodiflora**	■			
Baumea articulata	■			
Villarsia capitata	■			
*Conyza albida**	■			
Microtis alba	■			
Chenopodium glaucum	■			
*Aster subulatus**	■			
*Lactuca serriola**	■			
*Solanum nigrum**	■			
Centella cordifolia	■	■		
*Sonchus oleraceus**	■	■		
*Cynodon dactylon**	■	■		
Lobelia alata	■	■		
Myoporum capraroides	■	■		
*Ehrharta longiflora**	■	■		
*Agrostis avenacea **	■	■		
Spyridium gloulosum	■	■	■	
Melaleuca rhaphiophylla	■	■	■	
*Solanum laciniatum**	■	■		■
*Pentaschistis airiodies**		■		
*Orobanche minor**		■		
*Sonchus asper**		■	■	
Acacia saligna		■	■	■
*Ehrharta calycinus**		■	■	■
Jacksonia furcellata		■	■	■
*Fumaria officinalis**		■	■	■
Macrozamia riedlei			■	■
Dianella divaricata			■	■
Banksia prionotes				■
Banksia attenuata				■
*Gladiolus caryophyllaceus**				■
Stipa compressa				■
Gompholobium tomentosum				■
Lepidosperma longitudinale				■
*Conyza bonariensis**				■
Thysanotus patersonii				■
*Romulea rosea**				■
Viminea juncea				■
Haemodorum spicatum				■
*Avena barbarta**				■

Table 1.32

Dominant vegetation communities across Lake Joondalup South vegetation monitoring transect

Plot	Community
A	Closed *M. rhaphiophylla* forest
	Isolated clump of *B. articulata* and herbland
B	*M. rhaphiophylla* woodland
	Open shrubland
C	Open *M. rhaphiophylla*, *A. saligna* woodland
	Grassland
D	Open *B. prionotes*, *B. attenuata* woodland
	Open shrubland

North Kogolup Lake transect 1

Fifty percent of the 42 species found at this 80m long transect were exotic with the majority occurring over plots A and B and three found across all plots (Table 1.34). Plot B had the least number of total species while C and D had the greatest species diversity.

The native species included seven trees, seven shrubs and numerous grasses and herbs. Three of the seven tree species were wetland associates. There were no emergent macrophytes recorded at this site, however, a young clump of *T. orientalis* was observed beyond the transect during a field visit. None of the four plots had been inundated in recent years (Table 1.33).

Open mixed forest of *E. rudis, M. rhaphiophylla* and *M. teretifolia* dominated plot A above closed grassland (Table 1.35). A stand of young *E. rudis* was noted beyond plot A during a field trip. Isolated *M. preissiana* formed a drier overstorey with *B. menziesii* in plot B, also over a grassy understorey. Dryland shrubs including *Hibbertia hypericoides* and *J. furcellata* occurred under *B. menziesii, B. attenuata* and *Eucalyptus gomphocephala* woodland in plot C. *Eucalyptus gomphocephala* was replaced with isolated *E. rudis* across plot D above closed shrubland.

North Kogolup Lake transect 2

The species composition and richness of transect 2 was similar to transect 1, despite 2 being only the half the length (Table 1.37). Exotics accounted for 50% of recorded species and represented the majority of species that occurred in all plots, which, like those of transect 1, had not been inundated in recent years (Table 1.36). Patterns in species richness across the plots were also similar. Transect 2 had only four native

Table 1.33

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the North Kogolup Lake monitoring transect 1.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-264	0	supralittoral
B	-464	0	terrestrial
C	-644	0	terrestrial
D	-764	0	terrestrial

Table 1.34

Species presence/absence across North Kogolup vegetation monitoring transect 1

Species	A 0-25	B 25-50	C 50-65	D 65-80
	Plot and location along transect (m)			
*Ehrharta longiflora**	x	x	x	x
*Hypochoeris glabra**	x	x	x	x
*Cerastium glomeratum**	x	x	x	x
Centella asiatica	x			
Melaleuca teretifolia	x			
*Anagalis arvensis**	x			
*Aster subulatus**	x			
*Bromus diandrus**	x			
*Cynodon dactylon**	x			
*Lotus angustissima**	x			
*Polypogon monsplesiensis**	x			
*Sonchus asper**	x			
*Carpobrotus edulis**	x	x		
*Vulpia myuros**	x	x		
Eucalyptus rudis	x			x
Crassula colorata		x		
Melaleuca preissiana		x		
*Aira caryopyllacea**		x		
*Arctotheca calendula**		x		
*Geranium molle**		x		
Banksia menzeisii		x	x	x
Dianella laevis		x		x
*Sonchus olereacea**			x	
*Pelargonium capitatum**			x	
Banksia attenuata			x	
Dichopogon capillipes			x	
Eucalyptus gomphocephala			x	
Jacksonia furcellata			x	
Jacksonia sternbergiana			x	
Macrozamia riedlei			x	
*Homeria flaccida**			x	
*Briza maxima**			x	x
*Briza minor**			x	x
Allocasuarina fraseriana			x	x
*Euphorbia peplus**			x	x
*Zantedeschia aethiopica**			x	x
Hardenbergia comptoniana				x
Hibbertia hypericoides				x
Hibbertia subvaginata				x
Homalosciadium homalocarpum				x
Microlaena stipoides				x
Stipa flavescens				x

Table 1.35
Dominant vegetation communites across North Kogolup Lake vegetation monitoring transect 1

Plot	Community
A	Mixed *E. rudis, M rhaphiophylla, M. teretifolia* open forest
	Closed grassland
B	Isolated *M. preissiana, B. menzeisii* trees
	Closed grassland
C	Mixed *B. menzeisii, B. attenuata, E. gomphacephala* woodland
	Sparse shrubland
D	Mixed *B. menzeisii, B. attenuata, E. rudis* woodland
	Closed shrubland

trees, three less than transect 1, however, it had two more shrubs and an emergent macrophyte, *B. juncea*.

Eucalyptus rudis was recorded in all plots. It formed open forest above isolated shrubs and closed grassland in plot A and mixed with *B. menziesii* as woodland across plot B also over grassland and shrubs (Table 1.38). Open shrubland formed the understorey of plots C and D with an overstorey of *B. attenuata, E. rudis* and *B. menziesii* woodland (Table 1.38).

<u>South Kogolup Lake</u>

All plots of the 45m South Kogolup transect had been inundated within the past five years (Table 1.39). Only 20 species were recorded, with eight of these being exotic (Table 1.40). Three species, *M. teretifolia, E. rudis* and the native herb, *C. asiatica*, occurred across all plots. Two non-wetland trees, two shrubs and a number of native herbs and grasses made up the remainder of the native species list.

E. rudis and *M. teretifolia* occurred as woodland in plot A, while the added presence of *M. preissiana* resulted in denser open forest in all other plots (Table 1.41). Perennial herbs dominated the understorey with isolated *A. fascicularis* found in plot D.

Table 1.36

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the North Kogolup Lake monitoring transect 2.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-204	0	supralittoral
B	-284	0	terrestrial
C	-424	0	terrestrial
D	-604	0	terrestrial

Table 1.37

Species presence/absence across North Kogolup vegetation monitoring transect 2

Species	Plot and location along transect (m) A 0-10	B 10.-20	C 20-30	D 30-40
Eucalyptus rudis	X	X	X	X
*Briza maxima**	X	X	X	X
*Bromus diandra**	X	X	X	X
*Carpobrotus edulis**	X	X	X	X
*Ehrharta longiflora**	X	X	X	X
Centella asiatica	X			
*Adriana octandra**	X			
*Anagalis arvensis**	X			
*Aster subulatus**	X			
*Chenopodium vulgare**	X			
*Circium vulgare**	X			
*Cynodon dactylon**	X			
*Sonchus asper**	X	X		
*Trifolium campestre**	X	X		
Stipa flavescens		X		
Baumea juncea		X		
*Euphorbia peplus**		X		
*Sonchus oleareacea**		X		
*Hypochoeris glabra**		X	X	X
*Vulpia myuros**		X	X	X
Banksia menzeisii		X		X
Caladenia flava			X	X
*Stellaria media**			X	
Conostylis candicans			X	
Hibbertia hypericoides			X	
Dianella laevis			X	
Isolepis nodosus			X	
Leucopogon capitellatus			X	
*Zantedeschia aethiopica**			X	
Macrozamia riedlei			X	X
Microlaena stipiodes			X	X
Patersonia occidentalis			X	X
Desmocladus asper			X	X
*Cerastium glomeratum**			X	X
*Geranium molle**			X	X
Dichopogon capillipes			X	X
Hibbertia subvaginata				X
Homalosciadium homalocarpum				X
Casuarina fraseriana				X
Cotula australis				X

Table continued over

Table 1.37 North Kogolup 2

Species	A	B	C	D
Burchardia umbellata				
Banksia attenuata				
*Romulea rosea**				
Thysanotus manglesianus				
*Aira caryophyllea**				
*Briza minor**				

Table 1.38

Dominant vegetation communites across North Kogolup Lake vegetation monitoring transect 2

Plot	Community
A	Open *E. rudis* forest
	Isolated shrubs and grassland
B	Mixed *E. rudis, B. menzeisii* woodland
	Isolated shrubs and grassland
C	Mixed *E. rudis, B. menzeisii, B. attenuata* woodland
	Open shrubland
D	Mixed E. rudis, B. menzeisii, Banksia attenuata woodland
	Open shrubland

Table 1.39

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the South Kogolup Lake monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-28	3	littoral
B	-28	3	littoral
C	-48	2.2	littoral
D	-68	2	littoral/supralittoral

Table 1.40

Species presence/absence across South Kogolup Lake vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-15	15-25	25-35	35-45
Eucalyptus rudis	x	x	x	x
Centella asiatica	x	x	x	x
Melaleuca teretifolia	x	x	x	x
*Lotus angustissimus**	x	x		
*Sonchus asper**	x	x	x	
Hemarthria uncinata	x	x	x	
Melaleuca preissiana		x		
Acacia pulchella		x		
Deyeuxia quadriseta		x		
*Cynodon dactylon**		x		
*Ehrharta longiflora**		x		
*Circium vulgare**		x	x	
Acacia saligna		x	x	
*Bromus diandrus**			x	
*Hypochoeris glabra**			x	
Baumea rubiginosa				x
Agrostis avenacea				x
Lepidosperma effusum				x
Astartea fasciculata				x

Table 1.41

Dominant vegetation communites across South Kogolup Lake vegetation monitoring transect

Plot	Community
A	Open *E. rudis, M. teretifolia* forest Herbland
B	Open *E. rudis, M. preissiana, M. teretifolia* forest Herbland
C	Open *E. rudis, M. preissiana, M. teretifolia* forest Herbland
D	Open *E. rudis, M. preissiana, M. teretifolia* forest Herbland and isolated *A. fascicularis*

Lexia Wetland 86

The transect at Lexia Wetland 86 was 50m long, with plot A the only one to have flooded in recent years and B, C and D only becoming seasonally waterlogged (Table 1.42). Plot A had the lowest species richness, despite being the largest, followed by plot D, C and finally B (Table 1.43).

Only two of the 21 species recorded were exotic, with the native species dominated by perennial shrubs, 11 in total. The myrtaceous shrubs, *A. fascicularis* and *H. angustifolium* occurred across all plots. A field visit indicated that although these shrubs were listed as the dominant overstorey of plot A (Table 1.44), only *B. articulata* occurred at the start of the plot. A dense stand of *M. preissiana* occurred across plots B and C, thinning to form an open forest in plot D. Myrtaceous shrubs (Table 1.44) dominated the understorey of these three plots.

Lexia Wetland 186

None of the plots across the Lexia 186 transect were inundated during the past five years, however plots A and B were seasonally waterlogged (Table 1.45). Plots C and D occurred over a shallow groundwater table.

Perennial native shrubs also dominated this 40m transect, accounting for 14 of the 31 species recorded (Figure 1.46). *Astartea fascicularis, H. angustifolium* and *P. ellipticum* were three of the four species that occurred across all plots. As with the previous wetland, very few exotic species were found. Three trees, an emergent macrophyte and several herbs accounted for the rest of the native species. Species richness was similar between plots A, B and C with the fewest species found in plot D.

Table 1.42

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lexia Wetland 86 monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-9	0.6	littoral/supralittoral
B	-67	0	seasonally waterlogged
C	-95	0	seasonally waterlogged
D	-101	0	seasonally waterlogged

Table 1.43

Species presence/absence across Lexia Wetland 86 vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-30	30-40	40-50
Astartea fascicularis	■	■	■	■
Hypocalymma angustifolium	■	■	■	■
Baumea articulata	■			
Banksia littoralis (seedlings)	■			
Pericalymma ellipticum	■	■		
Hibbertia subvaginata		■		
Stylidium repens		■		
Stylidium brunoniianum		■		
Banksia ilicifolia		■		
Euchilopsis linearis		■	■	
Trachymene pilosa		■	■	
Agonis linearifolia		■	■	■
Pultenaea reticulata		■	■	■
Cassytha racemosa		■	■	■
Leucopogon propinquus		■	■	■
Melaleuca preisianna		■	■	■
Poranthera microphylla		■	■	■
*Hypochaeris glabra**		■	■	■
*Sonchus oleraceus**			■	
Calothamnus lateralis			■	
Dauchus glochidiatus				■

Table 1.44

Dominant vegetation communites across Lexia Wetland 86 vegetation monitoring transect

Plot	Community
A	*A. fascicularis, H. angustifolium, P. ellipticum* shrubland
	Sparse *B. articulata* sedgeland
B	Closed *M. preissiana* forest
	A. fascicularis, H. angustifolium, P. ellipticum shrubland
C	Closed *M. preissiana* forest
	A. fascicularis, H. angustifolium, P. ellipticum shrubland
D	Open *M. preissiana* forest
	A. fascicularis, H. angustifolium, P. ellipticum shrubland

Table 1.45

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lexia Wetland 186 monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-148	0	seasonally waterlogged
B	-198	0	seasonally waterlogged
C	-192	0	supralittoral
D	-208	0	supralittoral

Table 1.46

Species presence/absence across Lexia Wetland 186 vegetation monitoring transect

Species	Plot and location along transect (m) A 0-10	B 10.-20	C 20-30	D 30-40
Astartea fascicularis	x	x	x	x
Pericalymma ellipticum	x	x	x	x
Hypocalymma angustifolium	x	x	x	x
Melaleuca preissiana	x	x	x	x
Pulteneae reticulata	x			
Isolepsis cenua	x			
Mitrasacme paradoxa	x			
Trachymene pilosa	x	x	x	
Hibbertia subvaginata	x	x		
Banksia ilicifolia (seedlings)	x	x		
*Hypochaeris glabra**	x	x		x
*Briza maxima**		x		
Beaufortia elegans		x		
Dauchus glochidiatus		x		
*Briza minor**		x		
Lagenifra huegelii		x	x	
Hypolaena exsulca		x	x	
Lepidosperma longitudinale		x	x	x
Stylidium brunonianum		x	x	x
Orthrosanthus laxus		x	x	x
Patersonia occidentalis			x	
Macrozamia riedlei			x	
Allocasuarina fraseriana (seedlings)			x	
Gompholobium tomentoseum			x	
*Vulpia myuros**			x	
Adenanthos obovatus			x	x
Stylidium repens			x	x
Euchilopsis linearis			x	x
Xanthorrhoea preissii			x	x
Hibbertia hypericoides				x
Drosea pallida				x

Table 1.47

Dominant vegetation communites across Lexia Wetland 186 vegetation monitoring transect

Plot	Community
A	Open *M. preissiana* woodland
	Myrtaceous shrubland
B	Open *M. preissiana* woodland
	Myrtaceous shrubland
C	*M. preissiana* woodland
	Mixed shrubland
D	*M. preissiana* woodland
	Mixed shrubland

Melaleuca preissiana occurred across all plots, becoming denser with distance from the lake edge (Table 1.14). It formed open woodland in plots A and B and woodland in C and D. The myrtaceous shrubs mentioned previously formed the understorey across the transect mixing with dryland shrubs in plots C and D (Table 1.47).

Lake Mariginiup

This 60m transect was the only one to contain five plots. Plots A and B had both been flooded for close to two months of the year over the last five years (Table 1.48). Plots C, D and E were seasonally waterlogged.

More than 40% of the 36 species found were exotic, with numbers spread fairly evenly across all plots (Table 1.49). Total species richness of each plot, however, varied with plots A and E recording greater numbers than B, C and D. Six species occurred across all five plots, *E. rudis, B. articulata,* one exotic and two native herbs. During a field visit it was noted that *T. orientalis* and *B. articulata* occurred beyond plot A and into the wetland.

Sparse *E. rudis* dominated the overstorey across the transect (Table 1.50). Woodland occurred in plot A and open mixed *E. rudis, A. saligna* woodland was found in plot B. Isolated *M. teretifolia* and *E. rudis* were located in plot C and became more dense in plot D to form woodland. *Eucalyptus rudis* formed woodland in the last plot. *Baumea articulata,* grasses and herbs dominated the understorey across the transect.

Table 1.48

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Mariginiup monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	15	2.6	littoral
B	-28	1.8	littoral/supralittoral
C	-65	1	seasonally waterlogged
D	-83	0	seasonally waterlogged
E	-75	0	seasonally waterlogged

Table 1.49

Species presence/absence across Lake Mariginiup vegetation monitoring transect

	Plot and location along transect (m)				
	A	B	C	D	E
Species	0-10	10.-20	20-30	30-40	40-50
Eucalyptus rudis	X	X	X	X	X
Baumea articulata	X	X	X	X	X
*Hypochaeris glabra**	X	X	X	X	X
Agrostis avenacea	X	X	X	X	X
Villarsia capitata	X	X	X	X	X
*Lotus suaveolens**	X	X	X	X	X
*Poa annua**	X				
*Carpobrotus edulis**	X				
*Sonchus asper**	X				X
*Solanum nigrum**	X				X
Lepyrodia muirii	X	X			
*Briza maxima**	X	X	X		
*Conyza bonariensis**	X	X	X	X	
Podolepsis lessonii	X	X	X	X	
*Briza minor**	X	X	X		X
Lobelia alata	X	X			X
*Vulpia myuros**	X		X	X	X
*Wahlenbergia capensis**		X			
Centella cordifolia		X			
Acacia cyclops		X	X	X	
Acacia saligna		X	X	X	X
*Acacia longifolia**		X	X	X	X
Exocarpus sparteus		X	X	X	X
Viminaria juncea		X	X	X	X
*Pentaschistis airiodies**		X		X	
Melaleuca teretefolia			X	X	X
Epilobium billardierianum			X	X	X
*Sonchus olearus**				X	
*Avena fatua**				X	
*Pelagonium capitatum**				X	X
*Lolium rigidum**				X	X
*Ehrhata calycinus**					X
*Lagurus ovatus**					X
*Bromus diandrus**					X
Dianella divaricata					X
Baumea juncea					X

Table 1.50

Dominant vegetation communities across Lake Mariginiup vegetation monitoring transect

Plot	Community
A	*E. rudis* woodland
	Open *B. articulata* sedgeland
B	Open *E. rudis, A. saligna, A. longifolia* woodland
	Sparse *B. articulata* sedgeland
C	Isolated *E. rudis* and *M. teretifolia*
	Sparse B. articulata sedgeland
D	*E. rudis, M. teretifolia* woodland
	Open *B. articulata* sedgeland
E	*E. rudis, M. teretifolia* woodland
	Open *B. articulata* sedgeland

Melaleuca Park Wetland 173

Plot A of this wetland was located around the high water mark and had therefore been classified as littoral/supralittoral (Table 1.51). Plot B had only been seasonally waterlogged in recent years, while plots C and D were situated above a shallow groundwater table.

Twenty-six species were recorded along this 50m transect, only two of which were exotic (Table 1.52). More than 50 % of the native species were perennial shrubs, with two from this group found across all plots. *Lepidosperma longitudinale* also occurred in all plots. Plot A, the largest plot, had the lowest species richness, while plot C was the richest.

The absence of trees in plot A resulted in *A. fascicularis* again forming the dominant overstorey (Table 1.53). However, a field visit indicated that *B. articulata* and *L. scariosus* dominated the wetland end of the plot, forming a closed sedgeland. *A. fascicularis* occurred at the drier end of the plot.

Table 1.51

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Melaleuca Park EPP Wetland 173 monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-10	2	littoral/supralittoral
B	-61	0	seasonally waterlogged
C	-84	0	supralittoral
D	-87	0	supralittoral

Table 1.52

Species presence/absence across EPP Wetland 173 vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-30	30-40	40-50
Baumea articulata	x			
Leptocarpus scariosus	x	x	x	
Astartea fascicularis	x	x	x	x
Casytha racemosa	x	x	x	x
Lepidosperma longitudinale	x	x	x	x
Calothamnus lateralis		x		
Lepyrodia glauca		x		
Burchardia umbellata		x		
Agonis linearifolia		x	x	
Platytheca vertillcilata		x	x	
Euchilopsis linearis		x	x	
Melaleuca preissiana		x	x	x
*Lagurus ovatus**		x	x	x
Patersonia occidentalis		x		x
Dampiera linearis			x	
Tricoryne elatior			x	
Pultenaea reticulata			x	
Hypochaeris glabra			x	
Xanthorrhoea preissii			x	x
Sowerbaea laxiflora			x	x
Loxocarya flexuosa			x	x
Acacia pulchella			x	x
Hypocalymma angustifolium			x	x
Pericalymma ellipticum			x	x
Eucalyptus calophylla			x	x
Orthrosanthus laxus			x	x
Stylidium brunonianum				x

Table 1.53

Dominant vegetation communites across EPP Wetland 173 vegetation monitoring transect

Plot	Community
A	*A. fascicularis* shrubland
	Closed *B. articulata, L. scariosus* sedgeland
B	*M. preissiana* woodland
	Sparse *A. fascicularis* shrubland
C	Closed *M. preissiana, E. calophylla* forest
	Sparse A. fascicularis shrubland
D	Mixed *M. preissiana. E. calophylla* woodland
	Mixed shrubland

Melaleuca preissiana formed woodland in plot B and mixed with *Eucalyptus calophylla* in plots C and D as a closed forest and woodland respectively (Table 1.53). *Astartea fascicularis, L. longitudinale* and perennial herb species dominated the understorey of plot B, with *H. angustifolium, P. ellipticum* and numerous dryland shrubs the dominant species in the plots.

North Lake transect 1

Plots A and B of this transect had been inundated for less than one month of each of the last five years, however, as B was only partially flooded it was classified as seasonally waterlogged as was plot C (Table 1.54).

Wetland trees dominated the three plots of this 60m transect, representing more than 25% of the total 23 species recorded (Table 1.55). A further 25% was made up of exotic species. Three shrubs, two emergent macrophytes and a number of herbs made up the remaining native species. An aquatic fern, *Azolla sp.*, was recorded in plot A.

A sparse stand of *E. rudis* occurred in all plots. It mixed with *M. teretifolia* and *M. rhaphiophylla* in plot A to form mixed woodland above dense *L. longitudinale* sedgeland (Table 1.56). Open *M. preissiana,* E. *rudis* forest dominated plots B and C, with the understorey formed by mixed open shrubland.

Table 1.54

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the North Lake monitoring transect 1.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-51	0.8	littoral
B	-91	0.4	seasonally waterlogged
C	-131	0	seasonally waterlogged

Table 1.55

Species presence/absence across North Lake vegetation monitoring transect 1

	Plot and location along transect (m)		
	A	B	C
Species	0-20	20-40	40-50
Lepidosperma longitudinale	x	x	x
Eucalyptus rudis	x	x	x
Azolla sp	x		
Melaleuca rhaphiophylla	x		
Melaleuca teretifolia	x		
*Polypogon monspeliensis**	x		
*Aster subulatus**	x		
Isolepis marginata	x		
Lobelia alata	x		
Leucopogon australis	x	x	
*Vulpia myuros**	x		x
Isolepis nodosus		x	
Banksia littoralis (1 only)		x	
Deyeuxia quadriseta		x	
Patersonia occidentalis		x	
Aotus gracillima		x	
Dampiera		x	
Astartea fascicularis		x	
Melaleuca preissiana		x	x
Kunzea ericifolia		x	x
*Zantedeschia aethiopica**		x	x
*Sonchus olereacea**		x	x
Pteridium esculentum		x	x

Table 1.56

Dominant vegetation communites across North Lake vegetation monitoring transect 1

Plot	Community
A	Mixed *E. rudis, M. rhaphiophylla, M. teretifolia* woodland
	Closed *L. longitudinal* sedgeland
B	Mixed *E.rudis, M.preissiana* woodland
	Mixed shrubland
C	Mixed *E. rudis, M. preissiana* open woodland
	Mixed shrubland

North Lake transect 2

Four hydrological zones were represented across this transect (Table 1.57). Plot A had been inundated and was classified as littoral, plot B was seasonally waterlogged, C and D were both dry and deemed supralittoral and terrestrial, respectively.

Although this transect was only 20m longer than transect 1, more than twice as many species were found at this second site (Table 1.58). The ratio of exotics and native tree species was, however, the same across both transects. The number of shrub and emergent macrophytes did not follow this trend, nor did species richness within plots, as the fewest species were recorded in plot A.

The only native species of the three that occurred in all plots was *M. preissiana.* This species formed mixed woodland with *E. rudis* and *M. rhaphiophylla* in plot A, and with *E. rudis* only in plot B (Table 1.59). Plots C and D were dominated by open woodland, which included the dryland species *B. menziesii* and *Eucalyptus marginata.* The understorey of plots A and B consisted of open *L. longitudinale* sedgeland and sparse shrubland. Thicker shrubland with greater numbers of dryland species was found in plots C and D.

Lake Nowergup North

None of the four plots of this transect were inundated or seasonally waterlogged in recent years (Table 1.60). Plots A and B were classified as supralittoral, C and D were terrestrial.

Plot A had the highest species richness, however, eight of the seventeen species recorded were introduced (Table 1.61). In all, of the total 26 species identified, 35%

Table 1.57

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the North Lake monitoring transect 2.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-31	1	littoral
B	-91	0.4	seasonally waterlogged
C	-171	0	supralittoral
D	-251	0	terrestrial

Table 1.58

Species presence/absence across North Lake vegetation monitoring transect 2

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-40	40-60	60-80
Melaleuca preissiana	■	■	■	■
*Briza maxima**	■	■	■	■
*Zantedeschia aethiopica**	■	■	■	■
Melaleuca rhaphiophylla	■			
Baumea juncea	■			
Melaleuca teretifolia	■			
Leucopogon australis	■			
Pultenaea reticulata	■			
Opercularia hispidula	■			
Banksia littoralis	■			
Microtis media	■	■		
Lepidosperma longitudinale	■	■		
Astartea fascicularis	■	■		
Eucalyptus rudis	■	■	■	
Dampiera linearis	■	■	■	
Boronia crenulata		■		
Pimelea rosea		■		
Dianella laevis		■		
Hypocalymma robustum		■	■	■
Trachymene pilosa		■	■	■
Dasypogon bromelifolius		■	■	■
*Cerastium glomeratum**		■	■	■
*Sonchus oleareaceus**		■	■	■
*Hypochoeris glabra**		■	■	■
Xanthorrhoea preissii		■	■	■
Macrozamia riedlei		■	■	■
*Briza minor**		■	■	■
*Aira caryophyllea**		■	■	■
*Vulpia myuros**		■	■	
Kunzea ericifolia		■	■	
Phlebocarya ciliata		■	■	
Monotaxis occidentalis		■		
*Carpobrotus edulis**		■		
Quinetia urvillei		■		
Microlaena stipiodes			■	
Poranthera microphylla			■	
Gompholobium tomentosum			■	
Hibbertia hypericoides			■	■
Caladenia flava			■	■
Eucalyptus marginata			■	■

Table continued

Table 1.58

Species	Plot A	B	C	D
Melaleuca thymoides			■	■
Banksia menzeisii			■	■
Banksia ilicifolia			■	■
*Sonchus asper**			■	■
Lobelia tenuior				■
Banksia attenuata				■
Melaleuca seriata				■
*Cotula turbinata**				■
Bossiaea eriocarpa				■
*Anagalis arvensis**				■

Table 1.59

Dominant vegetation communites across North Lake vegetation monitoring transect 2

Plot	Community
A	Mixed *E. rudis, M. rhaphiophylla, M. preissiana* woodland
	Open *L. longitudinal* sedgeland
B	Mixed *E.rudis, M.preissiana* woodland
	Open *L. longitudinal* sedgeland
C	Mixed *M. preissiana, E. marginata, B. menzeisii* open woodland
	Mixed shrubland
D	Mixed *M. preissiana, E. marginata, B. menzeisii* open woodland
	Mixed shrubland

were exotic and only six were wetland species. The native species comprised three trees, six perennial shrubs, two emergent macrophytes and grass species.

The emergent macrophytes, *L. longitudinale* and *B. articulata* were only found in plot A, along with the exotic emergent *T. orientalis* (Table 1.61). Field trips indicated that these three species were only found at the start of the plot and extended into the water.

The overstorey of plots A and B was *M. rhaphiophylla, E. rudis* woodland (Table 1.62). As no tree species were recorded in plots C and D and the woody perennial *Jacksonia sternbergiana* was dominant, these plots were classified as shrubland. Dense grassland and sparse *Rhagodia baccata* shrubland dominated the majority of the understorey in plot A. The grassland continued through the other plots.

Lake Nowergup South

The species composition of the southern transect at Lake Nowergup was very similar to that of the northern plots despite this second transect being twice as long (Table 1.64). Species richness and the percentage of exotics were similar and the same emergent macrophytes, wetland trees and some shrub species were recorded at both transects. The dry plots, B, C and D (Table 1.63), of the southern transect, however, also contained the dryland trees *Banksia grandis* and *E. gomphocephala.*

As with the northern plot, *B. articulata* and *T. orientalis* only occurred at the bottom of plot A, which was the only part of the transect inundated in recent years (Table 1.63), and continued further into the wetland.

Table 1.60

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Nowergup North monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-94	0	supralittoral
B	-214	0	supralittoral
C	-284	0	terrestrial
D	-434	0	terrestrial

Table 1.61

Species presence/absence across Lake Nowergup North vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-10	10.-20	20-30	30-40
Rhagodia baccata	■	■	■	■
*Pelagonium capitatum**	■	■	■	■
Stipa compressa	■	■	■	■
*Ehrhata calycinus**	■	■	■	■
Lepidosperma longitudinale	■			
Acacia saligna	■			
*Lupinus cosentinii**	■			
*Typha orientalis**	■			
*Cynodon dactylon**	■			
Baumea articulata	■			
*Oxalis corniculata**	■			
Melaleuca rhaphiophylla	■	■		
Eucalyptus rudis	■	■		
*Ehrhata longifolia**	■	■		
*Bromus diandrus**	■	■		
Arthropodium capillipes	■		■	
Acanthocarpus preissii	■			■
Microtis alba		■		
*Geranium molle**		■		
Jacksonia sternbergiana		■	■	■
Stipa campylachne		■	■	■
*Briza maxima**			■	■
Conostylis candicans			■	■
Macrozamia riedlei			■	
Thysanotus patersonii				■
Gyrostemon ramulosus				■
Dianella divaricata				■

Table 1.62

Dominant vegetation community across Lake Nowergup North vegetation monitoring transect

Plot	Community
A	*M. rhaphiophylla, E. rudis, A. saligna* woodland
	Dense grassland
B	*M.rhaphiophylla, E. rudis* woodland
	Dense grassland
C	*J. sternbergiana* shrubland
	Dense grassland
D	*J. sternbergiana, A. preissi* shrubland
	Dense grassland

Table 1.63

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Nowergup South monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	16	0.6	littoral/supralittoral
B	-194	0	supralittoral
C	-484	0	terrestrial
D	-684	0	terrestrial

Table 1.64

Species presence/absence across Lake Nowergup South vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-40	40-60	60-80
*Pelagonium capitatum**	■	■	■	■
*Ehrhata calycinus**	■	■	■	■
*Bromus diandrus**	■	■	■	■
Melaleuca rhaphiophylla	■			
*Typha orientalis**	■			
Baumea articulata	■			
*Carpobrotus edulis**	■			
Lepidosperma longitudinale	■	■		
Rhagodia baccata	■	■		■
*Cynodon dactylon**	■		■	■
Eucalyptus rudis		■		
Dianella divaricata		■		
Jacksonia furcellata		■	■	
Jacksonia sternbergiana		■	■	
Stipa campylachne		■	■	
*Rumex crispus**		■	■	
Stipa compressa		■	■	■
Macrozamia riedlei		■	■	■
Lupinus cosentinii		■	■	■
*Homeria flaccida**			■	
Banksia grandis			■	
Acacia saligna			■	
Eucalyptus gomphocephala			■	■
Arthropodium capilles				■
Acanthocarpus preissii				■
*Oxalis corniculata**				■

Table 1.65

Dominant vegetation communites across Lake Nowergup South vegetation monitoring transect

Plot	Community
A	Open *M. rhaphiophylla* woodland
	Sedgeland, then grassland
B	Isolated *E. rudis*
	Grassland and dryland shrubs
C	*B. grandis* woodland
	Grassland and dryland shrubs
D	Open *E. gomphacephala* woodland
	Grassland and dryland shrubs

Melaleuca rhaphiophylla woodland dominated plot A, replaced in plot B by isolated *E. rudis* (Table 1.65). *B. grandis* and *E. gomphocephala* formed woodland in plots C and D respectively. The understorey of all plots consisted of grassland and dryland shrubs.

Shirley Balla Swamp 1

No part of this transect had been flooded within the past five years (Table 166). Plot A was, however, seasonally waterlogged, while B and C occurred over a shallow groundwater table and D over deeper groundwater.

Species richness was higher at this 80m transect than at any other of the study sites, with a total of 52 species identified, only 25% of which were exotic (Table 1.67). No species occurred across all plots and plot D had the greatest diversity.

Perennial shrubs, including *A. fascicularis* and *H. angustifolium* accounted for 19 of the 39 native species, along with one emergent macrophyte, *L. longitudinale,* five trees and herb species (Table 1.67). The only wetland tree recorded was *M. preissiana.*

Open *M. preissiana* forest formed the overstorey of plot A above open *A. fascicularis* shrubland and *L. longitudinale* sedgeland (Table 1.68). Denser *M. preissiana* dominated plot B as closed forest, with a thicker shrub understorey also forming. *M. preissiana* and *B. ilicifolia* mixed with dryland *Eucalyptus* and *Banksia* species to form woodland in plot C, with Banksia woodland dominate in plot D. *Kunzea ericifolia* and a number of non-wetland shrubs formed a dense understorey across these two plots.

Table 1.66

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Shirley Balla Swamp monitoring transect 1.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-82	0	seasonally waterlogged
B	-82	0	supralittoral
C	-142	0	supralittoral
D	-212	0	terrestrial

Table 1.67

Species presence/absence across Shirley Balla Swamp vegetation monitoring transect 1

	Plot and location along transect (m)			
	A	B	C	D
Species	0-20	20-40	40-60	60-80
*Vulpia myuros**	x			
Agrostis avenacea	x			
*Lagurus ovatus**	x			
*Sonchus asper**	x			
Lepidosperma longitudinale	x	x		
Melaleuca preissiana	x	x		
*Polypogon monspeliensis**	x	x		
*Sonchus olereacea**	x	x		
Leucopogon australis	x	x		x
*Briza maxima**	x	x		x
*Hypochoeris glabra**	x	x		x
Hypolaena exsulca	x		x	
Trachymene pilosa	x			x
Eutaxia virgata		x		
Astartea fascicularis		x		
*Zantedeschia aethiopica**		x		
Pterostylis nana		x		
Kunzea ericifolia		x	x	x
Pultenaea ochreata			x	
Schoenus rodwayanus			x	
*Circium vulgare**			x	
Allocasuarina fraseriana			x	
Hypocalymma angustifolium			x	
Burchardia umbellata			x	
Dasypogon bromeliifolius			x	x
Eucalyptus todtiana			x	x
Gompholobium tomentosum			x	x
Melaleuca polygaloides			x	x
Xanthorrhoea preissii			x	x
Phlebocarya ciliata			x	x
Acacia pulchella				x
Adenanthos cygnorum				x
Adenanthos obovatus				x
Banksia attenuata				x
Banksia ilicifolia				x
Bossiaea eriocarpa				x
Conostylis juncea				x
Crassula exerta				x
Dampiera linearis				x
Desmocladus asper				x

Table 1.67 continued over

Table 1.67 continued

	Plot			
Species	A	B	C	D
Eriostemon ramosa				
Jacksonia furcellata				
Hibbertia subvaginata				
Homalosciadium homalocarpum				
Lagenifera stipitata				
Laxmannia ramosa				
Pimelea rosea				
*Aira caryophyllea**				
Xanthorrhoea gracilis				
*Briza minor**				
*Ehrharta calycina**				
*Ursinia anthemoides**				

Table 1.68

Dominant vegetation communites across Shirely Balla Swamp monitoring transect 1

Plot	Community
A	Open *M. preissiana* forest
	Open *A. fascicularis* shrubland and *L. longitudinal* sedgeland
B	Closed *M. preissiana* forest
	Closed *A. fascicularsi, K. ericifolia* shrubland
C	Mixed *M. preissiana, B. ilicifolia, B. attenuata, E. todtiana* woodland
	Mixed closed shrubland
D	Mixed *B. ilicifolia, B. attenauta, B. menzeissi* woodland
	Mixed closed shrubland

Shirley Balla Swamp 2

Plot A of this transect had been flooded for a period of only a few weeks each year during the last five years (Table 1.69). Plot B did not flood, but was seasonally waterlogged, while plots C and D remained dry.

This transect was 30m shorter than transect 1, which was reflected by lower species richness (Table 1.70). Fifty percent of the 26 species recorded were introduced, the majority of which were found in plots A and B. Two exotics occurred across all plots.

One tree, five shrubs, again including *A. fascicularis* and *H. angustifolium,* and one emergent macrophyte, *L. longitudinale,* made up the bulk of the native species. The only tree, *M. rhaphiophylla* formed closed forest in plot A, thinning to open forest across plots B and C and to woodland in plot D (Table 1.71). Exotic species and grasses dominated the understorey of plots A and B, while mixed shrubland occurred across plots C and D.

Thomsons Lake transect 2

Plot A, the largest plot and the only one that was not totally dry (Table 1.72), had the highest species richness along this 80m transect with more than twice as many species as plots B and D and almost double that of plot C (Table 1.73). Thirty-five percent of the 23 species recorded at this site were exotic, three of which occurred in all plots.

The native species included two wetland trees, one shrub and two emergent macrophytes, *B. articulata* and *B. juncea,* which were found in plot A only. A third emergent macrophyte, *T. orientalis*, occurred beyond plot A.

Table 1.69

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Shirley Balla Swamp monitoring transect 2.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-52	0.4	littoral/supralittoral
B	-72	0	seasonally waterlogged
C	-72	0	supralittoral
D	-92	0	supralittoral

Table 1.70

Species presence/absence across Shirley Balla Swamp vegetation monitoring transect 2

Species	Plot and location along transect (m)			
	A	B	C	D
	0-20	20-30	30-40	40-50
*Sonchus oleareaceus**	■	■	■	■
Melaleuca rhaphiophylla	■	■	■	■
*Hypochoeris glabra**	■	■	■	■
*Aira caryophyllea**	■			
*Sonchus asper**	■			
*Poa annua**	■			
Cotula coronopifolia	■	■		
Agrostis avenacea	■	■	■	
*Circium vulgare**	■	■	■	
*Polypogon monspeliensis**	■	■	■	
*Vulpia myuros**	■		■	
Gratiola peruviana		■		
*Solanum americanum**		■		
*Briza minor**		■		
*Aster subulatus**		■		
Phyllangium paradoxum		■	■	■
Lepidosperma longitudinale		■	■	■
*Lotus angustissima**		■	■	■
*Briza maxima**			■	
Bossiaea eriocarpa			■	■
Astartea fascicularis			■	■
Caustis dioica				■
Homalosciadium homalocarpum				■
Hypocalymma angustifolium				■
Kunzea ericifolia				■
Patersonia occidentalis				■

Table 1.71

Dominant vegetation communites across Shirely Balla Swamp monitoring transect 2

Plot	Community
A	Closed *M. rhaphiophylla* forest
	Exotics and grassland
B	Open *M. rhaphiophylla* forest
	Exotics and grassland
C	Open *M. rhaphiophylla* forest
	A. fascicularis shrubland
D	*M. rhaphiophylla* woodland
	Mixed *a, fascicularis, H. angustifolium, K. ericifolia* shrubland

Table 1.72

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Thomsons Lake monitoring transect 2.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-125	0	seasonally waterlogged
B	-135	0	supralittoral
C	-215	0	supralittoral
D	-195	0	supralittoral

Table 1.73

Species presence/absence across Thomsons Lake vegetation monitoring transect 2

	Plot and location along transect (m)			
	A	B	C	D
Species	0-25	25-35	35-55	55-75
Eucalyptus rudis	x	x	x	x
*Bromus diandrus**	x	x	x	x
*Ehrharta longiflora**	x	x	x	x
*Sonchus asper**	x	x	x	x
*Circium vulgare**	x	x	x	x
Heliotropium curassavicum	x			
Baumea articulata	x			
*Arctotheca calendula**	x			
*Aster subulatus**	x			
*Crassula colorata**	x			
*Cynodon dactylon**	x			
*Hypochoeris glabra**	x			
*Vulpia myruros**	x			
Baumea juncea	x	x		
Sporobolus virginicus	x	x		
Isolepis nodosus	x	x		
*Zantedeschia aethiopica**	x		x	x
*Carpobrotus edulis**	x		x	x
*Lotus angustissima**	x			x
*Asparagus asparagoides**			x	
*Sonchus oleraeacea**			x	
Melaleuca teretifolia			x	
Acacia saligna			x	
*Phalaris minor**				x

Table 1.74

Dominant vegetation communities along Thomsons Lake monitoring transect 2

Plot	Community
A	Isolated *E. rudis* trees
	Open *B. articulata, J. pallidus* sedgeland
B	*E. rudis* woodland
	Exotics
C	*E. rudis* woodland
	Exotics
D	*E. rudis* woodland
	Exotics

The overstorey of plot A was formed by isolated *E. rudis* above an understorey of open *B. articulata* and *J. pallidus* sedgeland (Table 1.74). Exotic species dominated the understorey across the rest of the transect under *E. rudis* woodland.

Thomsons Lake transect 3

At 120m in length, this was the longest of all the study transects (Table 1.76). Despite this only 34 species were recorded at this site, 62% of which were introduced. As with transect 2, plot A was seasonally waterlogged while other plots had remained dry during recent years (Table 1.75).

Baumea articulata was the only emergent macrophyte recorded, occurring in plot A and into the wetland. The remainder of the native species consisted of three trees, four shrubs, herbs and grasses (Table 1.76).

Eucalyptus rudis was again the dominant wetland tree (Table 1.77). It formed open forest across plot A, however, only isolated individuals occurred in plot B. The understoreys of both of these plots were dominated by exotic species. No wetland species were identified in plots C and D, with *B. attenuata* woodland replacing *E. rudis* above a dryland shrub understorey.

Table 1.75

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Thomsons Lake monitoring transect 3.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-125	0	seasonally waterlogged
B	-145	0	supralittoral
C	-255	0	terrestrial
D	-605	0	terrestrial

Tabe 1.76

Species presence/absence across Thomsons Lake vegetation monitoring transect 3

Species	A 0-45	B 45-75	C 75-105	D 105-120
	Plot and location along transect (m)			
*Bromus diandrus**	■	■	■	■
*Ehrharta longiflora**	■	■	■	■
*Lagurus ovatus**	■	■	■	■
Baumea articulata	■			
Gratiola peruviana	■			
*Circium vulgare**	■			
*Cynodon dactylon**	■			
*Lotus angustissima**	■			
*Sonchus asper**	■			
Eucalyptus rudis	■	■		
*Vulpia myuros**	■	■	■	
*Carpobrotus edulis**	■	■	■	
*Medicago polymorpha**	■	■		■
*Hypochoeris glabra**	■	■		■
*Dischisma capitatum**		■		
Crassula exerta		■	■	
*Crassula glomerata**		■	■	■
*Ehrharta calycina**		■	■	■
*Ursina anthemoides**			■	
Macrozamia riedlei			■	
*Briza maxima**			■	■
Banksia attenuata			■	■
Grevillia vestita			■	■
Isolepis nodosus			■	■
Allocasuarina fraseriana				■
Corynotheca micrantha				■
Jacksonia sternbergiana				■
*Euphorbia peplus**				■
*Pelargonium capitatum**				■
*Romulea rosea**				■
*Sonchus olereacea**				■
*Stellaria media**				■

Table 1.77 Dominant vegetation communities along Thomsons Lake monitoring transect 3

Plot	Community
A	Open *E. rudis* forest
	Open *B. articulata* sedgeland
B	Isolated *E. rudis*
	Exotics
C	*B. attenauta* woodland
	Open shrubland
D	B. attenuata woodland.
	Shrubland

Thomsons Lake transect 4

Plots A and B of this transect had been inundated for short periods during recent years (Table 1.78), however, plot B was sufficiently dry to be classified as seasonally waterlogged. Plots C and D were described as terrestrial.

This transect was also species poor despite its length, with only 31 species recorded along 100m (Table 1.79). As with transect 3, exotics accounted for more than 60% of the total species count. Species composition was also similar between these two transects, with the same trees and emergent macrophyte recorded in both, along with similar exotic and shrub species.

The overstorey of plots A, B, and C was formed by isolated *E. rudis,* with denser *B. attenuata* forming open woodland in plot D (Table 1.80). Open *B. articulata* sedgeland dominated the understorey in plot A along with a number of exotic species. Exotics also dominated plots B and C, with shrubland found across plot D.

Twin Bartram Swamp

Plots A and B of this transect had both been flooded during the past five years, for periods longer than three months per year (Table 1.81). The aquatic species *Lemna sp.* was recorded in plot A (Table 1.82). Plot C was only seasonally waterlogged and plot D was dry.

This 50m transect a had higher percentage of exotic species than all other study wetlands, with 65% of its 32 species introduced (Table 1.82). Only two native shrubs were recorded at this site, along with three trees and two emergent macrophytes,

Table 1.78

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Thomsons Lake monitoring transect 4.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-35	1	littoral/supralittoral
B	-95	0.4	seasonally waterlogged
C	-195	0	terrestrial
D	-415	0	terrestrial

Table 1.79

Species presence/absence across Thomsons Lake vegetation monitoring transect 4

Species	Plot and location along transect (m) A 0-25	B 25-45	C 45-75	D 75-100
*Bromus diandrus**	■	■	■	■
*Cynodon dactylon**	■	■	■	■
*Ehrharta longiflora**	■	■	■	■
Eucalyptus rudis	■	■	■	■
Agrostis avenacea	■			
Baumea articulata	■			
*Geranium Molle**	■			
*Circium vulgare**	■			
*Lotus angustissima**	■	■		
*Medicago polymorpha**	■	■		
*Sonchus asper**	■	■		
*Arctotheca calendula**		■		
*Crassula glomerata**		■		
*Lagurus ovatus**		■		
*Vulpia myuros**		■		
*Stenotaphrum subsecundum**		■		
Crassula exerta		■	■	■
*Carpobrotus edulis**		■	■	■
*Ehrharta calycina**		■	■	■
*Hypochoeris glabra**		■		■
*Dischisma capitatum**			■	
Jacksonia sternbergiana			■	■
Grevillea vestita				■
Jacksonia furcellata				■
Corynotheca micrantha				■
*Trifolium campestre**				■
Banksia attenuata				■
Macrozamia riedlei				■
Scholtzia involucrata				■
*Romulea rosea**				■
*Sonchus oleareacea**				■

Table 1.80

Dominant vegetation communities along Thomsons Lake monitoring transect 4

Plot	Community
A	Isolated *E. rudis*
	Open *B. articulata* sedgeland
B	Isolated *E. rudis*
	Exotics
C	Isolated *E. rudis*
	Exotics
D	Open *B. attenauta* woodland
	Dryland shrubs

Table 1.81

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Twin Bartram Swamp monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-1	4.2	littoral
B	-21	3.4	littoral
C	-61	0.6	seasonally waterlogged
D	-121	0	supralittoral

Table 1.82

Species presence/absence across Twin Bartram Swamp vegetation monitoring transect

Species	A 0-10	B 10.-20	C 20-30	D 32-52
	Plot and location along transect (m)			
*Lotus angustissimus**	x	x	x	x
Melaleuca raphiophylla	x	x	x	x
Solanum symonii	x			
*Typha orientalis**	x			
*Chenopodium pallidum**	x			
Centella asiatica	x	x		
Isolepis producta	x	x		
Lemna sp.	x	x		
*Sonchus asper**	x	x		
*Polypogon monspeliensis**	x	x		
*Aster subulatus**	x	x	x	
Juncus pallidus		x		
Schoenus pennisetus		x		
*Circium vulgare**		x		
*Cyperus polystachyos**		x		
*Vicia sativa**		x	x	
Agrostis avenacea		x	x	
Epilobium hirtigerum		x	x	
*Vulpis myuros**		x	x	x
*Cynodon dactylon**		x	x	x
*Geranium molle**		x	x	x
*Hypochoeris glabra**		x	x	x
*Sonchus oleareacea**		x		x
*Briza maxima**			x	
*Stellaria media**			x	
Melaleuca teretifolia			x	x
*Ehrharta calycina**			x	x
*Ehrharta longiflora**			x	x
*Bromus diandrus**			x	x
*Carpobrotus edulis**			x	x
Banksia littoralis				x
Xanthorrhoea preissii				x

Table 1.83 Dominant vegetation communities along Twin Bartram monitoring transect

Plot	Community
A	Open *M. rhaphiophylla* forest
	Aquatic species- *I. producta, Leman sp.*
B	Open *M. rhaphiophylla* forest
	Exotics
C	Open *M. rhaphiophylla* forest
	Exotics
D	Mixed *M. teretifolia, B. Littoralis, B. menziesii* woodland
	Exotics

Isolepis producta in plots A and B and *J. pallidus* in plot B (Table 1.82). The introduced emergent *T. orientalis* was also found in plot A.

Melaleuca rhaphiophylla dominated the overstorey in the first three plots as open forest (Table 1.83). This was replaced in plot D with a mixed *M. teretifolia, B. littoralis, B. menzeisii* woodland. The understorey of this transect was dominated by exotic species, although *I. producta,* an aquatic herb, was prevalent across plot A.

Lake Wilgarup

The 40m transect at Lake Wilgarup contained 24 species of which 25% were introduced (Table 1.85). Plot D had the highest species richness followed by C, A and B with the least. Plots A and B had been flooded during recent years, while plots C and D were seasonally waterlogged (Table 1.84).

Emergent macrophytes dominated the understorey with *L. longitudinale* occurring across all plots, *B. articulata* in plots B, C and D, *Baumea vaginalis* in B and C and *B. juncea* in C (Table 1.85). Other native species included four trees, two shrubs and numerous herbs.

Melaleuca preissiana formed closed forest in plot A, but was replaced by less dense *M. rhaphiophylla* open forest in B (Table 1.86). Mixed M. *rhaphiophylla, B. littoralis* open forest dominated plot C and a drier *M. rhaphiophylla, E. gomphocephala* woodland formed the overstorey of plot D.

Table 1.84

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Wilgarup monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	14	3.8	littoral
B	-6	2.8	littoral
C	-42	0.6	seasonally waterlogged
D	-68	0	seasonally waterlogged

Table 1.85

Species presence/absence across Lake Wilgarup vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-10	10.-20	20-30	30-40
Lepidosperma longitudinale	X	X	X	X
Melaleuca priessiana	X			
*Solanum nigrum**	X			
Baumea articulata	X	X	X	
Sonchus oleraceus	X	X		X
Daucus glochidiatus	X			X
*Hypochaeris glabra**	X			X
Melaleuca rhaphiophylla		X	X	X
Baumea vaginalis		X	X	
Lobelia alata			X	
Banksia littoralis			X	
Baumea juncea			X	
Centella cordifolia			X	
Patersonia occidentalis			X	
Xanthorrhoea priessii			X	X
Spyridium globosum			X	X
Eucalyptus gomphocephala				X
Opercularia hispida				X
Lepidosperma gladiatum				X
*Pelagonium capitatum**				X
*Avena fatua**				X
*Briza maxima**				X
Arthropodium capillipes				X
Anagallis arvensis				X

Table 1.86

Dominant vegetation communites across Lake Wilgarup vegetation monitoring transect

Plot	Community
A	Closed *M. preissiana* forest
	Open *B. articulata, L. longitudinal* sedgeland
B	Open *M. rhaphiophylla* forest
	B. articulata, L. longitudinal sedgeland
C	Open *M.rhaphiophylla, B. littoralis* forest
	Closed *B. articulata, L. longitudianl. B. juncea, B. vaginalis* sedgeland
D	*M. rhaphiophylla, E. gomphacephala* woodland
	Sparse *L. longitudinal* sedgeland, open shrubland

Lake Yonderup

This transect was also 40m long and consisted of four 20 x 10m plots (Table 1.88) all of which had remained dry over the past five years (Table 1.87). Thirty-nine species were recorded at this site with eleven found in all plots and 23 identified as exotic. Species richness was similar between the four plots, however, C and D had a higher percentage of exotics.

Native species included five trees, three shrubs and one emergent macrophyte, *B. juncea*, which occurred across all plots (Table1.88). A second emergent, *T. orientalis*, was recorded in plots A and B, and field visits indicated it also occurred further into the wetland.

As with Lake Wilgarup, *M. preissiana* dominated plot A to be replaced by *M. rhaphiophylla* and other tree species in drier plots (Table 1.89). Plot A was described as open *M. preissiana* woodland above open shrubland and mixed sedgeland. The understorey of plot B was similar to A, however, mixed *M. rhaphiophylla, A. saligna* open forest formed the overstorey. Plots C and D were mixed *M. rhaphiophylla, A. saligna, B. littoralis* woodland with D also containing *E. gomphocephala.* Sedges and shrubs also dominated the understorey of these plots.

Table 1.87

Summary table of short-term (3-5 years) hydrological parameters at the start of each study plot across the Lake Yonderup monitoring transect.

Plot	Mean depth (cm)	Duration (mean months/year)	Hydrological zone
A	-64	0	supralittoral
B	-157	0	supralittoral
C	-148	0	supralittoral
D	-146	0	supralittoral

Table 1.88

Species presence/absence across Lake Yonderup vegetation monitoring transect

	Plot and location along transect (m)			
	A	B	C	D
Species	0-10	10.-20	20-30	30-40
*Epilobium ciliatum**	X	X	X	X
Acacia saligna	X	X	X	X
*Rumex crispus**	X	X	X	X
Xanthorrhoea priessii	X	X	X	X
*Briza minor**	X	X	X	X
*Sonchus olearus**	X	X	X	X
Baumea juncea	X	X	X	X
Cynodon dactylon	X	X	X	X
Agrostis avenacea	X	X	X	X
Lobelia alata	X	X	X	X
*Paspalum dilatatum**	X	X	X	X
Lepidosperma gladiatum	X			
Melaleuca priessiana	X			
*Silybum marianum**	X	X		
*Cirsium vulgare**	X	X		
*Typha oreintalis**	X	X		
*Carex divisa**	X	X		
Centella cordifolia	X	X		
Epilobium billardierianum	X	X	X	
*Paspalum distichum**	X	X		X
Plantago major	X		X	X
*Medicago polymorpha**	X		X	X
*Lotus suaveolens**	X			X
Melaleuca rhaphiophylla		X	X	X
Gahnia trifida		X	X	X
*Holcus lanatus**		X	X	X
Opercularia hispida		X	X	X
*Lolium perenne**			X	
*Polypogon monospeiliensis**			X	
*Vicia sativa**			X	
Banksia littoralis			X	X
*Pelagonium capitatum**			X	X
*Aster subulatus**			X	X
Spyridium globulosum			X	X
*Anagalis arvensis**			X	X
*Romulea rosea**			X	X
*Homeria flaccida**			X	X
Eucalyptus gomphocephala				X
Banksia attenuata				X
*Ficus carica**				X

Table 1.89

Dominant vegetation communites across Lake Yonderup vegetation monitoring transect

Plot	Community
A	Open *M. preissiana* woodland
	Mixed sedgeland and open shrubland
B	Open *M. rhaphiophylla, A. saligna* forest
	Mixed sedgeland and open shrubland
C	Mixed *M. rhaphiophylla, A. saligna, B. littoralis* woodland
	Mixed sedgeland and open shrubland
D	Mixed M. *rhaphiophylla, A. saligna, B. littoralis, E. gomphocephala* woodland
	Mixed sedgeland and open shrubland

Summary of differences and similarities in species composition across study wetlands

The highest species richness was recorded at Shirley Balla transect 1 with 52 species identified over an 80m transect. Second richest was North Lake transect 2 with 49 species over 80m and third was Lake Jandabup with 47 over 50m.

The fewest species recorded was 13 at Bibra Lake, followed by 20 at South Kogolup and 21 at Lexia Wetland 86. All three of these transects were 45-50m long. Lexia 86 also had the lowest percentage of exotic species. Next lowest were Lexia 186 and Lake Jandabup. The highest percentage of introduced species was recorded at Lake Goollelal, Twin Bartram Swamp and Thomsons Lake transects 3 and 4.

Melaleuca Park Wetland 173 had the greatest percentage of myrtaceous shrub species, followed by Lexia 86, Lexia 186, Lake Jandabup and Shirley Balla transect 1. No myrtaceous shrubs were recorded at Bibra Lake, Joondalup East, North Lake transect 1, Shirley Balla 2, Thomsons Lake transect 2 and Twin Bartram Swamp. The most commonly occurring shrubs were *A. fascicularis, H. angustifolium* and *K. ericifolia.*

Emergent macrophyte species were greatest at Lake Goollelal and Lake Wilgarup, while none were found at North Kogolup transect 1. *Baumea articulata,* the most common species, occurred at 16 of the 27 study transects, followed by *L. longitudinale* which was recorded at 12, *T. orientalis* at 7 and *B. juncea* at 6 transects. *Baumea articulata* and *T. orientalis* were generally located in wetter plots than the other two common species.

Melaleuca teretifolia generally only occurred as isolated trees, and most often across inundated plots. *Melaleuca rhaphiophylla, B. littoralis* and *M. preissiana* were recorded in both inundated and dry plots, however *M. rhaphiophylla* generally occurred in areas that were flooded more often and to greater depths than the other two species. *Eucalyptus rudis* occurred across a wide range of depths while *B. ilicifolia* was only found in seasonally waterlogged plots.

Melaleuca preissiana occurred in 13 of the 19 study wetlands and was most dense in seasonally waterlogged plots. *Eucalyptus rudis* was recorded at nine wetlands in all hydrological zones. It occurred at seven of the nine permanently inundated lakes, but only at two of the ten sumplands. This species was found more often as isolated individuals than other wetland trees. *Melaleuca rhaphiophylla* was found at eight of the study wetlands, most commonly in wetter plots. This species was most dense in littoral zones. *Melaleuca teretifolia*, recorded at four wetlands was most common in wetter plots, while *B. littoralis* was generally found in seasonally waterlogged areas of the six wetlands at which it was identified. Despite the fact that each wetland tree species was found to have a preferred depth range, there was no evidence to suggest a pattern in wetland preference based on hydrological regimes.

Floristic gradient analysis (Detrended Correspondence Analysis)

Ordination of presence/absence of all species across all plots

Site ordination (DCA) of presence/absence data of all 244 species over 105 plots showed a separation of plots along the first and second floristic axes (Figure 1.66). Axis 1 had an eigenvalue of 0.659 which accounted for 45% of the variance between plots, while axis 2, at 0.478, explained 32%.

Correlations (Pearsons product moment) between floristic and hydrological variables (Appendix 5) and axis 1 values showed a positive relationship ($P<0.01$) with the percentage of perennial shrubs in each plot and negative relationships with the percentage of exotic species ($P<0.01$) and the duration of flooding ($P<0.01$) (Table 1.90). Axis 2 values were negatively correlated with mean water depth ($P<0.01$) and the percentage of wetland species in each plot ($P<0.01$).

The ordination diagram (Figure 1.66) illustrated these relationships with plots from the Lexia Wetlands, Melaleuca Park Wetland 173, Lake Jandabup, Shirley Balla Swamp and North Lake transect 2 grouped on the right side of Axis 1. All of these wetlands had been previously shown to contain the highest number of perennial shrubs and lowest percentage of introduced species. The majority of these plots also remained dry as suggested by the negative relationship with flooding duration.

Plots on the left- hand side of the diagram (Figure 1.66) included those from Twin Bartram Swamp, Lake Goollelal, Lake Mariginiup and Yonderup Lake which represented those with the highest percentage of weeds and the lowest number of shrubs.

Axis 2 floristic gradient correlations were illustrated on the ordination diagram with many of the plots located at the top of the figure previously identified as belonging to the driest littoral zone and containing the least number of wetland species (Figure 1.66). The lower percentage of variation explained by this axis compared to axis 1 became evident with the location of Lake Goollelal, the wettest of all transects, towards the top of the diagram.

TWINSPAN analysis at the second cut level showed grouping of Lexia Wetland and Melaleuca Park plots with one plot from Shirley Balla Swamp as well as the grouping of Lake Jandabup and two Shirley Balla Swamp plots (Figure 1.66). This reflected the similarities in overall species composition previously noted between these wetlands. All Lake Nowergup plots formed a group with the majority of the Lake Joondalup plots which illustrated the high percentage of dryland species recorded at these wetlands. The fourth and final TWINSPAN group consisted of all other plots.

A trend not illustrated by TWINSPAN classification or correlations was the location of the majority of the Jandakot wetland plots in the centre to the bottom left-hand side of the ordination diagram (Figure 1.66). A second trend was that the wetlands from the Yanchep Suite (Semeniuk, 1998) on the Gnangara Mound, Lake Nowergup, Lake Joondalup, Lake Goollelal, Lake Wilgarup and Lake Yonderup, grouped together at the top left of the figure.

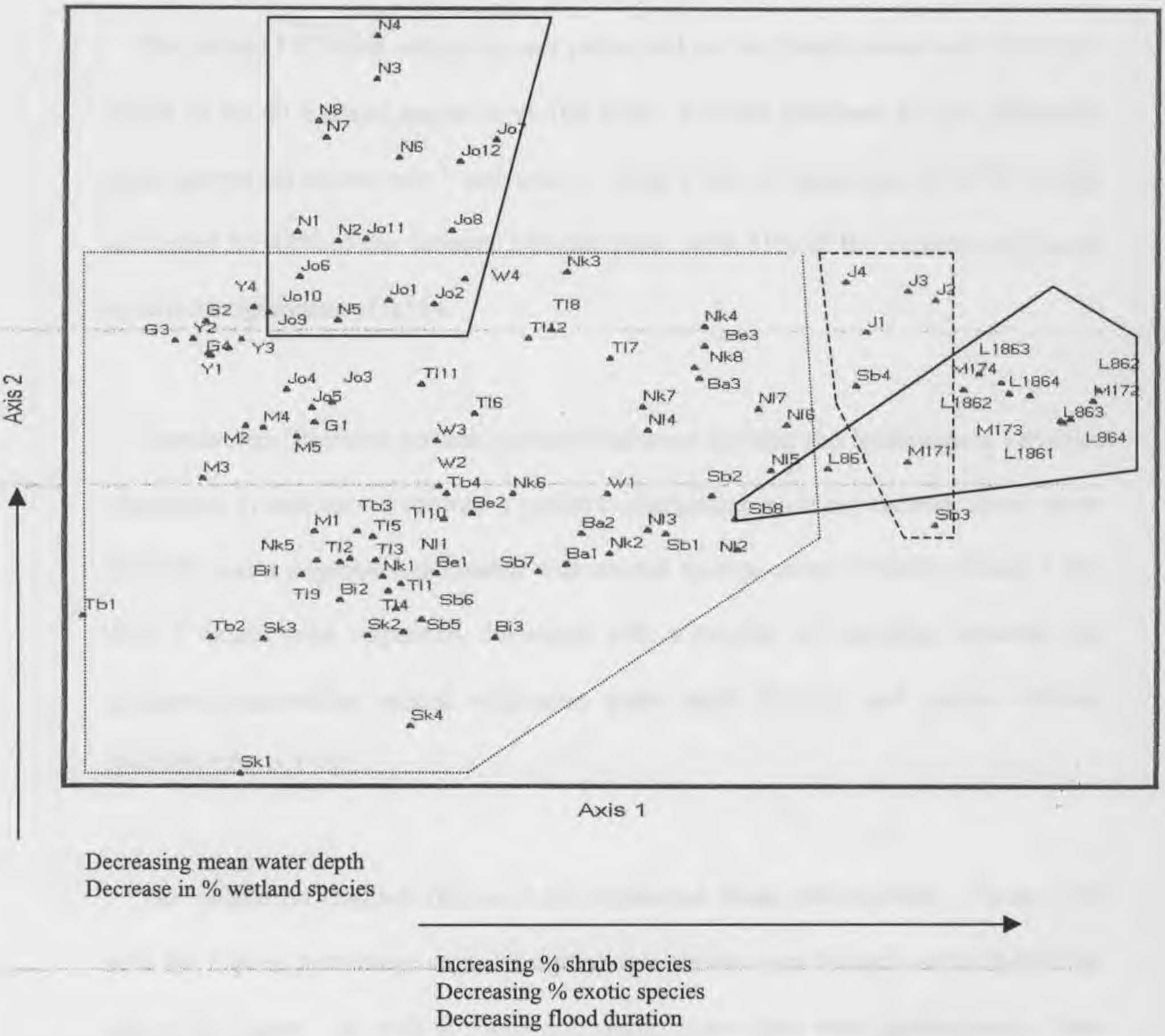


Figure 1.66

Ordination diagram showing position of plots along axes 1 and 2 of detrended correspondence analysis and the floristic and hydrological variables most strongly correlated to each axis. Ordination performed on the presence and absence of 244 species across 105 plots. Polygons drawn around groups represent TWINSPAN classification groupings.

Table 1.90

Correlation table showing the strength and direction of relationships between floristic and hydrological variables and DCA ordination axes values of presence and absence values of 244 species across 105 plots (p=*0.05,**0.01)

Variable	Axis 1	Axis 2
Mean water depth	-0.159	**-0.486
Duration of flooding	**-0.344	-0.183
Species richness	0.132	**0.296
% exotic species	**-0.564	*-0.238
% shrub species	**0.567	0.185
% wetland species	0.016	**-0.407

Ordination of 60 wetland species Domin values across 100 plots

The second DCA site ordination was performed on the Domin cover and abundance values of the 60 wetland species over 100 plots. Floristic gradients for this ordination were determined across axis 1 and axis 3. Axis 1 had an eigenvalue of 0.775, which accounted for 44% of the variance between plots, with 31% of the variation explained by axis 3s eigenvalue of 0.554.

Correlations (Pearsons product moment) between floristic and hydrological variables (Appendix 5) and axis 1 showed a positive relationship with myrtaceous shrub cover ($P<0.01$) and a negative relationship with annual species cover ($P<0.05$) (Table 1.92). Axis 3 values were negatively correlated with a number of variables, however, the strongest relationships existed with mean water depth ($P<0.01$) and species richness ($P<0.01$) (Table 1.91).

The ordination diagram (Figure 1.67) illustrated these relationships. Those plots with the highest percentage cover of myrtaceous shrubs were located on the right-hand side of the figure. As with previous ordinations these plots were predominately from Lexia and Melaleuca Park wetlands, Lake Jandabup, North Lake transect 2 and Shirley Balla Swamp.

The diagram illustrated three Lake Nowergup plots in the top left-hand corner (Figure 1.67). Axis 3 correlations were supported here as only one wetland species was recorded in these plots as opposed to the Twin Bartram plots at the bottom of the figure in which the highest number of wetland species was recorded.

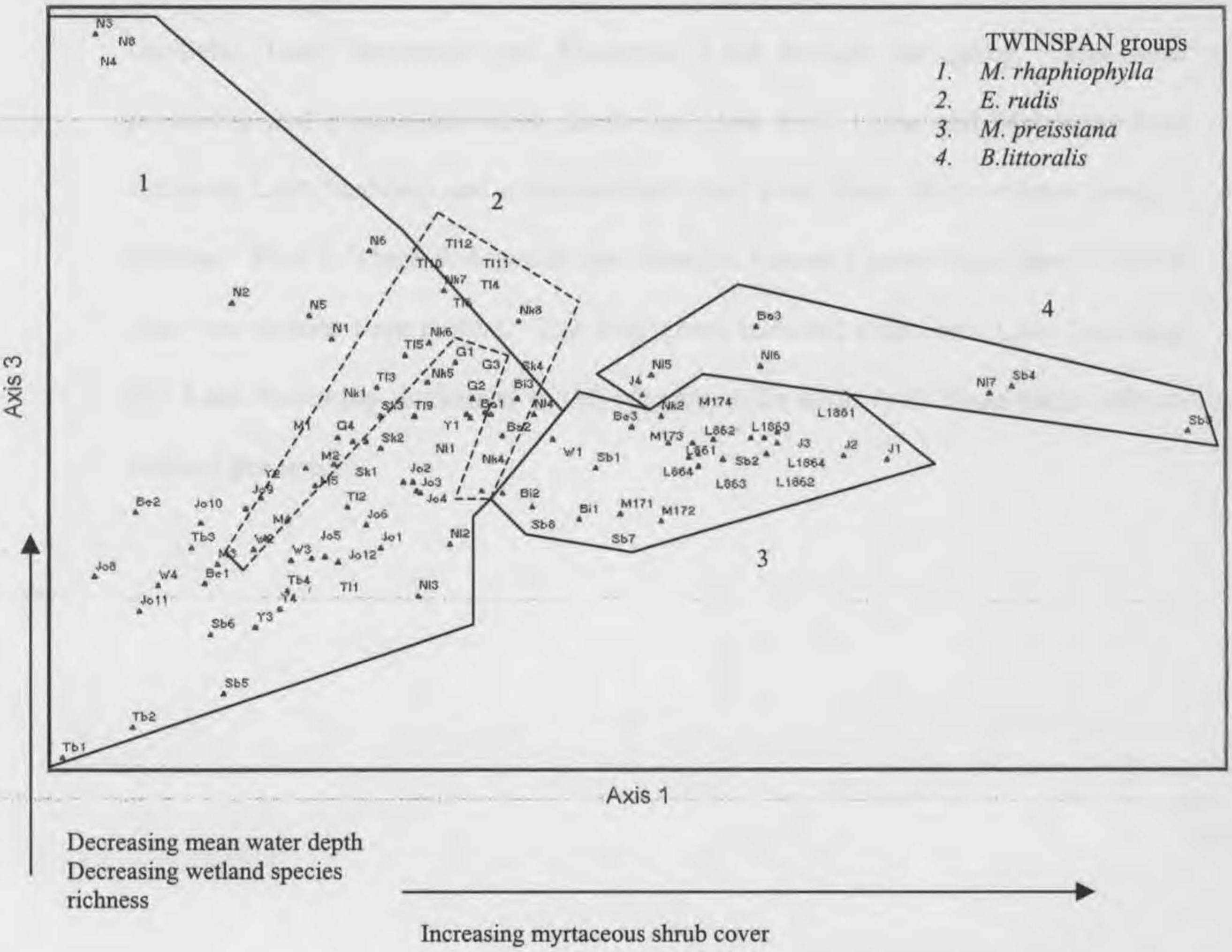


Figure 1.67
Ordination diagram showing position of plots along axes 1 and 3 of detrended correspondence analysis and the floristic and environmental variables most strongly correlated to each axis. Ordination performed on the Domin cover values of 60 wetland species across 100 plots. Polygons drawn around groups represent TWINSPAN classification groupings.

Table 1.91
Correlation table showing the strength and direction of relationships between floristic and hydrological variables and DCA ordination axes values of Domin cover values of 60 wetland species across 100 plots. (p=*0.05, **0.01)

Variable	Axis 1	Axis 3
Mean water depth	-0.76	**-0.459
Duration of flooding	-0.109	-0.073
Species richness	0.134	**-0.406
Tree cover	-0.114	**-0.275
Perennial shrub cover	**0.663	-0.002
Perennial herb cover	-0.074	-0.04
Annual species cover	*-0.242	**-0.391
Emergent macrophyte cover	-0.165	**-0.298

TWINSPAN analysis at the second cut level grouped plots by wetland tree species (Figure 1.67). Plots in which *E. rudis* was dominant, including those from Lake Goollelal, Lake Mariginiup and Thomsons Lake formed one group. *Melaleuca preissiana* and myrtaceous shrub dominated plots from Lexia and Melaleuca Park wetlands, Lake Jandabup and numerous individual plots from other wetlands grouped together. Plots in which *B. littoralis* was recorded formed a group, regardless of which other tree species were present. The final group included plots from Lake Joondalup and Lake Nowergup dominated by *M. rhaphiophylla* along with those plots with no wetland tree species.

1.3 DISCUSSION

The wetlands of the Swan Coastal Plain occur across a range of landforms formed from aeolian and alluvial deposition west of the Darling Scarp (Water Authority, 1995). The Pinjarra Plain lies at the base of the Scarp, next to this are the undulating, highly leached dunes of the Bassendean System. Adjacent to these are the younger Spearwood Dunes and finally, on the coast are the Quindalup Dunes (Water Authority, 1995).

For the purposes of this section study wetlands have been grouped together into the consanguineous suites developed by Semeniuk (1988). This allows wetlands of similar physical setting, origin and water characteristics (Semeniuk, 1988) to be considered together in any discussion of patterns in hydrology and vegetation composition. Characteristics can also be compared between suites of wetlands.

1.3.1 WETLANDS OF THE BIBRA SUITE

Wetlands belonging to the Bibra Suite occur in the Spearwood and Bassendean dunes. They form in contact depressions in which groundwater is impounded against the Spearwood dune ridge (Semeniuk, 1988). All of the study wetlands belonging to this group, Lake Banganup, Bibra Lake, North Kogolup and South Kogolup Lakes, North Lake and Thomsons Lake, were located on the Jandakot Mound. The vegetation form ascribed to these wetlands by Semenuik et al. (1990) indicated that they were all surrounded by a patch work of vegetation associations.

Despite surface water monitoring having been undertaken in all of these wetlands, with the exception of North Kogolup Lake since the 1950s or 1960s, groundwater data has only been recorded since the early 1990s for all bar Thomsons Lake.

Lake Banganup

The most southerly of the study wetlands, Lake Banganup is in fact not a lake but a sumpland as it is only seasonally inundated (Hill et al., 1996). The wetland and the vegetation surrounding it is relatively undisturbed as is it part of the University of Western Australia's Marsupial Research Station and as such has been fenced to restrict public access (Water Authority, 1991).

The long-term trend in surface water levels at Lake Banganup was for a constant depth, however short term ground and surface water levels decreased and the wetland has been dry for longer periods per year. Although it is difficult to explain the long-term trend, recent low rainfall years and increased groundwater abstraction may have resulted in lower water tables (Department of Planning and Urban Development, 1992).

The presence of *B. articulata* across much of the lake bed to the exclusion of other wetland species supports the finding that water levels have dropped following greater than usual depths in 1992. Froend et al. (1993) found that emergent macrophytes would extend their range towards the centre of a wetland under these drying conditions. The absence of other species on the lake bed, including *M. preissiana* and *M. teretifolia,* reflects either slower recruitment or increased competition from the encroaching *B. articulata* (Froend et al., 1993). A continued drying period may result in the spread of these species into the wetland.

The dramatic reduction in the seasonal amplitude between minimum and maximum water levels noted in the results for this and a number of other wetlands, may have been a function of falling water levels. However, there was also a change in the method of recording surface water data, which better accounts for this. Prior to the late 1980s, if a lake bed was dry, data collectors would dig down to the water table and record that level as the surface water level (N. Hyde, WRC, pers. comm., April, 2000). Data are now recorded no lower than the lake bed, which also explains the bottoming out of many of the surface water graphs at that level. It is also possible that this has influenced the results presented for annual and seasonal mean water levels, as negative levels are no longer recorded.

Despite the undisturbed nature of Lake Banganup, a number of weed species was recorded across the vegetation transect. This may be due to a fire that spread through the bushland in 1995 (Ladd, 1996) opening the canopy and allowing exotic seeds to germinate (Fox and Fox, 1986). A previous fire in 1975 resulted in a *M. preissiana* recruitment episode (Froend et al., 1993) indicating that water level changes are not the sole determinant of this species' range. Although *M. preissiana* was important at Lake Banganup, *E. rudis* was the dominant tree species across the entire transect.

North and South Kogolup Lakes

The Kogolup Lakes are also classified as sumplands as they do not hold water throughout the year (Hill et al., 1996). Homeswest and a number of private landholders own the area surrounding these wetlands, which is a proposed parks and recreation reserve (Water Authority, 1991). The presence of fence posts across the lakebed, however, suggests the area was once grazed. A rural history may explain the high percentage of weed species found across the three monitoring transects.

Surface water levels in South Kogolup Lake have risen since the 1960s. As with Lake Banganup this trend is difficult to explain, but it is possibly related to the clearing of native vegetation and increased run-off from urban areas (Balla, 1994). Long-term data were not available for North Kogolup, however, due to their close proximity, a similar trend could be assumed. Both wetlands have experienced declining water levels in recent years, staying dry for longer periods, which may be due to drier winters and groundwater abstraction (Balla, 1994).

Lower surface water over recent years may explain the presence of a young clump of *T orientalis* fringed by *E. rudis* saplings beyond the monitoring transects at North Kogolup. Recruitment of these species is known to occur when a period of drying follows higher water levels (Froend et al., 1993). Declining tree health in the monitoring plots (Ladd, 1999) may also be a result of lower water tables. Lower elevations at South Kogolup mean the inundation of the entire transect, which may explain the higher percentage of wetland species.

Continued decreases in water level and wetland tree health may result in the encroachment of the non-wetland species recorded at the dry ends of the transects.

Bibra Lake

Despite its history as a sanitary landfill site, this large permanently inundated lake is now managed for both conservation and recreation (Water Authority, 1991). One of the major recognized threats to the health of Bibra Lake is fertilizer run off from surrounding parklands and the nearby Adventure World recreation park (Department of Planning and Urban Development, 1992).

As with the wetlands already discussed, water levels have decreased in recent years, but not in the long term. Bibra Lake is unusual, however, as the number of months it is dry per year has not decreased. This may be due to a management objective aimed at maintaining the aesthetics of the wetland (Water Authority, 1991).

Heavy recreational use of the southern end of the lake where the transect is located may explain the high percentage of weed species recorded. This may also be due to the transfer of weed seed from nearby urban areas by storm water run off, wind and recreation (Fox and Fox, 1986). The dominance of wetland trees and emergent macrophytes at this site reflects the periodic inundation of the transect.

North Lake

One of the smallest of all permanently inundated study wetlands, North Lake is also managed for conservation and recreation (Water Authority, 1991). Urban development of the surrounding area following a history of rural use has modified this wetland, as has its use as a drainage basin (Water Authority, 1991).

Despite similar short and long term changes in water regime, North Lake had one of the highest seasonal variations in surface water depth of all study wetlands. This may explain the high species richness and structural diversity across the monitoring transects, as fluctuating water levels have been shown to increase species diversity (Keddy and Reznicek, 1986). The relatively low number of exotic species and the density of the native vegetation, suggests other forms of disturbance cannot explain the high number of species (Fox et al., 1997).

Thomsons Lake

The largest lake of the Bibra Suite, Thomsons Lake has been listed as a RAMSAR wetland of international importance for waterbirds (Department of Planning and Urban Development, 1992). It is fenced to restrict vehicle access to dieback infected areas, and is managed for passive recreation related to conservation (Water Authority, 1991). Historically, the surrounding area was used for rural purposes, but the main threat is now increased usage for urban drainage (Department of Planning and Urban Development, 1992).

Unlike the other wetlands of this suite, both long and short term data indicated that water levels at Thomsons Lake have decreased. Despite this the wetland is now wet for the entire year, where it once dried for an average of two months. Another anomaly is that peak surface water levels occur earlier in the year than in all other study wetlands. These findings may relate to increased drainage. In most wetlands there is a lag between the beginning of a wet season and runoff into the basin due to dry soils requiring saturation beforehand (Wheeler, 1999). At Thomsons Lake storm water is piped directly into the wetland causing an earlier peak level and keeping water in the lake longer (R. Froend, pers. comm., May, 2000).

The high number of exotics recorded in the transects may reflect historical use, disturbance from recreation or the transfer of seed from surroundings areas in storm water (Fox and Fox, 1986). A thick belt of *B. articulata* and *T. orientalis* around the wetland with younger plants closer to the water and dead individuals upslope, is possibly a result of lower water levels causing these species to encroach further into the wetland (Froend et al., 1993).

It can be seen from the discussion above that most of the wetlands of the Bibra Suite on the Jandakot Mound have not experienced the drying patterns experienced by the majority of the study wetlands across the Swan Coastal Plain. It was beyond the scope of the current study to determine why this may have occurred, but the suggestion could be made that it is related to different underlying geology or greater runoff from closer urban developments.

It was noted in the previous section that *E. rudis* only occurred in two of the nine study sumplands. Both of these belonged to the Bibra Suite, making this species the dominant wetland tree in this group of wetlands. *M. preissiana,* was also found at most of these sites, while *M. rhaphiophylla* only occurred in the wettest plots of North Kogolup and North Lake. Further studies on *E. rudis* could test whether there is a relationship between this species and wetland type. If there were, it may prove useful as an indicator of wetlands underlying hydrology.

1.3.2 WETLANDS OF THE JANDAKOT SUITE

Wetlands belonging to the Jandakot Suite occur in the Bassendean Dune system. They form either as sumplands or damplands in depressions as groundwater ponds at or near the surface (Semenuik, 1988). The study wetlands from this suite were all sumplands. *E. rudis* was not recorded at any of these wetlands, again suggesting it may be generally restricted to larger wetlands with permanent water.

Three wetlands, Beenyup Rd. Swamp, Shirley Balla Swamp and Twin Bartram Swamp, are located over the Jandakot Mound, while the remaining two, Lexia 86 and Lexia 186, are on the Gnangara Mound. Long term water level data for these wetlands were not available.

Beenyup Rd. Swamp

Beenyup Rd. Swamp is regarded as a semi-pristine wetland with unusual vegetation and internationally significant features (Water Authority, 1991). It is currently inaccessible to the general public and faces little pressure from recreation (Water Authority, 1991). Despite being relatively undisturbed, a number of exotic species were found at this site. This may have been due to the close proximity of a flower farm and other surrounding horticultural practices that were noted during a field visit.

Water levels at Beenyup Rd. Swamp have dropped in recent years and the wetland dried for longer periods. This lower water table is evidenced by a decrease in the cover of *B. articulata* in the monitoring plots (Ladd, 1999). If levels continue to drop the health of the unusual form of broad, bushy *M. rhaphiophylla* (Froend et al., 1993) that dominate the wettest areas may also deteriorate.

Shirley Balla Swamp

This wetland has been recognised for its high potential as a site for waterbird breeding and for internationally important features (Water Authority, 1991). Despite this, during periods when the lakebed is dry, it is used as a dumping ground for unwanted vehicles (Balla, 1994).

Water levels in Shirley Balla Swamp have also decreased in recent years. As with many wetlands in the Perth region this may be due to increased groundwater abstraction and lower annual average rainfall (Balla, 1994).

The high diversity in the vegetation of this wetland had been noted in a previous report (Water Authority, 1991). This study supported that finding, as Shirley Balla Swamp had the highest species richness of all wetlands examined and, despite the high level of disturbance, there were few exotic species.

An unusual feature of this wetland was that *M. preissiana* dominated one side of the depression while *M. rhaphiophylla* formed the overstorey on the other (Ladd, 1999). As fringing populations of both of these species have become rare (Froend et al., 1993) this may explain the listing of this site as a wetland with internationally important features (Water Authority, 1991). The presence of the myrtaceous shrubs, *A. fascicularis* and *H. angustifolium* was also an unusual feature as no other Jandakot Mound wetland contained this combination of species. This may explain why, in the ordination diagrams, plots from Shirley Balla Swamp grouped with those from the Lexia wetlands.

Twin Bartram Swamp

Despite its recognised high potential for waterbird breeding, this wetland is already degraded in part and is under increasing threat from urbanisation (Water Authority, 1991) as housing and parklands are developed close to its shores.

Water level monitoring of Twin Bartram Swamp commenced after a report by the Water Authority (1991) recognised levels may need to be artificially maintained to meet water level criteria. However, despite a general trend for decreasing levels, this has not occurred (L. Moore, WRC, pers. comm., November, 2000).

This wetland had the highest percentage of exotic species of all study wetlands. This was probably due to the high level of disturbance and the proximity of urban development (Fox et al., 1997). A fire in 1999 may have exacerbated this problem (Ladd, 1999).

Lexia Wetlands 86 and 186

The Lexia wetlands are unique amongst Swan Coastal Plain wetlands (Water and Rivers Commission, 1997). They are undisturbed by most impacts, support diverse vegetation and fauna and represent a large intact system (Water and Rivers Commission, 1997). These findings were supported by the study as the Lexia wetlands contained the lowest percentage of exotic species of any of the study wetlands.

The three years of water data available suggested little change in surface water but a general trend for lowering groundwater levels. This may be due to the same factors that have influenced other wetlands coupled with the impacts from the surrounding pine plantations (Water and Rivers Commission, 1997).

A field visit indicated that the vegetation of Lexia 186 formed in the bands described by Dames and Moore (cited in Water and Rivers Commission, 1997, p. 42) and Semeniuk et al. (1990). *B. articulata* occurred in the wettest zone surrounded by a band of myrtaceous shrubs, *M. preissiana* and finally dryland *Banksia* woodland. Similar species were recorded at Lexia 86, however, the vegetation formed as a mosaic rather than in zones (Semeniuk et al., 1999).

As previously discussed, the dominance of the myrtaceous shrubs at these wetlands may explain why the monitoring plots were located close to Shirley Balla and Melaleuca Park plots in the ordination diagrams.

1.3.3 WETLANDS OF THE MUCHEA SUITE

Muchea Suite wetlands are the most easterly group, located between the Bassendean Dunes and Pinjarra Plain (Semenuik, 1988). They occur in low areas where rain and groundwater pond over impermeable surfaces (Semenuik, 1988). The only study wetland belonging to this group was Melaleuca Park Wetland 173 located on the Gnangara Mound.

Melaleuca Park Wetland 173

This wetland is protected by the Environmental Protection Policy (1992) due to its landscape and environmental values and as it may be a remnant of a much larger wetland (Water and Rivers Commission, 1997). It is thought to be a perched wetland that relies on water from a spring rather than rising groundwater in wet seasons (Water and Rivers Commission, 1997).

Surface water levels have remained fairly constant over the past five years, however high water marks on tree trunks suggest that levels were previously up to 1m higher (Water and Rivers Commission, 1997).

The vegetation of this wetland was very similar in composition to that of the Lexia wetlands as myrtaceous shrubs and *M. preissiana* were also dominant, with *B. articulata* found at the wetter end of all transects. These species formed in bands around this wetland as they did at Lexia 186 (Water and Rivers Commission, 1997).

The similarity in species composition between the Lexia and Melaleuca Park wetlands may be due to the fact that they are both located in relatively undisturbed remnants within the Gnangara pine plantations. However, in the ordinations and TWINSPAN classification plots from these wetlands were grouped with those from Shirley Balla Swamp and Lake Jandabup. This relationship appears to be driven by the presence of *M. preissiana* and the myrtaceous shrubs, *A. fascicularis* and *H. angustifolium* at all of these wetlands.

1.3.4 WETLANDS OF THE GNANGARA SUITE

Wetlands of the Gnangara Suite form as an expression of the groundwater table along the western margins of the Bassendean Dunes (Semeniuk, 1988). The beds of these wetlands are covered by a thin layer of clay or diatom mud, which impedes surface drainage (Semeniuk, 1988), often trapping groundwater above the surface during periods of drying. Both lakes and sumplands belong to this suite, however, the two study wetlands from this group, Lake Jandabup and Lake Mariginiup, are generally both permanently inundated.

Lake Jandabup

Lake Jandabup is the second largest of the study wetlands. It is surrounded by freehold rural properties, but the majority of the lake and fringing vegetation is managed by the Department of Conservation and Land Management as a nature reserve (Allen, 1979).

The long-tem trend in surface water levels for this wetland showed an increase in depths during the 1960's, which coincided with vegetation clearing for nearby pine plantations and high rainfall years (Water Authority, 1995). Less rainfall between 1968 and 1973 resulted in lower water levels, which declined further from 1976 following the beginning of groundwater abstraction and growth of the pine plantations (Water Authority, 1995). Artificial water level maintenance through ground water pumping commenced in 1989 to ensure the conservation values of this wetland were preserved (Water Authority, 1995). Surface water levels rose in 1991 and 1992 following high rainfall, before dropping and leveling out in the past three years.

A broad band of emergent macrophytes has established around the open water of Lake Jandabup (Allen, 1979). This vegetation was not included in the monitoring transects, however, *B. articulata, T. orientalis, L. muirii* and *L. scariosus* were identified during a field visit.

The location of the actual monitoring plots some 200m from the start of the emergent species may partially explain why the vegetation composition of this wetland was unlike that of all other lakes and most closely resembled the Lexia and Melaleuca Park wetlands and Shirley Balla Swamp. That is, that although the wetland is permanently inundated the transect itself is only seasonally waterlogged. Lake Jandabup was also one of only three lakes at which *E. rudis* was not recorded. The dominant species in these wetlands were discussed in the previous section.

Lake Mariginiup

Lake Mariginiup, like Lake Jandabup, is surrounded by rural land and is managed for the conservation of flora and fauna (Water Authority, 1995). The management objectives for this wetland include the maintenance of habitat for wading birds and invertebrates as well as the preservation or enhancement of the fringing vegetation (Water Authority, 1995).

Long term surface water data for this wetland showed similar trends to the nearby Lake Jandabup, as both have experienced the same rainfall conditions and impacts from surrounding land use. However, water levels have not been artificially maintained at this wetland and have continued to decline in recent years.

Despite *B. articulata* being recorded across all monitoring plots the transect at this wetland did not encompass the entire range of the emergent macrophytes, which formed a band around the lake margins of up to 200m in width. A fire in 1997 reduced the density of this species and although it has begun to recover (Pettit and Froend, 2000), continued declines in water levels may result in the loss of *B. articulata* from the transect.

The fire may also have contributed to the relatively high number of exotics found at this site, especially the *Acacia* species which are known to germinate following fire (Gill, 1981). However, a firebreak has also been ploughed through the area disturbing 30% of three of the five plots (Pettit and Froend, 2000).

Eucalyptus rudis was the dominant tree at Lake Mariginiup, however, this was the only wetland on the Gnangara Mound at which *M. teretifolia* was found. Six of the seven other wetlands where this species was recorded belonged to the Bibra Suite. Unlike the other wetland trees, the presence of *M. teretifolia* did not cause plots to group together in the second ordination diagram. This was possibly due to the low DOMIN values recorded for this species at all sites.

1.3.4 WETLANDS OF THE YANCHEP SUITE

All wetlands of the Yanchep Suite occur in a linear belt about 5km inland from the coast in the Spearwood Dunes over the Gnangara Mound (Semeniuk, 1988). They form in depressions in limestone ridges as a result of limestone discharge and rising groundwater tables (Semeniuk, 1988). Despite both lakes and sumplands belonging to this suite four of the five study wetlands, Lake Goollelal, Lake Joondalup, Nowergup Lake and Lake Yonderup, were lakes (Hill et al., 1996).

In the ordination performed on all 244 species, all monitoring plots from this group of wetlands were located together at the top of the figure. This indicated that species composition was similar across these wetlands. This may be due to their occurrence in an area of similar landforms and soil types and supports the argument for grouping wetlands by physical characteristics as described by Semeniuk (1988).

Lake Nowergup

Lake Nowergup is managed by the Department of Conservation and Land Management for wildlife and landscape conservation, scientific study and historic purposes (Water Authority, 1995). As the deepest of all of the study wetlands and one of the deepest on the Swan Coastal Plain, this lake is important as a habitat for birds, aquatic invertebrates and fish and as a drought refuge for water birds (Water Authority, 1995). It is this habitat value that has resulted in the artificial maintenance of water levels in recent years following the impacts of low rainfall and, to a lesser extent, groundwater abstraction (Water Authority, 1995).

Despite artificial maintenance, surface water levels have declined since records commenced in the 1970s and groundwater since the late 1980s. This has encouraged the growth of emergent macrophytes (Water Authority, 1995) with a widening band of *T. orientalis* enclosed in a narrower belt of *B. articulata*. These species were only recorded in the plots closest to the water while little or no wetland vegetation was found in the dry plots. This is probably due to the steep incline along the western side of the lake (Water Authority, 1995) where the transects were located, placing wetland species too far above the groundwater table.

In the ordination diagram and TWINSPAN classification performed on the presence and absence of all species, Lake Nowergup plots clustered together along with the majority of the Lake Joondalup plots. This may have occurred due to the relatively high numbers of non-wetland species shared across these wetlands, which in turn may relate to the fact that one of the Lake Joondalup transects is also located on a steep incline.

Lake Joondalup

The largest of all study wetlands, Lake Joondalup is managed for conservation and public enjoyment (Water Authority, 1995). One of the major threats to the habitat value of this wetland is fertilizer runoff from surrounding parklands, horticultural businesses and the expanding area of urban gardens (Upton and Kinnear, 1997). A major road (Upton and Kinnear, 1997) has also dissected the southern end of Lake Joondalup. However, a drain has been installed to allow water to continue its northward passage from the groundwater source (Upton and Kinnear, 1997).

Despite increased storm-water runoff from urban areas (Balla, 1994), long and short term surface and groundwater data indicated that water levels have declined. These changed water regimes appear to have led to massive increases in midge populations controlled by pesticide spraying, which may also have negative impacts on the biota of the lake (M. Lund, pers. comm., October 2000).

Although much of the land surrounding Lake Joondalup is highly modified extensive areas of native vegetation remain relatively intact resulting in high species richness. As with Lake Nowergup, *B. articulata* and *T. orientalis* are found in the wettest plots and may expand their range if water levels continue to fall. *Eucalyptus rudis* and *M. rhaphiophylla* also occur at both wetlands with dryland species dominant in the drier areas.

Lake Wilgarup

Lake Wilgarup, the only seasonally inundated study wetland in the Yanchep Suite, is managed to maintain the environmental qualities related to wetland vegetation (Water Authority, 1995). Environmental Water Requirements were not established for Lake Wilgarup until after 1998 (Water Authority, 1995) as surface water level monitoring had only commenced in 1993, while groundwater has only been measured since 1996.

This short term data indicated that this wetland has become drier for longer periods of time in recent years as water levels decline. This may, however, be a much longer term trend as *M. preissiana* has formed a closed forest inside a band of *M. rhaphiophylla*, a species more tolerant of inundation and associated with wetter areas than the other species (Muir, 1981). As this wetland had one of the highest percentage of wetland species continued decreases in water levels might change the entire species composition including the loss or decline of *B. articulata* and other emergent macrophytes.

Lake Yonderup

Lake Yonderup is the most northern of the study wetlands and, like Lake Wilgarup, is managed to maintain its environmental qualities (Water Authority, 1995). Environmental Water Requirements for this wetland are set to maintain the existing hydrological regime, which, according to long-term surface water data, has become wetter with time. However, the seasonal variation in water depths has decreased dramatically, which may indicate that the increase may merely be a result of changed water measurement methods outlined earlier.

This apparent long-term increase in surface water levels has resulted in the wetland having been inundated by shallow water for most of the past 12 years. Prior to that time it dried completely in most dry seasons. Despite this long-term trend and the management objective to maintain current levels, short-term surface and groundwater data indicate that Lake Yonderup is becoming drier. This finding is supported by the spread of *T. orientalis* across the lake bed.

A number of exotic species were recorded at this site. This may be due to regular disturbance by vehicles as nearby stands of *Eucalyptus* are harvested for koala feed. The location of the transect parallel to the bottom of the wetland may explain why, despite a high species richness, there were relatively few wetland species found at Lake Yonderup.

Lake Goollelal

This wetland is managed for conservation and public enjoyment (Water Authority, 1995). It is recognised as a drought refuge for water birds and as habitat for fish and other aquatic species (Water Authority, 1995). The greatest threat to Lake Goollelal, like nearby Lake Joondalup, is fertilizer runoff from surrounding areas (Upton and Kinnear, 1997).

Unlike Lake Joondalup, however, long term surface and ground water data indicated that water levels have increased over time. This may be due to the earlier development of the urban area surrounding the lake or to an anomaly in the underlying geology and the flow of groundwater from the south (Upton and Kinnear, 1997).

Although only a small area of the original vegetation remains intact around Lake Goollelal, the species composition reflects the high water levels experienced across the monitoring transect. Wetland species and exotics dominate the plots with an open overstorey of *E. rudis* and *M. preissiana* over a sparse understorey of herbs in the wettest areas. The exotics reflect the highly modified and disturbed nature of this wetland (Water Authority, 1997).

1.4 CONCLUSION

The results from this section indicate that the hydrology of the Swan Coastal Plain wetlands is dynamic in its response to both climatic variations and human disturbances. Altered hydrology, in turn, leads to changes in the composition and structure of wetland vegetation.

The similarities in hydrology and vegetation that were found between wetlands with similar physical characteristics exemplify the patterns found in the environment. It is recurrent patterns such as these, which inspired the concept of functional groups to simplify the complexities experienced in describing the responses of individual species and populations to external influences. The notion that the grouping of wetland species into hydrotypes could be used as a tool to predict the response of wetland communities to altered hydrology is supported by these findings.

SECTION 2: HYDROLOGICAL ENVELOPES AND HYDROTYPES

Ecological water requirements are currently based on detailed knowledge of the life history traits and growth responses of a few key wetland species, such as *B. articulata* (Water and Rivers Commission, 1997). Water depth and the duration of flooding have been identified as the two major components of the water regime that determine the structure and composition of wetland species (Roberts et al., 1999). It has been suggested that these two factors alone could be used to describe the ecological requirements for a greater number of species. Hydrological envelopes could then be used to group species together into hydrotypes, which could be used as a tool to predict the impact of changed water regimes on the distribution and composition of wetland vegetation.

2.1 METHODS

2.1.1 HYDROLOGICAL ENVELOPES AND DURATON OF FLOODING

The allocation of each plot to a hydrological zone in the previous section enabled the compilation of a species list for each zone and its presentation in tabular form to show species occurrences across zones (Appendix 4). As this study related chiefly to wetland vegetation, only the hydrological ranges for species that occurred predominantly in the littoral zone or those identified in the literature as littoral or fringing species, were established.

This was achieved by determining the mean and mean minimum and maximum water depths and the duration of flooding at the start and end of each species' range across each transect. To establish the total and mean ranges, data from all transects in which a species occurred was combined.

As data were available for 20, 10 and 5 year periods for many wetlands, the life-span of individual species were considered before a time period was selected. For example, 20 year data were relevant to long-lived littoral and fringing tree species, however, would not be suitable for annuals, or small short-lived perennials. Species were grouped according to their life-form class (tree, perennial shrub, perennial herb, annual or emergent macrophyte) and the mean and absolute range in water depth experienced by each species within that group presented in a figure.

The permanent transects were initially established to allow ongoing monitoring of littoral tree health. As a result a number of transects finished before the waters edge and emergent macrophytes were not fully sampled. Field visits were therefore required to determine the hydrological range of these species. At each of the truncated transects a theodolite was used to measure the elevations between which emergent species occurred. These measurements were tied into known elevations of existing plots. Methods then followed those used to establish hydrological regimes of other species.

2.1.2 SPECIES ORDINATION (Canonical Correspondence Ananlysis)

In this study the ordination procedure Canonical Correspondence Analysis (CCA) was used to assess the impact of maximum water depth and the duration of flooding on wetland species to test the assumption that water depth was the more important of the two variables. This would then determine the relative value of using hydrological envelopes rather than flood duration to determine hydrotype classification. Annual species were not included in this ordination, due to the difficulty in establishing whether they occurred during wet or dry seasons.

Canonical Correspondence Analysis (CCA) is a direct ordination technique used to consider the variability of both environmental and species data (Kent and Coker, 1992). This method arranged species along environmental gradients in such a way that the resultant ordination diagram illustrated patterns in both floristic composition and the principal relationship between each species and the environmental factor (Kent and Coker, 1992). A biplot, or arrow, within the ordination diagram indicated the direction of change of the variable, with the length directly proportional to the strength of change in that direction (Kent and Coker, 1992). Species plotted towards the tip of an arrow were strongly positively correlated to that variable, while those at the opposite end were less influenced by that factor (Kent and Coker, 1992).

2.1.2 ESTABLISHMENT OF HYDROTYPES

Hydrological envelopes were used to establish hydrotypes. This was achieved by grouping wetland species together according to their absolute water depth ranges. Species that were shown to experience inundation were divided into groups according to the maximum depth tolerated at the wet end of their range and the greatest depth to groundwater at the dry end. Species not inundated were grouped by the greatest depth to groundwater at the dry end of their absolute range.

Annual species were considered separately due to the fact that some were known to be aquatic, and also to difficulties in establishing whether some species occurred during wet or dry seasons.

2.1.4 COMPARISON OF HYDROTYPE COMPOSITION BETWEEN WETLANDS OF DIFFERENT HYDROLOGIES

The study wetlands were of two hydrological types, permanently inundated lakes or seasonally inundated sumplands. To provide a visual comparison of hydrotype composition, the mean number of each species belonging to each hydrotype were graphed for the two wetland types. A one-way ANOVA was then conducted to establish any statistically significant differences between lakes and sumplands in the number of species from each hydrotype.

2.2 RESULTS

2.2.1 THE HYDROLOGICAL ENVELOPES AND DURATION OF FLOODING EXPERIENCED BY THE 60 WETLAND SPECIES.

Littoral and fringing trees

Tree species were considered to be longer-lived than other vegetation forms. Their ranges in water depths and the number of months they were flooded were therefore calculated over 20, 10 and 5 year periods. As 20 year data were deemed most relevant this was the material presented in Figure 2.1.

Calculations of the absolute range of water depths showed that all littoral tree species occurred at the same maximum depth while minimum depths varied between species (Figure 2.1). This finding illustrated a major limitation of the study. That is that all of these five species were recorded in the same inundated plot and, although presence and cover values were recorded for each species within each plot there is no distinction as to where in a plot a species was found. This meant that all species in an individual plot were classified as occurring at the same water depth, regardless of whether one end of the plot was inundated and the other dry, or whether it was all dry, or completely inundated. The dry end of the ranges of these species were different because they did not all occur in the same driest plot.

Eucalyptus rudis occurred at the greatest number of transects (n=14) and had the greatest absolute range (Figure 2.1). *Melaleauc teretifolia* (n=7) had the most restricted water depth range.

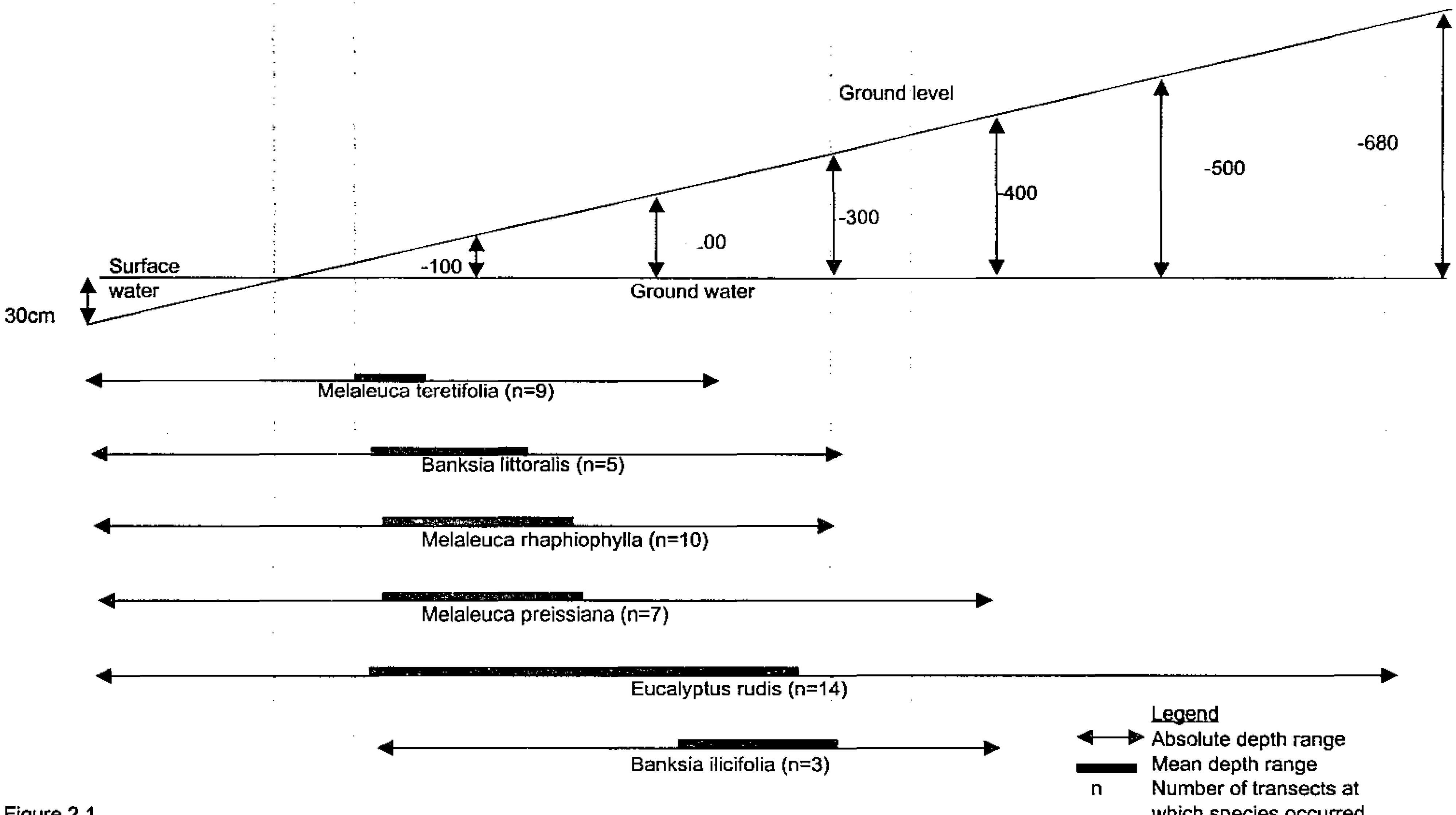


Figure 2.1
Absolute and mean water depth ranges (cm) for littoral and fringing trees (based on 20 year hydrological data)

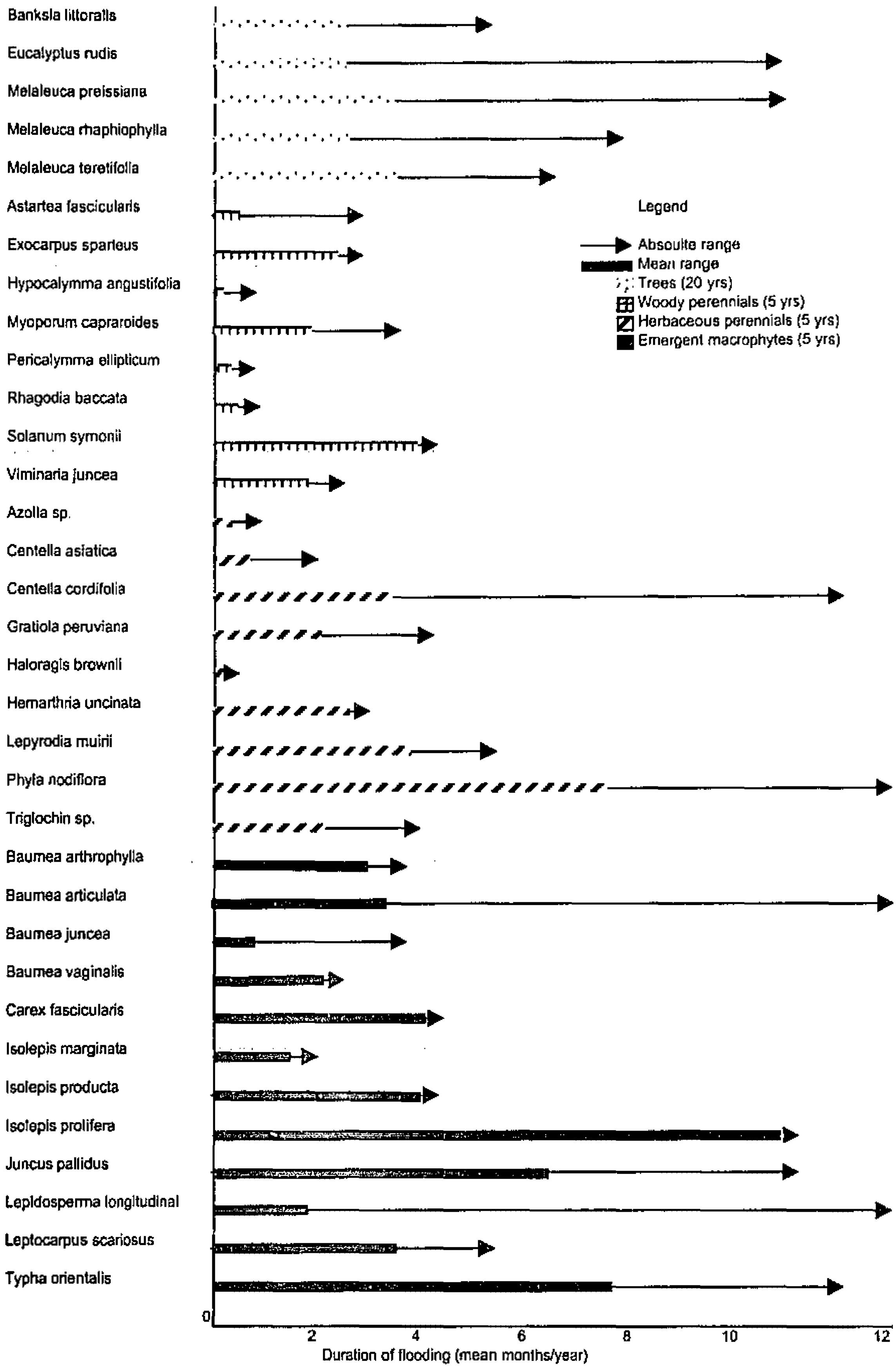


Figure 2.2

Absolute and mean duration of inundation experienced by wetland plant species (annuals and species which did not not expereince flooding in the study wetlands were not listed)

Mean depths showed greater variation in species water depth ranges as values for more than one plot were considered. Over a 20 year period *M. teretifolia* was shown to occur at greater mean depths than all other littoral tree species (Figure 2.1). It was found at depths of between 29cm and –76 cm for periods of almost 3.5 months each year (Figure 2.2). *Melaleuca preissiana* was the only tree inundated for longer periods (Figure 2.2).

Figure 2.1 suggested that all other trees with the exception of *B. ilicifolia* (n=3), a known fringing species, were also subject to inundation. Consideration of mean ranges in relation to one another showed that *E. rudis* occurred at the second greatest mean depths, followed by *B. littoralis* (n=5), *M. rhaphiophylla* (n=10) and *M. preissiana* (n=7).

Although *B. littoralis* flooded to greater depths than most other species it was inundated for the shortest periods each year (Figure 2.2). *Eucalyptus rudis* and *M. rhaphiophylla* were flooded for longer than *B. littoralis*, but less than *M. preissiana and M. teretifolia*. *B ilicifolia* was not inundated at all during the 20 year period .

Perennial wetland shrubs

The hydrological ranges of large shrubs were calculated over a 20, 10 and 5 year periods, however, five year data was selected for further consideration as some species are known to be short-lived.

None of the 15 wetland shrubs were inundated within their mean ranges, however, over half were flooded within their absolute ranges (Figure 2.3). *Astartea fascicularis* was the most commonly occurring species (n=10). It survived in deeper water than other species, but only for short periods (Figure 2.3, Figure 2.2). This species absolute range was only exceeded by *Myoporum capraroides* (n=2) and *R. baccata* (n=3). *Solanum symonii (n=1), Viminaria juncea (n=1), P. ellipticum* (n=3), *H. angustifolia* (n=5) and *E. sparteus* (n=2) were all inundated, however, their ranges were narrower than other flooded species. *Myoporum capraroides, V. juncea* and *S. symonii* were inundated for the greatest length of time (Figure 2.2).

Aotus gracillima (n=1), *Pultenaea ochreata* (n=1), *K. ericifolia* (n=4), *C. lateralis (n=2)* and *P. reticulata* (n=4) were not flooded within the five year period (Figure 2.2), however, they were restricted to narrow groundwater depth ranges (Figure 2.3). *Beaufortia elegans* (n=3) and *A. quadripatita* (n=2) had wider depth ranges, but remained uninundated.

Perennial herbs, ferns and grasses

Five year hydrological data were also used to describe the eco-hydrological ranges of this group as the majority of species were generally short-lived.

Phyla nodiflora(n=2), *Centella cordifolia* (n=5), *Leproydia muirii* (n=2) and *Halogaris brownii* (n=1) were the only other species flooded within their mean depth range, with *P. nodiflora* and *C. cordifolia* occurring at the greatest depths for the longest time periods (Figure 2.4, Figure 2.2). *Gratiola peruviana* (n=2), *Centella asiatica* (n=4), *Azolla sp.*(n=1) and *H. uncinata* (n=1) were inundated within their absolute ranges with *C. asiatica* found across the widest water depth range (Figure 2.4). Although *L. glauca* (n=1), *P. esculentum* (n=1), *Laxmania ramosa* (n=1), *Lyginia barbata* (n=1) and *Sporobolus virgincus* (n=1) were not flooded within the five year period these species are known to be associated with wetlands (Figure 2.4, Appendix 3).

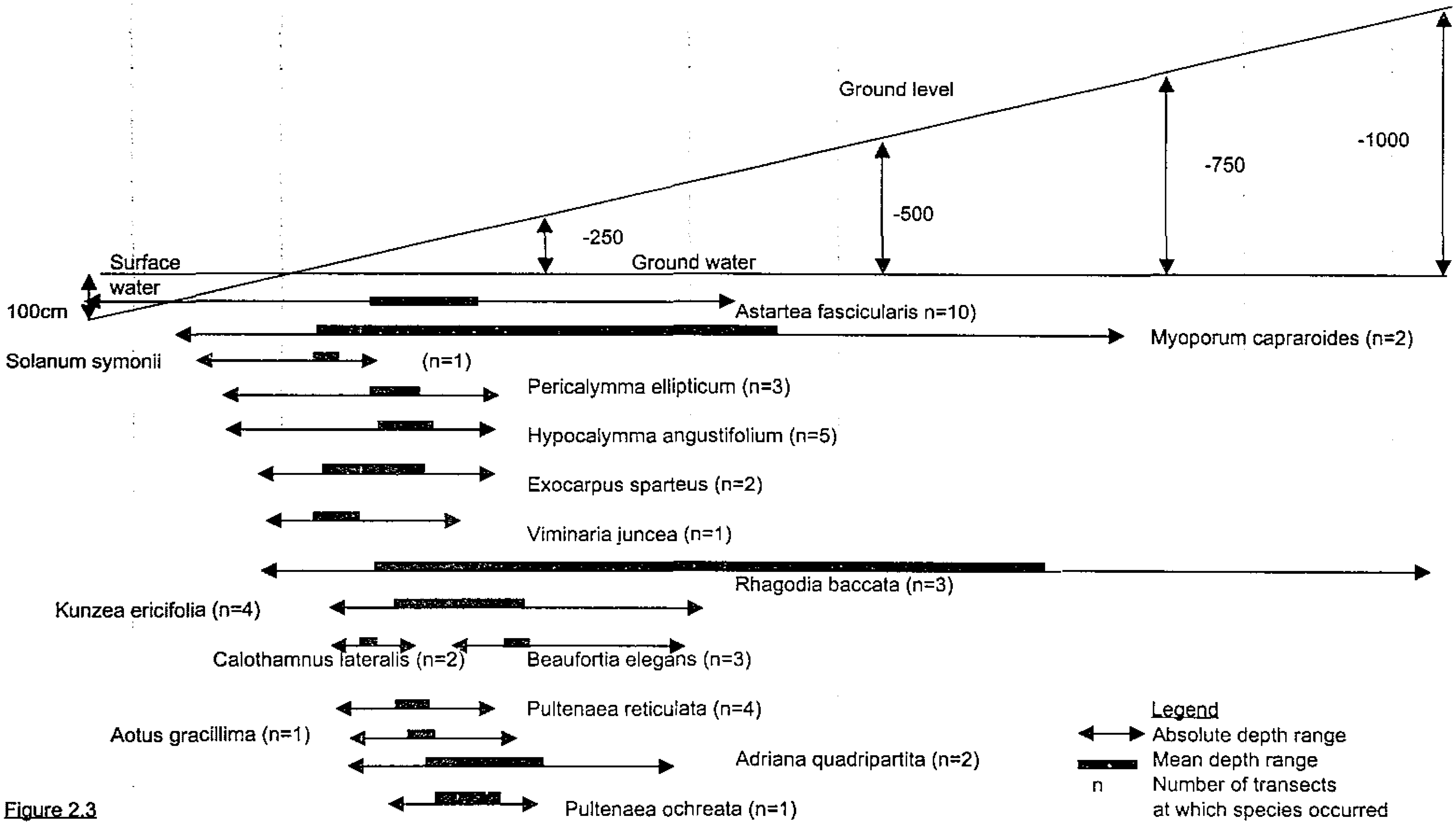


Figure 2.3
Absolute and mean water depth (cm) range for perennial wetland shrubs (based on 5 year hydrological data)

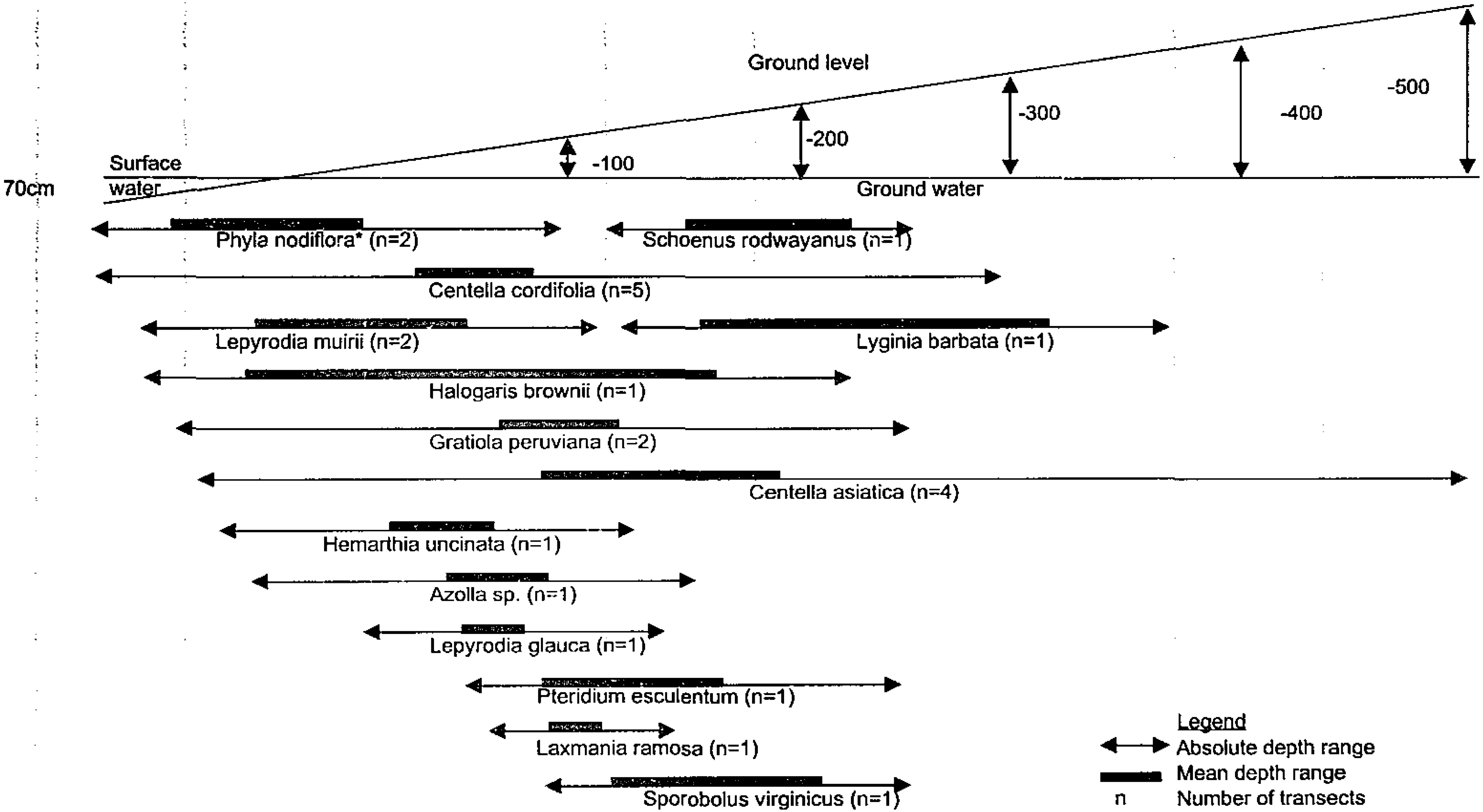


Figure 2.4
Absolute and mean water depth (cm) ranges for perennial herbs, ferns and grasses (based on 5 year hydrological data). Asterisks denote exotic species.

Annuals

Annuals found in flooded plots or those known to occur in winter wet areas (Appendix 3) were considered over a five year period only. Those species not identified as aquatic or semi-aquatic were not included in Figure 2.2 due to their short life-spans and the associated difficulties in determining if they occurred during wet or dry seasons. No annual species were found on inundated ground within their mean ranges.

The aquatic or semi-aquatic species, *V.capitata* (n=2), *Triglochin sp.* (n=2) and *Lemna sp.*(n=1), were found in water up to 50cm deep, but also on dry ground (Figure 2.5). *Polypogon monspeliensis* (n=7) and *Chenopodium glaucum* (n=2) occurred across the widest ranges, from inundated plots to groundwater depths in excessive of 5m (Figure 2.5). *Chenopodium pallidum* (n=1), *Conyza albida* (n=1), *Schoenus pennisetis* (n=1), *Cotula coronopifolia* (n=2) and *Gnaphalium sphaericum* (n=1) were also found in inundated plots, however, their range was restricted to plots with groundwater levels above 1m. *Isolepis cernua* (n=1) and *Homaloscadium homalocarpum* (n=4) were only found in dry plots (Figure 2.5).

Emergent macrophytes

The absolute maximum depth at which *T. orientalis* (n=7) occurred was greater than all other emergent macrophytes, with only *Isolepis prolifera* (n=1) found at greater mean depths (Figure 2.6). *Typha orientalis* was also second only to *I. prolifera* in the mean number of months per year it was inundated (Figure 2.2).

Baumea articulata (n=16), *B. juncea* (n=6) and *L. longitudinale* (n=12) were found across the widest absolute range of water depths, with *B. articulata* and *L. longitudinale* flooding for up to 12 months of the year (Figure 2.2) despite their mean ranges being

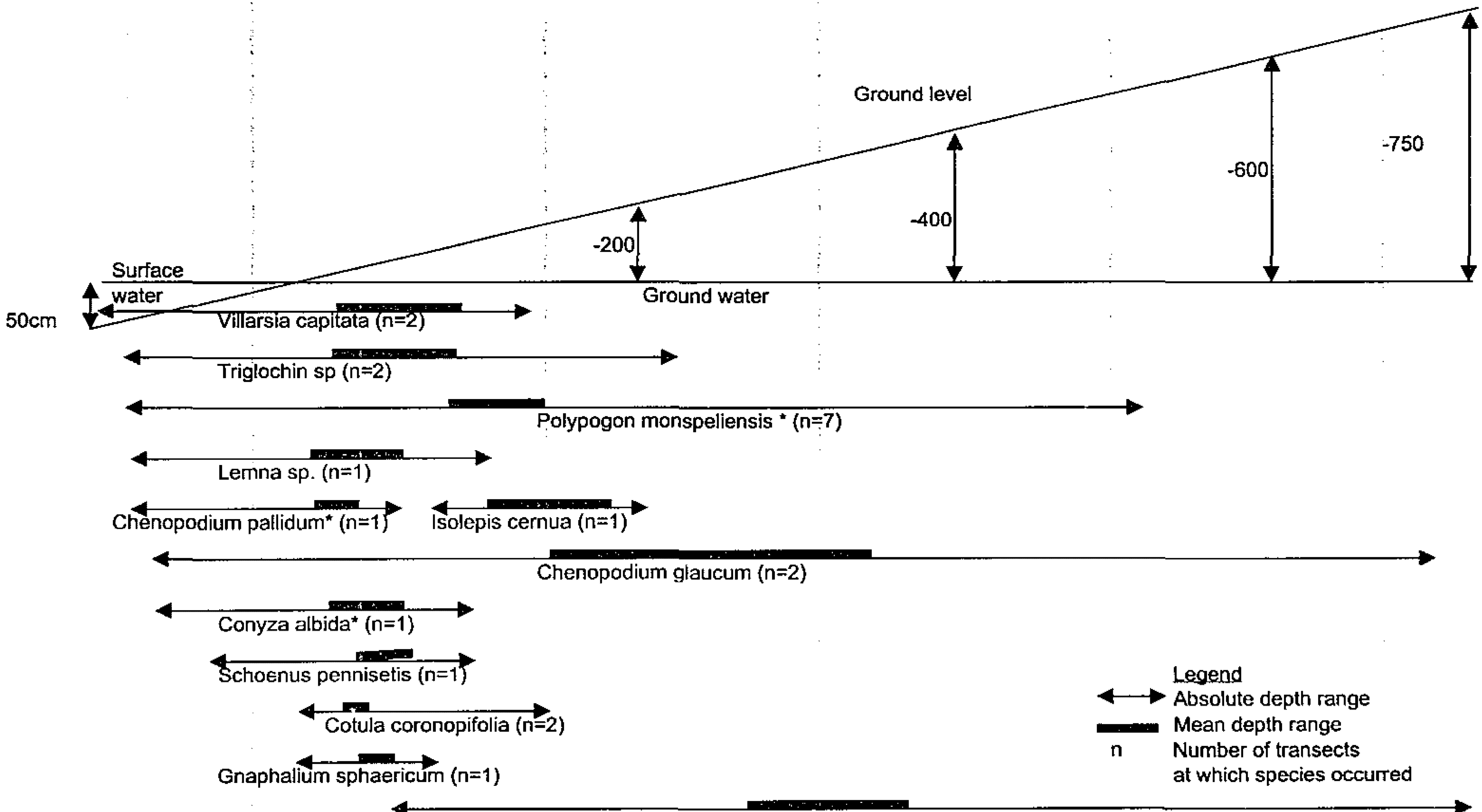


Figure 2.5
Absolute and mean water depth (cm) ranges for wetland annuals (based on 5 year hydrological data). Asterisks denote exotic species.

restricted to dry ground (Figure 2.6). Mean inundation for *L. longitudinale* and *B. juncea* was, however, less than two months, with *B. articulata* generally only flooding for 3.5 months (Figure 2.2).

Juncus pallidus (n=3) was inundated to depths of 70cm for up to 11 months with the remaining emergent macrophyte species found to depths less than 50cm (Figure 2.6) and flooding for less than six months of the year across the five-year period (Figure 2.2). *Isolepis producta* (n=1), *C. fascicularis* (n=1), *L. scariosus* (n=2) and *Baumea vaginalis* (n=1) were inundated within their mean ranges, while *Baumea arthrophylla* (n=1), *Isolepis marginata* (n=2) and *Lepidosperma elatius* (n=1) only flooded within their absolute ranges (Figure 2.6). None of these species were found above groundwater tables lower than 175cm (Figure 2.6).

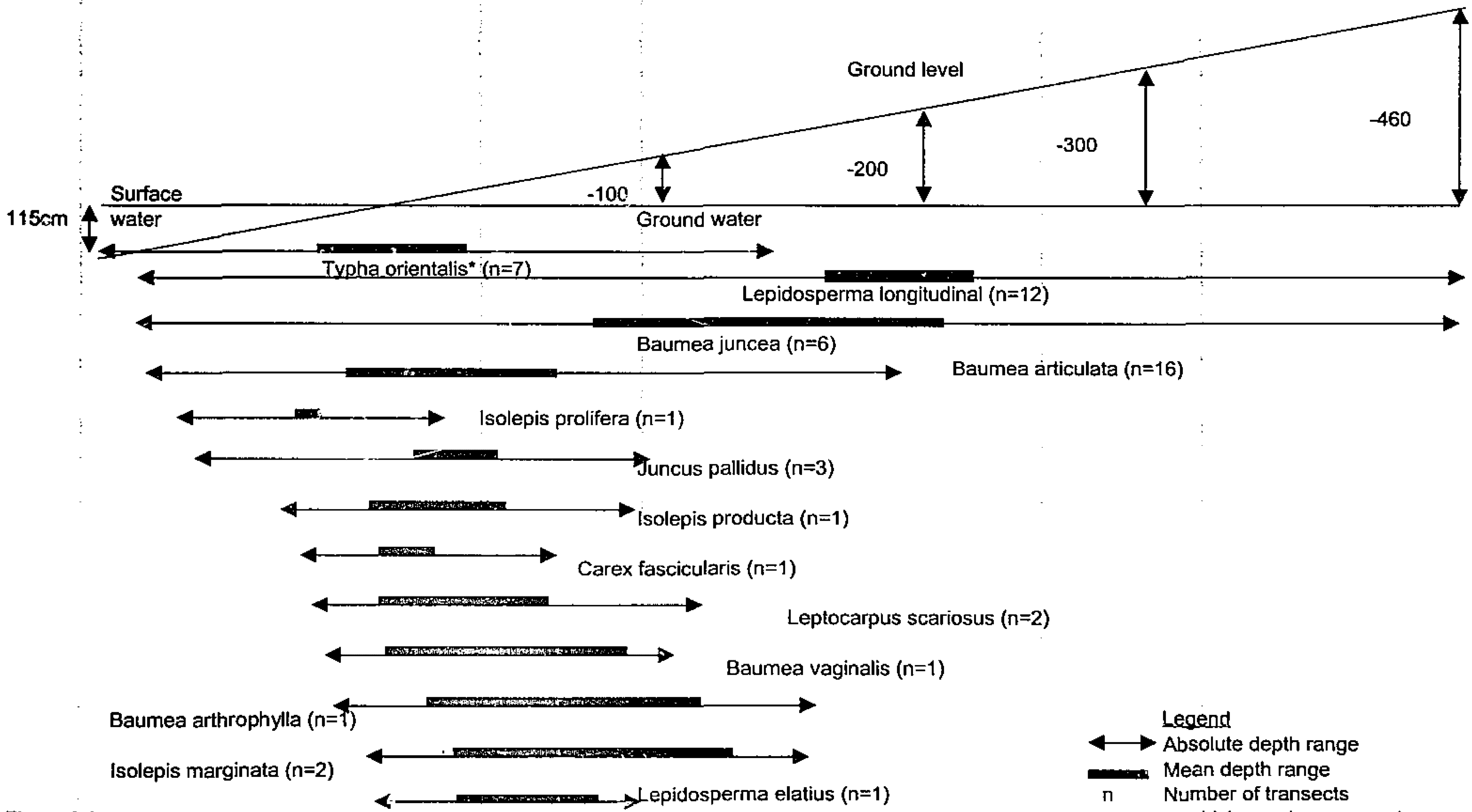


Figure 2.6
Absolute and mean water depth (cm) ranges for emergent macrophytes (based on 5 year hydrological data). Asterisks denote exotic species.

2.2.2 CANONICAL CORRESPONDENCE ANALYSIS TO DETERMINE THE STRENGTH OF HYDROLOGICAL VARIABLES ON SPECIES DISTRIBUTION

Prior to the establishment of hydrotypes Canonical Correspondence Analysis was used to access the strength of the relationship between the 48 perennial wetland species and the maximum depth and duration of inundation. These two hydrological parameters have been identified as among the most significant in the determination of wetland species composition in Swan Coastal Plain wetlands (Froend et al., 1993). Minimum and mean water depths were also important, however, due to the relative similarity between minimums, means and maximums at each study plot as shown in the previous section, only one water depth variable was selected for comparison. Annuals were not included in the ordination due to their seasonality.

The biplot diagram (Figure 2.7) and statistical results (Table 2.1) indicated that axis 1 was most strongly correlated to duration of flooding ($P<0.05$) while axis 2 was most correlated to maximum depth ($P<0.05$). Although the majority of species were aligned along the maximum water depth gradient, the biplot value for this variable was less than that for duration. This may be due to the fact that six species at the top right of the diagram showed a strong linear relationship with duration.

The biplot scores (Table 2.1) showed that *B. ilicifolia* and a number of perennial shrubs located at the top left hand side of the diagram (Figure 2.7) had a strong negative relationship to water depth, while those at the bottom of the figure, including *B. articulata,* were positively related. *Melaleuca preissiana, M. teretifolia, M. rhaphiophylla* and *B. littoralis* were located towards the centre of the diagram where the

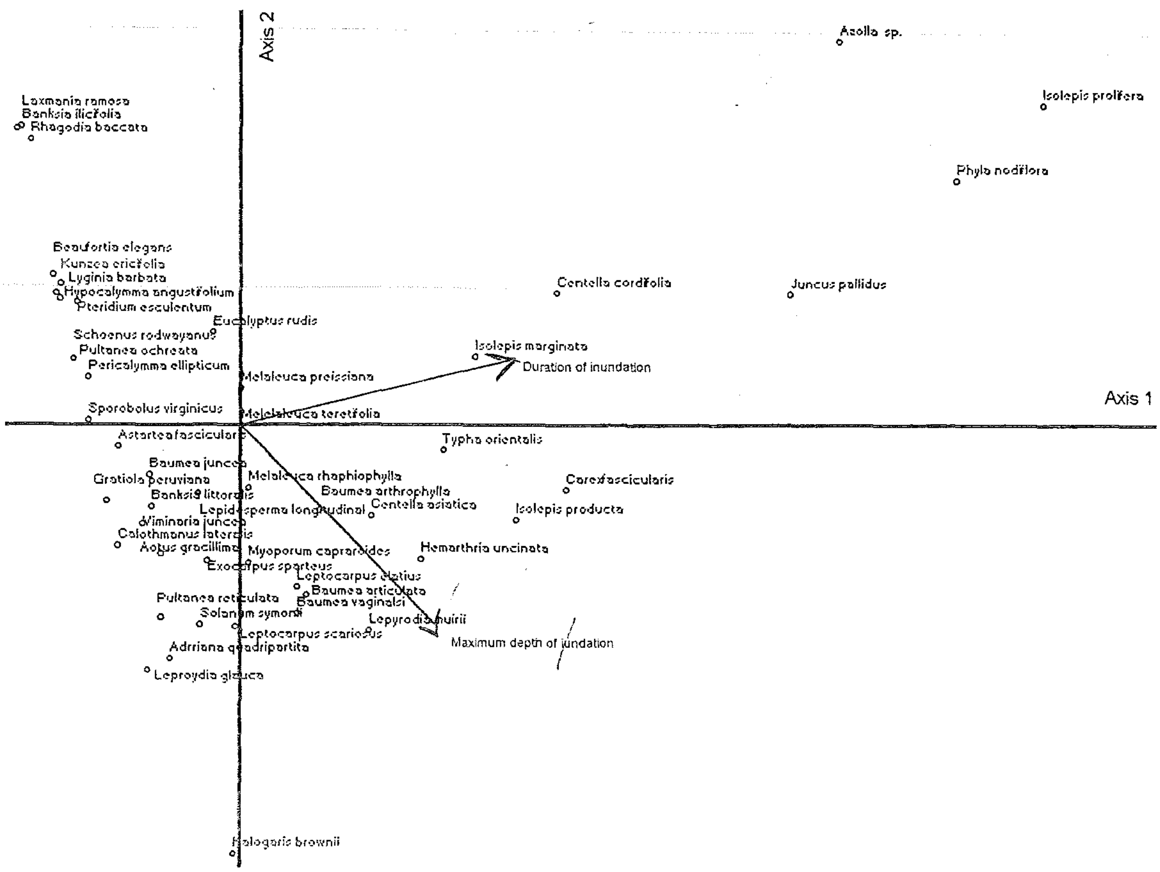


Figure 2.7
Biplot from the Canonical Correspondence Analysis (CCA) ordination of perennial wetland species Domin values of cover and abundance, showing correlation between species and environmental variables. The length of the arrows signifies the relative contribution of that variable. The direction of the arrow indicates the maximum change of the environmental variable across the diagram.

Table 2.1
Table showing the biplot scores of the environmental variables, maximum water depth and flood duration, for the Canonical Correspondence Analysis ordination of perennial wetland species Domin values of cover and abundance. The correlations between axis 1 and 2 from the ordination diagram and the variables are also shown.

	Biplot score		Correlation	
	Axis 1	Axis 2	Axis 1	Axis 2
Maximum water depth	0.703	-0.711	0.542	-0.438
Duration of flooding	-0.972	0.235	0.749	0.145

axes intersected and were more strongly separated along the depth gradient than that of duration.

From the results of this ordination it can be seen that maximum water depth had greater influence on the distribution of study wetland species than duration of inundation. As this variable was selected to represent all water depth parameters, the absolute water depth ranges illustrated by the hydrological envelopes will form the basis of hydrotype groupings.

2.2.3 HYDROTPYE CLASSIFICATION OF 60 WETLAND SPECIES.

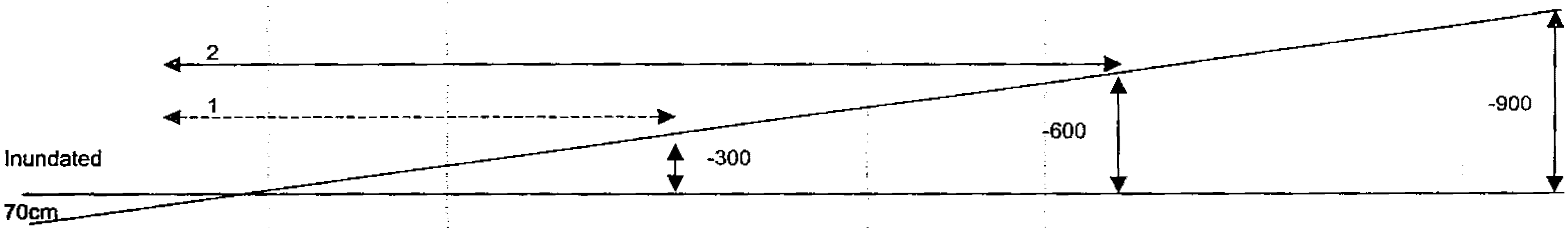
Hydrotypes groupings were based on the absolute water depth range of each of the 60 wetland species as presented in the previous section.

Annual species

Figure 2.8 indicated that the wetland annual species were divided into two hydrotypes, annual tolerators and annual avoiders. The names allocated to these two hydrotypes reflected the fact that *Lemna sp.* and *Triglochin sp.* are known to occur as floating mats on the surface of wetlands and do not survive drying periods. The fact that these two species were presented as having been recorded on dry land is a result of the limitation regarding the exact location of a species within a plot.

The other two species in this hydrotype, *Schoenus pennisetis* and *Villarsia capitata,* were found in winter wet depressions, but may have survived brief periods of inundation. These four species could therefore be regarded as having tolerated inundation.

The eight other annual species were grouped together as annual avoiders, which did not tolerate inundation, but rather avoided it by completing their life cycles during drier seasons. A second difference between the two groups stemmed from the avoiders being recorded over a greater range of groundwater depths.



1. Annual tolerators
Lemna sp.
Schoenus pennisetis
Triglochin sp.
Villarsia capitata

2. Annual avoiders
Chenopodium glaucum
Chenopodium pallidum*
Conyza albida*
Cotula coronopifolia
Gnaphalium sphaericum
Homalosciadium homalcarpum
Isolepis cernua
Polypogon monspeliensis*

Figure 2.8
Hydrotype categories of annual wetland species based on their hydrological ranges within the study wetlands.

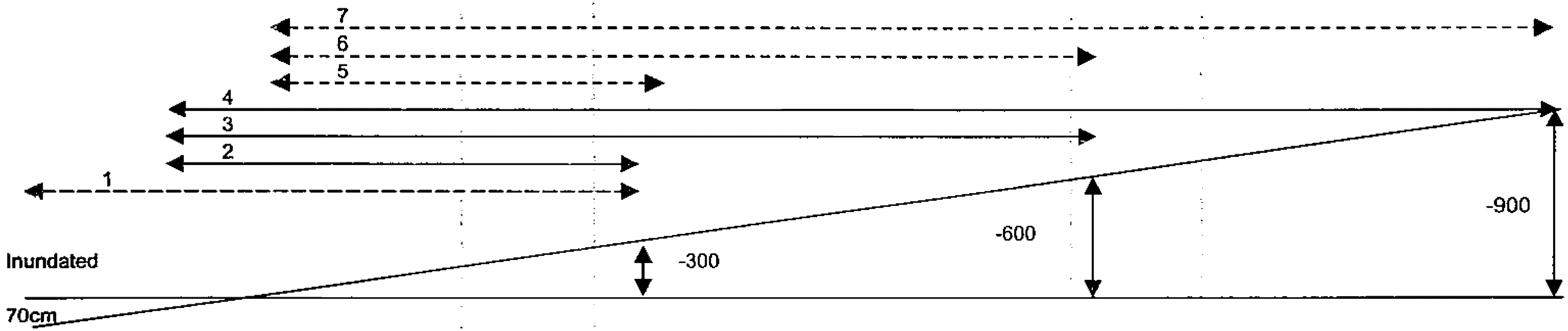
Perennial species

The 48 perennial wetland species were divided into seven hydrotypes (Figure 2.9). Type 1, the littoral species group, included the emergent macrophytes *T. orientalis, B. articulata, I. proliera* and *J. pallidus* and two perennial herbs, *P. nodiflora* and *C. cordifolia.* Species in this hydrotype were found to range from the wettest plots, which flooded to depths of at least 70cm, to plots located less than 300cm above the groundwater table.

Hydrotype 2, the eulittoral or seasonally wet species consisted of species from plots that occurred between surface water depths of around 25cm and groundwater depths of -300cm (Figure 2.9). This group contained the greatest number of species including one littoral tree, *M. teretifolia,* five emergent macrophytes, seven herbs and five shrubs.

The remaining two emergent macrophytes, *B. juncea* and *L. longitudinale*, were included in the third hydrotype, littoral/supralittoral, along with two herbs, one myrtaceous shrub and three littoral tree species, *M. preissiana, M. rhaphiophylla* and *B. littoralis* (Figure 2.9). The plots in which these species were recorded ranged from those that were also inundated to around 25cm to those 600cm above the groundwater table.

Two shrubs, *M. capraroides* and *R. baccata,* and the last of the littoral trees, *E. rudis*, were the only species assigned to the littoral/terrestrial hydrotype (Figure 2.9). These species were found to range from plots also inundated to around 25cm to some of the driest plots located 900cm above groundwater.



1. Littoral

Baumea articulata
Centella cordifolia
Isolepis prolifera*
Juncus pallidus
Phyla nodiflora*
Typha orientalis*

2. Eulittoral

Azolla sp.
Baumea arthrophylla
Baumea vaginalis
Carex fascicularis
Exocarpus sparteus
Gratiola peruviana
Halogaris brownii
Hemarthria uncinata
Hypocalymma angustifolium
Isolepis marginata
Isolepis producta
Lepidosperma elatius
Leptocarpus scariosus
Lepyrodia muirii
Pericalymma ellipticum
Solanum symonii
Viminaria juncea
Melaleuca teretifolia

3. Littoral/supralittoral

Astartea fascicularis
Banksia littoralis
Baumea juncea
Centella asiatica
Lepidosperma longitudinal
Melaleuca preissiana
Melaleuca rhaphiophylla

4. Littoral/terrestrial

Eucalyptus rudis
Myporum capraroides
Rhagodia baccata

5. Seasonally waterlogged

Beaufortia elegans
Lyginia barbata
Pteridium esculentum
Pultenaea ochreata
Schoenus rodwayanus
Sporobolus virginicus

6. Supralittoral

Adriana quadripartita
Banksia ilicifolia
Kunzea ericifolia

7. Terrestrial

Aotus sp.
Calothamnus lateralis
Laxmania ramosa
Lepyrodia glauca
Pultenaea reticulata

Figure 2.9
Hydrotype categories of wetland species based on their hydrological ranges within the study wetlands. Asterisks denote exotic species.

The final three hydrotypes occurred only in plots that were not inundated, but which may have experienced shallow groundwater tables (Figure 2.9). Species belonging to the seasonally waterlogged group included two shrubs, *B. elegans* and *P. ochreata*, and four herbs. These species were restricted to plots <300cm above groundwater.

Banksia ilicifolia, a fringing tree species, and two shrubs, *K. ericifolia* and *A. quadripartita*, made up the supralittoral hydrotype, which occurred in dry plots <600cm above groundwater levels (Figure 2.9).

The final group, the terrestrial hydrotype included four herb species and two shrubs, *C. lateralis* and *P. reticulata*. These species were also found in dry plots, ranging from those that experienced shallow groundwater tables to those 900cm above groundwater levels (Figure 2.9).

2.3 DISCUSSION

2.3.1 HYDROLOGICAL ENVELOPES

The hydrological envelopes presented in this study may expand the number of plant species considered in the process of establishing environmental water requirements for wetlands of the Swan Coastal Plain. The absolute and mean ranges in water depths experienced by 60 wetland plants, and the average length of time per year each is inundated, represents a less detailed yet broader knowledge base than that currently available.

Although this form of hydrological envelope has not been previously determined for wetland species other than *B. articulata* and *T. orientalis* (Froend et al., 1993), there is a body of work that describes the position of a number of species along the water level gradient (Briggs, 1981; Muir, 1983; Froend et al., 1993; Halse et al., 1993). These studies largely support the findings of the current research.

Wetland trees were discussed in all four studies. Halse et al., (1993) found that *M. teretifolia* occurred in wetter areas than the other trees. It was recorded from below the low watermark of wetlands to above the high watermark and could be inundated for most of the year (Halse et al., 1993). The current study also found that this species grew in the wettest areas. However, although it was flooded for the greatest length of time per year, *M. teretifolia* was not subject to constant inundation.

Despite the current study finding that *M. rhaphiophylla, M. preissiana* and *B. littoralis* shared similar hydrological envelopes, previous studies found that they varied. Froend et al. (1993) described *M. rhaphiophylla* as the species most tolerant of inundation capable of surviving several months of the year in flooded conditions. Halse et al. (1993) also found this species in wetter zones, occurring from the low watermark to above the high water line. The depth experienced during inundation was calculated by Briggs (1991) at between 25 and 45cm. This finding is similar to that of the current study. The period of inundation calculated for *M. rhapiophylla*, however, was less than that of all other study wetland trees except B. littoralis, which conflicts with the literature.

Melaleuca preissiana has been described as less tolerant of inundation than *M. rhaphiophylla* (Muir, 1983; Froend et al., 1993) and is generally recorded across drier ranges (Halse et al., 1993). The current study's finding that the dry end of this species envelope occurred over groundwater 400cm below the surface was supported by a research project in which the water level was physically determined by digging at the end of the species range at three Swan Coastal Plain wetlands (Valentine, 2000).

There is some discrepancy in the literature as to whether *B. littoralis* tolerates inundation. Froend et al. (1993) and Halse et al. (1993) both found that it occurs in waterlogged areas only, while Briggs (1981) recorded it to depths of 25cm. Briggs (1981) finding was supported by the current study, however, *B. littoralis* was inundated for the shortest period of time each year.

The hydrological envelope of *E. rudis* was broader than that of all other wetland trees. This may be a function of it having been recorded at a greater number of sites or due to its greater height (Froend et al., 1993) and hence more extensive root system (Marchant et al., 1987), it may be better able to access deeper groundwater. None-the-less it was shown to tolerate inundation of up to 25cm by Briggs (1981) and other studies support its tolerance of flooding (Muir, 1983; Froend et al. 1993; Halse et al. 1993).

Although *B. ilicifolia* was not found to tolerate inundation, it is dependent on the moisture available in the soils surrounding wetlands (Muir, 1983). The hydrological envelope described for this species in the current study was supported by this finding.

The wetter end of the absolute water depth ranges for the tree species as determined by the current study may be inaccurate as may the periods of inundation. However, the dry ends of the ranges are generally supported by the literature and if the inundation period of *M. rhaphiophylla* is discounted the flooding lengths also appear fairly accurate.

The finding that five tree species were recorded at the same absolute depth at the wet end of their ranges illustrates a major limitation of this study. That is that because the plots of the monitoring transects ranged from 10m to 45m in length, the ability to distinguish the difference between the water depth ranges of individual species was limited. For example, plot A of the North Lake 2 transect was 20m long and contained all five littoral tree species. As this plot was inundated to greater depths than most, the water depths recorded at the wet end of these species absolute ranges were all the same. Dividing this plot into two may have resulted in some species being recorded in one plot and some in another each plot with a different hydrological regime.

The occurrences along the water level gradient of seven of the fifteen perennial wetland shrubs recorded in the current study have also been examined in the literature. *A. fascicularis* was found at greater depths of inundation than all other study shrubs.

Muir (1983) recorded a similar finding for Melaleuca Park wetlands. Halse et al. (1993) described this species as occurring from around the high watermark into drier zones, a finding that supports the broad range of water depths it was found across in the current study.

The hydrological envelopes established for *H. angustifolium* and *P. ellipticum* were very similar. Although it has been shown that these species often occur together (Muir, 1983; Smith and Ladd, 1994), it is generally accepted that *P. ellipticum* is more likely to experience inundation than *H. angustifolium* flooding to depths of 25cm (Briggs, 1991). This depth is similar to that determined for this species in the current study. The finding that *P. ellipticum* was flooded for close to twice as long per year as *H. angustifolium* suggests that this species does indeed tolerate inundation better than *H. angustifolium*.

Viminaria juncea was only recorded at one site in the current study and was determined to have been inundated for a few months each year. This conflicts with the work of Halse et al. (1993) which found this species occurred around the high watermark of wetlands and was rarely inundated. This discrepancy may be due to the infrequency of its occurrence.

The hydrological envelopes of *K. ericifolia, P. reticulata* and *C. lateralis* suggested that none of these species experienced inundation in the study wetlands. Muir (1983) described similar ranges emphasising the dependence of *P. reticulata* on a high groundwater table. Halse et al. (1993) found that *K. ericifolia* occurred above the high watermark.

Thus it can be seen that the hydrological envelopes established for most of the commonly occurring shrubs in the study are supported by descriptions in the literature. Consideration of these species could become important in the establishment of environmental water requirements for wetland vegetation.

Only the two most commonly occurring of the perennial herbs examined in the current study have been discussed in the literature currently under review. The hydrological envelope of *C. cordifolia* suggested that it was recorded between areas that were inundated for several months of the year up to depths of 70cm to areas 300cm above groundwater. *Centella asiatica* occurred in areas of shallower water for shorter periods, but had a much greater overall range. Halse et al. (1993) found that neither species were inundated, however, *C. cordifolia* occurred around the high watermark and *C. asiatica* above the high watermark. This suggests that both of these species require shallow groundwater or water logged soils. However, as they are both relatively short-lived species, there value in establishing environmental water requirements may be limited.

Emergent macrophytes were discussed in four previous studies. Two important limitations to the current research can be illustrated by these species. As the data had not been collected specifically for this study and the monitoring transects were in fact established to monitor wetland tree health, the transects often did not sample the vegetation at the wetland edges. This was particularly noticeable at Lake Jandabup where the transect began some 200m from the wet end of the emergent macrophytes range. However, the ecological envelopes presented for two of the most common emergent macrophytes in the study, *T. orientalis* and *B. articulata*, were relatively accurate due to the physical measurement of their occurrence at a number of wetlands during the study.

However, another limitation may account for the discrepancy between previous work on these species by Froend et al., (1993) and the results of this study. Although both studies calculated a similar range for *T. orientalis*, Froend et al., (1993) reported the depth to groundwater for the dry end of *B. articulata* as only half the depth reported in the current study. This may be due to the fact that groundwater depth in the current study was extrapolated from surface water depth rather than physically measured or taken from monitoring bores.

Halse et al. (1993) also found that these two emergent macrophytes occurred in similar ranges from below the low watermark to above the high water mark, while Muir (1983) described *B. articulata* as occurring only in the wettest areas where surface water is available for the majority of the year. Briggs (1981) also only discussed the native species stating that it tolerated inundation to depths of 100cm, a result very similar to that of the current study.

Despite the literature describing these species as sharing virtually the same ranges, field visits during this study suggested that *T. orientalis* is often found in deeper water with *B. articulata* growing upslope of it. This may be due to the exotic species being more tolerant of inundation or possibly due to greater competitive abilities in the same depth (Froend and McComb, 1994).

The other two most common emergent macrophytes in this study were *B. juncea* and *L. longitudinale*, both of which had the broadest hydrological envelopes. Both species occurred in inundated areas to similar depths and for similar lengths of time. These findings were generally supported by the literature with Halse et al. (1993) allocating them to the zone around the high watermark and Froend et al. (1993) stating that although both tolerate inundation they prefer waterlogged sites. Froend et al. also noted that *B. juncea* only has a narrow range at water level.

The hydrological envelope of *J. pallidus* matched the findings of Halse et al. (1993) and Froend et al. (1993) that this species was most common in water logged sites. However, Halse et al. (1993) described *B. vaginalis* and *L. scariosus* as occurring in wetter areas in contrast to the current study's finding of drier ranges. The low occurrence of these three emergent macrophytes in the study wetlands may explain this discrepancy.

It was noted in the results that there were a number of limitations to this study. Most of these have already been discussed, however there are others. The different forms of the Domin scale of cover and abundance used between the Jandakot and the Gnangara wetlands and the different methods used to record them meant that the relative importance of all species within a plot was difficult to gauge. Although values were assigned to each of the 60 wetland species for each plot, the Jandakot values were based on the mean cover of three 1m x 1m quadrat and the written descriptions from the monitoring reports (Ladd, 1997; 1998; 1999). It is quite probable that final values were not accurate. Domin values for all species in each plot for each of the three years would also have enabled the identification of changes in the composition and structure of short-lived and annual species over that time.

The most important limitation, however, was related to the fact that the data had not been collected specifically for this study and that there was therefore no record of the exact location of a species within a plot. This resulted in all species in one plot being recorded as occurring at the same water depth. The ranges of the aquatic species *Azolla sp.*, *Lemna sp.* and *Triglochin sp.* best demonstrated this problem, as they were all shown to occur on dry land when it is known that they do not survive out of the water (Marchant et al., 1987).

Despite the obvious limitations of this study, the discussion above indicates that the hydrological envelopes for the more commonly occurring species in the study wetlands could be used to help determine environmental water requirements for wetlands of the Swan Coastal Plain. The ranges of the perennial shrubs discussed in this section may be of particular importance, as these species have not been studied in the same detail as littoral trees and emergent macrophytes. These species may also be significant, as they are not as long-lived and slow to respond to change as littoral tree species and generally occur across a greater range of water depths than emergent macrophytes.

Perennial herbs and annual species are probably not as useful due to their low occurrence and general short lifespans. However, they may serve as supplements to a basic list of common species or, as many of these species were exotics, they may be of use in areas that are heavily disturbed.

2.3.2 HYDROTYPES

Amended hydrotype groupings

Inaccuracies in water depth ranges, as discussed previously, lead to inaccuracies in hydrotype classifications. To improve this scheme for future use, the species listed above, *Azolla* sp., *Lemna* sp. and *Triglochin* sp., could be discarded. Other species with questionable ranges could either be discarded or re-allocated to different hydrotypes.

Under this proposal the exotic perennial herb, *Phyla nodiflora*, would be moved from the littoral hydrotype to the seasonally waterlogged group as it does not tolerate inundation, growing in damp areas only (Marchant et al., 1987). *Centella cordifolia* should also be removed from this hydrotype as, although it does tolerate some inundation, it would not survive to the same depths as the other species in this group (Marchant et al., 1987). It should be relocated to group two, the seasonally wet hydrotype. *Hypocalymma angustifolium* is another species not found in inundated areas (Water and Rivers Commission, 1997). It should therefore be moved from the eulittoral, or seasonally wet group to the seasonally waterlogged hydrotype, with *B. elegans*.

The replication of experiments to account for natural variability is standard scientific procedure (Bouma, 1996). Unfortunately, in this study a number of wetland species were only recorded at one site. The removal of these species would leave 24 perennial and five annual species to represent all nine hydrotypes (Table 2.2). The majority of the perennial species were discussed in the previous section and their ranges were generally supported by the literature.

Table 2.2

Amended hydrotype groupings. Species with low occurences (<2) have been omitted. Species with ranges questioned in the literature have be moved to a more appropriate hydrotype

Hydrotype	Species
1. Littoral	*B. articulata*
	J. pallidus
	T. orientalis
2. Eulittoral	*C. cordifolia*
	H. brownii
	L. elatius
	L. scariosus
	P. ellipticum
	M. teretifolia
3. Littoral/supralittoral	*A fascicularis*
	B. littoralis
	C. asiatica
	L. longitudinale
	M. preissiana
	M. rhaphiophylla
4. Littoral/terrestrial	*E. rudis*
	M. capraroides
	R. baccata
5. Seasonally waterlogged	*B. elegans*
	H. angustifolium
	P. nodiflora
6. Supralittoral	*B. ilicifolia*
	K. ericifolia
7. Terrestrial	*P. reticulata*
8. Annual tolerators	V. capitata
9. Annual avoiders	*C. glaucum*
	C. coronopifolia
	H. homalocarpum
	P. monspeliensis

Hydrotypes as a predictive tool

The second objective of the hydrotype classification scheme was to enable botanists to predict the possible impacts of changing water regimes on the composition and structure of wetland vegetation. It is therefore important to describe how this scheme could be applied.

A 10m wide transect would be established running from the vegetation at the edge of the wetland, through the wetland vegetation to the point at which only non-wetland species occurred. The length of the transect would be determined by the range of the wetland species. In a series of 10 x 10m plots all species would be identified and their cover and abundance recorded.

Following identification a species list would be compared to the amended hydrotype scheme to determine which groups were represented at the wetland and where they were located in relation to one another and the wetland edge. Once the existing vegetation structure and composition were determined the impacts of rising or falling water tables could be extrapolated. For example, if water tables fell species from the littoral and eulittoral hydrotypes may initially become less healthy and start to die thereby thinning their cover. If the fall was gradual they may migrate down the water gradient, or if sudden they may be lost (van der Valk, 1993). Tree species would respond more slowly to these changes than emergent macrophytes (Froend et al., 1993) and other perennial species (Keddy and Reznicek, 1986). However, long term extreme declines in water levels may have an impact.

The use of this scheme is better illustrated through an example. Pettit and Froend (2000) recorded the vegetation data in the following example as part of the annual wetland vegetation monitoring program from which all other vegetation data in this study was sourced. The wetland, Dampland 78, was not included in the original data analysis, as the monitoring of its surface water levels did not continue after 1987. The hydrological data used in this example was collected prior to that date.

Two scenarios will be discussed in this example. The first is the change in hydrotype composition two years after a 2m increase in water levels and the second, after a 2m decrease. In reality such dramatically altered water regimes are highly improbable. However, for this example a 2m rise is required for surface water to occur across plot A and the start of plot B.

Table 2.3 showed that seven wetland species representing five hydrotypes were identified across the transect at Dampland 78. *Baumea articulata*, the only species from the littoral hydrotype, was recorded in very low densities in plot A only. Species from the littoral/supralittoral group, *A. fascicularis* and *M. preissiana*, that tolerate inundation and groundwater depths to −600cm were found across all plots with declining cover and abundance. The seasonally waterlogged hydrotype was represented by one species, *B. elegans*, which remained fairly abundant across the entire transect. *Kunzea ericifolia*, from group 6, the supralittoral species intolerant of inundation, occurred in all plots, while *B. ilicifolia* also from this group was found only at the higher elevations of plot D. The final species, *P. reticulata* of the terrestrial hydrotype group, was also recorded in all plots, however it was less abundant in plot A than in B, C and D.

Table 2.3

Presence/absence and cover values of wetland species across Dampland 78 monitoring plots in spring 1999. Data presented as part of an example of how to use the hydrotype classifcation scheme developed in the current study. Numbers next to the species names represent the hydrotype to which it was allocated.

		Plot and location along transect			
Species		A 0-10	B 11.-20	C 21-30	D 31-40
Beaufortia elegans	5	7	9	7	8
Kunzea ericifolia	6	3	1	4	3
Pultenaea reticulata	7	3	4	4	4
Melaleuca preisianna	3	8	2	3	1
Baumea articulata	1	1	0	0	0
Astartea fascicularis	3	2	0	2	1
Adenanthos cygnorum					
Banksia menziesii					
Hibbertia subvaginalis					
Regelia inops					
Stylidium repens					
Patersonia occidentalis					
Banksia ilicifolia	6				2
Banksia attenuata					
Dasypogon bromeliifolius					

Scenario 1: the impact of a 2m water table rise on the hydrotype composition of Dampland 78

Using hydrotypes as a predictive tool this scenario could be expected to lead to the following changes in species composition.

After two years of a 2m higher water table, plot A is still dominated by littoral/supralittoral species and the cover of this hydrotype has increased across the transect (Figure 2.11). This may have occurred for two reasons. Firstly, *M. preissiana* as a tree species, responds much slower to water level changes than other perennial species (Froend et al., 1993) and its cover value should not have changed. Secondly, the cover of *A. fascicularis* may have increased either due to greater water availability or decreased competition from other shrub species. The single species from the littoral hydrotype, *B. articulata,* has also increased in cover and abundance in plot A as it now experiences seasonal inundation (Figure 2.11). It has also begun to encroach into plot B.

The seasonally waterlogged hydrotype represented by *B. elegans,* has declined in plots A and B following seasonal inundation. Similar cover values have been recorded in plot C and increased in D due to newly waterlogged conditions. As a supralittoral species, *K. ericifolia* has also declined in plot A. It has also increased across the rest of the transect due to greater water availability, however not to the same extent as *B. elegans* which prefers slightly wetter conditions.

Pultenaea reticulata from the terrestrial hydrotype was lost from plot A as it is intolerant of flooding. It has also declined noticeably in plot B due to a shallow groundwater table, less in plot C and remained fairly stable in plot D.

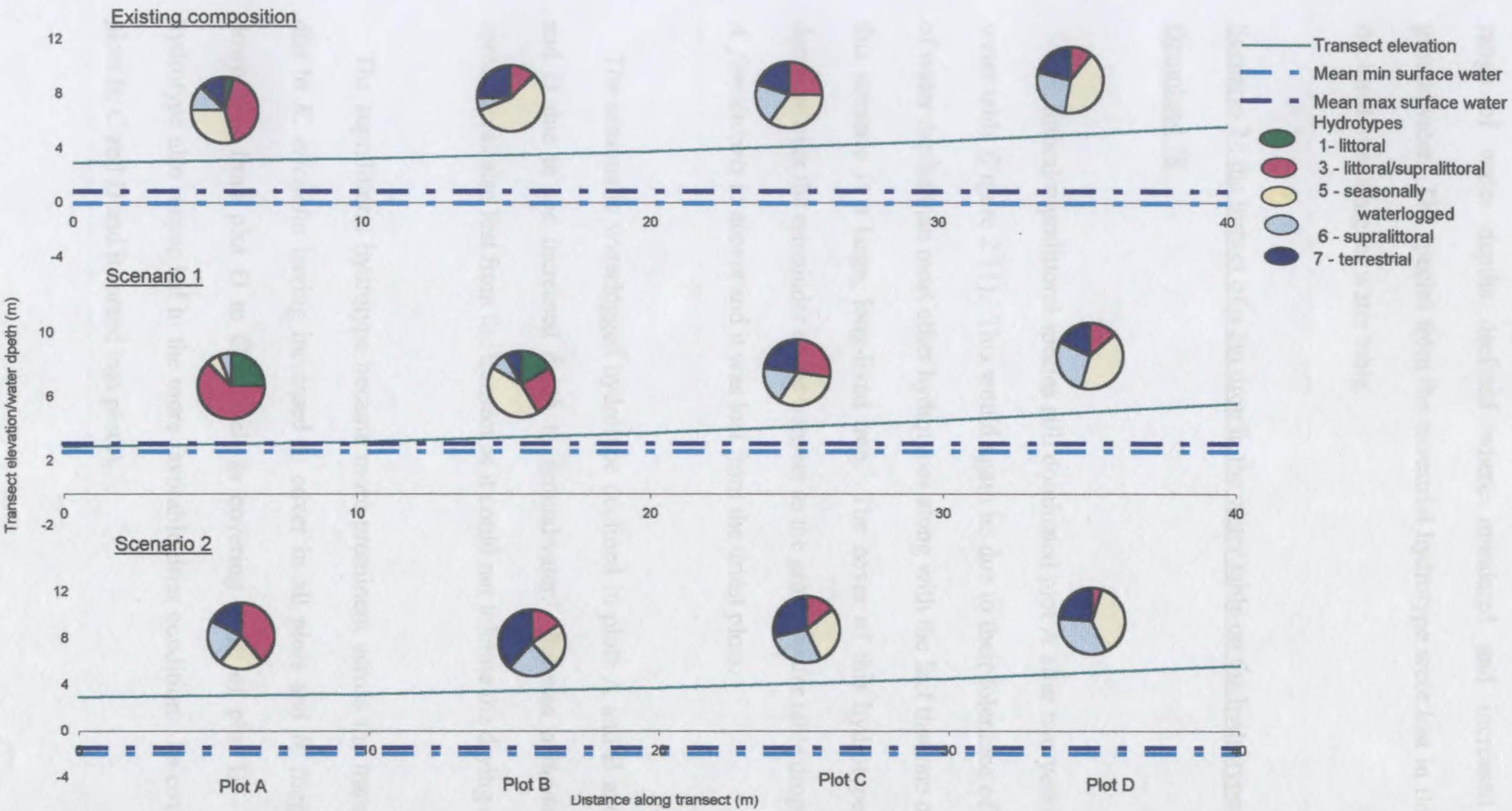


Figure 2.11 : An example of the use of the hydrotype scheme to predict the changes in vegetation composition. Two scenarios are presented. The top graph represents the actual hydrology and vegetation composition of Dampland 78. Scenario 1 represents the change after a 2 year period of a 2m higher water table. Scenario 2 represents changes after 2 years of a 2m lower water table. The pie charts represent as a percentage,the cover value of each hydrotype in each plot.

In this scenario species from the hydrotypes that favour inundation have increased in cover and abundance, while those that favour waterlogged conditions or that tolerate a range of water depths declined where inundated and increased over shallow groundwater. The species from the terrestrial hydrotype were lost in flooded areas and declined over a higher water table.

Scenario 2 : the impact of a 2m drop in the water table on the hydrotype composition of Dampland 78

The littoral/supralittoral species still dominated plot A after two years of a 2m lower water table (Figure 2.11). This would again be due to their tolerance of a greater range of water depths than most other hydrotypes along with the fact that one of the species in this scenario is a large, long-lived tree. The cover of this hydrotype did, however, decrease over the remainder of the transect as the groundwater table dropped too low for *A. fascicularis* to access and it was lost from the driest plots.

The seasonally waterlogged hydrotype declined in plots A and B and died out in C and D due to the increased depth to groundwater. *Baumea articulata*, the littoral species, was also lost from the transect as it could not tolerate the drying conditions.

The supralittoral hydrotype became more prominent across the transect. This was due to *K. ericifolia* having increased in cover in all plots and *B. ilicifolia* migrating downslope from plot D to C as well as covering more of plot D. The terrestrial hydrotype also responded to the more favorable drier condition. Its cover increased in plots B, C and D and it spread into plot A.

In this scenario species from the hydrotypes that favour wetter conditions either died out or declined in cover in response to a significant drop in the groundwater table. Species from the supralittoral and terrestrial groups increased their cover and migrated into the areas that had previously been too wet for them to tolerate.

Although far from perfect, this scheme for using plants grouped into hydrotypes by the water regimes they tolerate, could be used as a tool to predict the impact of changed water regimes on the vegetation composition and structure of wetlands of the Swan Coastal Plain.

REFERENCES

Allen, A.D. (1979). The hydrogeology of Lake Jandabup, Swan Coastal Plain, W.A. *Geological survey Western Australia, Annual report.* pp. 32-40. Perth.

Arnold, J. (1990). *Perth wetlands resource book.* Perth, Environmental Protection Authority.

Balla, S (1994). *Wetlands of the Swan Coastal Plain. Vol. 1. Their nature and management.* Perth, Water Authority of Western Australia and the Department of Environmental Protection

Barradas, D., Zunzunegui, M.C., Tirado, M., Ain-Lhout, F. and Garcia Novo, F. (1999). Plant functional types and ecosystem function in Mediterranean shrubland. *Journal of vegetation science, 10,* (5), 709-716.

Bennett, E.M. (1988). *Bushland plants of Kings Park.* Perth, Kings Park Board.

Bouma, G.D. (1996). *The research process. 3rd ed.* Melbourne, Oxford University Press.

Boutin, C. and Keddy, P.A. (1993). A functional classification of wetland plants. *Journal of vegetation science, 4,* 591-600.

Briggs, S.V. (1981). Freshwater wetlands. In R.H. Groves (Ed.) *Australian vegetation* pp. 335-360. Melbourne, Cambridge University Press.

Brock, M.A. (1991). Mechanisms for maintaining persistent populations of *Myriophyllum variifolium* J. Hooker in a fluctuating shallow Australian lake. *Aquatic botany, 39,* 211-219.

Brock, M.A. and Casanova, M.T. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying. In N. Klomp & I. Lunt (Eds.) *Frontiers in ecology.* pp 181-192. Oxford, Elsevier Science Ltd.

Brownlow, M.D., Sparrow, A.D. and Ganf, G.C. (1994). Classification of water regimes in systems of fluctuating water level. *Australian journal of* marine *and freshwater research, 45,* 1375-1385.

Burbidge, N. (1984). *Australian grasses.* Melbourne, Angus and Robertson Press.

Davidson, W.A. (1995). Hydrogeology and groundwater resources of the Perth region, Western Australia. *Geological survey of Western Australia, Bulletin 147.* pp. 3-15. Perth.

Department of Planning and Urban Development (1992). *Beeliar Regional Park: Proposals for establishment, administration and use. Final report.* Perth.

Diaz, S. and Marcelo, C. (1997). Plant functional types and ecosystem function in relation to global change. *Journal of vegetation science, 8,* 63-474.

Ellison, A.M. and Bedford, B.L. (1995). Response of a wetland vascular plant community to disturbance: A simulation study. *Ecological application, 5,*(1), 109-123.

Fox, M.D. and Fox, B.J. (1986). The susceptibility of natural communities to invasions. In R.H. Groves & J.J. Burdon (Eds.) *Ecology of biological invasions: an Australian perspective.* pp. 57-66. Canberra, Academy of Science.

Fox, B.J., Taylor, J.E., Fox, M.D. and Williams, C. (1997). Vegetation changes across edges of forest remnants. *Biological conservation, 82*, 1-13.

Froend, R.H., Farrell, R.C.C., Wilkins, C.F., Wilson, C.C. and McComb, A. J. (1993). *Wetlands of the Swan Coastal Plain. Vol. 4. The effect of altered water regimes on wetland plants.* Perth, Water Authority of Western Australia/Environmental Protection Authority.

Froend, R.H. and McComb, A.J. (1994). Distribution, productivity and reproductive phenology of emergent macrophytes in relation to water regimes at wetlands of South-western Australia. *Australian journal of marine and freshwater ecology, 45,* 1491-1508.

Gill, A.M. (1981). Adaptive responses of Australian vascular plant species to fire. In A.M. Gill, R.H. Groves & I.R. Noble (Eds.) *Fire and the Australian biota,* pp.243-272. Canberra, Australian Government Publishing Service.

Halse, S.A., Pearson, G.B. and Patrick, S. (1993). *Vegetation of depth-gauged wetlands in nature reserves of south-west Western Australia. Technical report no. 30.* Perth, Department of Conservation and Land Management.

Harding, M. (1993). Redgrave and Lopham fens, East Anglia, England: A case study of change in flora and fauna due to groundwater abstraction. *Biological conservation 66,* 35-45.

Hill, A.L., Semeniuk, C.A., Semeniuk, V. and Del Marco, A. (1996). *Wetlands of the Swan Coastal Plain. Vol. 2A. Wetland mapping, classification and evaluation, main report.* Perth, Water and Rivers Commission/Department of Environmental Protection.

Hill, A.L., Semeniuk, C.A., Semeniuk, V. and Del Marco, A. (1996). *Wetlands of the Swan Coastal Plain. Vol. 2B. Wetland mapping, classification and evaluation, Wetland Atlas.* Perth, Water and Rivers Commission/Department of Environmental Protection.

Jenik, J. (1990). Forested wetlands. In B.C. Patten (Ed.) *Wetlands and shallow continental water bodies.* Pp. 137-146. The Hague, SPB Academic Publishing.

Keddy, P.A. and Reznicek, A.A. (1986). Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seed. *Journal of Great Lakes research, 12,* (1). pp. 25-36.

Keddy, P.A., Twolan-Strutt, L. and Wisheu, I.C. (1994). Competitive effect and response rankings in 20 wetland plants: are they consistent across three environments? *Journal of ecology, 82,* 635-643.

Kent, M. and Coker, P. (1992). *Vegetation description and analysis: A practical approach.* London, Belhaven Press.

Kleyer, M. (1999). Distribution of plant functional types along gradients of disturbance intensity and resource supply in an agricultural landscape. *Journal of vegetation science, 10,* (5), 697-708.

Ladd, P.G. (1997). *Wetland vegetation monitoring. Jandakot wetlands, 1996 survey. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Perth, Curtin University.

Ladd, P.G. (1998). *Wetland vegetation monitoring. Jandakot wetlands, 1997 survey. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Perth, Curtin University.

Ladd, P.G. (1999). *Wetland vegetation monitoring. Jandakot wetlands, 1998 survey. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Perth, Curtin University.

Ladd, P.G. and Schmidberger, J. (2000). *Wetland vegetation monitoring. Jandakot wetlands, 1999 survey. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Perth, Curtin University.

Lund, M. and Hindmarsh, R. (1997). *Ecology practical manual.* Joondalup, Edith Cowan University.

Marchant, N.G., Wheeler, J.R., Rye, B.L., Bennet, E.M., Lander, N.S. and Macfarlane, T.D. (1987). *Flora of the Perth Region.* Perth, Western Australian Herbarium, Department of Agriculture.

McComb, A.J. and Lake, P.S. (1990). *Australian wetlands.* North Ryde, Angus and Robertson.

Mitsch, W.J. and Gosselink, J.G. (1993). *Wetlands. 2nd ed.* New York, Van Nostrand Reinhold.

Moore, D.R.G. and Keddy, P.A. (1988). Effects of water-depth gradient on the germination of lake-shore plants. *Canadian journal of botany, 66,* 548-552.

Mountford, J.O. and Chapman, J.M. (1993). Water regime requirements of British wetland vegetation: using the moisture classification of Ellenberg and Londo. *Journal of environmental management, 38,* 275-288.

Muir, B. (1983). Drainage, swamp structure and vegetation succession at Melaleuca Park, northern Swan Coastal Plain. *Western Australian Herbarium research notes,* 9. 27-39.

Neilsen, D.L. and Chick, A.J. (1997). Flood-mediated changes in aquatic macrophyte community structure. *Marine and freshwater research, 48*, 153-157.

Pettit, N. E. and Froend, R.H. (1997). *Wetland vegetation monitoring 1996. Survey of Gnangara wetlands. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Joondalup, Edith Cowan University.

Pettit, N. E. and Froend, R.H. (1998). *Wetland vegetation monitoring 1997. Survey of Gnangara wetlands. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Joondalup, Edith Cowan University.

Pettit, N. E. and Froend, R.H. (1999). *Wetland vegetation monitoring 1998. Survey of Gnangara wetlands. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Joondalup, Edith Cowan University.

Pettit, N. E. and Froend, R.H. (2000). *Wetland vegetation monitoring 1999. Survey of Gnangara wetlands. A report to the Water and Rivers Commission of Western Australia.* Unpublished manuscript, Joondalup, Edith Cowan University.

Ponting, C. (1991). *A green history of the world.* London, Sinclair-Stevenson Ltd.

Rigg,L.S., Enright, N.J. and Jaffre, T. (1998). Stand structure of the emergent conifer *Aracauria laubenfelsii,* in marquis and rainforest, Mont Do, New Calendonia. *Australian journal of ecology, 23*, (6), 514-527.

Roberts, J., Young, B. and Marston, F. (1999). The method book: estimating water requirements for plants of floodplain wetlands. *Consultancy report,* no. 99/60. Canberra, CSIRO Land and Water,

Seddon, G. (1972). *Sense of place.* Perth, UWA Press.

Semeniuk, C.A. (1988). Consanguineous wetlands and their distribution in the Darling System, Southwestern Australia. *Journal of the Royal Society of* Western *Australia, 70,* (3), 69-87.

Semeniuk, C.A., Semeniuk, V., Cresswell, I.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.

Smith, R.S. and Ladd, P.G. (1994). Wet heathlands of the southern Swan Coastal Plain: a phytosociological study. *Journal of the Royal Society of Western Australia, 77,* (3), 71-80.

ter Heerdt, G.N.J. and Drost, H.J. (1994). Potential for the development of marsh vegetation from the seed bank after a drawdown. *Biological Conservation, 67,* (1), 1-11.

Tiner, R.W. (1991). The concept of hydrophyte for wetland identification. *BioScience, 41,* (4), 236-248.

Upton, K. and Kinnear, A. (1997). Introduction. In A. Kinnear & P. Garnett (Eds.), *Yellagonga wetlands. A study of the water chemistry and Aquatic fauna. Research report no. 1.* pp 1-16. Joondalup, Centre for Ecosystem Management. Edith Cowan University.

Valentine, H.E. (2000). The applicability of stable carbon isotope analysis to measure the water use efficiency of *Melaleuca preissiana* populations on the Swan Coastal Plain of Western Australia. *Unpublished thesis, Joondalup, Edith Cowan University.*

van der Valk, A.G. (1981). Succession in wetlands: A Gleasonian approach. *Ecology, 63,* (3), 688-696.

van der valk, A.G. (1994). Effects of prolonged flooding on the distribution and biomass of emergent species along a freshwater wetland coenocline. *Vegetatio, 110,* 185-196.

Walker, J. and Hopkins, M.S. (1984). Vegetation. In R.G. McDonald, R.F. Isbell, J.G. Speight, J. Walker & M.S. Hopkins (Eds.) *Australian soil and land survey. Field handbook.* (pp. 44-59). Melbourne, Inkata Press.

Water Authority of Western Australia, (1991). *Jandakot groundwater scheme stage 2. Public Environmental Review. Vol. 1.* Perth, Water Resources Directorate, Groundwater Branch.

Water Authority of Western Australia, (1995). *Review of proposed changes to environmental conditions. Gnangara Mound groundwater resources. Section 46.* Perth.

Water and Rivers Commission (1997). *East Gnangara environmental water provisions plan. Public environmental review.* Perth.

Wheeler, B.D. (1999). Water and plants in freshwater wetlands. In A.J. Baird & R.L. Wilby (Eds.) *Eco-hydrology: plants and water in terrestrial and aquatic environments.* p 127-180. London, Routledge Press.

APPENDICES

Appendix 1: Maps of study wetlands showing locations of staff gauges, monitoring bores and vegetation transects.

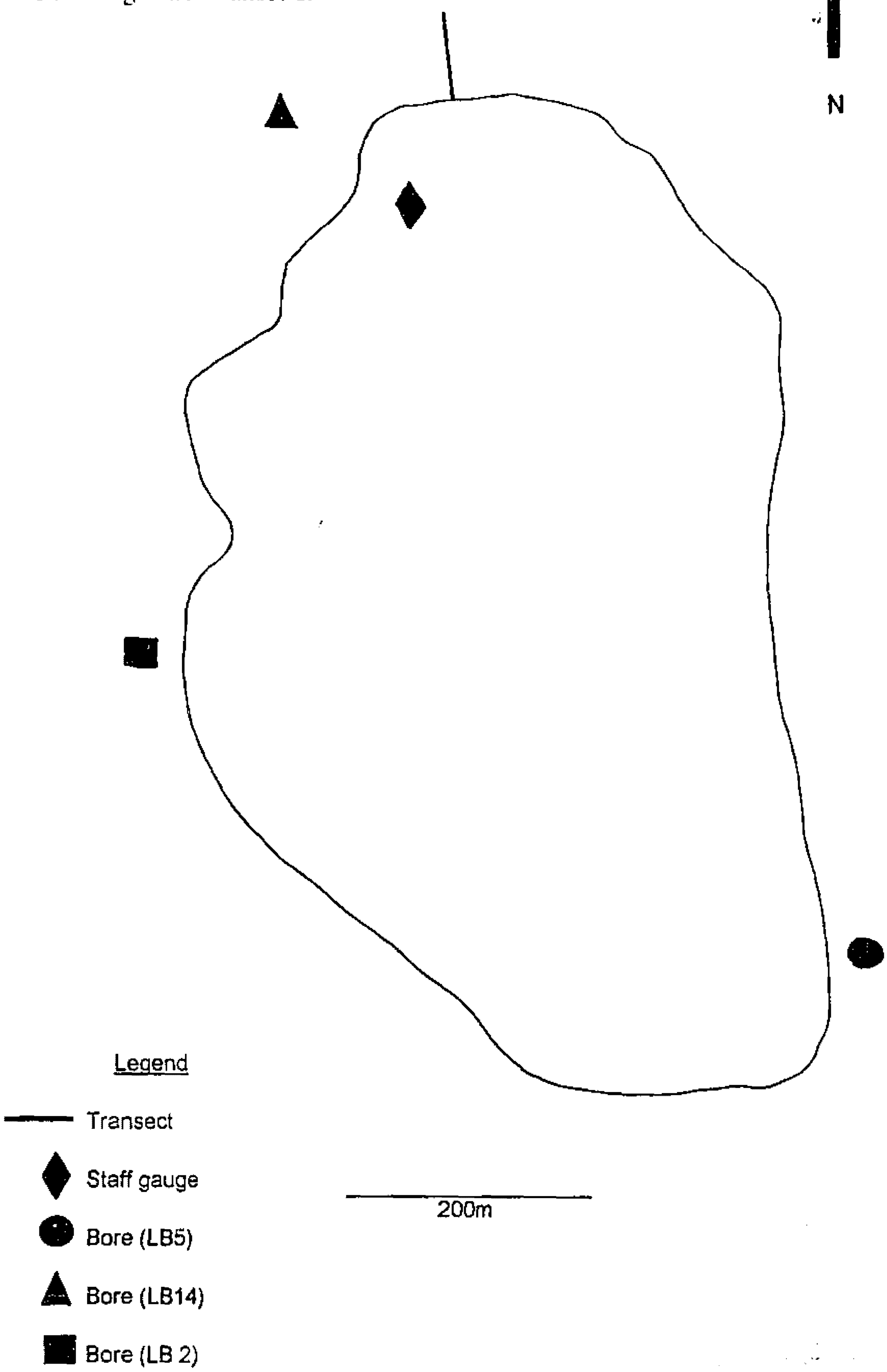


Figure A1.1
Lake Banganup staff gauge, bore and transect locations.
(source: Water and Rivers Commission, Mapping Division)

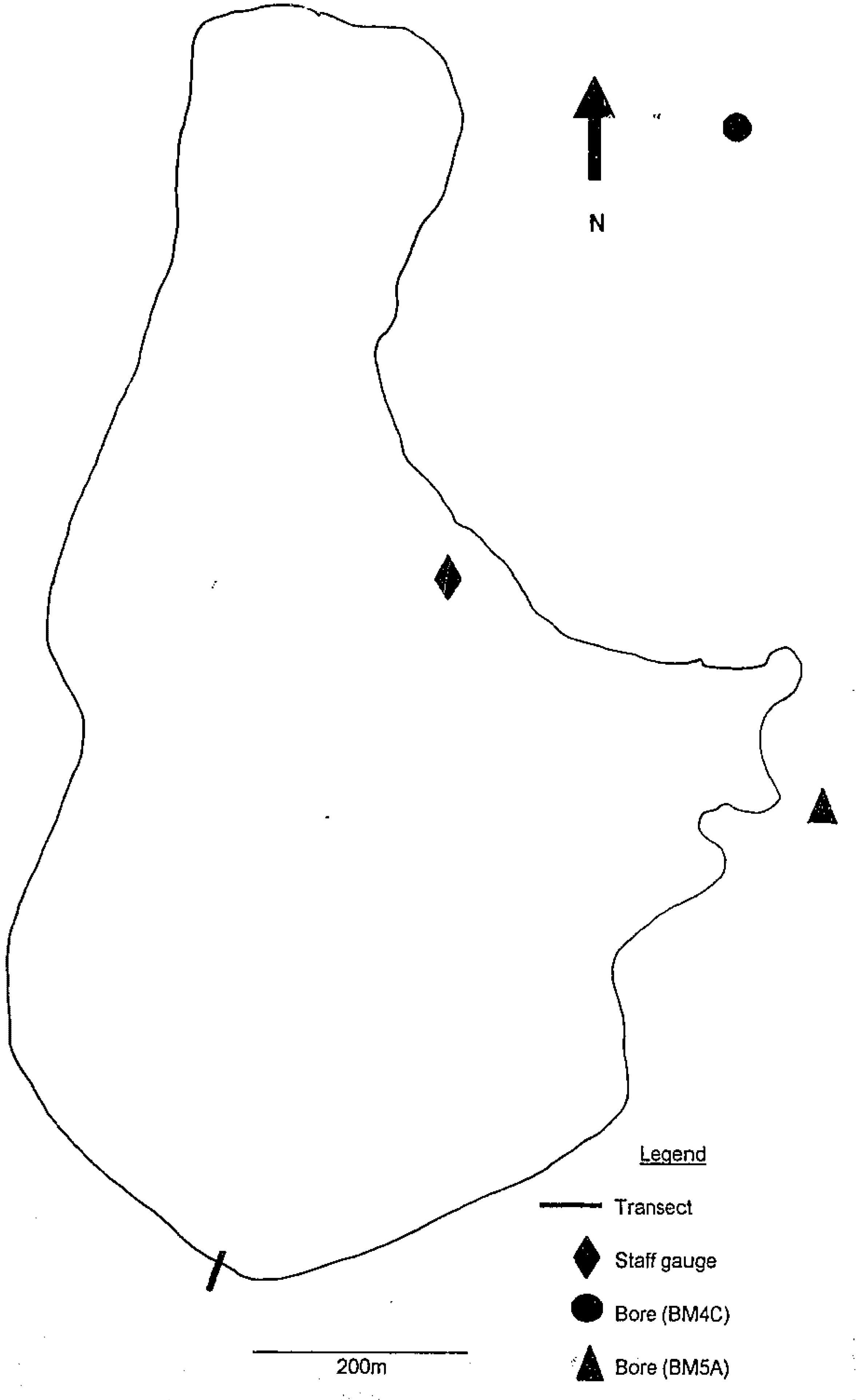


Figure A1.3
Bibra Lake staff gauge, bore and transect locations.
(source: Water Authority, 1991, p.133)

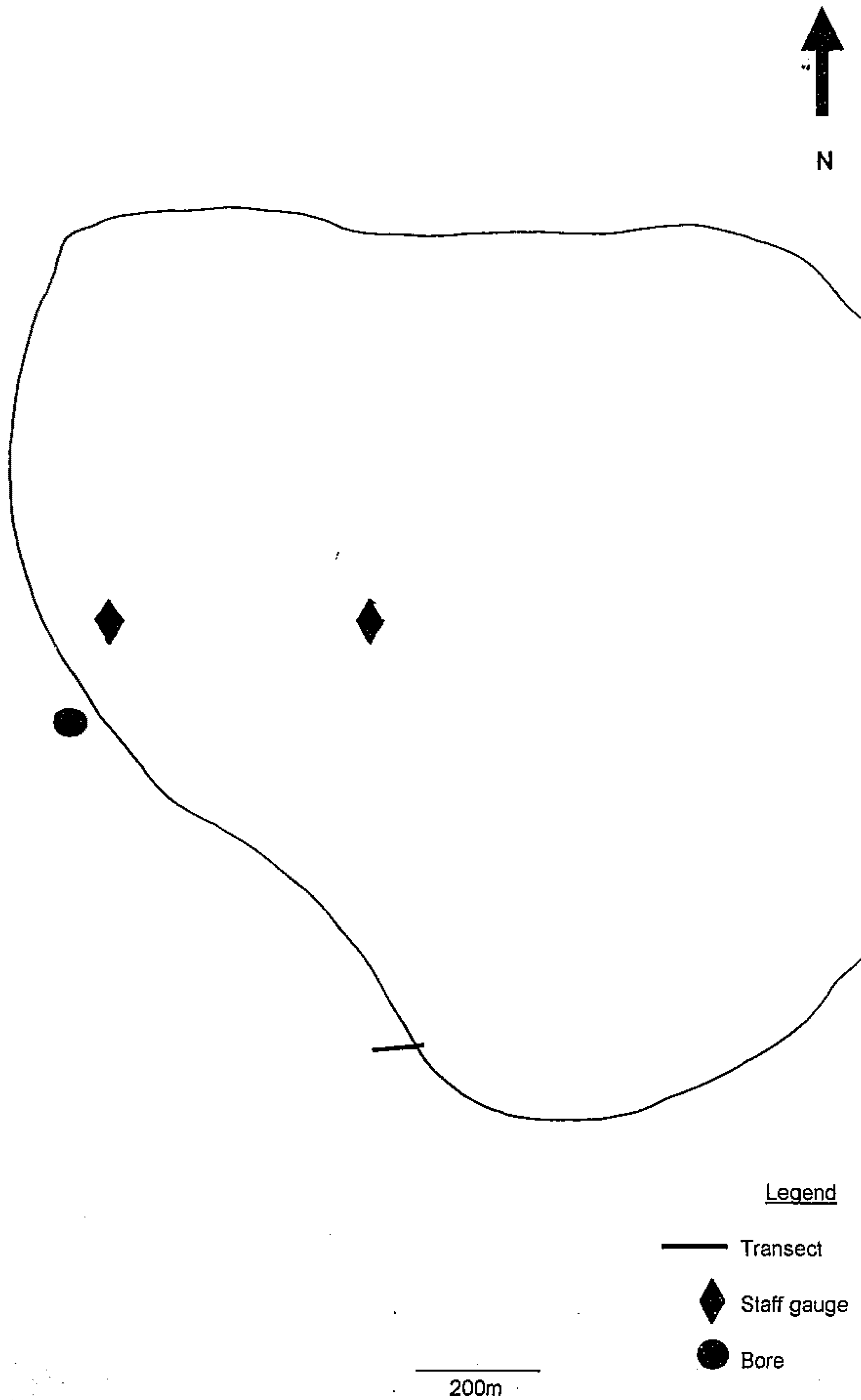


Figure A1.2
Beenyup Rd Swamp staff gauge, bore and transect locations.
(source: Water and Rivers Commission, Mapping Division)

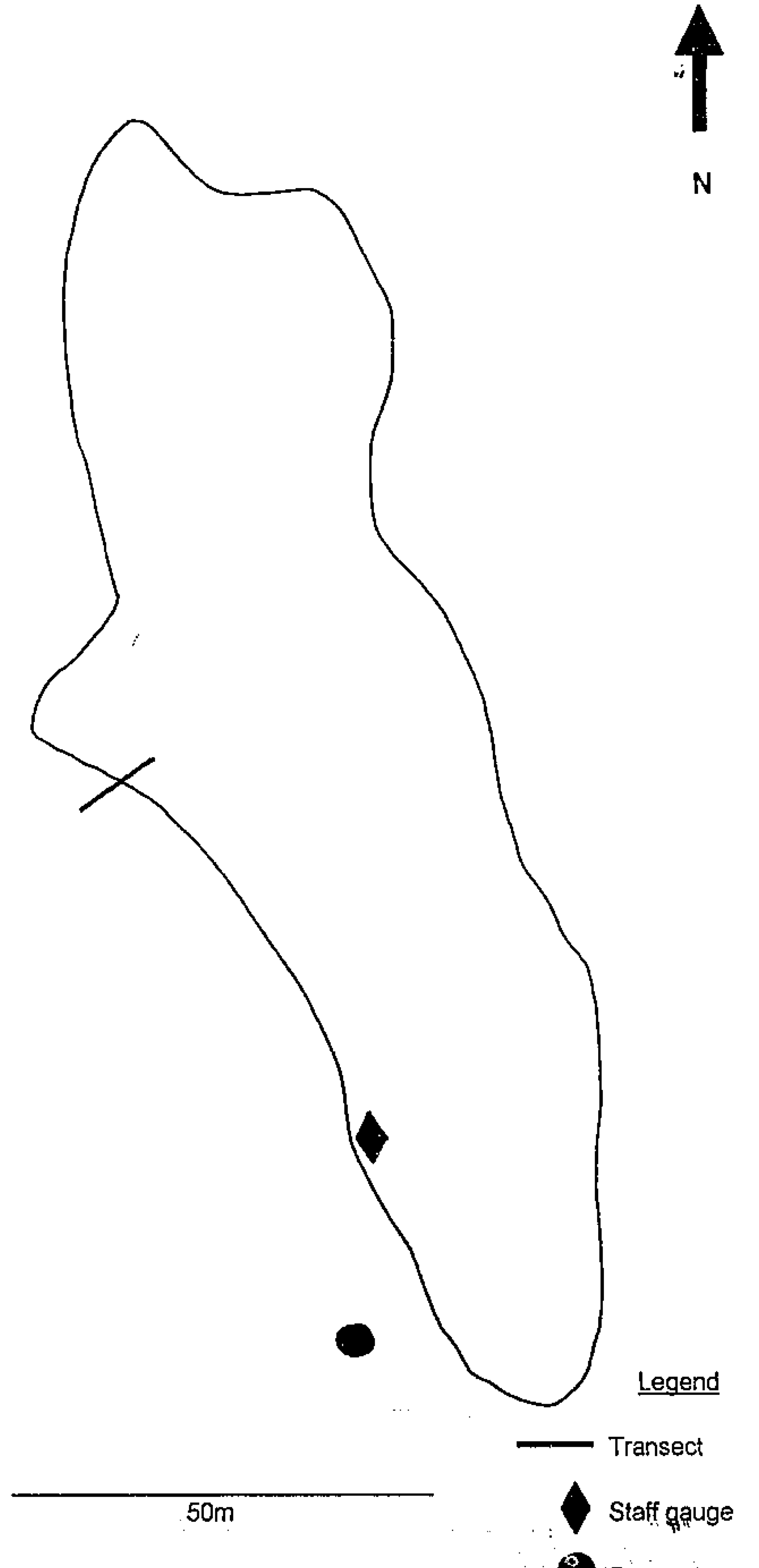


Figure A1.4
Lake Goollelal staff gauge, bore and transect locations.
(source: Water Authority, 1995, Fig.5.1)

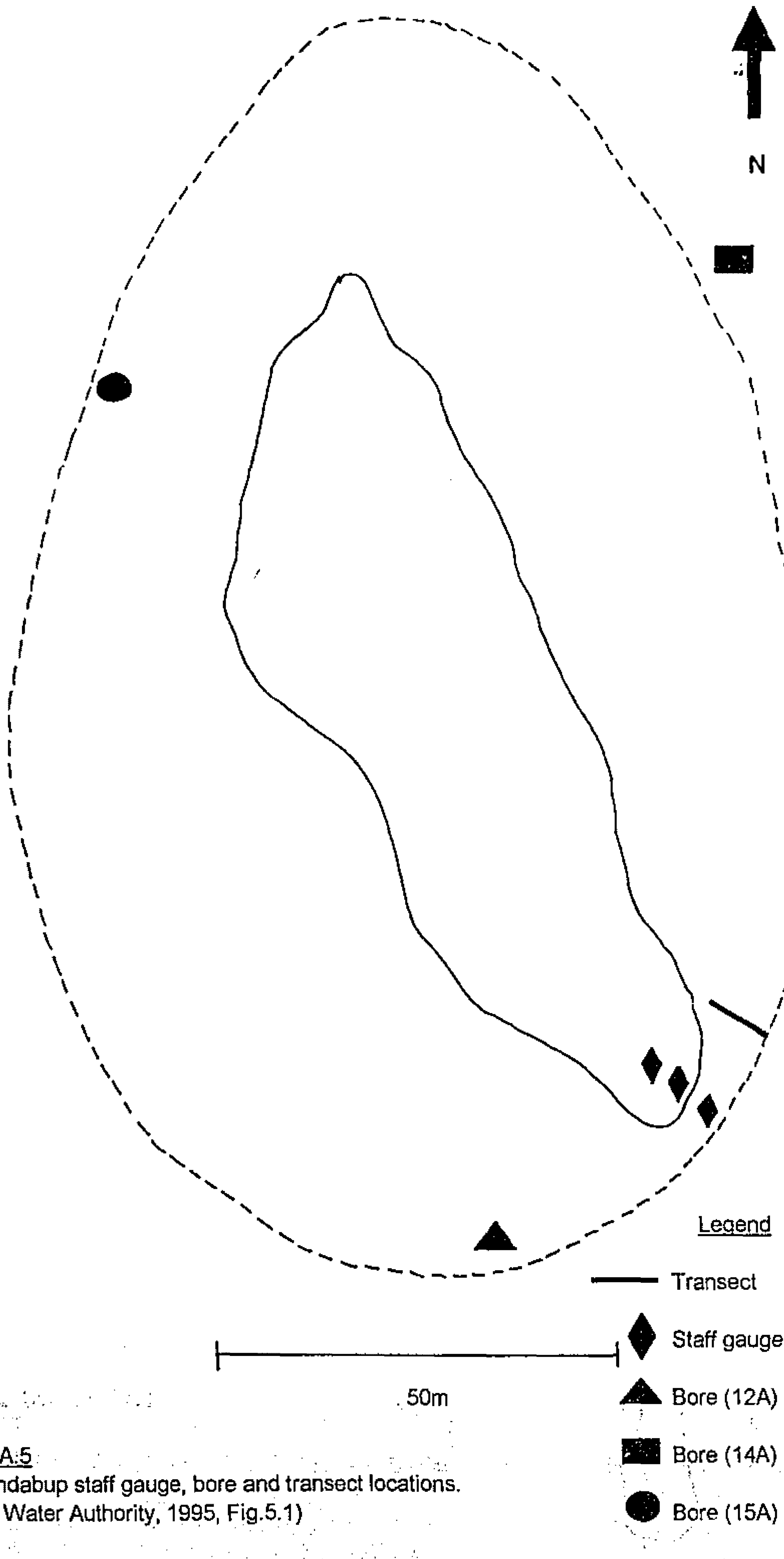


Figure 1A.5
Lake Jandabup staff gauge, bore and transect locations.
(source: Water Authority, 1995, Fig.5.1)

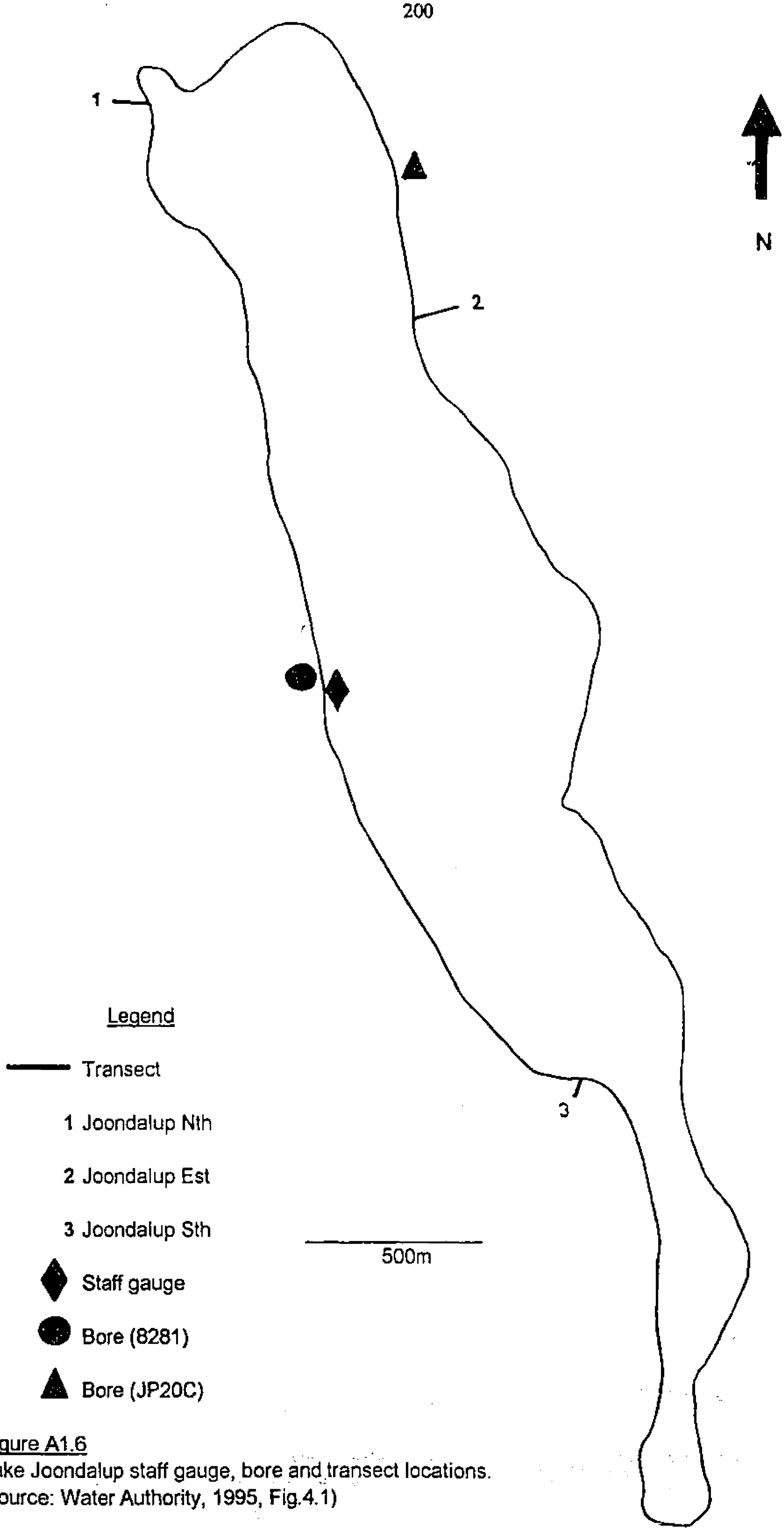


Figure A1.6
Lake Joondalup staff gauge, bore and transect locations.
(source: Water Authority, 1995, Fig.4.1)

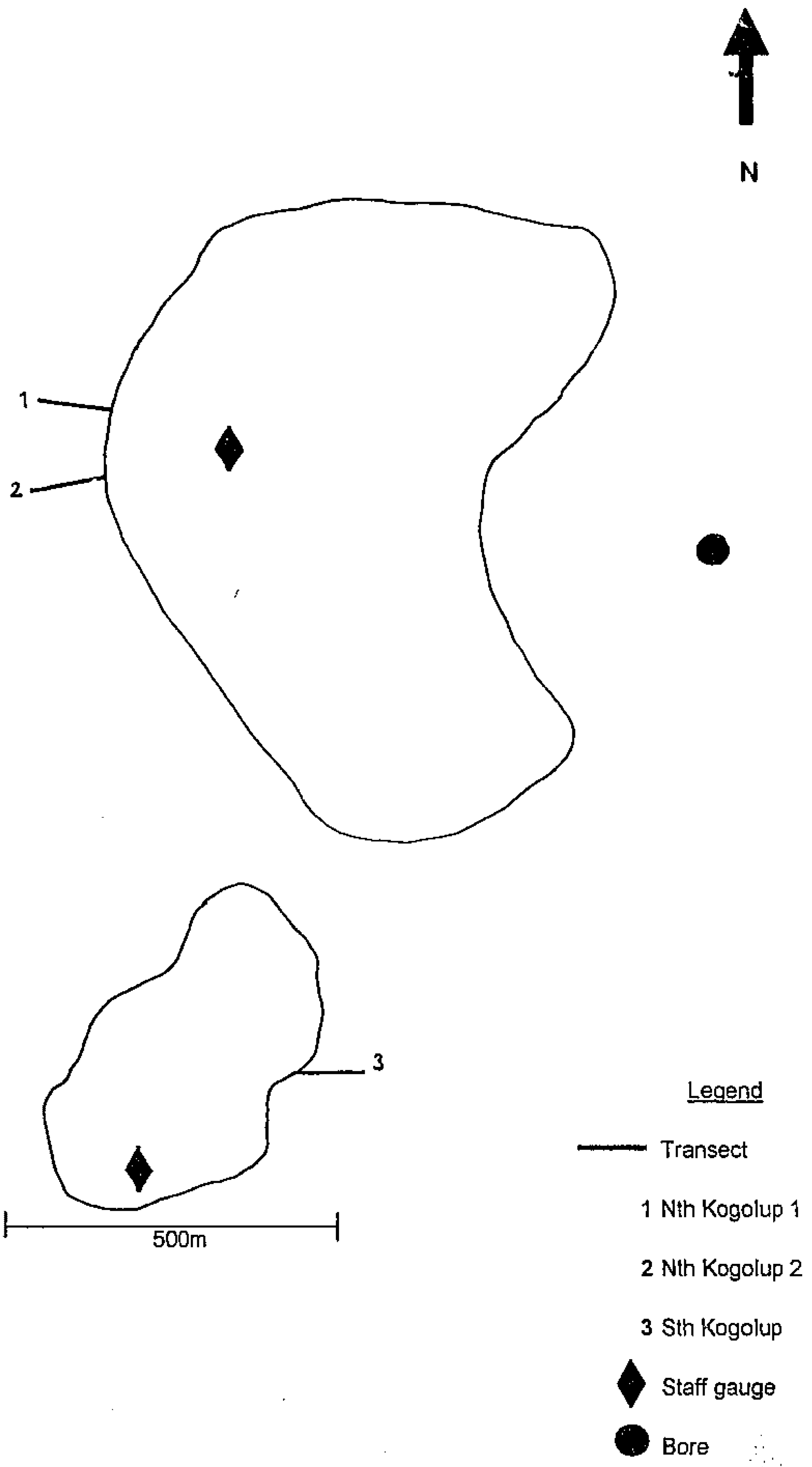


Figure A1.7
North and South Kogolup Lakes staff gauge, bore and transect locations.
(source: Water Authority, 1991, p.132)

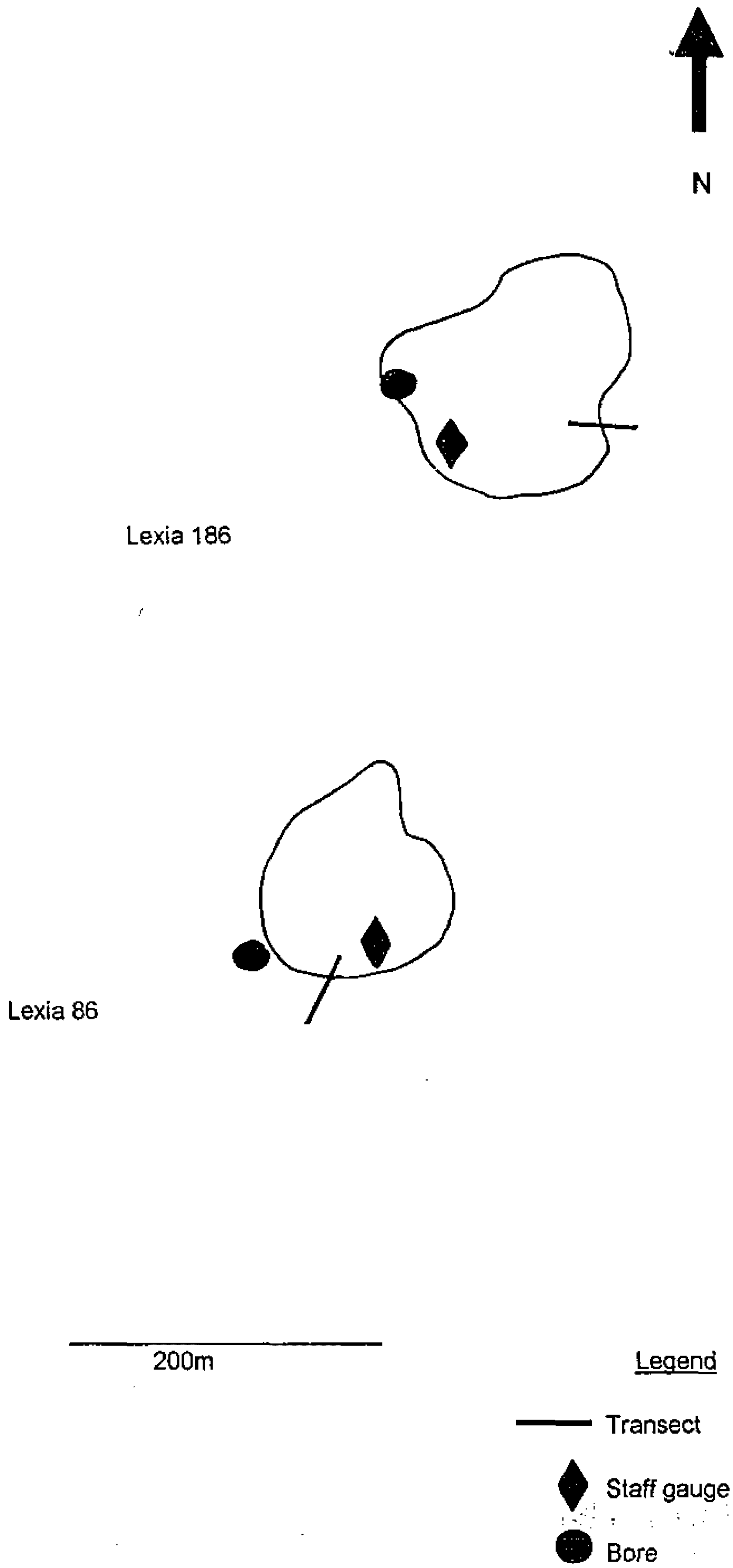


Figure A1.8
Lexia wetlands 86 and 186 staff gauge, bore and transect locations.
(source: Water and Rivers Commission, 1997, p 106)

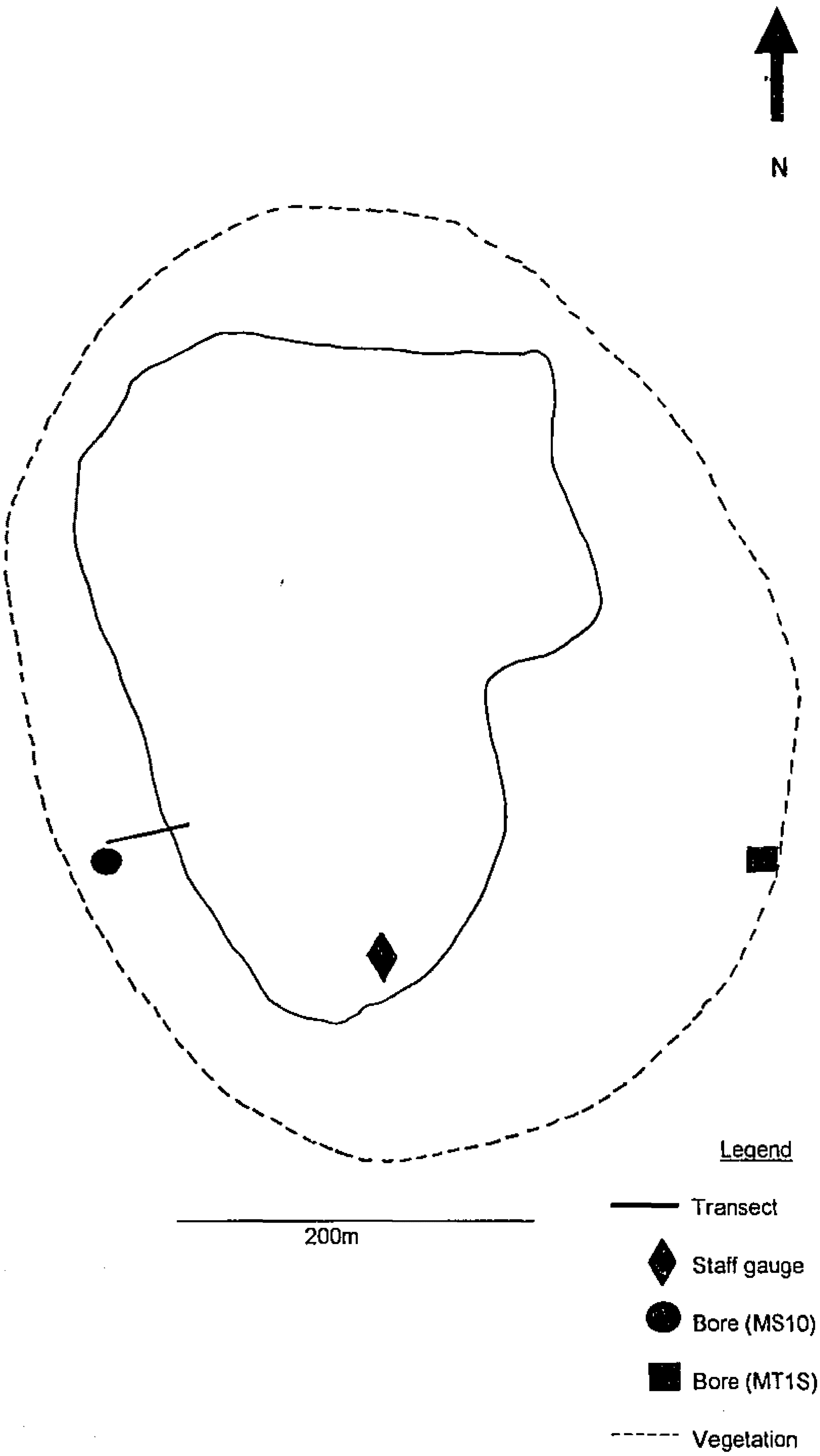


Figure A1.9
Lake Mariginiup staff gauge, bore and transect locations.
(source: Water Authority, 1995, Fig. 3.1)

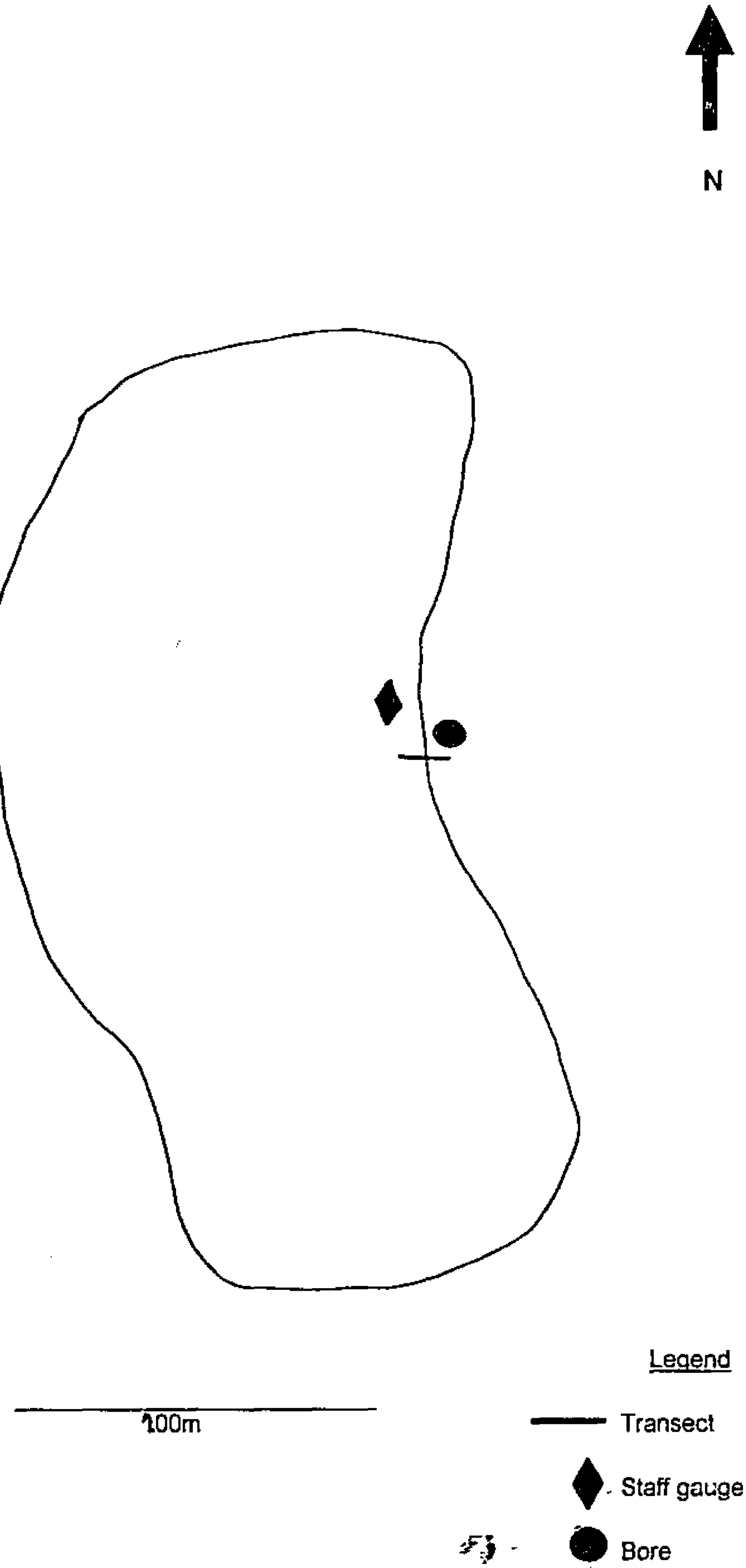


Figure A1.10
Melaleuca Park EPP wetland 173 staff gauge, bore and transect locations.
(source: Water and Rivers Commission, 1997, p.104)

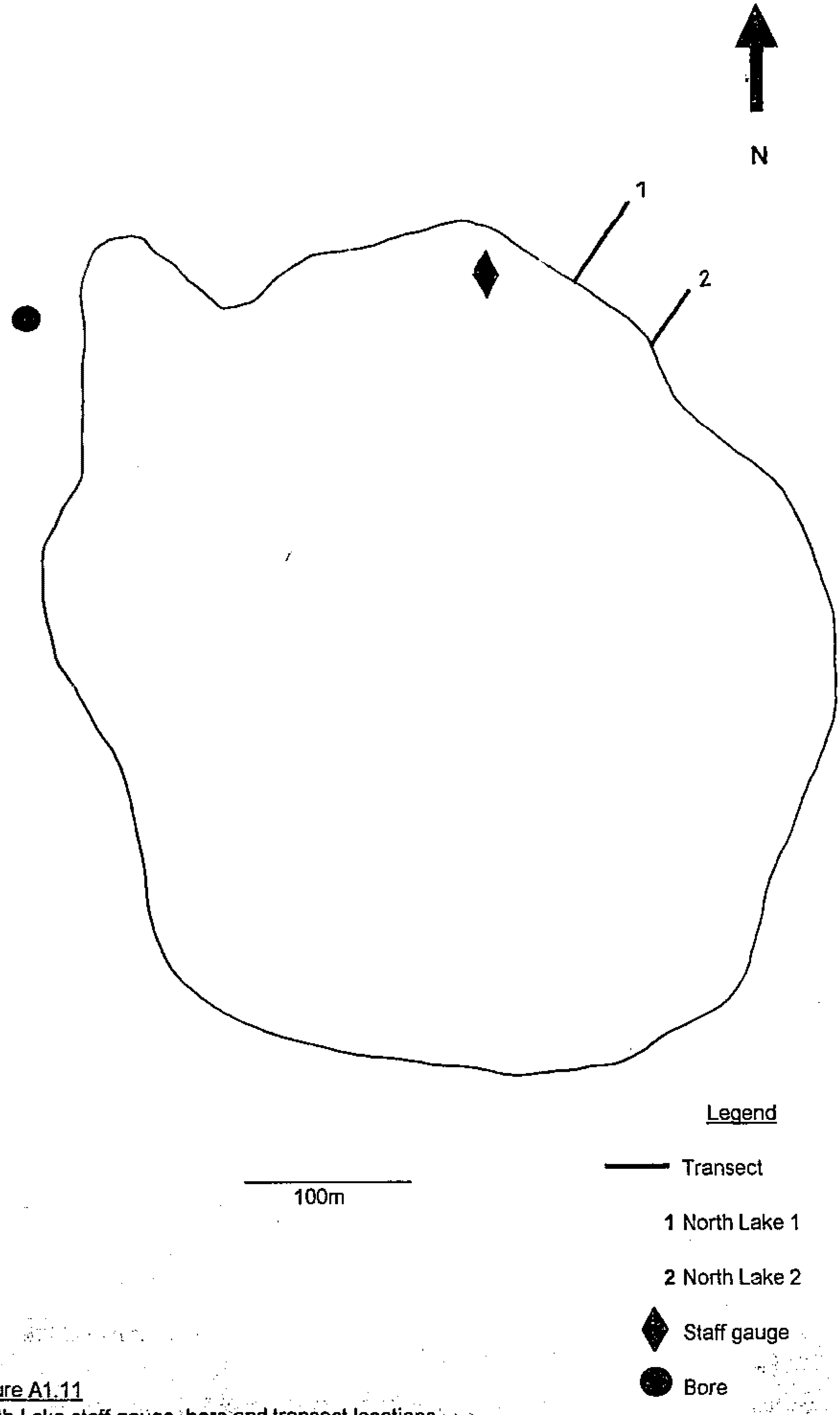


Figure A1.11
North Lake staff gauge, bore and transect locations.
(source: Water Authority, 1991, p.133)

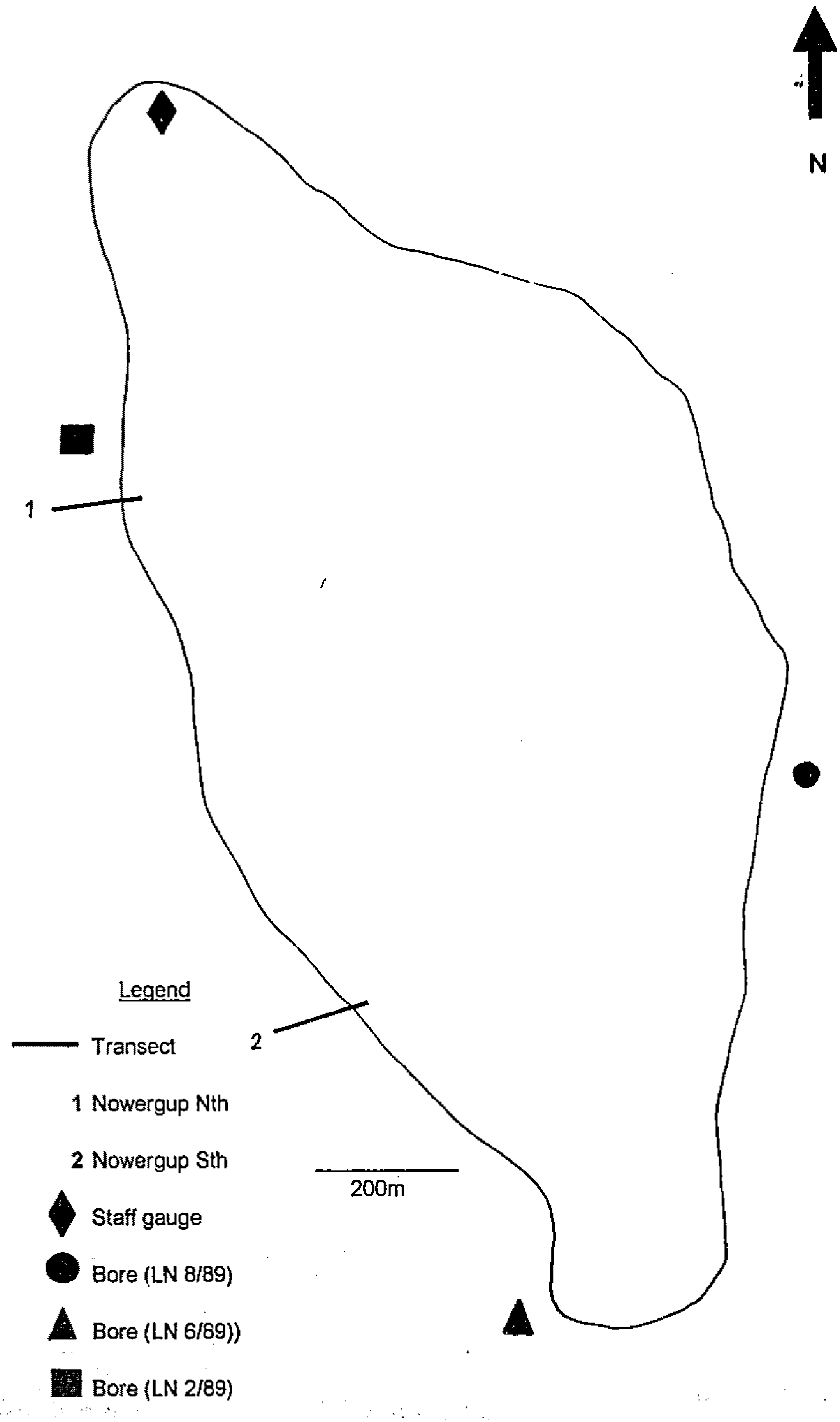


Figure A1.12
Nowergup Lake staff gauge, bore and transect locations.
(source: Water Authority, 1995, Fig.6.1)

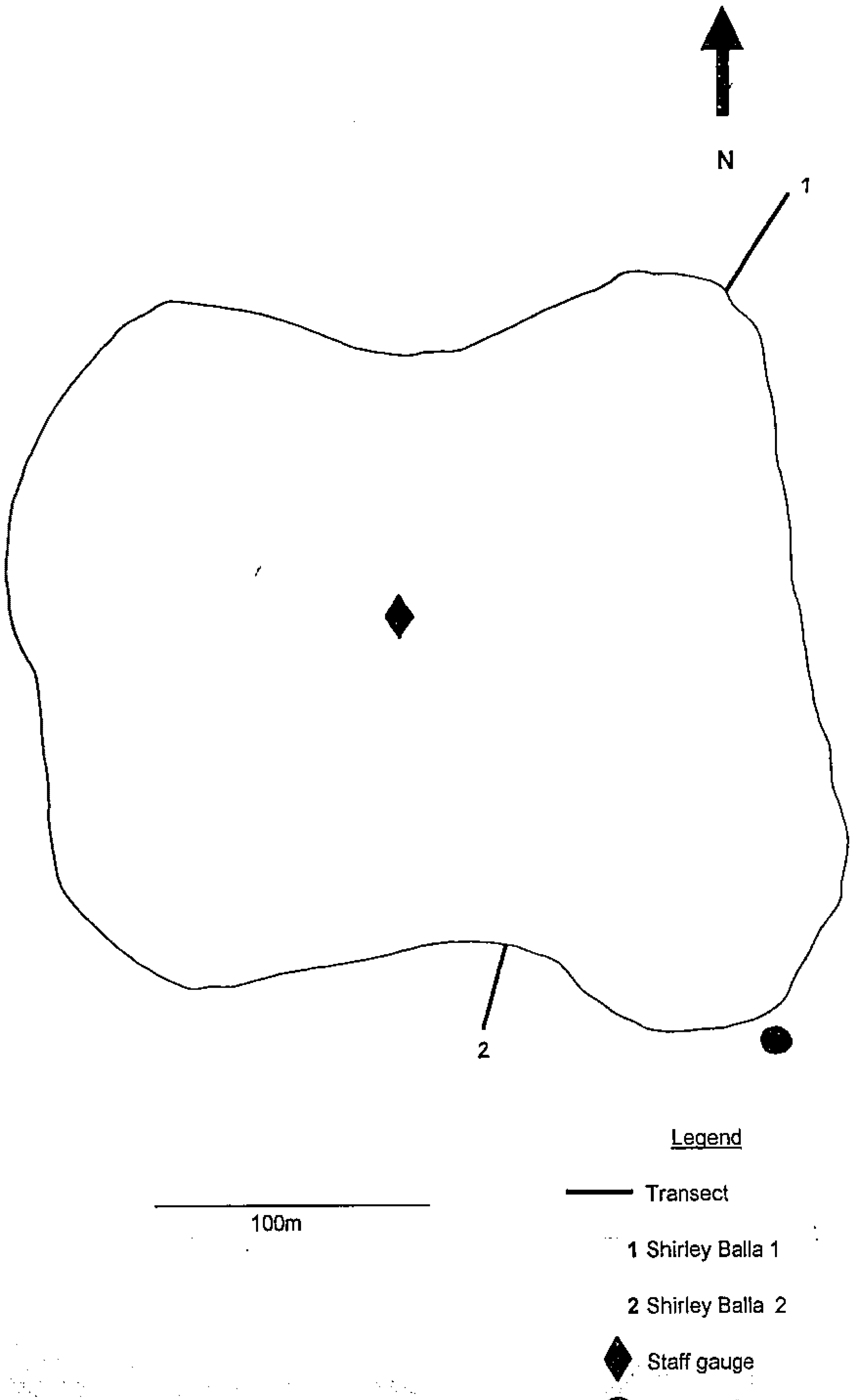


Figure A1.13
Shirley Balla Swamp staff gauge, bore and transect locations.
(source: Water and Rivers Commission, Mapping Division)

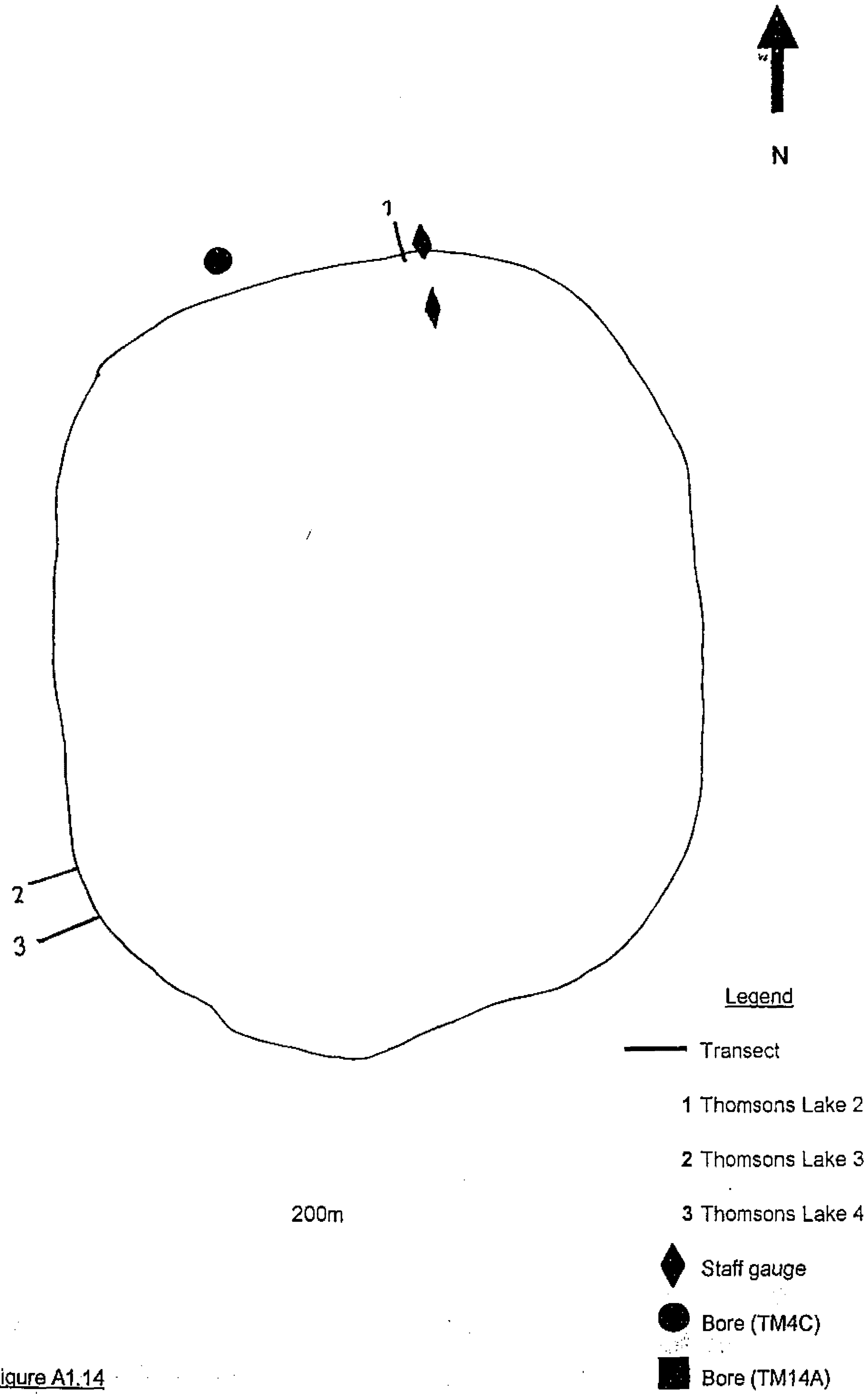


Figure A1.14
Thomsons Lake staff gauge, bore and transect locations.
(source: Water Authority, 1991, p. 135)

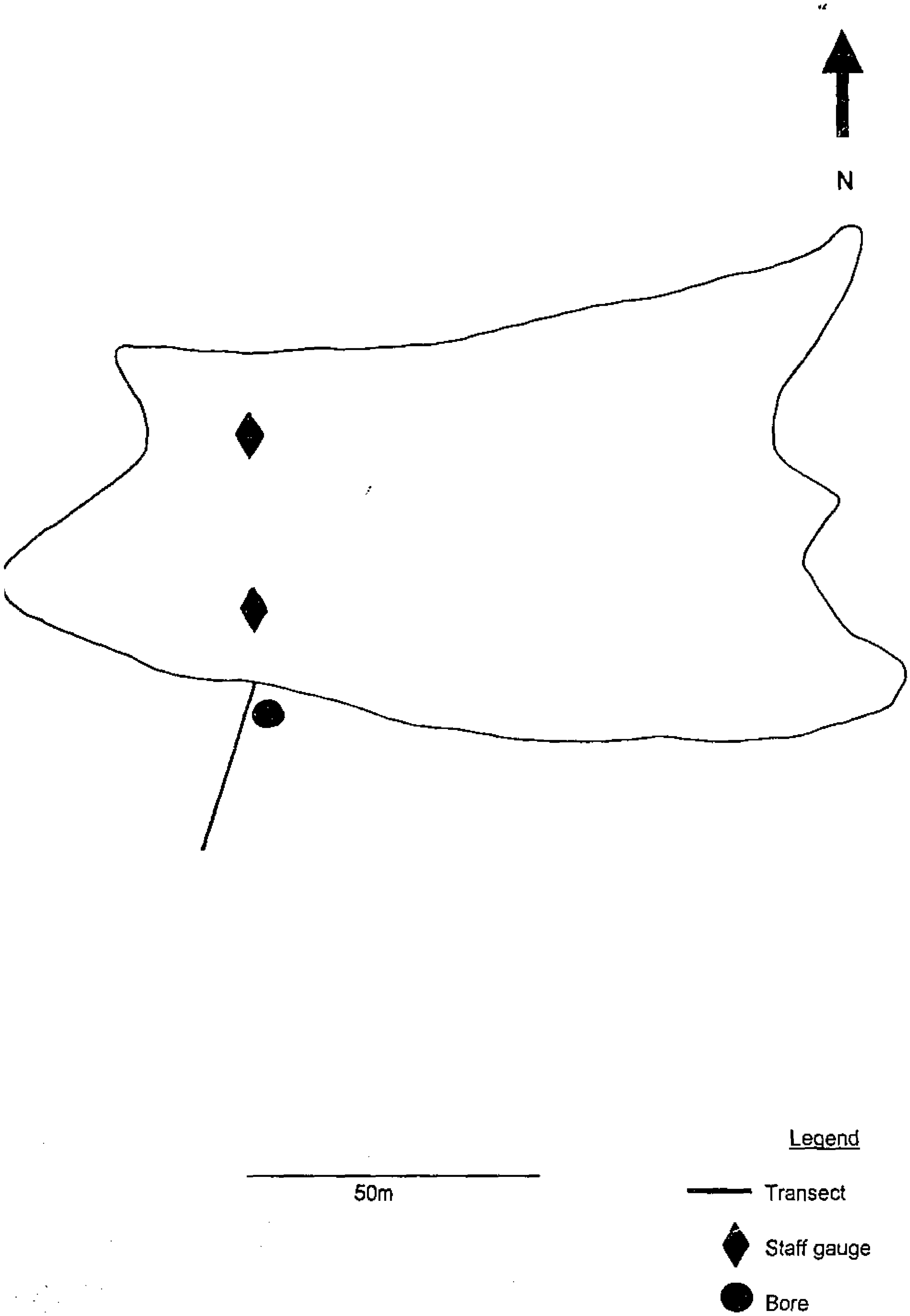


Figure A1.15
Twin Bartram Swamp staff gauge, bore and transect locations.
(source: Water and Rivers Commission, Mapping Division)

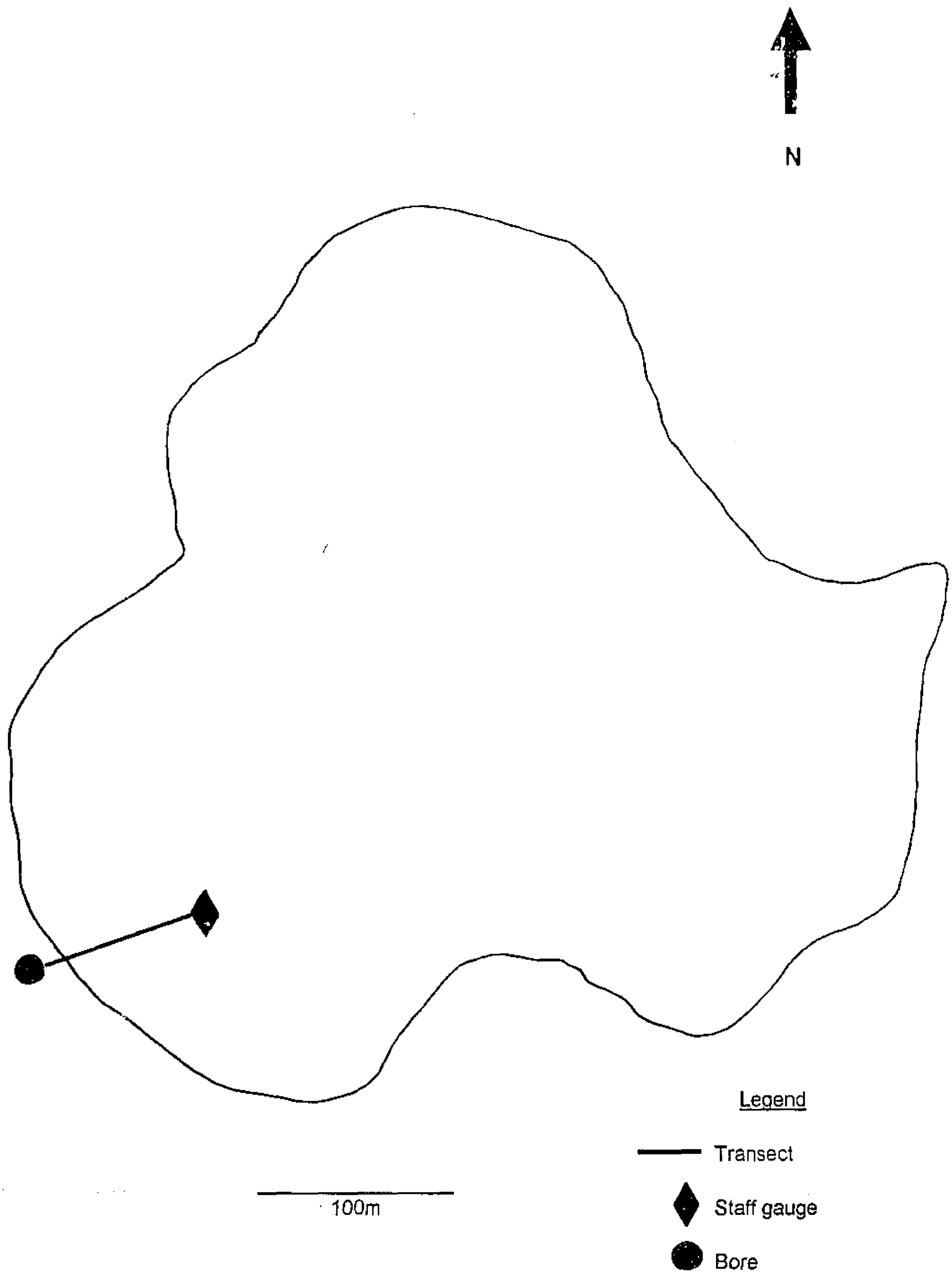


Figure A1.16
Lake Wilgarup staff gauge, bore and transect locations.
(source: Water Authority, 1991, Fig.10.1)

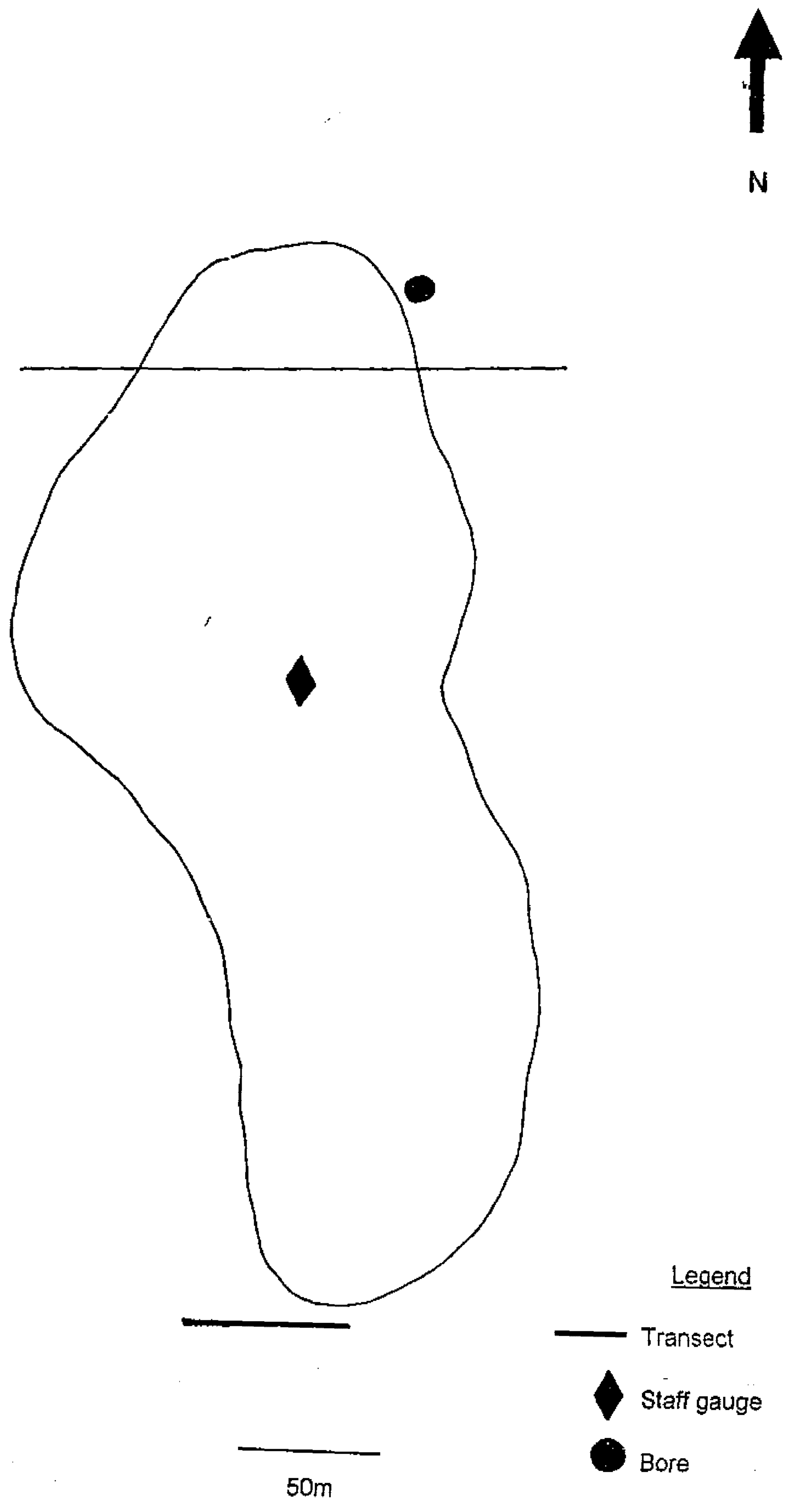


Figure A1.17
Yonderup Lake staff gauge, bore and transect locations.
(source: Water and Rivers Commission, Mapping Divison)

Appendix 2
Codes, names and locations of study wetland groundwater monitoring bores and staff gauges.

Wetland	Bores				Staff Gauges			
	Number	Name	Easting	Northing	Number	Name	Easting	Northing
Lake Banganup	G61419602	LB2	388928	6440403	Q6142516		400500	6446220
	G61419605	LB5	389564	6440180				
	G61419614	LB14	389137	6440832				
Beenyup Rd Swamp	G61410711		393313	6440919	Q6142547		393375	6440953
Bibra Lake	G61410185	BM4C	389585	6448822	Q6142520	425	388838	6447793
	G61410203	BM5A	390034	6448112				
Lake Goollelal	G61610112	459	387733	6479000	Q6162517	459	389800	6479000
Lake Jandabup	G61610763	JB12A	391015	6486688	Q6162578		389205	6487620
	G61610774	JB14A	390703	6488488				
	G61610728	JB15A	389205	6487780				
Lake Joondalup	G61610661	8281	385796	6487089	Q6162572	8281	358975	6485230
	G61610630	JP18C	383391	6490113				
	G61610629	JP20C	384690	6489187				
	G61610661	8281	385796	6487089				
North Kogolup Lake	G61410385	TD4	390306	6444421	Q6142557		389830	6444450
South Kogolup Lake					Q6142522		389634	6443588
Lexia 186	G61613214	GNM15	401662	6487389	Q6162629	GNM 15SG	401660	6487390
Lexia 86	G61613215	GNM16	401313	6486381	Q6162630	GNM 16SG	401310	6486380
Lexia 94	G61613216	GNM17A	402679	6486286				
	G61613217	GNM17B	402680	6486285				
Lake Mariginiup	G61610685	MS10	387207	6488976	Q6162577	1943	387165	6488985
	G61610736	MT1S	388392	6489267				
Melaleuca Park								
Dampland 78	G61613212	GNM13	397008	6491608	Q6162614	S19	397008	6491608
EPP wetland 173	G61613213	GNM14	401704	6491750	Q6162628	GNM 14SG	401700	6491750
North Lake	G61410726	424	388850	6450450	Q6142521	424	388871	6450493
Lake Nowergup	G61611247	LN2/89	379292	6499371	Q6162567	8756	379600	6499640
	G61611233	LN6/89	379679	6498680				
	G61611228	LN8/89	379961	6499146				
Shirley Balla Swamp	G61410713		394353	6441769	Q6142576		394250	6441950
Lake Thompson	G61410367	TM14A	388544	6442243	Q6142567	TH4	389120	6441820
	G61611111	TM4C	388735	6442829				
Twin Bartram Swamp	G61410715		391573	6443115	Q6142544		391568	6443169
Wilgarup Lake	G61618500				Q6162623		375700	6506500
Yonderup Lake	G61612106	YN7	375239	6508032	Q6162565	8780	375290	6506920

Appendix 3

Master list of all plant species identifed across the 27 monitoring transects.

Species	Form	Height	Conditions	Flower
Natives				
Acacia cyclops	Shrub (sometimes tree)	1-3m	Sand	Sep-Jan
Acacia pulchella	Shrub	0.5-2m	Light to medium well-drained	Jun-Oct
Acacia saligna	Shrub or tree	2-6m	Widespread	Aug-Sep
Acanthocarpus priessii	Rhizatomus shrub	1m	Limestone	Apr-Aug
Adenanthos cygnorum	Dense shrub	4m	Sand	Sep-Feb
Adenanthos obovata	Erect diffuse shrub	2m	Sand assoc with winter wet deps.	Aug-Nov
Adrinia quadripartia	Shrub	2m	Sometimes swampy	Sep-Nov
Agonis linearifolia	Shrub	4m	Sand assoc with winter wet deps.	All year
Agrostis avenacea	Grass		Poorly drained heavy soils	Aug-Jan
Alexgeorgea nitens	Rhizatomus herb		Winter wet depressions	Mar-May
Allocasuarina fraseriana	Tree	15m	Sand	May-Oct
Aotus gracillima	Shrub	1m	Swampy areas	Oct-Nov
Arthropodium capillipes	Tufted perennial	1m	Widespread	Nov-Mar
Arthropodium priessii	Tufted perennial	0.5m		Sep-Oct
Astartea fascicularis	Shrub	3m	Winter wet depressions	Oct-Feb
Azolla sp	Aquatic fern		Fresh water	
Banksia attenuata	Tree	10m	Sandy woodlands	Oct-Feb
Banksia grandis	Tree	10m	Sandy woodlands	Oct-Jan
Banksia ilicifolia	Tree	10m	Low lying flats	Sep-Dec
Banksia littoralis	Tree	12m	Winter wet depressions	Mar-July
Banksia menzeisii	Tree	10m	Sandy woodlands	Feb-Aug
Banksia prionotes	Tree	10m	Sandy woodlands	Feb-Aug
Baumea articulata	Sedge	2.5m	Waterlogged soils	Sep-Dec
Baumea juncea	Sedge	1.2m	Seasonally waterlogged	Oct-Jan
Baumea rubiginosa	Sedge			
Baumea vaginalis	Sedge	1.2m	Winter wet depressions	Oct-Nov
Beaufortia elegans	Erect shrub	1m	Assoc with winter wet depressions	Nov-Feb
Boronia crenulata	Shrub	1m	Widespread	Aug-Oct
Bossiaea eriocarpa	Low shrub	0.6m	Widespread	July-Oct
Burchardia umbelata	Low shrub	.28-.6m	Sandy Banksia woodland	Aug-Oct
Caladenia flava	Perennial herb	.1-.3m	Sand	Aug-Oct
Calandrinia corrigioloides	Decumbent annual		Sand	Aug-Nov
Calothamnus lateralis	Shrub	1-1.5m	Winter wet depressions	Aug-Dec
Calytrix fraserii	Erect shrub	1.5m	Woodland & winter wet deps.	Dec-Mar
Carex fascicularis	Sedge	1.5m	Winter wet depressions	Sep-Nov
Cassytha racemosa	Twinning herb		Widespread	most of yr
Caustis dioica	Sedge	.7m	Sand	Sep-Oct
Centella asiatica	Creeping perennial herb		Winter wet depressions	
Centella cordifolia	Creeping prennial herb		Winter wet depressions	most of yr
Chenopodium glaucum	Annual herb	.5m	Muddy eutrophic sites	Mar-June
Conostylis candicans	Tufted perennial	.3m	Sand	Aug-Oct
Corynotheca micrantha	Shrub	.4m	Sandy woodlands	Nov-Jan
Cotula australis	Slender annual	.2m	Usually near water	Aug-Nov
Cotula coronopifolia	Creeping annual		Damp situations	All year
Crassula exserta	Annual		Clay depressions	Aug-Oct
Dampiera linearis	Perennial herb	.5m	Widespread	July-Nov
Dasypogon bromelifolius	Xerophytic perennial		Dry conditions	Sep-Jan
Daucus glochidiatus	Erect annual herb	.6m	Limestone	Oct
Desmocladus asper			Dry conditions	
Deyeuxia quadriseta	Tufted perennial	.15-1m	Widespread	Oct-Dec
Dianella divaricata	Dense tufted perennial		Sandy woodlands	Oct-Nov
Dianella laevis	Dense tufted perennial			
Dianella revoluta	Dense tufted perennial			
Dichopogon capillipes	Tufted perennial			
Drosera erythroriza	Tuberous herb		Widespread	Mar-July
Drosera pallida	Climbing tuberous herb		Widespread	Aug-Nov
Epilobium ?hirtigerum	Robust perennial herb	.2-1.4m	Widespread	Nov-Mar
Epilobium billardierianum	Erect herb	.15-.95m		Dec-Mar
Eriostemon ramosa	Woody perennial			
Eucalyptus calophylla	Tree	30-40m	Sand	Jan-May
Eucalyptus gomphocephala	Tree	43m	Sand	Jan-Apr
Eucalyptus marginata	Tree	15-46m	Sand	Sep-Feb
Eucalyptus rudis	Tree	9-15m	Watercourses	Apr-Nov
Eucalyptus todtiana	Tree	9-16m	Woodland	Feb
Euchilopsis linearis	Small slender shrub	.6m	Winter wet depressions	Jun-Dec
Eutaxia virgata	Shrub	1m	Winter wet depressions	Aug-Nov
Exocarpus sparteus	Erect open shrub	3.5m	Sand or winter wet depressions	Feb-Oct
Gratiola peruviana	Erect or ascending herb	.3m	Swampy	Oct-Dec
Gnaphalium sphaericum	Erect annual herb	.3-.7m	Widespread	Jul-Dec
Gompholobium tomentoseum	Erect shrub	.3-1m	Widespread	Aug-Dec

Species	Form	Height	Conditions	Flower
Grevillea vestita	Erect shrub	1-2m		Jun-Sep
Gyrostemon ramulosus	Erect shrub or small tree	5m	Limestone	May-Oct
Haemodorum spicatum	Bulbous perennial herb	.5-2m	Sand or clay	Nov-Dec
Haloragis brownii	Aquatic or semi-aquatic herb		Damp soil or in water	Oct-Feb
Hardenbergia comptoniana	Climber		Sand	Jun-Sep
Heliotropium curassavicum	Perennial herb		Winter wet depressions	Dec-May
Hemarthria uncinata	Ascending perennial		Widespread	Dec-Apr
Hibbertia hypericoides	Spreading shrub	.3-.7m	Widespread	Apr-Nov
Hibbertia subvaginata	Low shrub	.3m	Widespread	Jul-Nov
Homalosciadium homalocarpum	Annual herb	.1m	Winter wet depressions	Oct-Dec
Hypocalymma angustifolium	Erect shrub	1.5m	Winter wet depressions	Jul-Oct
Hypocalymma robustum	Erect shrub	1m	Widespread	July-Oct
Hypolaena exsulca	Perennial herb	.25-.75m	Sand or winter wet depressions	Sep-Dec
Isolepis marginata	Sedge	.02-.2m	Winter wet depressions	July-Oct
Isolepis nodosus	Sedge	.9m	Sand along rivers	Nov-Mar
Isolepis producta	Aquatic herb		Water	Dec-Jan
Isolepsis cernua	Annual herb	.2m	Winter wet depressions	Oct-Dec
Jacksonia furcellata	Erect shrub	4m	Sand	Aug-Mar
Jacksonia sternbergiana	Erect shrub	4m	Sand	most of yr
Juncus pallidus	Perennial rush	2m	Winter wet depressions	Oct-Nov
Kunzea ericifolia	Erect shrub	3m	Bordering winter wet depressions	Sep-Nov
Lagenifera huegelii	Perennial herb	.07-.32m	Widespread	July-Dec
Laxmannia ramosa	Sprawling perennial		Sand often swampy	May-June
Lechenaultia floribunda	Erect shrub	.5m	Sand	Oct-Nov
Lemna sp.	Annual aquatic herb		Freshwater	
Lepidosperma effusum	Perennial sedge	1.5m	Winter wet depressions	Sep-Nov
Lepidosperma elatius	Perennial sedge	1.5m		
Lepidosperma gladiatum	Perennial sedge	1.5m	Coastal dunes	Nov-Jan
Lepidosperma longitudinale	Perennial sedge	2m	Winter wet depressions	May-June
Lepidosperma tenue				
Leptocarpus scariosus	Tufted perennial herb		Winter wet depressions	Sep-May
Lepyrodia glauca	Perennial herb	1.3m	Winter wet depressions	Oct-Dec
Lepyrodia muirii	Perennial herb	1.2m	Winter wet depressions	Sep-Nov
Leucopogon ?capitellatus	Shrub	.7m	Gravelly sand	Jul-Nov
Leucopogon australis	Shrub	1m	Damp	Jun-Dec
Leucopogon propinquis	Shrub	1m	Widespread	Mar-July
Lobelia alata	Perennial herb		Winter wet depressions	Mar-Apr
Lobelia rhombifolia	Annual herb	.1-.4m	Widespread	Sep-Nov
Lobelia tenuior	Annual herb	.3-.5m	Sand	Oct-Jan
Lomandra haemaphrodita	Perennial xerophyte		Sand	Apr-June
Lomandra priessii	Perennial xerophyte		Laterite	Apr-Jul
Loxocarya flexuosa	Tufted perennial herb		Banksia woodlands	Sep-Oct
Lyginia barbata	Perennial herb	.7m	Sand associated with winter wet d	Aug-Feb
Lyperanthus nigricans	Perennial herb (orchid)	.1-.3m	Widespread	Aug-Oct
Macrozamia riedlei	Palm-like	3m	Sand	
Melaleuca polygaloides	Shrub or small tree	5m		Jul-Oct
Melaleuca preisciana	Tree	10m	Bordering winter wet depressions	Nov-Jan
Melaleuca raphiophylla	Tree	10m	Permanent swamps	Sep-Jan
Melaleuca seriata	Shrub	1m	Sand	
Melaleuca teretefolia	Shrub or small tree	5m	Sand/winter wet depressions	Oct-Jan
Melaleuca thymoides	Shrub	2m	Sand/winter wet depressions	Sep-Jan
Microlaena stipiodes	Perennial, rhizomes	.5m	Widespread	Sep-Nov
Microtis alba	Perennial herb	.2-.6m		Oct-Dec
Microtis media	Perennial herb			
Mitrasacme paradoxa	Annual herb	.5-1m	Sand	Sep-Nov
Monotaxis occidentalis	Herb or small shrub	.15m	Widespread	Sep-Jan
Myoporum capraroides	Shrub	2m	Sand/winter wet depressions	Most of yr
Opercularia hispidula	Shrub	1m	Limestone	Sep-Dec
Orthrosanthus laxus	Strap-like perennial	.5m	Woodland	Aug-Oct
Patersonia occidentalis	Perennial herb		Sand	Sep-Oct
Pericalymma ellipticum	Erect shrub	1m	Winter wet depressions	Sep-Dec
Petrophile linearis	Undershrub	.7m	Sand	Aug-Nov
Phlebocarya ciliata	Tufted perennial		Widespread	Aug-Nov
Phyllangium paradoxum				
Pimelea argentea	Shrub	2m	Granitic soils	Jul-Oct
Pimelea rosea	Shrub	1m	Sand	Aug-Nov
Platytheca vertillcilata	Small shrub	.5m	Damp situtations	Jul-Nov
Pterostylis vittata	Perennial herb (orchid)	.05-.45m	Sand	June-Aug
Podolepsis lessonii	Annual herb	.4m	Open woodland	
Poranthera microphylla	Small annual herb	.1m	Widespread	Aug-Nov
Pteridium esculentum	Bracken fern		Moist sand	
Pterostylis nana	Perennial herb (orchid)	.05-.15m	Sand	July-Sep

Species	Form	Height	Conditions	Flower
Ptilotus stirlingii	Perennial herb		Sand	
Pultenaea ochreata	Erect shrub	.3-2m	Winter wet depressions	Jul-Sep
Pultenaea reticulata	Erect shrub	1-2m	Winter wet depressions	Aug-Nov
Quinetia urvillei	Annual herb	.2m	Moist sand	Aug-Dec
Rhagodia baccata	Shrub	2m	Sand	Mar-June
Schoenus pennisetus	Annual sedge	.13m	Winter wet depressions	Aug-Sep
Schoenus rodwayanus	Perennial sedge	1m	Winter wet depressions	Sep-Nov
Scholtzia involucrata	Shrub	1.5m	Sand	
Solanum symonii	Erect shrub	1.2m	Sand	Aug-Nov
Sowerbaea laxiflora	Tufted annual herb	.15-.45	Sand or clay, often near water	
Sporobolus virginicus	Perennial grass		Salt marshes	All year
Spyridium globulosum	Large shrub	1-4m	sand	June-Sep
Stipa ?flavescens	Grass			
Stipa campylachne	Tufted annual	.4-.6m		
Stipa compressa	Tufted annual	.45m		Sep-Dec
Stylidium brunonianum	Erect perennial herb	.5m		Sep-Nov
Stylidium repens	Small creeping perennial herb			most of yr.
Thysanotus patersonii	Ephemeral twinner	.1-.2m	Sand	
Thysanotus manglesianus	Ephemeral twinner		Woodland	Aug-Nov
Trachymene pilosa	Annual herb	.3m	Woodland	Aug-Oct
Tricoryne elatior	Several stemmed rhizomatus		Sand	Sep-Feb
Triglochin sp	Herb		Freshwater marshes, sometimes aquatic	
Villarsia capitata	Aquatic or semi-aquatic annual		Winter wet depressions	Oct-Jan
Viminaria juncea	Tall shrub	5m	Winter wet depressions	Oct-Dec
Wahlenbergia priessii	Annual	.4m	Woodland	Sep-Oct
Xanthorrhoea gracilis	Perennial		Sand	
Xanthorrhoea preissii	Perennial	.3-3m	Sand	Aug-Nov
Exotics				
Acacia longifolia				
Adriana octandra	Shrub	2m		
Aira caryophyllea	Erect annual grass	.4m		Oct-Nov
Anagallis arvensis	Spreading annual	.3m		Aug-Dec
Arctotheca calendula	Annual herb	.3m		July-Oct
Asparagus asparagoides	Twiner	1-2m	Disturbed sites	Aug-Sept
Aster subulatus				
Avena barbata	Erect annual grass	.3-1m		Aug-Dec
Avena fatua	Erect annual grass	.6m		Aug-Dec
Briza maxima	Erect annual grass	.3-.6m		Sep-Oct
Briza minor	Erect annual grass	.15-.5m		Sep-Nov
Bromus diandrus	Grass	.3m		Sep-Nov
Carex divisa	Grass			
Carpobrotus edulis	Prostrate shrub		Sandunes and winter wet deps	Aug-Oct
Cerastium glomeratum				
Chenopodium pallidum	Annual herb or shrub			
Chenopodium vulgare	Annual herb or shrub			
Cirsium vulgare	Biennial herb	3m		
Conyza albida	Annual herb	2m		Jan-Aug
Conyza bonariensis	Herb	1.2m		Ocy-May
Cortaderia selloana	Grass	2-4m		Jun-Sep
Cotula turbinata	Annual	.4m		July-Oct
Crassula glomerata				
Cynodon dactylon	Perennial grass	.1m		Oct-Nov
Cyperus polystachyos	Sedge	.6m	Damp	
Dischisma capitatum	Annual	.2m		Aug-Sep
Ehrharta calycina	Perennial grass	.6m		Aug-Sep
Ehrharta longiflora	Annual grass	.6m		July-Nov
Epilobium ciliatum				
Euphorbia peplus	Annual	.4m		July-Oct
Ficus carica				
Fumaria officinalis				
Geranium molle	Spreading annual	.5m long		Oct-Nov
Gladiolus caryophyllaceus	Annual herb	.8m		Aug-Oct
Holcus lanatus	Grass			
Homeria flaccida	Perennial	.3-.7m		Sep-Nov
Hypochoeris glabra	Annual or perennial herb	.2m long		Apr-Nov
Isolepsis prolifera				
Lactuca serriola				
Lagurus ovatus	Erect annual	.3m		Aug-Dec
Lolium perenne	Biennial or perennial grass	.9m		Sep-Dec
Lolium rigidium	Annual grass	1m		Sep-Dec

Species	Form	Height	Conditions	Flower
Lotus angustissimus	Prostrate herb			
Lotus suaveolens	Procumbent herb			
Lupinus cosentinii	Annual herb	1.5m		Aug-Nov
Medicago polymorpha	Prostrate annual herb (clover)			July-Oct
Orobanche minor				
Oxalis corniculata	Creeping annual			Oct-Nov
Paspalum dilatatum	Perennial grass	1.5m		Dec-Apr
Paspalum distichum	Perennial grass	.05-.5m	Common	Dec-April
Pelargonium capitatum	Straggling shrubby perennial			July-Nov
Pentaschistis airiodies	Grass			
Phalaris minor				
Phyla nodiflora	Perennial herb	2m	Wetlands	Feb-Apr
Pinus pinaster				
Plantago major				
Poa annua	Annual grass	.3m		Aug-Oct
Polypogon monspeliensis	Annual grass	.6m		May-Nov
Romulea rosea	Annual herb	.4m		Aug-Oct
Rumex crispus	Erect perennial	1.5m		Sep
Silybum marianum	Annual or biennial herb	.3m		
Solanum americanum	Shrub	1.3m		
Solanum laciniatum	Shrub	1-3m		
Solanum linneanum				
Solanum nigrum	Shortlived perennial shrub	.7m		July-Apr
Sonchus asper				
Sonchus oleraceus	Annual herb	1.5m		June-Dec
Stellaria media	Sprawling annual herb			July-Sep
Stenotaphrum subsecundum	Grass			
Trifolium campestre	Annual herb (clover)			Aug-Nov
Typha orientalis	Perennial rush		Patrly submerged or damp soil	
Ursina anthemoides	Annual herb	.5m		Aug-Sep
Vicia sativa	Twinning annual herb	1m		Sep-Nov
Vulpia myuros	Annual grass	.7m		July-Nov
Wahlenbergia capensis	Annual herb	.5m		Sep-Nov
Zantedeschia aethiopica	Erect perennial	1m		Aug-Oct

Appendix 4

Occurrence of 244 species from the 27 monitoring transects across the five hydrological zones

Species	Littoral	Littoral/ supralittoral	Seasonally waterlogged	Supralittoral	Terrestrial
Azolla sp	■				
Halogaris brownii	■				
Carex divisa*	■				
Carex fascicularis	■				
Chenopodium pallidum*	■				
Conyza bonariensis*	■				
Cortaderia selloana*	■				
Gnaphalium sphaericum	■				
Hemarthria uncinata	■				
Isolepis marginata	■				
Isolepis producta	■				
Isolepsis prolifera*	■				
Juncus pallidus	■				
Lactuca serriola*	■				
Lemna sp.	■				
Lepidosperma elatius	■				
Lolium rigidium*	■				
Phyla nodiflora	■				
Schoenus pennisetus	■				
Solanum laciniatum*	■				
Solanum symonii	■				
Conyza albida*	■				
Triglochin sp	■				
Leproydia muirii	■	■			
Villarsia capitata	■	■	■		
Baumea vaginalis	■		■		
Centella cordifolia	■		■		
Microtis media	■		■		
Opercularia hispidula	■		■		
Paspalum dilatatum*	■		■		
Daucus glochidiatus	■		■		
Epilobium ?hirtigerum	■		■		
Epilobium billardierianum	■		■		
Epilobium ciliatum*	■		■		
Holcus lanatus*	■		■		
Gahnia trifida	■		■		
Vicia sativa*	■		■		
Plantago major	■		■		
Lepidosperma gladiatum	■		■		
Paspalum distichum*	■		■		
Lobelia alata	■		■		
Lotus suaveolens*	■		■		
Cotula coronopifolia*	■		■	■	
Aster subulatus*	■		■	■	
Baumea juncea	■		■	■	
Typha orientalis	■	■		■	
Sonchus oleraceus*	■	■	■		■
Silybum marianum*	■			■	
Solanum nigrum*	■		■		
Stellaria media*	■		■		■
Chenopodium glaucum	■				■
Trifolium campestre*	■				■
Acacia pulchella	■		■	■	■
Acacia saligna	■		■	■	■
Anagallis arvensis*	■		■	■	■
Briza maxima*	■		■	■	■
Briza minor*	■		■	■	■
Dampiera linearis	■		■	■	■
Leucopogon australis	■		■	■	■
Melaleuca preissiana	■		■	■	■
Microlaena stipiodes	■		■	■	■
Trachymene pilosa	■		■	■	■
Xanthorrhoea priessii	■		■	■	■
Zantedeschia aethiopica*	■		■	■	■
Pultenaea reticulata	■		■	■	■
Rumex crispus*	■		■	■	■
Centella asiatica	■	■	■	■	
Circium vulgare*	■	■	■	■	
Banksia littoralis	■	■	■	■	

Species	Littoral	Littoral/ supralittoral	Seaonally waterlogged	Supralittoral	Terrestrial
Baumea articulata	■	■	■	■	
Agrostis avenacea	■	■	■	■	
Lepidosperma longitudinale	■	■	■	■	
Polypogon monspeliensis*	■	■	■	■	
Melaleuca teretifolia	■	■	■	■	
Lotus angustissimus*	■	■	■	■	
Aira caryophyllea*	■	■	■	■	■
Astartea fascicularis	■	■	■	■	■
Bromus diandrus*	■	■	■	■	■
Cynodon dactylon*	■	■	■	■	■
Ehrharta calycina*	■	■	■	■	■
Ehrharta longiflora*	■	■	■	■	■
Eucalyptus rudis	■	■	■	■	■
Geranium molle*	■	■	■	■	■
Hypochaeris glabra*	■	■	■	■	■
Medicago polymorpha*	■	■	■	■	■
Melaleuca rhaphiophylla	■	■	■	■	■
Pelargonium capitatum*	■	■	■	■	■
Sonchus asper*	■	■	■	■	■
Vulpis myuros*	■	■	■	■	■
Baumea rubiginosa		■			
Lepidosperma effusum		■			
Halogaris brownii		■			
Poa annua*		■			
Exocarpus sparteus		■	■		
Viminaria juncea		■	■		
Cassytha racemosa		■	■	■	
Leptocarpus scariosus		■	■	■	
Pericalymma ellipticum		■	■	■	
Hypocalymma angustifolium		■		■	■
Rhagodia baccata		■		■	■
Carpobrotus edulis		■	■	■	■
Adriana quadripartita			■		
Agonis linearifolia			■		
Aotus gracillima			■		
Solanum americanum*			■		
Pteridium esculentum			■		
Spyridium globosum			■		
Avena fatua*			■		
Boronia crenulata			■		
Deyeuxia quadriseta	■		■		
Ficus carica*			■		
Gratiola peruviana			■		
Heliotropium curassavicum			■		
Homeria flaccida*			■		
Isolepsis cenua			■		
Lepyrodia glauca			■		■
Leucopogon propinquus			■		
Lolium perenne*			■		
Melaleuca uncinata			■		
Mitrasacme paradoxa			■		
Platytheca vertillcilata			■		
Polypogon monospeiliensis*			■		
Stenotaphrum subsecundum*			■		
Quinetia urvillei			■		■
Romulea rosea*			■		■
Monotaxis occidentalis			■		■
Pimelea rosea			■		■
Melaleuca seriata			■		■
Lobelia tenuior			■		■
Eucalyptus gomphocephala			■		■
Crassula colorata*			■		■
Cotula turbinata*			■		■
Banksia attenuata			■		■
Arctotheca calendula*			■		■
Calothamnus lateralis			■	■	
Cerastium glomeratum*			■	■	
Hypocalymma robustum			■	■	
Lagurus ovatus*			■	■	
Melaleuca viminea			■	■	
Phyllangium paradoxum			■	■	

Species	Littoral	Littoral/ supralittoral	Seaonally waterlogged	Supralittoral	Terrestrial
Sporobolus virginicus			■	■	
Stylidium brunoniianum			■	■	
Arthropodium capillipes			■	■	■
Banksia ilicifolia			■	■	■
Banksia menzeisii			■	■	■
Bossiaea eriocarpa			■	■	■
Burchardia umbellata			■	■	■
Caladenia flava			■	■	■
Crassula exerta			■	■	■
Crassula glomerata*			■	■	■
Dasypogon bromelifolius			■	■	■
Dianella laevis			■	■	■
Eucalyptus marginata			■	■	■
Euchilopsis linearis			■	■	■
Gompholobium tomentosum			■	■	■
Hibbertia hypericoides			■	■	■
Hibbertia subvaginata			■	■	■
Hypolaena exsulca			■	■	■
Isolepis nodosus			■	■	■
Kunzea ericifolia			■	■	■
Macrozamia riedlei			■	■	■
Melaleuca thymoides			■	■	■
Patersonia occidentalis			■	■	■
Phlebocarya ciliata			■	■	■
Poranthera microphylla			■	■	■
Stylidium repens			■	■	■
Stipa flavescens				■	
Tricoryne elatior				■	
Trifolium campestre*				■	
Adriana octandra*				■	
Asparagus asparagoides*				■	
Caustis dioica				■	
Chenopodium vulgare*				■	
Drosea pallida				■	
Eucalyptus calophylla				■	
Eutaxia virgata				■	
Melaleuca polygaloides				■	
Orthrosanthus laxus				■	
Pentaschistis airoides*				■	
Phalaris minor*				■	
Pterostylis nana				■	
Pultenaea ochreata				■	
Schoenus rodwayanus				■	
Sonchus oleraeacea*				■	
Sowerbaea laxiflora				■	
Acanthocarpus preissii				■	■
Adenanthos cygornum				■	■
Adenanthos obovatus				■	■
Alexgeorgia nitens				■	■
Allocasuarina fraseriana				■	■
Beaufortia elegans				■	■
Dianella divaricata				■	■
Dianella revoluta				■	■
Dischisma capitatum*				■	■
Eucalyptus todtiana				■	■
Euphorbia peplus*				■	■
Gladiolus caryophyllaceus*				■	■
Homalosciadium homalocarpum				■	■
Jacksonia furcellata				■	■
Jacksonia sternbergiana				■	■
Lagenifra huegelii				■	■
Loxocarya flexuosa				■	■
Lyginia barbata				■	■
Microtis alba				■	■
Oxalis corniculata				■	■
Stipa campylachne				■	■
Stipa compressa				■	■
Ursinea anthemoides*				■	■
Acacia huegelii					■
Banksia grandis					■
Calandrinia corrigioloides					■

Species	Littoral	Littoral/ supralittoral	Seaonally waterlogged	Supralittoral	Terrestrial
Calytrix fraserii					
Cerastium glomeratum*					
Conostylis candicans					
Conostylis juncea					
Corynotheca micrantha					
Cotula australis					
Desmocladus asper					
Dichopogon capillipes					
Drosera erythroriza					
Eriostemon ramosa					
Grevillea vestita					
Gyrostemon ramulosus					
Hardenbergia comptoniana					
Homeria flaccida					
Isolepsis cenua					
Lagenifera stipitata					
Lagurus ovatus*					
Laxmannia ramosa					
Lechenaultia floribunda					
Lepidosperma tenue					
Leucopogon ?capitellatus					
Lobelia rhombifolia					
Lomandra haemaphrodita					
Lomandra priessii					
Lyperanthus nigricans					
Medicago polymorpha*					
Pinus pinaster					
Regelia inops					
Scholtzia involucrata					
Thysanotus manglesianus					
Thysanotus patersonii					
Wahlenbergia capensis*					
Wahlenbergia priessii					
Xanthorrhoea gracilis					

Appendix 5A

Raw data used in correlations between DCA axes 1 and 2 and vegetation and hydrological variables for presence/absence data of 244 species across 105 plots

Plot	Mean depth	Duration	Species rich	% wet sp.	% weeds	DCA Axis 1	DCA Axis 2
Ba1	-11	0.4	11	46	36	221	166
Ba2	-61	0.1	19	32	47	228	142
Ba3	-241	0	23	13	35	281	64
Be1	-20	1.6	14	36	64	159	156
Be2	-20	1.6	9	22	85	175	162
Be3	-84	0	23	13	48	282	83
Bi1	-9	4.4	7	57	57	103	214
Bi2	1	4	10	40	70	116	158
Bi3	-59	0.6	4	75	50	191	175
G1	55	12	8	88	38	99	263
G2	35	11	9	67	44	44	228
G3	30	10.2	19	26	68	30	204
G4	25	9.4	22	27	77	47	183
J1	-164	0	18	28	28	359	95
J2	-199	0	22	23	14	392	118
J3	-311	0	19	16	16	379	116
J4	-348	0	30	10	13	349	116
Jo1	-36	2.8	16	38	31	129	189
Jo2	-176	0	15	33	27	152	205
Jo3	-136	0	7	71	14	106	297
Jo4	-106	0	9	56	11	83	294
Jo5	4	0.4	9	78	11	84	224
Jo6	-176	0	10	40	40	85	194
Jo7	-276	0	17	0	35	176	115
Jo8	-306	0	24	8	42	157	88
Jo9	-6	3.4	21	38	52	60	188
Jo10	-46	0.6	19	16	58	73	191
Jo11	-102	0	10	10	30	117	170
Jo12	-173	0	22	9	41	159	92
Nk1	-264	0	15	27	80	134	117
Nk2	-464	0	12	8	67	240	40
Nk3	-644	0	18	6	56	214	120
Nk4	-764	0	19	10	42	283	43
Nk5	-204	0	13	15	92	112	111
Nk6	-284	0	14	7	78	192	72
Nk7	-424	0	22	4	45	254	47
Nk8	-604	0	26	11	42	279	45
Sk1	-28	3	7	57	43	72	85
Sk2	-28	3	14	36	43	129	140
Sk3	-48	2.2	9	33	44	79	100
Sk4	-68	2	7	57	8	151	207
L861	9	0.6	5	100	6	342	249
L862	-67	0	16	38	14	473	142
L863	-95	0	14	36	9	456	187
L864	-101	0	11	45	9	460	189
L1861	-148	0	11	64	18	454	117
L1862	-198	0	17	41	10	407	152
L1863	-192	0	20	20	7	414	171
L1864	-208	0	14	29	59	439	170
M1	15	2.6	17	24	38	100	31
M2	-28	1.8	21	33	44	65	17
M3	-65	1	18	33	48	46	0
M4	-83	0	21	28	33	73	28
M5	-75	0	24	29	0	89	65
M171	-10	2	5	80	8	381	298
M172	-61	0	13	46	9	469	257
M173	-84	0	21	33	7	429	205
M174	-87	0	15	27	27	426	202
Nl1	-51	8	11	64	14	143	241
Nl2	-91	0.4	14	57	38	302	290
Nl3	-131	0	8	62	14	259	266
Nl4	-31	1	14	57	38	256	244
Nl5	-91	0.4	24	12	32	316	169
Nl6	-171	0	28	14	35	324	103
Nl7	-251	0	26	12	50	310	81
N1	-94	0	16	38	42	82	217
N2	-214	0	12	33	30	102	175

Plot	Mean depth	Duration	Species rich	% wet sp.	% weeds	DCA Axis 1	DCA Axis 2
N3	-284	0	10	10	25	115	170
N4	-434	0	12	8	60	113	164
N5	16	0.6	10	50	23	105	216
N6	-194	0	13	15	43	129	179
N7	-484	0	14	0	36	93	202
N8	-684	0	11	9	54	89	181
Sb1	-82	0	13	23	42	267	189
Sb2	-82	0	12	42	7	290	277
Sb3	-142	0	14	21	18	385	244
Sb4	-212	0	34	12	73	354	147
Sb5	-52	0.4	11	27	57	146	146
Sb6	-72	0	14	36	54	154	203
Sb7	-72	0	13	31	21	208	221
Sb8	-92	0	14	36	68	300	260
Tl1	-125	0	19	21	50	136	113
Tl2	-135	0	8	38	73	118	123
Tl3	-215	0	11	18	89	130	110
Tl4	-195	0	9	11	73	140	93
Tl5	-125	0	15	20	77	128	120
Tl6	-145	0	13	8	60	174	64
Tl7	-255	0	15	0	58	238	41
Tl8	-605	0	19	0	73	207	81
Tl9	-35	1	11	27	88	96	137
Tl10	-95	0.4	16	12	67	162	63
Tl11	-195	0	9	22	50	147	68
Tl12	-415	0	18	11	50	197	73
Tb1	-1	4.2	10	70	67	0	201
Tb2	-21	3.4	21	29	76	56	163
Tb3	-61	0.6	17	12	71	121	118
Tb4	-121	0	14	21	25	162	149
W1	14	3.8	8	62	0	251	229
W2	-6	2.8	5	80	0	159	358
W3	-42	0.6	11	54	27	157	329
W4	-68	0	15	13	61	164	259
Y1	-64	0	23	17	54	46	247
Y2	-157	0	22	18	65	38	268
Y3	-148	0	26	15	62	56	254
Y4	-146	0	29	7	64	65	251

Appendix 5B

Raw data used in correlations between DCA axes 1 and 2 and vegetation and hydrological varaibles for Domin values of 60 wetland species across 100 plots.

Plot	Mean depth	Duration	Species rich	Shrubs % cover	Trees % cover	Em mac % cover	Peren % cover	Annuals % cover	Axis 1	Axis 2	Axis 3
Ba1	-11	0.4	5	3	100	45	0	0	236	250	210
Ba2	-61	0.1	6	3	100	0	1	0	257	224	197
Ba3	-241	0	3	0	4	0	0	1	406	260	263
Be1	-20	1.6	5	0	65	4	0	4	83	98	106
Be2	-20	1.6	3	0	65	4	0	1	42	50	150
Be3	-84	0	3	0	20	1	0	1	332	208	202
Bi1	-9	4.4	4	0	20	10	1	0	301	280	145
Bi2	1	4	4	0	45	0	4	0	257	318	161
Bi3	-59	0.6	3	0	100	0	10	0	250	315	210
G1	55	12	7	0	30	65	65	0	230	83	242
G2	35	11	6	0	100	1	45	0	265	123	219
G3	30	10.2	5	0	10	1	85	0	247	29	210
G4	25	9.4	6	0	65	1	85	0	170	44	194
J1	-164	0	5	100	4	0	4	0	481	197	182
J2	-199	0	5	100	10	0	1	0	456	200	184
J3	-311	0	3	30	10	0	0	0	411	201	186
J4	-348	0	4	0	45	0	0	0	339	214	222
Jo1	-36	2.8	6	1	30	100	0	0	185	85	128
Jo2	-176	0	6	0	20	65	10	0	204	42	169
Jo3	-136	0	6	0	65	100	10	0	206	53	162
Jo4	-106	0	7	0	100	100	10	0	208	67	161
Jo5	4	0.4	6	1	20	100	1	1	146	65	121
Jo6	-176	0	4	0	30	100	0	0	176	70	142
Jo8	-306	0	2	1	1	0	0	0	18	5	110
Jo9	-6	3.4	8	1	85	1	85	4	106	20	151
Jo10	-46	0.6	3	10	40	0	20	0	81	0	143
Jo11	-102	0	1	1	4	0	0	0	45	144	90
Jo12	-173	0	2	1	0	1	0	0	153	215	122
Nk1	-264	0	4	0	100	0	1	1	176	348	193
Nk2	-464	0	1	0	20	0	0	0	349	215	208
Nk4	-764	0	2	0	1	0	0	1	244	256	163
Nk5	-204	0	2	0	45	0	4	0	213	343	229
Nk6	-284	0	2	0	30	1	0	0	214	263	253
Nk7	-424	0	1	0	45	0	0	0	223	307	285
Nk8	-604	0	2	0	1	0	0	1	267	290	266
Sk1	-28	3	4	0	100	0	100	0	158	421	179
Sk2	-28	3	5	0	100	0	100	0	185	396	189
Sk3	-48	2.2	4	0	85	0	40	0	186	384	209
Sk4	-68	2	4	1	100	1	4	0	239	323	220
L861	9	0.6	5	100	1	4	0	1	372	183	186
L862	-67	0	6	100	85	10	0	0	380	181	194
L863	-95	0	5	100	85	20	0	0	372	173	178
L864	-101	0	4	100	45	10	0	0	367	174	183
L1861	-148	0	7	100	20	0	0	0	418	203	198
L1862	-198	0	7	100	20	0	0	0	417	201	192
L1863	-192	0	5	100	30	0	0	0	402	202	196
L1864	-208	0	5	100	20	0	0	0	410	201	195
M1	15	2.6	4	0	10	10	1	1	160	260	195
M2	-28	1.8	7	1	4	4	1	1	142	245	176
M3	-65	1	6	10	10	1	0	1	91	332	117
M4	-83	0	6	10	1	20	0	1	119	278	133
M5	-75	0	7	4	10	20	0	1	147	255	165
M171	-10	2	4	45	0	100	0	0	326	138	149
M172	-61	0	6	30	30	100	1	1	350	147	144
M173	-84	0	7	10	65	20	0	0	354	167	192
M174	-87	0	5	30	30	1	0	0	369	182	192
NI1	-51	8	7	0	100	65	4	1	199	180	168
NI2	-91	0.4	7	4	100	10	20	0	226	145	130
NI3	-131	0	5	1	100	1	0	0	208	150	98
NI4	-31	1	8	1	100	20	0	0	275	206	210
NI5	-91	0.4	4	4	65	4	0	0	345	215	234
NI6	-171	0	4	1	20	0	0	0	408	245	239
NI7	-251	0	3	65	20	0	0	0	540	222	223
N1	-94	0	6	1	45	10	0	0	157	156	255
N2	-214	0	3	4	30	0	0	0	99	176	277
N3	-284	0	1	1	0	0	0	0	19	152	443

Plot	Mean depth	Duration	Species rich	Shrubs % cover	Trees % cover	Em mac % cover	Peren % cover	Annuals % cover	Axis 1	Axis 2	Axis 3
N4	-434	0	1	1	0	0	0	0	19	152	443
N5	16	0.6	5	1	4	100	0	0	144	91	270
N6	-194	0	3	1	1	1	0	0	179	172	309
N8	-684	0	1	1	0	0	0	0	19	152	443
Sb1	-82	0	3	0	100	10	0	1	311	174	176
Sb2	-82	0	5	100	85	1	0	1	386	198	182
Sb3	-142	0	4	100	0	0	30	0	656	211	200
Sb4	-212	0	4	20	4	0	1	1	553	229	227
Sb5	-52	0.4	3	0	45	0	0	45	93	132	39
Sb6	-72	0	5	0	65	1	1	10	86	111	75
Sb7	-72	0	4	4	40	4	1	1	186	101	128
Sb8	-92	0	6	30	20	1	1	1	274	139	153
Tl1	-125	0	4	0	1	85	4	0	161	131	119
Tl2	-135	0	3	0	30	4	4	0	166	186	152
Tl3	-215	0	2	0	100	0	0	0	183	347	226
Tl4	-195	0	1	0	20	0	0	0	223	307	285
Tl5	-125	0	3	0	45	1	1	0	200	272	246
Tl6	-145	0	1	0	1	0	0	0	223	307	285
Tl9	-35	1	2	0	1	30	0	0	205	200	208
Tl10	-95	0.4	1	0	1	0	0	0	223	307	285
Tl11	-195	0	1	0	1	0	0	0	223	307	285
Tl12	-415	0	1	0	1	0	0	0	223	307	285
Tb1	-1	4.2	7	0	65	100	1	30	0	197	0
Tb2	-21	3.4	6	0	65	85	20	10	40	222	18
Tb3	-61	0.6	2	1	100	0	0	0	75	217	128
Tb4	-121	0	3	0	100	0	0	1	131	219	102
W1	14	3.8	3	0	65	30	0	1	287	192	194
W2	-6	2.8	4	0	45	100	0	0	111	108	126
W3	-42	0.6	7	0	100	100	4	0	133	73	120
W4	-68	0	2	0	4	0	0	0	56	68	104
Y1	-64	0	4	0	20	20	10	0	238	65	207
Y2	-157	0	5	0	45	1	10	0	115	22	159
Y3	-148	0	4	0	45	1	0	1	112	75	80
Y4	-146	0	3	0	40	1	0	0	126	58	90

Appendix 6

Water depths and duration of inundation at the start and end of each transect at which each of the 60 wetland species occurred.

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Littoral and fringing trees											
Banksia ilicifolia	Banganup	20	C	-265	-302	-220	C	-305	-342	-260	0
		10		-239	-248	-230		-279	-288	-250	0
		5		-241	-250	-219		-281	-290	-259	0
	Jandabup	20	D	-335	-386	-297	D	-348	-399	-310	0
		10		-336	-377	-298		-349	-390	-311	0
		5		-348	-386	-386		-361	-399	-320	0
	Lexia 86	3	B	-67	-76	-46	B	-95	-104	-74	0
	Lexia 186	3	A	-148	-150	-127	C	-208	-210	-187	0
	Nth Lake 2	20	C	-107	-172	-59	D	-247	-312	-199	0
		10		-126	-184	-79		-266	-324	-219	0
		5		-171	-227	-123		-311	-367	-263	0
	Shirley Balla 1	5	D	-212	-243	-182	D	-292	-323	-262	0
Banksia littoralis	Banganup	20	B	-85	-122	-40	B	-265	-302	-220	0.2
		10		-59	-68	-30		-239	-248	-230	0.2
		5		-61	-70	-41		-241	-250	-219	0.1
	Joondalup Est	20	A	-15	-63	25	A	-155	-201	-115	4.55
		10		-16	-66	26		-156	-206	-116	4.8
		5		-36	-89	8		-176	-229	-132	2.8
	Lexia 86	3	A	-9	0	30	B	-95	-104	-74	0.6
	Nth Lake 1	20	B	-27	-92	21	B	-67	-132	-19	2.75
		10		-46	-104	1		-86	-144	-39	2.5
		5		-91	-147	-43		-131	-87	-183	0.4
	Nth Lake 2	20	A	33	-32	81	A	-27	-92	21	5.15
		10		14	-44	61		-46	-104	1	4.4
		5		-31	-87	103		-91	-147	43	1
	Twin Bartram	8	C	-48	-93	0	D	-188	-233	-140	0
		5		-61	-100	-16		-201	-240	-156	0
	Wilgarup	5	C	-42	-59	-11	C	-68	-85	-37	0.6
	Yonderup	20	C	-154	-172	-142	D	-166	-184	-154	0
		10		-147	-148	-143		-159	-160	-155	0
		5		-148	-150	-145		-160	-162	-157	0
Eucalptus rudis	Banganup	20	A	-35	-72	10	C	-305	-342	-260	0.35
		10		9	0	20		-279	-288	-250	0.7
		5		-11	-20	11		-281	-290	-259	0.4
	Bibra	20	B	-8	-45	38	C	-88	-95	-12	5.4
		10		15	-23	34		-65	-73	-16	7.2
		5		1	-59	30		-99	-109	-2	4
	Goollelal	20	A	43	-16	61	D	3	-31	36	10.8
		10		54	-1	73		14	-26	48	11.8
		5		55	-4	72		15	-29	47	12
	Jandabup	20	D	-335	-386	-297	D	-348	-399	-310	0
		10		-336	-377	-298		-349	-390	-311	0
		5		-348	-386	-386		-361	-399	-320	0
	Joondalup Est	20	B	-155	-201	-115	D	-225	-271	-185	0
		10		-156	-206	-116		-226	-276	-184	0
		5		-176	-229	-132		-246	-299	-202	0

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Eucalptus rudis	Nth Kogolup 1	5	A	-264	-304	-229	D	-864	-904	-829	0
	Nth Kogolup 2	5	A	-204	-244	-169	D	-764	-804	-729	0
	Sth Kogolup	20	A	-32	-93	21	D	-92	-133	-19	2.7
		10		-3	-62	43		-63	-102	3	4.8
		5		-28	-83	25		-88	-123	-15	3
	Mariginiup	20	A	29	-21	71	E	-71	-131	-39	6.55
		10		31	-9	65		-69	-119	-45	3.2
		5		15	-30	48		-85	-140	-62	2.6
	Nth Lake 1	20	A	13	-52	61	C	-107	-152	-39	4.1
		10		-6	-64	41		-126	-164	-59	3.3
		5		-51	-107	3		-171	-227	-123	0.8
	Nth Lake 2	20	A	33	-32	81	C	-187	-252	-139	5.15
		10		14	-44	61		-206	-264	-159	4.4
		5		-31	-87	103		-251	-307	-203	1
	Nowergup Nth	20	A	-79	-115	-44	B	-269	-305	-234	0
		10		-86	-125	-50		-276	-315	-240	0
		5		-94	-140	-54		-284	-330	-244	0
	Nowergup Sth	20	B	-179	-215	-144	B	-469	-505	-434	0
		10		-186	-225	-150		-476	-515	-440	0
		5		-194	-240	-154		-484	-530	-444	0
	Thomsons 2	20	A	-113	-169	-73	D	-163	-214	-118	0.4
		10		-96	-137	-60		-146	-182	-105	0.8
		5		-125	-159	-91		-175	-204	-136	0
	Thomsons 3	20	A	-113	-174	-78	B	-243	-294	-198	0.2
		10		-96	-142	-65		-226	-262	-185	0.4
		5		-125	-164	-96		-255	-284	-216	0
	Thomsons 4	20	A	-23	-76	22	D	-623	-674	-578	1.3
		10		-6	-42	35		-606	-642	-565	2.1
		5		-35	-64	4		-635	-664	-596	1
Melaleuca preissiana	Banganup	20	A	-35	-72	10	B	-265	-302	-220	0.35
		10		9	0	20		-239	-248	-230	0.7
		5		-11	-20	11		-241	-250	-219	0.4
	Beenyup	8	C	-68	-97	-28	C	-188	-217	-148	0
		5		-84	-97	-62		-204	-217	-182	0
	Bibra	20	A	2	-35	48	C	-88	-95	-12	6.35
		10		25	-13	44		-65	-73	-16	7.8
		5		-9	-49	40		-99	-109	-2	4.4
	Goollelal	20	A	43	-16	61	D	3	-31	36	10.8
		10		54	-1	73		14	-26	48	11.8
		5		55	-4	72		15	-29	47	12
	Jandabup	20	A	-151	-202	-293	D	-348	-399	-310	0
		10		-152	-193	-114		-349	-390	-311	0
		5		-164	-202	-123		-361	-399	-320	0
	Nth Kogolup 1	5	B	-464	-504	-429	B	-644	-684	-609	0
	Lexia 86	3	B	-67	-76	-46	D	-85	-94	-64	0
	Lexia 186	3	A	-148	-150	-127	D	-229	-231	-208	0
	EPP 173	3	B	-61	-110	-18	D	-88	-137	-45	0
	Nth Lake 1	20	B	-27	-92	21	C	-107	-152	-39	4.1
		10		-46	-104	1		-126	-164	-59	3.3
		5		-91	-147	-43		-171	-227	-123	0.8

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Melaleuca preissiana	Nth Lake 2	20	A	33	-32	81	D	-247	-312	-199	5.15
		10		14	-44	61		-266	-324	-219	4.4
		5		-31	-87	103		-311	-367	-263	1
	Shirley Balla 1	5	A	-82	-113	-52	B	-142	-173	-112	0
	Wilgarup	5	A	14	-3	45	A	-6	-23	25	3.8
	Yonderup	20	A	-170	-188	-158	A	-163	-181	-151	0
		10		-163	-164	-159		-156	-157	-152	0
		5		-64	-166	-161		-157	-159	-154	0
Melaleuca rhaphiophylla	Beenyup	8	A	-8	-37	32	B	-68	-97	-28	3.38
		5		-20	-37	-2		-84	-97	-62	1.6
	Goollelal	20	D	13	-31	46	D	3	-31	36	7.95
		10		24	-16	58		14	-26	48	9.9
		5		25	-19	57		15	-29	47	9.4
	Jandabup	20	D	-335	-386	-297		-348	-399	-310	0
		10		-336	-377	-298		-349	-390	-311	0
		5		-348	-386	-306		-361	-399	-320	0
	Joondalup Est	20	A	-15	-63	25	D	-225	-271	-185	4.55
		10		-16	-66	26		-226	-276	-184	4.8
		5		-36	-89	8		-246	-299	-202	2.8
	Joondalup Nth	20	A	25	-21	65	B	-255	-301	-215	0.55
		10		24	-26	66		-256	-306	-214	1.1
		5		4	-49	48		-276	-329	-232	0.4
	Joondalup Sth	20	A	15	-31	55	C	-152	-191	-105	5.6
		10		14	-36	56		-153	-196	-104	5.7
		5		-6	-59	38		-173	-219	-122	3.4
	Nth Lake 1	20	A	13	-52	61	A	-27	-92	21	4.1
		10		-6	-64	41		-46	-104	1	3.3
		5		-51	-107	-3		-91	-147	-43	0.8
	Nth Lake 2	20	A	33	-32	81	A	-27	-92	21	5.15
		10		14	-44	61		-46	-104	1	4.4
		5		-31	-87	103		-91	-147	-43	1
	Nowergup Nth	20	A	-79	-115	-44	B	-269	-305	-234	0
		10		-86	-125	-50		-276	-315	-240	0
		5		-94	-140	-54		-284	-330	-244	0
	Nowergup Sth	20	A	31	-57	66	A	-179	-215	-144	0.02
		10		24	-67	60		-186	-225	-150	0.3
		5		16	-82	56		-194	-240	-154	0.6
	Shirley Balla 2	5	A	-52	-83	-22	D	-112	-143	-82	0
	Twin Bartram	8	A	12	-33	60	D	-188	-233	-140	6.7
		5		-1	-40	44		-201	-240	-156	4.2
	Wilgarup	5	B	-6	-23	25	D	-100	-117	-69	3.8
	Yonderup	20	B	-163	-181	-151	D	-166	-184	-154	0
		10		-156	-157	-152		-159	-160	-155	0
		5		-157	-159	-154		-160	-162	-157	0
Melaleuca teretefolia	Banganup	20	A	-35	-72	10	A	-85	-122	-40	0.35
		10		9	0	20		-59	-68	-30	0.7
		5		-11	-20	11		-61	-70	-41	0.4
	Bibra	20	B	-8	-45	38	B	-48	55	28	5.4
		10		15	-23	34		-5	-33	24	7.2
		5		1	-59	30		-59	-69	20	4

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Melaleuca teretefolia	Nth Kogolup 1	5	A	-264	-304	-229	A	-464	-504	-429	0
	Sth Kogolup	20	A	-32	-93	21	D	-92	-133	-19	2.7
		10		-3	-62	43		-63	-102	3	4.8
		5		-28	-83	25		-88	-123	-15	3
	Mariginiup	20	A	29	-21	71	E	-71	-131	-39	6.55
		10		31	-9	65		-69	-119	-45	3.2
		5		15	-30	48		-85	-140	-62	2.6
	Nth Lake 1	20	A	13	-52	61	A	-27	-92	21	4.1
		10		-6	-64	41		-46	-104	1	3.3
		5		-51	-107	-3		-91	-147	-43	0.8
	Nth Lake 2	20	A	33	-32	81	A	-27	-92	21	5.15
		10		14	-44	61		-46	-104	1	4.4
		5		-31	-87	103		-91	-147	-43	1
	Thomsons 2	20	C	-203	-254	-158	C	-183	-234	-138	0
		10		-186	-222	-145		-166	-202	-125	0
		5		-215	-244	-176		-195	-224	-156	0
	Twin Bartram	8	C	-48	-93	0	C	-108	-153	-60	0
		5		-61	-100	-16		-121	-160	-76	0
Woody shrubs											
Adriana quadripartita	Banganup	20	B	-85	-122	-40	B	-265	-302	-220	0.2
		10		-59	-68	-30		-239	-248	-230	0.2
		5		-61	-70	-41		-241	-250	-219	0.1
	Nth Kogolup 2	5	A	-204	-244	-169	A	-284	-324	-249	0
Astartea fascicularis	Banganup	20	A	-35	-72	10	B	-265	-302	-220	0.35
		10		9	0	20		-239	-248	-230	0.7
		5		-11	-20	11		-241	-250	-219	0.4
	Jandabup	20	A	-151	-202	-293	C	-335	-386	-297	0
		10		-152	-193	-114		-336	-377	-298	0
		5		-164	-202	-123		-348	-386	-306	0
	Sth Kogolup	20	D	-72	-133	-19	D	-92	-133	-19	1.65
		10		-43	-102	-3		-63	-102	-3	1.5
		5		-68	-123	-15		-88	-123	-15	2
	Lexia 86	3	A	-9	0	30	D	-85	-94	-64	0.6
	Lexia 186	3	A	-148	-150	-127	D	-229	-231	-208	0
	Mariginiup	20	A	29	-21	71	D	-61	-121	-29	6.55
		10		31	-9	65		-59	-109	-35	3.2
		5		15	-30	48		-75	-130	-52	2.6
	EPP 173	3	C	-84	-133	-41	C	-87	-136	-44	0
	Nth Lake 2	20	A	33	-32	81	B	-107	-172	-59	5.15
		10		14	-44	61		-126	-184	-79	4.4
		5		-31	-87	103		-171	-227	-123	1
	Shirley Balla 1	5	B	-82	-113	-52	B	-142	-173	-112	0
	Shirley Balla 2	5	C	-72	-103	-42	D	-112	-143	-82	0
Beaufortia elegans	Jandabup	20	A	-151	-202	-293	B	-298	-349	-260	0
		10		-152	-193	-114		-299	-340	-261	0
		5		-164	-202	-123		-311	-349	270	0
	Lexia 186	3	B	-198	-200	-177	B	-192	-194	-171	0
Calothamnus lateralis	Lexia 86	3	C	-95	-104	-74	C	-101	-110	-80	0
	EPP 173	3	B	-61	-110	-18	B	-84	-133	-41	0

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Exocarpus sparteus	Joondalup Est	20	A	-15	-63	25	A	-155	-201	-115	4.55
		10		-16	-66	26		-156	-206	-116	4.8
		5		-36	-89	8		-176	-229	-132	2.8
	Mariginiup	20	B	-14	-64	28	E	-71	-131	-39	6.55
		10		-12	-52	22		-69	-119	-45	3.2
		5		-28	-73	5		-85	-140	-62	2.6
Hypocalymma	Lexia 86	3	A	-9	0	30	D	-85	-94	-64	0.6
angustifolium	Lexia 186	3	A	-148	-150	-127	D	-229	-231	-208	0
	EPP 173	3	C	-84	-133	-41	D	-87	-137	-44	0
	Shirley Balla 1	5	C	-142	-173	-112	C	-212	-243	-182	0
	Shirley Balla 2	5	D	-92	-123	-62	D	-112	-143	-82	0
Kunzea ericifolia	Nth Lake 1	20	C	-67	-132	-19	C	-107	-152	-39	1.15
		10		-86	-144	-39		-126	-164	-59	2.1
		5		-131	-87	-183		-171	-227	-123	0
	Nth Lake 2	20	B	-27	-92	21	D	-247	-312	-199	2.75
		10		-46	-104	1		-266	-324	-219	2.5
		5		-91	-147	-43		-311	-367	-263	0.4
	Shirley Balla 1	5	B	-82	-113	-52	D	-292	-323	-262	0
	Shirley Balla 2	5	D	-92	-123	-62	D	-112	-143	-82	0
Myoporum capraroides	Joon Nth	20	A	25	-21	65	D	-655	-701	-615	0.55
		10		24	-26	66		-656	-706	-614	1.1
		5		4	-49	48		-676	-729	-632	0.4
	Joon Sth	20	A	15	-31	55	B	-81	-122	-39	5.6
		10		14	-36	56		-82	-125	-40	5.7
		5		-6	-59	38		-102	-154	-62	3.4
Pericalymma ellipticum	Lexia 86	3	A	-9	0	3	B	-95	-104	-74	0.6
	Lexia 186	3	A	-148	-150	-127	D	-229	-231	-208	0
	EPP 173	3	C	-84	-133	-41	D	-88	-136	-44	0
Pultenaea ochreata	Shirley Balla 1	5	C	-142	-173	-112	C	-212	-243	-182	0
Pultenaea reticulata	Nth Lake 2	20	B	-27	-92	21	B	-107	-172	-59	2.75
		10		-46	-104	1		-126	-184	-79	2.5
		5		-91	-147	-43		-171	-227	-123	0.4
	Lexia 86	3	B	-67	-76	-46	D	-85	-94	-64	0
	Lexia 186	3	A	-148	-150	-127	A	-198	-200	-177	0
	EPP 173	3	C	-84	-133	-41	C	-88	-136	-44	0
Rhagodia baccata	Nowergup Nth	20	A	-79	-115	-44	D	-519	-555	-484	0
		10		-86	-125	-50		-526	-565	-490	0
		5		-94	-140	-54		-534	-580	-494	0
	Nowergup Sth	20	A	31	66	14	D	-899	-935	-864	0.02
		10		24	60	8		-906	-945	-870	0.3
		5		16	56	4		-914	-960	-874	0.6
	Joondalup Sth	20	D	-152	-191	-105	D	-425	-471	-385	0
		10		-153	-196	-104		-426	-476	-384	0
		5		-173	-219	-122		-446	-499	-402	0
Viminaria juncea	Mariginiup	20	B	-14	-64	28	E	-71	-131	-39	4.1
		10		-12	-52	22		-69	-119	-45	3.8
		5		-28	-73	5		-85	-140	-62	1.8

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Small perennials											
Aotus gracillima	Nth Lake 1	20	B	-27	-92	21	B	-67	-132	-19	2.75
		10		-46	-104	1		-86	-144	-39	2.5
		5		-91	-147	-43		-131	-87	-183	0.4
Azolla sp.	Nth Lake 1	20	A	13	-52	61	A	-27	-92	21	4.1
		10		-6	-64	41		-46	-104	1	3.3
		5		-51	-107	-3		-91	-147	-43	0.8
Carex fascicularis	Bibra	20	A	2	-35	48	A	-8	-45	38	6.35
		10		25	-13	44		15	-23	34	7.8
		5		-9	-49	40		1	-59	30	4.4
Centella asiatica	Banganup	20	B	-85	-122	-40	B	-265	-302	-220	0.2
		10		-59	-68	-30		-239	-248	-230	0.2
		5		-61	-70	-41		-241	-250	-219	0.1
	Bibra	20	A	2	-35	48	A	-8	-45	38	6.35
		10		25	-13	44		15	-23	34	7.8
		5		-9	-49	40		1	-59	30	4.4
	Nth Kogolup 1	5	A	-264	-304	-229	A	-464	-504	-429	0
	Sth Kogolup	20	A	-32	-93	21	D	-92	-133	-19	2.7
		10		-3	-62	43		-63	-102	3	4.8
		5		-28	-83	25		-88	-123	-15	3
Centella cordifolia	Goollelal	20	A	43	-16	61	D	3	-31	36	10.8
		10		54	-1	73		14	-26	48	11.8
		5		55	-4	72		15	-29	47	12
	Joondalup Est	20	B	-155	-201	-115	D	-225	-271	-185	0
		10		-156	-206	-116		-226	-276	-184	0
		5		-176	-229	-132		-246	-299	-202	0
	Joondalup Sth	20	A	15	-31	55	B	-1	-122	-39	5.6
		10		14	-36	56		-82	-125	-40	5.7
		5		-6	-59	38		-102	-154	-62	3.4
	Mariginiup	20	B	-14	-64	28	B	-51	-101	-9	4.1
		10		-12	-52	22		-49	-89	-15	3.8
		5		-28	-73	5		-65	-110	-32	1.8
	Wilgarup	5	C	-42	-59	11	C	-68	-85	-37	0.6
Gratiola peruviana	Thomsons 2	20	B	-123	-174	-78	B	-203	-254	-158	0
		10		-106	-142	-65		-186	-222	-145	0
		5		-135	-164	-96		-215	-244	-176	0
	Twin Bartram	8	A	12	-33	60	A	-8	-53	40	6.7
		5		-1	-40	44		-21	-60	24	4.2
Haloragis brownii	Joondalup Nth	20	A	25	-21	65	A	-155	-201	-115	0.55
		10		24	-26	66		-156	-206	-114	1.1
		5		4	-49	48		-176	-229	-132	0.4
Hemarthria uncinata	Sth Kogolup	20	A	-32	-93	21	C	-72	-133	-19	2.7
		10		-3	-62	46		-43	-102	3	4.8
		5		-28	-83	25		-68	-123	-15	3
Laxmania ramosa	Shirley Balla 2	5	D	-92	-123	-62	D	-112	-143	-82	0
Lyginia barbata*	Jandabup	20	A	-151	-202	-293	B	-298	-349	-260	0
		10		-152	-193	-114		-299	-340	-261	0
		5		-164	-202	-123		-311	-349	-270	0

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Phyla nodiflora*	Goollelal	20	A	43	-16	61	D	3	-31	36	10.8
		10		54	-1	73		14	-26	48	11.8
		5		55	-4	72		15	-29	47	12
	Joon Sth	20	A	15	-31	55	A	-25	-71	15	5.6
		10		14	-36	56		-26	-76	16	5.7
		5		-6	-59	38		-46	-99	-2	3.4
Pteridium esculentum	Nth Lake 1	20	B	-27	-92	21	C	-107	-152	-39	2.75
		10		-46	-104	1		-126	-164	-59	2.5
		5		-91	-147	-43		-171	-227	-123	0.4
Schoenus rodwayanus	Shirley Balla 1	5	C	-142	-173	-112	C	-212	-243	-182	0
Solanum symonii*	Twin Bartram	8	A	12	-33	60	A	-8	-53	40	6.7
		5		-1	-40	44		-21	-60	24	4.2
Sporobolus virginicus	Thomsons 2	20	A	-113	-169	-73	B	-203	-254	-158	0.4
		10		-96	-137	-60		-186	-222	-145	0.8
		5		-125	-159	-91		-215	-244	-176	0
Triglochin sp.	Joondalup Nth	20	A	25	-21	65	A	-155	-201	-115	0.55
		10		24	-26	66		-156	-206	-114	1.1
		5		4	-49	48		-176	-229	-132	0.4
	Wilgarup	5	A	14	-3	45	A	-6	-23	25	3.8
Annuals											
Chenopdium glaucum	Joondalup Nth	5	D	-306	-369	-272	D	-676	-729	-632	0
	Joondalup Sth	5	A	-6	-59	38	A	-46	-99	-2	3.4
Chenopodium pallidium*	Twin Bartram	5	A	-1	-40	44	A	-21	-60	24	4.2
Conyza albida*	Joon Sth	5	A	-6	-59	38	A	-46	-99	-2	3.4
Cotula coronopifolia*	Beenyup	5	A	-20	-37	-2	A	-20	-37	-2	1.6
	Shirley Balla 2	5	A	-52	-83	-22	B	-72	-103	-52	0.4
Gnaphalium sphaericum	Beenyup	5	A	-20	-37	-2	B	-84	-67	-32	1.6
Homalosciadium homalocarpum	Banganup	5	C	-241	-250	-219	C	-281	-290	-259	0
	Beenyup	5	C	-84	-67	-62	C	-204	-217	-182	0.6
	Nth Kogolup 2	5	D	-604	-644	-569	D	-764	-804	-729	0
	Shirley Balla 1	5	D	-212	-243	-182	D	-292	-323	-262	0
Isolepis cenua	Lexia 186	3	A	-148	-150	-127	A	-198	-200	-177	0
Lemna sp.	Twin Bartram	5	A	-1	-40	44	B	-61	-100	-16	4.2
Polypogon monospeliens	Beenyup	5	A	-20	-37	-2	A	-20	-37	-2	1.6
	Nth Kog 1	5	A	-264	-304	-229	A	-464	-504	-429	0
	North Lake 1	5	A	-51	-107	-3	A	-91	-147	-43	1
	Shirley Balla 1	5	A	-82	-113	-52	B	-142	-173	-112	0
	Shirley Balla 2	5	A	-52	-83	-22	C	-92	-123	-62	0.4
	Twin Bartram	5	A	-1	-40	44	B	-61	-100	-16	4.2
	Yonderup	5	C	-148	-150	-145	C	-146	-148	-143	0
Schoenus pennisetus	Twin Bartram	5	B	-21	-60	24	B	-61	-100	-16	3.4
Villarsia capitata	Joondalup Sth	5	B	-46	-99	-2	B	-102	-154	-62	0.6
	Mariginiup	5	A	15	-30	48	E	-85	-140	-62	2.6
Emergent macrophytes											
Baumea arthrophylla	Jandabup	20	<A	-24	-61	28	<A	-103	-165	-76	5.1
		10		-11	-52	27		-111	-156	-77	5
		5		-22	-61	18		-129	-165	-86	3.6

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Baumea articulata	Banganup	20	<A	-14	-52	30	A	-30	-72	10	3.9
		10		19	2	40		1	-18	20	5
		5		13	0	31		4	0.2	11	3.4
	Beenyup	8	A	-8	-37	32	A	-8	-37	32	3.38
		5		-20	-37	-2		-20	-37	-2	1.6
	Goollelal	20	A	43	-16	61	A	23	-18	59	10.8
		10		54	-1	73		34	-3	71	11.8
		5		55	-4	72		35	-6	70	12
	Jandabup	20	<A	-2	-42	47	<A	-23	-62	27	7.2
		10		5	-33	46		-27	-53	26	7
		5		-7	-42	37		-31	-62	17	5.4
	Joon Est	20	A	-15	-63	25	A	-81	-134	-102	4.55
		10		-16	-66	26		-83	-136	-104	4.8
		5		-36	-89	8		-110	-166	-45	2.8
	Joon Nth	20	A	25	-21	65	B	-121	-159	-145	0.55
		10		24	-26	66		-141	-175	-154	1.1
		5		4	-49	48		-158	-184	-165	0.4
	Joon Sth	20	A	15	-31	55	A	-25	-71	15	5.6
		10		14	-36	56		-26	-76	16	5.7
		5		-6	-59	38		-46	-99	-2	3.4
	Lexia 86	3	<A	-9	0	30	A	-67	-76	-46	1
	Mariginiup	20	<A	-14	-30	-2	E	-71	-131	-39	0
		10		24	-18	58		-69	-119	-45	8.5
		5		-5	-39	39		-85	-140	-62	6.3
	EPP 173	3	<A	48	-10	102	A	-61	-110	-18	2
	Nowergup Nth	20	<A	-3	-34	37	A	-79	-115	-44	6
		10		-11	-44	31		-86	-125	-50	6.3
		5		-17	-59	27		-94	-140	-54	4.2
	Nowergup Sth	20	<A	36	-13	101	A	31	-57	66	0.02
		10		27	-23	96		24	-67	60	0.3
		5		19	-38	75		16	-82	56	0.6
	Thomsons 2	20	<A	-11	-78	47	A	-123	-174	-78	4
		10		4	-65	79		-106	-142	-65	4.4
		5		-9	-96	57		-135	-164	-96	3.6
	Thomsons 3	20	<A	-48	-96	-11	A	-133	-184	-88	1.4
		10		-36	-64	2		-116	-152	-75	2.5
		5		-59	-86	-29		-145	-174	-106	0.7
	Thomsons 4	20	A	-23	-76	22	A	-83	-174	-38	1.3
		10		-6	-42	35		-66	-102	-25	2.1
		5		-35	-64	4		-95	-124	-124	1
	Wilgarup	5	A	14	-3	45	C	-68	-85	37	3.8
Baumea juncea	Joon Nth	20	A	25	-21	65	B	-255	-301	-215	0.55
		10		24	-26	66		-256	-306	-214	1.1
		5		4	-49	48		-276	-329	-232	0.4
	Nth Kogolup 2	5	B	-284	-324	-250	B	-424	-464	-389	0
	Mariginiup	20	E	-61	-121	-29	E	-71	-131	-39	0
		10		-59	-109	-35		-69	-119	-45	0
		5		-75	-130	-52		-85	-140	-62	0
	North Lake 2	20	A	33	-32	81	A	-27	-92	21	5.15
		10		14	-44	61		-46	-104	1	4.4
		5		-31	-87	103		-91	-147	-43	1

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Baumea juncea	Thomsons 2	20	<A	-49	-106	47	B	-203	-254	-158	4
		10		-2	-74	79		-186	-222	-145	4.4
		5		-12	-96	57		-215	-244	-176	3.6
	Yonderup	20	A	-170	-188	-158	D	-166	-184	-154	0
		10		-163	-164	-159		-159	-160	-155	0
		5		-64	-166	-161		-160	-162	-157	0
Baumea vaginalis	Wilgarup	5	B	-6	-23	25	D	-100	-117	-69	2.8
Isolepis marginata	Beenyup	8	A	-8	-37	32	C	-188	-217	-148	3.38
		5		-20	-37	-2		-204	-217	-182	1.6
	EPP 173	3	A	-10	-85	8	A	-61	-110	-18	2
Isolepis producta	Twin Bartram	8	A	12	-33	60	B	-48	-93	0	6.7
		5		-1	-40	44		-61	-100	-16	4.2
Isolepis prolifera	Goollelal	20	B	23	-18	59	D	3	-31	36	9.85
		10		34	-3	71		14	-26	48	11.2
		5		35	-6	70		15	-29	47	11
Juncus pallidus	Bibra	20	A	2	-35	48	A	-8	-45	38	6.35
		10		25	-13	44		15	-23	34	7.8
		5		-9	-49	40		1	-59	30	4.4
	Goollelal	20	B	23	-18	59	D	3	-31	36	9.85
		10		34	-3	71		14	-26	48	11.2
		5		35	-6	70		15	-29	47	11
	Twin Bartram	8	B	-8	-53	40	B	-48	-93	0	4.88
		5		-21	-60	24		-61	-100	-16	3.4
Lepidosperma elatius	Beenyup	8	B	-8	-37	32	B	-68	-97	-28	2
		5		-20	-37	-2		-84	-97	-62	0.6
Lepidosperma long	Goollelal	20	A	43	-16	61	A	23	-18	59	10.8
		10		54	-1	73		34	-3	71	11.8
		5		55	-4	72		35	-6	70	12
	Joondalup Est	20	A	-15	-63	25	D	-225	-271	-185	4.55
		10		-16	-66	26		-226	-276	-184	4.8
		5		-36	-89	8		-246	-299	-202	2.8
	Joondalup Nth	20	A	25	-21	65	B	-255	-301	-215	0.55
		10		24	-26	66		-256	-306	-214	1.1
		5		4	-49	48		-176	-229	-132	0.4
	Lexia 186	3	B	-198	-200	-177	D	-229	-231	-208	0
	MP 173	3	A	-10	-85	8	D	-88	-137	-45	0
	North Lake 1	20	A	13	-52	61	C	-107	-152	-39	4.1
		10		-6	-64	41		-126	-164	-59	3.3
		5		-51	-107	-3		-171	-227	-123	0.8
	North Lake 2	20	A	33	-32	81	B	-107	-172	-59	5.15
		10		14	-44	61		-126	-184	-79	4.4
		5		-31	-87	103		-171	-227	-123	1
	Nowergup Nth	20	A	-79	-115	-44	A	-199	-235	-164	0
		10		-86	-125	-50		-206	-245	-170	0
		5		-94	-140	-54		-214	-260	-174	0
	Nowergup Sth	20	A	31	-57	66	B	-469	-505	-434	0.02
		10		24	-67	60		-476	-515	-440	0.3
		5		16	-82	56		-484	-530	-444	0.6
	Shirley Balla 1	5	A	-82	-113	-52	B	-142	-173	-112	0
	Shirley Balla 2	5	B	-52	-83	-22	D	-112	-143	-82	0.4
	Wilgarup	5	A	14	-3	45	D	-100	-117	-69	3.8

Species	transect	period (yrs)	plot	mean (cm)	min (cm)	max (cm)	plot	mean (cm)	min (cm)	max (cm)	duration (months)
Leptocarpus scaroisus	Jandabup	20	<A	-18	-52	37	<A	-61	-106	-17	7.6
		10		-11	-43	36		-57	-97	-18	7.4
		5		-8	-52	27		-59	-106	-27	5.2
	EPP 173	3	A	-10	-85	8	C	-87	-136	-44	2
Lepyrodia glauca	EPP 173	3	B	-61	-110	-18	B	-84	-133	-41	0
Lepyrodia muirii	Jandabup	20	<A	-18	-52	37	<A	-61	-106	-17	7.6
		10		-11	-43	36		-57	-97	-18	7.4
		5		-8	-52	27		-59	-106	-27	5.2
	Mariginiup	20	A	29	-21	71	B	-51	-101	-9	6.55
		10		31	-9	65		-49	-89	-15	3.2
		5		15	-30	48		-65	-110	-32	2.6
Typha orientalis	Goollelal	20	A	43	-16	61	A	23	-18	59	10.8
		10		54	-1	73		34	-3	71	11.8
		5		55	-4	72		35	-6	70	12
	Mariginiup	20	<A	29	-21	71	A	-14	-64	28	6.55
		10		31	-9	65		-12	-52	22	3.2
		5		15	-30	48		-28	-73	5	2.6
	Nowergup Nth	20	<A	48	26	97	A	-79	-115	-44	11
		10		43	16	91		-86	-125	-50	11
		5		34	-6	87		-94	-140	-114	9
	Nowergup Sth	20	<A	89	54	125	A	31	-57	14	11
		10		84	44	119		24	-67	8	11
		5		67	29	115		16	-82	4	10
	Thomson 2	20	<A	55	48	61		2	-8	11	7
		10		81	80	83		14	-5	24	8
		5		60	58	61		-9	-10	-7	4
	Twin Bartram	8	A	12	-33	60	A	-8	-53	40	6.7
		5		-1	-40	44		-21	-60	24	4.2
	Yonderup	20	<A	-104	-190	11	B	-154	-172	-142	8.29
		10		3	-5	10		-147	-148	-143	12
		5		4	-3	8		-148	-150	-145	12

Appendix 7

The number of species from each perennial hydrotype found at each transect as a comparison of hydrotype composition between permanent lakes and seasonally iundated sumplands

Lake transect

Hydrotype	Bibra	Gool	Jand	Jo E	Jo N	JoS	Mar	NL 1	NL 2	NowN	NowS	Thom 2	Thom 3	Thom 4	Yond	Mean
1	0	6	3	1	1	3	3	0	0	2	2	2	2	2	2	1.93
2	2	0	4	2	1	0	1	2	1	2	2	1	1	0	1	1.33
3	2	3	3	3	3	2	1	4	6	0	0	1	0	0	3	2.07
4	1	1	0	1	1	1	1	1	1	2	2	1	1	1	0	1
5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.07
6	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0.2
7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.07

Sumpland transect

	Bang	Been	N Kog 1	N Kog 2	S Kog	Lex 86	Lex 186	MP 173	Shir B 1	Shir B 2	T Bart	Wilg	Mean
1	1	1	0	0	2	1	0	1	0	0	2	2	0.83
2	1	2	1	0	0	2	2	3	1	2	3	1	1.5
3	4	2	2	2	3	2	3	3	3	3	3	4	3
4	1	0	1	1	1	0	0	0	0	0	0	0	0.33
5	0	0	0	0	0	0	1	0	2	0	0	0	0.25
6	2	0	0	0	0	1	1	0	2	1	0	0	0.58
7	0	0	0	0	0	2	1	2	0	0	0	0	0.42