JENNY ARNOLD'S

PERTH WETLANDS RESOURCE BOOK

CHAPTER 7

WANNEROO LINEAR LAKES

ENVIRONMENTAL PROTECTION AUTHORITY
AND THE WATER AUTHORITY OF WESTERN AUSTRALIA

BULLETIN 266 DECEMBER 1990

Jenny Arnold's Perth Wetlands
Resource Book

Chapter 7: Wanneroo Linear Lakes

Environmental Protection Authority and
the Water Authority of Western Australia

Bulletin 266 December 1990

ISSN 1030-0120
ISBN 0 7309 19730

Produced by the Australian Government Publishing Service, Perth, W.A. Tel. (09) 325 9121

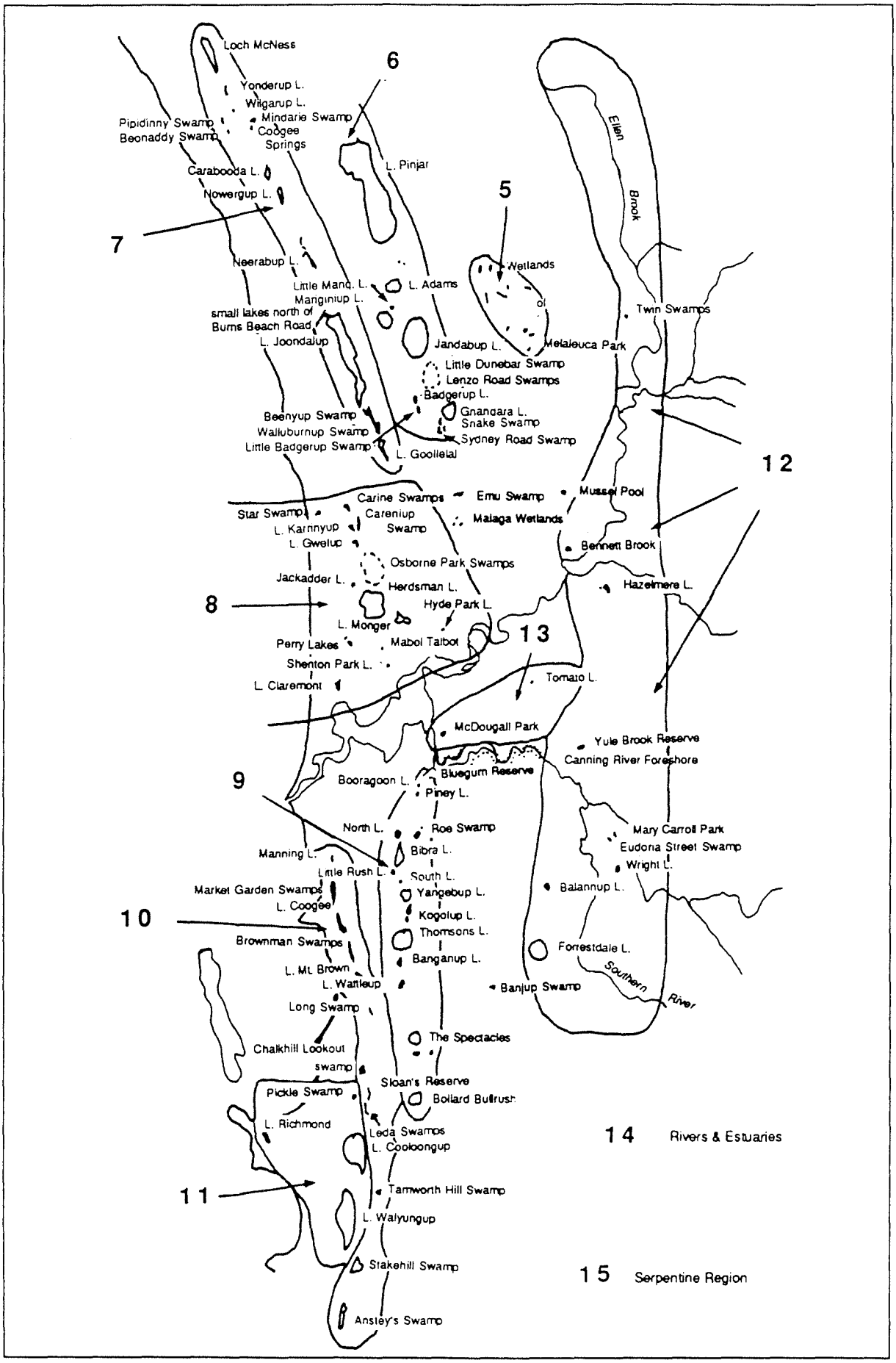
NOTES FOR USERS

Bulletin 266 consists of 15 chapters published in 6 separate volumes.

Chapters 1 - 4 (bound with the appendices) contain information general to wetlands. They form essential background to the subsequent chapters which describe most of the clearly definable seasonal and permanent lakes with open water. As such readers of Chapters 5 - 15 should be used in conjunction with Chapter 1 - 4.

The Bulletin is not an exhaustive inventory of all wetland types. Readers are referred to C. A. Semeniuk (1987), Wetlands of the Darling System - A geomorphic approach to habitat classification. Journal of the Royal Society of Western Australia. Volume 69, Part 3. pp 95-112 for a comprehensive classification of wetland types on the Swan Coastal Plain.

The index map on page (ii) shows how the wetland chains have been grouped into chapters. The position in the text where individual wetlands are discussed is shown in the index on page 418 (Chapters 1 - 4).



Map of Perth's wetlands showing the grouping of wetlands into Chapters in this Bulletin.

Chapter 7: Wanneroo Linear Lakes

FIGURES

FIGURES (Cont'd)

TABLES

Other chapters in this series

7. WANNEROO LINEAR LAKES

7.1 GENERAL SETTING (Figure 7.1)

The Wanneroo linear lakes occupy interdunal depressions within the coastal limestone. They are described as low level interbarrier marshes (Gozzard, 1982). Environmental geology maps show a range of karstic features in the limestone structure within which the lakes are situated. Le Provost, Semeniuk and Chalmer (1987) recognise this group of wetlands as a suite related in type and origin: the Spearwood Yanchep suite.

Elevations of the lakes range from 25 m AHD for Lake Goollelal to 6 m AHD for Loch McNess. Water level records for the lakes differ markedly. The differences suggest that the combination of geological structure and relationship to the groundwater is a most significant aspect of the lake systems.

Water level records for Lakes Neerabup, Carabooda, Coogee Springs, Yonderup and Loch McNess show that maximum water levels are similar each winter suggesting some outlet or overflow at high water levels, although winter levels have tended to remain high for fewer months in recent years. In contrast, the water level for Nowergup shows evidence of a consistent decline in peak winter levels in recent years.

In the southern basin of Loch McNess the water level shows little difference between summer and winter, indicating that not only is there outflow from the lake, identified as being southward to Lake Yonderup through a sub-surface channel (Gozzard, 1982), but that the lake is constantly replenished by groundwater as it flows in the unconfined flow system of the Gnangara Mound towards the sea. The water level records of all other lakes display a strong seasonal pattern, with high water levels in winter and low levels in summer. Very large variations in water levels between winter and summer occur at Carabooda and Neerabup, which are largely privately owned and subject to heavy groundwater draw for horticulture in summer. Lake Nowergup has relatively little horticulture on its margins, but a large lucerne farm and market gardens to the east draw large quantities of groundwater. It shows smaller water level falls in summer than the wetlands to the north and south but peak winter water levels have fallen steadily since 1974. There has also been a reduction in minimum levels over the same period.

With the exception of Loch McNess and Lake Yonderup which lie further west, all of the lakes are located on the steepest gradient of the groundwater flow system.

The areas and distribution of vegetation of the wetlands are summarised in Table 7.1 and the characteristics of each of the lakes are described below.

The wetland area of 15.26 km^2 makes up slightly less than 5% of the Spearwood dune system from the southern end of Goollelal to the northern end of Loch McNess.

A total of 1 112 ha of wetland is reserved. This equals 73 per cent of the total wetland in the system of linear lakes. Of this, 734 ha, or 48 per cent of the total, is within the Joondalup-Goollelal Parks and Recreation area reserved under the Metropolitan Region Scheme. Reserved wetlands in the linear system are in a more favourable position than those in the Wanneroo Groundwater Area because they have substantial buffers of reserved land

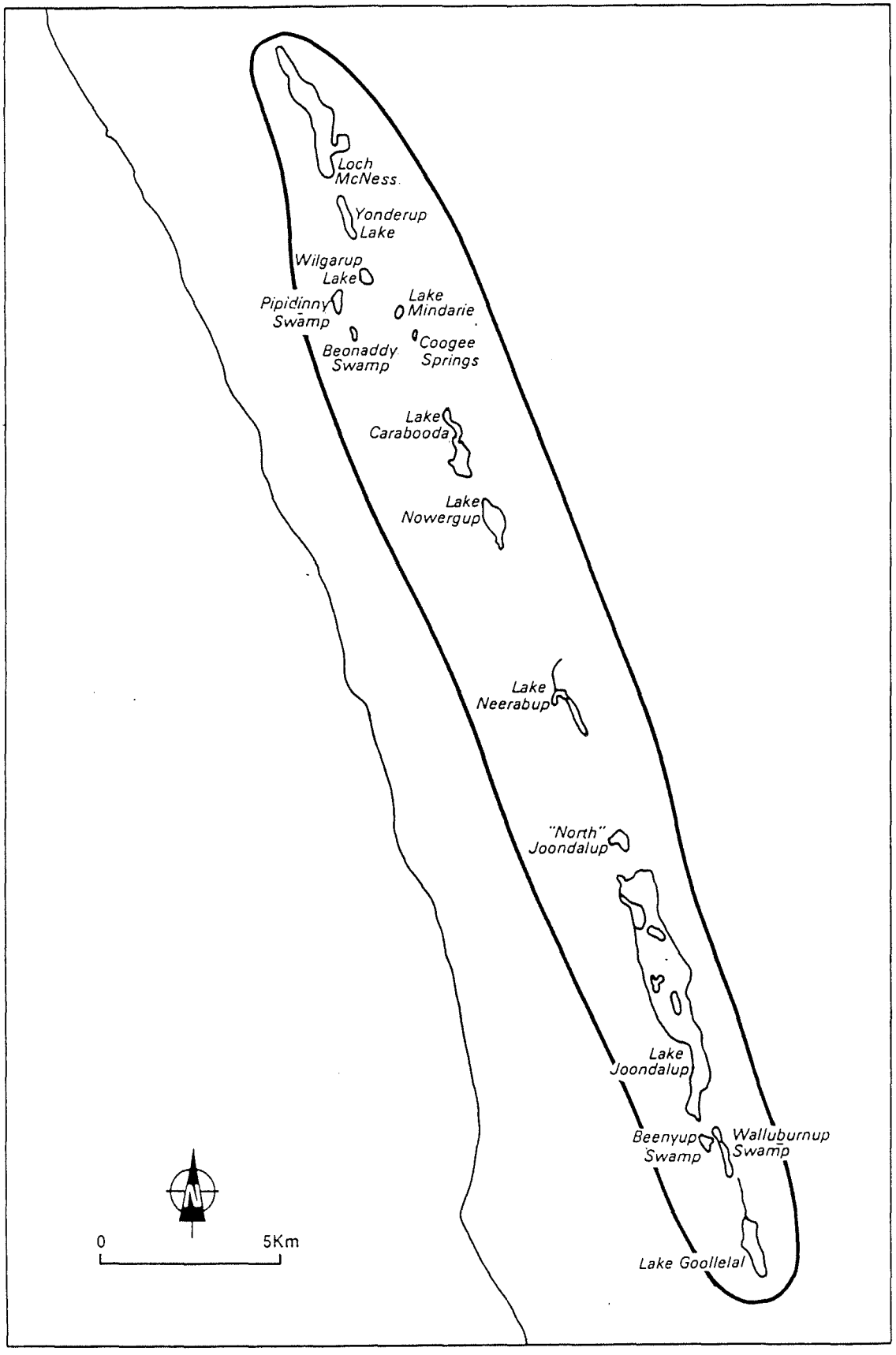


Figure 7.1 Map showing the Wanneroo linear wetlands.

Table 7.1. Areas (hectares) of wetland and vegetation types for the linear wetlands of Wanneroo.

WETLAND	APPROXIMATE AREA OF VEGETATION TYPE*				TOTAL AREA**
	PAPERBARK	SEDGE	OPEN WATER	MODIFIED+	
Goollelal	-	16	45	-	61
	-	(26)	(74)	-	(4.06)
Beenyup	16	13	3	8	40
	(40)	(32)	(8)	(20)	(2.66)
Walluburnup	12	34	-	3	49
	(25)	(69)	-	(6)	(3.26)
Joondalup	64	79	449	-	592
	(11)	(13)	(76)	-	(39.44)
N Joondalup	33	3	3	3	42
	(79)	(7)	(7)	(7)	(2.80)
Neerabup	42	80	71	19	212
	(20)	(38)	(33)	(9)	(14.12)
Nowergup	8	7	34	6	55
	(14)	(13)	(62)	(11)	(3.66)
Carabooda	16	19	16	10	61
	(26)	(31)	(26)	(17)	(4.06)
Coogee Sp	1	4	1	6	12
	(8)	(33)	(9)	(50)	(0.80)
Mindarie	3	1	-	21	25
	(12)	(4)	-	(84)	(1.67)
Pipidinny	3	6	0.4	10	19.4
	(15)	(31)	(2)	(52)	(1.29)
Beonaddy	6	0.4	-	5	11.4
	(52)	(4)	-	(44)	(0.76)
Wilgarup	15	1	1	-	17
	(88)	(6)	(6)		(1.13)
Yonderup	24	9	6	9	48
	(50)	(19)	(12)	(19)	(3.20)
McNess	57	149	50	-	256
	(22)	(58)	(20)	-	(17.06)
TOTAL	300	421.4	679.4	100	1501
	(20)	(28)	(45)	(7)	(100)

*Values in brackets are areas expressed as % of total.
**Values in brackets are areas expressed as % of total wetland in group.
+'Modified' includes pastures, lawn, parking area etc.

around them. Nowergup is the least well protected on its eastern side, with an open range piggery and small holdings adjoining the lake margin. Its reserve does, however, extend for a substantial area beyond its western shoreline.

Most of the linear lakes are continuing to function as wetland habitats and, compared with the wetlands of the Wanneroo Groundwater Area, are less affected by surrounding land uses. Even where clearing and modification has occurred the wetland vegetation is recovering when agricultural pressures are removed. The observable differences may reflect a more stable water supply and more fertile soils in the Spearwood system compared with the Bassendean system.

7.1.1 REFERENCES

Gozzard, J R (1982), Yanchep Sheet 2034 IV, Perth, Metropolitan Region, Environmental Geology Series. Geological Survey of Western Australia.

Le Provost, Semeniuk and Chalmer (1987), Environmental significance of wetlands in the Perth to Bunbury region, Vols 1 and 2. Report to the Western Australian Water Resources Council. Western Australian Water Resources Council, Perth.

7.2 LAKE GOOLLELAL

7.2.1 GENERAL INFORMATION

AMG REF: 647950 387750
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Parks and Recreation
RESERVE No: MRPA-owned
PURPOSE: Parks and Recreation
MANAGEMENT: State Planning Commission
SYSTEM 6 RECOMMENDATION: M7
WAC CLASSIFICATION: LE.f.1.p.so
WATER RESERVE: west of Wanneroo Groundwater Area
DRAINAGE: Local drains, urban runoff

7.2.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Goollellal is the highest of the linear lakes, situated in a steep-sided valley which slopes from the south towards the north, through Walluburnup and Beenyup Swamps towards Lake Joondalup. The lowest point on the lake bed is at about 25.3 m AHD.

7.2.3 AREAS

Area bounded by Hocking Road and Reserve boundary ..... 122 ha
Area of reeds and sedges ..... 15.8 ha
Area of open water zone ..... 44.9 ha

7.2.4 HYDROLOGY (Figure 7.3)

There is no published study of the hydrology and hydrogeology of the lake. It is a surface expression of the water table. A record of lake levels shows a rising trend over recent years, possibly as a result of increasing urban development in the region. The 28 m AHD contour of the maximum groundwater level lies on the east of the lake and the 27 m AHD contour lies on the western side.

Table 7.2. Lake Goollelal: water levels 1969-84.

i Maximum level recorded: 27 m (1964).

ii Number of years the maximum lake level has fallen within specified ranges.

m AHD	1969-75	1976-84
>27.5	0	1
27.0-27.5	6	8
26.5-27.0	1	0

iii Minimum level recorded: 25.8 (1973).

iv Number of years the minimum level has fallen within the specified ranges.

m AHD	1969-75	1976-84
>27.0	2	0
26.5-27.0	2	5
<26.0	1	0

7.2.5 WATER QUALITY

Congdon sampled Lake Goollelal in a detailed study of the nutrient budgets of Lake Joondalup during 1979 and 1980. Some values are published in Congdon (1986). The information suggests that while high nutrient levels were observed in Lake Goollelal, the inorganic nitrogen to phosphorus ratios were low and the levels of chlorophyll a observed suggest that Goollelal is less eutrophic than Joondalup.

Spot values measured by the Water Authority of Western Australia do not demonstrate any alteration in water quality over the period for which values are available.

They demonstrate that inputs of water during the winter and spring bring about significant dilution of nutrients and salts.

7.2.6 LAND USE

There are developing urban areas on the south, east, and west of the lake. Land surrounding the lake is used for a variety of rural uses but a large area on the east of the lake is being transformed from vineyard to 'special residential' uses, with large holdings having limited access to groundwater and reliant on septic tank effluent disposal. Land owned by the State Planning Commission within the reserved area is leased for rural uses.

7.2.7 VEGETATION (Figure 7.2)

There are considerable areas of emergent Baumea articulata within the lake basin. Lake margins support Baumea, introduced grasses and small areas of paper barks. The lake has had an infestation of water hyacinth (Eichornia).

Figure 7.2 Lake Goollelal: wetland plant communities and surrounding land use.

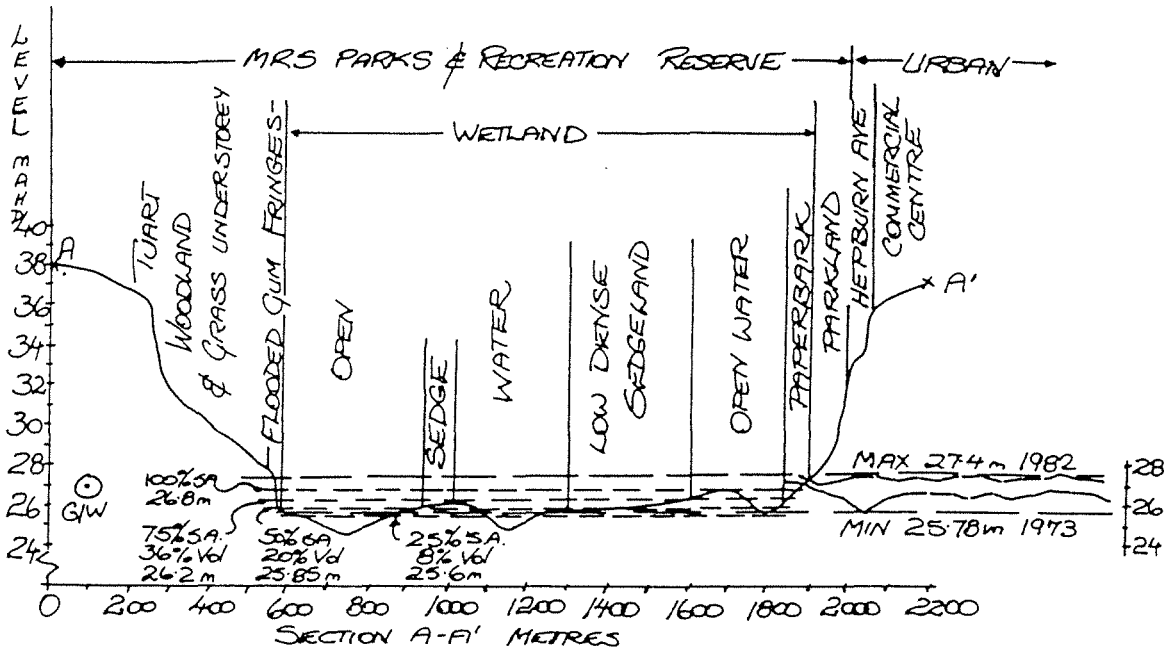


Figure 7.3 Lake Goollelal: diagrammatic cross-section and water level record.

7.2.8 FAUNA

Blair (1978) found mosquito breeding on the eastern shore in lake margins disturbed by grazing cattle. Trapping yielded low numbers of adult mosquitoes on the western side of the lake and relatively high numbers on the east. Four species were collected..

Suburban developments on the eastern side of the lake have been troubled by swarms of chironomid midge flies on summer nights for a number of years. Management of the problem is carried out by the City of Wanneroo (West, 1985).

The invertebrate fauna of the lake was sampled systematically in 1986-87 (Davis, Rolls and Balla, in preparation).

7.2.9 MANAGEMENT ISSUES - Refer to previous sections

7.2.10 REFERENCES

Blair, A (1978), Mosquito investigation No 2. Shire of Wanneroo. Bulletin No 36, Department of Conservation and Environment, Western Australia.

Congdon, R A (1986), Nutrient loading and phytoplankton blooms in Lake Joondalup, Wanneroo, Western Australia: Tech Ser 6. Department of Conservation and Environment, Western Australia.

Davis, J A, Rolls, S W and Balla, S A (in preparation), Environmental Protection Authority.

West, R M (1985), Update on the nuisance Midge. West Australian Health Surveyor. 6(1), 37-40.

7.3 BEENYUP AND WALLUBURNUP SWAMPS

7.3.1 GENERAL INFORMATION

AMG REFERENCE: 6481500 387000
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Parks and Recreation Reserve
RESERVE NUMBERS: Owned by State Planning Commission
PURPOSE: Parks and Recreation
MANAGEMENT: Local authority and State Planning Commission
SYSTEM 6 RECOMMENDATION: M6
WAC CLASSIFICATION: LE.f.l.s.c.
WATER RESERVE: west of Wanneroo Groundwater Area
DRAINAGE: Local drains - urban runoff

7.3.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). The swamps are seasonal wetlands and provide a link between Lake Goollelal and Lake Joondalup. Walluburnup is situated at about 19 m AHD; and Beenyup about 1 m lower.

7.3.3 AREAS

Beenyup:	Total wetland	39.9 ha
	Rush/sedgeland	12.8 ha
	Paperbark	15.8 ha
	Open Water Zone	2.9 ha
	Modified wetland	8.4 ha
Walluburnup:	Total Wetland	49.4 ha
	Rush/sedgeland	34.1 ha
	Paperbark	12.3 ha
	Modified wetland	2.8 ha

7.3.4 HYDROLOGY

Congdon (1986) stated that surface flow through the swamps accounted for 88% of the surface water input to Lake Joondalup in 1980.

No water level records are available.

7.3.5 WATER QUALITY

The swamps were sampled intensively by Congdon in 1979-80 in the course of a study of the nutrient status and water balance of Lake Joondalup (Congdon, 1986). He found that nutrient concentrations in the water column were very high in Walluburnup and Beenyup Swamps. His evidence suggests that there is considerable movement of nutrients northward from the swamps towards Lake Joondalup. Very high concentrations of nitrate-nitrogen were found in samples from the southern end of Walluburnup Swamp, while samples from these sites had relatively low concentrations of ammonium nitrogen. A high proportion of phosphorus was in soluble forms in samples from the swamps. The lowest pH and alkalinity readings were usually recorded in winter, and pH and optical densities suggested a flow of humic substances from Walluburnup and Beenyup Swamps into Lake Joondalup in winter. Fulvic and humic acid concentrations were found to be quite high in samples from the swamps.

Congdon estimated that in the period January to November 1980 more than 98% of the phosphorus input in surface discharge to Lake Joondalup came from the southern swamps, and this was dominated by reactive phosphorus. The inputs of total phosphorus and nitrogen were correlated with flow rate, with the greatest inputs occurring in winter. Low phytoplankton standing crops were observed in Beenyup Swamp despite the presence of high nutrient concentrations; this suggests that humic substances from the swamps may inhibit primary production.

7.3.6 LAND USE

Land use around the two swamps is rural, including horticulture, grazing and intensive poultry sheds.

High levels of nutrients have been identified emerging from the swamps, indicating that point sources of nutrients are located in the area. See Congdon, 1986.

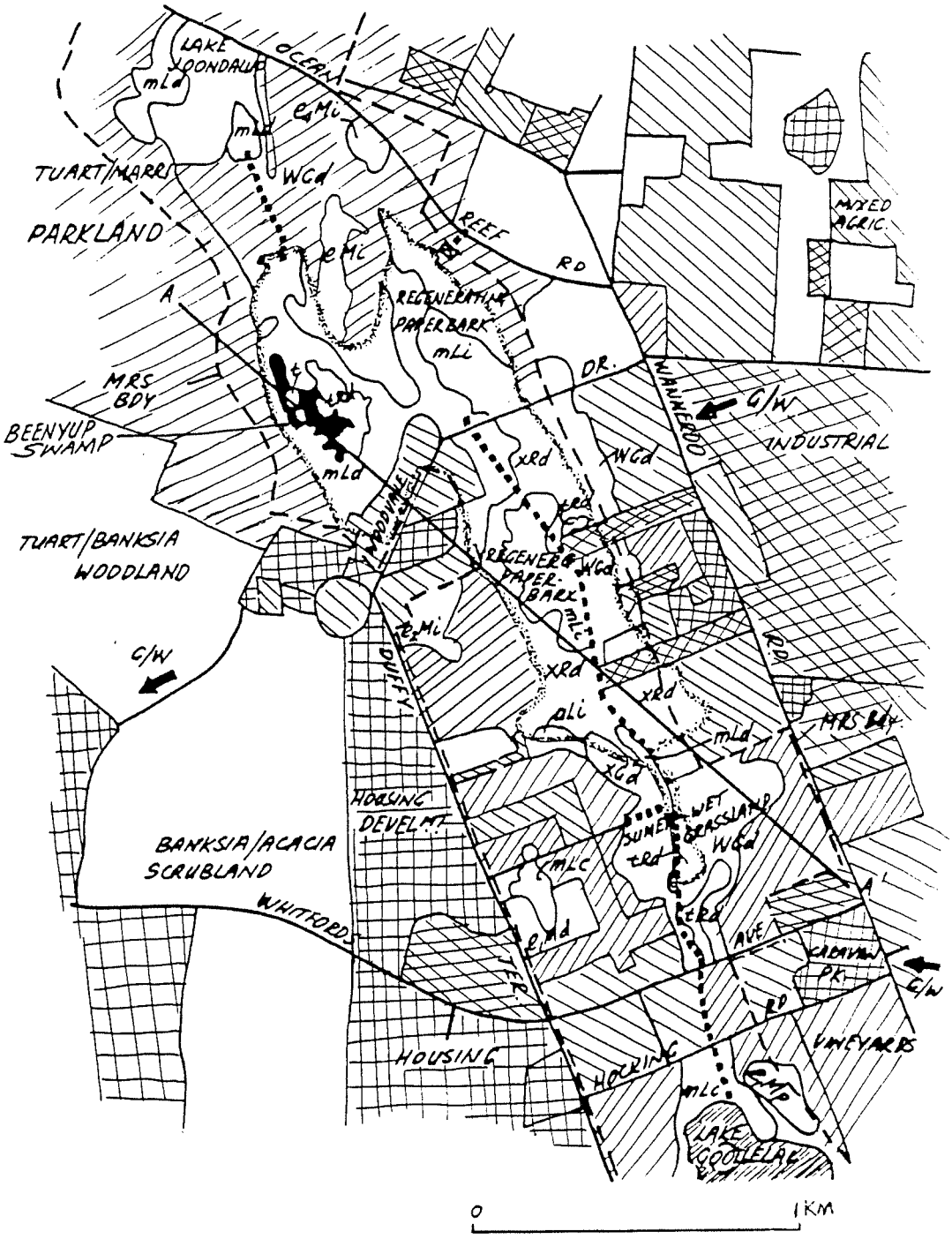


Figure 7.4 Beenyup and Walluburnup Swamps: wetland plant communities and surrounding land use.

7.3.7 VEGETATION (Figure 7.4)

The sedgelands appear to be invaded by young swamp paperbarks thus displaying a trend towards swamp woodland identified for north Loch McNess by McComb and McComb (1967).

7.3.8 FAUNA

There is little documented information about the fauna of Beenyup and Walluburnup Swamps. The swamps offer a range of habitat types (see Figure 7.4) including sedgeland, inundated shrubs and trees, shallow open water, non-living roost sites and nest sites. It is therefore probable that they support a range of resident and transitory bird populations.

Blair (1978) found mosquito breeding areas on the swamps in fringing paperbarks and in marginal puddles where larvae were secure from predatory fish.

7.3.9 MANAGEMENT ISSUES

The swamps will be affected by changes in land use and water balance in the surrounding area and hinterland and it is likely that the swamps will have an increasing drainage function. As a result it can be expected that there will be:

- increased inputs of nutrients;
- leaching out of humic materials, thus removing their inhibitory effects on phytoplankton;
- increased water levels resulting in a change towards more open water;
- potential for increased breeding of pest insects (Blair, 1978);and
- increased development of Typha orientalis and loss of habitat diversity.

These potential stresses should be considered in management plans for the area. Long-term plans for the Goollelal-Joondalup Open Space area may involve modification of the swamplands for active recreation. Management of the swamps will affect Lake Joondalup so that any management should be compatible with intentions for the larger lake.

7.3.10 REFERENCES

Blair, A (1978), Mosquito investigation No 2. Shire of Wanneroo. Bulletin No 36, Department of Conservation and Environment, Western Australia.

Congdon, R A (1986), Nutrient loading and phytoplankton blooms in Lake Joondalup, Wanneroo, Western Australia. Tech Ser 6 Department of Conservation and Environment, Western Australia.

7.4 LAKE JOONDALUP

7.4.1 GENERAL INFORMATION

AMG: 64865000 385000
LOCAL AUTHORITY: City of Wanneroo

MRS ZONE: Parks and Recreation Reserve
RESERVE Nos: A311048 plus a number of small reserves
PURPOSE: Conservation of Fauna; Parks and Recreation
MANAGEMENT: CALM; Joondalup Corporation; City of Wanneroo: State Planning Commission
SYSTEM 6 STUDY RECOMMENDATION: M7
WAC CLASSIFICATION: LE.1.b.p.so.
WATER RESERVE: west of Wanneroo Groundwater Area
DRAINAGE: local urban and rural

7.4.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Joondalup is described as marsh and lake in a low level interbarrier depression (Gozzard, 1982) within sands derived from Tamala limestone. The lake lies at the interface of the Karrakatta and Cottesloe landforms (Department of Conservation and Environment, 1980) with the northern third of the lake lying within the Cottesloe system. Land on the western side of the lake rises rapidly and limestone is quarried at sites on the western shore. The eastern shore slopes more gently. There are accounts of a cave system on the north-west which functions as an overflow when the lake reaches high levels.

There are two islands in the lake and a number of beds of jointed twig-rush. The southern end of the lake has been isolated from the remainder by the causeway for Ocean Reef Road. Submerged fences north of the causeway and north of Lake Island, and standing dead trees within the water body, indicate that water levels are higher now than at some time in the past. Bathymetry indicates that the lake basin is deeper in the north than the south. The deepest point on the lake bed is 15.4 m AHD.

7.4.3 AREAS

Area within MRS Reserve (includes upland buffer)	908 ha
Area of reed/sedgeland	79 ha
Area of paperbark	64 ha
Area of open water	449 ha
Total recorded/water area	529 ha

7.4.4 HYDROLOGY (Figure 7.6)

The hydrology of Lake Joondalup is described by Congdon (1985) following studies in 1978-80. He showed:

- the input of water due to rainfall amounted to 70% of the loss due to evaporation;
- stormwater from rain events drains rapidly into stormwater sumps and thence into the lake on the eastern side, amounting to 12% of the surface water input in 1980;
- surface water flows into the lake from the south, from the Walluburnup-Beenyup Swamp system. This accounted for some 88% of surface discharge into the lake in 1980;
- surface discharge into the main basin of the lake, through the Ocean Reef Road culvert, was equivalent to 27% of the input due to rainfall;

- there was a net input of groundwater to the lake during 1980. A net inflow of groundwater occurred in autumn, winter and spring and a net outflow in summer; and

- seepage of groundwater into the lake appears to occur on the eastern shore and there is some evidence of seepage near the western shore.

Congdon pointed to changes in the lake catchment as a result of urbanisation and to a need for management of surface inflow and nutrient load to the lake, recognising problems of algal blooms, chironomid midges and increasing demands for groundwater.

Unlike Lake Goollelal, both maximum and minimum water levels in Lake Joondalup have been lower since 1976 than in the preceding years although they have not reached the low minimum levels recorded in the early 1960s.

Table 7.3. Lake Joondalup: water levels 1969-84.

i Maximum level recorded: 18.31 m AHD (1968).

ii Number of years in which maximum lake levels fell within specified ranges.

m AHD	1969-75	1976-84
>18.0	1	0
17.5-18.0	2	0
17.0-17.5	2	9

iii Minimum level recorded: 15.7 m AHD (1962).

iv Number of years minimum lake levels fell within the specified ranges.

m AHD	1969-75	1976-84
>17.5	1	0
17.0-17.5	2	0
16.5-17.0	4	7
16.5	0	2

It is probable that water levels in Lake Joondalup have been much lower in the past. The Journals of Grey (1841) give the following description of his travels on 20 April, 1838, which is purported to refer to Lake Joondalup:

> 'The country through which we were travelling is intersected by a long line of lakes, which run nearly parallel to the sea for a distance of about forty-five miles. ... we suddenly came out on the bed of a dried up swamp, looking like a desert of white sand studded with reeds. The forms of natives were seen wandering about this, one mile from us, who were searching for frogs. ... Anxious questions were put by the men, as to their distance from Perth, and the natives all told them they would see it the next morning, "whilst the sun was still small"... '

In the first half of this century the southern part of Lake Joondalup was farmed. Mr Nick Crisafuli (personal communication) has told of the location of vegetable gardens on the eastern side of the lake and problems caused by grazing cattle crossing the lake basin from the west. Fencelines can still be seen in the lake. Subsequently, rising water levels caused these gardens to be abandoned.

7.4.5 WATER QUALITY

Congdon (1986) described the results of a detailed survey of the seasonal and spatial changes in physical and chemical aspects of the lake waters and sediments, the phosphorus and nitrogen budgets of the lake and changes in phytoplankton standing crop. Some points to emerge from the study are:

- nutrient levels were higher in 1979-80 than they were in 1973 and 1975;
- phosphorus concentrations in the water column showed an increasing gradient with distance south, with very high concentrations in Beenyup and Walluburnup Swamps;
- highest phosphorus concentrations occurred in late summer to early winter;
- highest nitrogen levels occurred in the southernmost basin of the lake;
- water samples from Lake Joondalup contained ratios of inorganic nitrogen to phosphorus of less that 15:1;
- high inorganic N:P rations were recorded in stormwater in winter and early spring when concentrations of NO_3 were high;
- more that 98% of the phosphorus input in surface discharge to Lake Joondalup comes from the southern swamps, and is dominated by reactive phosphorus;
- sedimentation resulted in the loss of 78% of the external input of phosphorus from the water column in 1979-80;
- between January and November 1980 there was a net increase of 81 kg of phosphorus in the water column of the lake;
- the sediments contain a large nutrient pool. The surface 10 cm of sediment contains more that 100 times the nitrogen and phosphorus found in the water column; and
- the vegetation of the lake contains less than 10% of the nitrogen and phosphorus found in the water column.

For the period January to November 1980, the gross external nutrient loadings were 86 mg P m^{-2} and 655 mg N m^{-2}. The phosphorus loading exceeds that considered to be permissible for shallow lakes:

- the mean chlorophyll concentrations indicate that Lake Joondalup is eutrophic;

- mean concentrations of chlorophyll a (indicating presence of algae) were higher in the southernmost basin of Lake Joondalup than in the main water body;

- chlorophyll a concentrations in the main waterbody were highest in late summer to early autumn and were higher in 1980 than 1979;

- in January 1979, March 1979, August 1980 and September 1980 the highest concentrations of chlorophyll a within Lake Joondalup were found near the eastern shore. This may reflect the inflow of nutrients in groundwater; and

- phytoplankton blooms appear to be caused by the high phosphorus loads in water flowing from Walluburnup and Beenyup Swamps. The low nitrogen to phosphorus ratio of the water favours the atmospheric nitrogen fixing blue green algae Anabaena spiroides.

Water samples collected and analysed during 1985-87 are reported by Davis and Rolls (1987). They permit comparisons with Congdon's results and provide useful indications of the current water quality status of the lake.

7.4.6 LAND USE - Refer to Figure 7.5

7.4.7 VEGETATION (Figure 7.5)

Congdon and McComb (1976) described the vegetation. Blair (1979), Bekle (1981) and James (1982) have also mapped the vegetation of the lake. The WA Museum (How, 1978) also mapped the vegetation of the lake margin.

Through the work of Congdon, the benthic vegetation of the lake is better known than for any other lake on the coastal plain.

More than 50% of the lake has a wide buffer of native vegetation although the buffer is being altered by development for recreation. Some notable features of the vegetation include an even-aged stand of Eucalyptus rudis on the south-western side, north of Ocean Reef Road, and very clearly defined zonation of the vegetation along the mid-western shore, north and south of Hawkins Park. The vegetation bands are narrow, reflecting the relative steepness of the lake shore. The zonation includes Baumea articulata as an emergent on the lake margin, a zone of swamp paperbark and E.rudis higher up the bank with a marked transition to Tuart woodland. Typha orientalis appears to be becoming increasingly abundant along the eastern and northern shores.

7.4.8 FAUNA

7.4.8.1 Invertebrate Fauna

Ayre et al. (1977) showed that the lake invertebrate fauna is characterised by large numbers but limited diversity. The work of Davis and Rolls (1987) provides a record of spatial and seasonal differences in the fauna and enables comparisons to be made with other metropolitan wetlands.

Blair (1978) investigated the mosquito fauna of the Wanneroo area, sampling at two sites on Lake Joondalup. He found six species of mosquitoes, four of which are known to breed in shallow fresh water, usually in disturbed areas of the lake margin. The larval stages of one species, Coquellettidia linealis, have never been found but are thought to be associated with fringing rushes and sedges.

Large swarms of chironomid midges emerge on the eastern side of the lake and have, on occasions, caused a nuisance to residents in the lake-side streets of Wanneroo (West, 1985). The pesticide ABATE has been applied to the lake to control the chironomid midges. Removal of vegetation buffers on the eastern shore in order to open lake views may increase the movement of midge swarms on the prevailing evening south-westerly winds into the urban developments of the Wanneroo town site.

7.4.8.2 Birds

There have been a number of studies of the bird fauna (How, 1978; Bekle 1979; Jaensch, in press). In the course of the extensive surveys carried out during the South West Waterbird (Jaensch, in press) Project 51 species of waterbirds were observed at Lake Joondalup Nature Reserve and it was found to be an important reserve for the Great Crested Grebe, Dusky Moorhen, Black-fronted Plover, Red-necked Avocet and Eurasian Coot. Joondalup is important for breeding by the Great Crested Grebe, Blue-billed Duck and Musk Duck and the most regular haunt of the uncommon Cattle Egret.

Only four reserves in the region in which Joondalup was included (Jurien - Gingin region) are more important than Joondalup in terms of number of species recorded breeding.

Six species listed in the Japan - Australia Migratory Birds Agreement occur at Joondalup Lake - four migratory waders and the Cattle and Great Egrets.

Van Delft (1988) provides notes about bird-watching around Lake Joondalup.

7.4.9 MANAGEMENT ISSUES

Stresses

Changing land uses will continue to impose stresses on Lake Joondalup. These will include:

. a changing water regime;

. increased nutrient levels;

. competing demands for recreation, lake views and wildlife conservation;

. location of bores on the eastern shore near where groundwater enters the lake; and

. unsewered suburban areas on the eastern side of the lake.

Management Issues

The City of Wanneroo is addressing management issues through the agency of its Lakes Management Committee, which has been given the short-term task of advising on appropriate management of the Wanneroo lakes. The Council has also involved the Wanneroo branch of the Western Australian Naturalists Club in management initiatives for Lake Joondalup.

Particular issues will be:

. management of surface runoff;

. management of water quality;

. management of Typha expansion;

. protection of sedge margins of the lake;

. management of insect pests and nuisance insects; and

. protection of landscape and amenity values.

Emphasis should be placed on initiatives which protect and enhance the existing biota and minimise disturbances to the physical integrity of the lake margins and water supply.

It is clear that Lake Joondalup as a landscape feature is extremely important in the developing suburban setting. The community responses to projected increases in groundwater extraction for public water supply in the course of the public review of the Gnangara Mound (Water Authority 1986) reflect this importance. This importance is no doubt reflected in the value of properties with lake views. There is need for the community to recognise the need to manage the groundwater resource if the amenity of the lake is to be protected.

7.4.10 REFERENCES

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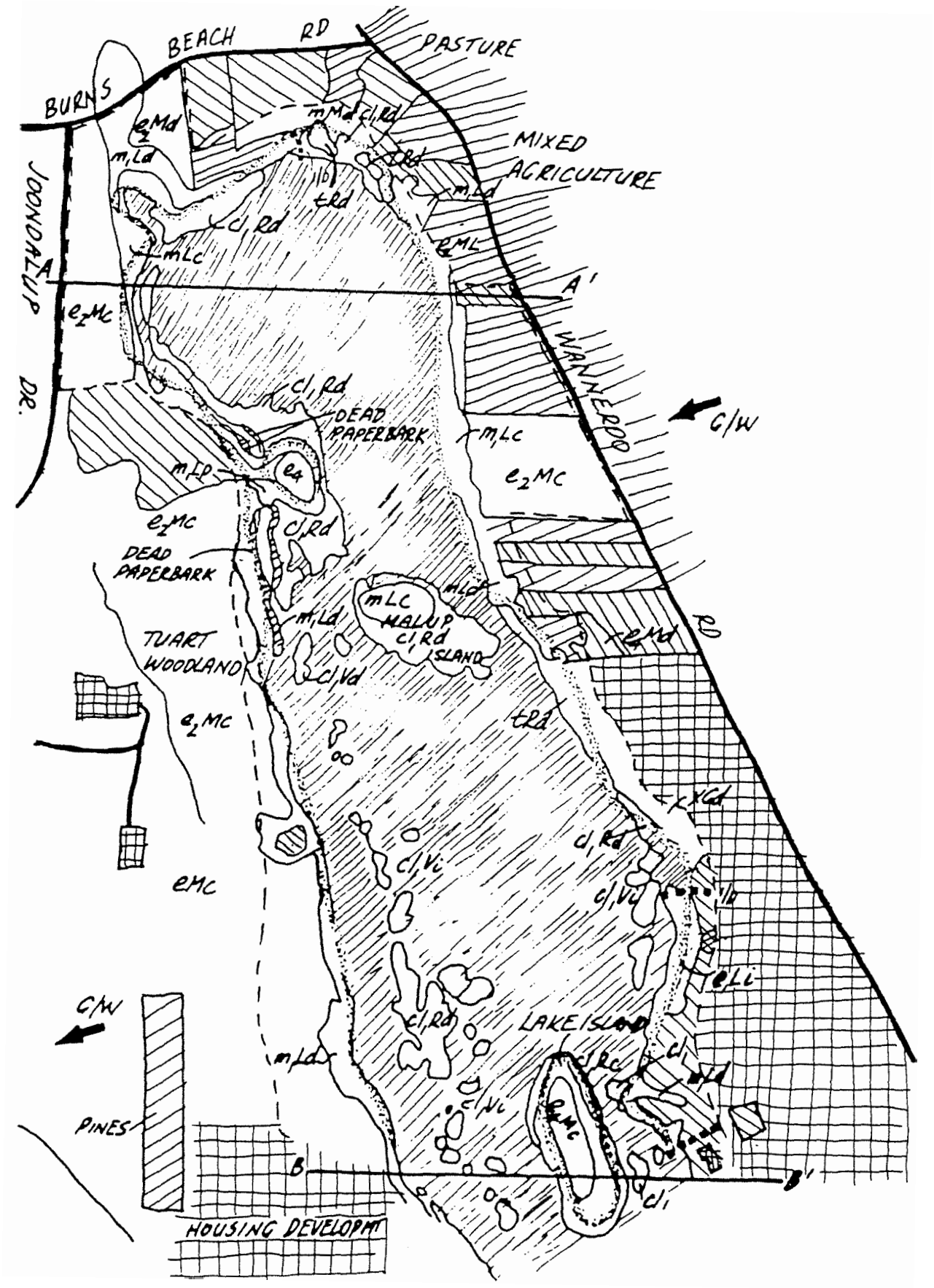

Figure 7.5 (a) Lake Joondalup: (North Section) wetland plant communities and surrounding land use.

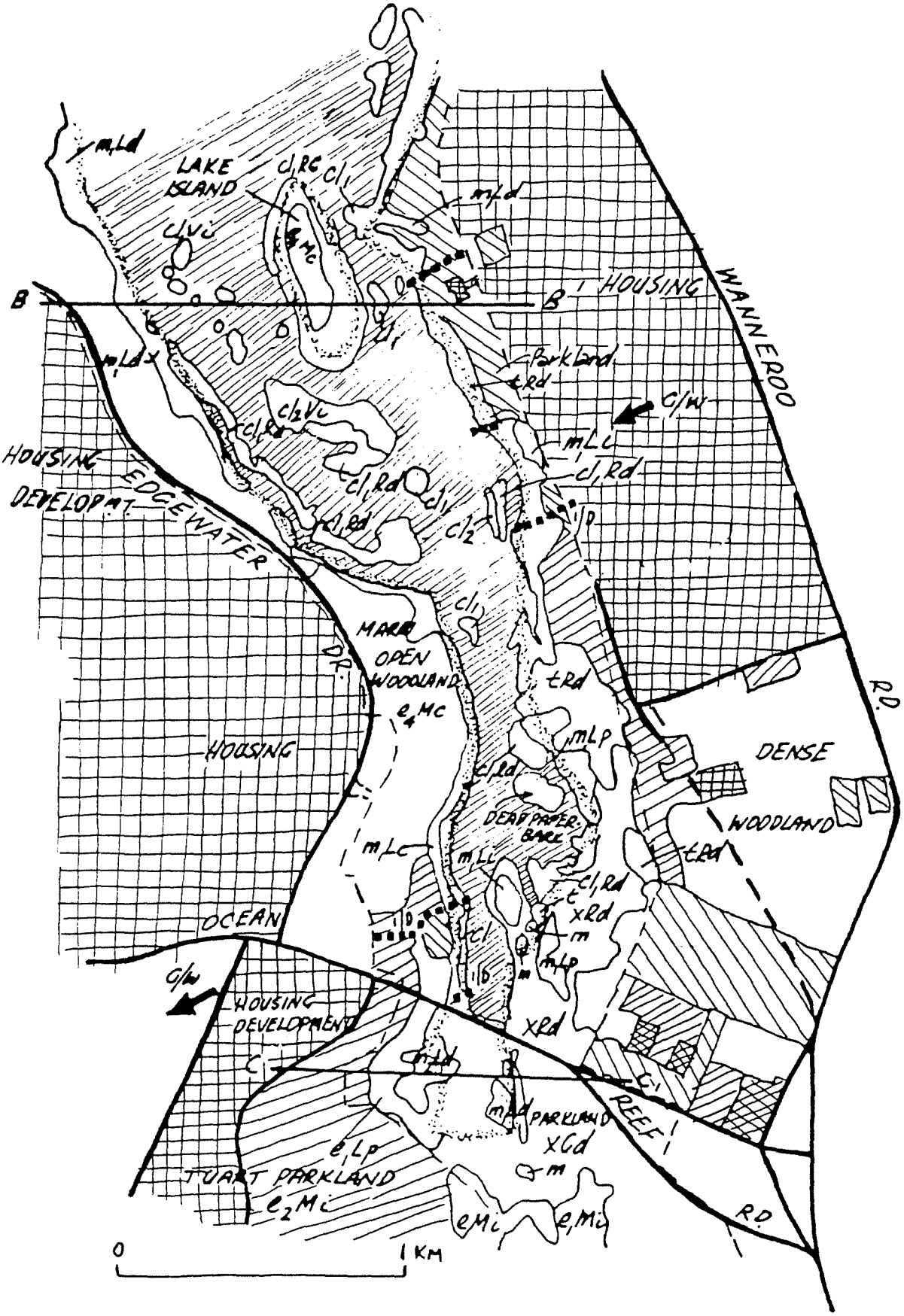

Figure 7.5 (b) Lake Joondalup: (South Section) wetland plant communities and surrounding land use.

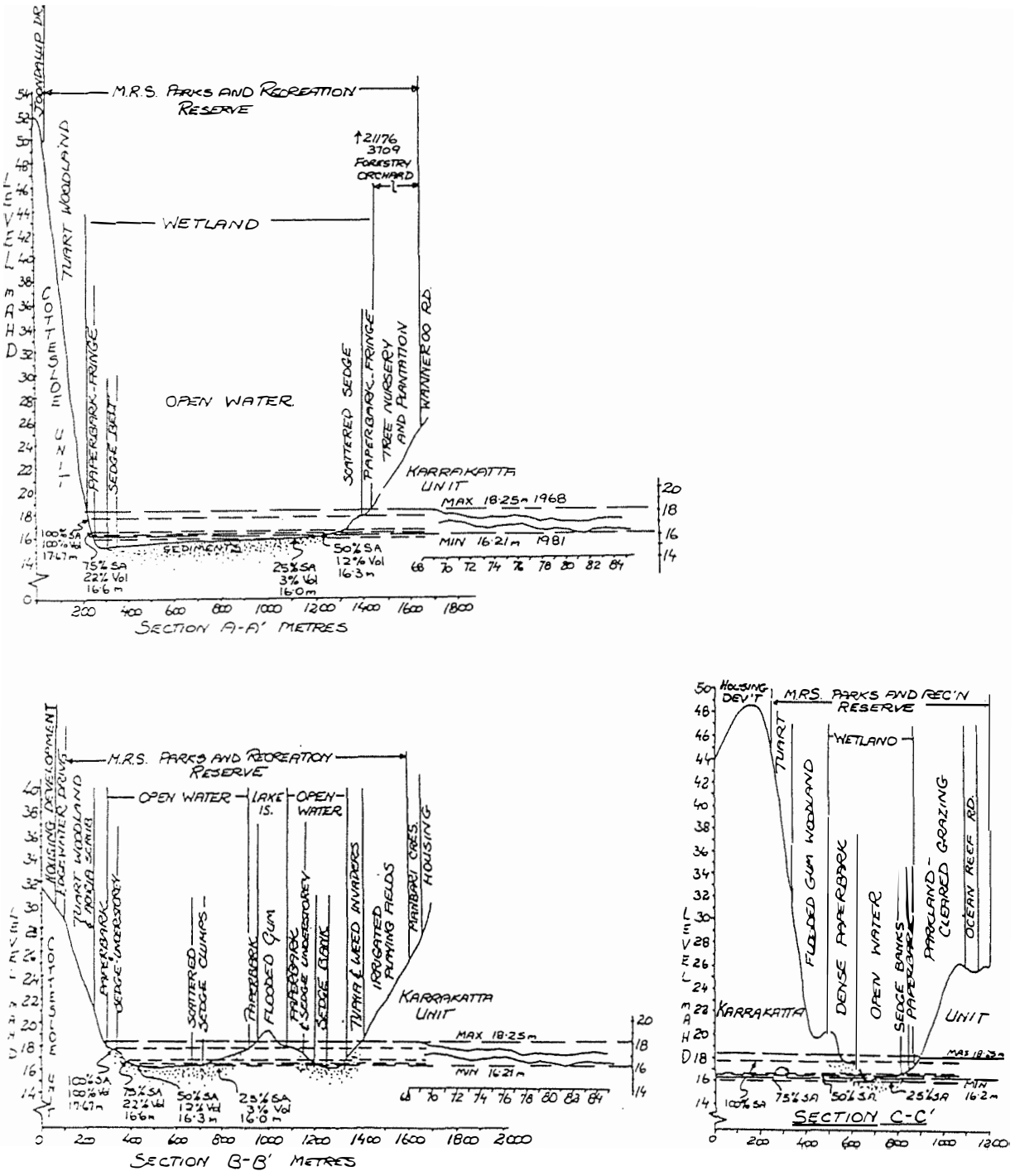

Figure 7.6 Lake Joondalup: diagrammatic cross-sections A-A', B-B' and C-C' and water level record.

7.5 SMALL LAKE NORTH OF BURNS BEACH ROAD (NO NAME - identified as Joondalup, North)

7.5.1 GENERAL INFORMATION

AMG: 6491000 383500
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE No: privately owned
PURPOSE: rural uses
MANAGEMENT: Private
SYSTEM 6 STUDY RECOMMENDATION: M6
WAC CLASSIF: LE.f.m.p.sc
WATER RESERVE: West of Wanneroo Groundwater Area
DRAINAGE: no formal drains

7.5.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The physiography of the lake is similar to Joondalup with a strongly marked rise on the western side of the lake and a less severe slope up to Wanneroo Road on the eastern side. High land to the north of this wetland separates it from Lake Neerabup, the next of the north-south series of the Wanneroo wetland chain. Continuity between this wetland and Lake Joondalup to the south is indicated by surface contours.

7.5.3 AREAS

Total area of wetland	42.0 ha
Reed/sedgeland	3.4 ha
Closed paperbark	32.5 ha
Open water zone	3.1 ha
Modified and cultivated	3.0 ha

7.5.4 HYDROLOGY

There is apparently no record of water levels in this wetland. The water body appears to be permanent.

It is likely that changes in land use around the wetland would be reflected in water level changes, with any significant sustained rises in water level leading to death of the closed paperbark woodland on the western part.

During cycles of high rainfall, it is to be expected that the continuity between this lake and Joondalup would be more marked.

7.5.5 WATER QUALITY - No data available.

7.5.6 LAND USE - Refer to Figure 7.7

7.5.7 VEGETATION (Figure 7.7)

The western part of the wetland is closed paperbark wetland with *Melaleuca rhaphiophylla* being the dominant species and some *M. lateritia*. The eastern half of the wetland is open water to closed *Typha* swamp. This section is directly affected by horticulture and grazing stock.

Some large *M. preissiana* in deep grey sand to the south of this wetland appear to represent an uncharacteristic occurrence of this species which is normally found in Bassendean sands.

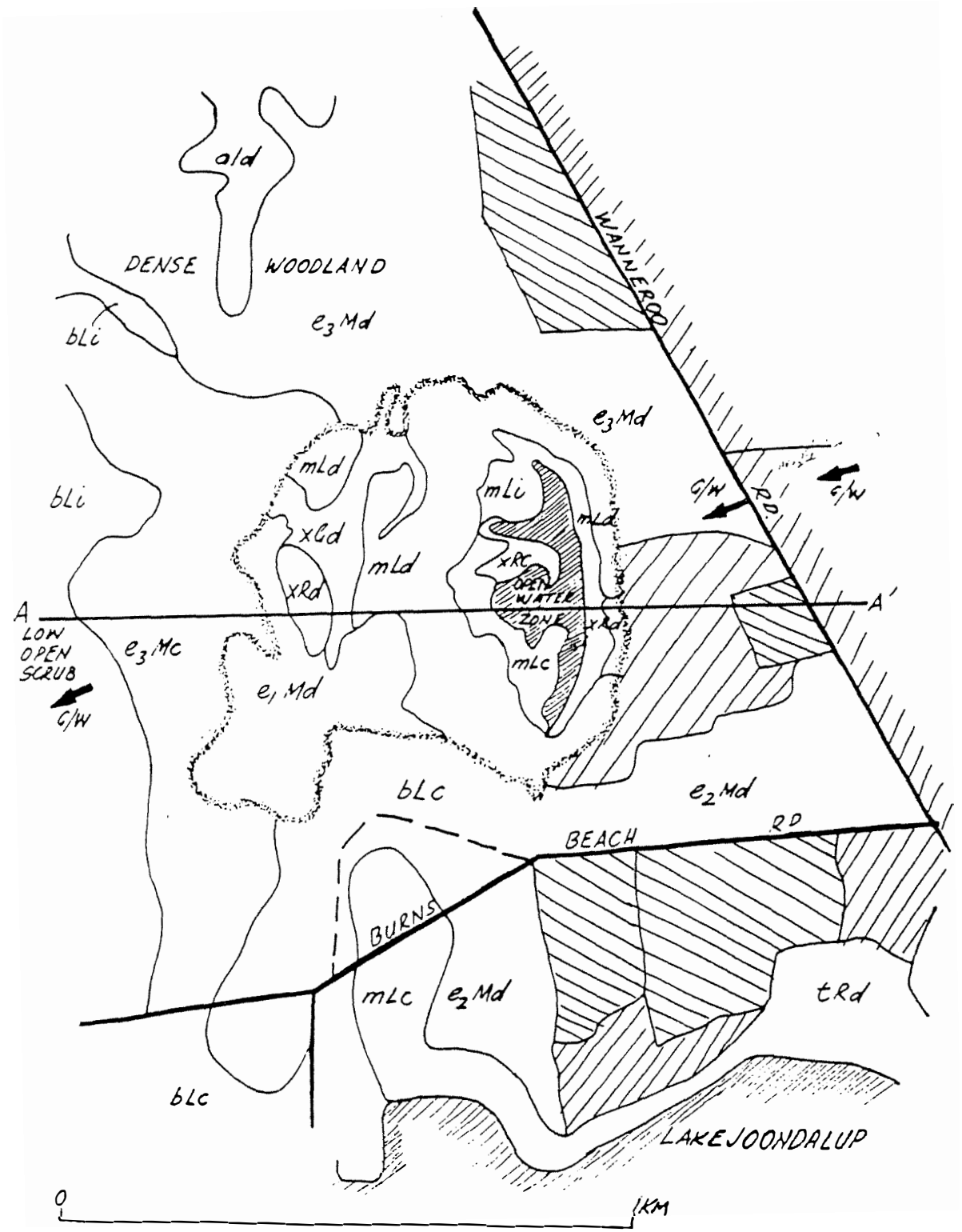

Figure 7.7 Unnamed wetland north of Lake Joondalup: wetland plant communities and surrounding land use.

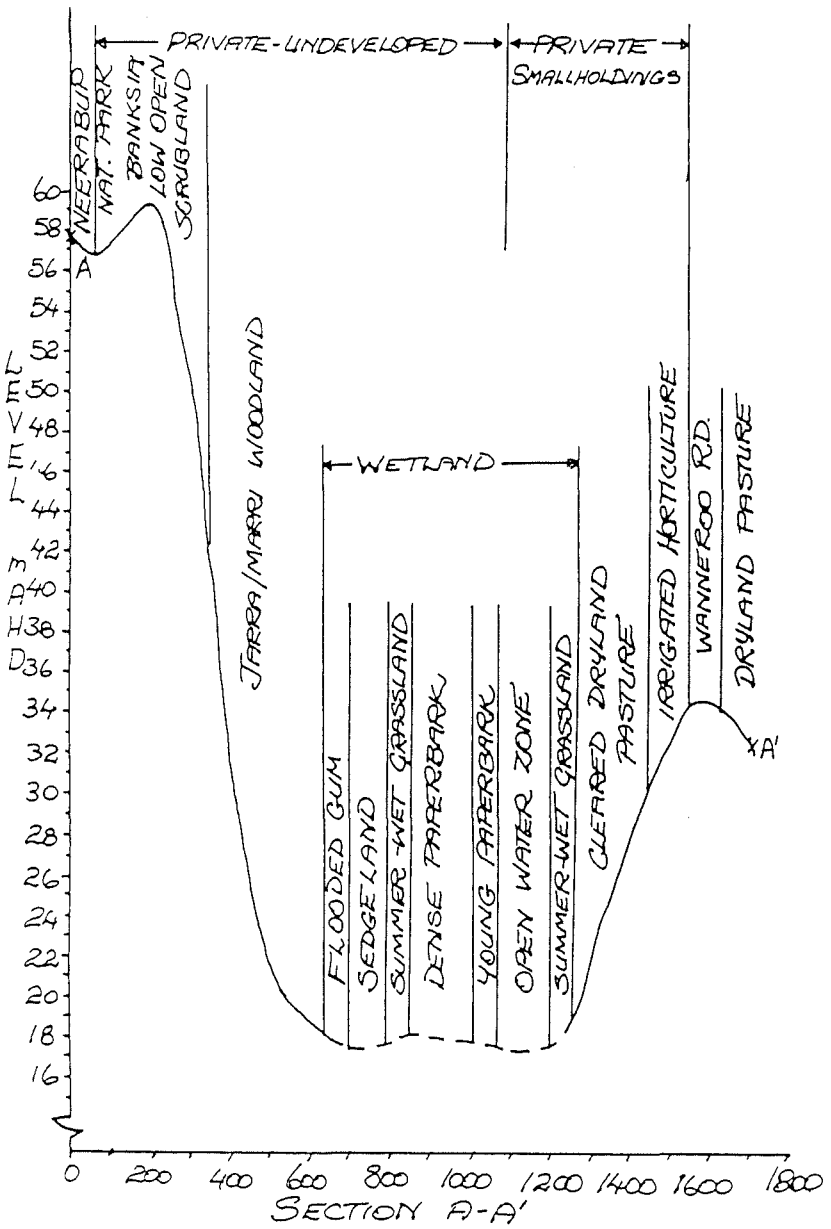

Figure 7.8 Unnamed wetland north of Lake Joondalup: diagrammatic cross-section.

7.5.8 FAUNA

Blair (1979) noted that mosquitoes were very abundant in the vicinity of this wetland. As he was unable to find the mosquito fish (Gambusia) in the wetland waters he speculated that this may account for the large numbers of mosquitoes present. If Gambusia are indeed absent from this wetland, it may represent an interesting relic of undisturbed native fauna. No further data appear to be available on the fauna of this wetland.

7.5.9 MANAGEMENT ISSUES

Stresses on this wetland will result from the effects of horticulture on water availability and water quality. Increased water levels resulting from clearing and urbanisation could result in increased flows of water and nutrients towards Lake Joondalup.

Fire may be an additional factor that would encourage the spread of Typha. Future roadworks may impinge upon the wetland margins.

This area should be managed similarly to Lake Joondalup. In particular the existing vegetation should be protected and managed to encourage regeneration of Melaluca so that deep shade within the paperbark prevents the spread of Typha from the western section.

7.5.10 REFERENCE

Blair, A (1978), Mosquito investigation No 2. Shire of Wanneroo. Bulletin No 36, Department of Conservation and Environment, Western Australia.

7.6 LAKE NEERABUP

7.6.1 GENERAL INFORMATION

AMG REF: 6498500 383200
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NUMBERS: None - privately owned
MANAGEMENT: Private owners
SYSTEM 6 RECOMMENDATION: No recommendation
WAC CLASSIFICATION: LE.b.s.c.
DRAINAGE: informal only
MINING: informal peat excavations

7.6.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Gozzard (1982a) shows two sink holes on the eastern side of the lake. Bridge (1968, 1969, 1971) reported on investigations of karstic features around the lake including Orchestral Shell Cave and channels and springs.

7.6.3 AREAS

Total wetland	212 ha
Sedgeland	80 ha
Paperbark	42 ha
Open water zone (summer grassland)	71 ha
Modified wetland	?45 ha+

7.6.4 HYDROLOGY (Figure 7.10)

The water level record is characterised by consistent upper levels at or slightly above 13.2 m AHD. Bridge (1968) observed on 21.7.1968 a very strong flowing stream entering the lake on the western side; on 9.11.68 the flow in the stream was reversed. Bridge (1971) commented further on caves and springs related to the lake.

Table 7.4. Lake Neerabup: water levels 1973-84.

i Maximum level 13.45 m AHD (1973).

ii Number of years maximum lake level has fallen within specified ranges.

LEVEL (m AHD)	1973-84
>13.4	1
13.2-13.4	9
13.0-13.2	1

iii Minimum level 10.14 m AHD (1978).

iv Number of years minimum lake level has fallen within specified ranges.

m AHD	1973-85
>12.0	1
11.5-12.0	2
11.0-11.5	1
10.5-11.0	5
10.0-10.5	3

The average range between spring maximum levels and autumn minimum levels is 2.3 m. The length of time the water level exceeds 13.0 m is tending to become shorter. It was six months prior to 1976, four to five months in 1976-82 and three months in 1984.

7.6.5 WATER QUALITY

No information available.

7.6.6 LAND USE

All of Lake Neerabup is privately owned. The holdings are generally small and are used for a range of activities including horticulture and grazing. Some small-scale peat mining takes place on the lake bed.

The lake bed supports extensive beds of Typha. Expansion of Typha may have occurred following cultivation of the lake bed in earlier years.

The most intensive horticulture takes place on the western side of the lake. On the eastern side, south of Wattle Avenue, the holdings are larger than on the west and appear to be largely extensive grazing. The land east of the lake has closed heath indicating shallow soils over limestone.

7.6.7 VEGETATION (Figure 7.9)

The vegetation has been strongly modified by clearing and farming activities; extensive Typha beds are probably an artefact induced by cultivation of the lake bed.

7.6.8 FAUNA

No information available. Lake Neerabup was treated by the Department of Agriculture during the early 1980's to eradicate Argentine Ants.

7.6.9 MANAGEMENT ISSUES

The System 6 Study did not make a specific recommendation about Lake Neerabup because it was considered that purchase of the land to bring it into public ownership would be too expensive. Nevertheless, the lake is a significant feature in the region, situated close to the eastern margin of the north-west urban corridor.

The topography of the lake and its notable karstic features impart considerable interest to it. Orchestral Shell Cave, while not specifically related to the wetland, is of considerable ethnographic and scientific interest (Hallam, 1974) and is vested in the City of Wanneroo. The lake environs also retain some relics of the early European activities in the region, including lime kilns (Brittain, 1985) and buildings.

The lake provides landscape interest to the area, and is visible from Wanneroo Road, an important tourist route.

Management of the groundwater use in the area may be warranted to maintain some control on the draw so that summer water levels do not fall below present limits and so that high levels are maintained for several months during late winter and spring.

7.6.10 REFERENCES

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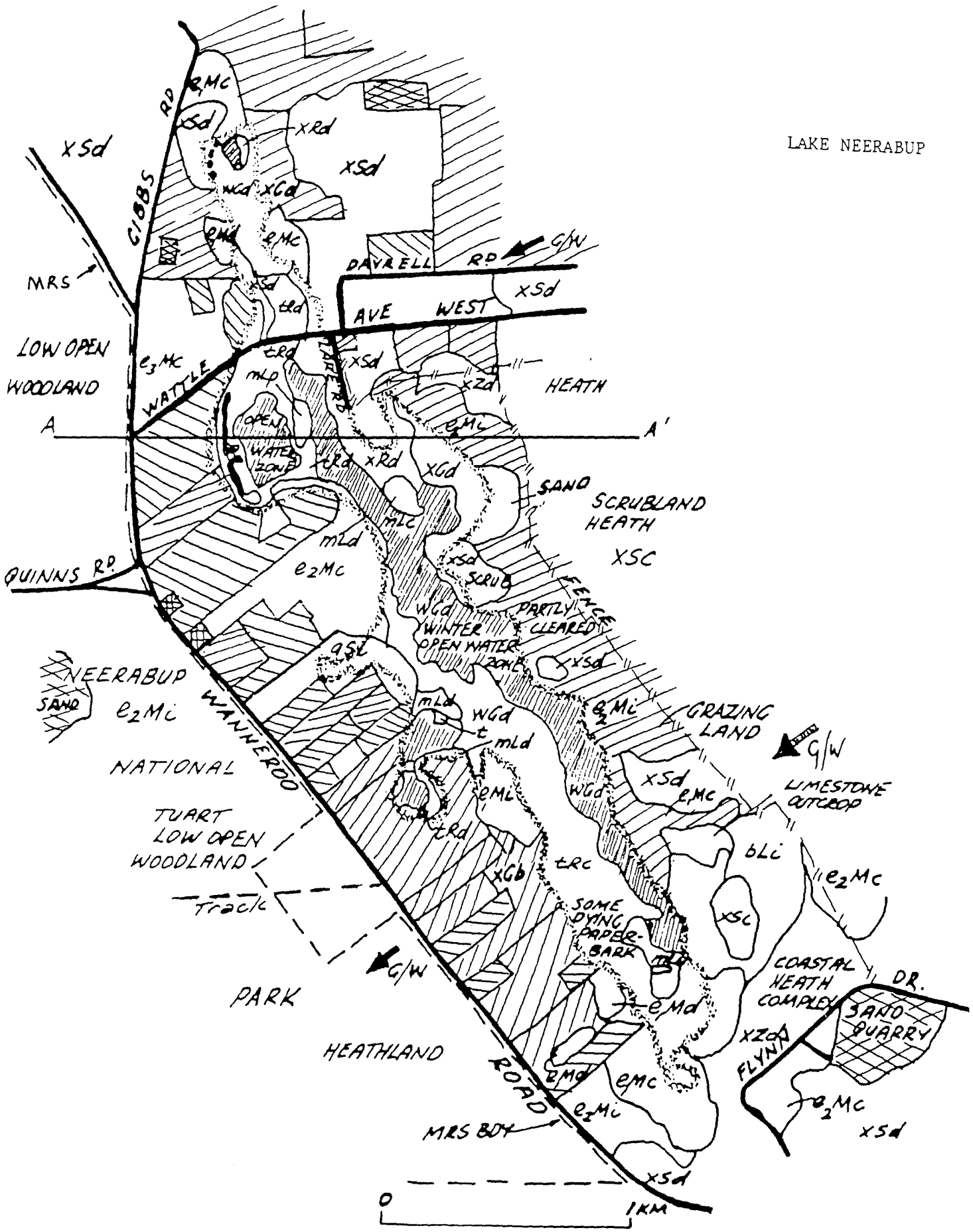

Figure 7.9 Lake Neerabup: wetland plant communities and surrounding land use.

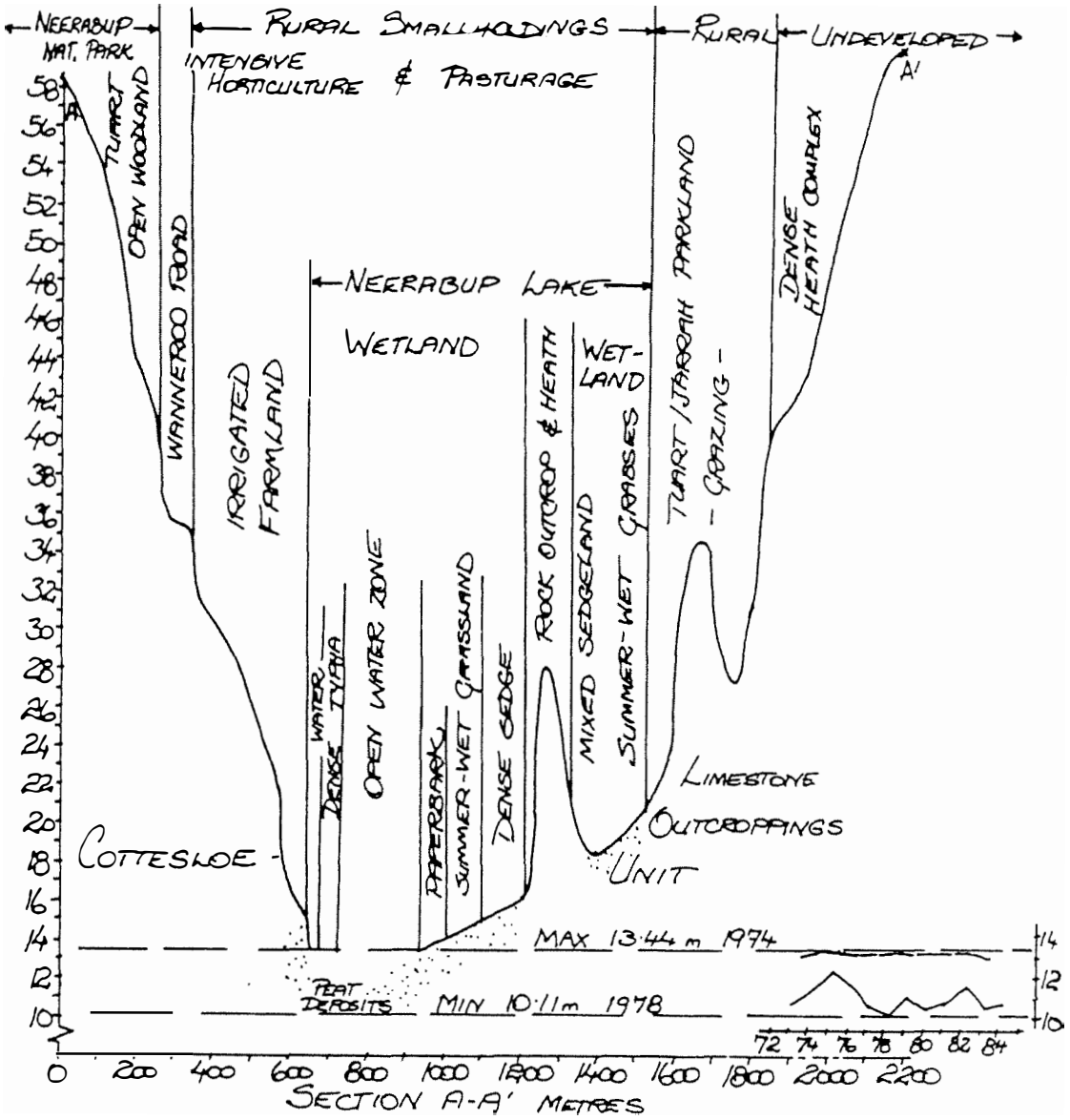

Figure 7.10 Lake Neerabup: diagrammatic cross-section and water level record.

7.7 LAKE NOWERGUP

7.7.1 GENERAL INFORMATION

AMG REF: 649500 379500
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NOS: A24581;8398
PURPOSE: Sanctuary for Fauna; access to lake
MANAGEMENT: CALM
SYSTEM 6 RECOMMENDATION: M6
WAC CLASSIFICATION: LE.b.l.p.o.
DRAINAGE: informal - piggery effluent

7.7.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Nowergup is higher in the landscape than either Neerabup to the south or Carabooda, 500 m to the north. It is situated between the 19 m groundwater contour to the east and the 18 m contour on the west. Its maximum water levels are some 4 m above those of Lake Neerabup and its minimum levels are some 6 m above Lake Neerabup. The basin appears simpler in structure than either of the nearby lakes, lacking karstic features.

7.7.3 AREAS AND BATHYMETRY (Figure 7.13)

Total area of Reserves: ..... 116.4 ha

Area of wetland ..... 54.3 ha
Area of sedgeland ..... 6.9 ha
Area of paperbark ..... 7.8 ha
Area of open water zone ..... 34 ha
Area of modified wetland ..... 5.6 ha

A series of soundings was carried out on the lake on 7 November 1986 to obtain some information about the lake basin. From data from the Water Authority of Western Australia, the water level at that time was 17.106 m AHD.

The greatest depth measured was 4.0 m (13.106 m AHD).

The soundings enabled approximate lake basin contours to be drawn. On the basis of these data the following approximate areas have been estimated from a tracing on squared paper:

Area of lake to water level 17.1 m AHD: ..... 44.7 ha (100%)
(includes some areas of fringing vegetation)
Area of lake below 16.1 m AHD ..... 27.1 ha (61%
(below lowest water level yet recorded)
Area of lake below about 15.5 m AHD ..... 14.8 ha (33%)
Area of lake below about 14.5 m AHD ..... 7.7 ha (17%)

Further detailed bathymetric surveys have since been undertaken and the results are presented as Figure 7.13.

7.7.4 HYDROLOGY (Figure 7.12)

The water level record differs from those of the adjacent lakes in that there is no evidence of an overflow system at high water levels.

The lake level varies less than that of adjacent lakes. The twelve years of water level records are summarised below. There is visably a trend towards lower levels and shorter periods of high levels. It might be expected that if these trends continue there will be changes in the fringing vegetation with young paperbarks and rushes appearing in what is at present open water.

Table 7.5. Lake Nowergup: water levels 1973-84.

i Maximum level: 17.72 m (1974).

ii Number of years maximum lake level has fallen within the specified ranges.

m AHD	1973-84
>17.5	3
17.25-17.5	3
17.00-17.25	6

iii Minimum level 16.31 m (1980).

iv Number of years minimum lake level has fallen within the specified ranges.

m AHD	1973-85
16.5-17.0	10
<16.5	3

v Number of months the water level exceeded 17.0 m in the years 1973-84.

1973	5
1974	9
1975	6
1976	4
1977	4
1978	6
1979	5
1980	5
1981	3
1982	4
1983	2
1984	1

7.7.5 WATER QUALITY

There are no data available. Nutrients from the free-range piggery on the eastern shore are likely to cause nutrient enrichment, increased Biological Oxygen Demand and increased bacterial levels. (Nitrogen and phosphorus input from one pig is said to be equivalent to that from four humans. If this is the case, nutrients emanating from this small piggery (2.6 ha) with, say, 100 pigs, could be equivalent to the sewage output of a small country town).

7.7.6 LAND USE

Lake Nowergup (A↑24581) and Neerabup National Park (A↑27575) are proposed as a regional park. The reserves are currently vested in the National Parks and Nature Conservation Authority. Adjoining the eastern shore of the lake are a free-range piggery and a number of small holdings. Cattle have free access to the lake, although the margin of the lake is reserved. East of Gibbs Road is a large lucerne farm with very large "water-cannon"-type sprinklers. To the south-east of the lake is a large, intensive market garden.

Bailey (1977) carried out a recreation survey of Lake Nowergup and found that no recreational use was made of the lake. Access to the lake is difficult but can be gained via Reserve 8398 which links Gibbs Road to the southern end of the lake.

7.7.7 VEGETATION (Figure 7.11)

There is intact vegetation on the west and south of the lake and mature closed swamp paperbark woodland at the southern end. Comparison of aerial photographs of the lake indicate that there has been a fourfold increase in the area occupied by Typha orientalis between December 1976 and April 1985.

Vegetation in Reserve A↑24581 contains representatives of most vegetation types of the Spearwood dune system (David Lamont pers comm) including:

- wetland plant communities - sedgelands, swamp paperbark and swamp banksia;
- tuart woodland;
- jarrah - banksia woodland;
- prickly bark - banksia; and
- limestone heath.

7.7.8 FAUNA

No data are available on the invertebrate fauna.

Large numbers of waterfowl use the lake (David Lamont pers comm) including Black Swan, Pacific Black Duck, Australian Shelduck, Maned Duck and Blue-billed Duck. Many of these species had clutches of young birds in December 1985 (J Arnold personal observation). Wading birds utilise the lake margins as water levels fall.

It is probable that the lake is a significant drought refuge and breeding area. These functions are enhanced by the limited human use of the area and the large area of woodland in the reserve.

7.7.9 MANAGEMENT ISSUES

The piggery and other stock impose nutrient loads on the lake (Wetlands Advisory Committee 1977). There is likely to be increasing drawdown of the groundwater but this may be manageable through manipulation of the density of pine plantations on the eastern side of the lake.

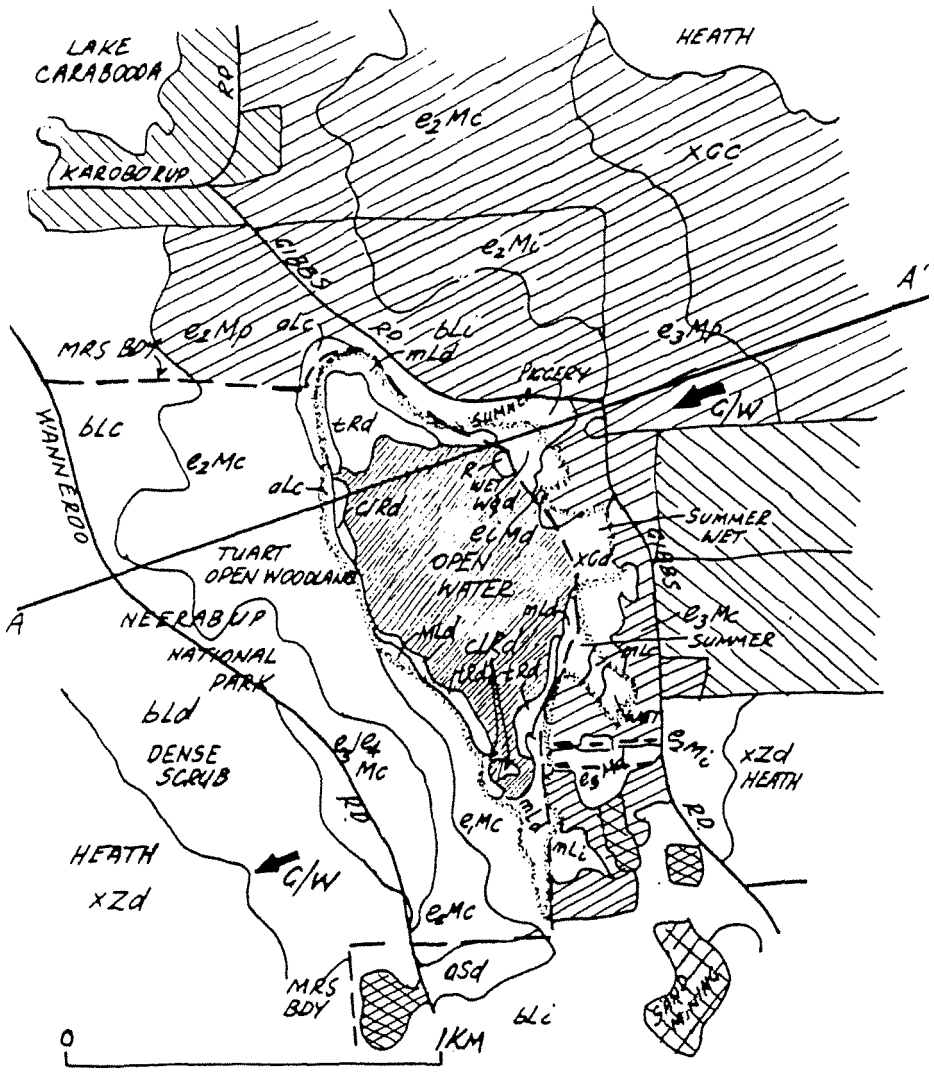

Figure 7.11 Lake Nowergup: wetland plant communities and surrounding land use.

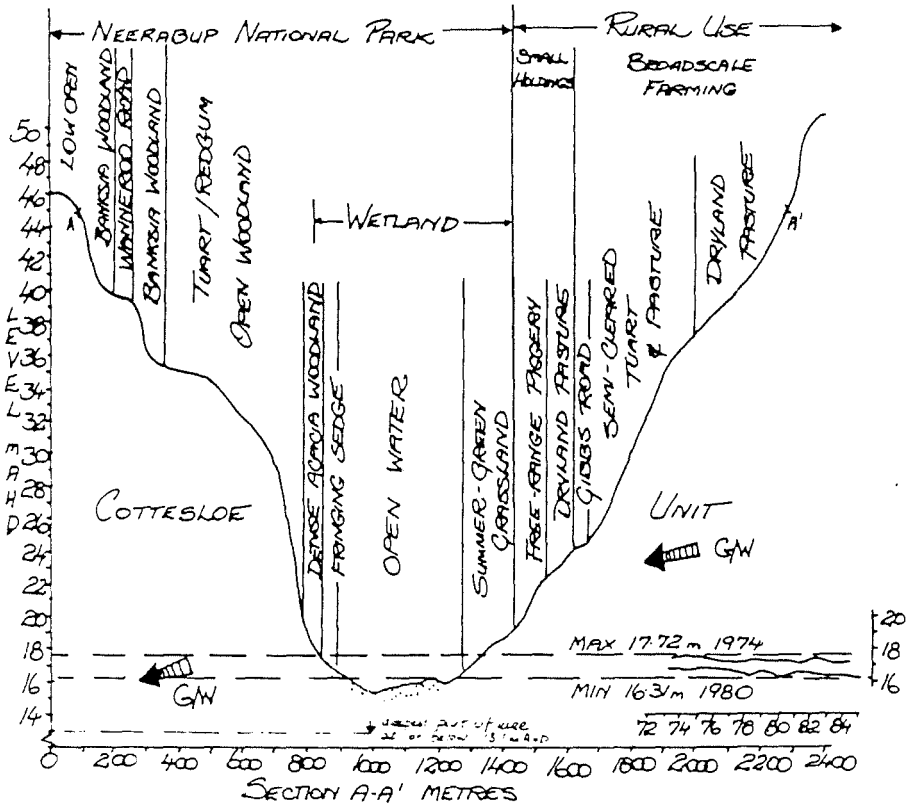

Figure 7.12 Lake Nowergup: diagrammatic cross-section and water level record.

Figure 7.13 Sketch diagram showing contours of the Basin of Lake Nowergup.

It would be useful to have improved information about the bathymetry and hydrogeology of the lake so that the impact of drawdown on the summer occurrence of permanent water can be better assessed.

The Water Authority of Western Australia (1986) and the Environmental Protection Authority (1987) have recognised that Lake Nowergup is an important wetland. There is now scope for the management authority to implement at least the minimum management initiative of requiring that landowners on the eastern side of the lake respect the reserve boundaries and prevent access by stock.

7.7.10 REFERENCES

Environmental Protection Authority (1987), Gnangara Mound groundwater resources: Water Authority of Western Australia - Report and Recommendations of the EPA. Bulletin 295, Environmental Protection Authority, Western Australia.

Water Authority of Western Australia (1986), Gnangara Mound groundwater resources: Environmental Review and Management Programme. Water Authority of Western Australia, Leederville.

Wetland Advisory Committee (1977), The status of wetlands in reserves in System 6. Report of the Wetlands Advisory Committee to the Environmental Protection Authority. Department of Conservation and Environment, pp 67-71, 91-92.

7.8 LAKE CARABOODA

7.8.1 GENERAL INFORMATION

AMG REFERENCE: 6501000 378500
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NUMBERS: none
MANAGEMENT: Private landowners
SYSTEM 6 RECOMMENDATION: none
WAC CLASSIFICATION: LE.f b.l.s.c
DRAINAGE: informal - private owners

7.8.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). The southern end of the lake is about 500 m north of Lake Nowergup and is about 3 m lower.

The lake is situated west of the 16 m regional groundwater contour and east of the 15 m contour. A doline is located in the northern part of the lake basin (Gozzard, 1982).

7.8.3 AREAS

Total wetland area	61.0 ha
Woodland (paperbark)	15.9 ha
Sedgeland	19.1 ha
Open water zone	16.2 ha
Modified wetland (horticulture)	9.8 ha

7.8.4 HYDROLOGY (Figure 7.15)

There is no published report on the hydrology of the lake.

Table 7.6. Lake Carabooda: water levels 1974-84.

i Maximum recorded level: 14.25 m AHD (1974, 1982).

ii Maximum level between 14.0 and 14.2 m for all other years 1974-1984.

iii Minimum level recorded: 10.91 m AHD (1963).

iv Number of years minimum levels fall between specified limits (m AHD) 1975-84.

12.5-13.0	3
12.0-12.5	2
11.5-12.0	2
11.0-11.5	2
10.5-11.0	1

v Number of months lake water level was above 14 m and difference between maximum and minimum levels.

YEAR	NO OF MONTHS	DIFFERENCE BETWEEN MAXIMUM AND MINIMUM LEVELS
1974	5	?
1975	4	1.75 m
1976	2	1.90 m
1977	2	1.40 m
1978	4	2.80 m
1979	4	2.40 m
1980	4	2.30 m
1981	5	2.00 m
1982	3	1.55 m
1983	4	3.20 m
1984	1	3.10 m

The water level record suggests that Lake Carabooda is like Lake Neerabup in having an outlet so that it discharges at around 14.2 m AHD and does not rise much higher. The record also shows that the lake is tending towards more extreme falls in level in summer of recent years.

7.8.5 WATER QUALITY

No information available.

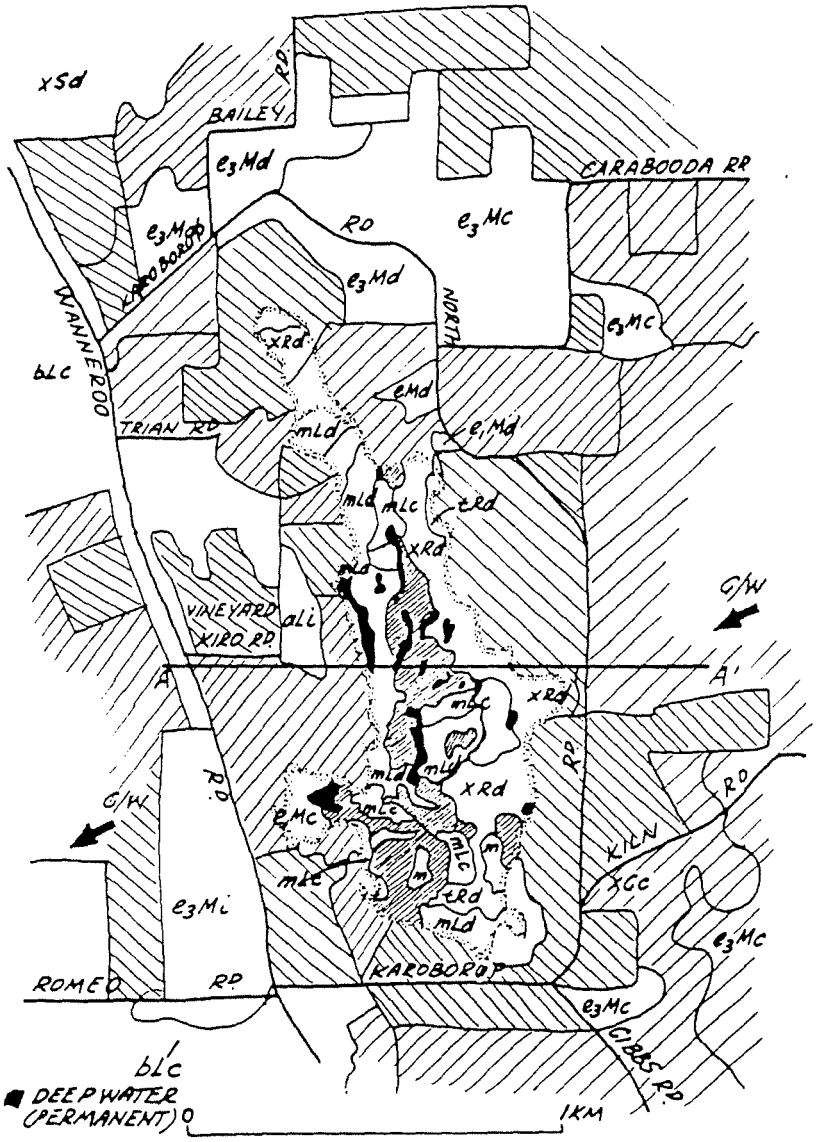

Figure 7.14 Lake Carabooda: wetland plant communities and surrounding land use.

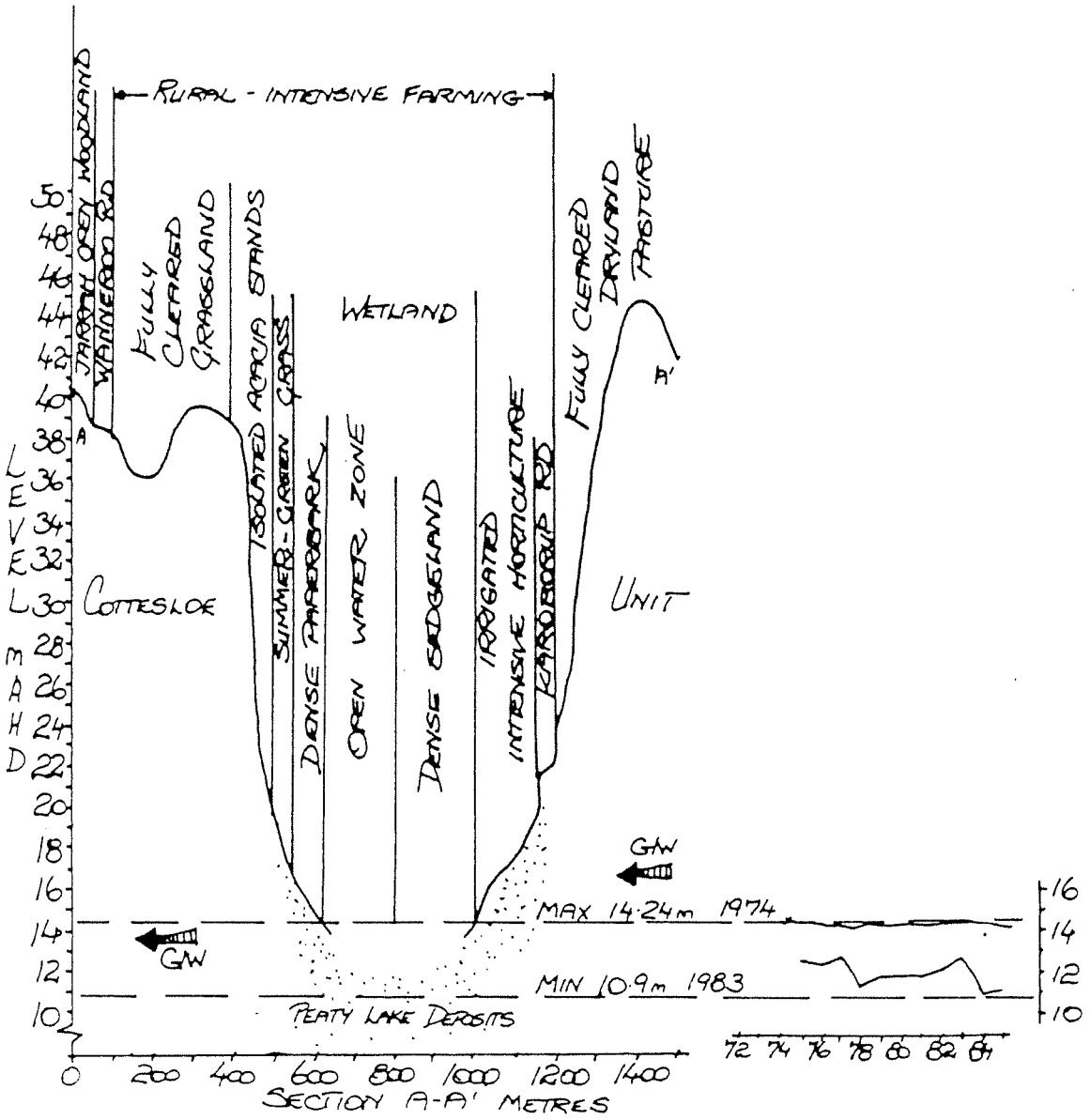

Figure 7.15 Lake Carabooda: diagrammatic cross-section and water level record.

7.8.6 LAND USE

Intense horticultural use is made of land in the area bounded by Wanneroo Road and Karoborup Road. Comparison of 1976 and 1985 air photographs shows intensification of land use although some small areas have tree regrowth. Intensification of horticulture has occurred east of Karoborup Road and Kiln Road, and north-east of the lake around the lion park.

7.8.7 VEGETATION (Figure 7.14)

The lake basin is a mosaic of swamp paperbark and sedgeland with increasing areas of Typha abutting farmed areas. There is a high degree of inter-spersion of the vegetation types. Since 1976 there has been some reduction of paperbark but also some areas in which the paperbark is denser and taller than in 1976.

7.8.8 FAUNA

No information available.

7.8.9 MANAGEMENT ISSUES

The lake can be regarded as an indicator of increasing water use in the area. If the trend towards more extreme summer drawdown continues this may result in a reduction in the area of wetland vegetation and its replacement with either cultivated areas, weeds or regenerated woodland. The observed recovery of wetland areas farmed prior to 1976 suggests that the wetland vegetation would quickly regenerate on low-lying areas should farming pressure be reduced. However, unless the Melaleuca stands survive to provide shade it is likely that the trend would be towards a Typha fenland. Once Typha becomes established on open areas it tends to inhibit regeneration of other species of sedges or Melaleuca.

7.8.10 REFERENCE

Gozzard, J R (1982), Yanchep Sheet 2034 IV, Perth Metropolitan Region, Environmental Geology Series. Geological Survey of Western Australia.

7.9 COOGEE SPRINGS

7.9.1 GENERAL INFORMATION

AMG REFERENCE: 6504500 377000
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NUMBER: None
MANAGEMENT: Private landowners
SYSTEM 6 RECOMMENDATION: M3
WAC CLASSIFICATION: LE.s.f.p.so

7.9.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Coogee Springs is situated in a doline (Gozzard, 1982). The outlook north across this wetland from Bernard Road South is an attractive feature of this area.

7.9.3 AREAS

Total wetland area ..... 12.3 ha
Typha ..... 4.1 ha

Paperbark ..... 0.7 ha
Modified and cultivated wetland ..... 6.2 ha
Open water area ..... 1.2 ha

7.9.4 HYDROLOGY (Figure 7.17)

There is no published study of the hydrology of Coogee Springs, but there are water level records from 1973-1984 (Table 7.7).

There is little change in the upper levels recorded in the lake. There are large variations in the minimum levels which may reflect variations in pumping for horticulture.

Like Carabooda, Coogee Springs is remaining at high water levels for shorter periods recently than in the early 1970's.

Table 7.7. Coogee Springs: water levels 1973-84.

i Maximum level recorded 12.43 m AHD (1973).
ii Number of years maximum lake level has fallen within specified limits.

m AHD	1973-84
>12.4	1
12.2-12.4	2
12.0-12.2	9

iii Mimimum level recorded 1973-85: 10.35 m AHD (1985).
iv Number of years minimum lake level has fallen within specified limits.

m AHD	1973-84
11.5-12.0	1
11.0-11.5	5
10.5-11.0	6
>10.5	1

v Number of months lake water level exceeded 12.0 m AHD 1973-85.

YEARS	NUMBER OF MONTHS
73-74	5
74-75	7
75-76	7
76-77	4
77-78	2
78-79	4
79-80	4
80-81	2
81-82	3
82-83	3
83-84	4
84-85	3

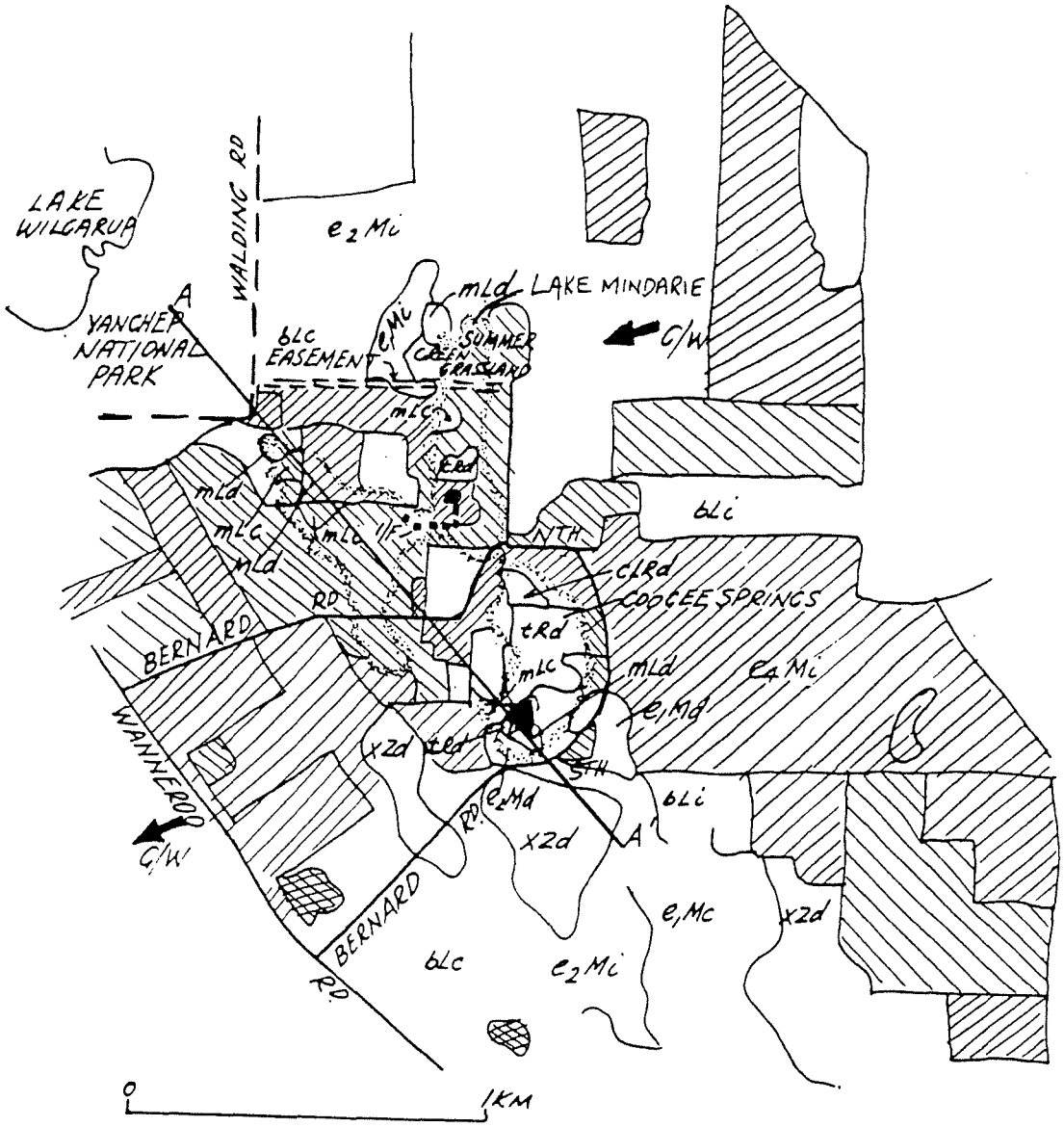

Figure 7.16 Coogee Springs and Lake Mindarie: wetland plant communities and surrounding land use.

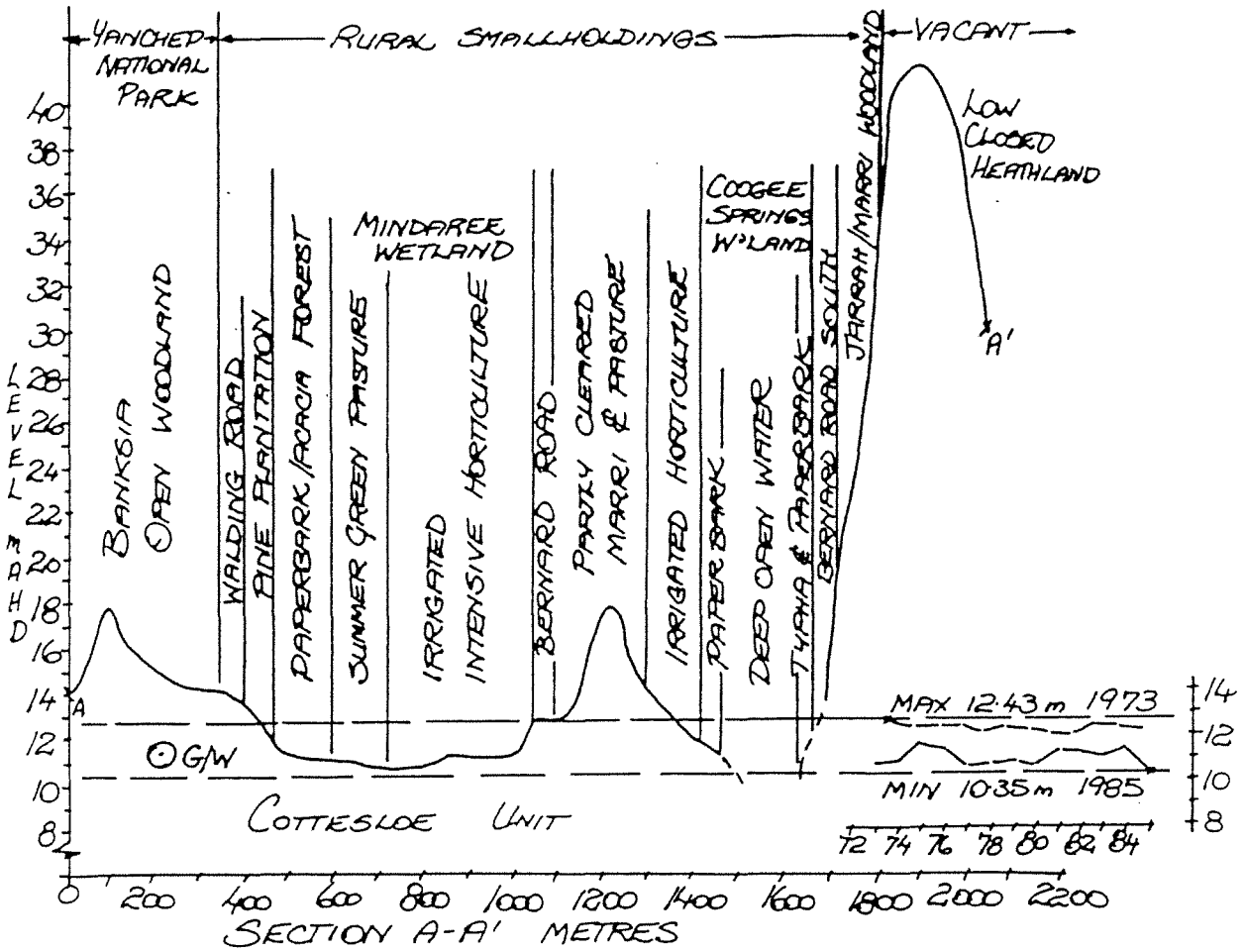

Figure 7.17 Coogee Springs and Lake Mindarie: diagrammatic cross-section, and water level record for Coogee Springs.

7.9.5 WATER QUALITY

No information available.

7.9.6 LAND USE

Comparison of air photos taken in 1976 and 1985 show that there is now more intense horticulture within a 1.5 km radius of Coogee Springs, particularly on the south-east, east, north-east and north-west sectors of the wetland.

7.9.7 VEGETATION (Figure 7.16)

There has been a pronounced expansion of Typha and a reduction in open water between 1976 and 1985.

7.9.8 FAUNA

No information available.

7.9.9 MANAGEMENT ISSUES

Some restriction on groundwater use near Coogee Springs to prevent summer water levels falling below about 10.7 m AHD would assist in maintaining landscape amenity. The Springs appear to be topographically related to Lake Mindarie and Lake Wilgarup. Land use in the area may affect the National Park.

Coogee Springs was the focus for early settlement in the Wanneroo area and hence has considerable historical interest (City of Wanneroo: Map DWG 7.2.7 - Historic Sites). This should be considered in managing water use and landscape amenity around the Springs.

7.9.10 REFERENCES

Gozzard, J R (1982), Yanchep Sheet 2034 IV. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Shire of Wanneroo (1974), Map DWG 7.2.7: Historic Sites and Separate List. City of Wanneroo, Western Australia.

7.10 LAKE MINDARIE

7.10.1 GENERAL INFORMATION

AMG REFERENCE: 6506000 377000
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NUMBERS: None
MANAGEMENT: Private landowners
SYSTEM 6 RECOMMENDATION: M?

7.10.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). There is a limited area of open water which has been much modified by farming activities.

7.10.3 AREAS

Total wetland area	24.8 ha
Typha	1.1 ha
Paperbark	2.9 ha
Modified and cultivated wetland	20.8 ha

7.10.4 HYDROLOGY (Figure 7.17)

No information available.

7.10.5 WATER QUALITY

No information available.

7.10.6 LAND USE

Over 80% of Lake Mindarie is cleared and used for vegetable growing and summer grazing. There has been intensification of horticulture within a 1 km radius of Lake Mindarie since 1976.

7.10.7 VEGETATION (Figure 7.16)

The vegetation has been markedly altered by farming activity. There is expanding Typha and a little remnant flooded gum and paperbark.

7.10.8 FAUNA

No information available.

7.10.9 MANAGEMENT ISSUES

This area has been cleared for farming and little of the original vegetation remains. It has low priority for management but it is likely that it would recover rapidly if farming pressure is removed. It is close to the edge of Yanchep National Park and to Lake Wilgarup so that activities around the lake could affect the Park.

7.11 PIPIDINNY AND BEONADDY SWAMPS

7.11.1 GENERAL INFORMATION

AMG REFERENCES: Pipidinny 6505500 374750
Beonaddy 6504500 375000
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Rural
RESERVE NUMBERS: none
MANAGEMENT: Private landowners
SYSTEM 6 RECOMMENDATION: M3
WAC CLASSIFICATION: LE.f - b.s.s.modified
DRAINAGE: informal;? runoff from Wanneroo Road
WATER RESERVE: West of the Gnangara Water Reserve
MINING: Marl pit used by MRD (System 6 Report)

7.11.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The western side of Pipidinny abuts the face of a Quindalup parabolic dune, the oldest phase of the Quindalup dune system (McArthur and Bartle, 1980).

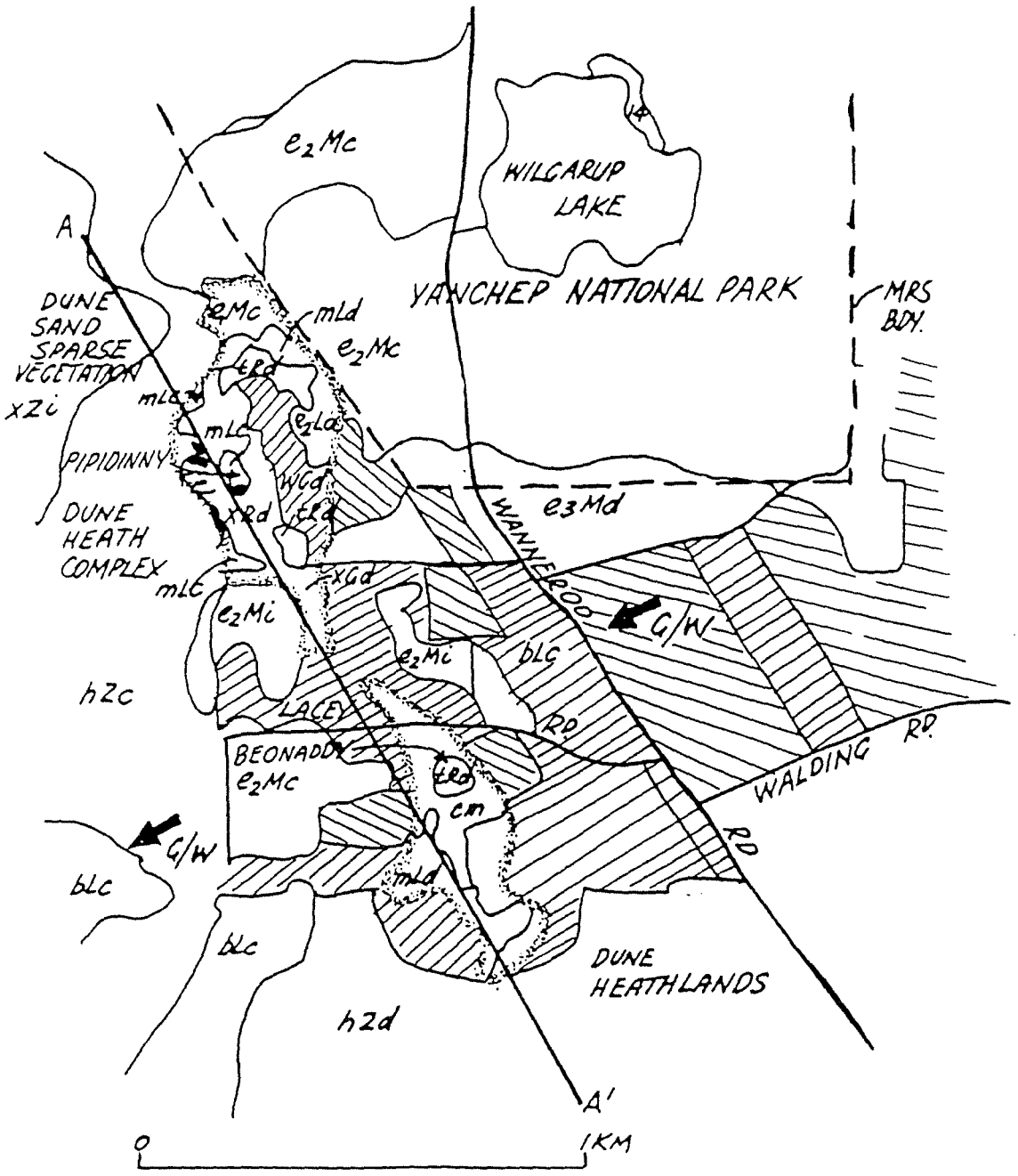

Figure 7.18 Pipidinny Swamp and Beonaddy Swamp: wetland plant communities and surrounding land use.

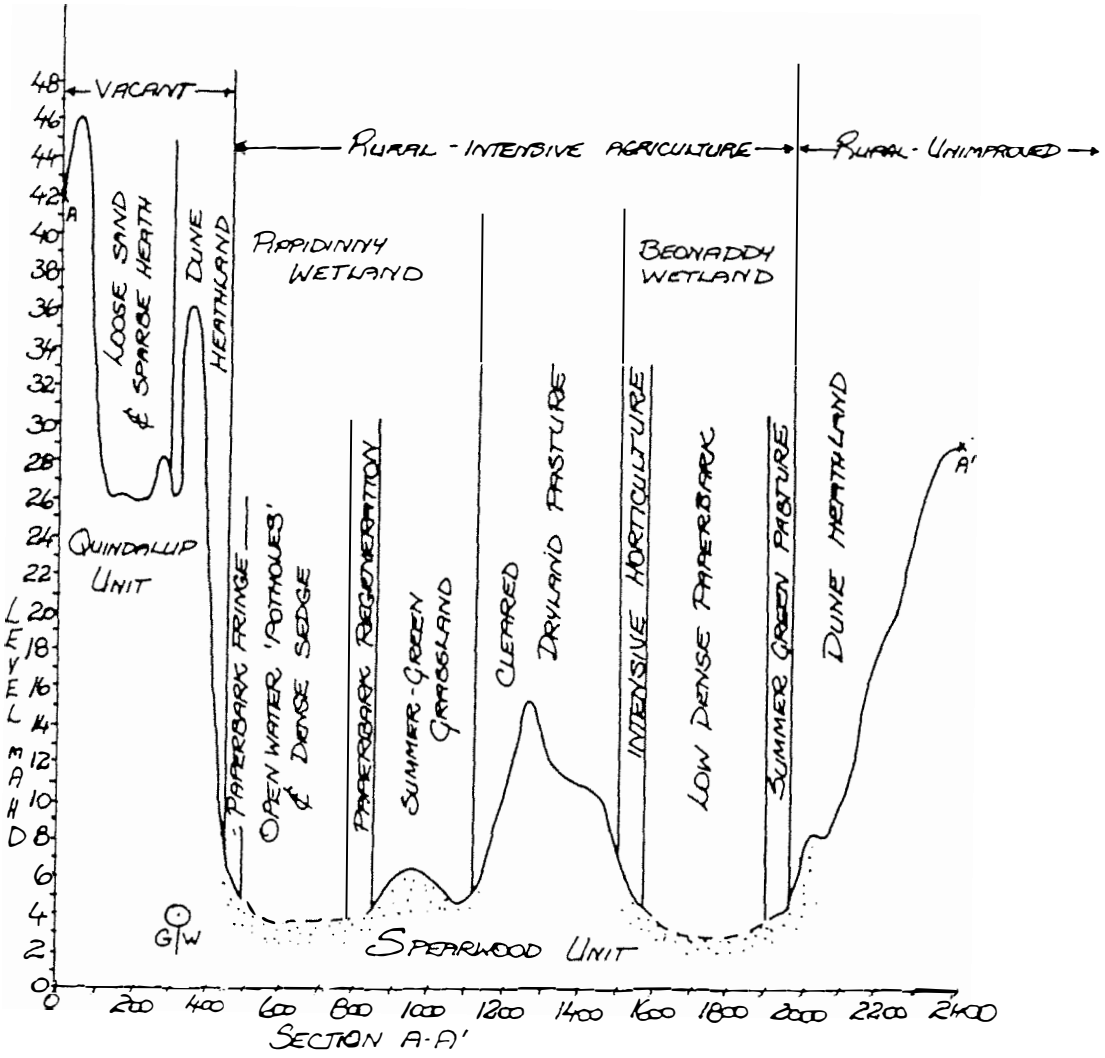

Figure 7.19 Pipidinny Swamp and Beonaddy Swamp: diagrammatic cross-section.

7.11.3 AREAS

	Pipidinny	Beonaddy
Total wetland area	19.3 ha	11.0 ha
Sedge	6.5 ha	0.4 ha
Paperbark	2.8 ha	6.0 ha
Modified and cultivated	9.6 ha	4.6 ha
Open water	0.4 ha	-

7.11.4 HYDROLOGY (Figure 7.19)

There is no record of water levels in these swamps. They receive water from groundwater flow from the east. There may also be some local seepage from the dune on the western side of Pipidinny Swamp. There is a marked seasonal variation in water levels but apparently some free water is retained in excavated channels throughout the year.

7.11.5 WATER QUALITY

No information available.

7.11.6 LAND USE

The swamps are used for horticulture and grazing. There appears to be a good deal of year-to-year variation in farming intensity.

7.11.7 VEGETATION (Figure 7.18)

The swamps support remnant flooded gum and melaleuca in what are probably the wettest areas - those least usable for vegetable growing. Typha appears to have invaded areas that are no longer cultivated.

7.11.8 FAUNA

No information is available for Beonaddy. Pipidinny Swamp has been surveyed by RAOU members for the last three years.

7.11.9 MANAGEMENT ISSUES

Both the North West Corridor Planning Report and the System 6 Study Report suggest the inclusion of these small wetlands within a reserve for open space. There is a likelihood that the swamps will be affected by road construction. The Draft Management Plan for Yanchep National Park proposes that part of Pipidinny Swamp be included in Yanchep National Park (Department of Conservation and Land Management, 1988).

7.11.10 REFERENCES

Department of Conservation and Land Management (1988), Yanchep National Park: Draft Management Plan.

McArthur, W M & Bartle, G A (1980), Landforms and soils as an aid to urban planning in the Perth Metropolitan Northwest Corridor, Western Australia. CSIRO, Australia, 1980. Land Resources Management Series No 5.

7.12 WILGARUP LAKE

7.12.1 GENERAL INFORMATION

AMG: 6507000 375500
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Parks and Recreation
RESERVE NO: A9868
MANAGEMENT: Department of Conservation and Land Management
SYSTEM 6 RECOMMENDATION: M3
WAC CLASSIFICATION: LE.f.s.se.c
WATER RESERVE: West of the Gnangara Water Reserve
DRAINAGE: May be affected by run-off from Wanneroo Road.

7.12.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Wilgarup lies in a shallow valley which is continuous with Lake Mindarie and Coogee Springs.

7.12.3 AREAS

Total wetland area	16.6 ha
Swamp banksia/paperbark	14.6 ha
Sedgeland	0.9 ha
Open water zone	1.1 ha

7.12.4 HYDROLOGY (Figure 7.21)

There is no published information and no record of water levels for this lake. There is little open water, even in winter. The lake may be affected by stormwater runoff from Wanneroo Road.

7.12.5 WATER QUALITY

No information available.

7.12.6 LAND USE

Wilgarup lies within Yanchep National Park. It is surrounded by native bushland which is relatively undisturbed except for tracks and firebreaks. A plantation on the southern side is used to provide food for the Park's koalas. There appears to be a small limestone quarry near the northern side of the lake. The lake attracts little recreational use.

7.12.7 VEGETATION (Figure 7.20)

Lake Wilgarup supports a dense vegetation of swamp banksia, swamp paperbark and jointed twig rush. Much of the lake margin has been planted with Tasmanian bluegum which is harvested to feed koalas in Yanchep National Park.

7.12.8 FAUNA

No information available.

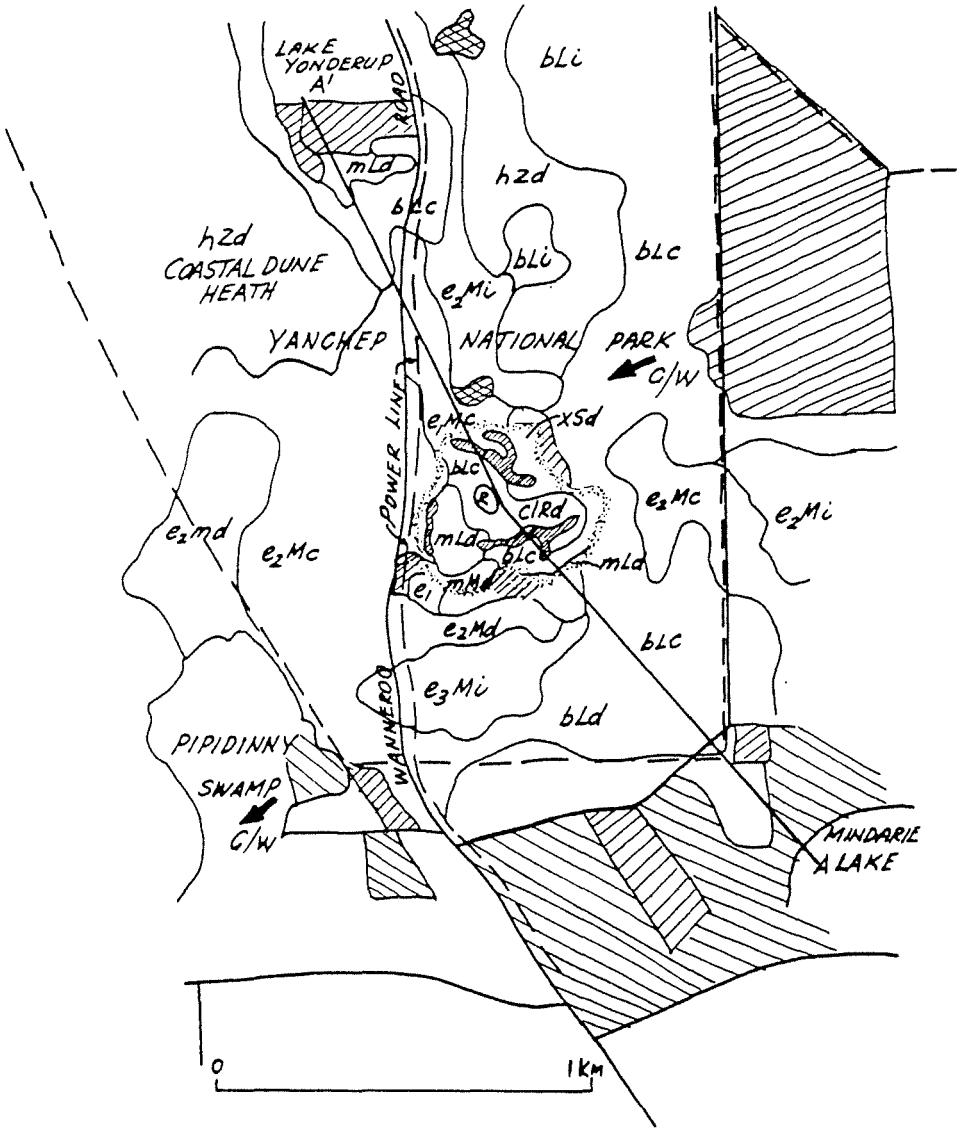

Figure 7.20 Wilgarup Lake: wetland plant communities and surrounding land use.

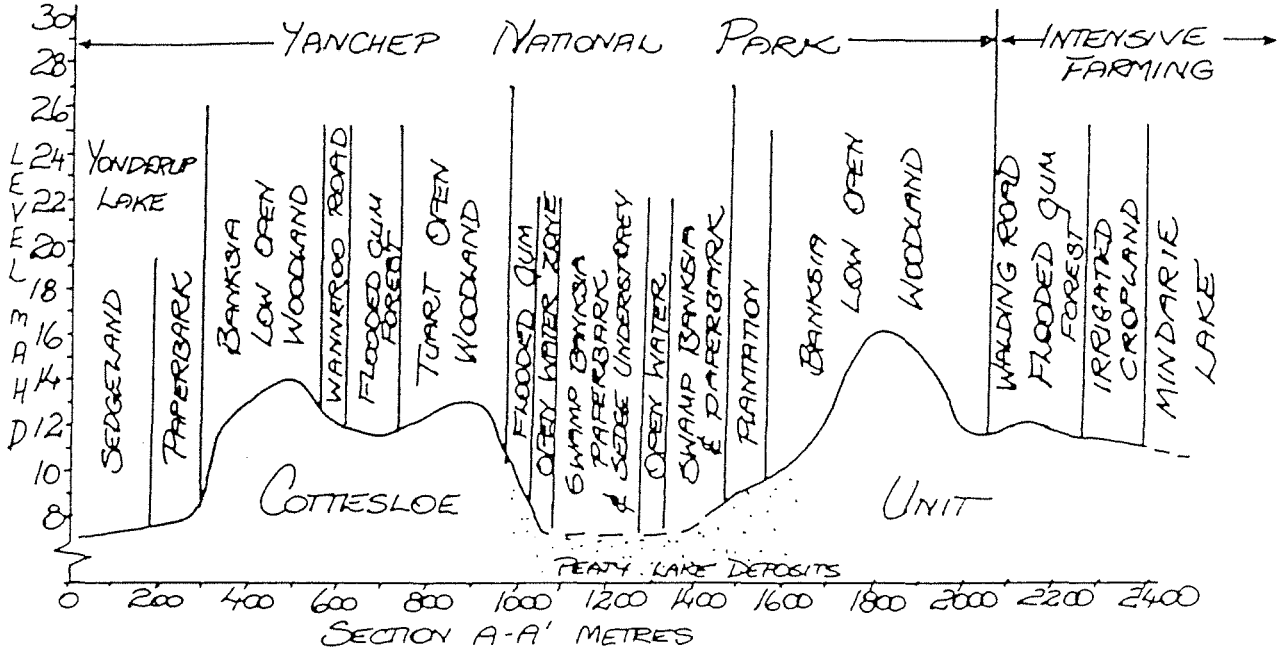

Figure 7.21 Wilgarup Lake: diagrammatic cross-section.

7.12.9 MANAGEMENT ISSUES

The lake is under a relatively low level of stress. Future stresses could result from roadworks, intensified horticulture on land adjoining the Park and groundwater extraction for public supply leading to regional groundwater drawdown. Falling water levels will accelerate the trend towards seasonal wetland and to dryland habitat.

Management issues are thoroughly addressed by the Department of Conservation and Land Management (1988).

7.12.10 REFERENCE

Department of Conservation and Land Management (1988), Yanchep National Park: Draft Management Plan.

7.13 YONDERUP LAKE

7.13.1 GENERAL INFORMATION

AMG REFERENCE: 6508000 375000
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Parks and Recreation
RESERVE NUMBER: A9868
MANAGEMENT: Department of Conservation and Land Management
SYSTEM 6 RECOMMENDATION: M3
WAC CLASSIFICATION: LE.f.m.p.sc
WATER RESERVE: West of the Gnangara Water Reserve
DRAINAGE: Local drainage from Yanchep Beach Road

7.13.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Bridge (1969) described experiments to identify channels through cave systems around Lake Yonderup and showed the presence of a channel through which water flows from Loch McNess. Yonderup is situated west of the steep gradient in the groundwater contours with its maximum water levels around 6.2 m AHD.

7.13.3 AREAS

Total wetland area	47.3 ha
Swamp banksia/paperbark	24.0 ha
Sedgeland	8.9 ha
Open water zone	5.7 ha
Modified: plantation & grassland	8.7 ha

7.13.4 HYDROLOGY (Figure 7.22)

Unlike Lake Carabooda, there is no appreciable increase in the seasonal range in water levels or shortening of the duration of high water levels.

7.13.5 WATER QUALITY

No information available

Table 7.8. Yonderup Lake: water levels mid 1974 to mid 1985.

i Maximum water level recorded: 6.28 m AHD (1973).
ii Number of years the maximum water level has fallen within specified ranges.

m AHD	NUMBER OF YEARS
>6.2	1
6.0-6.2	3
5.8-6.0	7

iii Minimum water level recorded: 5.12 m AHD (1981).
iv Number of years the minimum water level has fallen within specified ranges.

m AHD	NUMBER OF YEARS
5.4-5.6	4
5.2-5.4	6
<5.2	1

v Number of months when water level exceeds 5.8 m in the years 1975-85.

1975-76	8
1976-77	4
1977-78	4
1978-79	7
1979-80	9
1980-81	5
1981-82	7
1982-83	6
1983-84	6
1984-85	6

7.13.6 LAND USE

Lake Yonderup is situated within Yanchep National Park. Access to the lake is through dense woodland and sedgeland and recreational use of its surroundings is low.

Old fences, remnants of stock yards and fig trees on the north-west indicate that there has been a farm centred on the lake.

Plantations of eucalypts for koala food are situated on the margins of the southern half of the lake.

7.13.7 VEGETATION

A stand of Typha on the northern side of the Yanchep Beach Road suggests that disruption of the vegetation has occurred there, probably as a result of roadworks.

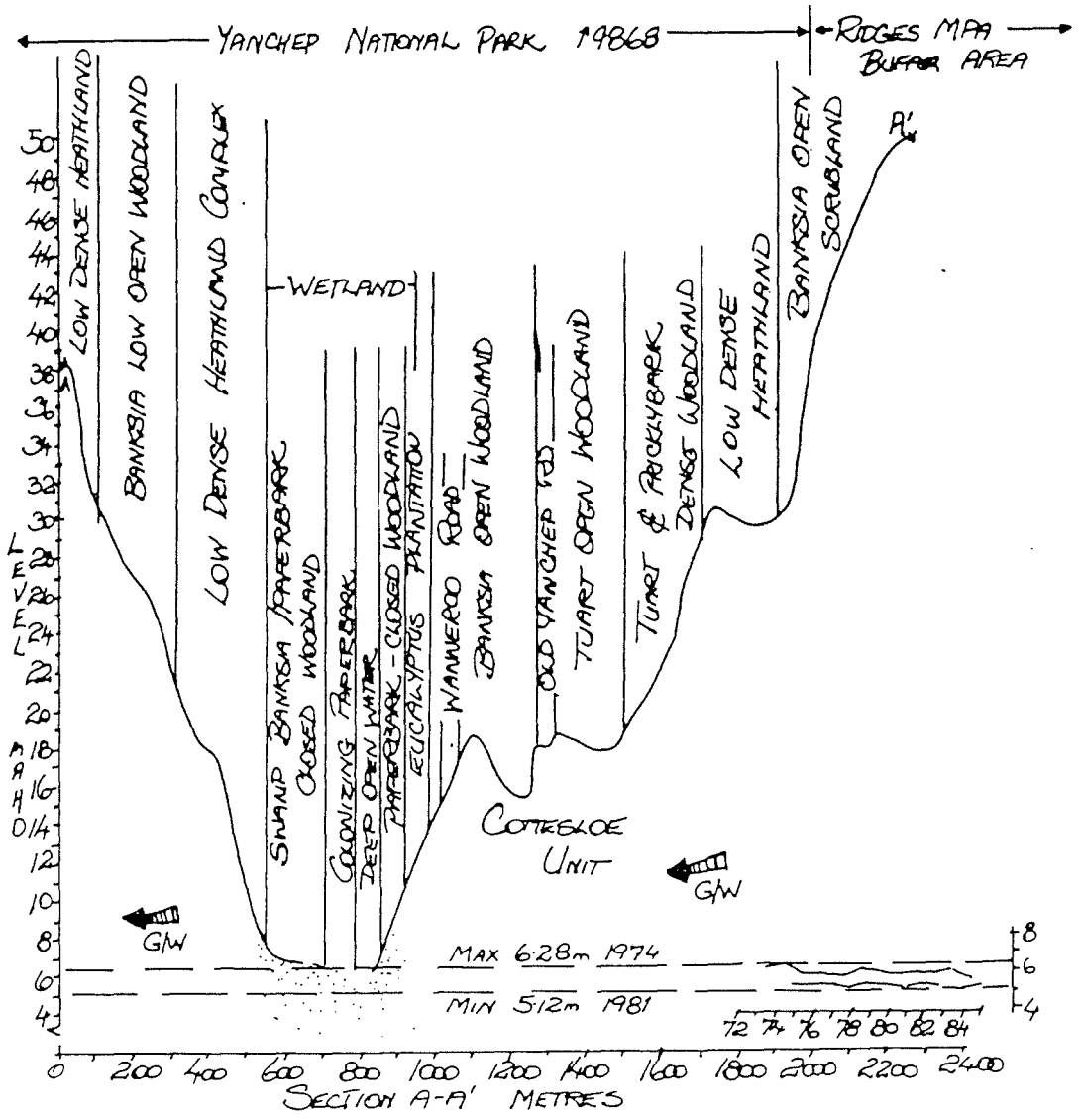

Figure 7.22 Yonderup Lake: diagrammatic cross-section and water level record.

7.13.8 FAUNA

There is no published information. The presence of permanent open water and a range of vegetation types suggests that the lake may provide habitats for a range of bird species as well as small mammals, frogs and reptiles. Because of the limited disturbance to the lake and permanence of its water, it is likely that Yonderup would provide insights into the unmodified fauna of permanent freshwater wetlands.

7.13.9 MANAGEMENT ISSUES

The native vegetation within Yanchep National Park provides a substantial buffer against stress. The Department of Conservation and Land Management (1988) gives detailed attention to management issues.

7.13.10 REFERENCES

Bridge, P (1969), Report of trip to Wanneroo - Yanchep caves. Western Caver 9(6), 124-125.

Department of Conservation and Land Management (1988), Yanchep National Park: Draft Management Plan.

7.14 LOCH McNESS

7.14.1 GENERAL INFORMATION

AMG REFERENCE: 6510000 374250
LOCAL AUTHORITY: City of Wanneroo
MRS ZONE: Parks and Recreation
RESERVE NUMBER: A9868
MANAGEMENT: Department of Conservation and Land Management
SYSTEM 6 RECOMMENDATION: M3
WAC CLASSIFICATION: LE.1.f.sc
WATER RESERVE: West of Gnangara Water Reserve
DRAINAGE: runoff from parkland

7.14.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

See also General Setting (Section 7.1). Bridge (1969) described water tracing trials carried out by the Western Australian Speleological Association which identified channels linking the southern end of Loch McNess with Lake Yonderup. McComb and McComb (1967) provide a description of the area and of dredging and fill operations carried out on the southern end of the lake in the 1930's.

The eastern side of north Loch McNess is characterised by fractured limestone with numerous small caverns.

7.14.3 AREAS

Total wetland area	255.3 ha
Sedge complex	149.3 ha
Swamp banksia/paperbarks	56.6 ha
Open water	49.5 ha
Total size of Yanchep National Park	2 789.0 ha

7.14.4 HYDROLOGY (Figure 7.24)

There is no published account of the hydrology of the lake.

The southern end of the lake was deepened between 1936 and 1940 (McComb and McComb, 1967; Gentilli and Scott, 1963). McComb and McComb (1967) described the lake, stating that the pH is alkaline and the water extremely fresh. They noted that the water level is constant, varying only by some 20 cm throughout the year.

The water level record for the years 1973 to mid 1985 shows that the water level ranges between a maximum of 7.18 m AHD in 1983 and a minimum of 6.9 m in early 1978. The water level has fallen below 7.0 m AHD only twice in this period.

In the metropolitan region Loch McNess is the only wetland for which water level records are available which displays this constancy in its water level. Even Lake Yonderup, into which Loch McNess overflows, shows marked seasonal variations in water level with an annual range of 0.6-0.8 m, indicating that it does not receive continuous overflow from Loch McNess and its water level reflects its slightly lower level relative to the regional water table at other times.

The Western Australian Museum Study of the northern Swan Coastal Plain concluded that Loch McNess is likely to be less affected by borefields on the Gnangara Mound than Lake Jandabup. This contention is supported by water level records. McComb and McComb (1967) considered the possibility that water levels in Loch McNess may be rising but concluded from evidence from the vegetation that this is not the case, with the plant succession occurring in the direction: open water to sedgeland to woodland.

7.14.5 WATER QUALITY

See Ayre et al. (1977). Davis and Rolls (in preparation) have sampled the waters of the lake in 1986-87. The Department of Conservation and Land Management (1988) summarises the water quality of Loch McNess as having low salinity and compared with other wetlands in the region, very low nutrient levels.

7.14.6 LAND USE

The lake lies within Yanchep National Park and is thus buffered to some extent from effects of agriculture and cultivation of pines. However, it shows some signs of cultivation. McComb and McComb (1967) noted that the eastern section of the lake displays "cropping marks" which result from attempts in the 1930's to establish playing fields and also that part was deepened in the 1930's, with dredge spoil being used to form a causeway between the northern and southern parts (now utilised as part of the Yangidi Trail). McComb and McComb also make reference to the frequent occurrences of fire in the northern section.

The Department of Conservation and Land Management (CALM) (1988) provides a detailed review of visitor use and activities.

Very dense growth of woodland fringing the northern section of the lake may be an artefact arising from frequent burning to improve access to the lake. McComb and McComb (1967) identified a need for an understanding of the ecological significance of fire in the region.

Loch McNess has been used regularly by students of wetland biology from the Botany Department of the University of Western Australia and is a valuable educational resource. The growing body of information about the lake makes it a significant scientific resource and provides a baseline against which to compare other wetlands in the region.

Pine plantations and groundwater extraction may affect the water balance of the region. Plans for the North-West Corridor allow for urban development to adjoin the Yanchep National Park.

7.14.7 VEGETATION (Figure 7.23)

McComb and McComb (1967) described the vegetation in detail and discussed the vegetation succession. They suggest that the vegetation is following the widely observed trend from open water to swamp to fen to woodland. The McCombs list over 70 species including only 6 or 7 introduced species. They pointed out that only 35% of the species are endemic, compared with 75% for the south-west province of Western Australia, emphasising the general observation that swamps and fens characteristically include species of cosmopolitan distribution.

7.14.8 FAUNA

The Western Australian Museum (How, 1978) sampled Loch McNess every two months from April 1977 to May 1978. It was found to contain all the major aquatic habitats with the exception of wading areas recognised for the northern Swan Coastal Plain as a whole and the widest range of microhabitats, including running water habitats, of all the lakes surveyed. Loch McNess was found to have the highest number of species but to be poor in terms of the number of animals per sample. It had the highest number of species of both molluscs and crustacea and contains two species, the pea clam and the marron, not found elsewhere in the lakes of the region.

The Western Australian Museum listed 21 species of birds observed on the southern part of the lake. The relatively inaccessible northern part of the lake was not studied. The species observed included diving and dabbling ducks, grebes, herons, cryptic species such as crakes and rails, and the marsh harrier. Absent from the list are wading birds, reflecting the absence of exposed banks and wading areas.

Aquatic environments in eleven caves in the Yanchep National Park have been studied since 1981 (B Knott, personal communication). Sixteen species of animals are considered to be adapted to live in caverns. The cave fauna includes two species of amphipods not known to occur elsewhere in Western Australia. These two species belong to a group which is a Gondwana relict. One species of copepod is known only from this area and from Mt Gambier, South Australia. Dr Knott and his co-workers found that the richest of the cave habitats studies were the tree root mats derived from the tuart trees growing above the caves.

The macrobenthic fauna of the lake is being sampled at three-monthly intervals in a study being carried out by Dr Jenny Davis of Murdoch University. This work will permit direct comparisons between Loch McNess and nine other wetlands in the Perth region.

CALM (1988) provides a more detailed consideration of the fauna of Yanchep National Park.

7.14.9 MANAGEMENT ISSUES

Loch McNess appears the least vulnerable of the linear lakes to lowering of the water table, whether by pumping for public water supply or for horticulture or by pine plantations. It is, nevertheless, dependent upon groundwater and this should be recognised in any future land use plans for the region. The current management is clearly effective in protecting its integrity. Any activities which would alter the nutrient status of the lake should be avoided.

The Department of CALM (1988) thoroughly addressed management issues for Loch McNess within Yanchep National Park.

7.14.10 REFERENCES

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Gentilli, J and Scott, D R (1963), The Yanchep area (roneo). Geog Soc WA.

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McComb, J A and McComb, A J (1967), A preliminary account of vegetation of Loch McNess, a swamp and fen formation in Western Australia. J. Roy. Soc. West. Austral. 50, 105-112.

Milligan, A W (1903), Notes on Lake Yanchep. Emu 3, 20-22.

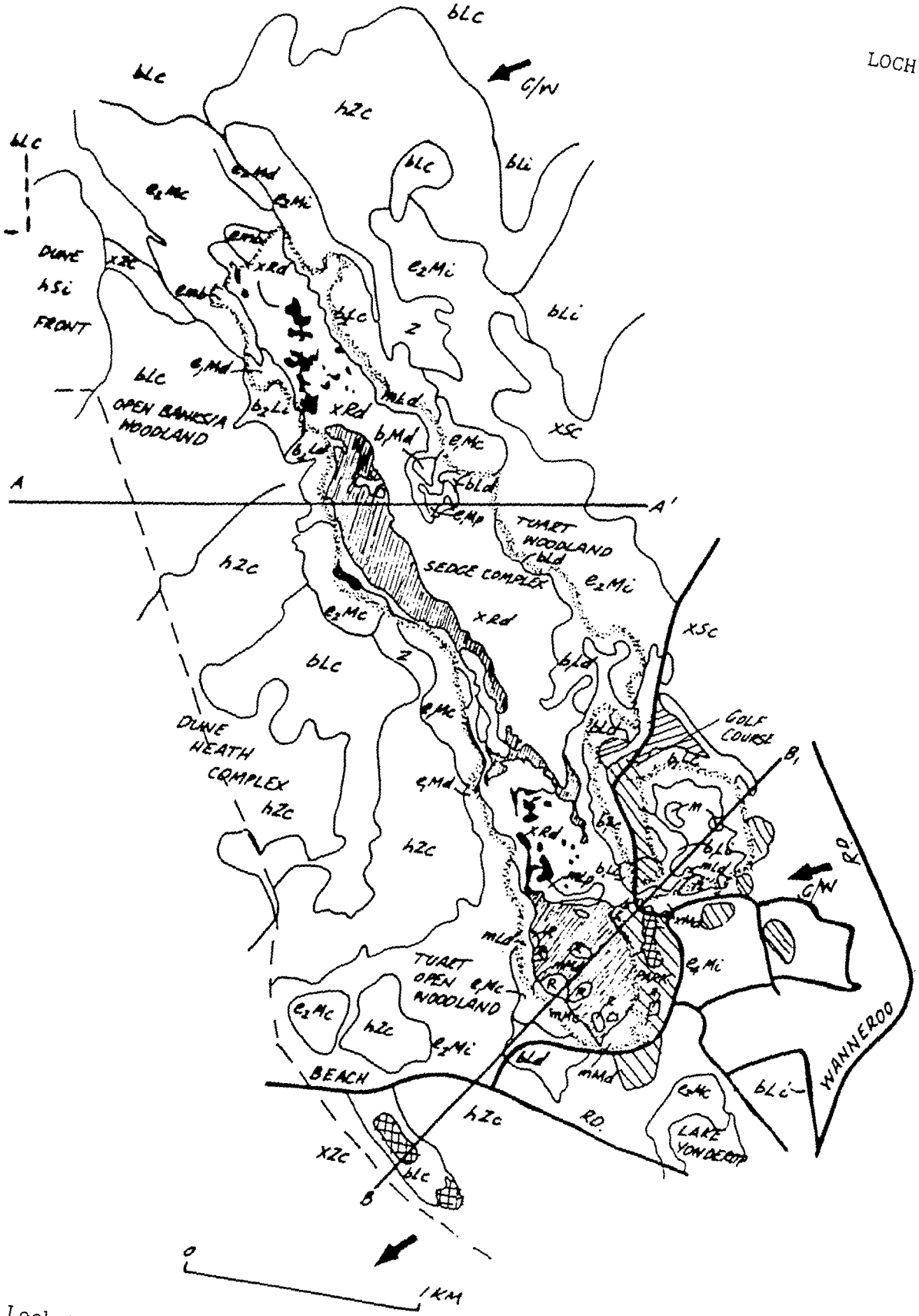

Figure 7.23 Loch McNess: wetland plant communities and surrounding land use.

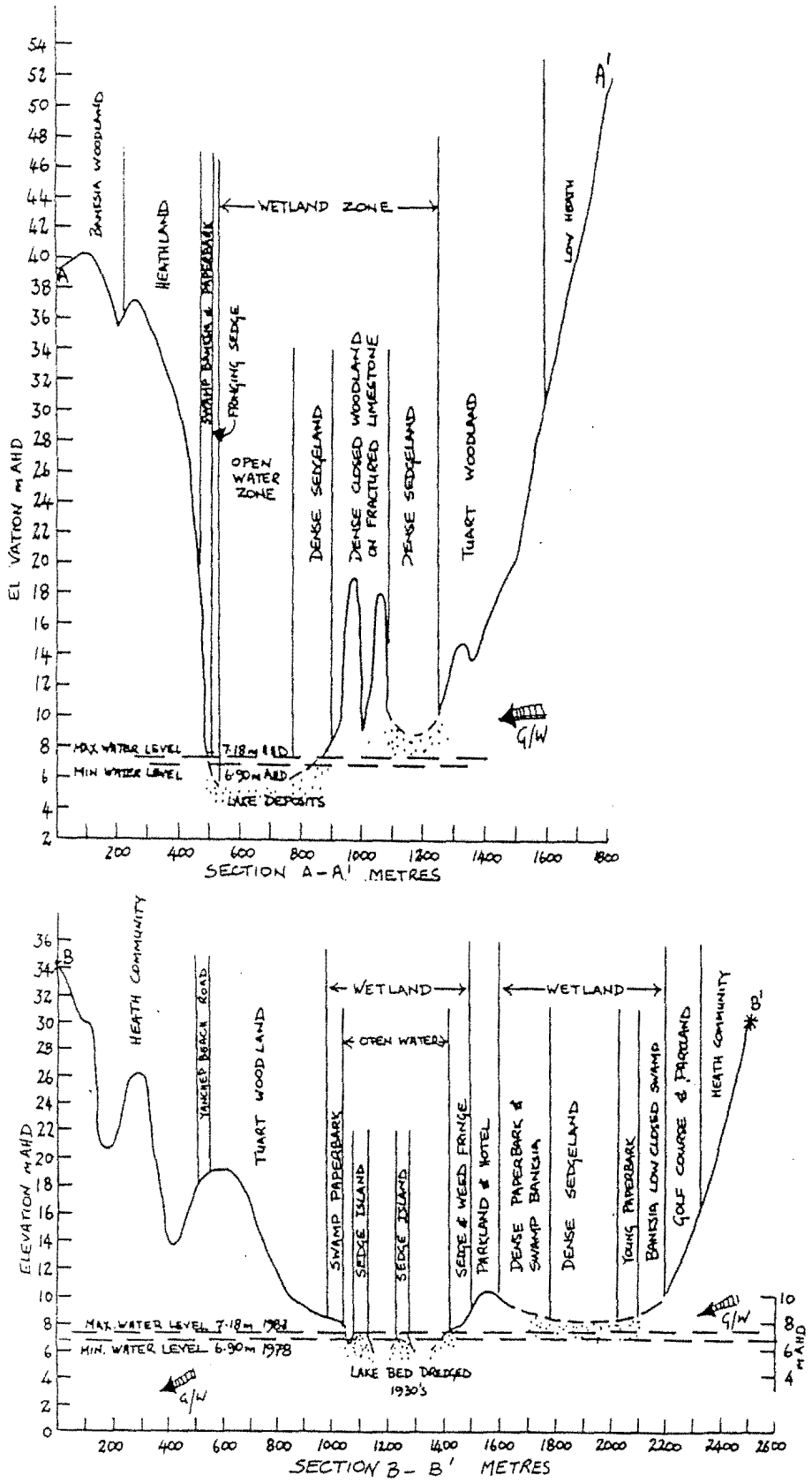

Figure 7.24 Loch McNess: diagrammatic cross-sections A-A' and B-B' and water level record.

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