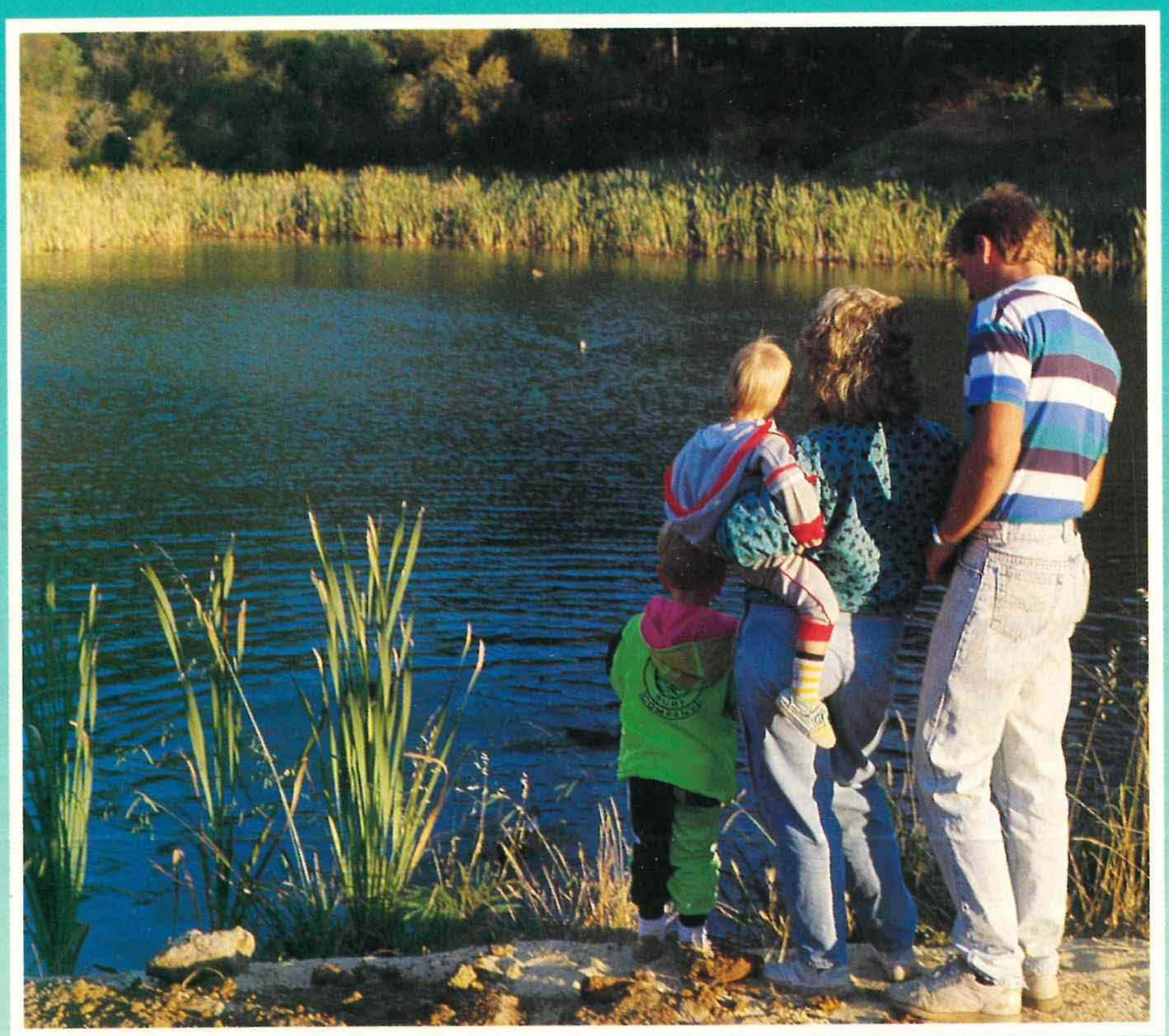
JENNY ARNOLD'S

PERTH WETLANDS RESOURCE BOOK



CHAPTERS 9 - 11

EAST BEELIAR WETLANDS

WETLANDS OF THE SOUTH WEST CORRIDOR
AND OF THE ROCKINGHAM PLAIN

ENVIRONMENTAL PROTECTION AUTHORITY
AND THE WATER AUTHORITY OF WESTERN AUSTRALIA

BULLETIN 266 DECEMBER 1990

Jenny Arnold's Perth Wetlands Resource Book

Chapters 9 - 11: East Beeliar Wetlands, Wetlands of the South West Corridor and of the Rockingham Plain

Environmental Protection Authority and
the Water Authority of Western Australia

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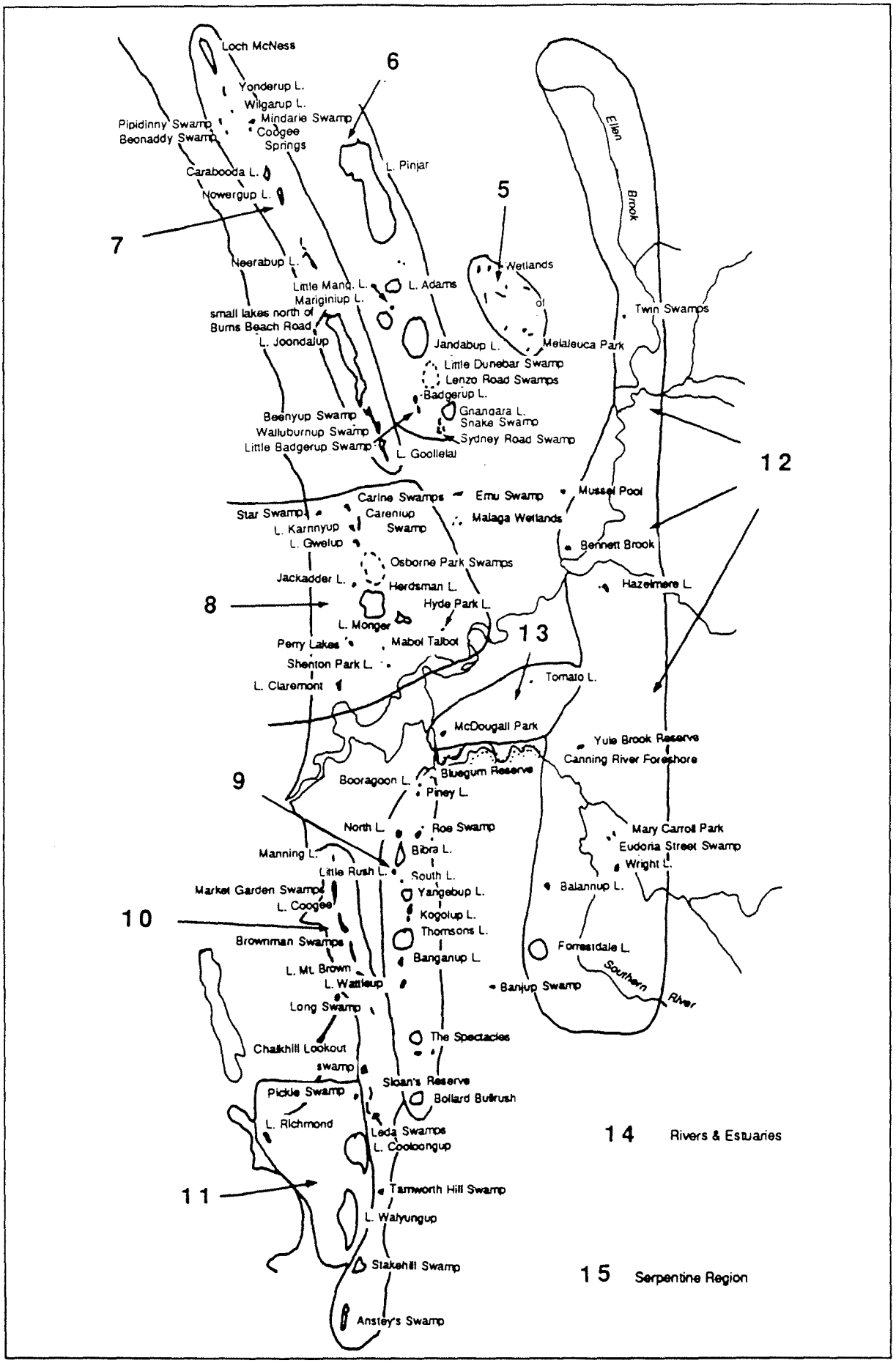
NOTES FOR USERS

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.

Chapters 9 - 11: East Beeliar Wetlands, Wetlands of the South West Corridor and of the Rockingham Plain

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Other chapters in this series

9. EAST BEELIAR WETLANDS

9.1 GENERAL SETTING

The name "East Beeliar Wetlands" used for the group of wetlands described below extends the normal use of "Beeliar". Figure 9.1 shows the wetlands described in this section.

The name "East Beeliar" is usually applied to the eastern chain of wetlands in the City of Cockburn, extending from North Lake southwards and its use arises from a recommendation made by Newman (1976) and taken up by the System 6 Study (Environmental Protection Authority, 1983). Bluegum, Booragoon and Piney Lakes have been included in the group for convenience. Thus, the wetlands considered here extend from Bluegum Lake on the Applecross peninsula in the north, for 25 km along the interface between the Bassendean Dunes and the Spearwood Dunes, to Bollard Bullrush Swamp in the south. Semeniuk (1987) recognises this group of wetlands as a related suite, the Bibra Suite at the interface of the Spearwood and Bassendean Dunes. On the south of Bollard Bullrush Swamp, the Bassendean Dunes abut the fluviatile deposits of the Serpentine River (See Department of Conservation and Environment, 1980).

The wetlands form a distinct, natural grouping on the western and northern flanks of the Jandakot unconfined groundwater flow system. The group includes marshes in high level interbarrier depressions between the Bassendean and Spearwood dune systems and marshes in interdunal swales (Gozzard, 1983). They can be compared to the group of wetlands which occupies an analogous position on the Gnangara Mound and which includes Lakes Pinjar, Adams, Mariginiup, Jandabup, Badgerup and Gnangara. However, there are a number of significant differences:

1. Natural eutrophication processes are further advanced in the southern wetlands which have deep lake deposits (eg 7-8 m at Bibra Lake) and evidence of several rejuvenation processes (Megirian, 1982). Lake deposits at Jandabup Lake (Allen, 1979) and Mariginiup Lake (Hall, 1980) are 1-2 m deep and principally of diatomite, suggesting a lower nutrient status.

2. The east Wanneroo lakes are higher in the landscape (higher than 40 m AHD compared with 10-16 m AHD for the southern wetlands).

3. The southern wetlands have been subjected to a longer period of disturbance, which includes rural uses, industrial uses (Lake Yangebup), sanitary landfill (Bibra) and drainage (Mandogalup, Spectacles and Bollard Bullrush).

Students of Murdoch University carried out a detailed survey of the east and west Beeliar wetlands in 1976 for the City of Cockburn (Newman, 1976) and Murdoch University has since carried out many studies (eg Newman and Hart, 1984; Murray et al., 1986-1988). The involvement of Murdoch University with these wetlands continues with current studies at North, Bibra, Yangebup and Thomsons Lakes.

Megirian (1982) made a study of the hydrogeology of North and Bibra Lakes and aspects of his work have subsequently been supported by Davidson (1983). Megirian put forward three possible explanations for the formation of the Bluegum to Bollard Bullrush wetland chain in the course of marine regressions in the Quaternary:

. the lakes were formed from a lagoon or lagoons behind a beach bar; or

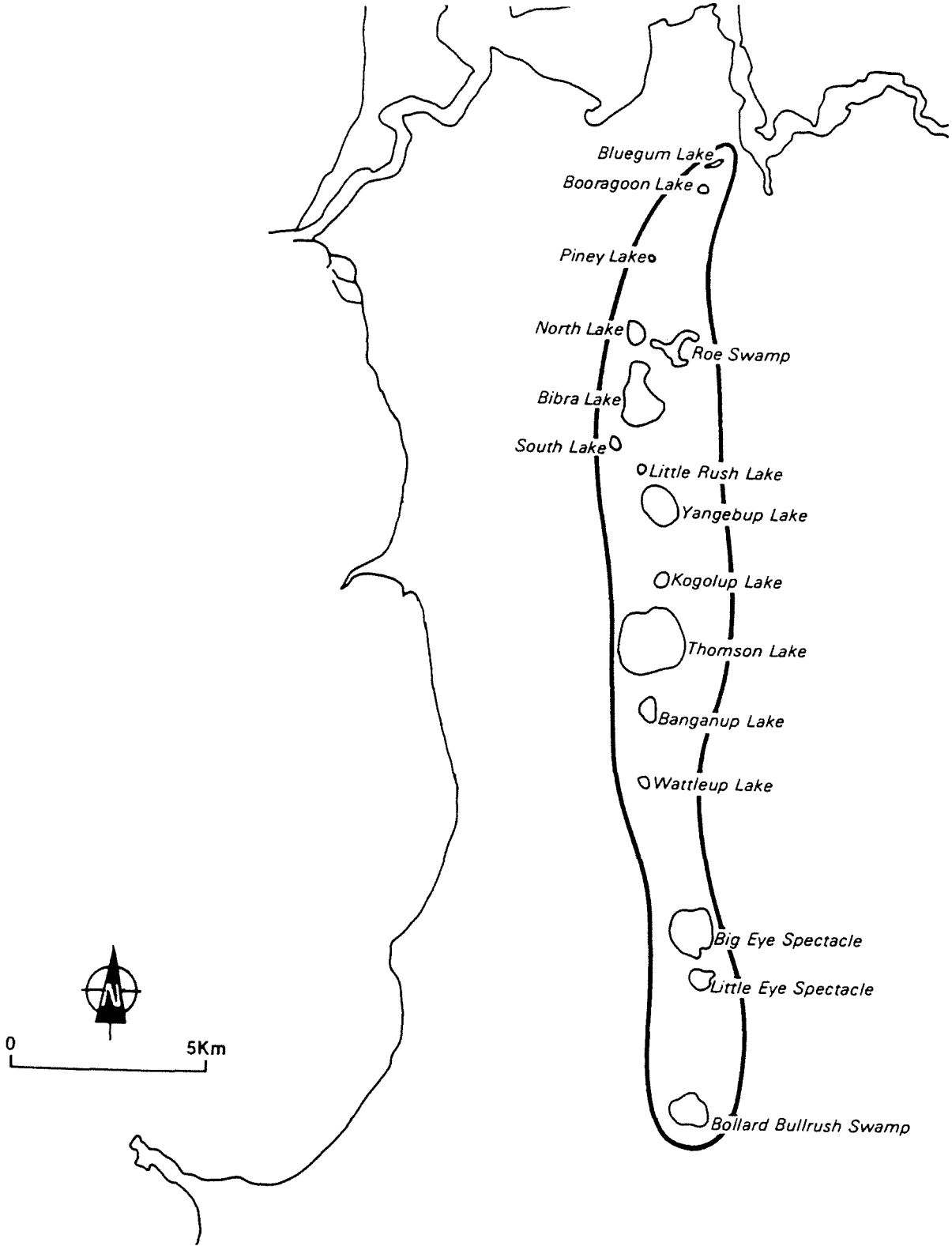

Figure 9.1 Map showing the wetlands of the East Beeliar series.

. inundation of the interdunal swale between the Bassendean and Spearwood Dunes occurred as a result of a change in the water balance; or

. an arm of an estuary occupied the interdunal depression and was eventually isolated from the estuary by a sand bar.

The origins and ages of these lakes warrant further investigation. The responses of the wetlands to past climatic changes, natural eutrophication and other historical changes may provide useful insights relevant to future management.

The lakes display the full range of pressures and responses to 150 years of European settlement (Table 9.1). Recommendations of the Perth Urban Water Balance Study (Water Authority of Western Australia, 1987) are relevant to the ongoing management of this wetland chain.

Table 9.1: Past and current land uses impinging on the East Beeliar Wetlands.

WETLAND NAME	PAST PRESSURES	CURRENT SURROUNDING INFLUENCES
Bluegum	horticulture	urban; water level maintenance
Booragoon	rural, pine plantation	urban; water level maintenance
Piney Lake	pine plantation	developing urban
North Lake	rural	developing urban
Roe Swamp	rural; roads	developing urban; roads
Bibra	rural;sanitary landfill	developing urban; roads
South	rural; industrial	developing urban
Little Rush	rural	developing urban
Yangebup	rural; industrial	developing urban; effluent disposal roads
Kogolup	rural	developing urban
Thomsons	rural; reserve	developing urban; conservation reserve
Banganup	little disturbance	research; developing urban
Wattleup	horticulture	horticulture; rural
Mandogalup	drainage; intensive horticulture	intensive horticulture
Spectacles	drainage; horti-culture, rural	?; regenerating wetland
Bollard Bullrush Swamp	drainage; intensive horticulture; rural	horticulture; rural; regenerating wet-land

The lakes and swamps were very important elements in the various phases of settlement and development of the region (Berson, 1978).

The Beeliar wetlands represent a substantial proportion of the wetland resources of Perth. Reservation for Parks and Recreation under the Metropolitan Region Scheme imposes strong planning control over the area from Piney Lake south to and including Yangebup Lake.

Some indication of the range of values for water quality in Beeliar lakes can be gained from Table 9.2.

Table 9.2. Total nitrogen levels for six Beeliar lakes - autumn and spring samples collected by the Metropolitan Water Authority (now the Water Authority of Western Australia).

TOTAL NITROGEN mg/L				
LAKE	PRE 1976		1976-1984	
	AUTUMN	SPRING	AUTUMN	SPRINT
Booragoon				
no samples	4	6	8	7
mean	2.41	0.94	1.19	1.18
Range	1.50-4.50	0.50-1.20	0.05-4.90	0.20-1.60
Bluegum				
no samples	5	5	8	7
mean	4.68	1.62	2.61	1.54
Range	2.65-8.0	0.55-3.60	1.0-7.90	0.75-2.50
North Lake				
no samples	5	6	8	7
mean	5.19	1.65	2.74	0.97
Range	2.25-8.4	0.10-3.20	0.20- 6.30	0.60-1.90
Bibra Lake				
no samples	5	6	7	7
mean	4.30	2.12	12.1	5.07
Range	3.00-6.85	0.10-3.50	3.05-20.95	2.00-7.60
Yangebup Lake				
no samples	5	6	6	7
mean	5.54	3.33	25.2	5.06
Range	4.00-7.80	1.40-5.00	8.20-67(?)	3.55-7.60
Thomson Lake				
no samples	5	6	3*	7
mean	3.91	2.09	5.12	<2.65
Range	2.05-5.45	1.0-2.85	0.75-8.35	<0.05-3.95

Groundwater levels (Cargeeg, McFarlane and Smith 1983)
Bassendean groundwater at 7.2 m depth 4.51 mg/L.

*Sampling point dry each autumn since 1979.

The areas of wetlands in the group are summarised in Table 9.3.

Table 9.3. Areas (hectares) of wetland habitats in the East Beeliar Wetlands.

WETLAND	OPEN WATER	SEDGELAND	WOODLAND (MELALEUCA & E RUDIS)	MODIFIED	TOTAL
Bluegum	4.3	-	1.8	0.8	7.0
Booragoon	3.8	-	7.6	1.7	13.1
Piney	0.8	1.6	7.9	9.9	20.2
North) Roe Swamp)	24.7	2.3	19.1	5.8	51.9
Bibra	100	8.0	40	63.6	212
South	3.8	5.5	9.2	4.3	22.8
Little Rush	-	6.8	2.5	2.2	11.5
Yangebup	68.4	11.7	5.9 (includes dead trees)	4.8	90.8
Kogolup	28.1	15.9	3.3	1.8	49.1
Thomson	151	101	1.3	-	253
Banganup	1.7	24.7	11.1	-	37.5
+ other wetland areas in Reserve	-	1.9	8.1	-	10.0
Wattleup) N & S)	5.3	4.1	6.1	9.0	24.5
Spectacles					
Big Eye	3.7	46.3	56.2	6.9	113.1
Little Eye	1.9	15.6	10.9	-	28.4
Bollard Bullrush	3.2	11.4	76.6	95 (approx)	186
TOTALS (rounded off)	401	257	268	206	1131

Efforts are being made to implement a System 6 recommendation (Environmental Protection Authority, 1983) to declare the wetlands from North Lake to Banganup as a Regional Park.

Hollick et al. (1986) considered wetland conservation in this region in the context of groundwater management in the Jandakot area.

9.1.1 REFERENCES

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9.2 BLUEGUM LAKE

9.2.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Melville
MRS ZONE: Urban
RESERVE NUMBER 25562 + ADJOINING REC: Res 29571
PURPOSE: Recreation and Conservation of Fauna
MANAGEMENT: City of Melville
SYSTEM 6 RECOMMENDATION: N/A
WAC CLASSIFICATION: LE.f.sm.p.so.
DRAINAGE: Local Authority

9.2.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The lake is in a roughly triangular depression below 10 m AHD. It lies in an interdunal depression within the predominantly leached sands of the Spearwood Dunes (Gozzard, 1983). Figure 9.3 shows the relationship of Bluegum Lake to Booragoon Lake.

An investigation by Carbon, Bartle and Murray (Carbon pers comm) showed that the lake deposits are largely coarse sand with a small proportion of organic material and clay; with the organic material extending to a depth of less than 0.5 m in the centre of the lake.

9.2.3 AREAS

Total Reserve	9.7 ha
Area of wetland	7.0 ha
Paperbark/flooded gum	1.8 ha
Open water	4.3 ha
Modified	0.8 ha

9.2.4 HYDROLOGY (Figure 9.3)

The lake is a surface expression of the groundwater of the Jandakot flow system, on a northerly flow path.

The water level record up to the end of 1973 displays a seasonal oscillation with high winter and low summer levels.

Since 1974 the pattern of oscillations has been less regular. Since that time the water level has been controlled with the lake playing an increased drainage function and being recharged with bore water to maintain summer water levels. Water levels appear to be maintained between roughly 5.5 m and 7 m AHD.

9.2.5 WATER QUALITY

Water quality parameters were monitored once monthly from 1975-1976 and these values are reported in the report of the algae odour control working group (Aplin, 1976).

The Water Authority has sampled the lake twice yearly, in autumn and spring, since 1970 (see Table 9.2).

9.2.6 LAND USE

Bluegum Lake was used for a time as a vegetable garden. It is now surrounded by residential development and provides a focus for passive recreation. Some of the surrounding residential area is dependent upon septic tanks.

9.2.7 VEGETATION (Figure 9.2)

The vegetation is highly modified. The trunks of dead trees (Eucalyptus rudis and Melaleuca rhaphiophylla) bear witness to problems of vegetation maintenance when high static water levels occur as a result of alterations to the water balance of the surrounding area or water level control. There are some exotic trees planted around the lake with managed grassland and weed communities occupying the lake margins. A replanting programme using Eucalyptus rudis and Melaleuca raphiophylla on the lake margins was tried in 1983.

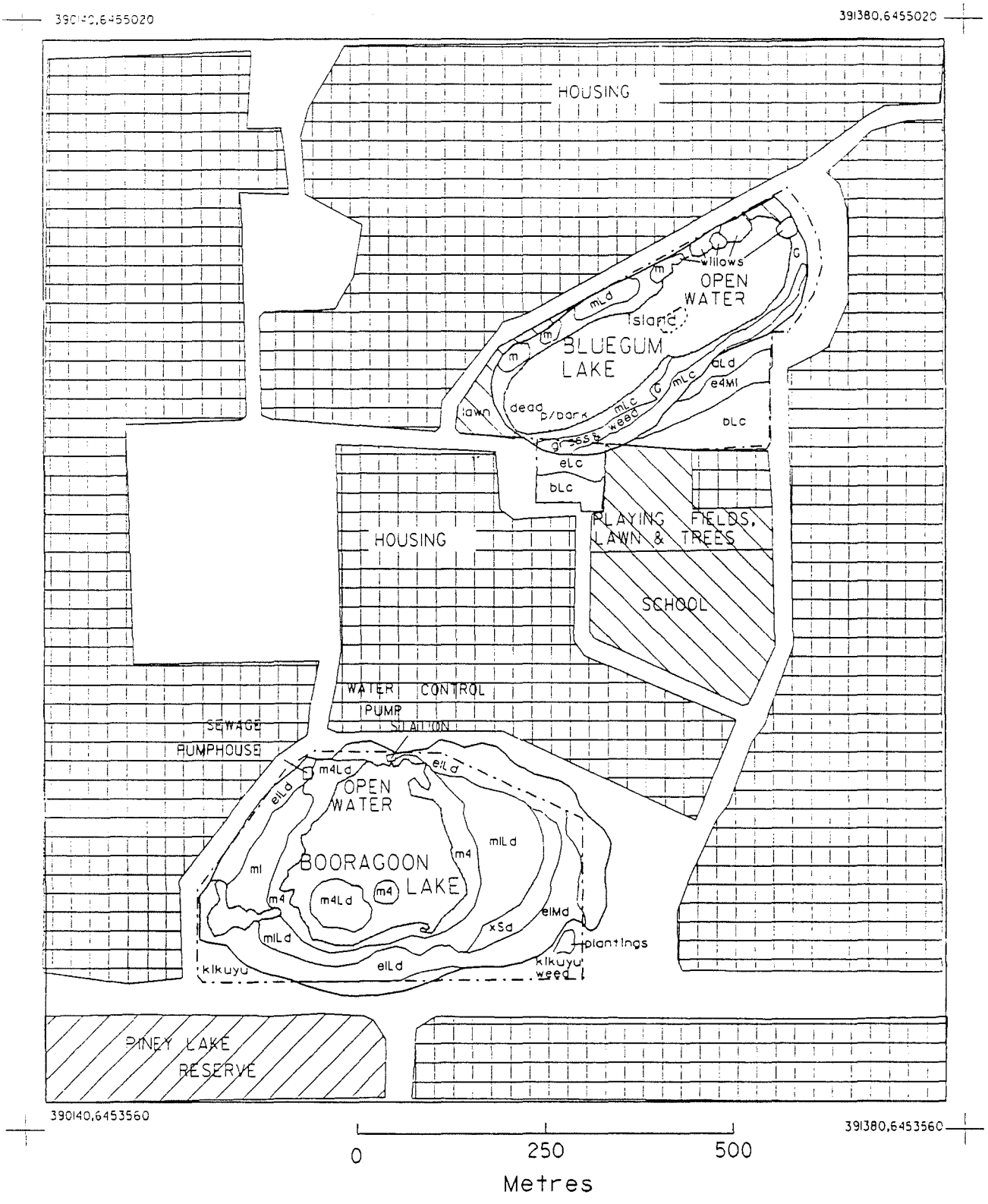

Figure 9.2 Bluegum Lake and Booragoon Lake: wetland plant communities and surrounding land use.

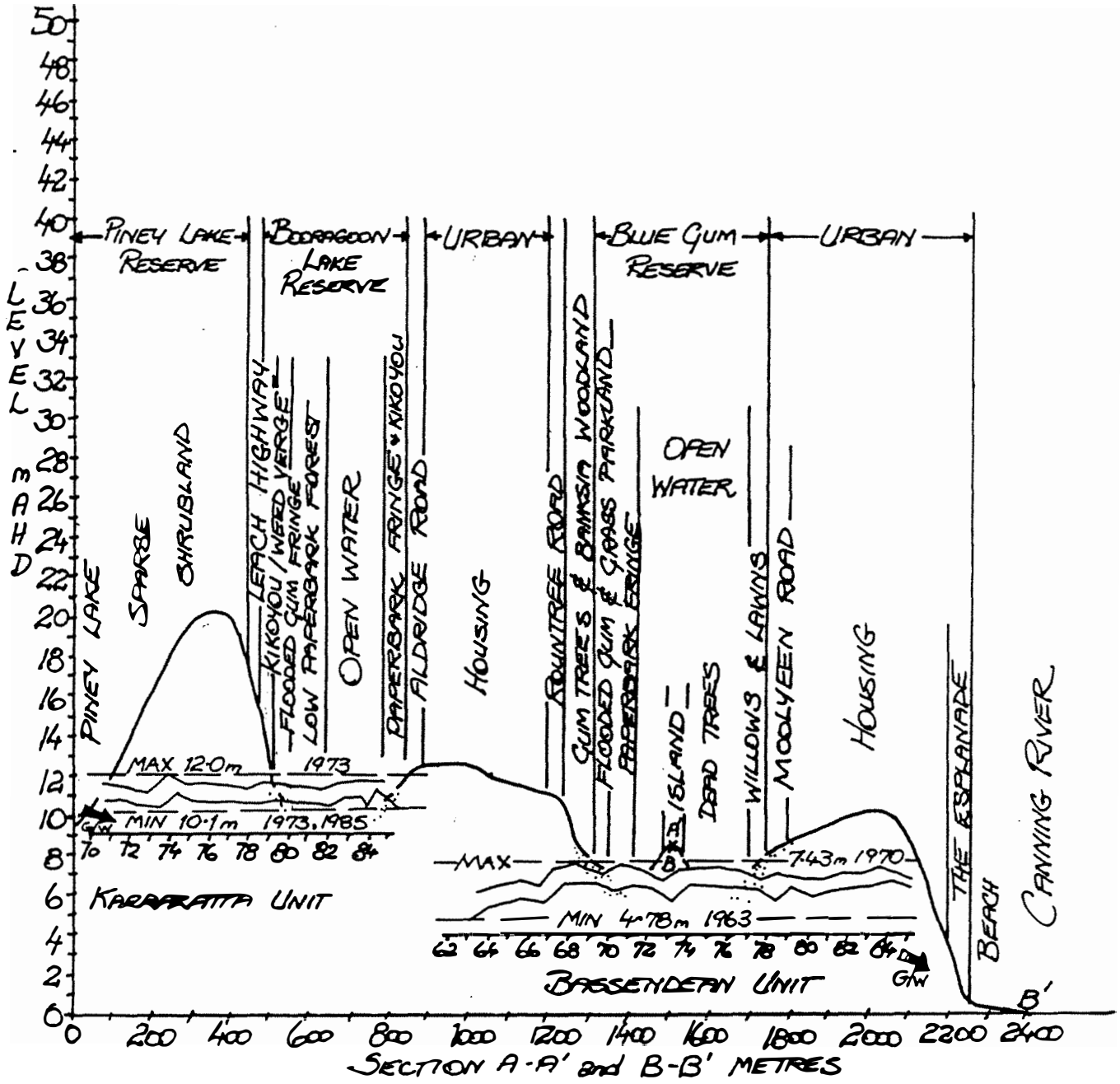

Figure 9.3 Bluegum Lake and Booragoon Lake: diagrammatic cross-section and water level records.

9.2.8 FAUNA

There is little published information. Van Delft (1988) provides notes about Bluegum Lake as a bird observation site. The Royal Australasian Ornithologists Union has a considerable amount of data on waterbirds in this area.

9.2.9 MANAGEMENT ISSUES

The lake is managed by the City of Melville to serve as a landscape feature. Water levels are controlled by pumping from Booragoon Lake and then using excess water to irrigate a recreation area. The lake is aerated by a spray system in an effort to oxygenate the waters to reduce algal blooms and noxious odours.

There is need to consider the priorities of water use in the Brentwood-Applecross area where groundwater extraction may be exceeding inflow due to heavy extraction by private bores. The Perth Urban Water Balance Study (1987) made a detailed study of the water balance of the Applecross peninsula in the course of its broad investigation of the groundwater resources of the metropolitan region.

9.2.10 REFERENCES

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9.3 BOORAGOON LAKE

9.3.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Melville
MRS ZONE: Urban
RESERVE NUMBER: 25318
PURPOSE: Public Recreation and Drainage
MANAGEMENT: City of Melville
SYSTEM 6 RECOMMENDATION: M73
WAC CLASSIFICATION: LE.f.sm.p.sc.
DRAINAGE: Local Authority Drains, recharged with bore water - excess to Bluegum Lake
ROADWORKS: Leach Highway

9.3.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Booragoon Lake is bounded by the 12 m AHD contour, close to the interface between the Bassendean landform and the Karrakatta landform. Coring carried out by Carbon, Bartle and Murray (Carbon pers comm) showed that organic

matter makes up the bulk of the lake sediments to a depth of 2 m at the centre of the lake with an increase of silt and clay to 3 m. This suggests that Booragoon has been subject to longer inundation than the neighbouring Bluegum Lake.

Smith (1986) described the physical features of the lake.

9.3.3 AREAS

Total Reserve	13.2 ha
Area of wetland	13.1 ha
Paperbark/flooded gum	7.6 ha
Open water	3.8 ha
Modified	1.7 ha

9.3.4 HYDROLOGY (Figure 9.3)

Booragoon Lake is situated on the northern flank of the Jandakot Mound. Groundwater flow in the unconfined aquifer is towards the Swan and Canning Rivers.

The water level record shows stable annual variations between about 10.6 m and 11.7 m AHD, reflecting the control maintained over water levels by the City of Melville.

9.3.5 WATER QUALITY

Aplin (1976) reported on water quality in Lake Booragoon in the Report of the Algae odour working group which sought an explanation for odour problems around the lake in 1974.

Compared with Bluegum and Lake Monger, Booragoon has very high phosphorus levels and a high colour. It has been suggested that the high colour of the lake waters prevents light penetration and hence limits growth of benthic plants and phytoplankton.

Carbon (pers comm) showed that there is a large store of phosphorus but relatively low nitrogen levels in the lake sediments and that equilibria exist between nutrient levels in the sediments and in the water column.

Table 9.2 compares Water Authority twice-yearly total nitrogen level data for six East Beeliar lakes including Booragoon.

9.3.6 LAND USE

Booragoon is remarkable as a small, relatively unmodified wetland abutting a busy highway and close to a freeway interchange. The surroundings of the lake are now completely urbanised.

9.3.7 VEGETATION (See Figure 9.2)

Smith (1986) mapped the vegetation of the lake. Comparison of 1947 air photographs with current photography shows a similar distribution of wetland vegetation but with an apparent slight increase in area relative to open water.

Paperbarks around the lake are showing signs of senescence. It is debatable whether this a consequence of maintaining permanent water in the lake through summer or of the activities of the large numbers of cormorants which roost and nest at the lake.

9.3.8 FAUNA

Smith (1986) described the aquatic and bird fauna of the lake. It is remarkable that a small lake such as Booragoon, within 50 m of Leach Highway, functions as a rookery for four species of cormorants, the Darter and the Sacred Ibis, as well as Coots, Purple Swamphens, and Dusky Moorhens. Notes on Booragoon Lake as a bird observation site are provided by Van Delft (1988). The Royal Australasian Ornithologists Union has a considerable amount of data on waterbirds for this area. In this respect it is an extraordinary resource and every effort should be made to conserve it. On the other hand, it should be recognised that it is not a static system and that changes in the vegetation and bird populations will occur.

9.3.9 MANAGEMENT ISSUES

The City of Melville has given a great deal of attention to preserving and managing Booragoon Lake. Smith (1986) outlined the history of efforts to conserve the lake. It is clearly a notable success of the Council to have achieved firstly its conservation and, more recently, to have carried out revegetation of the margins. The City's commitment to good management of the lake is shown by the implementation of the management plan.

Ongoing management issues include maintenance of the vegetation and wildlife values and the degree of control over water levels. The latter has to achieve a balance between protecting the amenity of nearby residents, control of nuisance insects and appropriate use of groundwater.

Because the lake is directly or indirectly sustained by groundwater, its water requirements have to be considered as part of the water balance for the region. There is a need for understanding of impacts of demands for water use for management of open space, and for private gardens.

9.3.10 REFERENCES

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9.4 PINEY LAKE

9.4.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Melville
MRS ZONE: Parks and Recreation
RESERVE NUMBER: Freehold land
PURPOSE: Parks and Recreation
MANAGEMENT: City of Melville
SYSTEM 6 RECOMMENDATION: N/A
WAC CLASSIFICATION: LE.f.sm.s.c.
WATER RESERVE: N/A
DRAINAGE: Local Drains.

9.4.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING.

Piney Lake is one of a number of low-lying areas within the now logged Winthrop pine plantation. It lies within an interdunal swale in the leached sands of the Spearwood Dunes near their eastern margin. The level of Piney Lake is slightly higher than Booragoon lake, to its north (See Figure 9.4).

9.4.3 AREAS

Total Reserve	approx 68 ha
Total wetland	20.2 ha
Paperbark	7.9 ha
Sedgeland	1.6 ha
Open water	0.8 ha
Modified (including scrub, weed & grass)	9.9 ha

9.4.4 HYDROLOGY (Figure 9.5)

The wetland is maintained by groundwater inflow and direct precipitation. The water balance of the area has been affected by clearing of the pine plantation and its replacement by residential development. Stormwater run-off will become an increasing component of water input but attempts are being made to manage it by infiltration rather by direct input to the lake.

Megirian (1982) plotted water levels in the region in the course of a study of the hydrogeology of North and Bibra Lakes. Twelve-point moving averages of monthly water levels at Dick Piercy Way, about 2 km south-west of Piney Lake, show a rise in water levels since a minimum in 1978, in spite of annual rainfall close to, or below, average, since that time. Thus removal of water drawn by the pine plantation is being reflected in groundwater levels. Severe problems resulting from rising water levels near Frederick Baldwin Park in Kardinya are further evidence of the effects of changing land use on the water balance.

9.4.5 WATER QUALITY

Rodda (1986) reported means and ranges of soluble phosphorus, nitrate-nitrogen and ammonia-nitrogen in water samples from the lake between March and December, 1985, as well as other physical and chemical characteristics. She noted that the lake waters are highly coloured.

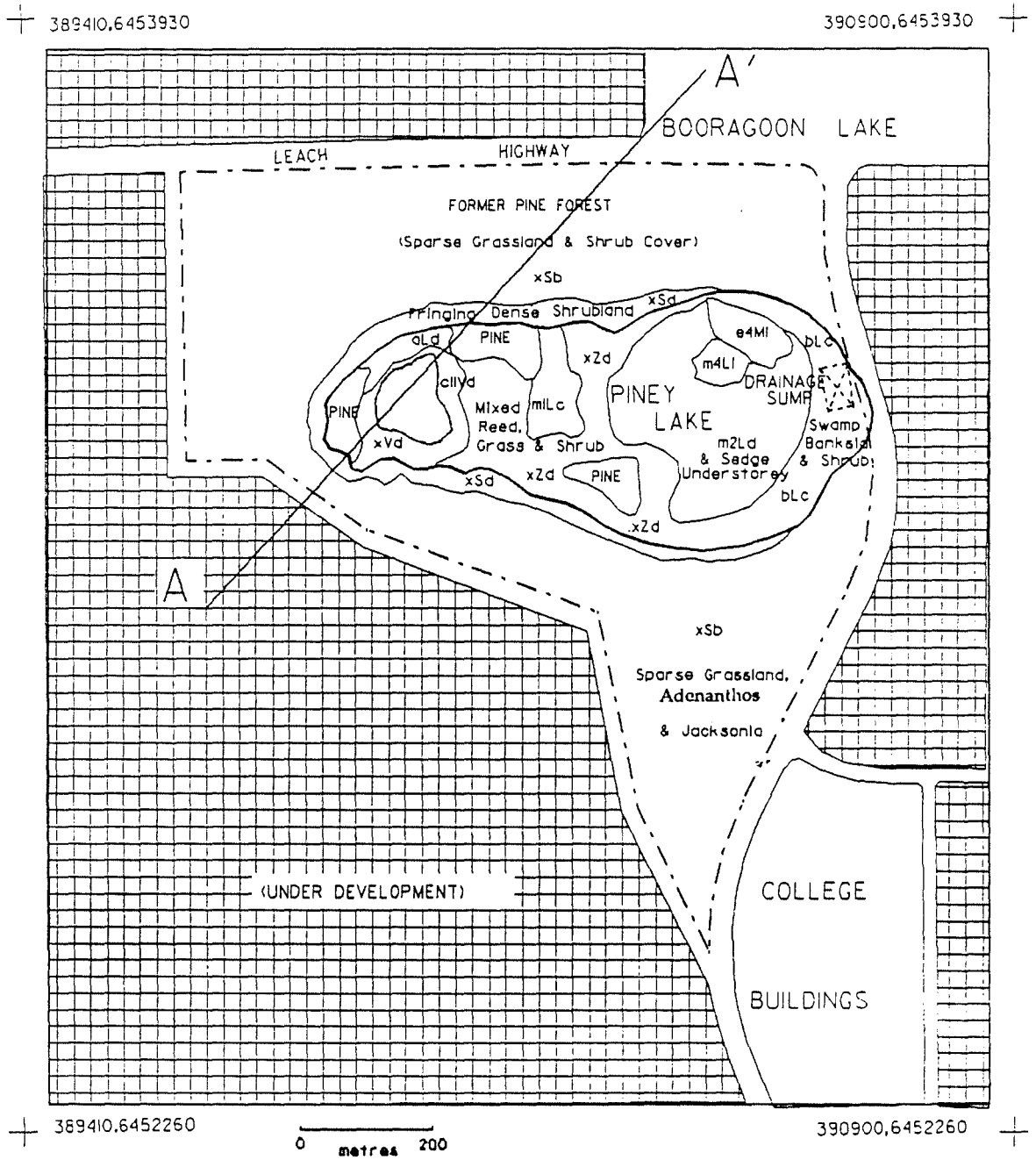

Figure 9.4 Piney Lake: wetland plant communities and surrounding land use.

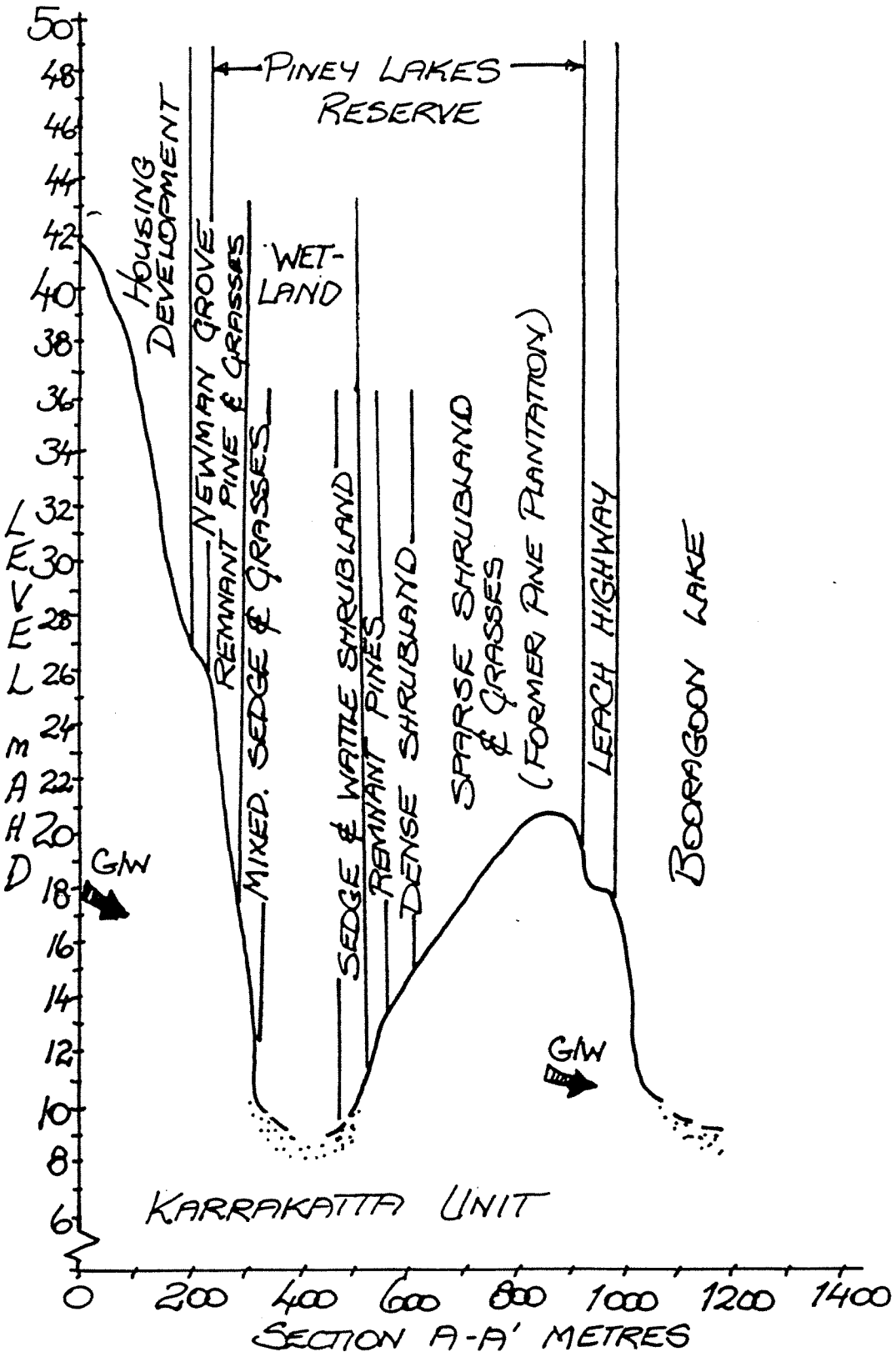

Figure 9.5 Piney Lake: diagrammatic cross-section.

9.4.6 LAND USE

Until recently Piney Lake has been surrounded by pine plantations. Rezoning of Piney Lake and surrounding land from "urban" to "parks and recreation" reflects strong recognition of the natural features of Piney Lake.

9.4.7 VEGETATION (Figure 9.4)

Rodda (1986) made a detailed study of the vegetation of Piney Lake reserve and published a list of over 100 plant species.

The area is a mosaic of wetland woodland, sedgeland, residual pines and small areas of open water. There is a high degree of interspersion of the plant communities, adding to the interest and diversity of the area. Careful management of access to the area, and good control of fire will be essential to protect this valuable relic of swampland vegetation.

9.4.8 FAUNA

Rodda (1986) investigated the fauna of the Piney Lake reserve. Her report includes lists of aquatic invertebrates, aquatic vertebrates and terrestrial vertebrates, including 17 species of waterbirds.

9.4.9 MANAGEMENT ISSUES

It is understood that efforts are being made to infiltrate drainage waters to the sand to achieve as natural a water regime as possible. This should assist in sustaining the diverse vegetation.

Any modification of the lake and development of the open space should be planned to minimise water demand so that the integrity of the natural vegetation is maintained.

9.4.10 REFERENCES

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9.5 NORTH LAKE AND ROE SWAMP

9.5.1 GENERAL INFORMATION

LOCAL AUTHORITY: Cockburn City Council
MRS ZONE: Parks and Recreation Reserve
RESERVE NUMBERS: N/A freehold land
MANAGEMENT: Not yet defined
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.l.p.o. (North) LE.f.l.s.c. (Roe Swamp)
DRAINAGE: Murdoch farm drain and Kardinya Drain
ROADWORKS: Proposed Roe Freeway.

9.5.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

North Lake is an oval-shaped, flat-bottomed bowl-shaped lake with relatively steep sides. The deepest section of the lake is below 12.4 m AHD on the eastern side.

Roe Swamp is a seasonal swamp on the eastern side of North Lake with its wettest areas below 16 m AHD. Comparable wet areas occur on the eastern side of other major wetlands in the Beeliar chain.

9.5.3 AREAS (North Lake and Roe Swamp combined)

Total MRS Reserve	approx 147 ha
Total wetland	51.9 ha
Paperbark	19.1 ha
Sedgeland	2.3 ha
Modified wetland	5.8 ha
Open water	24.7 ha

9.5.4 HYDROLOGY (Figure 9.8)

The lake and wetland are groundwater expressions situated on the western flank of the Jandakot unconfined groundwater flow system. Megirian (1982) pointed out the hydrologic similarities between North Lake and Lake Jandabup which is in an analogous position relative to the Gnangara unconfined flow system.

Prior to 1977, water input to North Lake was entirely from precipitation and groundwater seepage. Since that time there has been increasing surface input from drains from developing urban areas (Megirian, 1982). Megirian also identified the impact of urbanisation on the lake. This has resulted in rising water levels. Groundwater inflow to North Lake from the unconfined aquifer enters the lake through the sandy eastern shore and via a drain connecting North Lake to Roe Swamp. Impermeable lake deposits on the bottom of the lake do not inhibit exchange through the sides of the lake at any groundwater level so far recorded. In contrast, Bibra Lake has relatively impermeable lake deposits on the lake sides with sandy shores being restricted to one small area on the west. Consequently, when the water table falls below about 14.7 m AHD, groundwater inflow and outflow is limited. Megirian drew attention to differences between total dissolved solids in the waters of the two lakes. At low groundwater levels, North Lake shows a less marked concentration in total dissolved solids than Bibra, indicating the strong connection to through-flowing fresh groundwater at North Lake.

Table 9.4. North Lake: water levels 1971-84 (Water Authority of Western Australia water levels records).

i Maximum level recorded: 14.45 m AHD (1967).
ii Number of years in which maximum level has fallen within the specified ranges.

m AHD	1971-75	1976-84
14.5-15.0	3	6
14.0-14.5	1	2
13.5-14.0	1	1

Table 9.4. North Lake: water levels 1971-84 (Water Authority of Western Australia water levels records) (Cont'd).

iii Minimum level recorded: 11.85 m AHD (1963).
iv Number of years in which the minimum level has fallen within the specified ranges.

m AHD	1971-75	1976-84
13.5-14.0	2	2
13.0-13.5	2	6
12.5-13.0	1	1

North Lake has not dried out since 1971 when regular monthly recordings of water levels commenced. It is showing a trend towards increased summer water levels, in spite of continuing below-average rainfall. Earlier records show that the lake was dry in 1961 and 1963.

9.5.5 WATER QUALITY

North Lake has been sampled twice yearly by the Water Authority since 1971. Newman and Hart (1984) published mean values for water quality. Davis & Rolls (1987 and in preparation) have sampled the waters of the lake at regular intervals since April 1985.

Table 9.5. North Lake: chemical analyses of spring and autumn water samples (data from Water Authority of Western Australia).

PARAMETER	PRE 1976			POST 1975		
	n	MEAN	RANGE	n	MEAN	RANGE
Inorg. N mg/L						
autumn	5	<0.50	<0.10-1.0	9	0.14	0.10-0.40
spring	5	<0.42	<0.10-1.0	8	0.16	0.10-0.25
Total N mg/L						
autumn	5	5.19	2.25-7.20	8	2.74	0.20-6.30
spring	6	1.65	0.10-3.20	7	0.97	0.60-1.05
Phosphorus as P mg/L						
autumn	5	0.52	0.10-0.86	9	<0.41	<0.05-1.50
spring	5	0.28	0.08-0.40	9	<0.21	<0.05-0.75
Total Dissolved Solids mg/L						
autumn	5	754	610-1030	9	612	440-756
spring	6	418	366- 484	9	380	288-446
pH						
autumn	5	8.48	7.5-9.40	9	8.83	7.2-10.40
spring	6	8.72	7.4-9.80	9	7.38	7.0- 8.40

Table 9.5. North Lake: chemical analyses of spring and autumn water samples (data from Water Authority of Western Australia) (Cont'

Heavy metals mg/L	Range of values
Chromium:	<0.02 - <0.05
Zinc:	<0.01 - 0.07
Cadmium:	all readings <0.01
Lead:	all but one reading <0.04 one reading <0.1
Copper:	<0.01 - 0.01
Mercury:	all readings <0.0002.

The data available indicate an improvement in water quality since 1975 compared with earlier years. However, blooms of blue-green algae occur in the lake in summer. A pronounced occurrence followed late spring rains in 1985 and may have been attributable to fertiliser applications to developing suburban gardens in the lake's drainage catchment. Severe algal blooms occurred in the summer of 1986-87. Intervention was necessary to remove accumulations of rotting algae.

North Lake is the subject of an intensive investigation being carried out jointly by the Environmental Protection Authority and Murdoch University to determine the sources and loadings of nutrients entering the lake and to identify means of mitigating the detrimental effects of these inputs. The City of Melville and the State Planning Commission are also contributing to this investigation.

9.5.6 LAND USE

Land use around North Lake has been examined by the Murdoch University students (Newman, 1976; Murray, 1986). Recent changes include the removal of the pine plantation and its replacement with residential development on the north-west, and intensification of agricultural activities on the Murdoch farm on the east. Residential development on the south-east is also influencing the lake water balance. The proposed Roe Freeway immediately south of the lake may have very marked effects.

9.5.7 VEGETATION (Figure 9.6)

Rural land uses have changed the fringing vegetation of North Lake so that it includes grasses, weeds and acacia. A sensitive replanting programme has been carried out under the Community Employment Programme. This includes the successful establishment of Baumea articulata. However, this may be in jeopardy as a result of rising water levels.

Roe Swamp consists of dense, closed wetland vegetation, including closed paperbark woodland and sedgebeds.

9.5.8 FAUNA

Newman (1976) investigated the birdlife of North Lake.

The invertebrate fauna of North Lake has been studied by Davis & Rolls (1987 and Davis, Rolls and Balla, in preparation). This work provides insights into the seasonal changes in the invertebrate fauna of the lake, allows

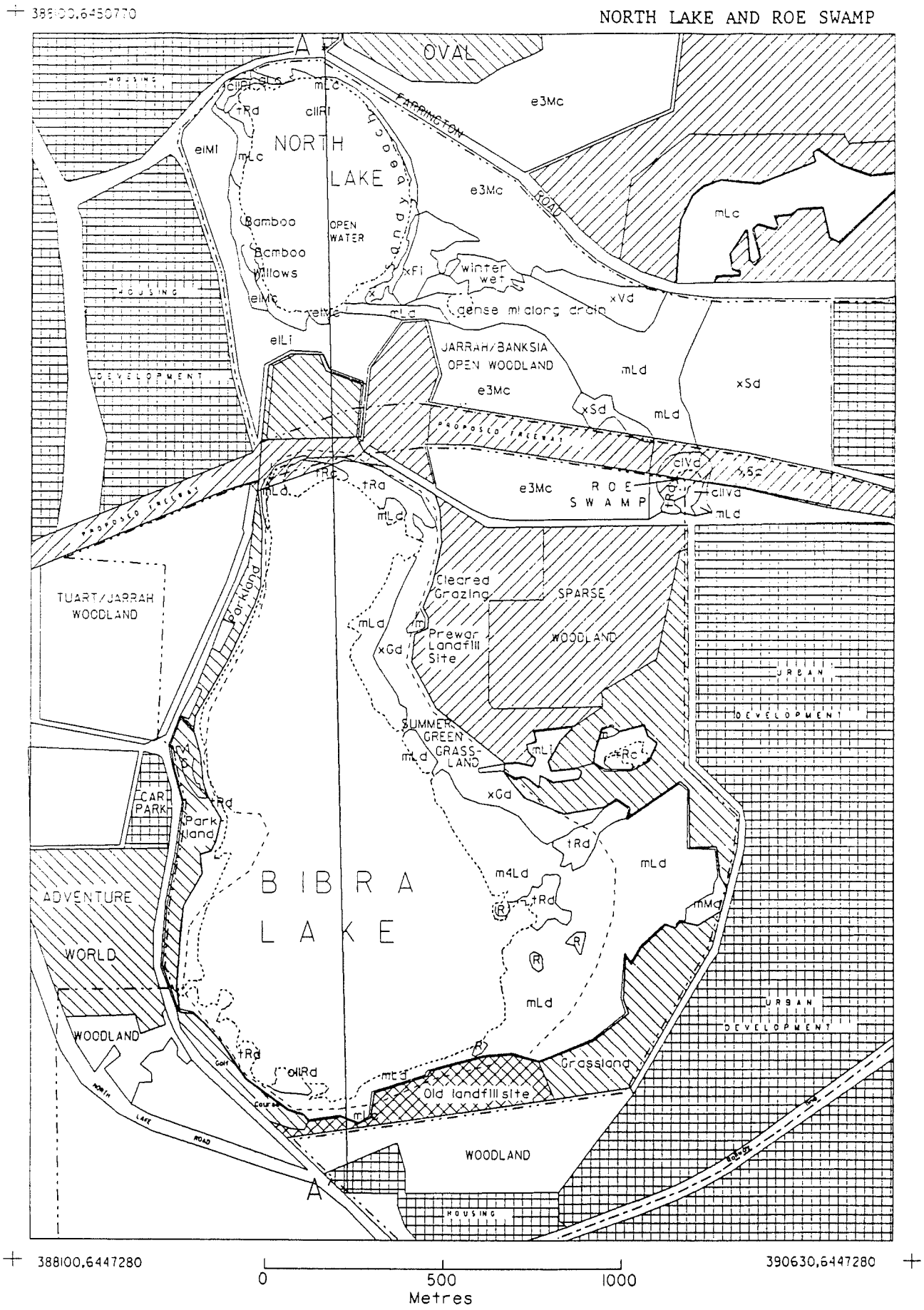

Figure 9.6 North Lake, Roe Swamp and Bibra Lake: wetland plant communities and surrounding land use.

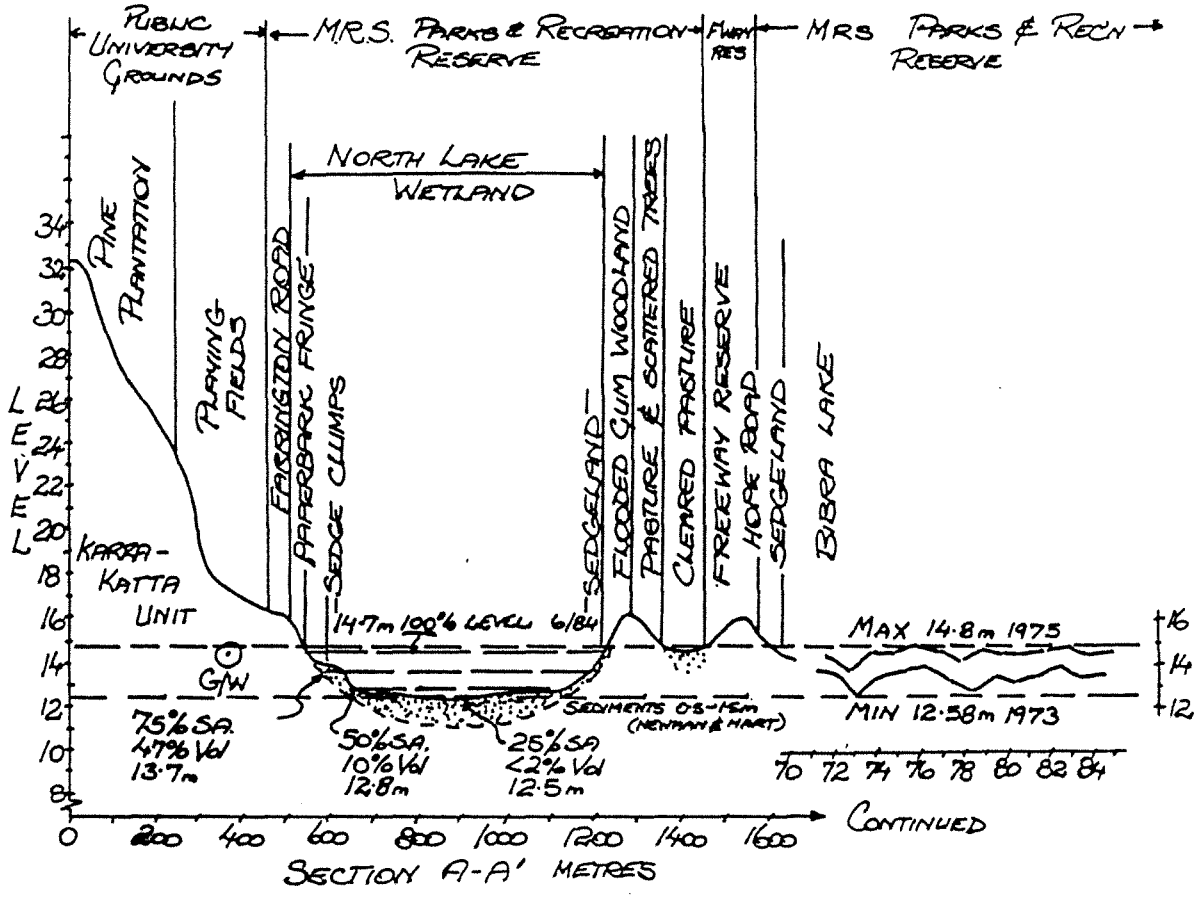

Figure 9.7 North Lake: diagrammatic cross-section and water level records.

comparisons with other metropolitan lakes and provides an invaluable body of information for people wishing to use the lake as an educational resource. Chironomid (non-biting) midges breed in North Lake and swarms of adults emerging from the lake cause annoyance to residents living nearby. The lake has been routinely sprayed with Temephos (ABATE) for a number of years to control midge breeding. There is now increasing concern that this method of control is losing its effectiveness. State agencies and concerned local authorities have recently initiated investigations of the issues.

9.5.9 MANAGEMENT ISSUES

Stresses

- Increasing urban development with impacts on water quality and water balance.
- Requirements for insect pest control.
- Increasing recreation demands.
- Possible loss of wetland vegetation on Roe Swamp.
- Impact of road works - including increased runoff and impacts on water quality.

Management Issues

North Lake is a significant element in the surburban setting and it contributes to the amenity and recreation opportunities of the area. However, investigations carried out in 1987-88 show that unacceptably high nutrient loads are entering the lake from its catchment (Bayley, in prep).

Because the lake basin has steep sides and a flat bottom, it retains a considerable water surface, even when lake levels are low - therefore it remains a water feature rather than mudflats in summer. Megirian (1982) has shown that the lake is in close contact with the groundwater, even when the water table is at low levels, so that groundwater recharge is maintained throughout the summer.

The dense wetland vegetation of Roe Swamp may represent a heavy evapotranspiration loss but may also play a role in moderating the chemistry of groundwater inputs from the east. Efforts should therefore be made to retain this vegetation.

9.5.10 REFERENCES

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9.6 BIBRA LAKE

9.6.1 GENERAL INFORMATION

LOCAL AUTHORITY: Cockburn City Council
MRS ZONE: Parks and Recreation
RESERVE NUMBERS: A6208
MANAGEMENT: Cockburn City Council
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.l.p.o.
WATER RESERVE: West of Jandakot Public Water Supply Area
ROADWORKS: Future Roe Freeway - northern end

9.6.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Bibra Lake is a marsh in the high level interbarrier depression between the Bassendean and Spearwood Dunes (Gozzard, 1983). Megirian (1982) described the lake deposits and provided insights into the processes which have shaped the wetlands of the region. Megirian showed that Bibra lake deposits have been formed during at least three cycles of sedimentation to form three shallow infilled depressions. The lake deposits show evidence of three phases of rejuvenation and Megirian suggested possible explanations for these cycles, including climatic change, tectonism or eustatic changes and changes in the position of the Swan River channel with consequent alterations of the configurations of the water table.

The geology and hydrology have been described by Megirian and Davidson (1984). Deep grey sands occur on the eastern side of the lake while limestone pinnacles exposed in a sandpit on the west of the lake have now been incorporated into the landscape of the amusement park 'Adventure World'. The lake is separated by a low barrier from North Lake and related wetlands to the north. The margins of the lake have been substantially modified by landfill on the western and southern margins. Rubbish dumping also occurred on the north-eastern side of the lake prior to World War Two. (K Cole, pers comm.)

9.6.3 AREAS

Area defined by Progress Dr, Hope Road, and Bibra Drive	approx 237	ha
Water surface defined by water boundary 13.11.74 (15.03 m AHD)	135	ha
Water surface free from emergent vegetation	100	ha
Melaleuca thicket - eastern side	30	ha
Fringing Melaleuca	10.0	ha
Typha and sedges - fringe & islands	8.0	ha
Modified - parkland & grazed area	63.6	ha
Woodland - eastern side	23.7	ha

9.6.4 HYDROLOGY (Figure 9.8)

The lake is a groundwater expression situated on the western flank of the Jandakot Mound. As urban development expands in the region, it will result in the groundwater inputs being increasingly replaced by surface inflows from urban drains.

According to Davidson (1984) the 15 m groundwater contour intersects the eastern side of the lake and the 12 m contour lies to the west of the lake. These levels are of course subject to seasonal changes and to changes reflecting recharge and use of the groundwater. The water level used to mark the upper limit of bathymetric contours is 15.034 m (November 1974).

The lowest point of the lake basin is about 12 m AHD in the channel on the western side. For the last 20 years the maximum water level has always exceeded 13.7 m (50% surface area; 10% volume).

The maximum level recorded was 15.61 m AHD in the winter of 1968 and the lowest recorded level was 12.56 m AHD in the autumn of 1978. Since 1978 both maximum and minimum water levels in the lake have been rising, reflecting the changing water balance of the region brought about by clearing and development east of the lake.

Megirian showed that the lake deposits are relatively impermeable. As a consequence, when groundwater levels fall below the top of the lake deposits, at about 14.7 m, groundwater inflow is restricted and the lake tends to dry out as evaporation exceeds input. Increased salinities during summer are a result of concentration effects. Bibra Lake differs from North Lake which lacks the dense marginal peat and hence allows inflow of groundwater levels even when the water table is low.

9.6.5 WATER QUALITY

Newman (1976) identified water quality problems at Bibra Lake associated with sanitary landfill on the lake shores. Newman and Hart (1984) documented nutrient levels in the lake. Table 9.2 suggests that, with regard to total nitrogen, Bibra Lake and Yangebup Lake have higher levels than other lakes in the group.

9.6.6 LAND USE

Bibra Lake has been strongly affected by activities on surrounding land, ranging from grazing and farming in colonial times through to landfill, and urban development and road works more recently. These activities have left a legacy of high nutrient levels and reduced biotic diversity.

9.6.7 VEGETATION (Figures 9.6)

The fringing vegetation of Bibra Lake has been substantially changed around much of the lake. The thickets of Melaleuca teretifolia represent a significant remnant of the native vegetation and contribute to the conservation value of the lake (see Newman, 1976). Fringing Typha orientalis has expanded in recent years, probably as a symptom of low summer water levels and high levels of nutrients. There is little benthic vegetation in the lake basin.

9.6.8 FAUNA

Newman (1976) pointed out the differences in wildlife values between the eastern and western shores. The south-east has been identified as a valuable area for bird life: with mud flats and shelter in the Melaleuca thickets; while the western shore has been more highly modified and has large numbers of more common bird species, eg Black Duck, Black Swans, Silver Gulls, feral ducks and domestic geese. These birds are very tame and provide some of the attraction for people visiting the playground and lookout. Notes on Bibra Lake as a bird-watching site are provided by Van Delft (1988).

9.6.9 MANAGEMENT ISSUES

There have been pressures to dredge the lake to improve its value as a landscape feature by maintaining permanent water in the lake basin. Advocates have suggested that the effects of dredging would include lowering of water temperatures and removal of nutrient-enriched sediments with consequent improvement of water quality (Newman and Hart, 1984). Use of dredge spoil to provide habitat islands in the lake basin has also been suggested. Megirian (1982) and Davidson (1984) investigated the hydrogeology of the lake basin and showed that selection of areas to be dredged should be made on the basis of an understanding of the groundwater inputs and outputs.

Bibra is a well-used picnic spot and considerable use is made of its cycle path and the golf course now developed on one of the landfill sites. The western side receives the heaviest use but with increased suburban development on the south side of the lake, recreational use is likely to increase.

Recognising the importance of Bibra Lake to the local community it would be appropriate to maintain landscape value. It would be reasonable to maintain the water level to provide a significant coverage of the surface area to protect landscape values.

Water quality is poor; there are frequent blooms of Microcystis. Poor water quality may be the result of leachates from the old tip sites. It would therefore be preferable to avoid undue concentration of water in summer.

If the water level is maintained at 13.7 m AHD minimum this would provide for 50% of the lake area to be covered with water and for there to be a minimum of 10% of total lake volume.

Management of water supplies to the lake should seek to enhance its year-round landscape values and to improve water quality. Dredging remains possible. Improvement of the lake contact with the groundwater by removing impermeable lake sediments on the eastern side of the lake may be possible. Increasingly, management of the water supply of lakes like Bibra has to be seen in the context of management of the regional groundwater.

9.6.10 REFERENCES

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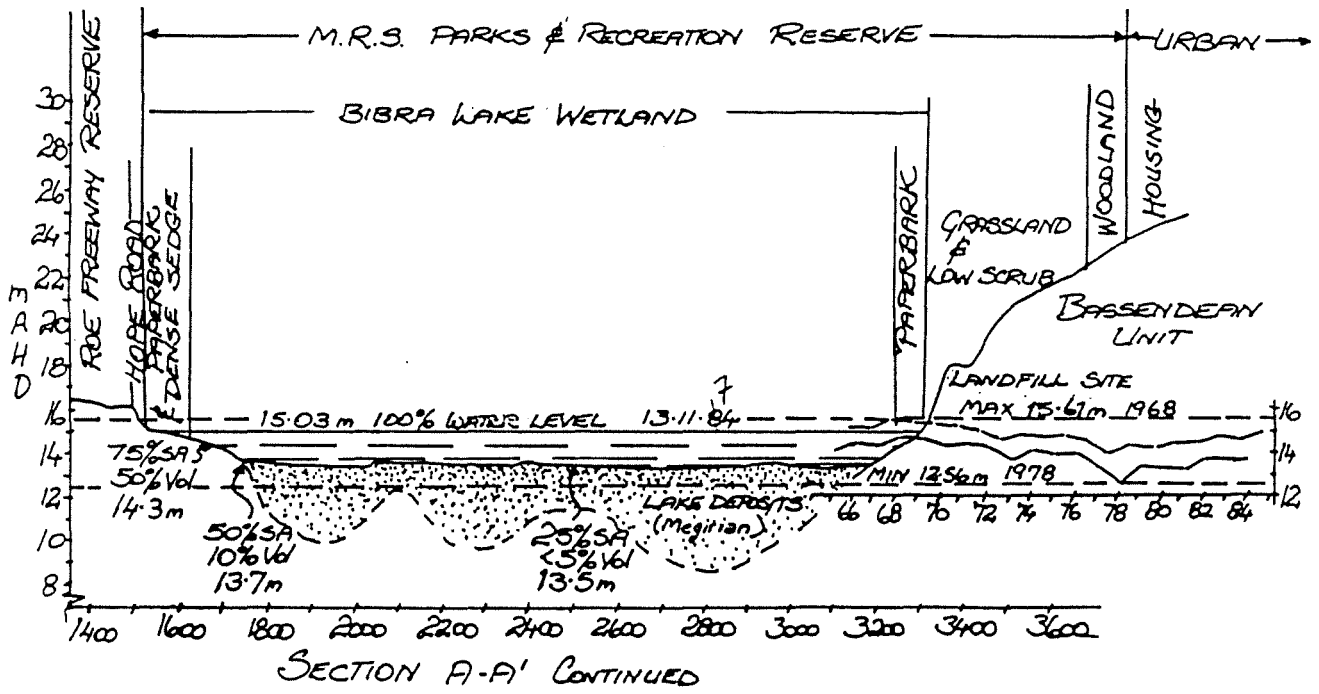

SECTION A-A' CONTINUED

Figure 9.8 Bibra Lake: diagrammatic cross-section and water level record.

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Van Delft, R (1988), 'Birding sites around Perth'. University of Western Australia Press, Nedlands.

9.7 SOUTH LAKE AND LITTLE RUSH LAKE

9.7(a) GENERAL INFORMATION

(i) South Lake

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation
MANAGEMENT: State Planning Commission
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.sm.s.so.
WATER RESERVE: West of Jandakot Public Water Supply Area

(ii) Little Rush Lake

As per South Lake except : WAC CLASSIFICATION: LE.f.sm.s.c.

9.7(b) AREAS

South Lake Area including surrounding reserve	approx 47 ha
Total wetland	22.8 ha
Paperbark	9.2 ha
Sedgeland	5.5 ha
Open water	3.8 ha
Modified wetland	4.3 ha

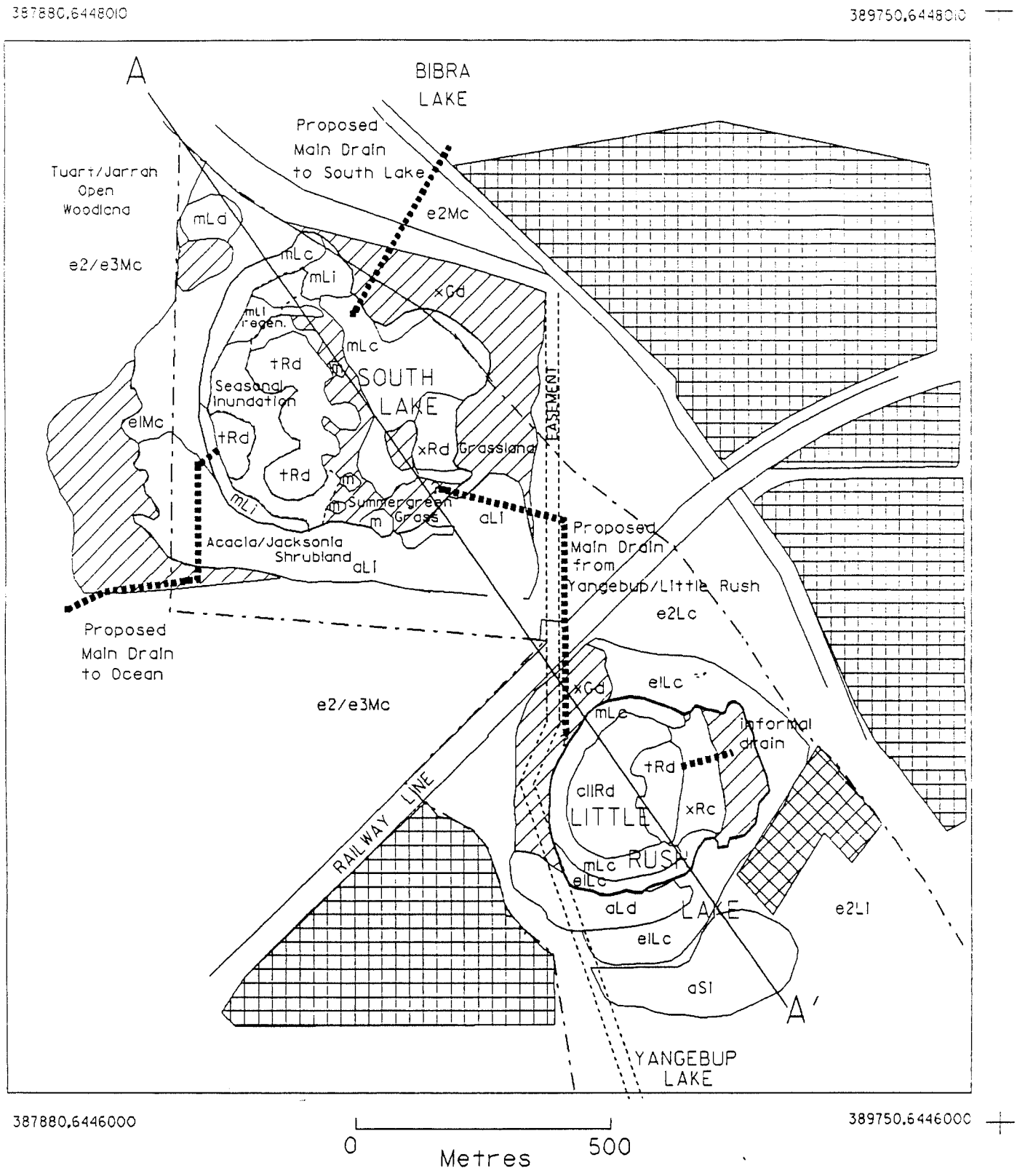

Figure 9.9 South Lake and Little Rush Lake: wetland plant communities and surrounding land use.

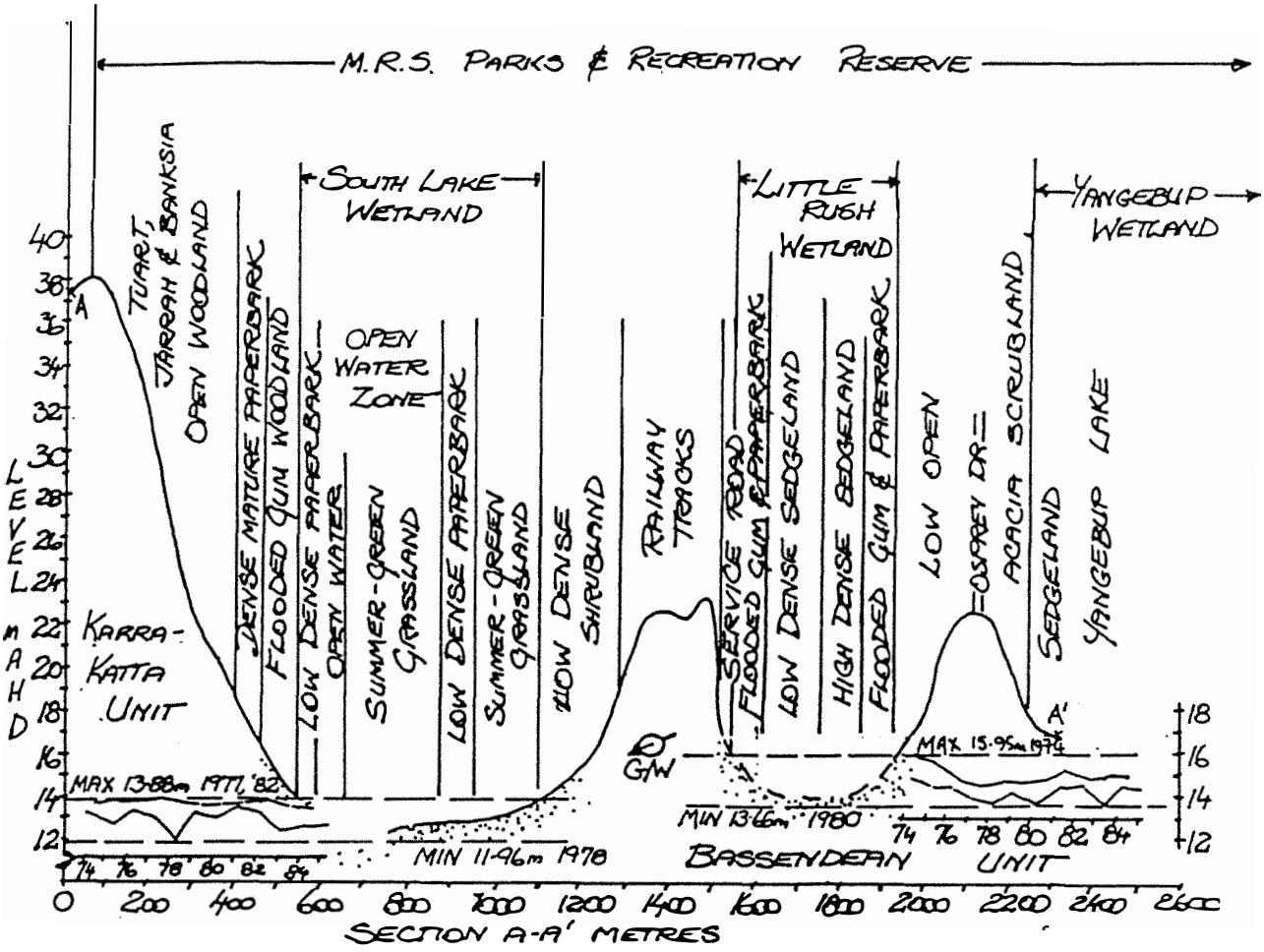

Figure 9.10 South Lake and Little Rush Lake: diagrammatic cross-section and water level records.

Little Rush Lake Area including surrounding reserve	approx 44 ha
Total wetland	11.5 ha
Paperbarks	2.5 ha
Sedgeland	6.8 ha
Open water	nil
Modified wetland	2.2 ha

9.7(c) VEGETATION, FAUNA AND MANAGEMENT

Figures 9.8 and 9.10 show wetland plant communities and diagrammatic cross-section of these two small wetlands. In spite of some invasion by Typha, both wetlands have complex vegetation patterns. It will be regrettable if rising water levels resulting from changing land use cause loss of the sedgelands and reduction of the paperbark fringes.

9.7(d) REFERENCE

Newman, P, (editor) (1976). The Cockburn wetland study. Prepared by students of Murdoch University for the Town of Cockburn.

9.8 YANGEBUP LAKE

9.8.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation Reserve
RESERVE NUMBER: n/a freehold land
MANAGEMENT: State Planning Commission
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.m.p/s.o
WATER RESERVE: West of the Jandakot Public Water Supply Area
DRAINAGE: Local drainage from South Lake and Yangebup localities.
ROADWORKS: Future Yangebup Road and Spearwood Avenue.

9.8.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Yangebup is a circular depression with lake deposits, situated at the interface of the Bassendean and Spearwood Dunes. The lake has relatively steep sides and a flat bottom.

9.8.3 AREAS

Area of wetland plus surrounding reserve (bounded by roads)	approx 142 ha
Total wetland	90.5 ha
Paperbark/Acacia	2.6 ha
Sedgeland	11.7 ha
Open water	68.4 ha
Modified wetland	4.8 ha
Area within lake with skeletal trees	2.9 ha
Area of effluent ponds (outside wetland proper)	approx 6.5 ha

9.8.4 HYDROLOGY (Figure 9.12)

No study of the hydrogeology of the lake has been made but a consultants' study has examined drainage of developing urban land on the north-east (South Lakes Estate).

There has been a marked fall in both maximum and minimum levels of the lake since 1968 with maximum levels since 1976 being close to minimum levels prior to 1976. Lowest water levels were recorded in 1980-81 and for several summers the lake bed dried early in summer. Since that time the lake levels have been rising. Sub-surface drains in developing urban land on the north-east of the lake discharge to Lake Yangebup and as urban development occurs the water inputs will change from being principally groundwater seepage to partly surface inflow from urban drains. The location of the effluent ponds of the woolscourers on the east of the lake are in an unfavourable position relative to groundwater inflow to the lake.

Table 9.6. Yangebup Lake: water levels 1968-1985.

i Maximum level recorded 17.54 m AHD (1968).
ii Number of years in which the maximum level has fallen within the specified ranges.

LEVEL m AHD	1968-84	1976-84
17.5-18.0	1	0
17.0-17.5	0	0
16.5-17.0	2	0
16.0-16.5	1	0
15.5-16.0	3	0
15.0-15.5	1	2
14.5-15.0	0	3
14.0-14.5	0	4

iii Minimum level recorded: 13.1 m AHD (1980).
iv Number of years in which the minimum level has fallen within the specified ranges.

LEVEL m AHD	1968-75	1976-85
16.0-16.5	2	0
15.5-16.0	1	0
15.0-15.5	1	0
14.5-15.0	3	2
14.0-14.5	1	1
13.5-14.0	0	3
13.0-13.5	0	4

9.8.5 WATER QUALITY

The following values are from monitoring data obtained by the Water Authority since 1970. Single autumn and spring samples taken each year provide some indication of condition and trend of nutrient levels in the lake waters.

Water quality in the lake is poor compared with other lakes (but note relatively poor quality at Bibra). It is likely that poor water quality can be related to the activities of the woolscourers on the eastern side of the lake. The effluent ponds are situated in an unfavourable position relative to groundwater flow in the lake and there is evidence of seepage from the

ponds closest to the lake towards the lake during the winter (J Arnold: personal observation winter 1985). Effluent management from the works has probably been less satisfactory in the past than it is at present and the Cockburn Wetlands Study suggested that dead trees in the lake basin may have been killed by effluent discharge many years ago.

Table 9.7. Yangebup Lake: chemical analyses of spring and autumn water samples (data from Water Authority of Western Australia).

	PRE 1976			1976-84		
	n	MEAN	RANGE	n	MEAN	RANGE
Inorganic N mg/L						
Autumn	5	1.35	0.20-5.00	7	0.39	0.10-0.65
Spring	5	<0.35	<0.02-1.10	8	1.24	0.10-3.30
Total Nitrogen mg/L						
Autumn	5	5.54	4.00-7.80	6	21.0	8.20-67
Spring	6	3.33	1.40-5.00	7	5.06	3.55-7.6
Phosphorus as P mg/L						
Autumn	5	0.81	0.08-1.46	7	1.29	0.25-3.3
Spring	5	0.88	0.44-1.00	9	0.71	0.55-1.1
Total Dissolved Solids mg/L						
Autumn	5	2909	1992-3796	7	6531	3575-12520
Spring	6	1857	1432-2380	9	1749	1050-2778
pH						
Autumn	5	8.72	8.30-8.90	7	9.07	8.60-9.7
Spring	6	8.57	8.30-9.10	9	8.43	8.00-8.8

9.8.6 LAND USE

Current land use around the lake is outlined in the Management Proposal for Yangebup Lake (Students of N319 Environmental Management, 1988, pp 64-70).

9.8.7 VEGETATION (Figure 9.11)

Comparison of 1:5000 orthophotomaps (1.11.1974) with 1:5000 air photos (April 1983) shows some expansion of both paperbarks and rushes on the western side of the lake in the nine years between the two photographs. This suggests that some recovery is taking place at a distance from the effluent ponds.

9.8.8 FAUNA

9.8.8.1 Invertebrate Fauna

The lake is a breeding place for chironomid midges - small flies which, although they do not bite, cause distress to lakeside residents when they occur in large swarms at dusk. The swarms are attracted to lights and are small enough to pass through fly-screens. The larval stages of chironomids live in nutrient-rich, low-oxygen muds.

9.8.8.2 Birds

Detailed bird counts were made at Yangebup Lake in the mid-70's by Brian and Pauline Clay, managers of the Harry Waring Reserve at Banganup. The counts were made as part of a study of birds of the Cockburn lakes, including Banganup and Lake Thomson. A sample count follows (Brian Clay, pers comm).

Date: 31/3/76

Black Swan	35
Pacific Black Duck	1 300
Grey Teal	800
Australasian Shoveller	400
Grebes	90
Pink-eared Duck	250
Australian Shelduck	24

Pink-eared Duck appear to have occupied the lake each summer for a number of years.

In the course of an inspection of the lake on 24 July, 1985, moderate numbers of Pink-eared Duck and Grey Teal were noted, together with Black Swans and Black-winged Stilts. This suggests that the lake's value for bird life is being maintained.

9.8.9 MANAGEMENT ISSUES

- The lake clearly has conservation value, in spite of the proximity of the woolscourers' effluent ponds.

- The conservation value is probably impaired by the effects of the ponds; loss of fringing vegetation on the southern side reduces habitat diversity; it is likely, but not possible to document, that leachate from the ponds poses some threat to wildlife and may enhance midge breeding at the lake.

- The landscape value of the lake is impaired by the presence of the ponds and the disrupted vegetation on the southern and eastern sides of the lake.

- Insects such as small flies and chronimid midge (See Section 9.8.8.1)

An investigation of the management requirements of Lake Yangebup was undertaken in the spring of 1987 by Murdoch students of Environmental Management (Students of N319 Environmental Management, 1988).

9.8.10 REFERENCES

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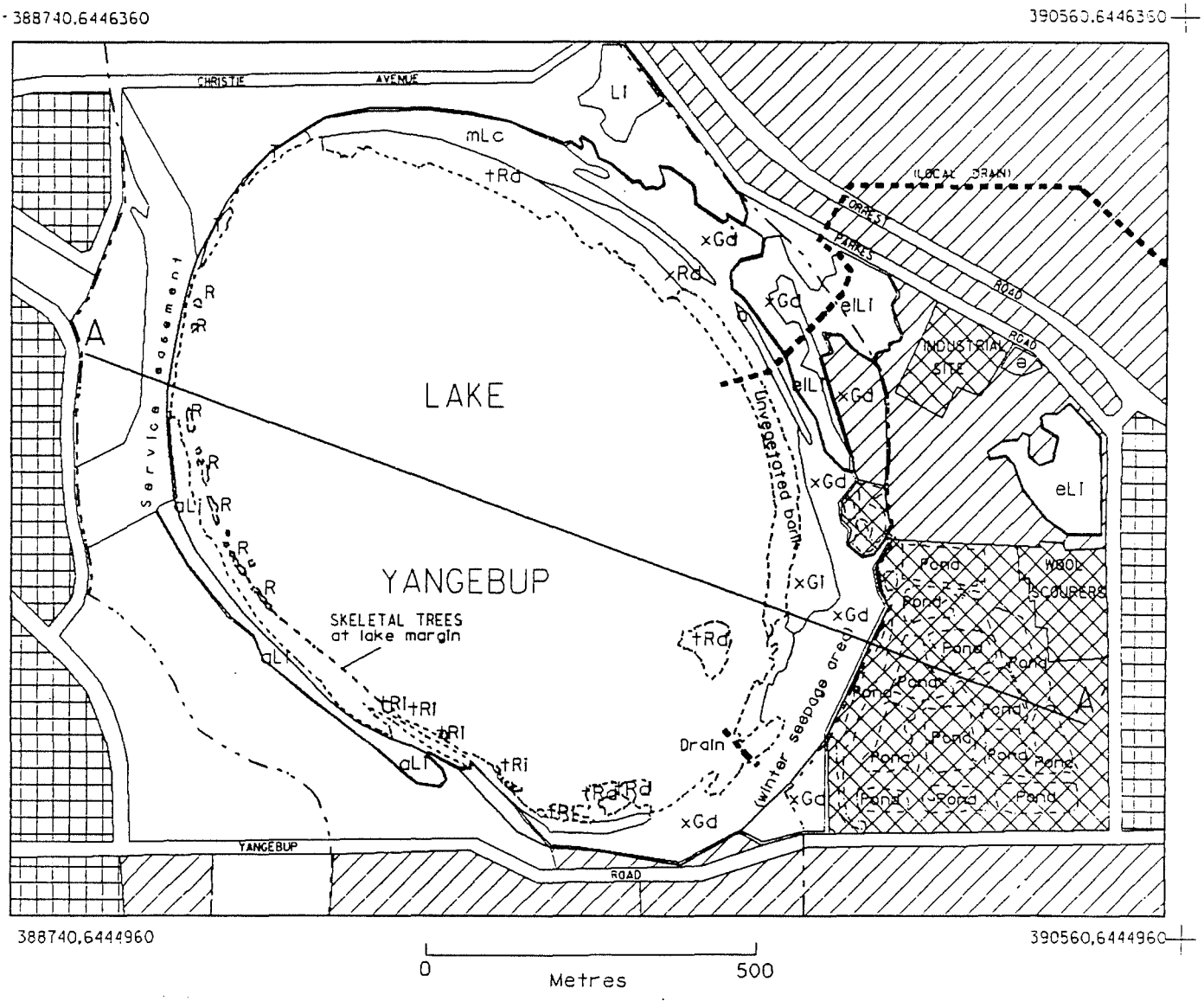

Figure 9.11 Lake Yangebup: wetland plant communities and surrounding land use.

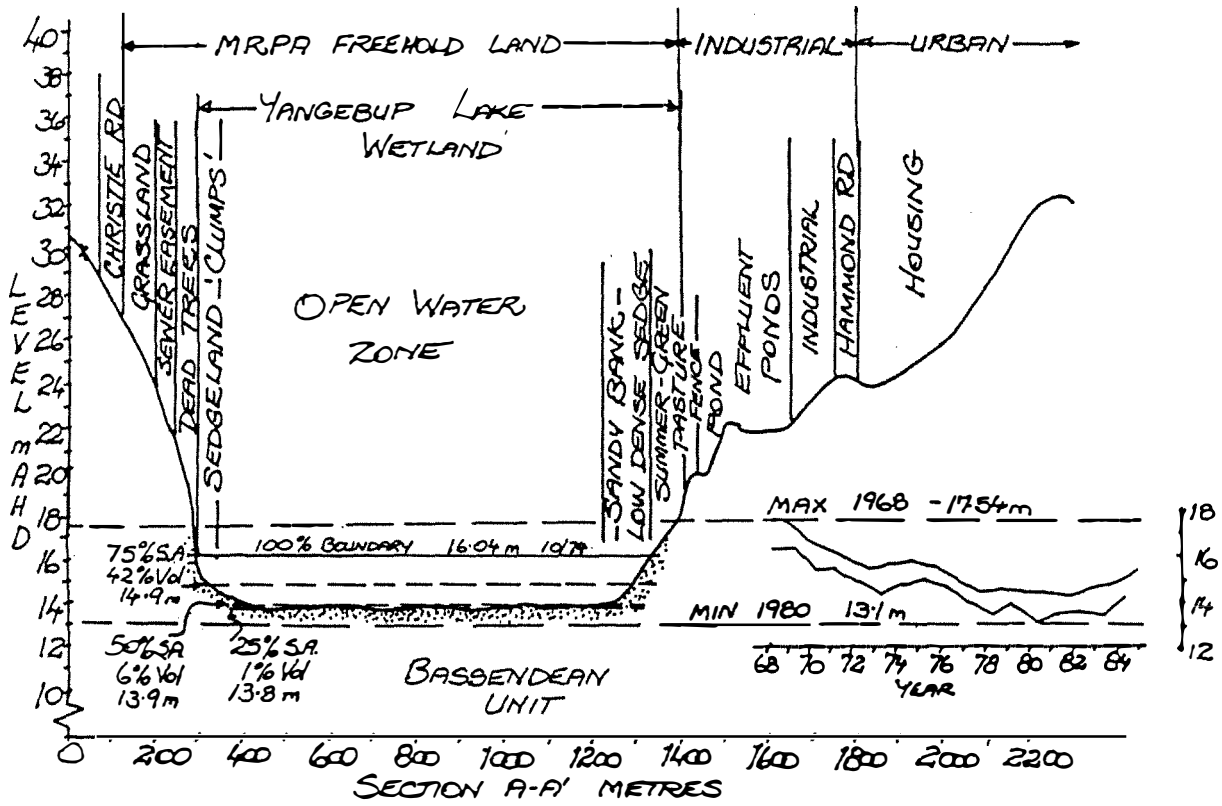

Figure 9.12 Lake Yangebup: diagrammatic cross-section and water level record.

9.9 LAKE KOGOLUP

9.9(a) GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Rural
RESERVE NOS: n/a
MANAGEMENT: Private landholders
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.m.p/s.so.
WATER RESERVE: West of Jandakot Public Water Supply Area
DRAINAGE: Future drainage of proposed urban areas.

9.9(b) AREAS

Total wetland	58.7 ha
Paperbarks	3.3 ha
Sedgeland	15.9 ha
Open water zone	28.1 ha
Flooded gum/Acacia within wetland	9.6 ha
Modified wetland	1.8 ha

9.9(c) VEGETATION AND FAUNA

Figures 9.13 and 9.14 show wetland plant communities and a diagrammatic cross-section for Lake Kogolup. Newman (1976) described the vegetation and fauna of Lake Kogolup.

9.9(d) REFERENCE

Newman, P (editor) (1976), The Cockburn wetland study. Prepared by students of Murdoch University for the Town of Cockburn.

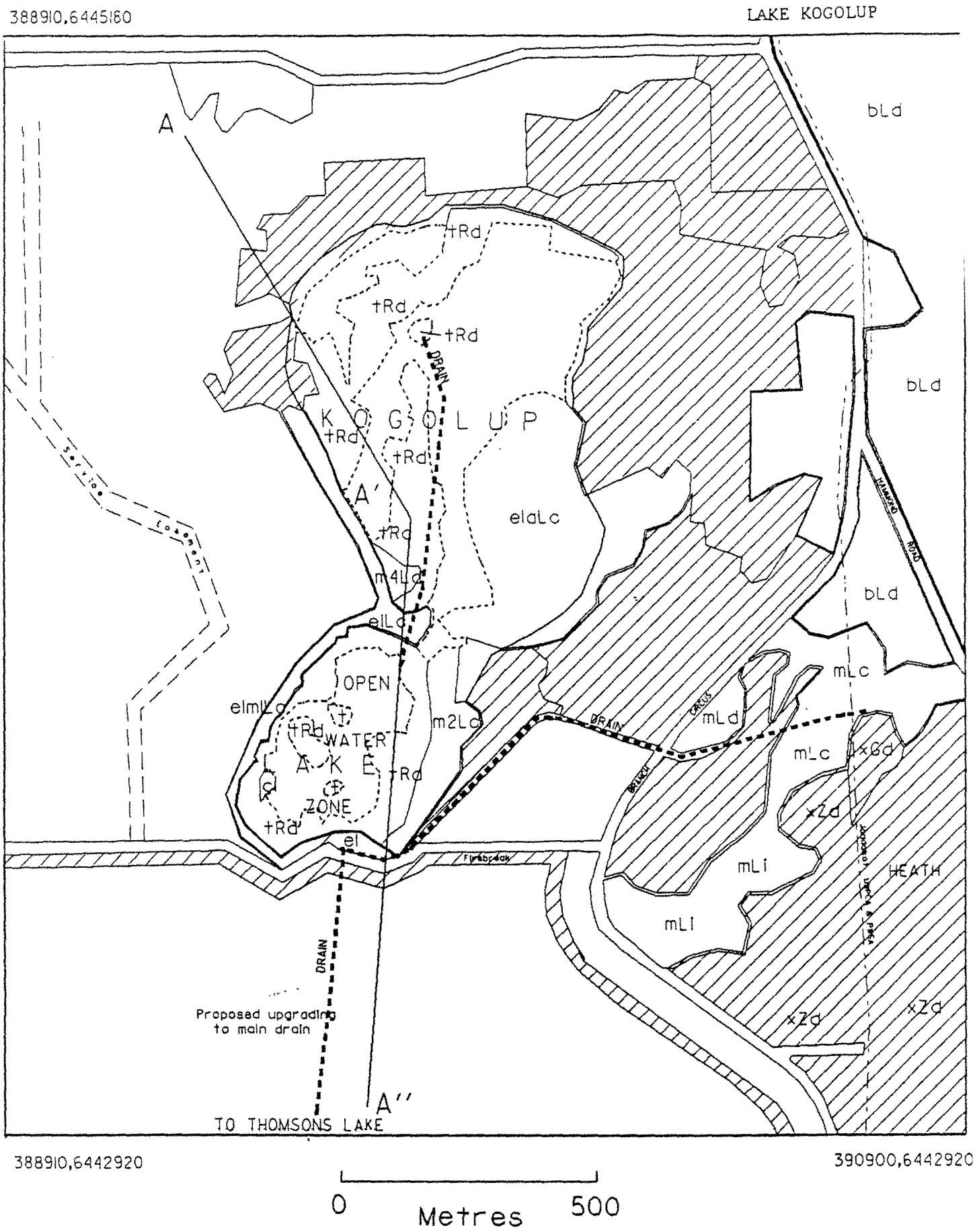

Figure 9.13 Lake Kogolup: wetland plant communities and surrounding land use.

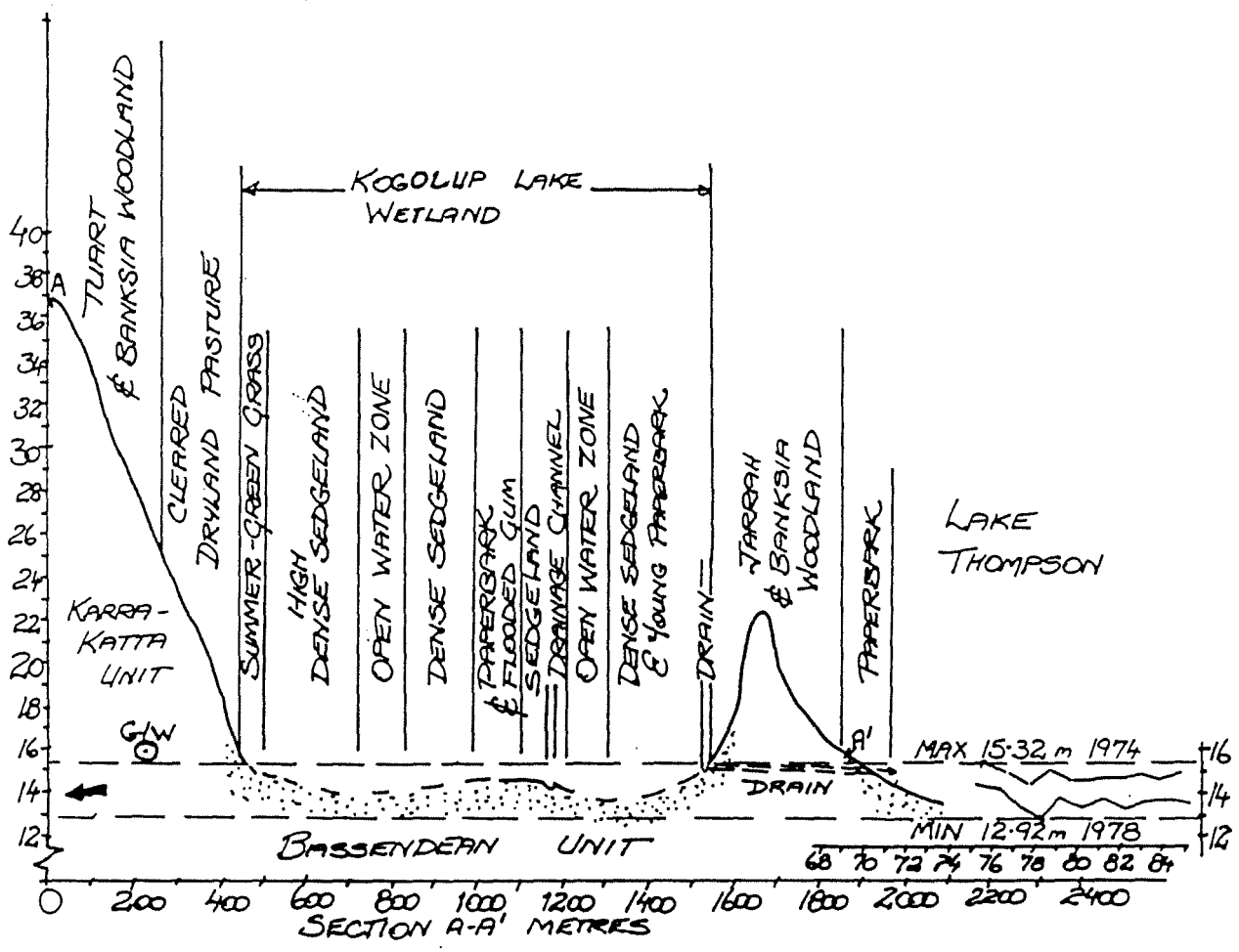

Figure 9.14 Lake Kogolup: diagrammatic cross-section and water level record.

9.10 THOMSONS LAKE

9.10.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation
RESERVE NUMBER: A15556
PURPOSE: Conservation of Flora and Fauna
MANAGEMENT: Department of Conservation and Land Management
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.l.s.o
WATER RESERVE: West of Jandakot Public Water Supply Area
DRAINAGE: Current rural; future urban.

9.10.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Thomsons Lake is a depression at the interface of Bassendean and Karrakatta systems. It is surrounded by a ring of sand dunes, most pronounced on the eastern side.

The western margin of the lake rises to high Spearwood Dunes. The land surrounding the lake shows evidence of previous shorelines.

The lake is circular in shape except for a notch at the northern end. The lake basin is saucer-shaped.

9.10.3 AREAS

Total area of Reserve ..... 508.7 ha
Total wetland area ..... 253.7 ha
Melaleuca/wetland woodland ..... 1.3 ha
Sedgeland ..... 101.2 ha
Open water zone ..... 151.0 ha

9.10.4 HYDROLOGY (Figure 9.16)

Table 9.8. Thomsons Lake: summary of water level records related to lake bathymetry for the years 1971-84.

VOLUME		LEVEL	NO YEARS MAX EXCEEDS LEVEL AND VOLUME	NO YEARS MIN LESS THAN LEVEL AND VOLUME
$m^3 \times 10^6$	%	m AHD		
3.75	100	13.8*	3	15
2.81	75	13.4	4	15
1.87	50	13.0	6	15
0.94	25	12.5	12	10
0.40	10	12.1	15	10
0.07	2	11.9	15	8

Table 9.8 (Cont'd) Thomsons Lake: summary of water level records related to lake bathymetry for the years 1971-84.

SURFACE (ha)	SURFACE %	LEVEL m AHD	NO YEARS MAX EXCEEDS LEVEL AND SURFACE AREA	NO YEARS MIN LESS THAN LEVEL AND SURFACE AREA
250	100	13.8*	3	15
187	75	12.6	10	10
125	50	12.0	14	8
62	25	11.85	15	8
35	14	11.8	15	8

*13.795 m AHD - water boundary 6/11/74 - used as top level for bathymetry.

The shape of the lake basin is such that at a level of 11.9 m AHD, about 96 ha of the lake bed is covered with water but this represents only 2% of the lake volume.

A drain has been excavated between Lake Kogolup (north of Thomsons) and Thomsons Lake. A drain enters from rural land on the eastern side.

The hydrogeology of Thomsons Lake is under investigation by the Geological Survey of Western Australia. Proposed urban development on land east of Thomsons Lake is likely to affect water levels. Strong efforts are to be made to prevent significant changes to the current regime (Environmental Protection Authority, 1987).

9.10.5 WATER QUALITY

The few water chemistry data available for the years prior to 1985 show that phosphorus levels were much lower than those in Bibra Lake but that while nitrogen levels were about the same level as those in Bibra during the early seventies, they showed a less marked rise than Bibra in the first half of the 1980s (See Table 9.2).

There has been a marked fall in pH from above 8 before 1981 to below 7 in 1983 and 1984.

The lake waters have been regularly sampled since 1985 (Davis and Rolls, 1987; Davis, Rolls and Balla, in prep).

9.10.6 LAND USE - Refer to Figure 9.14

9.10.7 VEGETATION (Figure 9.14)

A fringe of rushes borders the lake bed. The dominant species in the past has been Baumea articulata but there has been a marked expansion of Typha orientalis recently (1974 orthophotomap compared with 1983 air photograph).

The wetland tree fringe is poorly developed. It is represented by a thin band on the north-east and a narrow band of Viminaria on the southern side. A relatively bare, weed-infested area lies between the rush fringe and the woodland around much of the lake. This may reflect land use, fire and grazing (Crook and Evans, 1981). A strong development of pampas grass occurs in the rush fringe on the northern side.

The vegetation will respond to falling water levels by advancing towards the centre of the lake, reducing the open area and isolating the margins from the centre.

The bed of the lake is covered with ephemeral Myriophyllum. This plant cover is considered to play an important part in the nutrient status and habitat function of the lake (Davis and Rolls, 1987).

9.10.8 FAUNA

Davis and Rolls (1987 and in preparation) have investigated the macrobenthic invertebrate fauna of Thomsons Lake 1985-87. They found that the fauna was the richest of five urban lakes studied.

The Royal Australasian Ornithologists' Union studies of waterbird usage of wetlands in south-western Australia 1981-85 showed that Thomsons Lake is of very high importance (Jaensch, in press). Only the Peel Inlet Reserves are important for more species than the Thomsons Lake Nature Reserve. Thomsons Lake was ranked second in terms of the maximum number of individual waterbirds that used the reserve during the study. Fourteen species listed in the Japan-Australia Agreement on Migratory Birds occur at Thomsons Lake. Notes on Thomsons Lake as a bird-watching site are provided by Van Delft (1988).

Because of its current importance as a waterbird habitat, there is concern that land-use induced changes in the regional water balance will increase water levels in the lake and have detrimental effects on habitat values (Environmental Protection Authority, 1987).

Murdoch students have carried out trapping studies at the lake and have some information about small mammals and bush birds in the area.

Clay (1981) studied the biology of the Long-necked Tortoise at Thomsons Lake.

9.10.9 MANAGEMENT ISSUES

Dieback has been identified on the eastern side of the reserve (Crook and Evans, 1981).

At times large numbers of bird deaths occur and these have been attributed to botulism or algal poisoning.

Large populations of chironomid midges arise from the lake resulting in demands for pesticide control. Complaints have been received attributing occurrences of Ross River Fever to mosquitoes breeding on the lake.

The City of Cockburn has adopted a policy requiring a significant buffer of vegetation between wetlands and residential development.

Urban development on the eastern side of the lake and on the north-west would place added stress on the lake.

The lake is a very important bird habitat. The drying of the lake serves an important function - waders feed in the shallow water and on exposed mudflats. This function is jeopardised by factors causing duck deaths (high water temperatures, algal blooms).

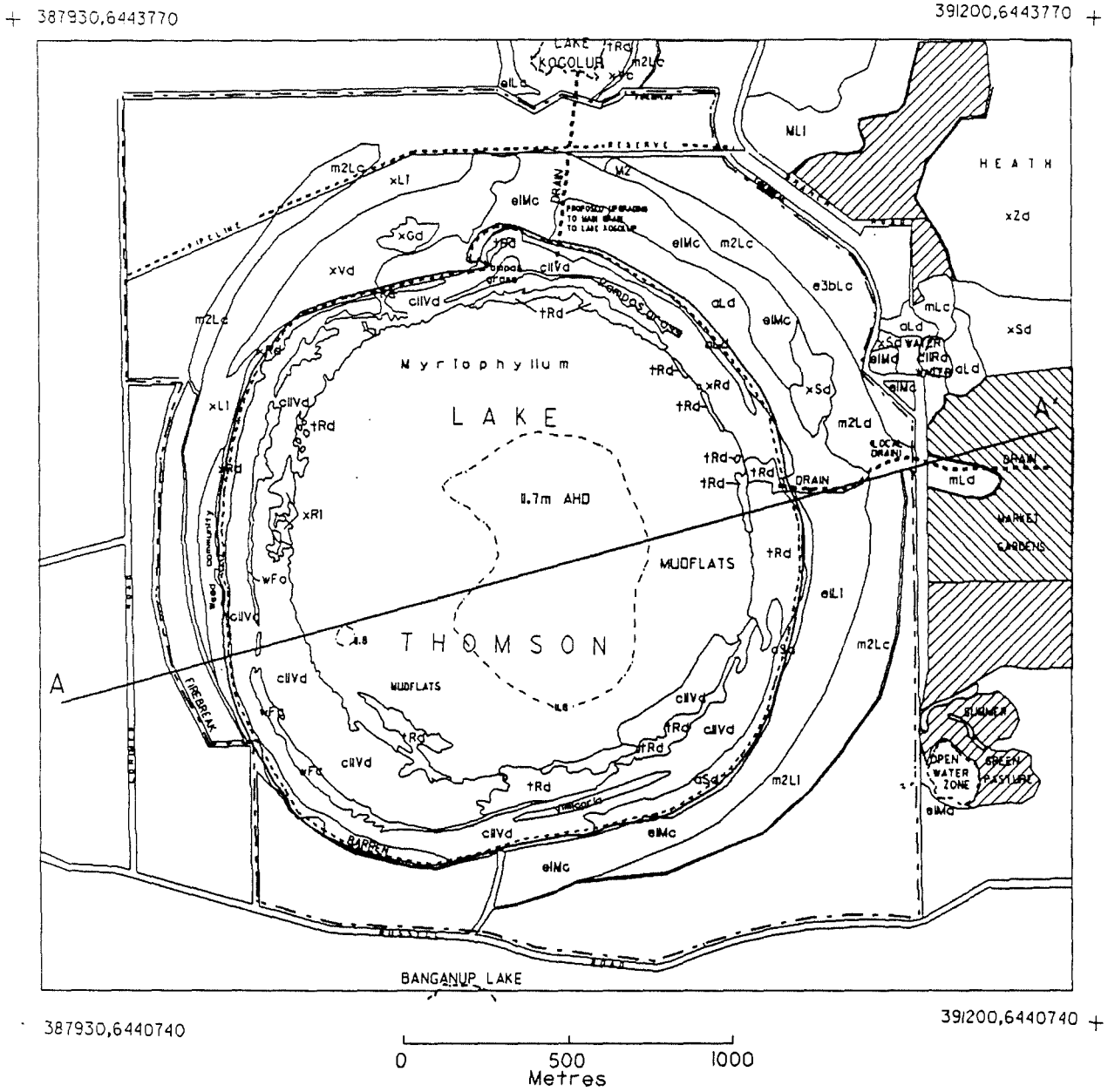

Figure 9.15 Thomsons Lake: wetland plant communities and surrounding land use.

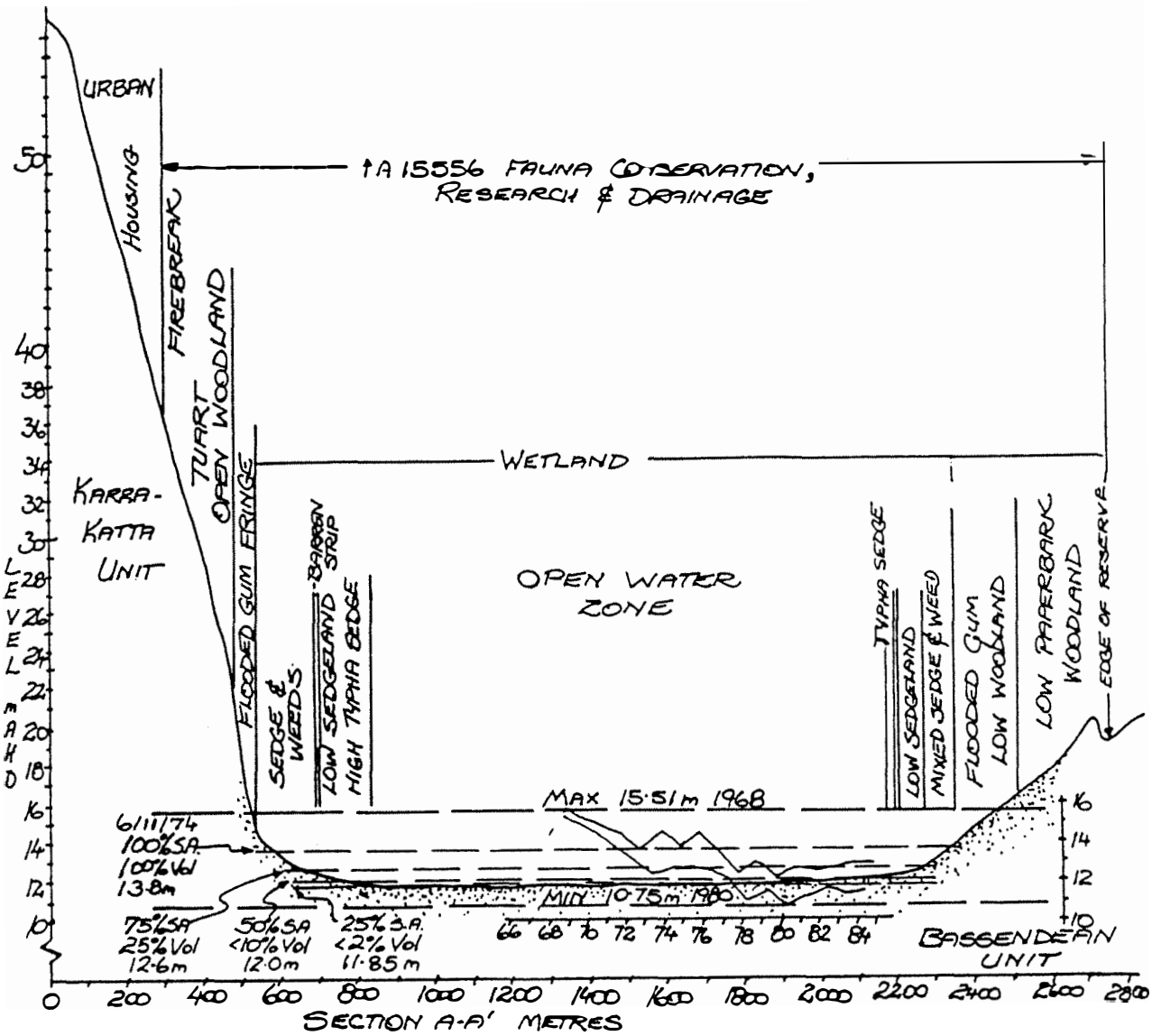

Figure 9.16 Thomsons Lake: diagrammatic cross-section and water level record.

Previously falling water levels were perceived to threaten the lake; however, with the planned development of residential areas east of Thomsons Lake (State Planning Commission, 1986) and the associated need to control groundwater levels and surface runoff by directing drainage west towards Thomsons Lake, rising water levels are now recognised as challenging the environmental value of the lake.

Le Provost, Semeniuk and Chalmer (1987) investigated the environmental value of wetlands east of Thomsons Lake and implications of drainage works.

9.10.10 REFERENCES

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9.11 LAKE BANGANUP

9.11.1 GENERAL INFORMATION

LOCAL AUTHORITY: Cockburn City Council
MRS ZONE: Rural
RESERVE NUMBERS: 29241 Vested in Department of Conservation and Land Management
PURPOSE: Marsupial Research
MANAGEMENT: University of Western Australia.
SYSTEM 6 RECOMMENDATION: M93
WAC CLASSIFICATION: LE.f.m.s.c.
WATER RESERVE: West of Jandakot Public Water Supply Area
DRAINAGE: Unaffected at present; but may be affected by urban drainage in future.

9.11.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Banganup is the largest of four wetland depressions within the Harry Waring Reserve. It is elliptical in shape with its longest axis orientated north - south and situated slightly west of the interface of the Spearwood Dunes with the Bassendean Dunes.

9.11.3 AREAS

Lake Banganup

Total area of wetland	37.5 ha
Paperbarks/flooded gums	11.1 ha
Sedgeland	24.7 ha
Open water zone	1.7 ha

Other wetlands in the Banganup Reserve

Total area of wetland	10.0 ha
Paperbarks/ flooded gums	8.1 ha
Sedgeland	1.9 ha
Open water zone	nil

9.11.4 HYDROLOGY (Figure 5.18)

The water level record for Lake Banganup shows that there has been a fall in both winter maximum and summer minimum water levels since regular records began in 1984.

Minimum levels in the mid 70s were in the same range as maximum levels being recorded 10 years later.

Table 9.9. Lake Banganup: water levels 1974-85 (Water Authority of Western Australia data).

i Maximum recorded water level: 14.75 m AHD (1968).
ii Number of years in which the maximum level has fallen within the specified ranges.

m AHD	1974-80	1981-84
>13.5	2	0
13.0-13.5	4	1
12.5-13.0	1	3

iii Minimum level recorded: 11.14 m (1983).
iv Number of years in which the minimum levels have fallen within the specified ranges.

m AHD	1975-80	1981-85
13.0-13.5	1	0
12.5-13.0	1	0
12.0-12.5	1	0
11.5-12.0	3	4
11.0-11.5	0	1

9.11.5 WATER QUALITY

No data available.

9.11.6 LAND USE

Lake Banganup is favourably situated within the Jandakot Marsupial Breeding Station (Harry Waring Reserve), with relatively undisturbed Banksia woodland buffering it from rural land uses to the east and west, and the reserve fence and firebreaks protecting it from off-road vehicles and wildfire.

9.11.7 VEGETATION (Figure 9.17)

The native vegetation of the wetland and surrounding woodlands is relatively intact except for management tracks and firebreaks.

The wetland is largely a fenland of Baumea articulata with mature Melaleuca preissiana forming a closed woodland on the eastern side. A thicket of young M preissiana downslope at the margin of the sedgebeds suggests a vegetation response to low water table levels of recent years. E rudis has also germinated within the sedgeland.

Open water is restricted to a small area (1.7 ha) at the northern end of the wetland, adjoining a meadow of grasses and water buttons. Melaleuca teretifolia occurs in a clump on the south-west of the open water area and appears to have expanded since 1975.

The lake margins between the paperbark and the sedgelands show evidence of grazing by the wallabies and kangaroos maintained on the reserve. A small fenced plot at the northern end of the lake encloses tall sedge and Acacia pulchella while the surrounding area supports a low lawn-like plant community. This observation provides some insight into the effects of wildlife on wetland ecosystems. It may be that the grazing marsupials played a role in limiting fuel loads in undisturbed wetland systems in the past.

9.11.8 FAUNA

The reserve is being used to maintain healthy, captive populations of the Quokka (Setonix brachyurus) away from the stresses currently imposed at Rottnest Island, as well as small populations of kangaroos.

It has provided opportunities for research into a number of vertebrate and invertebrate animals and ecological problems. One of the few known populations of the south-western Australian species of the uncommon relict animal, Peripatus, occurs at the reserve (Van der Lande, 1978). The reference list includes a number of published papers, theses and other studies which have been carried out at the reserve since 1970.

9.11.9 MANAGEMENT ISSUES

The Reserve provides a relatively undisturbed sample of banksia woodland and closed wetland which should be regarded as a potential source of baseline information about the functions of coastal wetlands.

Increased urban development with elevated nutrient levels in groundwater and changes to the water balance resulting from drainage and clearing could compromise its value as a benchmark for ecosystem function. Changes to the water balance could either rejuvenate the wetland by raising the water level, or accelerate the trend towards paperbark woodland if water levels remain at the current low levels or fall further.

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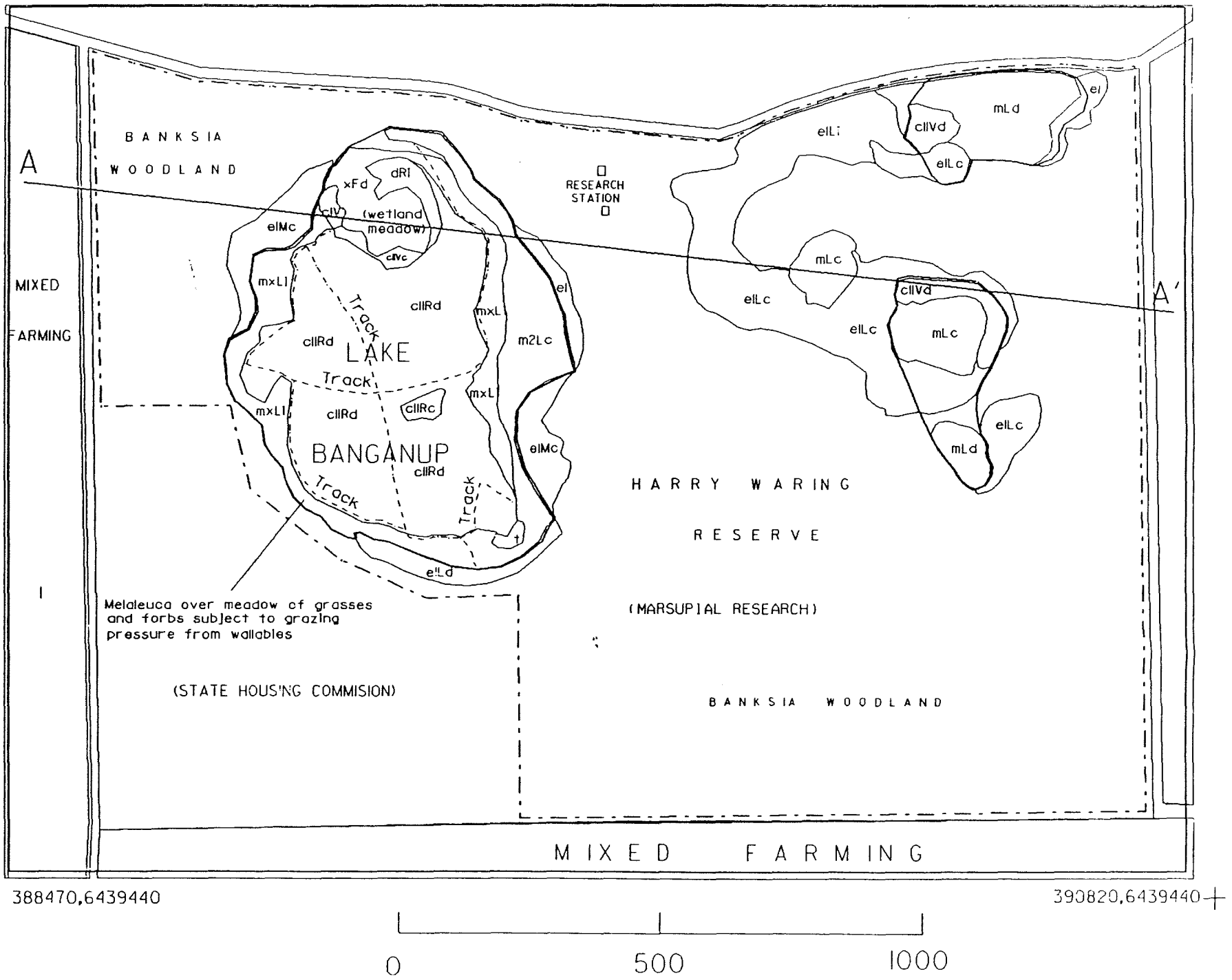

Figure 9.17 Lake Banganup: wetland plant communities and surrounding land use.

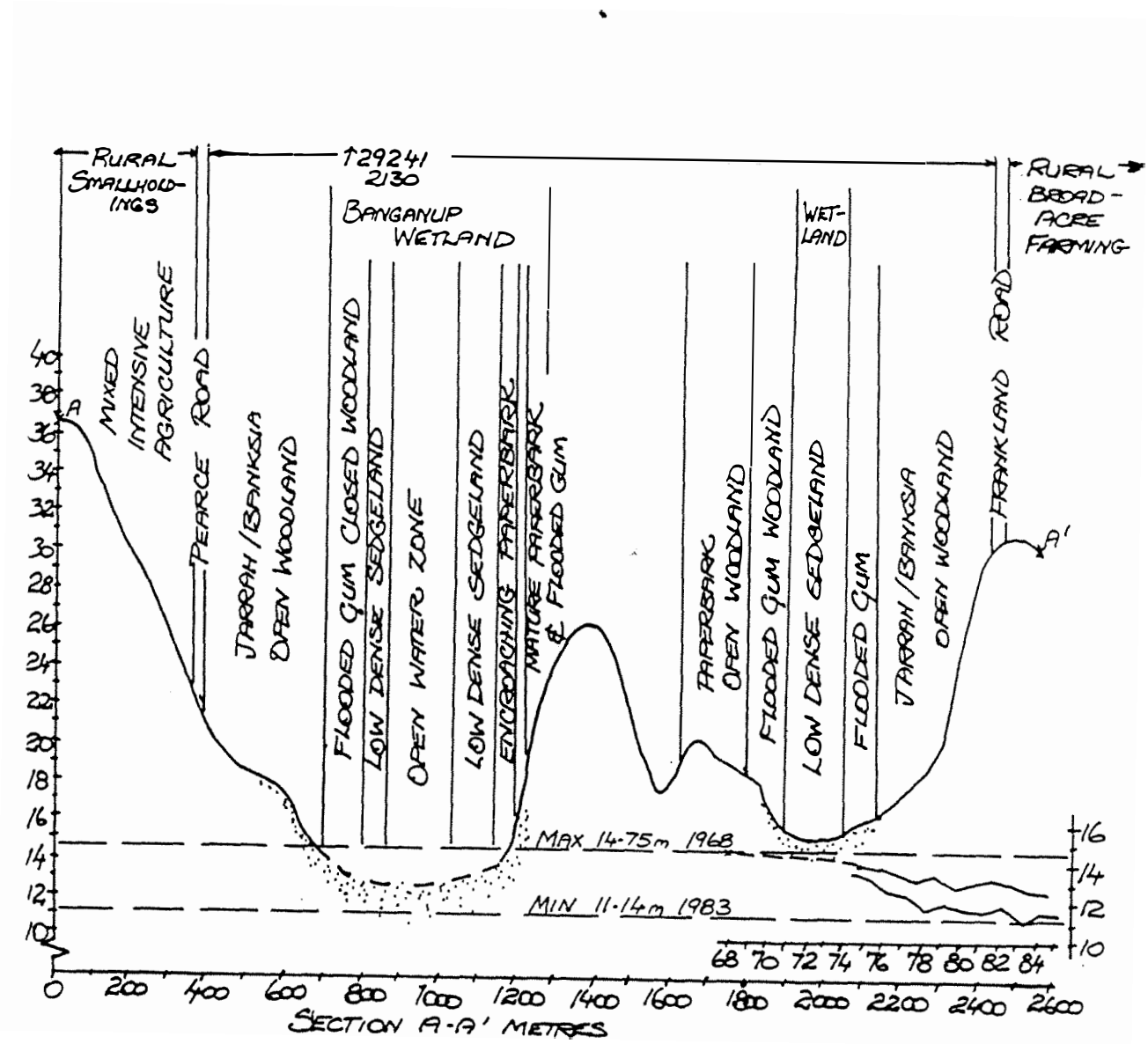

Figure 9.18 Lake Banganup: diagrammatic cross-section and water level record.

9.12 WATTLEUP WETLANDS

9.12.1 GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Rural
RESERVE NUMBERS: n/a Freehold land - private owners
MANAGEMENT: Landowners
SYSTEM 6 RECOMMENDATION: M93
WETLAND ADVISORY COMMITTEE CLASSIFICATION: LE.f.m.p.so.
PURPOSE: n/a
DRAINAGE: n/a

9.12.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

There appears to be some confusion in the naming of two wetlands in the Wattleup locality: a small wetland north of Wattleup Road is named Wattleup Swamp (Australian Map Grid Reference: 389003/6439264) in Water Authority hydrograph records, while a larger area, also in private property east of Mandogalup Road (Australian Map Grid Reference: 389020/6438476), is referred to by the Water Authority as Mandogalup Swamp. The Cockburn Wetlands Study (1976) described the more southerly wetland as Wattleup Swamp and the System 6 Study made a recommendation, following the Cockburn Wetlands Study terminology.

Both wetlands are situated within the Karrakatta unit of the Spearwood landform, slightly west of the interface of Spearwood and Bassendean landforms. Both areas are situated below the 12 m AHD contour and have been modified by clearing and market gardening.

9.12.3 AREAS

Small wetland north of Wattleup Road and private property east of Mandogalup Road:

Total area of wetland	24.5 ha
Paperbark	6.1 ha
Sedgeland	4.1 ha
Open water zone	5.3 ha
Modified wetland	9.0 ha

9.12.4 HYDROLOGY (Figure 9.20(a) and 9.20(b))

Both these small wetlands are on the south-western flank of the Jandakot unconfined flow system and are surface expressions of the water table.

Although both wetlands have shown some fall in water level over the last ten years, the falls have been less marked than those observed at Thomsons Lake and other more northern wetlands in the chain.

The water level record for the wetland south of Banganup displays a more marked fall in water level:

Table 9.10. Wattleup Wetland (south): water levels 1974-1984.

Water Authority water level record: AMG 389020/6438476.

i Maximum water level recorded: 11.95 m AHD (1979).
ii Number of years in which the maximum level has fallen within the specified ranges.

LEVEL m AHD	1974-80	1981-84
12.0-12.5	3	0
11.5-12.0	2	4
11.0-11.5	1	1

iii Minimum water level recorded: 8.87 m AHD (1979).
iv Number of years in which the minimum water level has fallen within the specified ranges.

LEVEL m AHD	1975-80	1981-85
10.0-10.5	2	3
9.5-10.0	0	2
9.0- 9.5	2	1
8.5- 9.0	1	0

Table 9.11. Wattleup Wetland (north): water level record 1974-85.

Water Authority water level record AMG Reference: 389003/6439264.

i Maximum water level: 11.2 m AHD (1974).
ii Number of years in which the maximum water level has fallen within the specified ranges.

LEVEL m AHD	1974-80	1981-84
>11.0	1	0
10.5-11.0	2	0
10.0-10.5	3	5

iii Minimum water level recorded: 8.85 m AHD, 1983.
iv Number of years in which the minimum water level has fallen within the specified ranges.

LEVEL m AHD	1975-80	1981-85
10.0-10.5	1	0
9.5-10.0	1	0
9.0- 9.5	3	4
8.5- 9.0	0	2

9.12.5 WATER QUALITY - No data are available for either wetland.

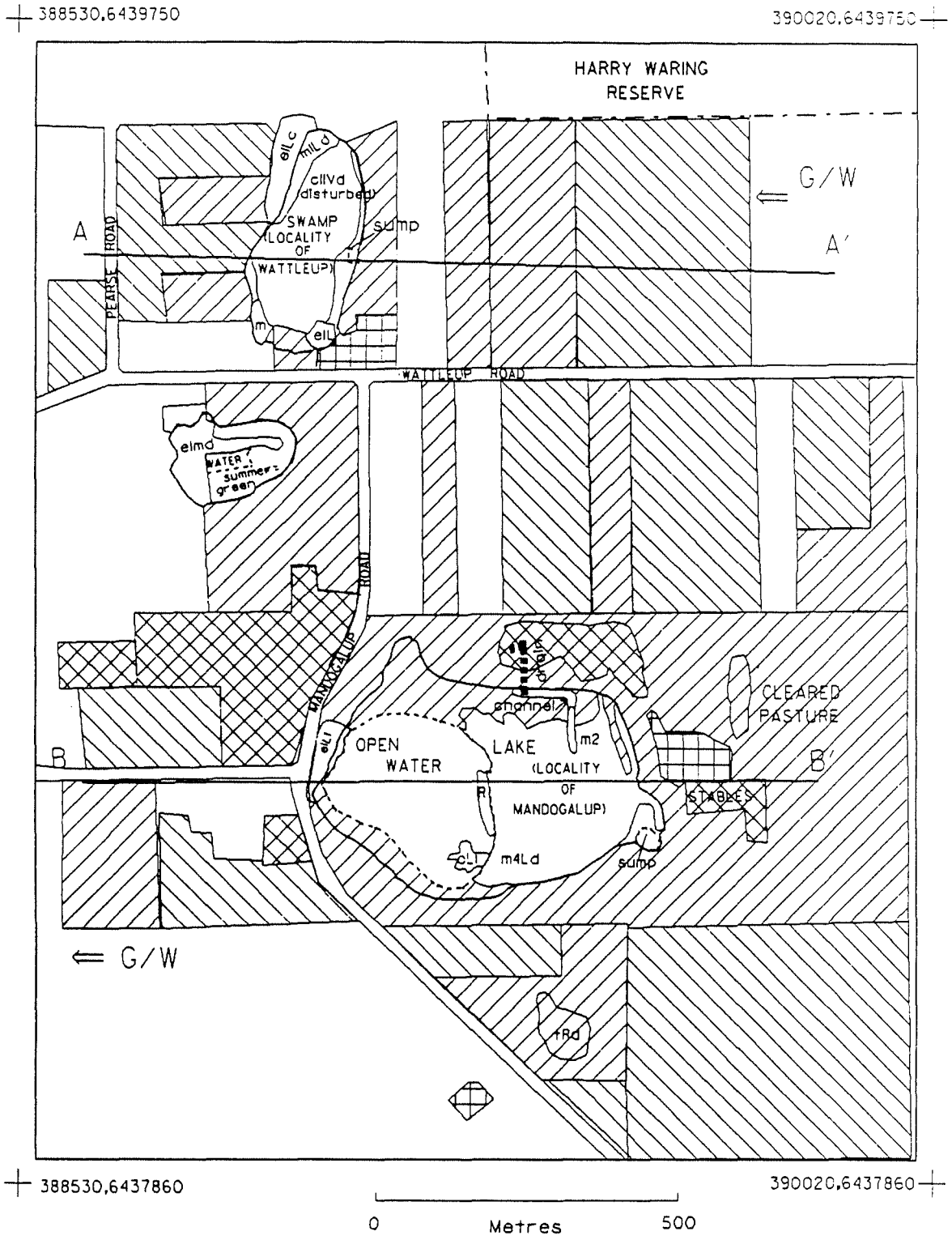

Figure 9.19 Wetlands in Wattleup and Mandogalup localities: wetland plant communities and surrounding land use.

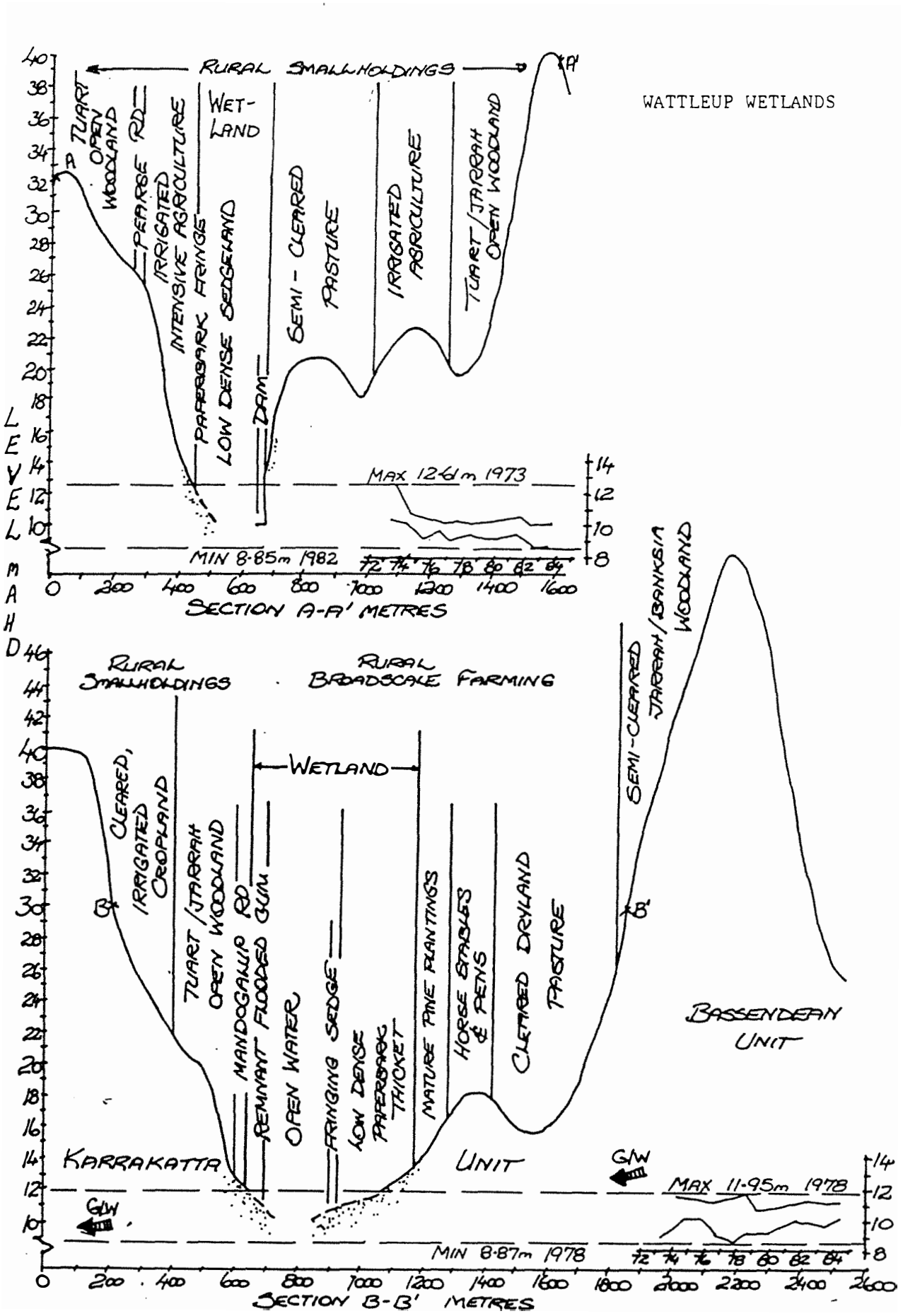

Figure 9.20 Wetlands in Wattleup and Mandogalup localities: diagrammatic cross-sections and water level records (a) Section A-A - north of Wattleup Road; (b) Section B-B - east of Mandogalup Road.

9.12.6 LAND USE

The wetlands are adjacent to land used for market gardening.

The northern wetland has been affected by filling and clearing of wetland vegetation. Should an increase in water levels occur it would be expected that it would move from sedgeland to open water as in the southern wetland.

The southern wetland appears to be managed by the landowner as a landscape feature. The open water and paperbark woodland provide a range of waterfowl habitats.

9.12.7 VEGETATION (Figure 9.19)

These two areas provide some wildlife habitats.

9.12.8 FAUNA - See above. (Section 9.12.7)

9.13 THE SPECTACLES

9.13.1 GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Rural
RESERVE NUMBERS: n/a - owned by Alcoa, Industrial Lands Development Authority and private landowners
MANAGEMENT: Landowners
SYSTEM 6 RECOMMENDATION: n/a
WETLAND ADVISORY COMMITTEE CLASSIFICATION: LE.f.l.se.c
PURPOSE: n/a
DRAINAGE: Bisected north to south by the Peel Main Drain; subsidiary east west drains - two in Big Eye, one in Small Eye.
ROADWORKS: Kwinana Freeway extension will pass east of the Spectacles.

9.13.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The Spectacles is situated at the interface of the Bassendean and Spearwood Dunes but differs from lakes to the north in that there is an outcrop of Spearwood Dunes on the eastern side (Gozzard, 1983).

9.13.3 **AREAS**

Large Eye Spectacle

Total wetland	113.1 ha
Paperbark	56.2 ha
Sedgeland	46.3 ha
Open water zone	3.7 ha
Modified wetland	6.9 ha

Small Eye Spectacle

Total wetland	28.4 ha
Paperbark	10.9 ha
Sedgeland	15.6 ha
Open water	1.9 ha

9.13.4 HYDROLOGY

The hydrology of the lake has been modified by the Peel Main Drain which conveys water from the drained Mandogalup Swamp through the Large Eye on the north. Water flows southward from the Small Eye Spectacle towards Bollard Bullrush Swamp. Figure 9.22 is a diagrammatic cross-section of the Large Eye Spectacle.

9.13.5 WATER QUALITY

No water quality data are available. Some data may have been collected in the late 1970's by ALCOA.

9.13.6 LAND USE

The Spectacles lie within the Peel Estate which was developed for agriculture following World War 1. The Peel Main Drain was constructed to lower the water table in the area. Accounts of this period can be found in Coy (1984) and Taggart (1984).

Agricultural use appears to have substantially ceased following the purchase of the area by the Industrial Lands Development Authority (ILDA) and Alcoa in the 1960's. The area was intended for use as a disposal pond for red mud from the Kwinana alumina refinery. Alcoa carried out a biological survey of the lake. The area has been under investigation as a possible addition to the proposed East Beeliar Regional Park in recognition of its conservation and historical value.

9.13.7 VEGETATION (Figures 9.21)

The Big Eye has a large area of closed paperbark woodland, dominated by Melaleuca rhaphiophylla but with a considerable mixture of M.teretifolia. This woodland appears to be pristine, but the presence of fences through the dense woodland indicates that the wetland has been cleared in the past and that the present woodland represents regeneration. This being the case, the area provides useful insight into the regenerative capacity of wetlands.

During the winter this section has water in excess of one metre deep, with a fairly marked flow. During summer, the amount of water is limited.

The Spectacles present a mosaic of plant communities, with a high degree of interspersion. Its ecological value is likely to lie not in the large number of animals it supports but in the range of habitat types offered.

Regenerating Eucalyptus rudis occurs around the perimeter of the Spectacles and is providing a good buffer to the wetland proper.

9.13.8 FAUNA

Alcoa has carried out a biological survey of the lake.

9.13.9 MANAGEMENT ISSUES

- Increased water abstraction may not be a significant issue because the Folly Main Drain could be manipulated if necessary.

- The effects of non-point sources of nutrients would be mitigated by the vegetation cover; however, inappropriate land uses on the immediate perimeter of the wetland could impinge on the value of the wetland.

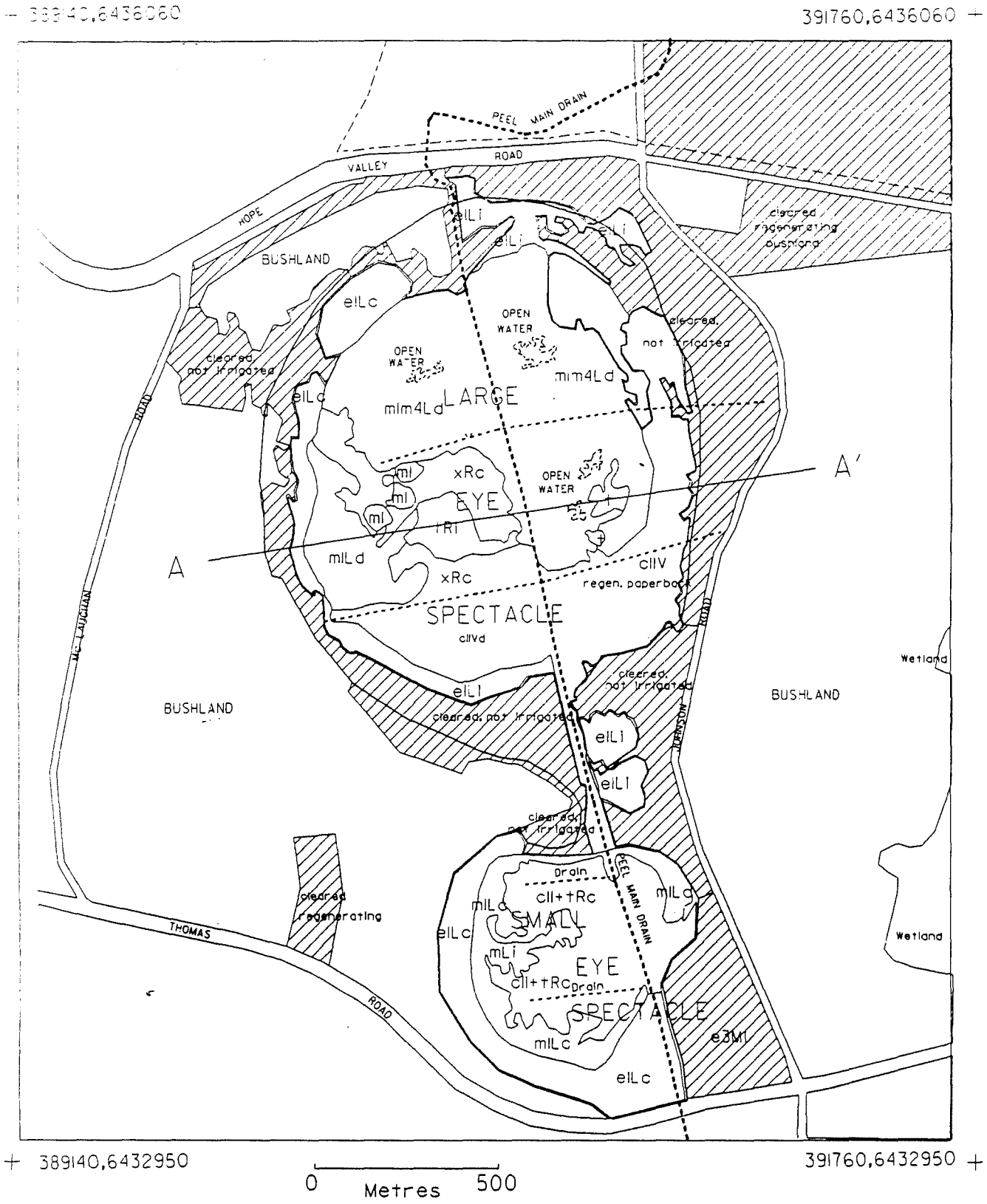

Figure 9.21 The Spectacles: wetland plant communities and surrounding land use.

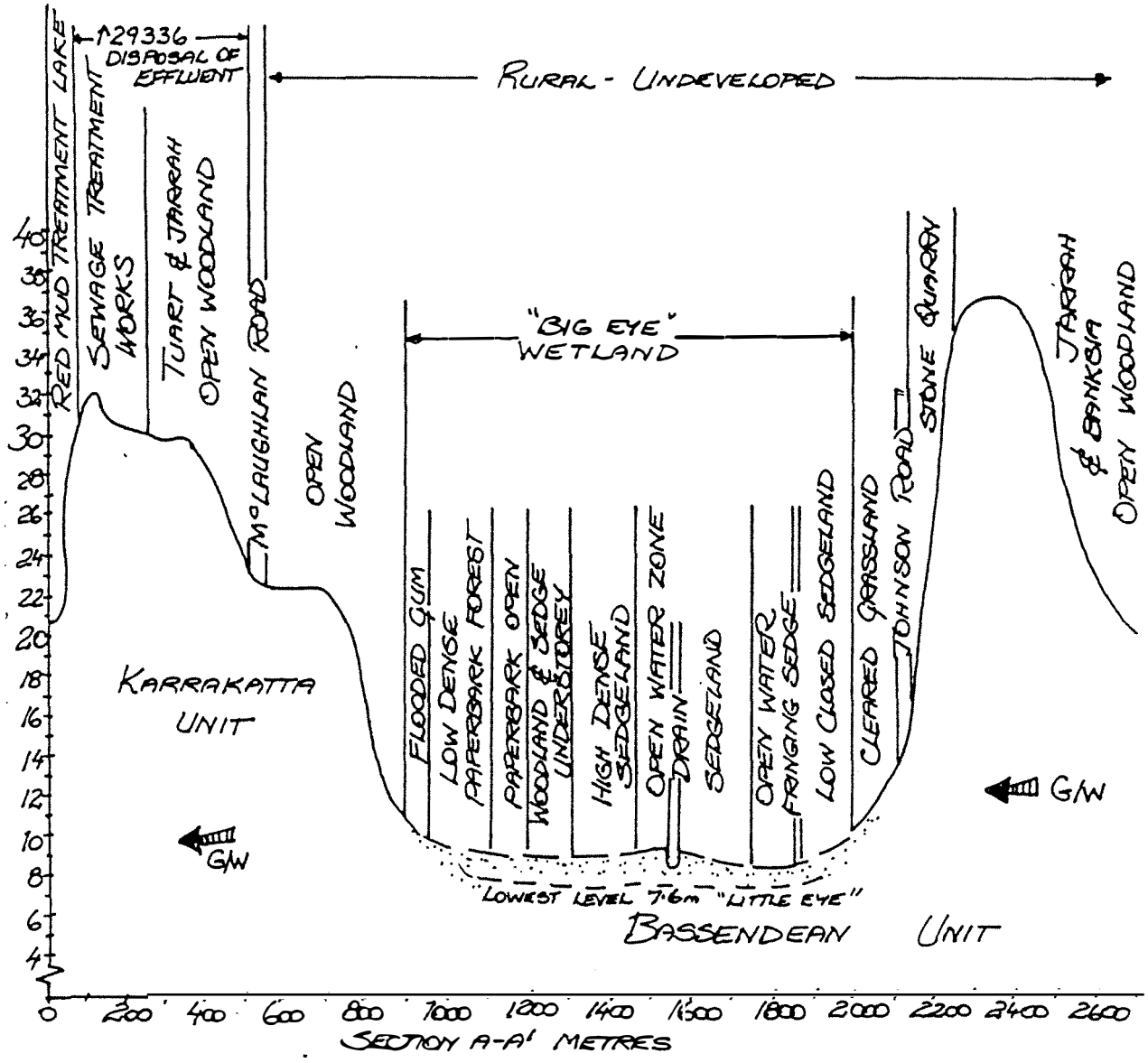

Figure 9.22 Large Eye Spectacle: diagrammatic cross-section.

. The Spectacles is worthy of reservation as a conservation area. Its function should be primarily conservation with very limited recreational use, restricted to activities which cause minimal disturbance. There would be merit in preventing vehicle access. The current good condition of the wetland could be largely attributed to Alcoa's good fences.

9.13.10 REFERENCES

Coy, N J (1984), 'The Serpentine: a history of the Shire of Serpentine-Jarrahdale'. Shire of Serpentine-Jarrahdale, Western Australia.

Gozzard, J R (1983), Fremantle Part Sheets 2033 I and 2033 IV. Environmental Geology Series, Geological Survey of Western Australia.

Taggart, N (1984), 'Rockingham looks back'. Rockingham Historical Society, Western Australia.

9.14 BOLLARD BULLRUSH SWAMP

9.14.1 GENERAL INFORMATION

LOCAL AUTHORITY: Kwinana Town Council
MRS ZONE: Rural
RESERVE NUMBERS: Drain reserve only; remainder freehold land
MANAGEMENT: Private landowners
SYSTEM 6 RECOMMENDATION: n/a
WAC CLASSIFICATION: LE.f.l.se.c. (modified)
WATER RESERVE: Peel Groundwater Area
ROADWORKS: Wellard Road - Important Regional Road
DRAINAGE: Peel Main Drain bisects the swamp, circled by ring drain.

9.14.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Bollard Bullrush Swamp occupies a circular depression at the interface of the Karrakatta and Bassendean landforms below the 6 m AHD surface contour. It is located at the southern end of the Jandakot block of the Bassendean Dunes, near its contact with the Serpentine fluviatile plain.

9.14.3 AREAS

Total wetland	approx 186 ha
Paperbark/flooded gum	76.6 ha
Sedgeland	11.4 ha
Open water (channels)	3.2 ha
Modified (cleared)	approx 95 ha

9.14.4 HYDROLOGY (Figure 9.24)

There is no water level record available for the swamp. The Peel Main Drain runs through the Swamp from north to south and is excavated to below 4 m AHD. The swamp is circled by a ring drain at about the 6 m AHD contour. The bulk of the swamp lies between the 6 m and 4 m contours, on the south-western flank of the Jandakot unconfined flow system (see Davidson, 1984).

9.14.5 WATER QUALITY

No information on water quality is available.

9.14.6 LAND USE

The drain which bisects the swamp was constructed in the 1920's in the course of developing the Peel Estate. Land uses are in transition now from grazing, dairying and mixed farming around the summer-wet areas, to large-scale irrigated horticulture. The expanding paperbark woodland on the body of Bollard Bullrush Swamp suggests that agricultural use of the swamp and its margins has been reduced and that the wetland vegetation is in the course of regenerating.

9.14.7 VEGETATION (Figure 9.23)

The vegetation of the swamp is a complex of flooded gum and paperbark woodland and sedgeland. The paperbark woodland is a mosaic of different aged stands, no doubt reflecting different lengths of time since grazing pressure has been reduced. A study of the history of land use around the swamp would provide useful insight into the rates of paperbark and flooded gum regeneration.

The Peel Main Drain supports spring blooms of floating Lemna and rooted water weed. The role of these plants in assimilating nutrient loadings in the drain waters may be significant.

9.14.8 FAUNA

No information is available. Spoil has been recently dumped on the banks of the drain from maintenance work on the drain (observation: J Arnold Summer, 1986). This spoil contains shells of the native freshwater clam Westralunio and indicates that the drain is developing a freshwater stream fauna.

9.14.9 MANAGEMENT ISSUES

Like the Spectacles, Bollard Bullrush Swamp could become rehabilitated to a useful freshwater wetland if land use pressures are maintained at their current level or reduced further.

9.14.10 REFERENCE

Davidson, W A (1984), A flow-net analysis of the unconfined groundwater in the superficial formations of the southern Perth area, Western Australia. Geological Survey of Western Australia. Record 1984/9.

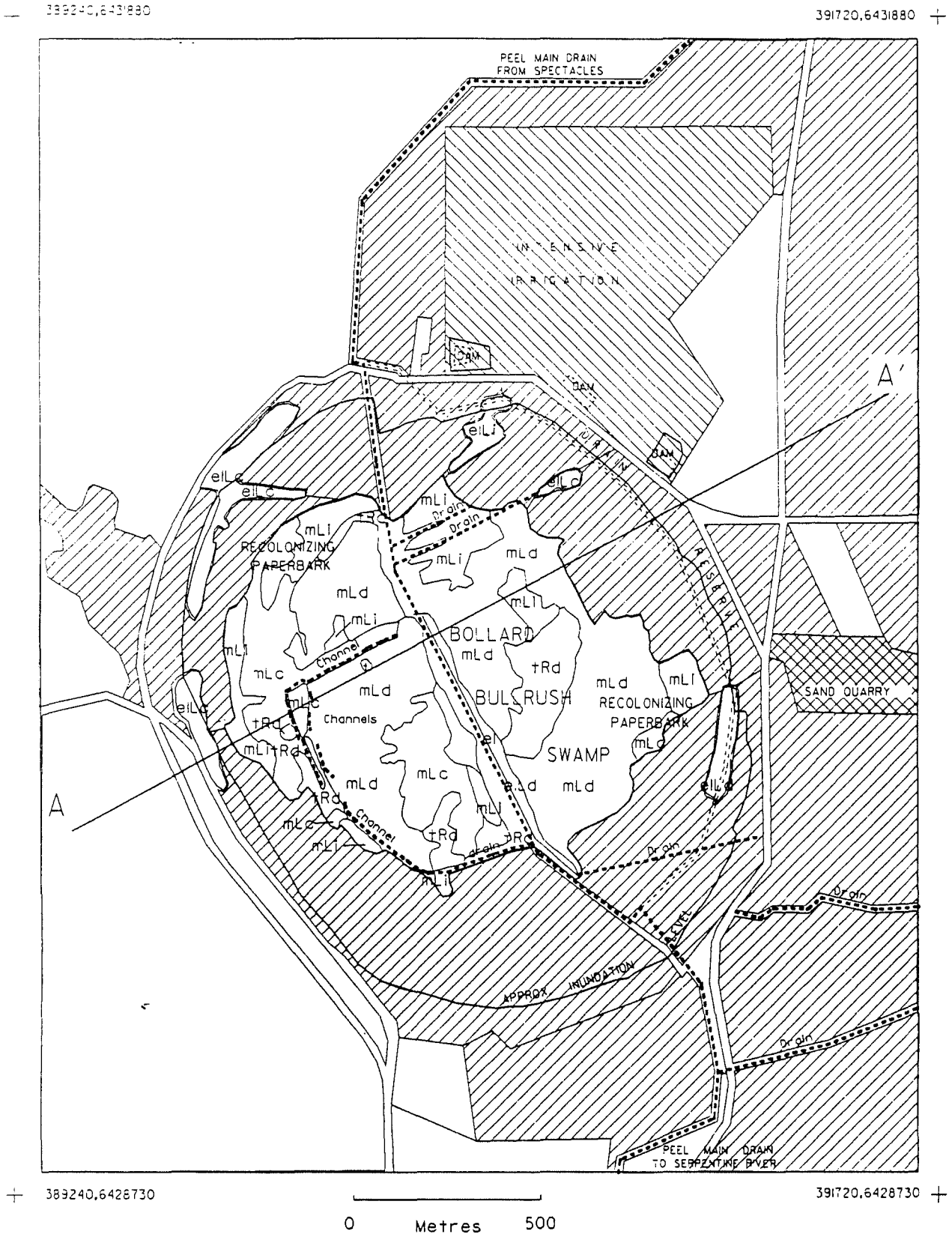

Figure 9.23 Bollard Bullrush Swamp: wetland plant communities and surrounding land use.

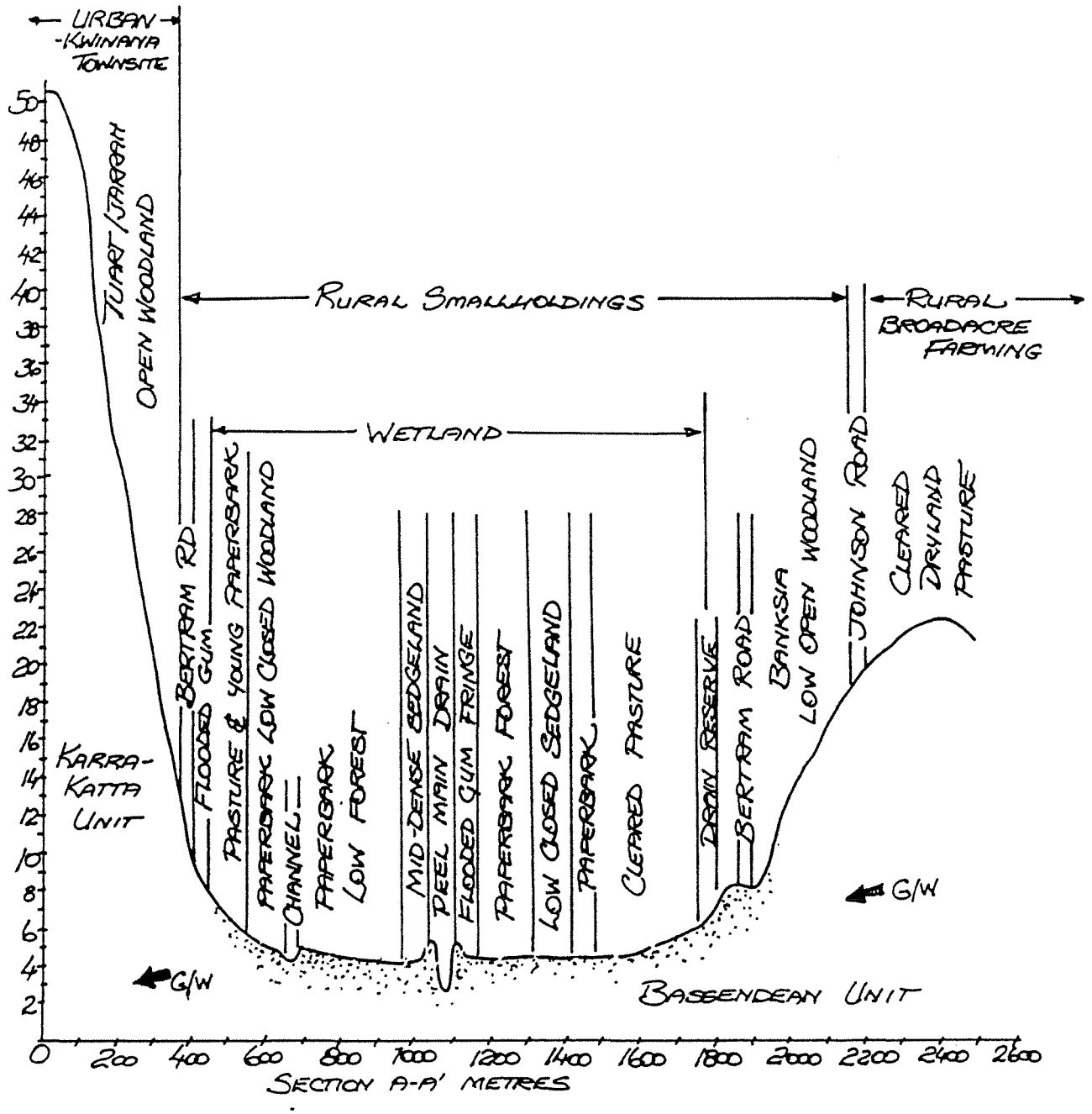

Figure 9.24 Bollard Bullrush Swamp: diagrammatic cross-section.

Page

FIGURES

TABLE

10. WETLANDS OF THE SOUTH WEST CORRIDOR

10.1 GENERAL SETTING (See Figure 10.1)

The wetlands to be considered in this section are situated in interdunal depressions behind the seaward line of Spearwood Dunes from Hamilton Hill in the north into the Shire of Mandurah in the south. The more northerly wetlands of this chain, Manning Lake to Lake Mount Brown, form the western part of the proposed Beeliar Regional Park. The Cockburn Wetlands Study (Newman, 1976) continues to be a most useful reference on these wetlands.

The wetlands grouped in this section constitute two of the related wetland suites identified by Semeniuk, the Coogee and Stakehill suites within the Spearwood Dunes (Semeniuk, 1987).

The vegetation of these more northern wetlands indicates that their waters are brackish to saline, for instance:

- remnant samphire at the northern end of Lake Manning;
- samphire in the more southern of the Market Garden Swamps;
- a transition from swamp paperbark (freshwater) to saltwater paperbark near the southern end of the Market Garden Swamps;
- samphire and saltwater paperbark fringing Lake Coogee;
- small numbers of samphire plants in the western Brownman Swamp;
- Gahnia trifida and saltwater paperbark on the margins of Lake Mount Brown; and
- salt marsh in the higher parts of Long Swamp.

Long Swamp is situated east of the northern end of the beach ridges of the Rockingham Plain. The series of wetlands described as 'marsh in low-level interbarrier depressions' (Gozzard, 1983 and 1983a) within the Spearwood Dunes continues southward and includes the Chalk Hill Lookout Swamp in Medina, the swamps in the Kwinana Golf Course, the swamps of Sloans Reserve in Leda, the Leda Swamps to the south of Sloans Reserve, wetland north of Kerosene Lane, the Tamworth Hill Swamp, Churcher and Pike Swamps, StakeHill Swamp, Anstey's Swamp and other unnamed swamps on the eastern side of Mandurah Road. The vegetation of the wetlands south of Long Swamp is more characteristic of freshwater systems than that of those to the north, possibly because the wetlands are to some extent shielded from marine influences by the Rockingham Plain and may receive significant inputs of fresh water from the Jandakot Mound (Kerosene Lane northwards) and the Stakehill Mound (Tamworth Hill southwards).

The total area of wetland in this series, from Manning Lake at the northern end to Leda Swamps, is about 315 ha, of which about 170 ha is reserved. The area of the southern wetlands in the chain has not been estimated. None of the wetlands south of Leda Swamps are reserved and there is no means of ensuring that the systems are protected from disturbance to the water regime and vegetation.

For environmental geology and geomorphology see Gozzard (1983) and Gozzard (1983a).

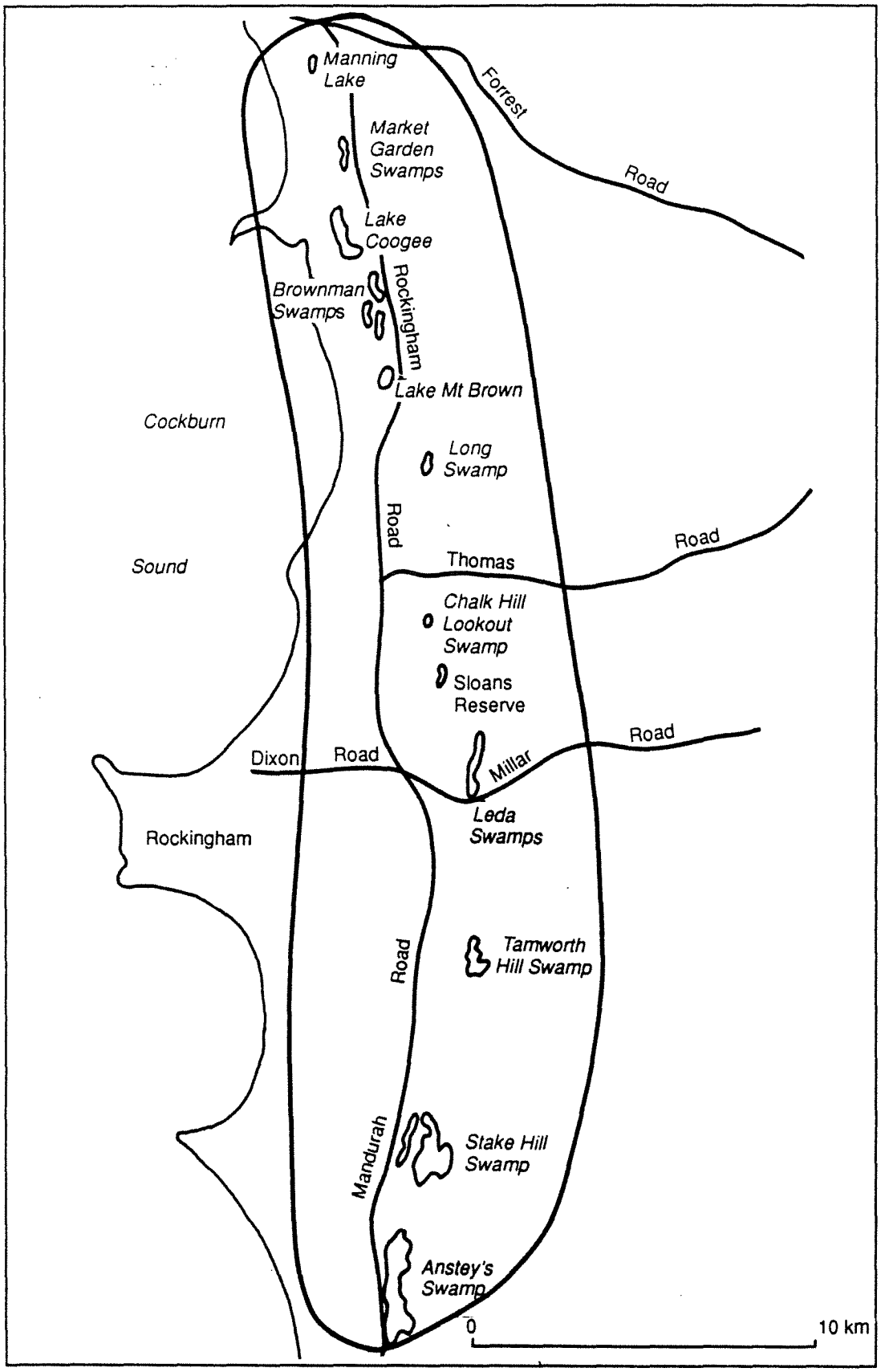

Figure 10.1 Map showing the wetlands of the South West Corridor.

10.1.1 REFERENCES

Gozzard, J R (1983), Rockingham Part Sheets 2033 III and 2033 II. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1983a), Fremantle Part Sheets 2033 I and 2033 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Newman, P (editor)(1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn.

Semeniuk, C A (1987), Appendix 5 in Environmental significance of wetlands in the Perth to Bunbury Region. Vol 2, Western Australian Water Resources Council, Leederville, Western Australia.

10.2 MANNING LAKE

10.2.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation Reserve
MANAGEMENT: City of Cockburn
RESERVE NUMBERS: C26870 + Freehold (State Planning Commission)
SYSTEM 6 RECOMMENDATION: M92
WAC CLASSIFICATION: Le.f/b.s.p.o
DRAINAGE: Local drainage inputs.

10.2.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Manning is a small oval-shaped lake occupying a striking position on the boundary of Hamilton Hill and Spearwood. High limestone dunes lie to the west of the lake. The lake was described in the Cockburn Wetlands Study (Newman, 1976).

10.2.3 AREAS

Area within MRS Reserve	approx 58 ha
Total area of wetland	11.6 ha
Paperbark	6.1 ha
Sedgeland/samphire	1.2 ha
Open water	4.0 ha
Modified area	0.3 ha

10.2.4 HYDROLOGY (Figure 10.3)

The regional water table around Lake Manning is at 1-2 m AHD. There is a relatively thin layer of fresh groundwater overlying saline water. Sources of lake recharge include surface drains and groundwater recharge from the east. No bathymetric contours are available.

At periods of high water in winter, the lake waters extend beyond the paperbark fringe.

The water level record shows that maximum lake levels are between 0.8 and 1.0 m AHD and minimum levels are between 0.1 and 0.2 m AHD. As is to be

expected with wetlands close to sea level, there is much less between-year variation in water levels than for wetlands higher on the unconfined groundwater flow systems.

Although situated north of the Lake Coogee area (Western Australian Water Resources Council, 1984), it is likely that the conditions described for Lake Coogee with shallow fresh groundwater overlying a zone of mixing at a fresh salt water interface apply.

10.2.5 WATER QUALITY

Newman (1976) noted water quality problems at the lake. The presence of sprinkler systems within the lake suggests that efforts are made to aerate the lake waters to alleviate problems arising from poor water quality in summer.

10.2.6 LAND USE - Refer to Figure 10.2.

10.2.7 VEGETATION (Figure 10.1)

Large Melaleuca rhaphiophylla fringe the lake on the west, north and east. The aquatic plant Ruppia occurs in the lake. There is considerable weed incursion into the fringing vegetation, including kikuyu, buffalo grass, aniseed, castor oil, and thistles. As the lake dries in summer, an area of samphire is exposed within the northern part of the lake. There is no buffer of upland vegetation.

10.2.8 FAUNA

Newman (1976) observed relatively low bird species diversity and abundance at the lake. Notes on Manning Lake as a bird-watching site are provided by Van Delft (1988). The Royal Australasian Ornithologists Union has a considerable amount of data on waterbirds for this area.

10.2.9 MANAGEMENT ISSUES

The lake will continue to receive urban drainage. The balance between freshwater input from surface drainage and extraction of groundwater may be significant in maintaining Lake Manning as a relatively freshwater system. Heavy use of water pumped from bores near the lake to maintain parklands around the lake may have the effect of altering the balance between fresh and salt water in the immediate area.

Manning Lake appears to be more significant as a landscape feature and a focus for passive recreation than as a wildlife habitat. Management emphasis is therefore appropriately towards maintaining amenity and good water quality.

The parkland around Manning Lake includes the Azelia Lea homestead. Manning Lake and its surroundings have strong links with early European settlement of the district (Berson, 1978).

10.2.10 REFERENCES

Berson, M (1978), 'Cockburn: the making of a community'. Town of Cockburn, Western Australia.

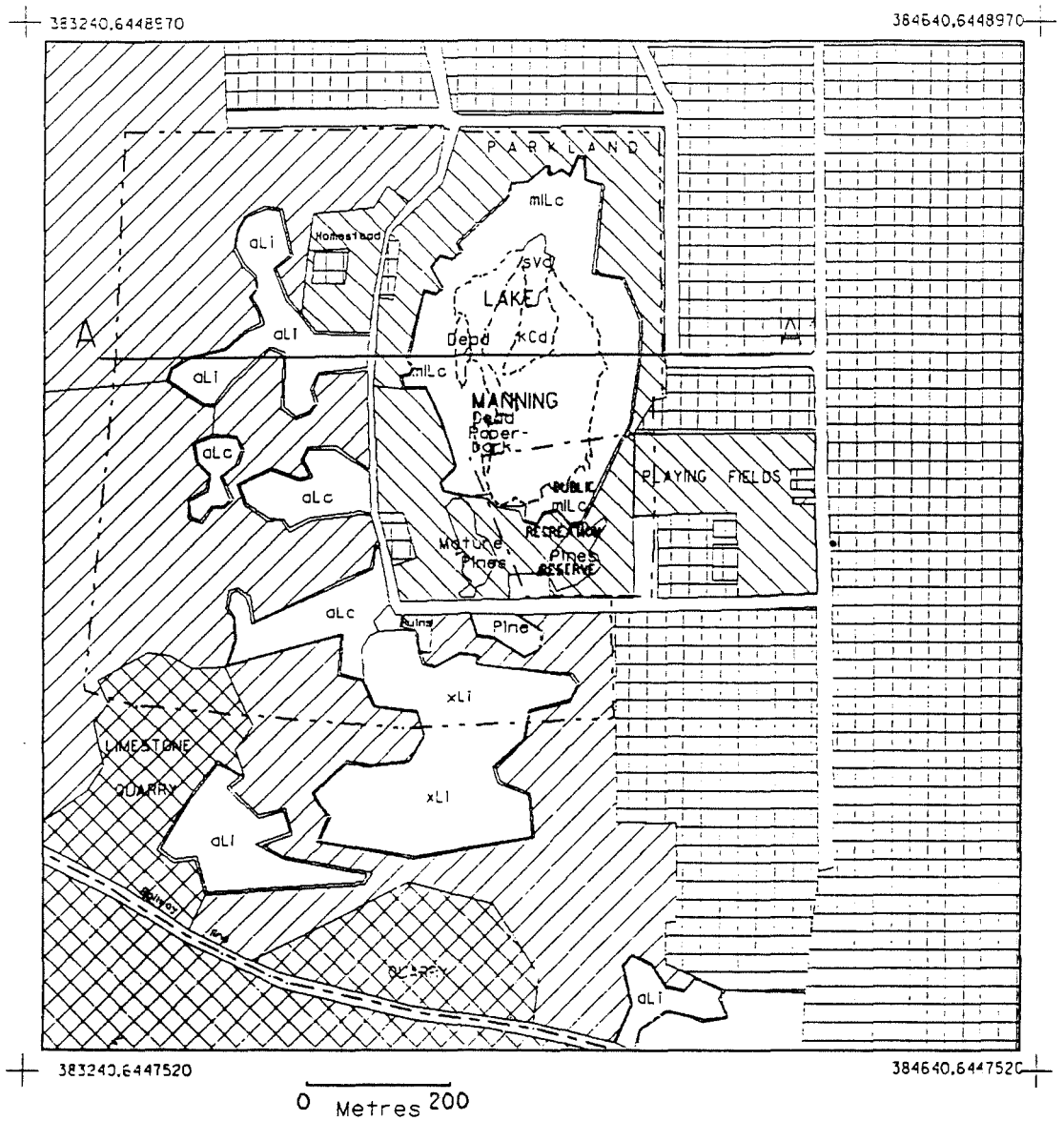

Figure 10.2 Manning Lake: wetland plant communities and surrounding land use.

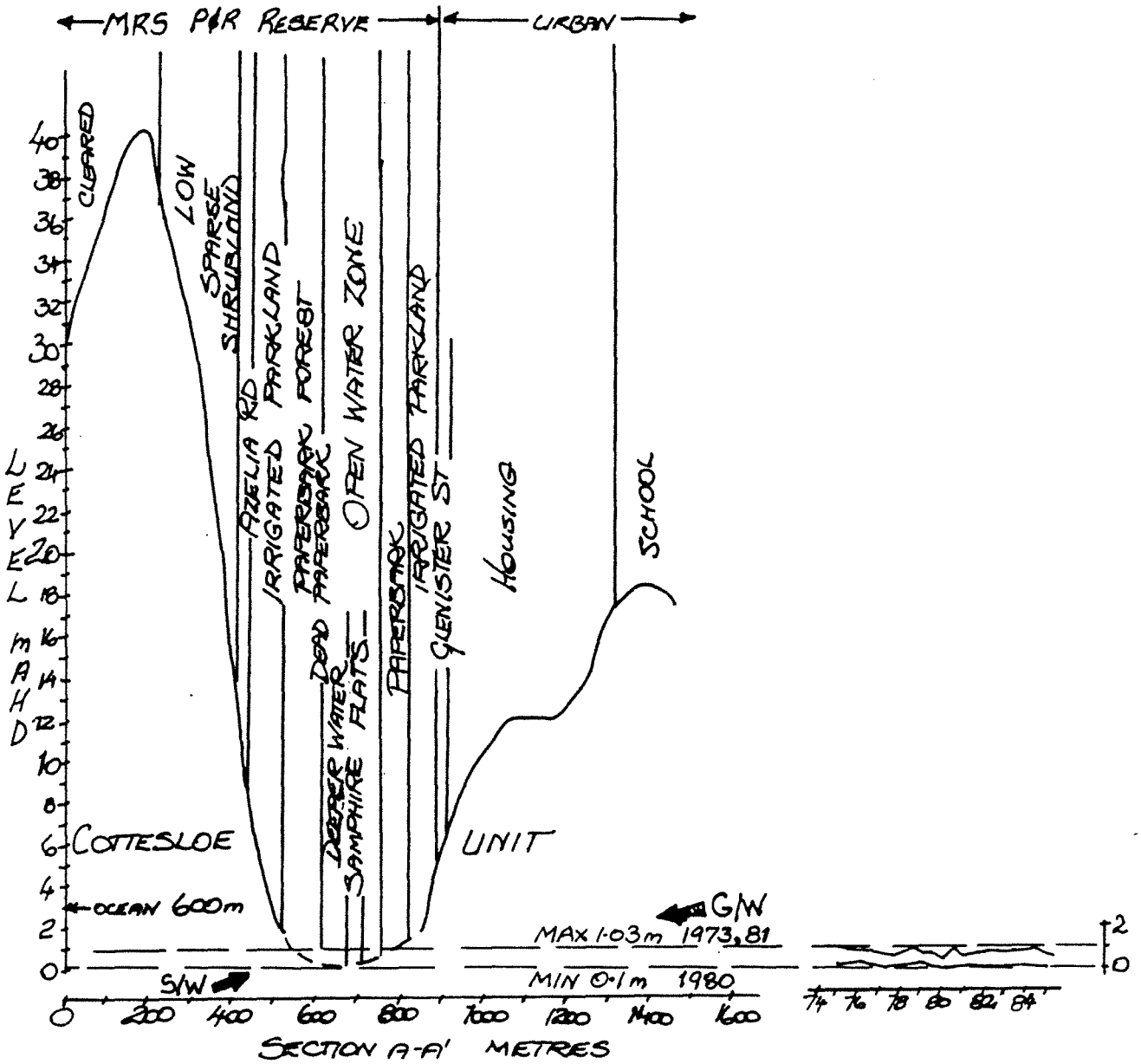

Figure 10.3 Manning Lake: diagrammatic cross-section and water level record.

Newman, P (editor) (1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn, Western Australia.

Van Delft, R (1988), 'Birding sites around Perth'. University of Western Australia Press, Nedlands.

Western Australian Water Resources Council (1984), Lake Coogee area: review of groundwater problems. Government of Western Australia.

10.3 MARKET GARDEN SWAMPS

10.3.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Urban deferred
MANAGEMENT: Private landowners, Water Authority
LAND OWNERSHIP: Reserve 22227 (drainage) and Freehold
SYSTEM 6 RECOMMENDATION: M92
WAC CLASSIFICATION: Le.f/b.m.p.so
DRAINAGE: Local drainage inputs; future major drainage function.

10.3.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The Market Garden Swamps lie in a pronounced north-south trending depression within the Spearwood Dunes.

10.3.3 AREAS

(i) Swamps north of Mayor Road:

Total area of wetland	59.8 ha
Paperbark	25.2 ha
Sedgeland	3.2 ha
Samphire	0.5 ha
Open water	6.5 ha
Modified	24.4 ha
Ski-tow pond	3.6 ha

(ii) Swamp south of Mayor Road:

Total area of wetland	16.1 ha
Paperbark	6.9 ha
Sedgeland/samphire	1.6 ha
Open water	4.2 ha
Modified	3.4 ha

10.3.4 HYDROLOGY (Figure 10.5)

Concern about increasing salinity in bore water used for market gardens in the Coogee area led to a study of the hydrology of the region (Western Australian Water Resources Council. 1984).

10.3.5 WATER QUALITY - See Newman, 1976.

10.3.6 LAND USE

The swamps have been substantially altered by rural land uses. The swamp margins have been filled to extend the area of market gardens and the swamps themselves have been used to dump litter. There are pronounced incursions of weed plant species.

Newman (1976) described the effects of market gardening on the swamps and noted that there were significant environmental problems. Nevertheless, when viewed from a high position, for instance from Smart Park on the eastern side of the swamps, the swamps, with Lake Coogee, contribute a great deal to the amenity of the coastal landscape.

Earlier regional planners considered that the swamps were not of regional significance and thus there is no 'Parks and Recreation' reserve over the area in the Metropolitan Region Scheme - the entire area being zoned Urban Deferred. However, there is increasing recognition of the significance of these wetlands in the landscape of the region. It appears that reservation of the swamps as recommended by the EPA in the System 6 Report will be carried out in the context of providing a drainage reserve to accommodate urban development.

An area of land adjacent to the southern end of the swamps has been excavated to form a water-ski-tow facility, providing for active recreation.

10.3.7 VEGETATION (Figure 10.4)

The swamps are fringed by paperbarks. In the northern swamps, where the water inputs are relatively fresh, the swamp paperbark Melaleuca rhaphiophylla is the dominant species. Near the southern end of the swamps there is a transition to saltwater paperbark (M.cuticularis) with sedgeland understorey and samphire. The upland vegetation has been entirely removed apart from a few remnant tuarts.

10.3.8 FAUNA

The waterbird habitat provided by the swamps appears to be more limited than that found in the East Beeliar wetlands. Newman (1976) noted low waterbird abundance and species diversity as well as the occurrence of birds dead or dying from environmentally induced disease. No other data on bird usage appear to exist.

10.3.9 MANAGEMENT ISSUES

If the importance of the swamps in the landscape of the Spearwood - Munster area is to be recognised and retained there needs to be a plan which takes the values into account. Otherwise the attractive features of these remnants of indigenous vegetation will be lost.

The following are relevant to the management of the Market Garden Swamps:

- achievement of a decision on the extent of the reservation;
- rationalisation of active uses such as the ski-tow, and passive and landscape values;

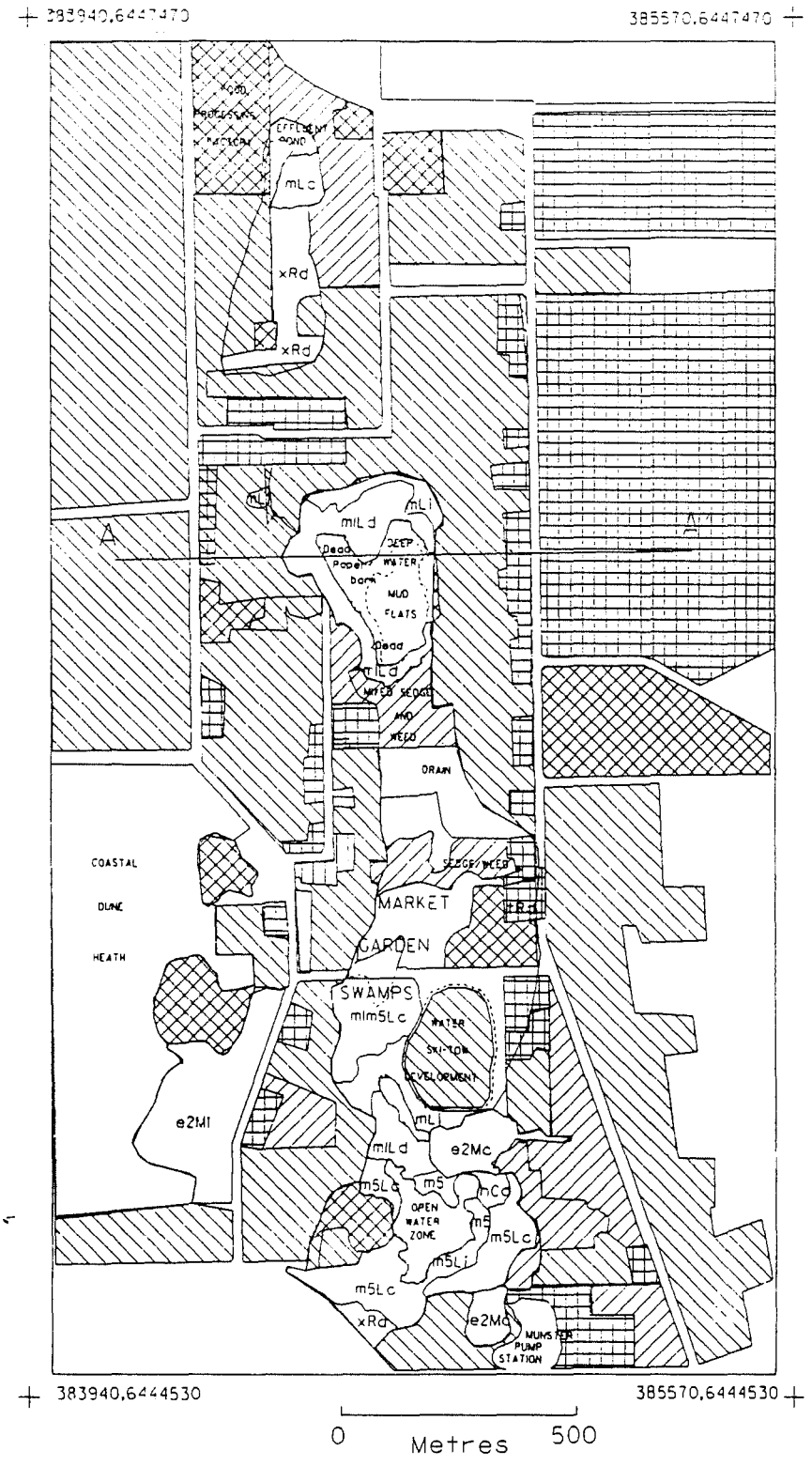

Figure 10.4 Market Garden Swamps: wetland plant communities and surrounding land use.

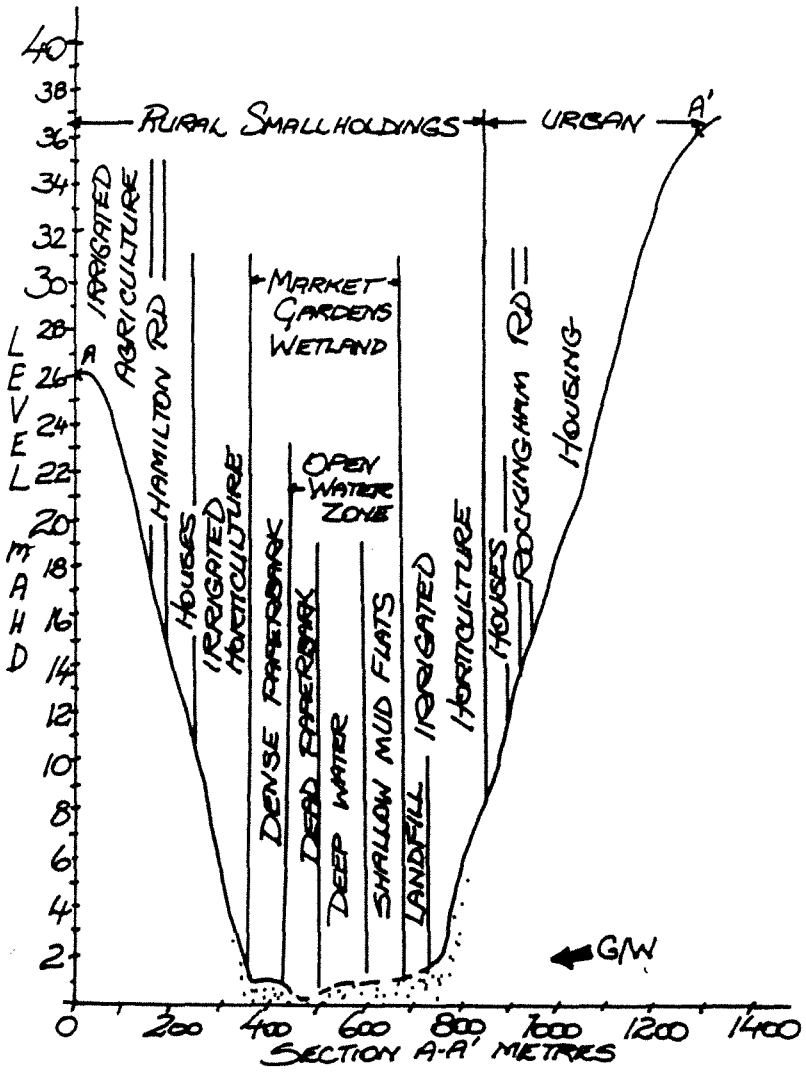

Figure 10.5 Market Garden Swamps: diagrammatic cross-section.

. appropriate management of drainage inputs; and

. recognition that heavy use of groundwater for park management could increase the salinity of the system.

10.3.10 REFERENCES

Newman, P (editor) (1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn.

Western Australian Water Resources Council (1984), Lake Coogee area: review of groundwater problems. Government of Western Australia.

10.4 LAKE COOGEE

10.4.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Rural
MANAGEMENT: City of Cockburn
LAND OWNERSHIP: Reserve 30861 and Freehold
SYSTEM 6 RECOMMENDATION: M92
WAC CLASSIFICATION: Le.b/s.1.p.o
DRAINAGE: Local drainage inputs; future major drainage function.

10.4.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Coogee is a shallow, permanent lake to the south of Market Garden Swamps and immediately east of the westernmost limestone dune ridge of the Spearwood system. Its waters range from brackish in winter to saline in summer.

10.4.3 AREAS

Total Reserve	approx 65 ha
Total wetland area	approx 90 ha
Paperbark	15.4 ha
Sedgeland/samphire	6.2 ha
Open water	60.4 ha
Modified	4.6 ha
Samphire	3.1 ha

10.4.4 HYDROLOGY (Figure 10.7)

Water level records since 1972 show that the maximum winter water level appears to be about 1.0 m AHD with summer minimum levels between 0.1 and 0.3 m AHD. Marked oscillations in the water levels, apart from seasonal changes, suggest that the lake is subject to large inputs of surface run-off at times.

10.4.5 WATER QUALITY

The lake waters are alkaline with pH in the range of 8.1 to 8.9 (spring and autumn values, 1975-1984).

The salinity of the lake shows great seasonal variation as shown by the following tabulation of spring and autumn concentrations of NaCl (mg/L).

Table 10.1. Lake Coogee: salinity (NaCl mg/L) in autumn and spring 1980-84.

YEAR	AUTUMN	SPRING
1980	28 600	8 880
1981	34 960	2 900
1982	6 080 (high Jan rain)	3 400
1983	13 500	3 900
1984	15 000	2 600

10.4.6 LAND USE - Refer to Figure 10.6.

10.4.7 VEGETATION (Figure 10.6)

Lake Coogee is surrounded by a narrow band of saltwater paperbark (Melaleuca cuticularis) with an understorey of sedge and samphire.

10.4.8 FAUNA

Like the nearby wetlands, Lake Coogee does not appear to support large populations of wildlife. However, apart from Newman (1976), no systematic studies of the fauna appear to have been made.

10.4.9 MANAGEMENT ISSUES

Lake Coogee, with the Market Garden Swamps, adds a great deal to the landscape of the area. As urban development increases this function will become more important, as will its role as a recreation focus.

Issues to be considered in the management of Lake Coogee include:

. maintenance of an adequate vegetation fringe to contribute to the amenity of the lake and to provide wildlife habitat;

. determination of the role of the lake in regional drainage; and

. management of lake water quality.

10.4.10 REFERENCES

Newman, P (editor) (1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn.

Western Australian Water Resources Council (1984), Lake Coogee area: review of groundwater problems. Government of Western Australia.

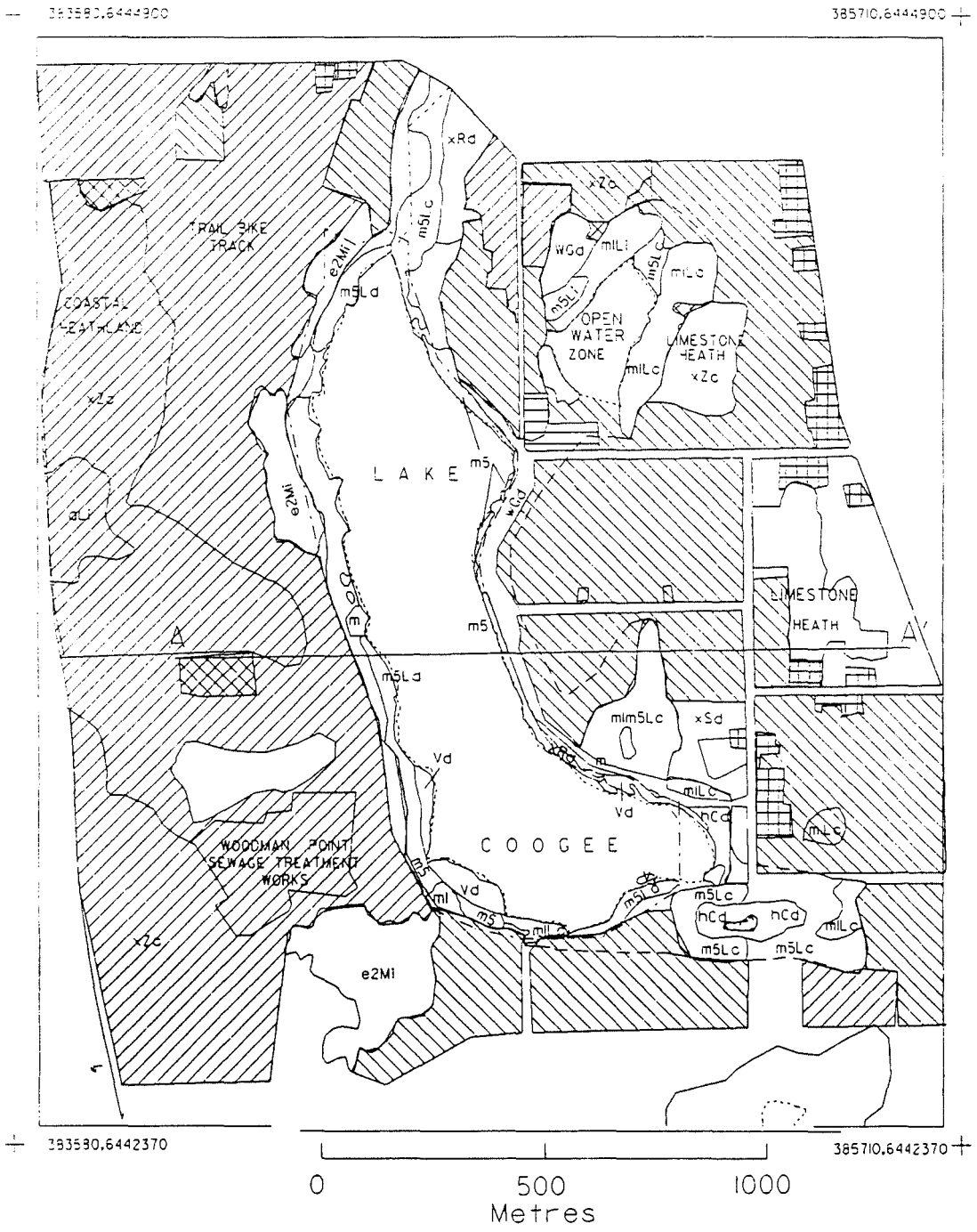

Figure 10.6 Lake Coogee: wetland plant communities and surrounding land use.

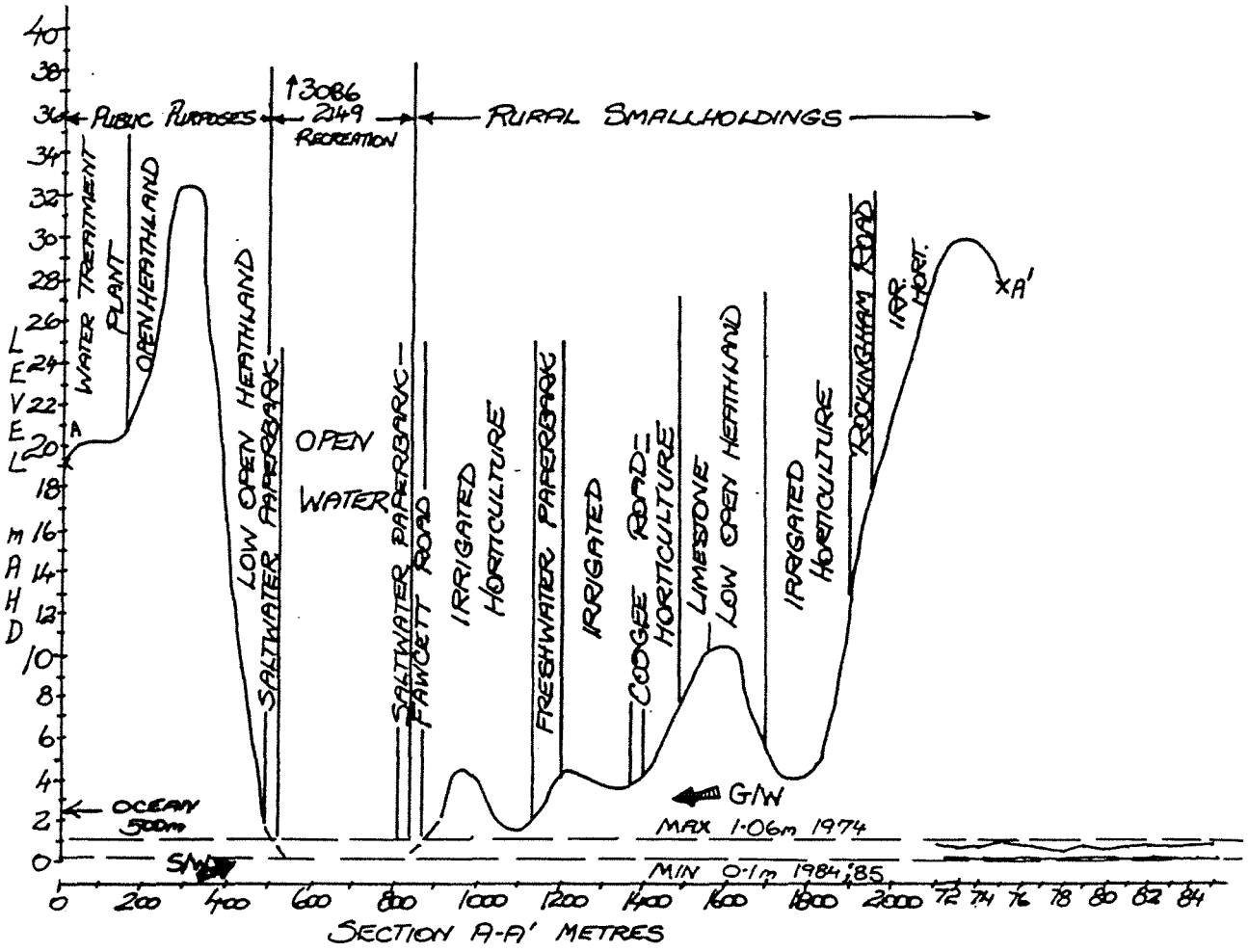

Figure 10.7 Lake Coogee: diagrammatic cross-section and water level record.

10.5 BROWNMAN SWAMPS (Henderson Swamps)

10.5.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation Reserve; northernmost section of swamp lies in private property, north of the Parks and Recreation Reserve
LAND OWNERSHIP: Crown and Freehold
MANAGEMENT: not defined
SYSTEM 6 RECOMMENDATION: M92
WAC CLASSIFICATION: Le.f.1.se.c
DRAINAGE: not affected

10.5.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The Brownman Swamps (sometimes referred to as the Henderson Swamps) occupy a series of north-south trending depressions south of Lake Coogee and between Rockingham Road and the Cape Peron pipeline easement. Massive limestone outcrops occur on the ridges between the swamps.

10.5.3 AREAS

Total wetland ..... 54.2 ha
Wetland within Reserve ..... 49.8 ha

10.5.4 HYDROLOGY

Apart from direct input from rainfall, the water supply would be largely from groundwater as there is little surface runoff.

The swamps have seasonal surface water. Recent observations suggest that water dries out about January. There is apparently no record of water levels in the swamp.

10.5.5 WATER QUALITY

No data available

10.6.6 LAND USE

The most northerly extension of the Brownman Swamps and the only part with permanent water extends into private property and is surrounded by market gardens (Figure 10.8). Brownman Swamp was the site of very early European settlement in the area (Berson, 1978).

10.5.7 VEGETATION (Figure 10.8)

Distinct vegetation boundaries detectable in air photographs can be clearly seen on the ground. There is a sharp boundary between the wetland - with swamp paperbark and rushes - and the upland vegetation, consisting of tuart trees with a blackboy understorey. This boundary occurs at about 2 m AHD. Gahnia trifida occurs on the north and west of the swamps. Ruppia was abundant in standing water in the swamps in September, 1985.

Another boundary can be detected at about 4 m AHD. This edge is a transition between tuart woodland with a largely blackboy understorey to coastal heath.

The relatively intact vegetation boundaries present at Brownman Swamps add to their biological interest and suggest a very strong relationship between plant species and the depth of the water table.

There is relatively little weed incursion but species such as Cape Tulip, Guildford Grass and Blue Pimpernel are widespread.

Some very small salt marsh plants were observed on the western swamp. This suggests that the swamps may once have been more saline than they are now. A fall in groundwater levels and incursion of salt water may lead to a change towards salt marsh.

A rise in water level in the swamp could markedly alter the vegetation patterns now present.

10.5.8 FAUNA - No information available.

10.5.9 MANAGEMENT ISSUES

The swamps lie within the Kwinana Air Pollution Shadow and tuarts within the area show evidence of damage. (Fox and Dunlop, 1985; Meney, 1986.)

The following factors could contribute to detrimental changes to the swamps:

. weed incursions;

. unmanaged wildfire;

. changes in patterns of water use;

. inputs of surface drainage waters;

. increased draw on groundwater; and

. changed land use to the east.

Salt water intrusion or a rise in the water level of the swamp would have the potential to significantly alter the vegetation.

Easy access to the area could increase rubbish dumping and trail bike damage. Fencing carried out by the State Planning Commission has no doubt contributed greatly to the protection of the area. Nevertheless, incursions into the swamps take place and there has been a number of summer wildfires of recent years.

Whereas Market Garden Swamps and Lake Coogee are situated in a landscape strongly affected by rural uses and a developing urban area, the Brownman Swamps and Lake Mount Brown have good buffers of upland vegetation. The relative lack of disturbance to the vegetation confers conservation value on this group of swamps because there are limited occurrences of this type of wetland in the metropolitan region.

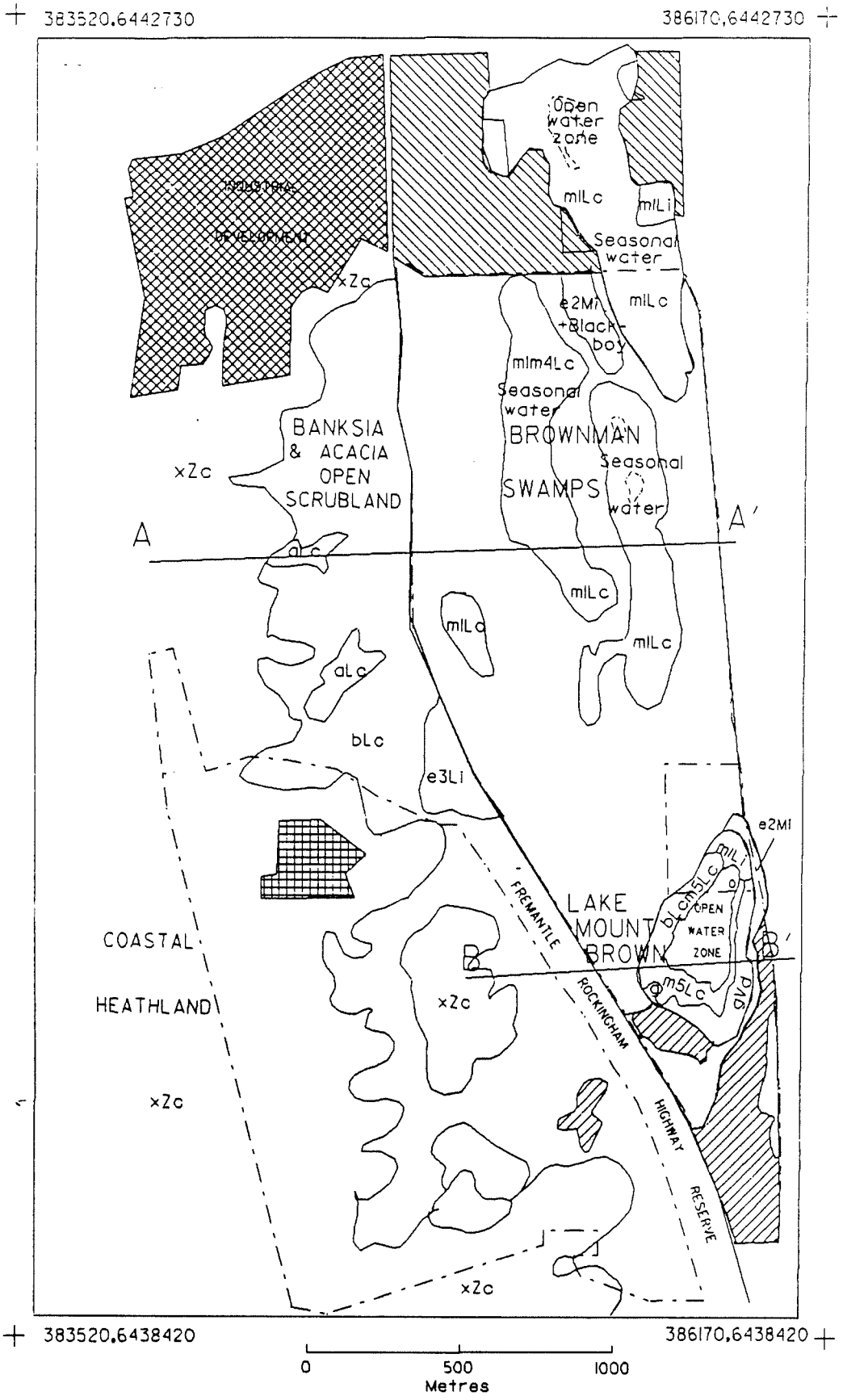

Figure 10.8 Brownman Swamps and Lake Mount Brown: wetland plant communities and surrounding land use.

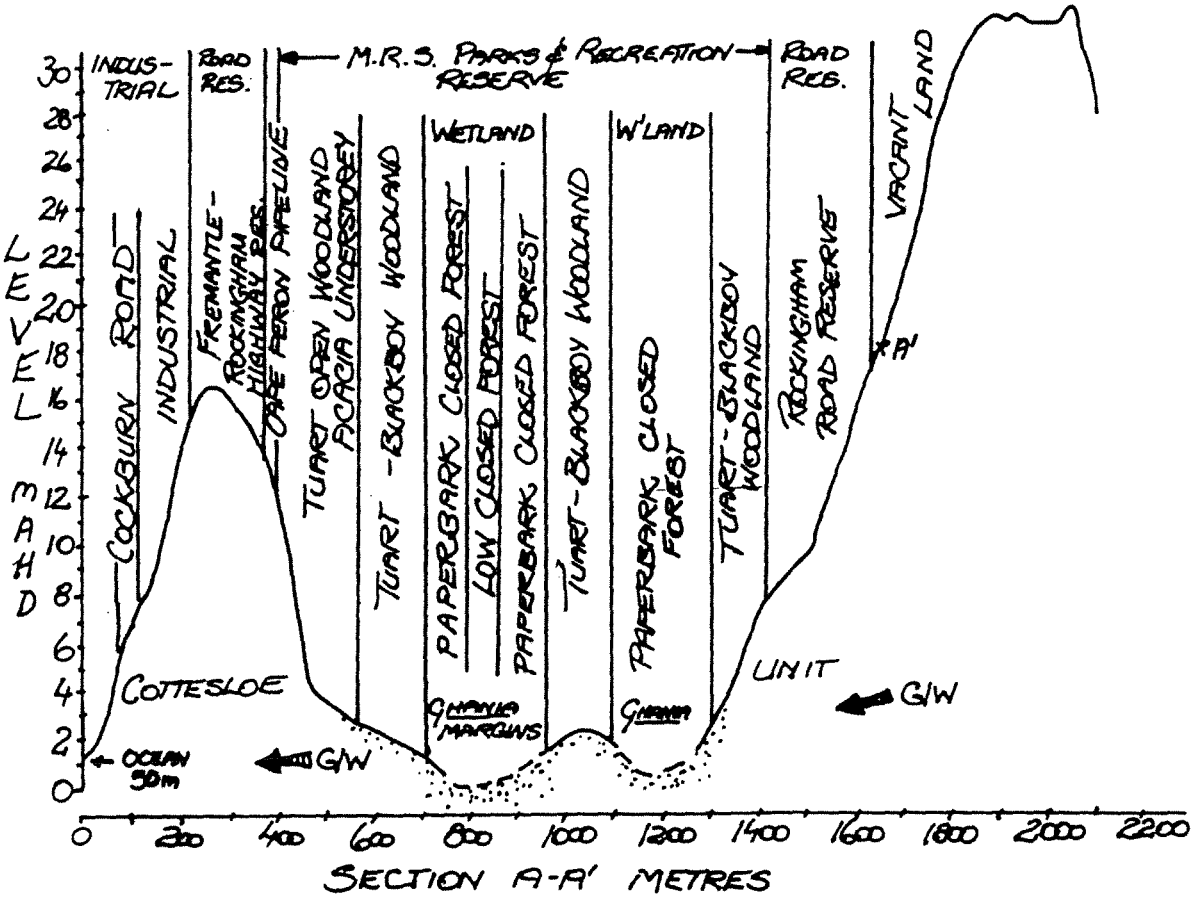

Figure 10.9 Brownman Swamps: diagrammatic cross-section.

10.5.10 REFERENCES

Berson, M (1978), 'Cockburn: the making of a community'. Town of Cockburn, Western Australia.

Fox, J E D and Dunlop, J N (1985), Tuart study: preliminary investigations. Mulga Research Centre, School of Biology. Western Australian Institute of Technology (now Curtin University), Bentley, Western Australia.

Meney, K A (1986), Further investigations at Mt Brown - Wattleup 1986. Mulga Research Centre, School of Biology. Western Australian Institute of Technology (now Curtin University), Bentley, Western Australia.

Newman, P (editor)(1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn.

10.6 LAKE MOUNT BROWN (Brownman Lake; Dalison Avenue Swamp)

10.6.1 GENERAL INFORMATION

LOCAL AUTHORITY: City of Cockburn
MRS ZONE: Parks and Recreation Reserve
LAND OWNERSHIP: Crown and Freehold
MANAGEMENT: not defined
SYSTEM 6 RECOMMENDATION: M92
WAC CLASSIFICATION: Le.b.s.se.o.

10.6.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

This small lake is situated at the foot of Mt Brown in Henderson, west of Rockingham Road from Wattleup townsite. Its position, surrounded by high dunes, is striking. The open central lake basin is filled with shallow water in winter and dries out during summer. The open water area is surrounded by a fringe of paperbarks and rushes. Walking on the lake basin sets the surface quaking, as though there is a substantial deposit of organic sediments.

10.6.3 AREAS

Total wetland	15.9 ha
Paperbark	8.4 ha
Sedgeland	2.2 ha
Open water	5.3 ha

10.6.4 HYDROLOGY (Figure 10.10)

The water level record for Dalison Avenue Swamp shows that the maximum winter level recorded was 0.96 m AHD in 1981.

The minimum summer water level was 0.1 m AHD in 1983 and 1985. The record shows marked oscillations in water level within a given season, suggesting that the lake responds strongly to heavy rainfall events.

10.6.5 WATER QUALITY

Newman (1976) reported that Lake Mount Brown had the best water quality of any of the western Cockburn wetlands.

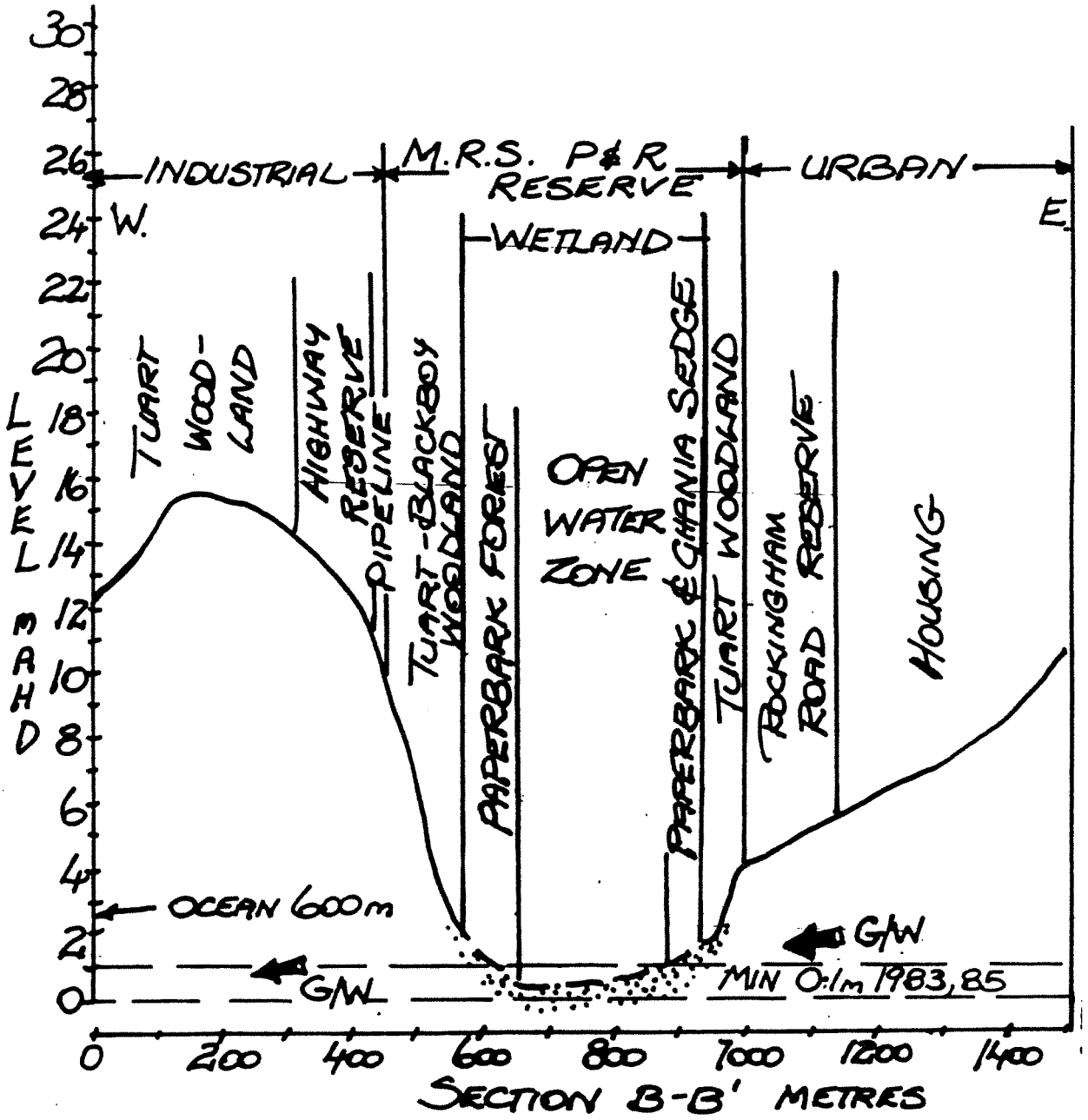

Figure 10.10 Lake Mount Brown: diagrammatic cross-section.

10.6.6 LAND USE - Refer to Figure 10.8

10.6.7 VEGETATION (Figure 10.8)

The lake is surrounded by a fringe of saltwater paperbark and rushes. There is an extensive area of Gahnia trifida on the eastern and southern sides of the lake, outside the paperbark fringe. Ruppia was noted in the lake in early summer 1985.

10.6.8 FAUNA

Newman (1976) reported that this lake had a greater abundance and species diversity in bird fauna than other wetlands in the series. There appears to be no information about other elements of the fauna of the lake.

10.6.9 MANAGEMENT ISSUES

The following issues are relevant to management of the lake:

. prevention of off-road vehicle use of the lake bed;

. prevention of rubbish dumping;

. protection and enhancement of the fringing vegetation; and

. management of drainage inputs to the lake, particularly road runoff.

10.6.10 REFERENCES

Fox, J E D and Dunlop, J N (1985), Tuart study: preliminary investigations. Mulga Research Centre, School of Biology. Western Australian Institute of Technology (now Curtin University), Bentley, Western Australia.

Meney, K A (1986), Further investigations at Mt Brown-Wattleup 1986. Mulga Research Centre, School of Biology. Western Australian Institute of Technology, Bentley, Western Australia.

Newman, P (editor)(1976), The Cockburn wetlands study. Prepared by students of Murdoch University for the Town of Cockburn.

10.7 LONG SWAMP

10.7.1 GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Rural
RESERVE: N/A Freehold
MANAGEMENT: Landowner/s
SYSTEM 6 RECOMMENDATION: N/A
WAC CLASSIFICATION: Le.f/b.s.se.sc.

10.7.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

10.7.3 AREAS

Total wetland ..... 18.1 ha
Paperbarks ..... 11.9 ha
Sedgeland ..... 0.9 ha

AREAS (Cont'd)

Samphire	0.5 ha
Open water	1.8 ha
Modified	2.0 ha

10.7.4 HYDROLOGY (Figure 10.12)

The vegetation of the wetland includes samphire, suggesting that it receives some saline groundwater.

The water level record shows that the maximum winter level on record was 1.43 m AHD in 1977 while the lowest summer minimum level was 0.1 m in 1983.

Since 1978 winter maxima have been in the range 0.8-0.9 m AHD and summer minima within the range 0.1-0.5 m AHD.

10.7.5 WATER QUALITY - No information available.

10.7.6 LAND USE

Long Swamp is some 2 km south of Lake Mount Brown, in a rural area in which there has been considerable quarrying for limestone. An excavation on the eastern side of the wetland has been used to deposit fly-ash. The swamp is intersected by fence lines (Figure 10.11).

10.7.7 VEGETATION (Figure 10.11)

The swamp is surrounded by a dense fringe of swamp paperbark on the south and east and by a mixed stand of swamp paperbark and Melaleuca teretifolia on the northern side. There is a central open area which is inundated in the winter and spring. At the margins of the open area samphire occurs, associated with swamp paperbark. A small area of Baumea articulata is situated in the deepest, most permanently wet, part of the swamp.

10.7.8 FAUNA

There appears to be no information about the fauna of the swamp.

10.7.9 MANAGEMENT ISSUES

As the swamp is in private ownership, the task of management resides with the landowner. The swamp warrants conservation because of its relatively intact vegetation. Preservation of the wetland vegetation and prevention of access to stock and itinerant rubbish dumpers would go a long way to maintaining the wetland in a healthy state.

10.7.10 REFERENCE

Gozzard, J R (1983). Fremantle Part Sheets 2033I and 2033IV Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

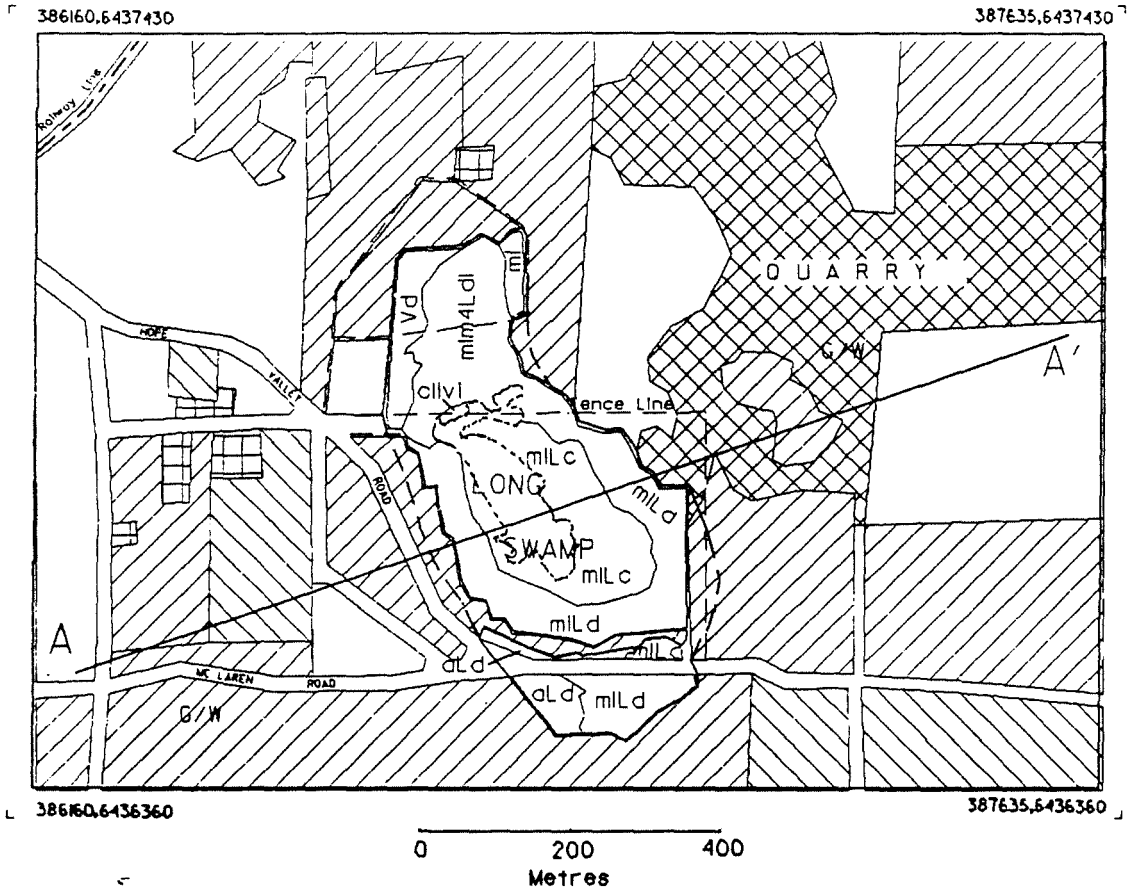

Figure 10.11 Long Swamp: wetland plant communities and surrounding land use.

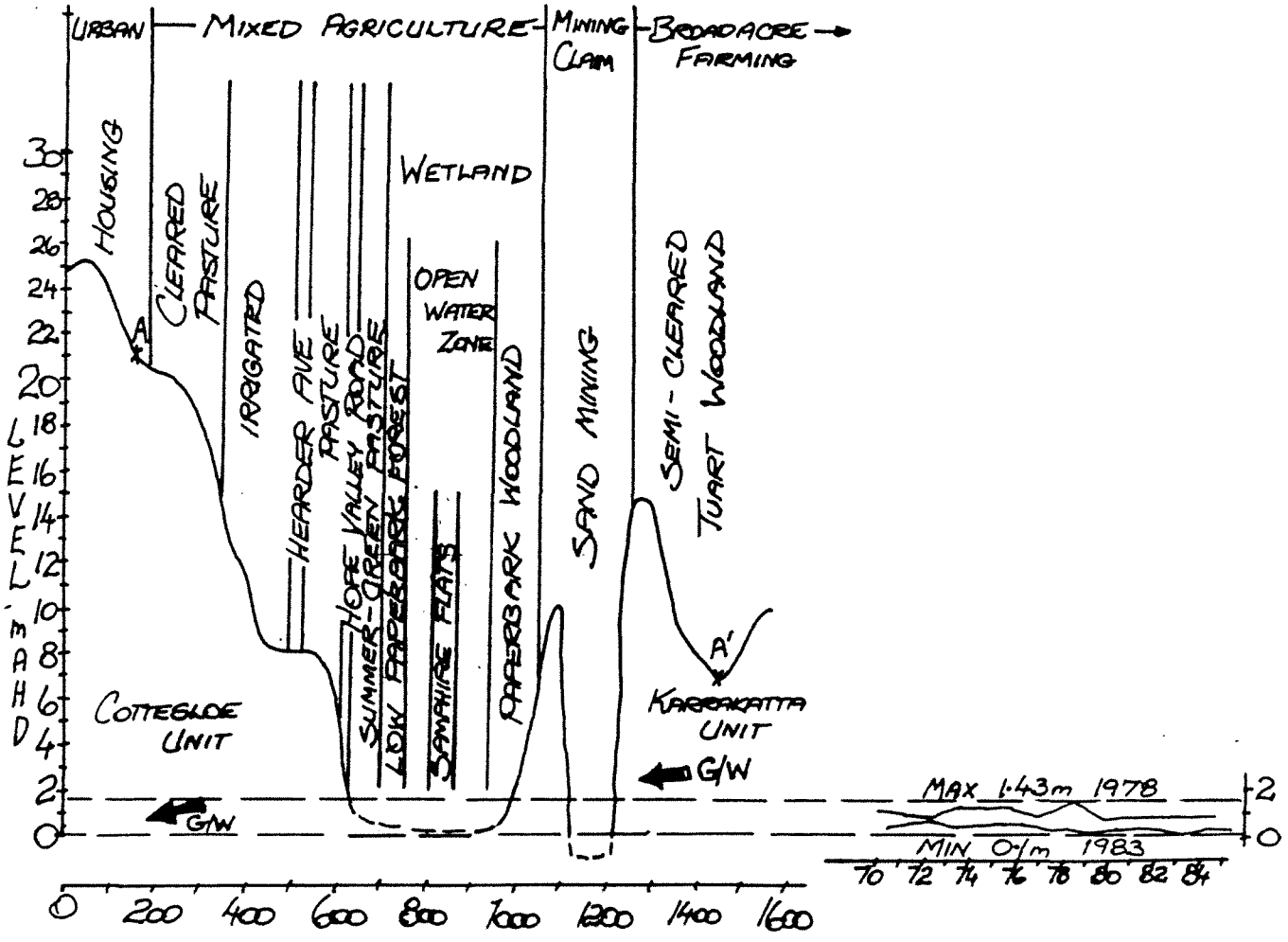

Figure 10.12 Long Swamp: diagrammatic cross-section and water level record.

10.8 CHALK HILL LOOKOUT SWAMP

10.8(a) GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Parks and Recreation
RESERVE: Freehold
MANAGEMENT: Town of Kwinana
SYSTEM 6 RECOMMENDATION: N/A
WAC CLASSIFICATION: Le.f.s.se.c
DRAINAGE: Local drainage.

10.8(b) DESCRIPTION

This small area of swamp lies within land reserved for Parks and Recreation and is close to Smirk Cottage which is of historical significance.

The absence of a System 6 recommendation for the area can be explained by its small size.

The swamp is approximately 3.5 ha in area. It appears on air photographs as approximately oval in shape with its long axis running from north-east to south-west and with some clearing or weed incursion on the north-western and southern sides.

The water supply of the swamp is from direct rainfall and from groundwater seepage to its eastern side from regional flow in the unconfined groundwater flow system. The water level thus reflects the regional water table, responding to winter rains by a gradual rise to a peak in August-September and a gradual fall in spring and summer to a minimum level in March-April. The swamp does not have permanent surface water but the vegetation indicates that there is sufficient groundwater seepage to keep the soil damp throughout the dry season.

The vegetation of the swamp has been affected on its margins by clearing and weed incursions. Nevertheless, within the body of the swamp, the vegetation is healthy and relatively undisturbed.

The dominant plant species is swamp paperbark which is present as tall, mature trees and young specimens. The canopy of the paperbarks forms a closed cover, providing deep shade to the floor of the swamp. Flooded gums are present as tall straight specimens. The flooded gums appear to be free from damage from leaf miners. No swamp banksia were noted. This species is normally to be found on the eastern side of swamps like this one. It is likely that the Banksia has been cleared away to make room for the development which has taken place on the eastern side of Seabrook Way.

The deep shade provided by the paperbarks and flooded gums has a strong influence on the understorey of swamps such as this one, with surface water for part of the year only. The swamp is relatively accessible with Centella (Indian Pennywort) providing ground cover. In other swamps of this type there are a variety of rushes and sedges to be found. Patches of the jointed twig rush occur in parts of this swamp, indicating the areas which are the most low lying and which have the most permanent water supply. Twig rush appears to grow more vigorously in the open than in deep shade. The submerged aquatic plant Ruppia grows in areas of the swamp which are inundated during winter, spring and early summer.

Swamps such as the one under consideration here usually open out towards the west, displaying a change from closed woodland to sedgeland or heath. In this case there is a striking occurrence on the south-western part of the swamp.

This is a pure stand of the rush Typha domingensis occupying several hundred square metres. Unlike the more abundant Typha orientalis which invades shallow, disturbed wetlands, this species is relatively rare in the region and is of sufficient interest to warrant its protection.

There has been some proliferation of weeds around the margin of the swamp.

There has been no attempt to document the species of animals to be found in the swamp. It is to be expected that, in its present form, the swamp provides habitats for the relatively rare, shy birds such as night herons, crakes, rails and small bush birds. The rich food supply of the swamp could also support nesting ducks.

Surface runoff to the swamp will increase as clearing and development increases on the margin of the swamp. This might have the effect of increasing the level and permanence of the water. An increased water level could alter the vegetation pattern of the swamp. The paperbarks do not tolerate soils that are water-logged throughout the year. Under such circumstances they will be less vigorous, become senescent and fail to replace themselves with seedlings. As a result the canopy will become more open, reducing the shade to the floor of the swamp. This would make conditions more suitable for weeds.

The result of changes to the hydrology and vegetation would be a change to a permanent, or semi-permanent, open water lake.

10.9 SLOANS RESERVE

10.9(a) GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Parks and Recreation
RESERVE: Freehold
MANAGEMENT: Town of Kwinana
SYSTEM 6 RECOMMENDATION: N/A
WAC CLASSIFICATION: Le.f.m.se.c
DRAINAGE: local drainage.

10.9(b) AREAS

Total reserve	23 ha
Total wetland	17.7 ha
Wetland within reserve	12.3 ha
Acacia/paperbark	10.8 ha
Sedgeland	0.3 ha
Modified	6.8 ha

10.9(c) DESCRIPTION

The swamps of Sloans Reserve appear to have undergone a change in their water supply of recent years so that the wetland vegetation is retreating and being replaced by Acacia woodland. See also Figures 10.13 and 10.14.

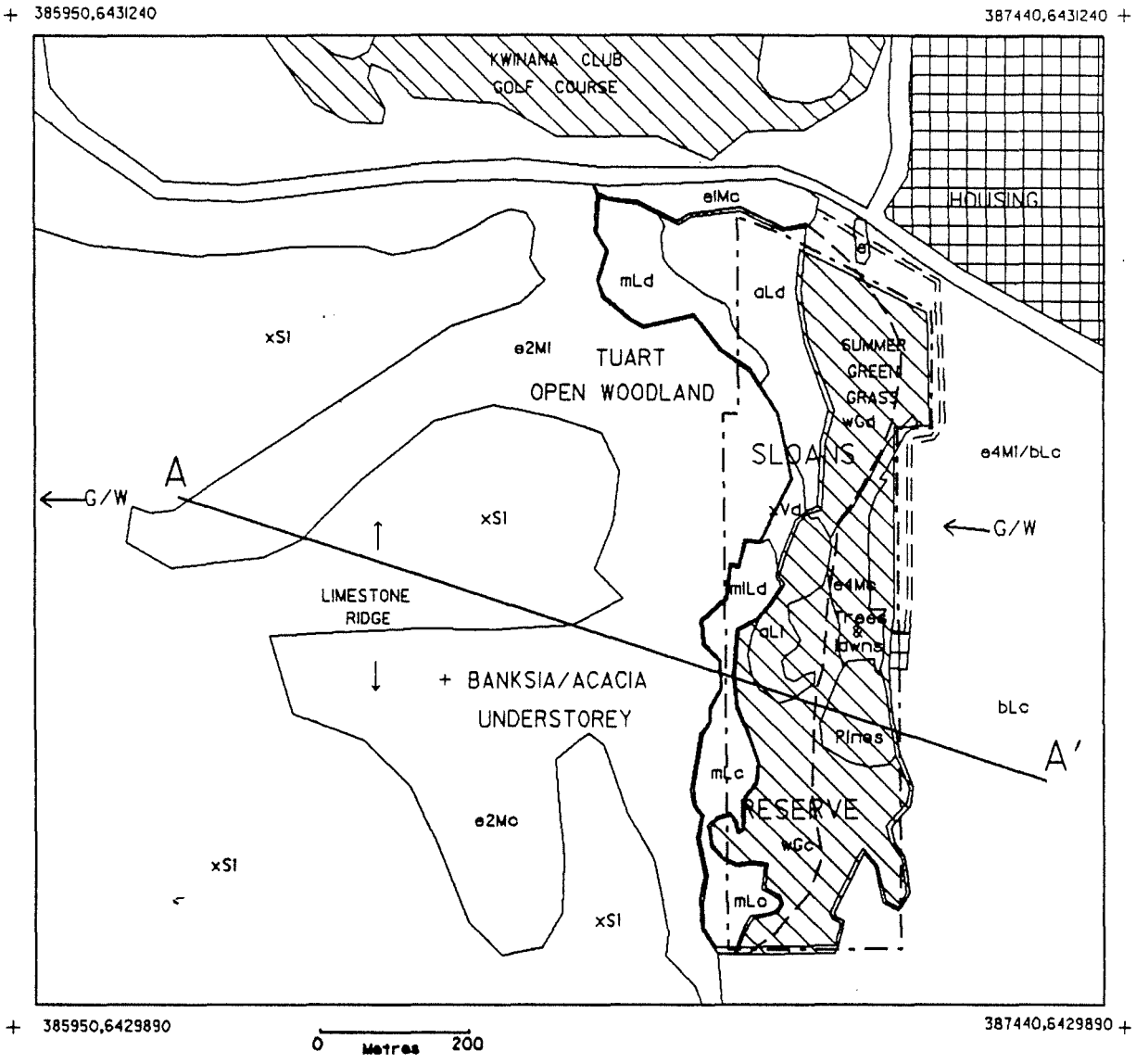

Figure 10.13 Sloans Reserve: wetland plant communities and surrounding land use.

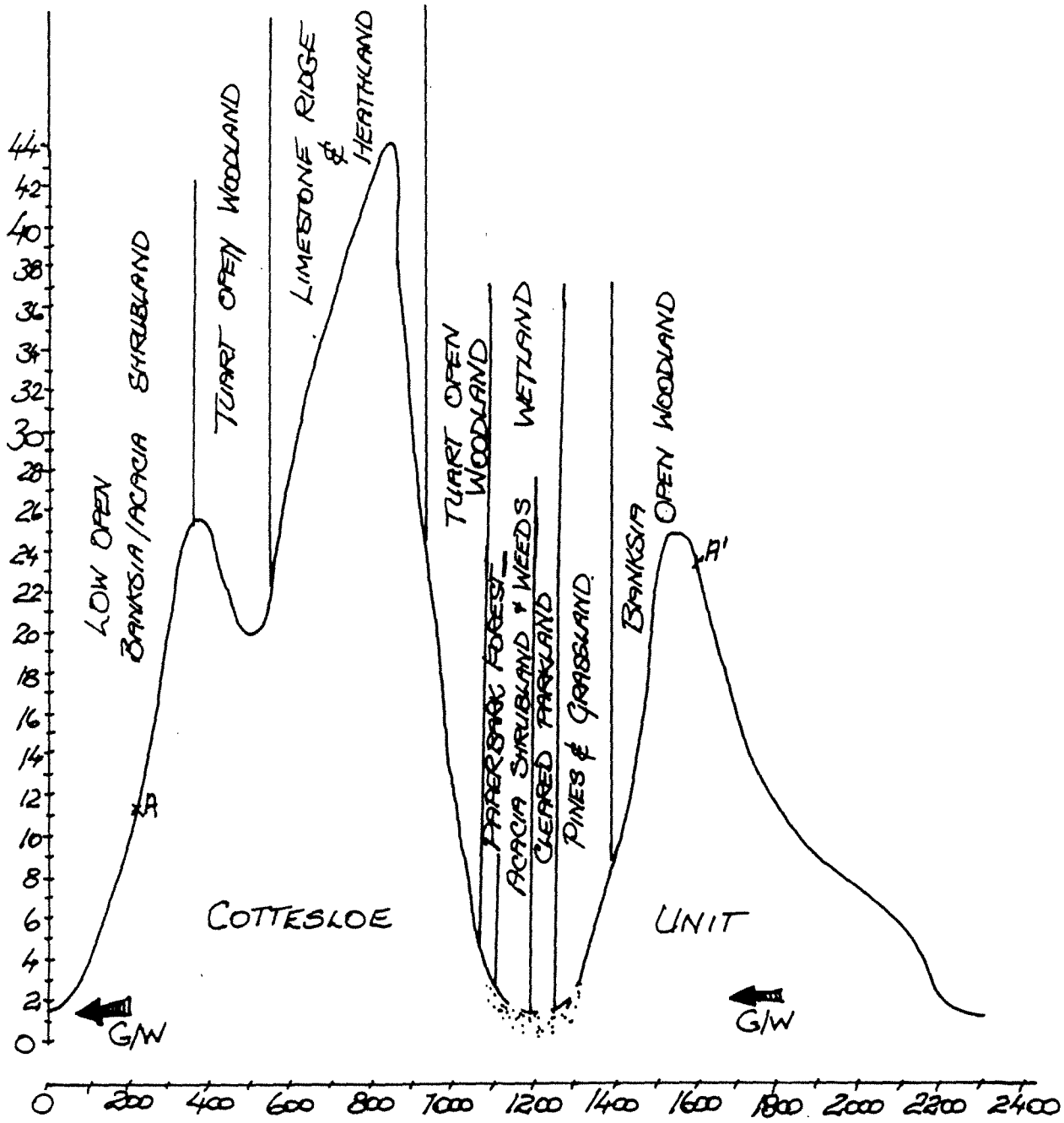

Figure 10.14 Sloans Reserve: diagrammatic cross-section.

10.10 LEDA SWAMPS

10.10(a) GENERAL INFORMATION

LOCAL AUTHORITY: Town of Kwinana
MRS ZONE: Parks and Recreation
RESERVE: †33581, vacant Crown land
MANAGEMENT: Town of Kwinana
SYSTEM 6 RECOMMENDATION: M104
WAC CLASSIFICATION: Le.f.s.se.c

10.10(b) AREAS

Total wetland	approx 33 ha
Wetland within reserve	17.2 ha
Paperbark	21.6 ha
Sedgeland/heath	5.9 ha
Open water/low sedge	4.9 ha

10.10(c) DESCRIPTION

The Leda Swamps are relatively undisturbed. Their vegetation warrants careful description. The following account is based on a brief visit to the area.

The distribution of plant species across the swamps from east to west appears to follow a pattern common to the undisturbed wetlands of the region. On the eastern side of the swamp, presumably where seepage of groundwater from the unconfined aquifer is strongest, there is tall closed woodland of swamp banksia and swamp paperbark over a low shaded understorey. The tall saw sedge Gahnia trifida occurs in the understorey. West of the band of banksia and paperbark is tall jointed twig rush, suggesting that this part of the swamp remains well supplied with water throughout the year. Further west again, there is a change to a low wetland heath community (Figures 10.15 and 10.16).

10.11 TAMWORTH HILL SWAMP

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Rural
LAND OWNERSHIP: Freehold
MANAGEMENT: Private landowner
SYSTEM 6 RECOMMENDATION: n/a
WAC CLASSIFICATION: Le.f.m.se.c.

Notes: Jointed twig rush sedgeland with paperbark fringe and a small area of open water.

10.12 STAKEHILL SWAMP

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Rural
LAND OWNERSHIP: Freehold
MANAGEMENT: Private landowner
SYSTEM 6 RECOMMENDATION: n/a
WAC CLASSIFICATION: Le.f.m.se.c.

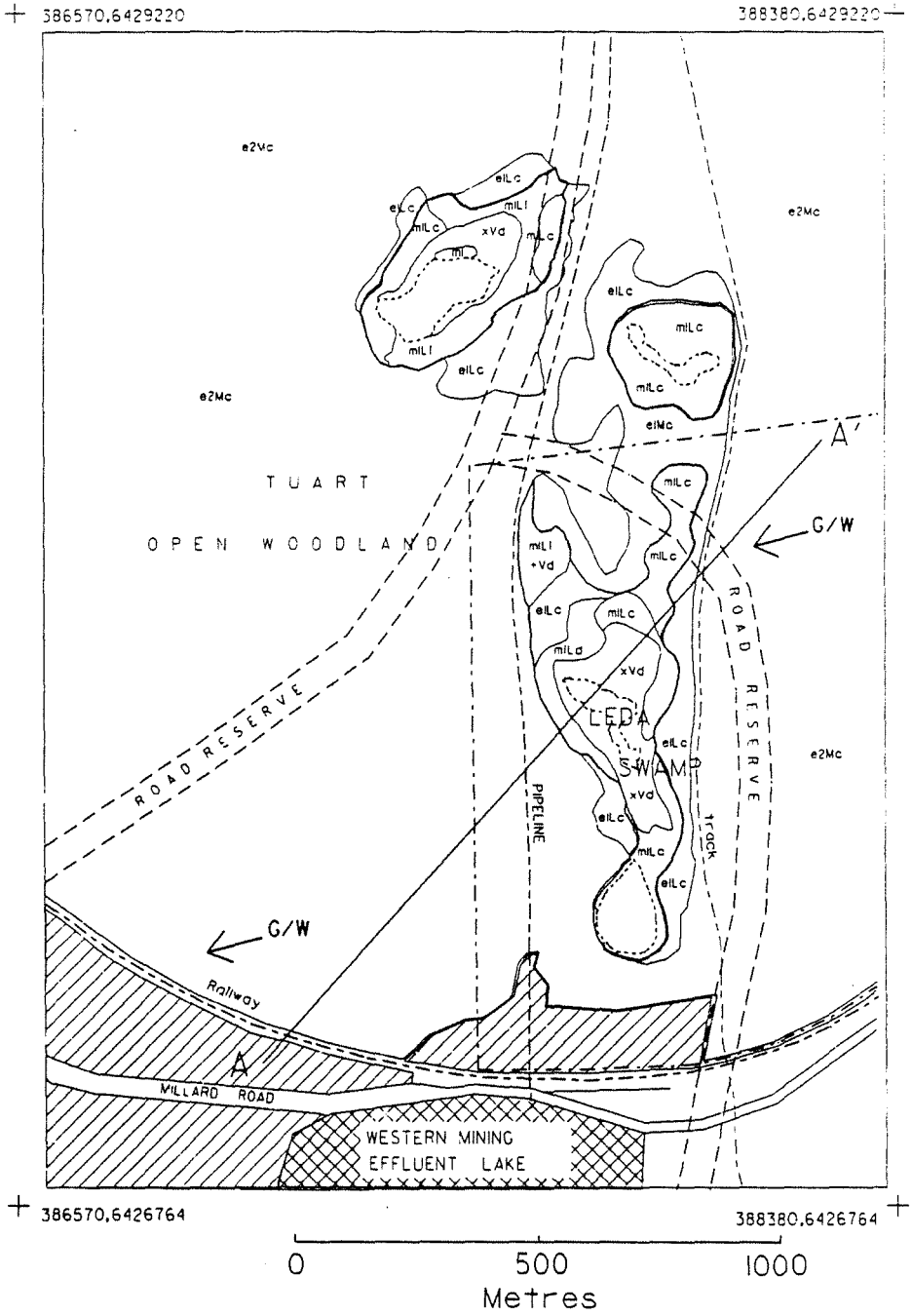

Figure 10.15 Leda Swamps: wetland plant communities and surrounding land use

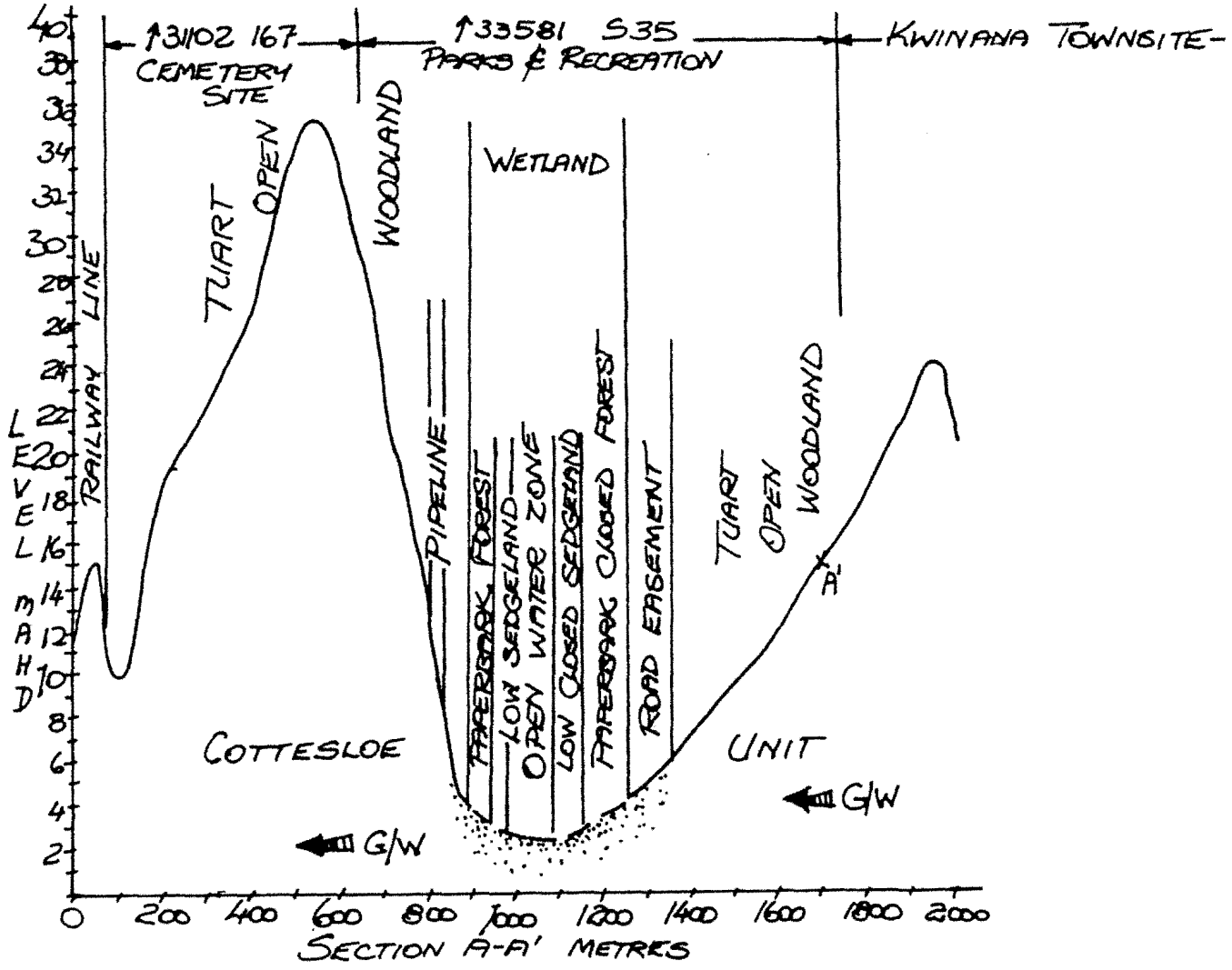

Figure 10.16 Leda Swamps: diagrammatic cross-section

Notes: Jointed twig rush sedgeland with swamp paperbark fringe. There is intensive horticulture around the margins with clearing up to the wetland margins and paperbarks being bulldozed into the swamp.

10.13 ANSTEY'S SWAMP

10.13.1 GENERAL INFORMATION

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Rural
LAND OWNERSHIP: Freehold
MANAGEMENT: Private landowner
SYSTEM 6 RECOMMENDATION: n/a
WAC CLASSIFICATION: Le.f.l.se.c.

10.13.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Anstey's Swamp lies within the Spearwood Dunes, immediately east of interface with Holocene beach ridge plain. It is described as Marsh in low level interbarrier depression within the Spearwood Dunes (Gozzard, 1983). The Environmental Geology map identifies the soil type of Anstey's Swamp and the swamp to the south of it as differing from the wetlands further to the north:

Anstey's Swamp and Wetland on South: Soil Types

CLAYEY SAND - black, fine to medium grained quartz sand with clay matrix, variable organic matter, of lacustrine origin. Elevation of Anstey's swamp and wetland on south - 3 m AHD.

SANDY CLAY - dark grey to black, firm, variable quartz sand content, occasionally some silt in matrix - of lacustrine origin. Elevation - 5 m AHD.

10.13.3 AREAS - No information

10.13.4 HYDROLOGY

The swamp receives groundwater seepage from the unconfined aquifer along the eastern shoreline. A record of water levels in the swamp exists for the period 1975 - present (Water Authority).

Maximum levels recorded winter 1975: 3.01 m; winter 1982:3.0 m.

Minimum levels recorded summer 1981: 1.11 m; summer 1978: 1.42 m.

10.13.5 WATER QUALITY - No information recorded.

10.13.6 LAND USE

The swamp is privately owned by a number of landholders.

10.13.7 VEGETATION

The swamp is almost completely vegetated. There appear to be at least five identifiable wetland vegetation communities:

- Swamp banksia on the eastern side;
- Fringing and extensive swamp paperbark;
- Mixed sedgeland/shrubland;
- Sedgeland; and
- Sedgeland (jointed twig rush) - small areas where there is permanent dampness.

The plant communities are healthy and there is a high degree of interspersion - maximising the interfaces between the communities.

10.13.8 FAUNA

In the course of visits to the site a number of grey kangaroos have been noted. The swamp would provide winter breeding areas for ducks and other waterbirds. The extensive areas of paperbark thicket may provide for rookery sites for birds requiring perching sites. The shelter and flowering shrubs would support bush birds.

10.13.9 MANAGEMENT ISSUES

Anstey's Swamp was recognised as having environmental value in the course of environmental assessment of the Secret Harbour Project (Environmental Protection Authority, 1982). Concern was expressed that proposed extraction of groundwater to supply the project would lower the water table in the swamp.

The preferred option for the South West Corridor reserves Anstey's Swamp for Parks and Recreation.

10.13.10 REFERENCES

Environmental Protection Authority (1982), Report and recommendations of the Environmental Protection Authority on the Secret Harbour Development. Bulletin 121, Department of Conservation and Environment, Western Australia.

Gozzard, J R (1983), Rockingham Part Sheets 2033 III and 2033 II, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

END OF SECTION

Page

FIGURES

TABLES

11. WETLANDS OF THE ROCKINGHAM PLAIN (Figure 11.1)

11.1 GENERAL SETTING

The wetlands of the Rockingham Plain comprise a range of types including:

- wetlands of the "Pickle Swamp" series between Wellard Road and Millar Road in East Rockingham, at the interface of the Spearwood Dunes and the beach ridge plain;

- the large shallow lakes, Cooloongup and Walyungup on the eastern side of the Rockingham Plain, with their associated seasonal wetlands;

- Lake Richmond, the deepest lake on the coastal plain, which has marine origins (Fairbridge, 1947); and

- swales between beach ridges on the plain.

Seddon (1972, pp 64-66) described the structure and origins of the Rockingham Plain. The hydrology of the plain has been investigated (Passmore, 1967,1970; Layton Groundwater Consultants,1976). Woods and Searle (1983) used radiocarbon dating to estimate the age of the beach ridges on the Rockingham Plain and concluded that the seashore advance of beach ridges west of the Spearwood Dunes commenced around 6 500 BP and is continuing to the present. Lake Cooloongup and Lake Walyungup developed on the landward side of the beach ridge plain. Contemporary evaporate deposits in the lake basins overlie beach sands. The water and salt balances of the lakes have been investigated by Passmore (1967, 1970) and Layton (1976). Semeniuk (in Western Australian Water Resources Council, 1987), recognises three related suites of wetlands in this region: the Cooloongup, Becher and Peelhurst suites.

See Gozzard (1983) for Environmental Geology and Geomorphology .

11.1.1 REFERENCES

Fairbridge, R W (1947), Geology and geomorphology of Point Peron. J Royal Soc Western Australia, 34, pp 35-72.

Gozzard, J R (1983), Rockingham Part Sheets 2033 III and 2033 II. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

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Passmore, J R (1967), The geology, hydrology and contamination of shallow coastal aquifers in the Rockingham District. Ph D thesis, University of Western Australia.

Passmore,J R (1970), Shallow coastal aquifers in the Rockingham District, Western Australia. Bulletin No 18, Water Research Foundation of Australia.

Seddon, G (1972), 'A sense of place'. University of Western Australia Press, Perth.

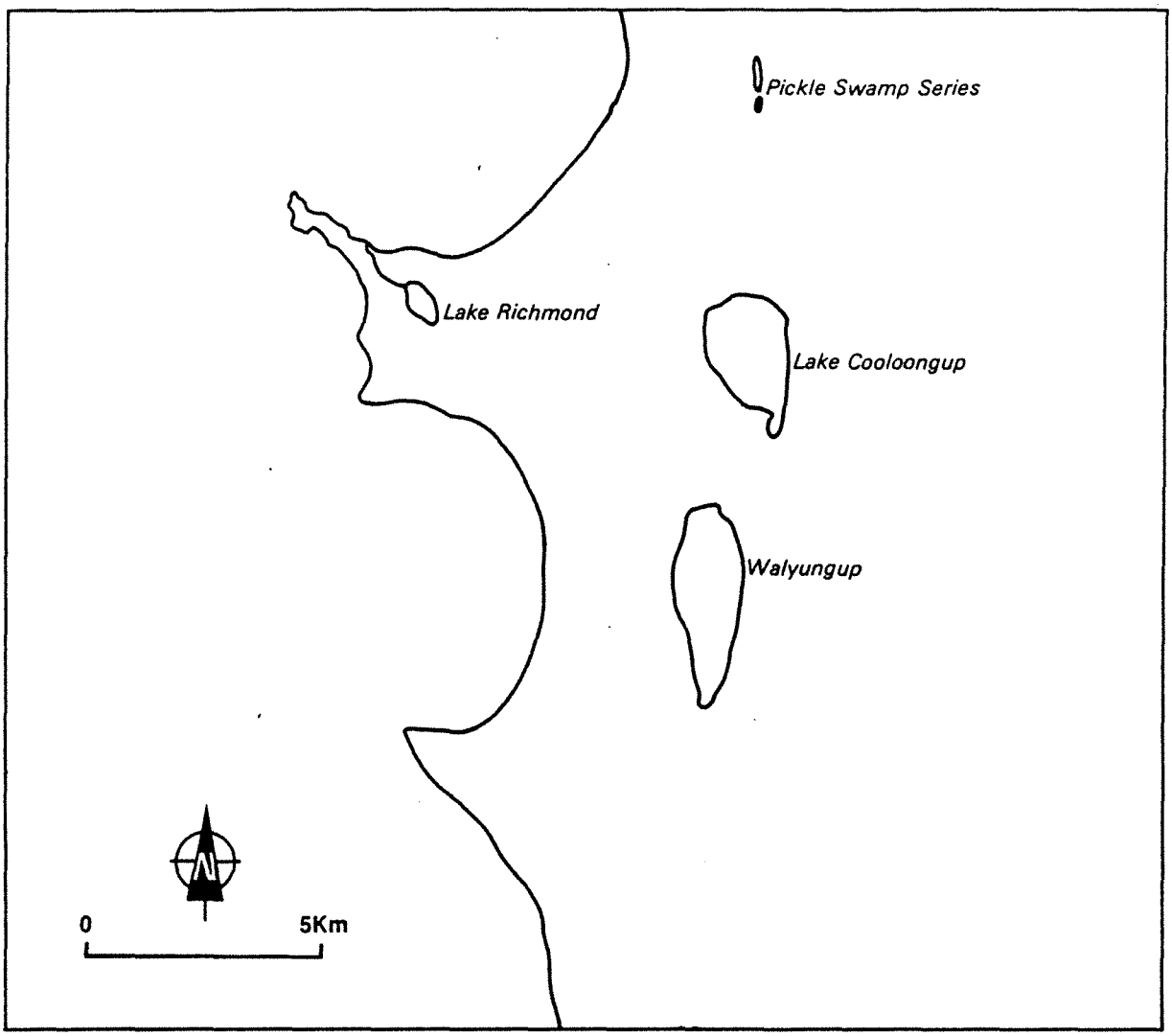

Figure 11.1 Map showing the wetlands of the Rockingham Plain.

Tingay, A & Tingay, S (1977), The Lakes Region Open Space. Biological survey for the Shire of Rockingham (unpublished).

Western Australian Water Resources Council (1987), Environmental significance of wetlands in the Perth to Bunbury Region. Vol 2, Appendix 5. WAWRC, Leederville, Western Australia.

Woods, P J & Searle D J (1983), Radiocarbon dating and Holocene history of the Becher/Rockingham Beach Ridge Plain, West Coast, Western Australia. Search, 14 (1-2), pp 44-46.

11.2 WETLANDS OF THE PICKLE SWAMP SERIES

A north-south series of wetlands extends on the eastern side of the railway reserve from south of Wellard Road in East Rockingham to north of Millar Road. The wetlands provide a buffer between the proposed East Rockingham industrial area and the proposed Leda residential area on the east.

The geomorphological classification applied by the Geological Survey of Western Australia to this series is 'marsh in interdunal swale', between the Spearwood Dunes on the east and the Holocene foredune plain on the west (Gozzard, 1983).

A considerable area of the wetland area south of Wellard Road - roughly 35 ha - has been utilised by superphosphate manufacturers to deposit gypsum waste. There is concern that leachate from the gypsum deposits has entered the groundwater. This suggests that it would be unwise to consider further effluent disposal in this wetland.

The area of unfilled wetlands south of the gypsum dump is roughly 60 ha (estimated from a tracing from a 1:25000 air photo by counting squares).

The wetland soils are greyish deposits of peaty clays. The deposits appear to be unusual in that they include large numbers of fossil snail shells which are similar in form to recently dead freshwater snail shells occurring on the surface.

The wetland vegetation as approached from the east consists of tall, dense swamp paperbark around the margins, surrounding open areas of low Melaleuca teretifolia and sedgelands of jointed twig rush which are seasonally inundated. The eastern side of the swamps is marked by a dense woodland of swamp banksia and swamp paperbark with understorey of Gahnia trifida and Centella. Whereas the western side of the swamps has been affected by clearing, grazing and fire, the eastern side appears remarkably little disturbed.

The following notes were made after a visit to the western side of the swamps near Mead Road in winter 1986:

The wetland has been extensively affected by fire, probably during late summer 1986. The swamp paperbarks and Melaleuca teretifolia are now shooting from the branches in the case of larger trees and from the base in the case of smaller trees. One of the effects of the fire has been to remove leaf litter and to open up the leaf canopy to allow increased light to reach ground level. A consequence has been a vigorous growth of weeds. This weed invasion would be partly reversible if the leaf canopy is restored.

The paperbarks in the area had previously been covered by a tangle of the parasitic plant, dodder (Cassytha). The vegetation may receive some benefit from the fire which has removed the dodder for the time being.

Only limited comments can be made about the fauna. On 21/8/86 there were large numbers of two species of frogs calling in the flooded areas of the swamp. There were a number of species of bush birds feeding in the canopies of some burnt paperbarks. There was some evidence that there are kangaroos in the area and a bandicoot digging was sighted. The value of the wetlands will have been affected by the fire damage but this will recover as the trees regenerate. There were abundant aquatic snails.

The management effort required to maintain the wetlands need not be large. Requirements would be for prevention of garbage dumping; prevention of access to wheeled vehicles and protection from wildfire.

Weed problems would be minimised if the leaf canopy is allowed to regenerate to make deep shade and leaf litter is allowed to accumulate, and disruption to the swamp deposits is prevented to avoid invasion by Typha orientalis. Walk paths on the limestone areas on the eastern side, with access points to the slightly elevated areas between the swamps proper, should allow for passive recreational use.

11.3 LAKE COOLOONGUP (White Lake)

11.3.1 GENERAL INFORMATION

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Parks and Recreation Reserve
MANAGEMENT: Shire of Rockingham
RESERVE NUMBERS: 24411
SYSTEM 6 RECOMMENDATION: M103
WAC CLASSIFICATION: LE.s.l.p.o
WATER RESERVE: Peel.

11.3.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Cooloongup, with Lake Walyungup to the south, provides a striking landscape feature between the Spearwood Dunes on the east and the Rockingham Plain. For further physiographic and geological information refer to the General Comments (Section 11.1). Both Lake Cooloongup and Lake Walyungup are surrounded by wetland vegetation on lagoonal deposits.

11.3.3 AREAS

Total wetland area	approx 720 ha
Sedgeland	270 ha
Paperbark/Acacia	104 ha
Open water zone	344 ha

7.3.4 HYDROLOGY (Figure 11.3)

Passmore (1967) and Layton Groundwater Consultants (1977) have described the hydrology and geology of the area. Water balances were calculated for Lake

Cooloongup, demonstrating that it receives groundwater inputs from the Stakehill Mound and from the Rockingham Plain to the west, and that there is through-flow of groundwater from the east to the north-west. This through-flow is believed to play a part in limiting the concentration of salts in Lake Cooloongup.

The maximum water levels recorded for Lake Cooloongup were 3.03 m AHD, prior to 1960, and 3.0 m AHD in 1967. Water levels have been lower in more recent years with winter maxima at 1.8-2.4 m AHD and summer minima at about 1.5-1.8 m AHD. The lowest minimum level recorded was 1.46 m AHD in 1984 (Figure 11.3).

11.3.5 WATER QUALITY

The Water Authority takes twice yearly samples from the lake for chemical analysis. The lake is subject to blooms of algae.

11.3.6 LAND USE - Refer to Figure 11.2

11.3.7 VEGETATION (Figure 11.2)

Tingay and Tingay (1977) mapped the vegetation of Lake Cooloongup and Lake Walyungup.

The lake supports considerable amounts of Ruppia in spring to early summer. The extensive areas of seasonal wetland on the margins of the lake and particularly on the south provide a link to Lake Walyungup and add a great deal to the habitat diversity of the area.

Fringing trees on the eastern and western shores are Acacia, not paperbarks. However, there is dense growth of paperbark at the northern end of the lake.

There is no sign of Typha invasion in the sedge fringe of the lake. This may reflect the relatively high salinity and low nutrient status of the area.

11.3.8 FAUNA

Serventy (in Seddon, 1972) noted that the fish Atherinosoma rockinghamensis of estuarine and marine affinities, occurs in Lake Cooloongup.

11.3.9 MANAGEMENT ISSUES

Effluent from the effluent ponds east of Mandurah Road may be leaking into the groundwater, with a risk of entering Lake Cooloongup.

Some breeding of chironomid (non-biting) midges occurs in the lake and the swarms may cause a nuisance should urban development occur on the ridge to the east of the lake in future.

Changes to the salt and water balance of the lake may occur if the lake receives large quantities of urban runoff. Urban runoff could also add nutrients to the lake, leading to changes in the ecological balance and concomitant management problems.

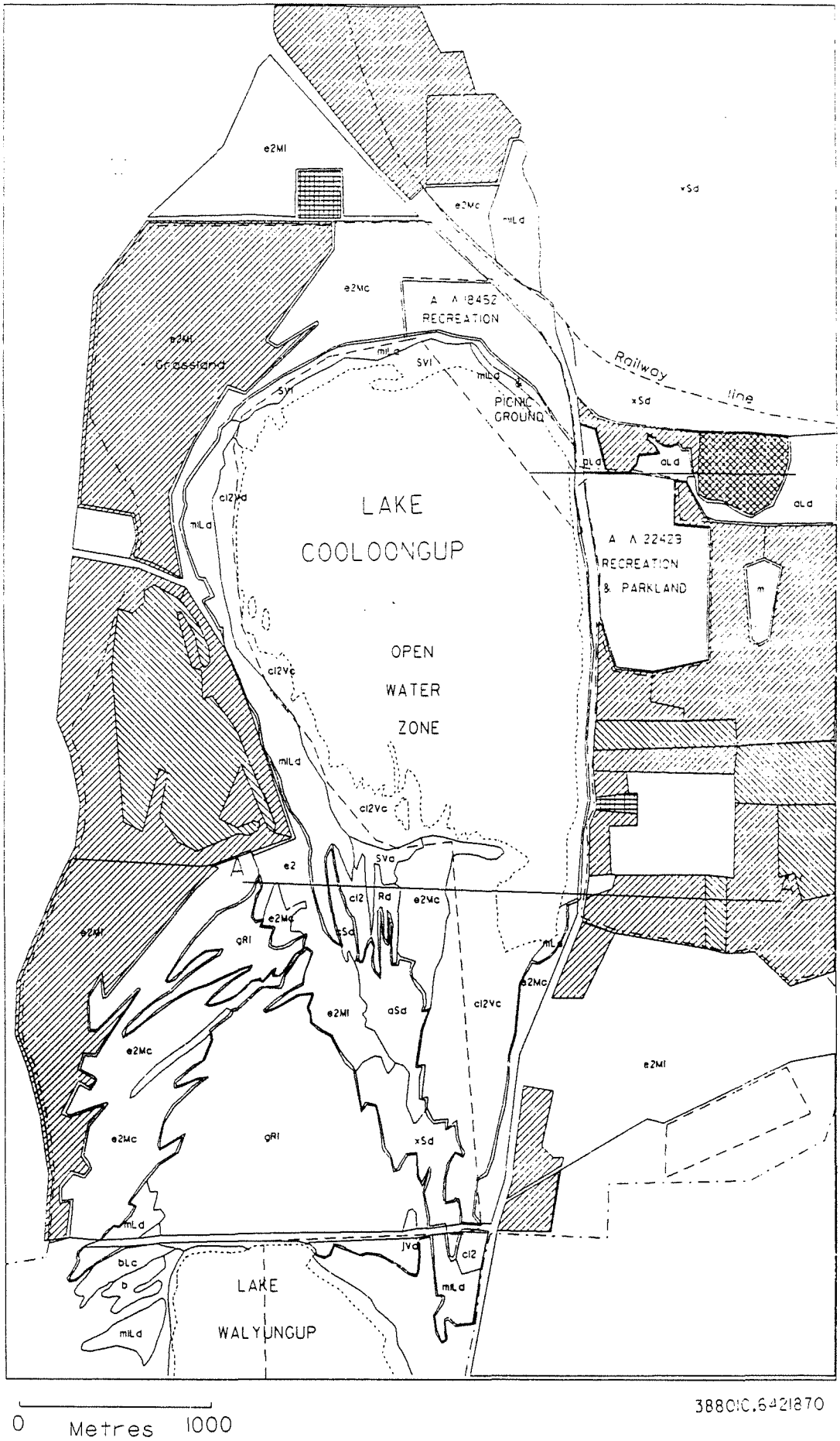

Figure 11.2 Lake Cooloongup: wetland plant communities and surrounding land use.

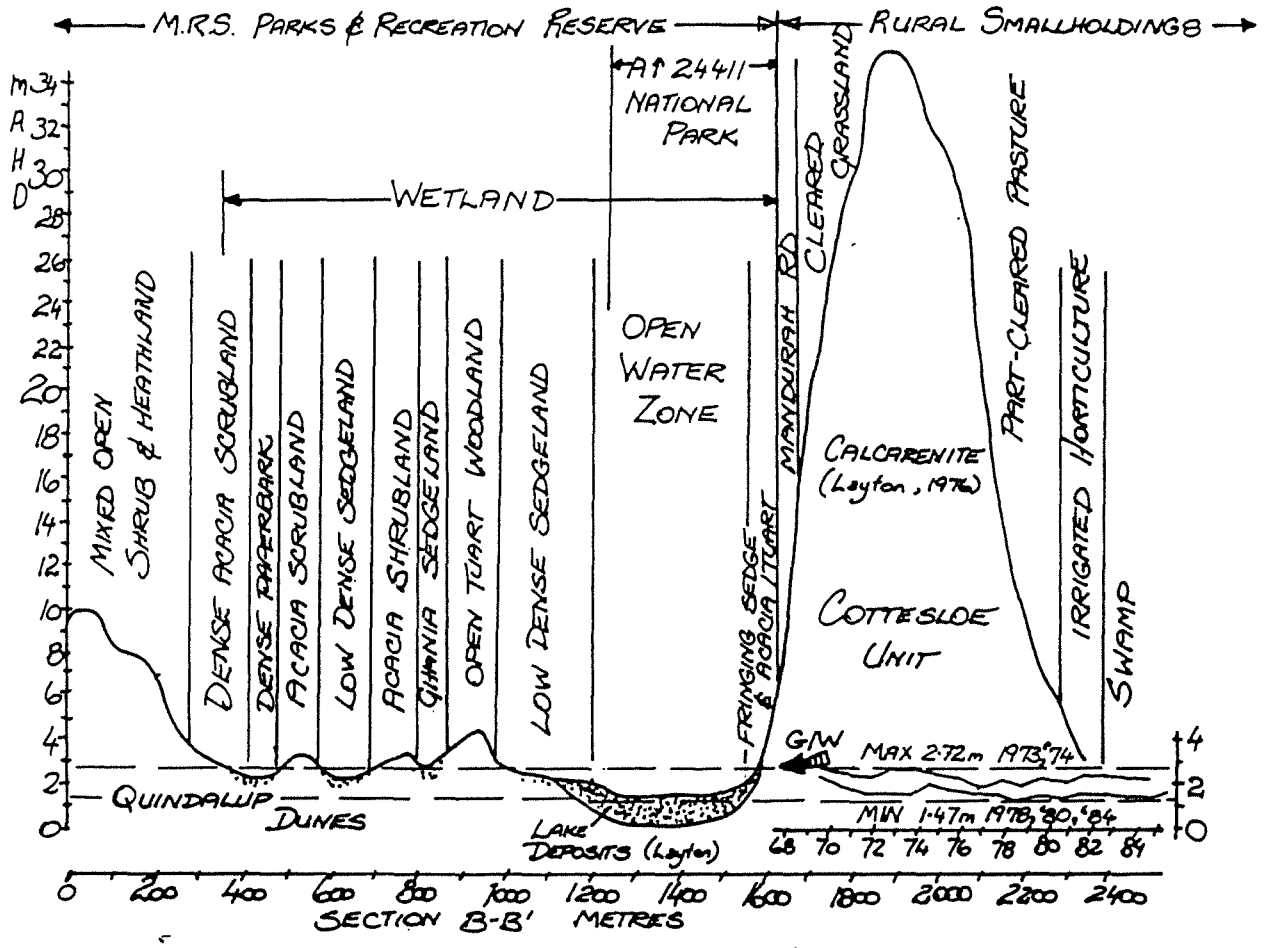

Figure 11.3 Lake Cooloongup: diagrammatic cross-section and water level record.

The Rockingham Lakes were afforded a strong commitment to management in the mid 1970s and efforts were made to develop resource inventories (Layton Groundwater Consultants, 1976; Tingay and Tingay, 1977). Management is currently being implemented.

11.3.10 REFERENCES

Layton Groundwater Consultants (1976), The Lakes Regional Open Space hydrological and geological study for the Shire of Rockingham (Company Report).

Passmore, J R (1967), The geology, hydrology and contamination of shallow coastal aquifers in the Rockingham District. Ph D thesis, University of Western Australia.

Passmore, J R (1970), Shallow coastal aquifers in the Rockingham District, Western Australia. Bulletin No 18, Water Research Foundation of Australia.

Seddon, G (1972), 'A sense of place'. University of Western Australia Press, Perth.

Tingay, A & Tingay, S (1977), The Lakes Region Open Space. Biological survey for the Shire of Rockingham (unpublished).

Woods,P J & Searle, D J (1983), Radiocarbon dating and Holocene history of the Becher/Rockingham Beach Ridge Plain, West Coast, Western Australia. Search, 14 (1-2), pp 44- 6.

11.4 LAKE WALYUNGUP (Salt Lake)

11.4.1 GENERAL INFORMATION

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Parks and Recreation Reserve
MANAGEMENT: Shire of Rockingham and State Planning Commission
RESERVE NUMBERS: 23780
SYSTEM 6 RECOMMENDATION: M103
WAC CLASSIFICATION: LE.s.1.p.o
WATER RESERVE: Peel

11.4.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Walyungup occupies a comparable position on the Rockingham Plain to Lake Cooloongup. See Section 11.1 for further notes and references.

11.4.3 AREAS

Total wetland area	536 ha
Sedgeland	48 ha
Paperbark	35 ha
Open water zone	407 ha
Modified	47 ha

11.4.4 HYDROLOGY

The water level record for the lake shows that the highest water level recorded (apart from one anomalous level of 3.34 m in June 1984 - perhaps a recording error) was 3.11 m AHD in 1967. A marked fall in both maxima and minima occurred from 1974 to 1978. Since that time there has been an increase in the amplitude of seasonal variation in levels resulting largely from a rising trend in winter maxima. Summer minimum levels have been in the range 1.3-1.8 m AHD of recent years.

Passmore (1967, 1970) and Layton Groundwater Consultants (1976) investigated the water and salt balances of the lake, noting its high salinity, compared with Cooloongup.

11.4.5 WATER QUALITY - See Section 11.4.4

11.4.6 LAND USE - Refer to Figure 11.4

11.4.7 VEGETATION (Figure 11.4)

Tingay and Tingay (1977) mapped the vegetation of Lake Walyungup.

11.4.8 FAUNA - Refer to Tingay and Tingay (1977)

11.4.9 MANAGEMENT ISSUES

The Rockingham Lakes were afforded a strong commitment to management in the mid 1970s and efforts were made to develop resource inventories (Layton Groundwater Consultants, 1976; Tingay and Tingay, 1977). Management is currently being implemented.

11.4.10 REFERENCES

Layton Groundwater Consultants (1976), The Lakes Regional Open Space hydrological and geological study for the Shire of Rockingham (Company Report).

Passmore, J R (1967), The geology, hydrology and contamination of shallow coastal aquifers in the Rockingham District. Ph D thesis, University of Western Australia.

Passmore, J R (1970), Shallow coastal aquifers in the Rockingham District, Western Australia. Bulletin No 18, Water Research Foundation of Australia.

Seddon, G (1972), 'A sense of place'. University of Western Australia Press, Perth.

Tingay, A & Tingay, S (1977), The Lakes Region Open Space. Biological survey for the Shire of Rockingham (unpublished).

Woods,P J & Searle, D J (1983), Radiocarbon dating and Holocene history of the Becher/Rockingham Beach Ridge Plain, West Coast, Western Australia. Search, 14 (1-2), pp 44- 6.

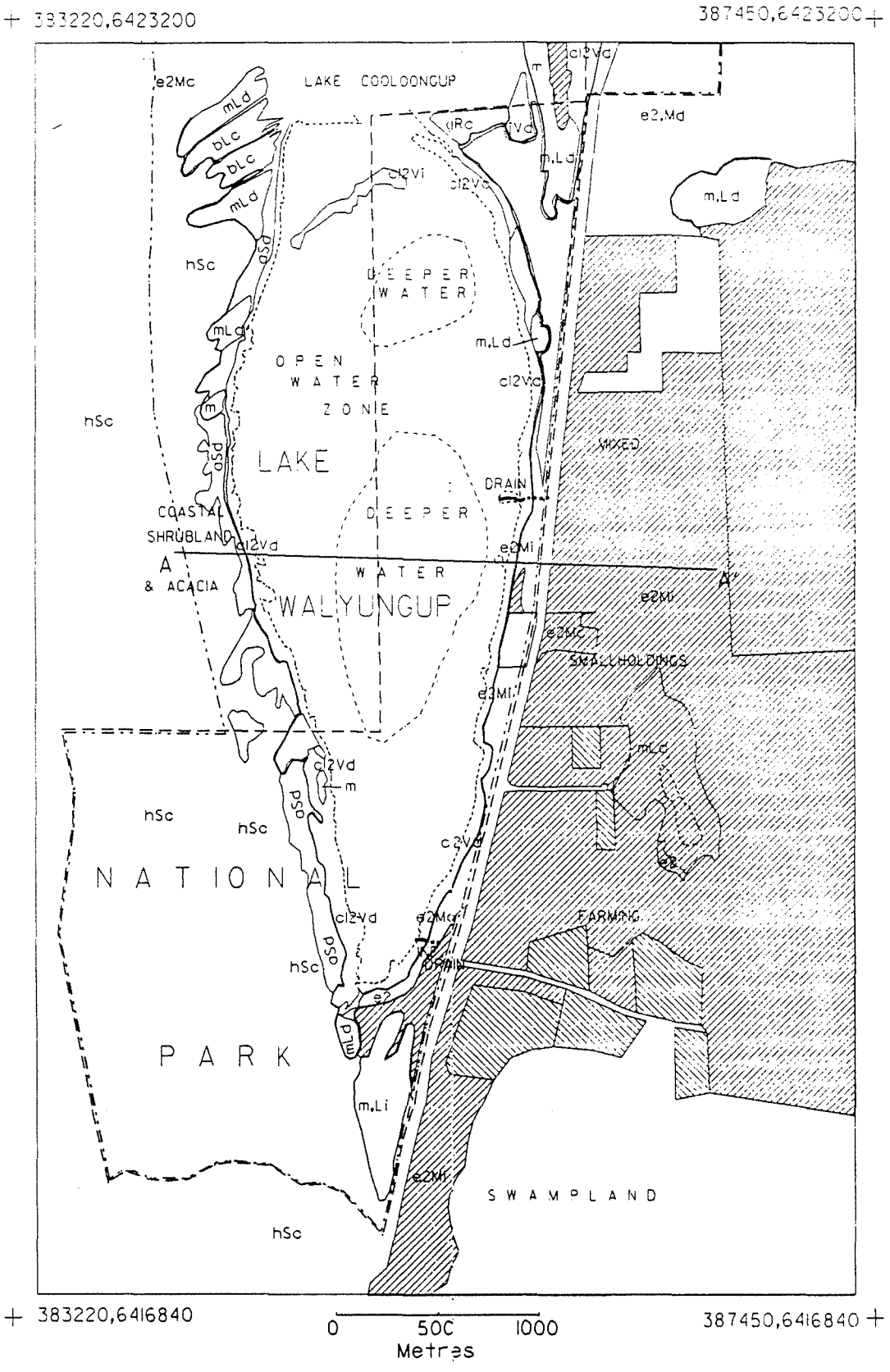

Figure 11.4 Lake Walyungup: wetland plant communities and surrounding land use.

11.5 LAKE RICHMOND

11.5.1 GENERAL INFORMATION

LOCAL AUTHORITY: Shire of Rockingham
MRS ZONE: Parks and Recreation Reserve
MANAGEMENT: Shire of Rockingham
RESERVE NUMBERS: †33659;†9458;†35176
SYSTEM 6 RECOMMENDATION: M102
WAC CLASSIFICATION: LE.f.m.p.o
DRAINAGE: Main drains from Rockingham Locality; outflow to ocean.

11.5.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

Lake Richmond is of marine origin. It is considered to have been formed in a marine embayment resulting from tombolo formation linking a limestone island (now Cape Peron) to the mainland. Subsequently the embayment was enclosed by beach ridge formation (Fairbridge, 1947; Seddon, 1972). Woods and Searle (1983) aged beach ridges on the south-west and south of Lake Richmond as 4650+/-110 and 2790+/-90 years BP respectively using radiocarbon dating.

The lake is reported to be up to 15 m deep in the middle. The deep central part of the lake is surrounded by shallow banks.

11.5.3 AREAS

Total area of the reserve	79 ha
Total area of lake	56.3 ha
Deep water	28.2 ha
Shallow banks	17.4 ha
Sedgeland	10.7 ha
Weed/sedge community	2.3 ha
Sedge/Acacia community	5 ha

11.5.4 HYDROLOGY (Figure 11.6)

The lake has reportedly been more saline than it is at present (Kevin Kenneally, WA Naturalists' Club: personal communication) and this observation is borne out by measurements of total dissolved solutes which have been falling progressively since 1970. Drainage of Rockingham and Safety Bay localities to lower the water table sufficiently for urban development has increased the flow of fresh water to the lake. Outflow from the lake to the ocean is via a drain flowing from the north-west of the lake. This drain does not allow tidal backflow.

The level of water in the lake is effectively controlled by inflow and outflow in the drains.

The water level record for 1978-1985 shows that the water level ranges from 0.9-1.2 m AHD in winter to 0.1-0.4 m AHD in late summer.

11.5.5 WATER QUALITY

The Water Authority of Western Australia has analysed twice-yearly samples from the lake since 1970, sampling in late summer and spring.

Table 11.1. Lake Richmond: means and ranges for pH, nitrogen and phosphorus in water samples taken from the middle of the lake at about 7 m deep.

PARAMETER	MEAN	RANGE
pH (1970-84:29 values)	8.7	7.9-9.30
Total Nitrogen (mg/L) (1970 - 83:26 values)	0.96	0.1-4.15
Phosphorus as P (mg/L) (1970-84:29 values)	17 values <0.05	Highest value 1.3 mg/L

There has been a progressive fall in salinity since 1970 as shown in Table 11.2.

Table 11.2. Lake Richmond: salinity (mg/L) in autumn and spring at three-yearly intervals 1970-1984.

YEAR	SALINITY (mg/L)	
	AUTUMN	SPRING
1970	890	405
1973	360	265
1976	250	230
1979	330	210
1982	120	100
1984	135	110

None of the samples indicated heavy metal levels of concern.

11.5.6 LAND USE - Refer to Figure 11.5 and Section 11.5.9

11.5.7 VEGETATION (Figure 11.5)

The lake is purported to support algal mats and stromatolites, possibly on the shallow bank on the south side.

The lake margin is characterised by sedge beds. The lower margin of the sedges appears to be determined by winter water levels at about 1.2 m AHD. The upper margin of the sedges is situated at about 2 m AHD. Comparing an

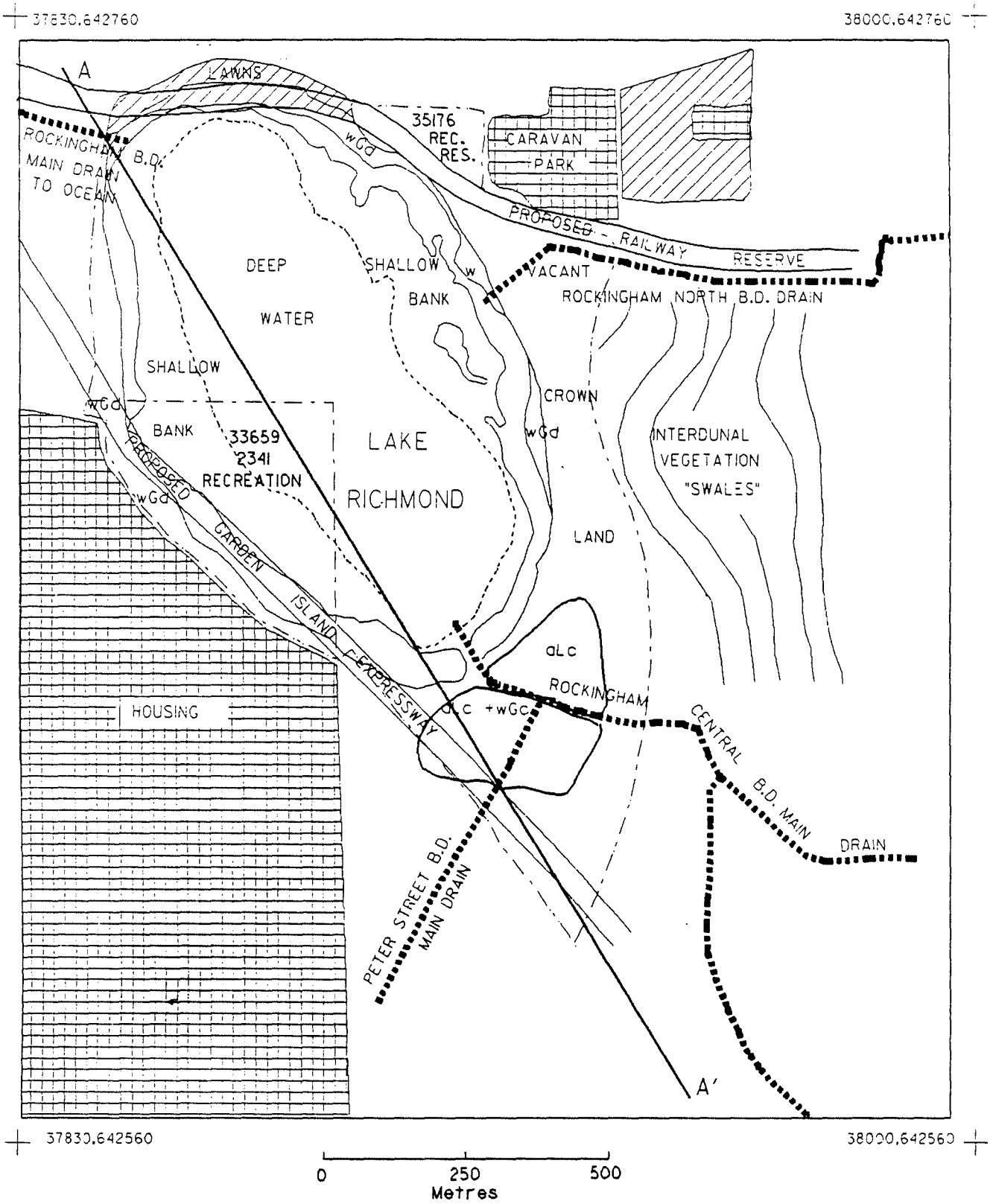

Figure 11.5 Lake Richmond: wetland plant communities and surrounding land use.

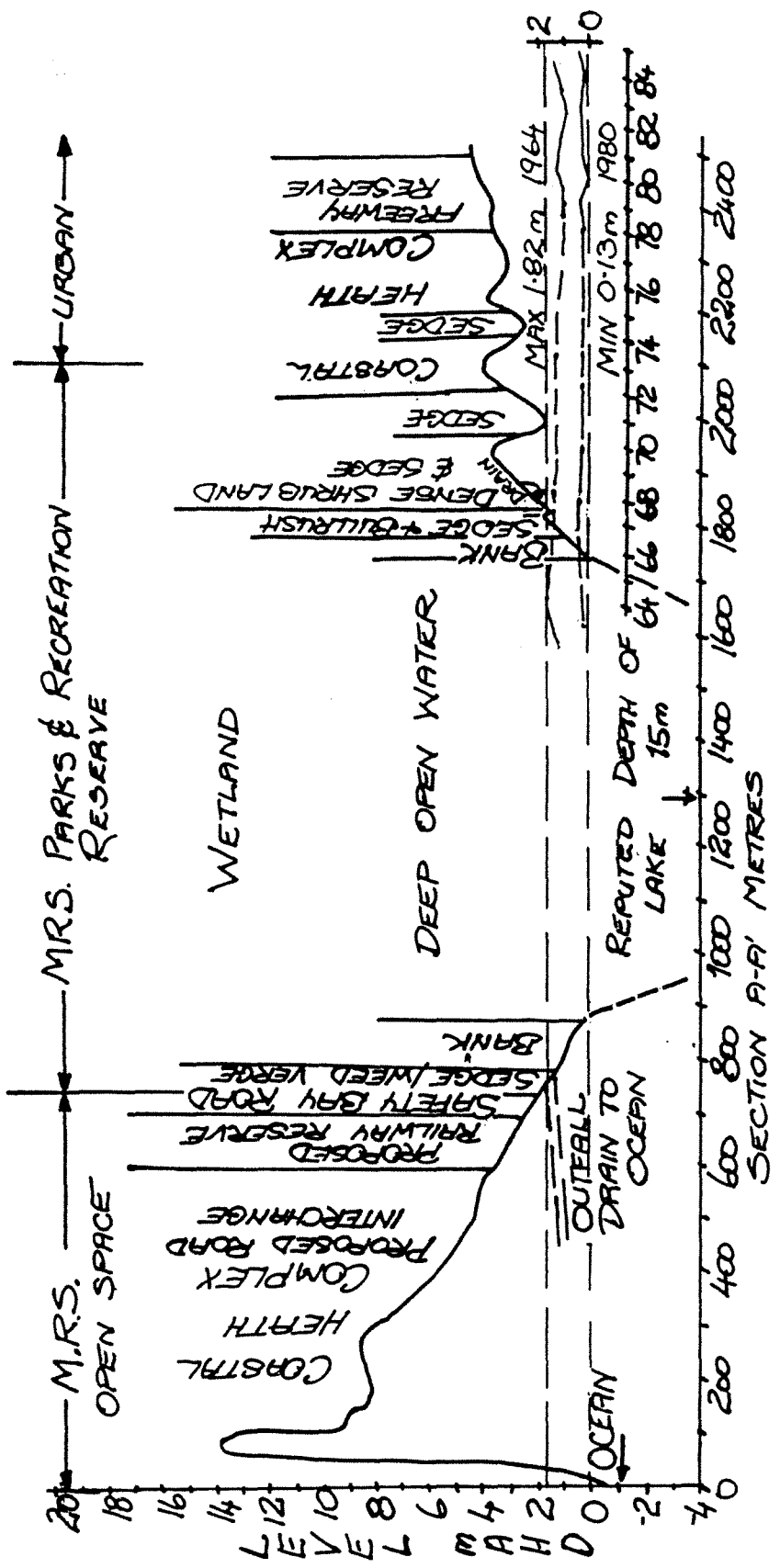

Figure 11.6 Lake Richmond: diagrammatic cross-section and water level record.

air photograph taken in 1983 with one taken in 1985, the sedge beds on the shallow bank on the north-east of the lake appear to have expanded. This extensive sedge fringe is becoming invaded with Typha. This may be the outcome of falling salinities.

The fringing vegetation above the sedge beds consists of some small shrubs, weed community and, with recent development south of Lake Street, an area of mowed grass. The Cape Peron sewer pipeline passes through this part of the lake margin and regeneration of sedges on the pipeline easement appears to have been very successful.

There is a need for attention to be given to selecting plant species native to the area for replantings around the lake.

11.5.8 FAUNA

There seems to be no systematic record of the fauna of the lake. It is to be expected that a freshwater lake close to the ocean would be a favoured feeding and resting place for waterbirds. Clutches of cygnets and ducklings on the lake in spring 1985 indicate that some breeding takes place there. While the shallow margins offer wading areas for waterbirds, the very deep water in the centre of the lake would be relatively unproductive.

11.5.9 MANAGEMENT ISSUES

Transport corridors are planned for the lake margins both on the north-east and south to south-west. Major road and rail corridors carry the risk of damage to wildlife habitats through spills. The planned roads are also so close as to limit the value of the lake as a passive recreation area.

The limited fringing vegetation restricts the range of habitats available for wildlife and the relative lack of shelter limits the options for good multiple use of the lake.

Control of water levels and changes to salinity of the lake could lead to changes in the fringing vegetation.

11.5.10 REFERENCES

Fairbridge, R W (1947), Geology and geomorphology of Point Peron. J. Roy. Soc Western Australia. 34, pp 35-72.

Passmore, J R (1967), The geology, hydrology and contamination of shallow coastal aquifers in the Rockingham District. Ph D thesis, University of Western Australia.

Tingay, A & Tingay, S (1977), The Lakes Region Open Space. Biological survey for the Shire of Rockingham. (Unpublished.)

11.6 BEACH RIDGE SWALES

Linear swales between the beach ridges on the Rockingham Plain act as seasonal wetlands (Semeniuk, in print 1987). There has been considerable disturbance to this type of wetland and it is unlikely that any will survive urban development of the area. An area of such wetland near Hawker Street in Safety Bay has been adapted to function as a drainage basin and landscape feature.

END OF SECTION