The Status and Future of Lake Toolibin as a Wildlife Reserve

A report prepared by the
Northern Arthur River Wetlands Committee

May 1987

Water Authority of Western Australia

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Report No. WS 2

Contents

	Page
ACKNOWLEDGEMENTS	v
PREFACE	vi
SUMMARY	1
RECOMMENDATIONS	3
1. INTRODUCTION	5
Objectives	5
Definition	5
Hypotheses	5
2. BACKGROUND	6
Historical Review	6
Climatic and Physical Features of the Lake Toolibin Catchment	7
Land-use and Soil Salinity	8
Fauna	8
Vegetation	9
3. DETAILED STUDIES OF LAKE TOOLIBIN	10
Waterbirds of Lake Toolibin	10
Surface Hydrology of Lake Toolibin	11
The Hydrogeology of Lake Toolibin	15
Vegetation Trends of Lake Toolibin	18
4. CONCLUSIONS	21
5. RECOMMENDATIONS FOR MANAGEMENT OF LAKE TOOLIBIN	22
Revegetation of the Western Buffer Zone	22
Groundwater Control	22
Maintain Health of Lake Toolibin Reserve Vegetation	23
Diversion of Saline Flow from Interceptor Banks	23
Catchment Regeneration to Reduce Inflow Salinity	23
Monitoring	24
Further Investigation of Groundwater Pumping	24
Strategic Lake Emptying	24
6. COMMITTEE MEMBERSHIP	25
7. REFERENCES	26

Tables

Page

1. Number of breeding species in 250 wetlands surveyed by the Royal Australasian Ornithologists Union in south-western Australia between 1981 and 1985. 10

2. Aggregate water and salt inputs to Lake Toolibin between 1981 and 1984. 12

3. Losses of water and salt to groundwater beneath Lake Toolibin. 14

Figures

Page

1. Lake Toolibin and Catchment. 4

2. Flora and Fauna Conservation Reserves around Lake Toolibin. 6

3. Soils and geology of the Lake Toolibin Catchment. 7

4. Salinity and volume of Lake Toolibin in relation to wetting and drying cycles: 1981/82. 13

5. West-east cross-section through Lake Toolibin showing general geology 16

6a. Schematic of groundwater flow and salt distribution with lake dry and acting as discharge area. 17

6b. Schematic of groundwater flow and salt distribution with lake containing water. 17

7. Vegetation map of Lake Toolibin and associated Reserves. 19

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Detailed technical reports to support this review were prepared by Dr E. M. Mattiske, Messrs R. A. Stokes and R. J. Sheridan, M. W. Martin, and Dr S. A. Halse and are listed in the references. This report was written for the committee by Mr P. R. George of the Department of Agriculture. The skills and application of these authors are gratefully acknowledged.

Preface

In 1977 the then Minister for Fisheries and Wildlife established the Northern Arthur River Wetlands Rehabilitation Committee with its main purpose being to carry out investigations and develop recommendations for the conservation of Lake Toolibin as a freshwater lake. The Committee initiated the necessary field investigations and the review of all relevant information. Sufficient data have now been collected and analysed for the Committee to conclude its role with the presentation of this review with recommendations for management.

Summary

The status of Lake Toolibin as one of the few remaining inland, freshwater lakes with a healthy emergent (lake-bed) vegetation is threatened by secondary salinisation. Loss or damage to the structure and function of the natural aquatic ecosystem of the lake has serious implications for the maintenance of a diverse waterbird population in the inland areas of the south-western region of Australia.

In addition to the review of available information on Lake Toolibin and environs, the Committee arranged studies on:

- the use and the value of the lake to waterbirds;
- the status of the vegetation and trends in its condition; and
- the surface and groundwater hydrology of the lake. As far as the Committee can determine, this study is the most comprehensive assessment carried out in Australia of the effects of man-induced salinisation on a terrestrial aquatic environment.

Surveys of waterbird populations show that Lake Toolibin is the most important inland wetland of the region. More species have been recorded as breeding there than any other wetland in the region. Also, apart from Lake Wannamal, a greater diversity of species use Toolibin than any other inland lake. It is one of the few remaining breeding habitats for the rare Freckled Duck and a vital breeding area for maintaining the populations of other, less rare, waterbirds.

The emergent vegetation of Lake Toolibin is the prime reason for its value as a waterbird habitat. However surveys reveal an unequivocal trend of vegetation decline. Although significant natural regeneration of Swamp Sheoak was observed in 1986, there is no regeneration occurring near or on severely degraded areas of the lake surface. In addition, no significant regeneration is occurring within communities adjacent to the lake. The poor vegetation condition on Lake Toolibin appears to be largely related to high soil salinity, possibly in combination with increased water-logging. Deterioration in other adjacent vegetation communities appears to relate to a lack of active management of the vegetation.

Lake water salinity fluctuates over an annual filling and drying cycle from 500 mg/L to 6000 mg/L Total Soluble Salts, but during the spring waterbird breeding period it is usually less than 3000 mg/L. On the basis of water depth and salinity, Lake Toolibin is currently suitable for breeding for about 70 per cent of the time. Without improved catchment management, the salinity of inflow to Lake Toolibin is expected to further increase as the full effects of past clearing for agriculture are reflected in stream water quality. If this salinity increase exceeds 30% the lake would no longer be suitable for breeding of the more critical waterbird species.

A key to the future of Lake Toolibin is the level of the saline groundwater beneath and adjacent to the lake. Currently Toolibin is an effluent lake with slow leakage through its bed to groundwater occurring whenever the lake contains water. This prevents a build-up of lake water salinity.

The watertable levels beneath and around the lake are shallow, saline and generally rising by about 50 millimetres per annum. During periods when the lake contains water, the

general groundwater flow is south away from the lake. However during prolonged dry periods, the lake environment acts as a groundwater discharge area. Where vegetation is healthy groundwater discharge is by transpiration but on the western shore where vegetation has died evaporation from the soil is salinising the bed. It is expected that, without improved management, increasing salinity of the lake bed will expand the area of degraded vegetation outwards from the boundary between healthy and degraded vegetation. The death of vegetation along the western shore is likely to have been initiated by local saline seepage from an adjacent area of saline soils on cleared land.

It will be necessary to implement a number of management actions to stabilise and improve the lake ecosystem and to limit further increases in regional groundwater levels and inflow salinities. Also, it will be important to continue with a minimal but significant programme of hydrologic and vegetation monitoring to provide warning of any need for greater management intervention that may become necessary to save this valuable State asset.

Only through the existence of high quality breeding grounds, like Lake Toolibin, where large numbers of birds nest, will population sizes of waterbird species remain at their present level in south-western Australia.

Recommendations

Active management will be essential for Lake Toolibin to retain its current high environmental value. Recommendations for ongoing management, discussed in detail in Chapter 7, are summarised below.

1. That a 100 to 200 metre wide strip of farmland adjacent to the full length of the western edge of the lake be acquired and revegetated promptly. Revegetation of this buffer strip should be carried out using techniques and species appropriate to the various site conditions.

2. That the system of interceptor banks currently discharging saline water into the western side of Lake Toolibin be modified to divert this flow to the south of the lake, keeping this diversion well to the west of the proposed western buffer strip.

3. That active management of vegetation in the Lake Toolibin Reserve be carried out to maximise health of the vegetation and increase evapotranspiration. Sequential, small-scale burning and planting of native seedlings should be considered to encourage regeneration and increase species diversity.

4. That there be active encouragement of all practical actions for control of groundwater levels and salt discharges across the catchment. These actions to include: encouraging the development of farming systems and farm plans to reduce recharge while at the same time increasing farm productivity; rehabilitation of salt seeps and salt flats; and fencing off and revegetating areas adjacent to streamlines to control groundwater discharge.

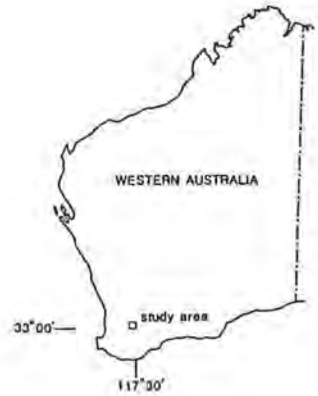
   The Wickepin Soil Conservation District in collaboration with Greening Australia have embarked on a saltland revegetation programme which deserves every encouragement.

5. That a borefield be designed, and costed, to assist the vegetation to lower the watertable beneath the degraded western shoreline to at least 1.5 metres beneath the soil surface. An essential first action is to arrange a sustained pump test to obtain the hydraulic parameters required for the design of this borefield. Implementation would then depend on an assessment of the cost and current condition of that section of the lake.

6. That the condition of all 26 vegetation plots established for flora surveys be monitored and re-assessed every four years with annual inspection of a sub-set of these plots. The next comprehensive survey to be in 1990.

7. That monitoring of the boreholes in and around Lake Toolibin be carried out annually at the end of summer with the data analysed and stored in the State Water Resources Information System. Consideration to be given to instrumenting key sites for continuous monitoring.

8. That operation of the established gauging stations monitoring lake level and the quantity and quality of inflow from the Northern Arthur River be continued; and that the lake water quality be sampled at appropriate intervals following each major inflow event.



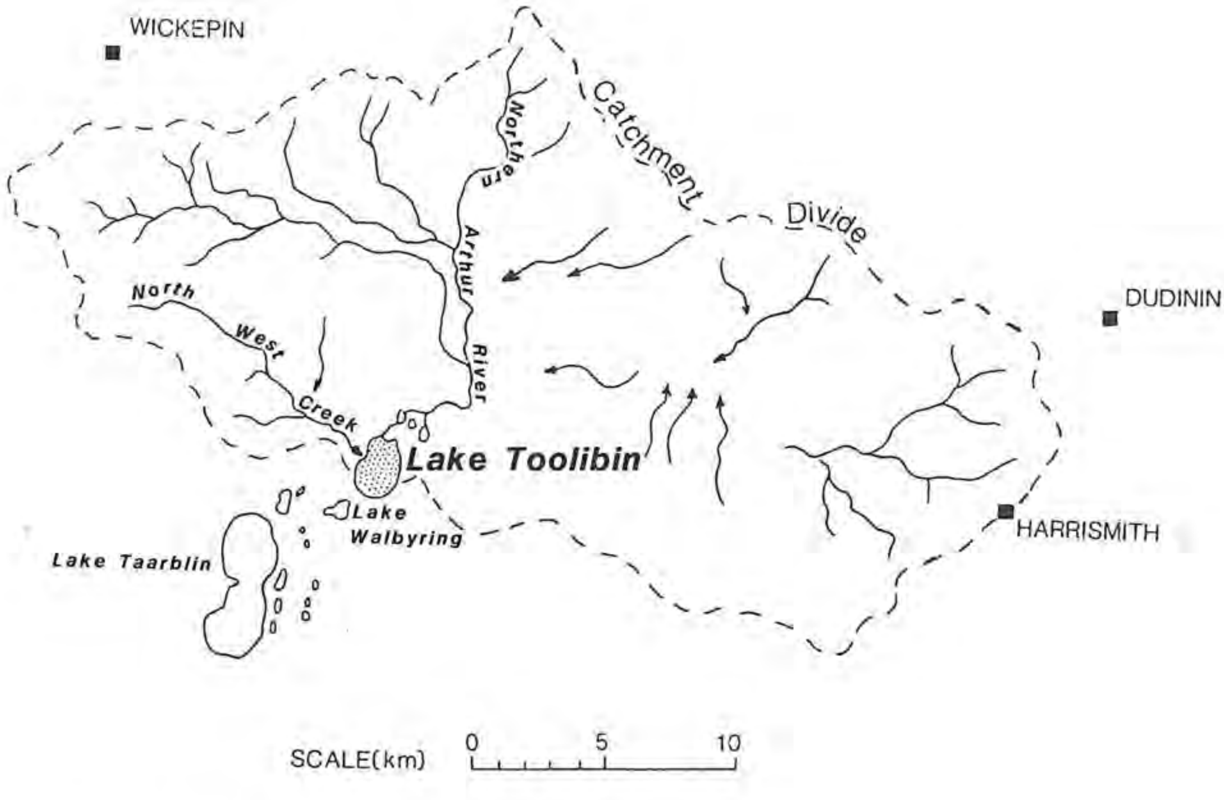


Figure 1 - Lake Toolibin and Catchment

1. *Introduction*

Objectives

The Committee for the Rehabilitation of the Northern Arthur River Wetlands (N.A.R.W.R.C.) was set up under the authority of the Minister of Fisheries and Wildlife in March 1977. The main purpose of the Committee was to recommend measures to:

(i) preserve Lake Toolibin as a freshwater lake; and

(ii) rehabilitate other lakes and foreshores downstream from Toolibin to improve the waterbird carrying capacities, water quality and the wildlife value of the system.

Because of the perceived importance of Lake Toolibin as a waterbird habitat and nursery and its relevance to future preservation and rehabilitation of the Northern Arthur River wetlands (see Figure 1 for location), the specific studies pursued by the Committee focused on the ecological and hydrological regime of Lake Toolibin and its catchment. Lack of resources prevented the Committee addressing and reporting on aspects embraced by part (ii) above.

Definition

For this study a freshwater lake is defined as one which has a salinity level low enough for the present suite of breeding waterbird species to nest and rear young. The desirable range of water salinity during the spring breeding period following winter inflow is set as 1000 to 3000 milligrams per litre Total Soluble Salts.

Hypotheses

The specific studies of Lake Toolibin carried out by the Committee were related to the following hypotheses:

(i) Lake Toolibin is one of the few remaining freshwater lakes in the Western Australian wheatbelt and is a vital breeding area for a wide range of waterbirds, including some rare species such as the Freckled Duck.

(ii) A healthy and viable vegetation complex is vital to maintaining the effectiveness of the Lake Toolibin habitat for waterbirds.

(iii) Trends in the health and structure of the lake vegetation communities will provide an index of the long-term future of Lake Toolibin.

(iv) Increasing waterlogging and salinity threaten the Lake Toolibin habitat. An altered water balance following clearing for agriculture has increased the salt load of the surface inflow and raised regional and local groundwater levels. This is leading to vegetation death and the salinisation of Lake Toolibin.

2. *Background*

Historical Review

The first Europeans to have any impact on the Northern Arthur River catchment were nomadic shepherds and sandalwood cutters before the turn of the century.

Land was first taken up for farming during the late 1890's. As farming practices then were pastoral rather than arable, there was little clearing of natural vegetation. By 1910, clearing was confined to twelve farms established south-east of Lake Toolibin.

Large scale clearing of the better class, clay soils occurred after World War 1, and most of the heavy land was under cultivation by about 1934. Development of the lighter, sandier soils did not commence until the late 1940s or early 1950s.

A local farmer, resident since 1904, has recorded that Lake Toolibin had not been dry until the drought period commencing in 1969. In his experience, the lake always filled in wet years, but water was confined to the centre of the lake when rainfall was below average.

Lake Taarblin, downstream of Lake Toolibin, consisted of a series of swampy lagoons prior to 1926 when it completely filled for the first time. It was after this inundation that trees within the southern half of the lake died. During the 1930s Lake Taarblin was mostly dry and the trees in the northern half were dead by the mid 1930s. The lake was flooded again in 1945 and 1955 when, as in 1926, the annual rainfall was some 200 mm above average. The dense thickets of *Casuarina obesa* round the perimeter of the lake regenerated

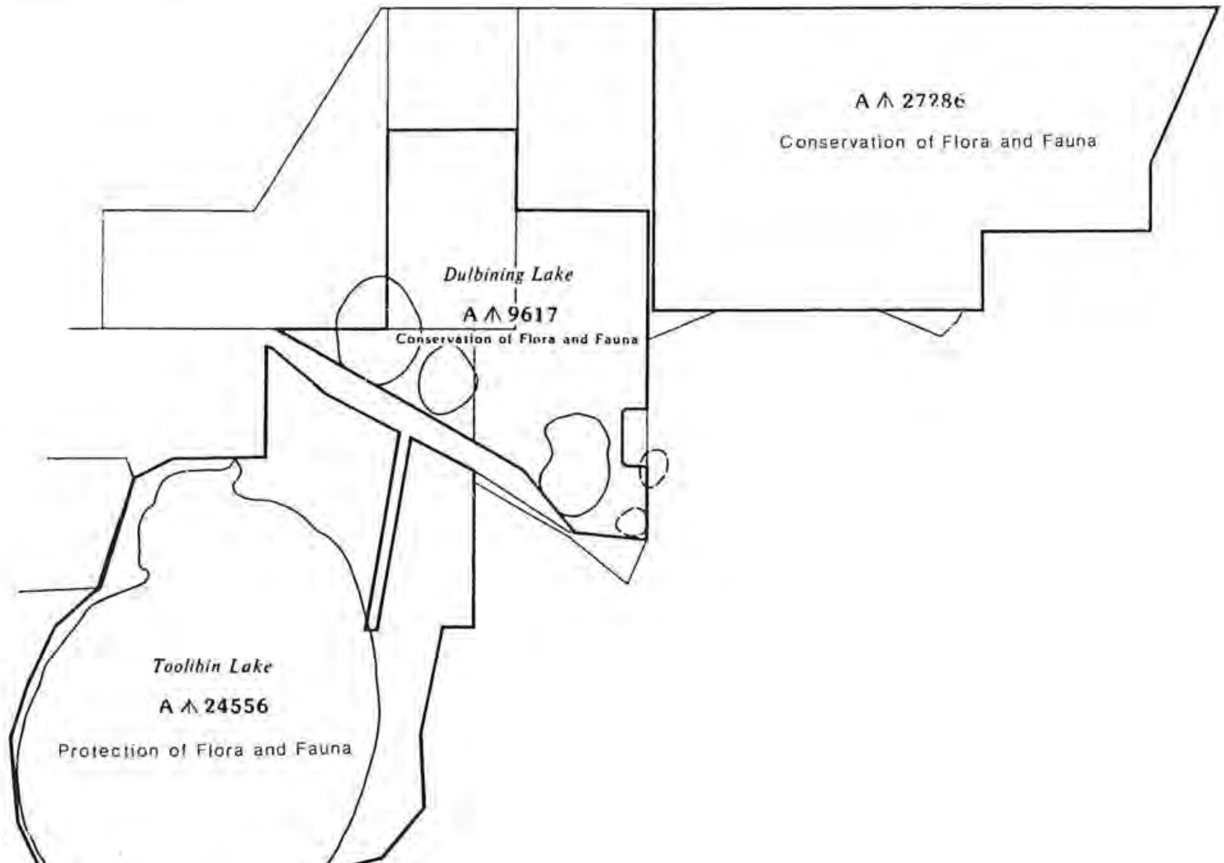
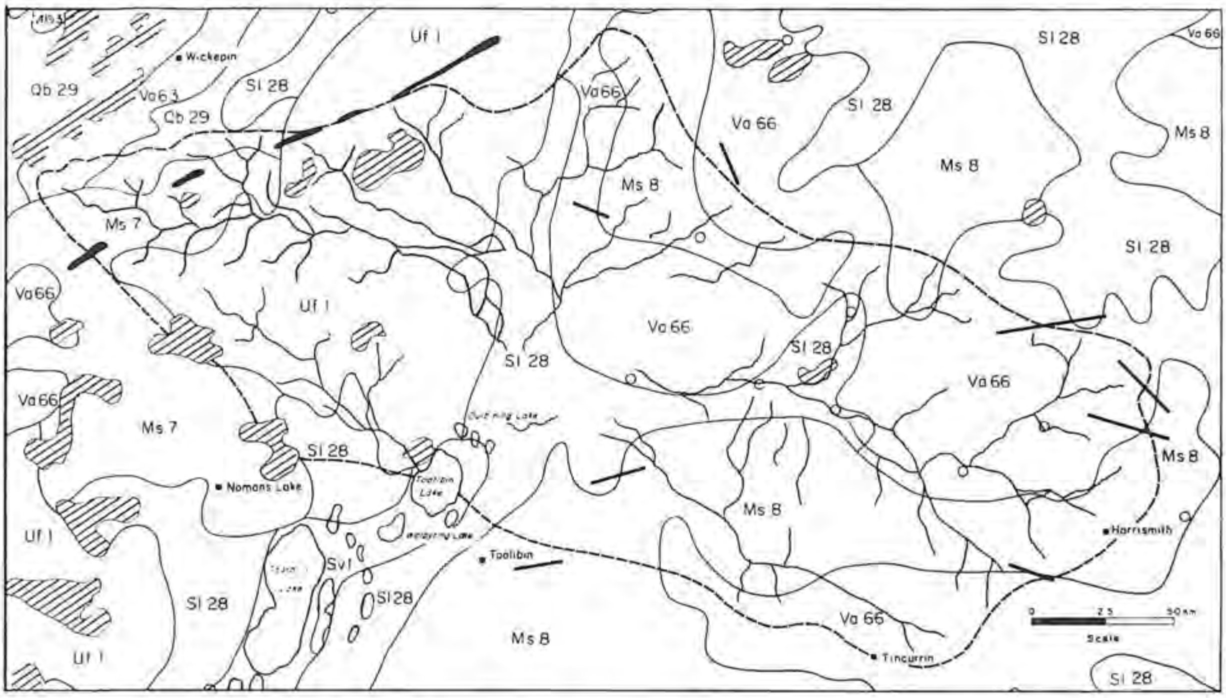


Figure 2 - Flora and Fauna Conservation Reserves around Lake Toolibin



Soil Landscape Units (C.S.I.R.O. Atlas of Australian Soils)

Hard-setting loamy duplex soils, mottled yellow clayey subsoils, bleached A_2 horizon (waterlogging prone):
- Uf 1 - undulating with ridges, spurs and lateritic mesas and buttes.
- Va 63 - valley plains and terraces.
- Va 66 - gently undulating to rolling terrain.

Yellow earths:
- Ms 7 and Ms 8 - gently sloping to gently undulating plateau area. Sandplain soils and gravelly ridges.

Hard-setting loamy duplex soils, red clayey subsoils:
- Ob 29 - Rolling to hilly with some steep slopes, gneiss outcrops common.

Hard-setting loamy soils, yellow clayey subsoils:
- Sl 28 - broad flat valley with clay pans.

Calcareous and siliceous loamy soil of minimal development:
- Sl 1 - Saline valleys and salt lakes.

Key

- Dolerite dykes
- Catchment divide
- Rock outcrop
- Soak
- Drainage
- Townsite

Figure 3 - Soils and geology of the Lake Toolibin Catchment

above the 1955 highwater mark, and salt crusting became evident in the lake bed at about this time. In the 1950s sampling of the water in Lake Taarblin revealed salinities ranging between 6000 mg/L (September 1956) and 57000 mg/L (March 1957).

Little White Lake, some 15 km downstream of Toolibin, did not fill regularly before the 1940s although it held water in wet seasons. By the 1920s the trees within the lake were dead, or dying; however *C. obesa* and Paperbarks *(Melaleuca spp.)* have persisted above high water level.

Figure 2 shows the gazetted reserves around Lake Toolibin. All are A Class Reserves vested in the National Parks and Nature Conservation Authority for the purpose of conservation of flora and fauna. The Department of Conservation and Land Management is responsible for their management.

Reserves 24556 (351 ha) and 27286 (343 ha) were gazetted as reserves in 1956 and 1964, respectively. Reserve 9617 (290 ha) was originally vested in the Narrogin Road Board in 1908 for water supply purposes. This vesting was transferred to the Western Australian Wildlife Authority (now National Parks and Nature Conservation Authority) in 1963.

Climatic and Physical Features of the Lake Toolibin Catchment

The catchment to Lake Toolibin (Figure 1) is about 435 km^2 in area. The average annual rainfall over the catchment ranges from about 370 mm at the lake (Toolibin 374 mm) to about 420 mm along the divide (Wickepin 427 mm, Dudinin 427 mm).

Lake Toolibin lies at the head of a chain of lakes forming the headwaters of the Arthur River. The lake chain occupies an old valley of the Great Plateau. This broad, flat valley, typical of the Baandee Type valley, has been infilled with fluviatile and aeolian deposits, on which playa lakes and associated dunes have developed.

The distribution of soil landscape units for the Lake Toolibin catchment is shown on Figure 3 (Northcote, *et al.*, 1967). To the east, the sandplain soils of the ancient Plateau are extensively preserved. To the west, greater stripping of the landscape has produced shallow duplex soils formed on the truncated laterite profile, and resulted in the surface drainage system being better defined than that to the east.

The main surface water inflow to Lake Toolibin occurs from the north-east via the Northern Arthur River (Figure 1), a sluggish drainage line containing heavy and medium textured soils typical of the Belka Type valley. Most of the salt-affected soils of the catchment occur along this valley. Surface flow also enters Lake Toolibin via the Northwest Creek which has a catchment area of 41 km^2.

It can be safely assumed that surface runoff has increased in volume and salinity since clearing began. This hydrologic response has been demonstrated in catchment studies elsewhere in the south-west of Australia and is supported by the observations of more frequent flooding of the lakes downstream of Toolibin after about 1926.

The geology of the catchment has been recently mapped by the Geological Survey of Western Australia. Rock outcrops (Figure 3) are mainly confined to the catchment of Northwest Creek and indicate that the catchment is underlain by Archean granites of the Yilgarn block. Generally the basement rocks are mantled by a lateritised, deeply weathered profile. Large dolerite dykes outcrop frequently on the catchment divides indicating that they may exert a predominant geological control on the current drainage pattern. It is assumed that the topographic divide is also the groundwater divide and that regional groundwater flow from outside the catchment does not occur.

Numerous soaks (Figure 3) occur in the eastern part of the catchment at the contact between the sandy slopes and the clay flats and indicate the existence of perched groundwaters beneath the sandplain soils. The sandplain areas, cleared in the 1950s, are possibly now a major recharge area for the regional groundwater system of the catchment. However, clearing of the western part of the catchment has undoubtedly raised groundwater levels thereby inducing increased saline seepage to Northwest Creek and to the western parts of Lake Toolibin. In addition, recent work by the Department of Agriculture shows that direct groundwater recharge occurs beneath the clay flats that lie to the north of Lake Toolibin.

The evidence that groundwater levels and salinity have risen since clearing includes:

(i) The appearance and spread of salt-affected land and the salinisation of the lakes downstream from Lake Toolibin.

(ii) Bore data which reveal a rise of 12 to 15 metres in the water table in the past 50 to 60 years.

(iii) Records of soaks used for stockwater being abandoned due to high salinity during the 1930s.

Land-use and Soil Salinity

Agricultural land use has made a considerable impact on the catchment. There are no precise figures available for the rate of agricultural clearing before 1962, but most of the heavier soils or one-third of the catchment had been cleared by the mid 1930s. By 1962, 85% of the area was cleared, and this had increased to 90% by 1972.

One of the most noticeable effects of clearing has been the appearance and spread of saline land since the 1930s. At present about 3% of the total catchment is severely salt affected, and a further 2.6% is moderately salt affected. On the farm abutting the west bank of Lake Toolibin, the area of saline soil has doubled in the 16 years between 1961 and 1977.

Fauna

Eighty-five terrestrial and 40 aquatic bird species have been recorded using Lake Toolibin and environs, and of these some 78 terrestrial and 24 aquatic species have nested there. However a declining trend in the use of the lake by nesting waterfowl had been noted prior to the Committee being formed.

A small number of terrestrial fauna species have been recorded in the Toolibin Reserves; namely - 7 mammal, 2 amphibian and 4 reptile species. This paucity of species is because the bushland habitats are too small to support a viable fauna population.

Vegetation

The natural vegetation of the catchment consisted of heath and open woodlands of White Gum *(Eucalyptus wandoo)* and Jam *(Acacia acuminata)* on the gravelly sands of the interfluves, and woodlands of Salmon Gum *(E. salmonophloia)*, York Gum *(E. loxophleba)*, and Red Morrel *(E. oleosa* var. *longicornis)* on the heavier valley soils. Drainage lines were frequently fringed with galleries of Flooded Gum *(E. rudis)* and "wetlands" supported dense thickets of *Casuarina* and *Melaleuca* species.

At present only small stands of natural vegetation remain on the more gravelly ridges or in the wetter parts of the valleys. The most significant of these for the current survival of Lake Toolibin as a viable habitat for wildlife is the valley vegetation in and to the north-east of the lake.

The post-clearing deterioration in wetland vegetation is epitomised by Lake Taarblin and has occurred in all the lakes downstream of Taarblin. At the beginning of this study, deterioration of the vegetation in Lake Toolibin was evident in areas adjacent to salt scalds on cleared land to the west of the lake.

3. *Detailed Studies of Lake Toolibin*

The following detailed studies of the status and condition of Lake Toolibin were carried out between 1978 and 1986:

(i) A survey of lake water levels and waterbird populations (Jaensch, in preparation) and an assessment of the impact of increased salinity on water bird populations (Halse, 1987).

(ii) A study of the trends in the condition of the vegetation (Mattiske, 1982, 1986).

(iii) The groundwater hydrology in relation to future salinity (Martin, 1986).

(iv) The surface hydrology and the salt and water balance of the lake (Stokes and Sheridan, 1985).

The results of these studies are summarised below.

Waterbirds of Lake Toolibin

Population and Importance

Lake Toolibin is undoubtedly one of the most important wetlands for waterbirds in south-western Australia.

More waterbird species were recorded breeding in Lake Toolibin than in any other of the 251 wetlands examined in Royal Australasian Ornithologists Union (R.A.O.U.) surveys conducted between 1981 and 1985 (Table 1). The lake also had the second highest number of species of any inland wetland.

The term "waterbird" is used to define those species which complete at least a substantial part of their life cycle in wetlands. Ninety-nine such species are known in south-western Australia.

Over the past 20 years, 41 species of waterbird have been recorded in Lake Toolibin and 24 are known to have bred there. Between 1981 and 1985, 39 species were seen in Lake Toolibin, of which breeding activity was observed in 22. Only species that were resident in the lake were recorded as breeding there.

Lake Toolibin is a particularly important breeding site (i.e. nesting recorded in five or fewer of the wetlands in the south-west surveyed by the R.A.O.U.) for Freckled Ducks, Great Egrets, Yellow-Billed Spoonbills, Rufous Night Herons and Great Cormorants.

Table 1

Number of breeding species in 251 wetlands surveyed by the R.A.O.U. in south-western Australia between 1981 and 1985

Number of breeding species	Number of wetlands
0	111
1-4	87
5-10	42
11-20	10
> 21	1*

* Lake Toolibin

The lake is the stronghold of the Freckled Duck *(Stictonetta naevosa)* in south-western Australia, being the wetland where this species was seen most frequently and in greatest numbers between 1981 and 1985. Freckled Ducks are gazetted as a rare species under the Wildlife Conservation Act.

There appear to be three reasons for the high number of breeding species at Lake Toolibin:

(i) Extensive, dense thickets of *C. obesa* and *Melaleuca* spp. occur through much of the inundated area. Live vegetation in the lake is of paramount importance in providing suitable nesting sites for most of the species breeding there.

(ii) The fresh/brackish water is of sufficiently high quality for growth of emergent vegetation and is potable for very young birds.

(iii) The periodic drying out of the lake allows persistence of the trees growing in it. It may also increase the productivity of vegetation, leading to a greater availability of food for breeding waterbirds.

The reasons for Lake Toolibin having the highest recorded number of species of any inland lake other than Lake Wannamal are the same as those given for its high breeding numbers: the extensive area of emergent vegetation provides habitats that are not available in open lakes and thus more species use the lake.

It is much easier to conserve and manage animals when they are abundant and population sizes are large enough to accommodate natural fluctuations in numbers than when they are rare. Moreover there is an aesthetic appeal in the presence of large numbers of waterbirds of all kinds and this is being increasingly recognized by the community at large. It is therefore important to conserve suitable breeding places for all water birds.

Effect of Increased Salinity

Increased salinity of the lake bed will cause death of the emergent vegetation. That alone will render the lake an unsuitable nesting habitat for the Freckled Duck and most of the large, tree-nesting wading birds.

The species that will be most affected if the lake becomes saline is the Freckled Duck. Freckled Duck have specific breeding requirements, using fresh/brackish-water lakes with dense tree vegetation. Besides Lake Toolibin, there are only three wetlands in south-western Australia in which Freckled Duck are known to breed regularly - Benger Swamp, Lake Wannamal and Crackers Swamp.

Breeding at Lake Wannamal is also threatened by increasing salinity and Crackers Swamp only allows sporadic breeding because it is frequently dry.

Increased salinity of Lake Toolibin would also cause the loss of breeding colonies of the Great Cormorants, Great Egrets, Yellow-Billed Spoonbills, Rufous Night Herons and both the Pacific and White Faced Herons.

A further, more direct effect of increasing salinity is that the water in the lake may no longer be potable for young birds. Loss of Lake Toolibin as a fresh-water breeding habitat will thus have an effect on overall numbers of waterbirds. Large numbers of ducks breed there in most years, which contributes to the overall population sizes of these game species.

To ensure that all the species now breeding at Lake Toolibin continue to do so regularly, the salinity of the lake water must not be allowed to increase by more than 30% above present winter and spring levels. However, there are only a few species that are particularly sensitive to salt itself; most would continue to breed in the lake even after an increase in salinity of 100%, *provided* the vegetation remained intact.

Because it is desirable to maintain the full suite of breeding species at Lake Toolibin, all that is possible should be done to maintain Lake Toolibin as a vegetated fresh-water lake. This will ensure:

- The continued existence of a sizeable population of the Freckled Duck.
- The maintenance of breeding colonies of Great Egrets and several species of large wading birds that breed in few wetlands in south-western Australia.
- Substantial recruitment for many common waterbird species, including ducks.

Surface Hydrology of Lake Toolibin

Surface Water Inflow

Lake Toolibin is ephemeral, only filling in years of above average rainfall. When full, the lake is about 3 km^2 in area and 2 to 3 metres deep.

Surface water inflow to the lake is from the catchment of the Northern Arthur River (435 km^2) and from the smaller catchment (41 km^2) of the Northwest Creek. Surface water outflow occurs via an overflow channel to the south of the lake and drains through a series of smaller lakes into Lake Taarblin.

Approximately 6 mm of runoff from the catchment is required to fill Lake Toolibin to the point of overflow and this represents a runoff of 1.5% of average rainfall.

In the winter of 1981, 5 mm of run-off partially filled the lake. In 1983 total runoff was 36 mm with a maximum daily inflow of 5.6 mm. Very little runoff occurred in the winters of 1982 and 1984. Thus, since the record of lake level commenced in December 1977, the lake has received substantial inflow in only two of the last seven years (1981 and 1983).

In the absence of long-term records of lake level or inflow, the probability of inflow was simulated from the long-term rainfall records (78 years) of Wickepin and Narrogin.

Inflow sufficient to fill the lake probably occurred in 33 of the 78 years (42%) with no inflow in 22 of the years (29%). In the remaining years inflow occurred, but was probably insufficient to fill the lake. Inflow therefore occurs on average in about 7 out of 10 years.

A five year sequence of no inflows occurred between 1940 and 1944, which appears to be the most severe on record, followed by the four years 1977 to 1980. Other sequences of little or no inflow include 1922 to 25 (4 years), 1948 to 52 (5 years), 1959 to 62 (4 years) and 1969 to 72 (4 years).

The low inflow period of 1969-72 coincided with the emergence of concern about the condition of Lake Toolibin and perhaps indicates the importance (under current groundwater conditions) of fresh inflows into the lake for preventing accumulation of salt in the lake bed.

Lake Toolibin is probably more than one metre deep for about 70% of the time because of the carry-over effect of previous wet years. However, in the context of present salinities, this water may be above 3000 mg/L. Thus although the high probability of being more than one metre deep may explain the lake's current suitability as a breeding habitat for waterbirds, increased salinity may begin to reduce the utility of the habitat.

Salinity of Surface Water Inflow

Streamflow occurs for relatively short periods, with little sustained baseflow. Runoff is generally of short duration, associated with the more intense rainfalls.

Streamflow salinities of the Northern Arthur River vary between 100 mg/L and 8000 mg/L. Concentrations during high flows are lower than either the first flows or the recession flows which occur towards the end of winter. As expected, average salinities are lower for higher volumes of runoff.

In 1981 and 1983, streamflow salinity of the Northern Arthur River from August onwards was above the annual flow-weighted salinity. For 1983 this meant that persistent inflow, beyond August, increased lake salt storage by displacing earlier, fresher inflows.

Northwest Creek flows, relative to Northern Arthur River, are generally more saline and continue for a longer period of time. During August 1983, concentrations varied from 100 mg/L to 4000 - 5000 mg/L with each flow event. At the beginning and end of the period of flow, however, salinities were in excess of 10 000 mg/L. The dynamic range of salinities of Northwest Creek indicates substantial dilution of a saline groundwater baseflow by rainfall during an event.

Table 2
Aggregate water and salt inputs to Lake Toolibin between 1981 and 1984

Inflow Period	North Arthur River			Northwest Creek		
	Water inflow (10^3m^3)	Total salt load (tonnes)	TSS[a] (mg/L)	Water inflow (10^3m^3)	Total salt load (tonnes)	TSS (mg/L)
Winter 1981	2100	2590	1230	NR	NR	NR
January 1982	1100	450	410	NR	NR	NR
Winter 1982	0.5	2	4000	36.7	220	6000
Winter 1983	15600	8500	550	430[b]	1100	2500
Winter 1984	10.7	NR[c]	NR	2.5	NR	NR

a. Total Soluble Salts (flow weighted salinity).
b. Northwest Creek inflow records are incomplete in Winter 1983 because of a rating problem.
c. NR : No record.

Water and Salt Inputs

The total amounts of water and salt discharged into Lake Toolibin by the Northern Arthur River and the Northwest Creek are summarised in Table 2.

Large quantities of water and salt were discharged into the lake during the 1983 winter. Water inflow was more than six times the maximum lake volume. Salt input in excess of 10 000 tonnes probably occurred. By contrast, very little surface inflow was measured in the 1984 winter and the salt input, though not listed in Table 2, was about 200 tonnes.

These events confirm the ephemeral nature of the lake and highlight the range of inflow events to which the lake is subjected depending upon seasonal conditions.

Lake Volume in Relation to Salinity

Lake volume during the period of monitoring has varied between zero and 5.5 million cubic metres. At the point of overflow the lake contains 2.7 million cubic metres. Lake salinity also shows a large range of values, varying between 500 mg/L and 6000 mg/L. The lake waters are freshened following larger inflow events as in winter 1983 and are then concentrated by evaporation. This salinity cycle is shown clearly in Figure 4.

Under current hydrologic conditions, lake salinities are above 3000 mg/L, through the concentrating effects of evaporation, when the lake volume reduces to about one million cubic metres (average depth of 1 metre).

During the main waterbird breeding period of September to November, lake salinities are generally below 3000 mg/L. It is uncertain what effect the temporary rise in salinity above 3000 mg/L has on the lake food chain in relation to breeding requirements, but it is likely to be minor.

With the current regime of inflow salinity and concentration of lakewater by evaporation, a sequence of years where sufficient rainfall occurred to cause inflow but no outflow would cause salinities to remain well above 3000 mg/L. In the situation starting with the lake containing one

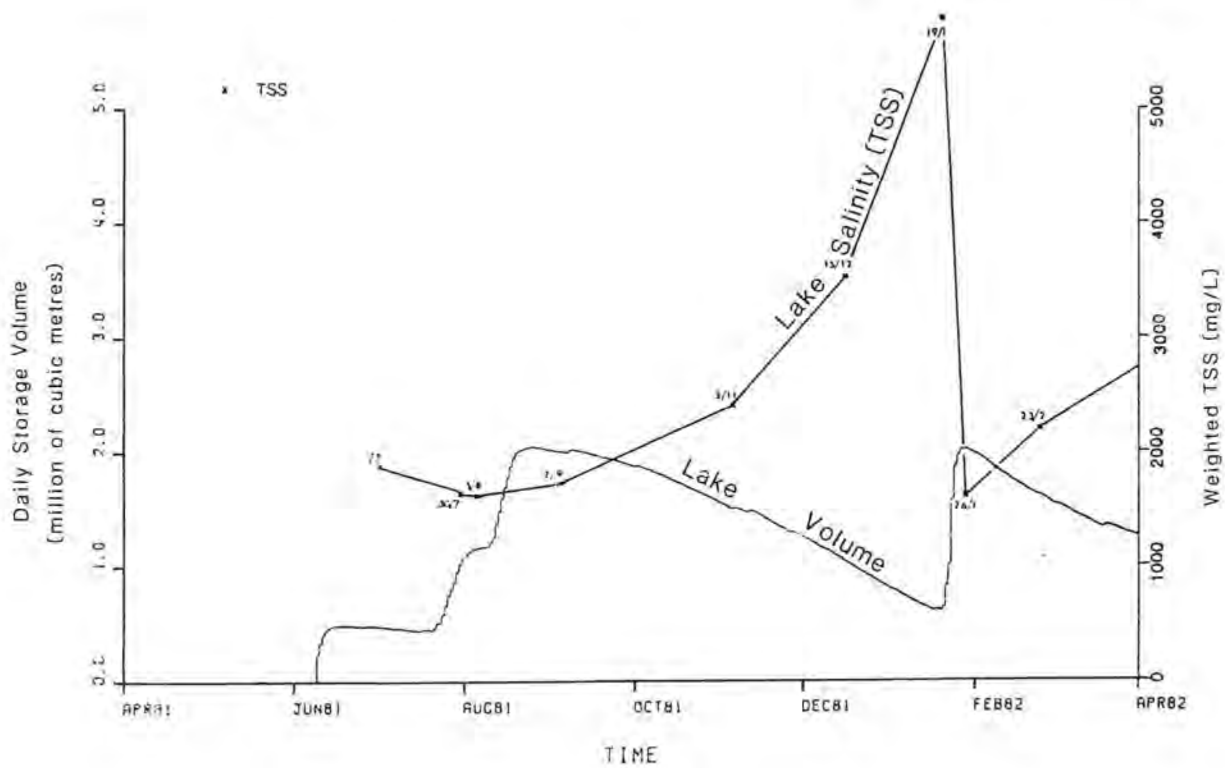


Figure 4 - Salinity and volume of Lake Toolibin in relation to wetting and drying cycles: 1981/82

million cubic metres and 3000 tonnes of salt followed by a sequence of two years where inflow was just sufficient to top up the lake, lakewater salinity would increase to 7500 mg/L. Such salinities would make the lake far less suitable for breeding for that season and could damage the vegetation.

Lake-Groundwater Interactions

Overall the lake is currently losing water and salt through the lake bed to the groundwater.

As an increase in lake salinity due to groundwater inflow would be most readily detected during periods of no surface inflow or outflow, the changes in lake salt storage over ten such periods were measured. Seven of the ten periods indicate a loss of salt from the lake. Of the three periods when a minor increase (< 2%) in lake salt storage occurred, this was almost certainly due to small, but undetected amounts of surface inflow.

Estimates of the magnitude of salt and water loss are given in Table 3, for five periods when the observed changes in lake salt storage were more than 5% of the total.

The mean seepage loss of 0.4 mm/day is less than one-tenth of the average daily pan evaporation for the periods of measurement. Therefore although most water is lost to the atmosphere, a very small seepage loss is apparently sufficient to reduce the store of salt in the lakewater over summer.

Table 3 shows that there is a strong inverse relationship between apparent seepage rate and lake area, despite the expectation that the higher water levels would cause higher seepage rates.

This strongly suggests that only part of the bed is leaking and at high water levels and presumably high watertable levels, apparent seepage rates are reduced by the ingress of saline groundwater around all or part of the lake edge.

Seepage into lakes is known to occur primarily around their edge and in the case of Lake Toolibin the likely source of in-seepage is on the western shore.

Future Salinity of Surface Flows

The long-term inflow salinity will be one of the crucial factors in maintaining the viability of Lake Toolibin as a wildlife habitat. The current salinity of inflow, from the small data set, provides a baseline against which increases in salinity can be compared. Although the salinity of inflow over the next decades cannot be predicted, it is unlikely to decrease in the medium-term and may well increase as a result of the delayed effects of the extensive clearing of the lighter, upslope soils during the late 1940s and early 1950s. Based on modelling of groundwater recharge-discharge relationships in other areas of south western Australia, the time for the full effects of clearing on groundwaters to be felt in this area may be of the order of 50 years.

Soil salinity surveys and particularly hydrogeologic investigations in the valley of the Northern Arthur River by the Department of Agriculture

Table 3 - Losses of water and salt to groundwater beneath Lake Toolibin

Period	Change in Lake storage		Average lake salinity	Seepage loss to groundwater	
	Water (m^3)	Salt (t)	(mg/L)	(m^3/day)	(mm/day)
11/12/81 - 19/1/82	447 100	178	4660	1060	0.5 (2.0)a
23/2/82 - 20/4/82	511 300	175	3175	900	0.4 (2.25)
20/4/82 - 27/5/82	115 500	100	3175	900	0.4 (2.25)
27/10/82 - 8/12/82	325 900	210	5050	970	0.55 (1.75)
17/10/84 - 29/11/84	373 400	143	3856	852	0.34 (2.5)

a. Value in brackets is average surface area of lake (km^2)

have indicated the potential for a significant increase in the area of saline land. Salt storage in soils beneath the valley is very high and groundwater salinities range between 14 000 and 48 000 mg/L, Total Soluble Salts. Because of the flatness of the valley floor, a continued rise in watertable levels is likely to salinise large areas of land.

If increased areas of saltland caused a doubling in salt load into the lake for example, without much additional water, the lake salinity would also double.

The Hydrogeology of Lake Toolibin

Observation bores were constructed in and around Lake Toolibin in 1977 and monitoring of groundwater quality and level commenced at the same time. A seismic refraction survey was carried out at Lake Toolibin in 1980. This indicated an approximately 3 metre thick clay layer on the lake bed overlying indurated lake sediments or weathered granite which in turn overlies fresh granite at depths between 27 and 46 metres.

In 1983 additional drilling was carried out on the western bank of Lake Toolibin. In 1985 a multiport piezometer was constructed in the lake centre to investigate more fully groundwater salinity layering and the vertical distribution of groundwater pressure heads.

Geology

Detailed geological mapping of the lake system has not been undertaken, and the origins of the various superficial deposits and their relationships are uncertain.

Dune systems are developed on the eastern sides of Lakes Toolibin and Taarblin. Lake Toolibin is ringed inside the dunes by a narrow strip of poorly sorted, medium to very coarse sands of granitic origin.

A cored hole drilled near the centre of Lake Toolibin during 1985 intersected a profile which consists of a thin (0.1 to 0.7 m) alluvial layer which is underlain by 8 metres of grey, slightly sandy clay, then sands, sandy clays and clayey sands to 49.2 metres. Examination of core specimens suggest that the profile below 0.7 metre is derived from the in-situ weathering of the basement rocks.

A west-east geological section for Lake Toolibin which combines information from earlier work with the more recent drilling information is shown on Figure 5.

Groundwater Hydrology

Apart from two bores to the east of the lake, the water-level trends in bores in the study area during the period of record can be classified into the following two groups:

(i) A constant rising trend occurred in bores in the valley to the north of Lake Toolibin. The rate of rise varied between 20 mm/year and 68 mm/year and averaged 46 mm/year.

(ii) All remaining bores, except for two bores situated close together to the east of the lake, showed a decline in water level between 1977 and 1980 followed by a rise during the remainder of the record. This trend is in accordance with the variations in rainfall over the period.

Both trends are in accord with those expected under a changed water balance regime following clearing and indicate that the impact of clearing on groundwater levels may not yet have been fully expressed.

Groundwater salinity

Watertable salinities in the area are generally high, in the order of 18 000 mg/L to 20 000 mg/L Total Soluble Salts but deep groundwater beneath Lake Toolibin contains about 60 000 mg/L Total Soluble Salts. Drilling by the Department of Agriculture has revealed that deeper groundwaters beneath the clay flats of the Northern Arthur River contain up to 48 000 mg/L Total Soluble Salts.

No trend or pattern to the groundwater salinity variations is evident. The occurrence of highly saline groundwater in the shallow bores in Lake Toolibin indicates that salt is concentrated by evapotranspiration when the lake is dry.

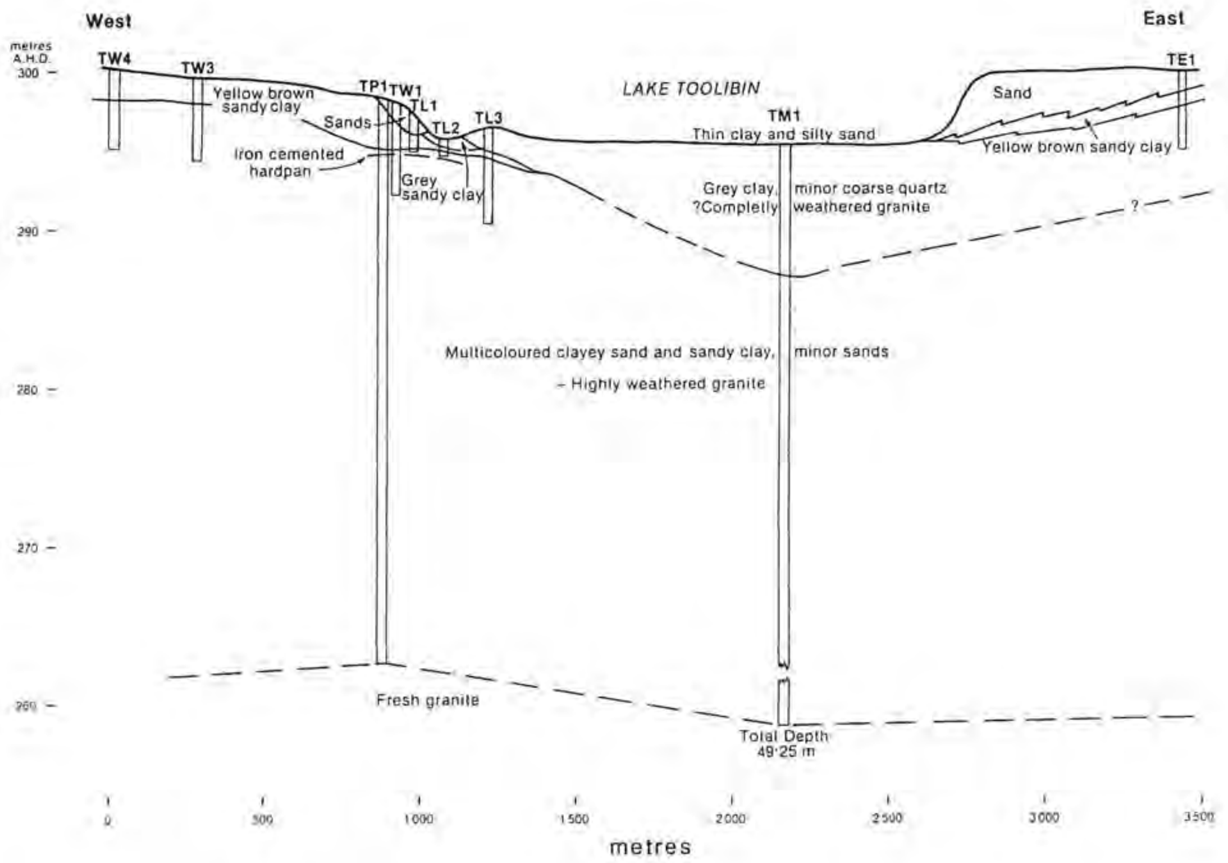


Figure 5
West-east cross section through Lake Toolibin showing general geology

Groundwater flow

Watertable contours around Lake Toolibin show that groundwater flow to the lake can alternate between a closed and an open system.

Following prolonged dry spells, for example prior to January 1978, groundwater contours are closed indicating that the lake acts as a discharge area. This contrasts with the period of higher rainfall and prolonged inundation from June 1983 to December 1984, when watertables rose and groundwater outflow occurred southwards, away from the lake.

Monitoring of the vertical groundwater head distribution in the multiport bore indicates that downward groundwater flow can occur through the lake bed and flush salts into the deeper (regional) groundwater system. This is confirmed by the salt balance studies which show an apparent downward seepage rate of about 0.4 mm/day when water is in the lake.

In contrast to this evidence for downward leakage, the deterioration of vegetation along the western bank of the lake and field observations indicate that seepage is occurring into the lake along this edge. Thus, while the western section of the lake is receiving groundwater inflow, other parts of the lake are losing water to the groundwater system.

This leads to a complicated picture of groundwater - lake interaction where groundwater flows are compounded by the transient effects of climate fluctuations and where both groundwater inflow and outflow have an influence on the lake.

Under the situation of generally higher watertable levels following clearing, the following scenario of lake salinisation in relation to the interaction between groundwater and vegetation condition can be postulated.

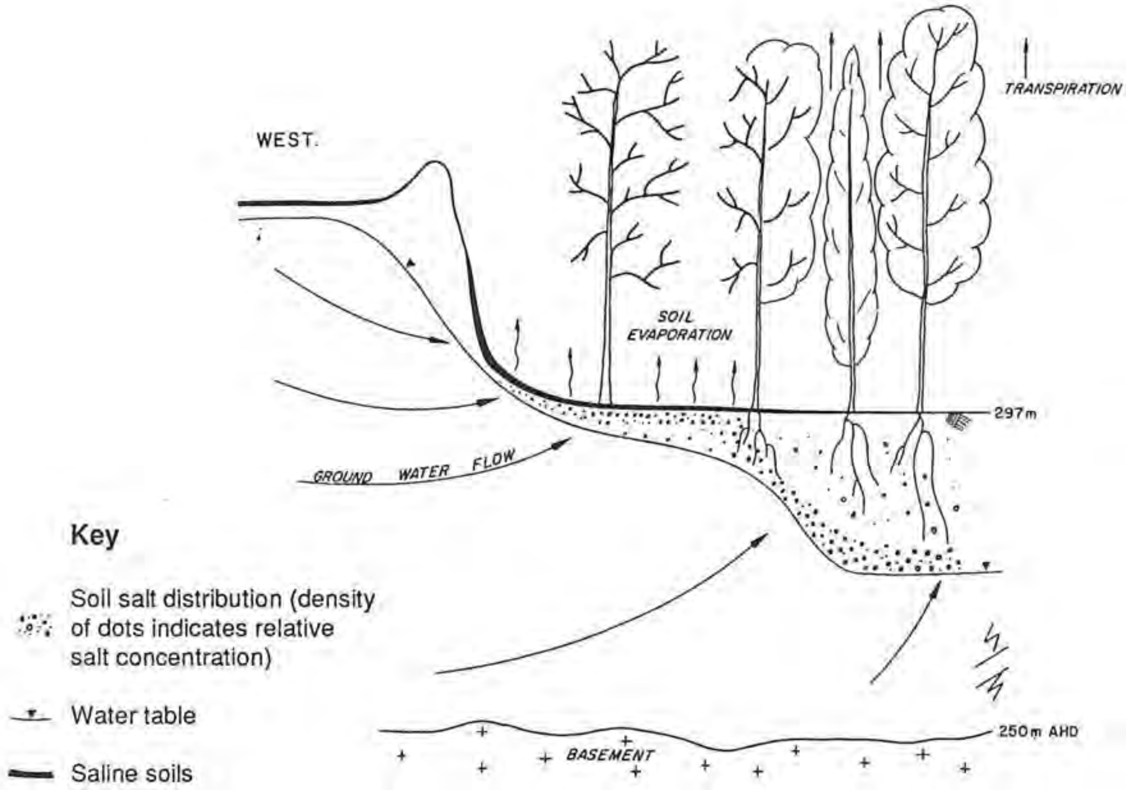


Figure 6a - Schematic of groundwater flow and salt distribution with lake dry and acting as discharge area

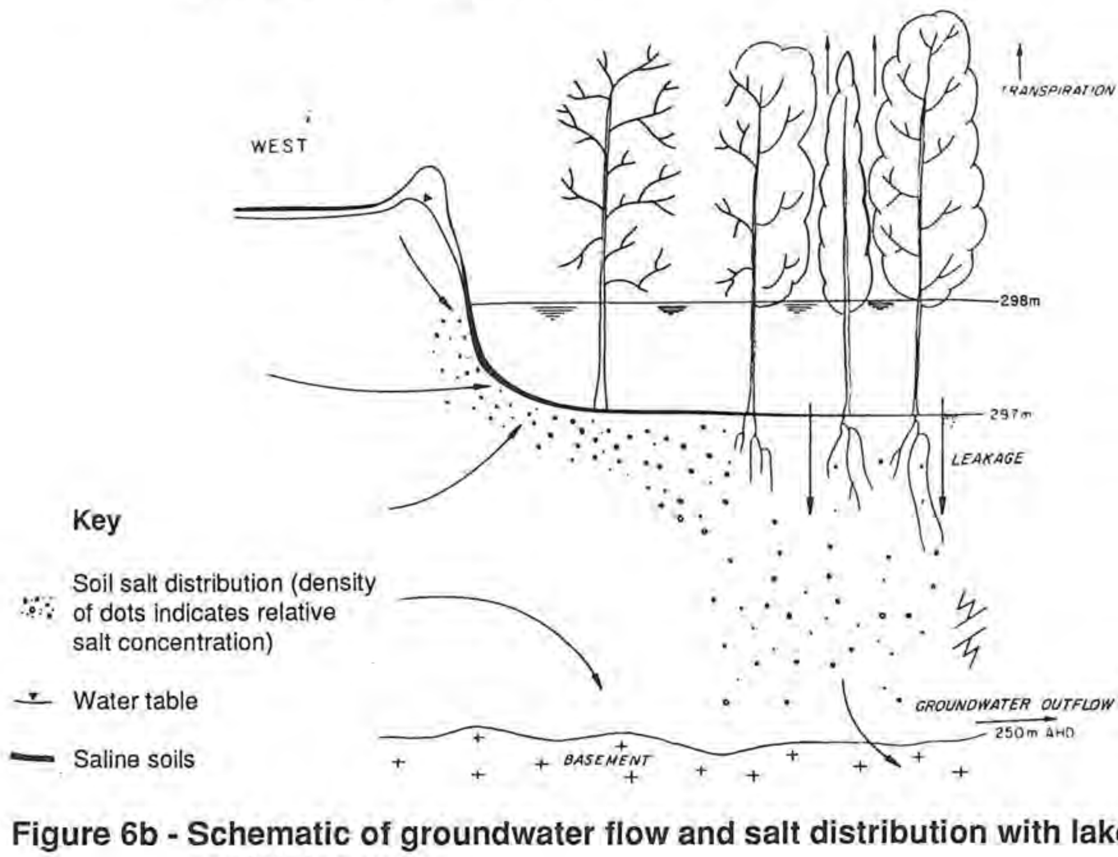


Figure 6b - Schematic of groundwater flow and salt distribution with lake containing water

On the western bank where clearing and secondary soil salinisation have extended to the lake edge, high watertable levels and possibly some local seepage have salinised the adjacent portion of the lake bed. During lake full or partially full conditions leakage occurs and maintains the overall lake salt balance preventing salt accumulation in the lake waters.

During dry periods, local seepage into the lake from adjacent saline areas increases soil salt levels and waterlogging, resulting in the death of vegetation. Reduced transpiration then causes watertables to rise further, increasing soil evaporation and causing an expansion of saline and waterlogged conditions.

Figures 6a and 6b depict schematically for the western shoreline the groundwater flow and soil salt distribution for the lake dry and lake full situations.

Healthy phreatophytic vegetation can control the salinisation of surface soils in dry periods by maintaining lower watertable levels in the lake bed and by concentrating salts below the root zone. Once vegetation is destroyed by salinity however, natural regeneration is prevented and the inexorable spread of salinity at the margin of the unhealthy/healthy vegetation results. Dry years without inflow will favour this process as will the continuing rise of groundwater levels that has followed clearing.

The documented steady decline and loss of vegetation, principally on the western side of the lake, without subsequent regeneration on these areas is evidence of this process.

Vegetation Trends of Lake Toolibin

The health and persistence of the vegetation in Lake Toolibin is viewed as a vital indication of its condition in relation to salt encroachment. Tree death and poor vigour was one of the signs that focussed attention on the possible deterioration of the lake habitat. The question was whether the loss of vegetation was a result of seasonal factors or due to a permanent change in the lake environment. Experience with the deterioration of lakes downstream from Lake Toolibin indicated that encroaching salinity could be such an environmental change.

Accordingly vegetation studies were carried out with the aims of:

(i) Mapping the vegetation of Lake Toolibin and the immediate catchment.

(ii) Establishing permanent field plots to provide baseline data on the vegetation condition and to provide a basis for future monitoring.

(iii) Establishing a flora list as a reference for future work.

(iv) Determining the effect of soil salinity and waterlogging on plant communities.

In 1977 a vegetation survey was carried out and 22 field plots were established to monitor changes in the structure and health of their vegetative components in relation to soils and soil salinity. Vegetation maps based on floristic and structural composition were prepared and a reference list made of the plant species collected.

The 1977 survey found that the most stressed, unhealthy or dead trees were adjacent to saltland on cleared land located on the west bank of Lake Toolibin, and along the southern margin of the reserve to the North East of the lake (Reserve 27286), as shown in Figure 7. Areas of degraded vegetation are marked on the vegetation map and clearly show their relationship to the saline soils on the western bank.

The monitoring plots established in 1977, together with a further four plots established in 1980, were again assessed in 1982 and 1986. In essence, these assessments showed a continual, slow deterioration of the plant communities due to saline conditions. This deterioration was manifested by an increase in the number of sick and dead plants in the plots.

The woodland of *C. obesa - Melaleuca* spp. which dominates a large section of the low-lying areas of Lake Toolibin and its surrounds, overwhelmingly shows signs of deterioration. The woodland of *E. rudis* also appears to be particularly susceptible to increased salinity. Currently the rate of deterioration of the vegetation is relatively slow, but the trends clearly do not favour a re-establishment of healthy tree stands in these areas of the Reserve.

This trend of deterioration was also evident in other plant communities, although the causes

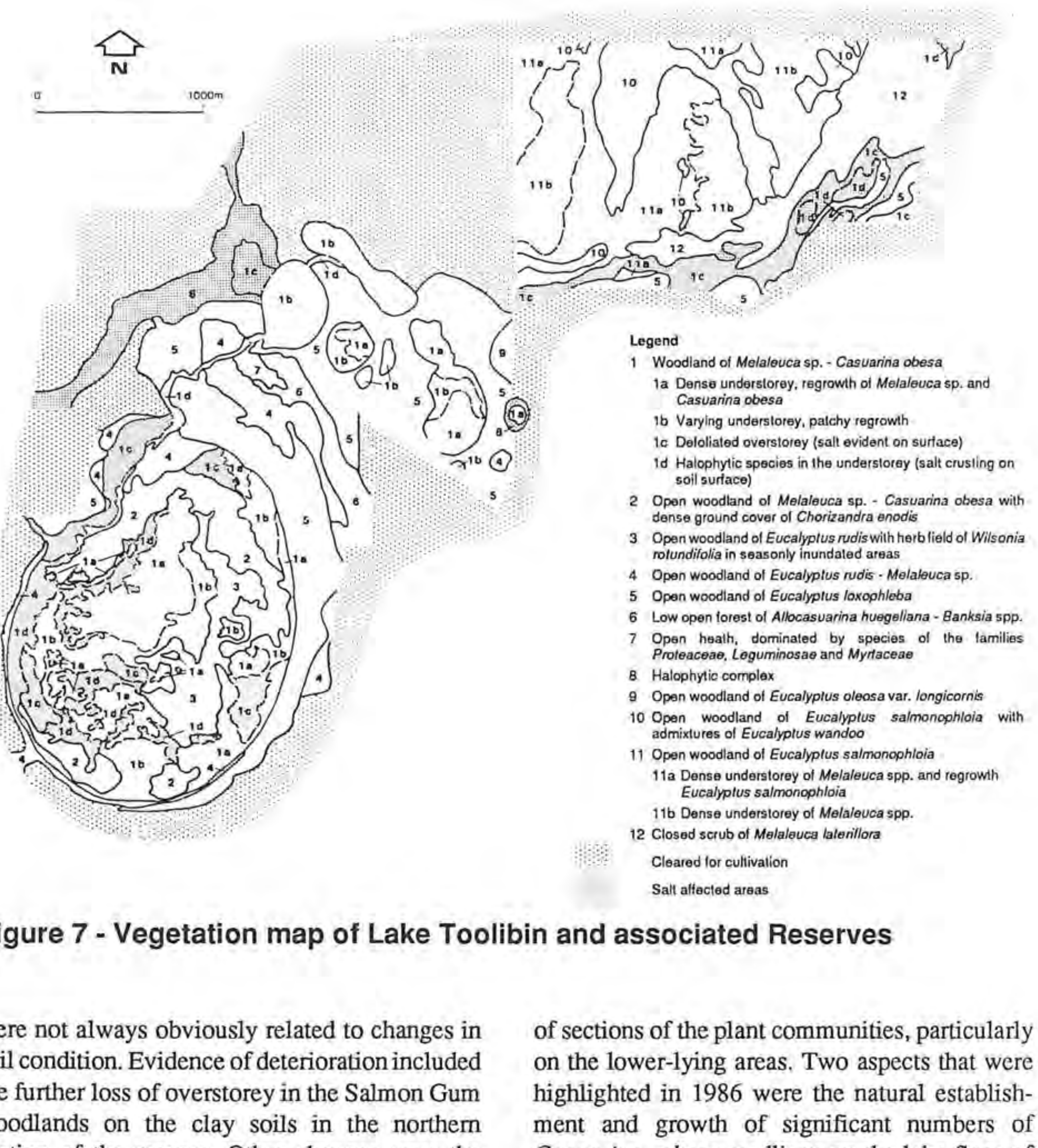


Figure 7 - Vegetation map of Lake Toolibin and associated Reserves

were not always obviously related to changes in soil condition. Evidence of deterioration included the further loss of overstorey in the Salmon Gum woodlands on the clay soils in the northern section of the reserve. Other changes were the deterioration in the *Allocasuarina huegeliana - Banksia* spp. community on the sandier soils. The latter changes were evident from the loss of vigour in the Banksia trees and the decrease in numbers of sclerophyllous native understorey species. In addition the thicket of *Melaleuca* shrubs were maturing, dying and falling (with only the occasional seedling arising). These latter changes appear to relate to a lack of fire or other environmental triggers which encourage re-growth and establishment of seedlings.

Continued debilitation of the vegetation both on the lake and surrounding areas will lead to the loss of sections of the plant communities, particularly on the lower-lying areas. Two aspects that were highlighted in 1986 were the natural establishment and growth of significant numbers of *Casuarina obesa* seedlings on the lake floor of Toolibin and the health and vigour of the recently bulldozed and burnt section of the reserve (formerly private land).

Both these events provide opportunities for a longer maintenance of the communities in the reserve. Although in the shorter term the seedlings of Sheoak cannot alter the local hydrological conditions on the lake floor, it is hoped that in the longer term, if they increase the size and vigour of adjacent Sheoak thickets, the rate of growth and extent of the saline affected areas will be minimised. In view of the significance of these seedlings, an annual monitoring of selected plots has been suggested. Monitoring of other communities which are deteriorating upslope of the wetlands should be also addressed. Although bulldozing is not recommended, the options of seeding with natives, planting of native seedlings and burning should be considered. If these are carried out on a sequential small scale it should be possible to encourage regeneration and greater species diversity.

Vegetation Condition in Relation to Salinity and Waterlogging

A study to relate the vigour of major tree species to soil salinity and waterlogging was carried out in conjunction with the University of Western Australia (Froend *et al.* 1987). The degree of waterlogging was expressed as a percentage of the time sites were inundated relative to the 1981 maximum lake level. Soil salinity values in the top one metre of soil ranged between 0.02% and 0.2% Chloride and percentage inundation values between 0 and 58.4%.

The study concluded that death in *Melaleuca* spp. and *C. obesa* is due to high levels of salinity and that death and low vigour in E. rudis is due to both high salinities and high inundation percentages.

Some tree death and loss of vigour may also be attributable to an antagonistic interaction between both high salinity and increased waterlogging. Nevertheless control of soil salinity will be vital to the preservation of the lake vegetation and by implication its continued suitability as a breeding area for waterbirds.

4. Conclusions

(i) Lake Toolibin is the most important breeding habitat for waterbirds in south-western Australia. Between 1981 and 1985, a greater diversity of species have been recorded as breeding there than at any other lake in the region. It is one of the few remaining suitable breeding habitats for the rare Freckled Duck. It is also a vital inland breeding area for maintaining the populations of less rare waterbirds including game species such as ducks.

(ii) One of the prime attributes of Lake Toolibin for breeding is the presence of a healthy emergent vegetation. This vegetation provides a wide range of niches that meet the specific requirements of many waterbird species.

(iii) The vegetation within Lake Toolibin shows a slow but continuous trend towards poor health and death with only localised patches of natural regeneration upslope from the degraded areas. Vegetation loss is worst on the western side of the lake and increased soil salinity is the primary cause.

(iv) Lakewater salinity currently varies between 500 mg/L and 6000 mg/L Total Soluble Salts. Salinities of less than 3000 mg/L generally occur when the lake is more than one metre deep. The lakewater is freshened by surface inflows (which generally occur in winter) and then concentrated by evaporation over summer. On the basis of salinity and depth, the lake is considered suitable for waterbird breeding 70% of the time.

(v) Large areas of the Northern Arthur River flats are at risk of becoming saline from shallow, saline groundwater which is slowly rising towards the surface. An increase in the salinity of inflow waters, resulting from an expansion of salt affected soils in the catchment, will further increase lakewater salinity. Even at current inflow salinity levels, a sequence of years with inflow but no outflow would cause lakewater salinity to increase to 7500 mg/L.

(vi) Watertables in the vicinity of Lake Toolibin are still showing rising trends, indicating that the groundwater system is not at equilibrium with the new water balance established following clearing. Watertables beneath the lake bed are at depths of 2 metres or less and highly saline. Clearly the lake is at threat from salinisation due to the capillary rise of salts from the groundwater.

Groundwater monitoring and salt balance studies however show that overall the lake currently is exporting salt to the groundwater system when full or partly full.

(vii) An actively transpiring lake vegetation appears vital to control watertable levels and prevent salts accumulating in the lake bed. Encroaching soil salinity on the western bank of the lake has killed vegetation there and without restorative action salt encroachment will continue to expand outwards from this area.

5. *Recommendations for Management of Lake Toolibin*

Both immediate and longer term actions are required for the preservation of Lake Toolibin and environs. These actions apply to both the lake and its catchment.

Revegetation of the Western Buffer Zone

Lowering the watertable is the key to the preservation of Lake Toolibin with the western shore being the area where urgent action is required. Adjacent to this western shore is privately owned land which has been developed for farming and now provides ready recharge to the local groundwaters.

Revegetation of a 100 to 200 metre strip of farmland adjacent to this western edge of the lake should proceed with urgency. Obtaining access to this land is a matter for the Department of Conservation and Land Management.

Ownership and revegetation of this buffer will enable rehabilitation of saltland, help reduce watertable levels and local saline seepage onto the lake edge and improve the micro-environment for trees within the lake.

Revegetation of the buffer area should be carried out using techniques and species appropriate to the various site conditions:

(i) On saline land initial revegetation with halophytes possibly followed by appropriate tree species as improvement of the area allows.

(ii) On non-saline land planting of trees adapted to site conditions and at maximum densities appropriate to the site.

The buffer zone should be fenced to control traffic through the area and to keep out grazing animals and appropriate fire control procedures should be instigated. Surface drainage to remove excess foreign and local surface water will also be required in some areas.

Groundwater Control

Revegetation of the strip to the west of the lake is necessary but it will not, by itself, be sufficient to control the groundwater level in the degraded western shoreline area, particularly in the early years of vegetation establishment.

It will be necessary to assist the vegetation by lowering the groundwater artificially. Low capacity pumping is considered to be the only practical means of withdrawing this excess groundwater because of the low permeability of the upper lake bed sediment and the general flatness of the area.

The following actions are needed:

(i) Initial pump-testing to determine the feasibility of pumped drainage and to obtain hydraulic parameters for design purposes.

(ii) Design and installation of a borefield to lower the watertable to 1.5 metres beneath the areas of degraded vegetation and determination of drainage effluent disposal requirements.

(iii) After an initial period of leaching, a revegetation programme using the natural lake bed species should be carried out. At this stage it may be necessary to prevent excessive inundation of seedlings during the establishment phase.

(iv) Propogation of seedlings of required species to be in phase with the drainage and reclamation work.

Plans are in place, subject to funding approval, for the Geological Survey Branch of the Mines Department to carry out the pumped drainage feasibility testing in 1987/88.

Cost estimation for this scheme will have to await the results of this test and design of the borefield, but the capital costs could exceed $100 000.

Maintain Health of Lake Toolibin Reserve Vegetation

Maintaining the health and vigour of the vegetation in and around Lake Toolibin can assist significantly in controlling the groundwater by maximising evapotranspiration.

It is therefore recommended that this entire reserve be actively managed. The options of seeding with natives, planting of native seedlings and burning should be considered. If burning is adopted as a management action, it must only be carried out on a sequential small scale to minimise the risks of short-term side effects on the watertable levels. As evident from results within the study area, this proposed small-scale burning should encourage regeneration, vegetation-vigour and increase species diversity.

Diversion of Saline Flow from Interceptor Banks

A system of interceptor banks is currently discharging saline water into the western side of Lake Toolibin and exacerbating the deterioration of vegetation in the lake. Flow from saltland that would have normally passed to the south of the lake is now being diverted into the Northwest Creek and thence into the lake.

Urgent action is required to prevent the continued flow of effluent from the interceptors into the lake. This will require re-diverting this flow to the south and west away from the lake and the western buffer zone.

Catchment Regeneration to Reduce Inflow Salinity

The development of the catchment for agriculture has resulted in rising groundwater levels, salinisation of river flats and an increase in the salinity of inflow to Lake Toolibin.

Although it is considered that the birdlife could contend with a further 30% increase in the salinity of the water in the lake, they certainly could not contend with extensive loss of the vegetation within the lake. Further rises in the groundwater levels under and near the lake or a substantial increase in the salinity of inflow to the lake would accelerate the death of the lake vegetation and severely damage the ecosystem.

Practical action to control groundwater levels across the catchment must be actively encouraged. By increasing the utilization of water where it falls, together with extensive plantings along streamlines, groundwater discharges could be substantially reduced with a corresponding reduction in the volume of salt flushed into Lake Toolibin.

The following action should be completed:

(i) Fence and revegetate saline land within the catchment. This will reduce the spread of saltland and lower watertables beneath saltland. Revegetation and grazing protection will lower surface soil salinities and reduce the amount of salt flushed from the soil by surface flow.

(ii) Encourage the development and implementation of farming systems that minimise groundwater recharge. Changed cropping rotations, greater plantings of shelter belts and fodder trees, and alternative tree crops should all be considered.

(iii) With the farmers, complete the development of comprehensive individual farm plans that will reduce groundwater levels and the salinity of runoff while at the same time maintaining or improving the economic viability of the farm.

The Wickepin Soil Conservation District has already embarked on an ambitious saltland revegetation programme in collaboration with Greening Australia. It is important that the impetus of their work be encouraged and maintained because of the importance of the programme and because it will foster community involvement in the future of Lake Toolibin.

Monitoring

Active management of the lake and nearby vegetation and the catchment as a whole will be essential for Lake Toolibin to be retained as a viable waterbird breeding habitat. Long-term monitoring is required to maintain surveillance of the lake's condition, to assess the effectiveness of measures implemented in farms within the catchment and to guide the management programme.

The on-going monitoring requirements are as follows:

Lake Reserve Vegetation:

Annual monitoring of a selected set of the established vegetation plots with a re-assessment of the condition of all 26 vegetation plots every four years. The next comprehensive survey to be in 1990.

Groundwater:

Monitoring of the boreholes in and around Lake Toolibin to be carried out annually at the end of summer. Some key groundwater observation sites should be continuously monitored by automatic recorders.

Lake level and Quality:

The lake level to be continuously monitored at the established gauging station and lake water quality to be sampled at appropriate intervals following each major inflow event.

Lake inflow:

The quantity and quality of inflow from the North Arthur River to be continuously monitored at the established gauging station.

Catchment:

Progress with the implementation of farm plans and the effectiveness of the treatments to reduce groundwater levels and stream salinity to be reviewed every three years, with the initial assessment to be in 1988.

Further Investigation of Groundwater Pumping

If monitoring indicates continuing deterioration of the lake despite the effective implementation of remedial measures, groundwater control of the entire lake by pumping appears to be the final option for preserving the lake. This would be costly and safe disposal of saline effluent (up to 60 000 mg/L) would present a problem.

Before proceeding on such a proposal, a full feasibility study including pump-testing, design, disposal and costing would need to be undertaken.

Strategic Lake Emptying

A two year carry-over of lake water without substantial outflow will result in high water salinity. Discharge of this water by pumping would help reduce the lake salt load and ensure lower lake salinity following the next inflow event.

6. Committee Membership

Mr K. L. Barrett (Chairman)	Water Authority of Western Australia
Mr P. R. George	Western Australian Department of Agriculture
Mr J. A. K. Lane	Department of Conservation and Land Management
Mr M. W. Martin	Geological Survey of Western Australia
Dr E. M. Mattiske	Consultant Botanist
Mr R. A. Stokes	Water Authority of Western Australia
Mr R. J. Sheridan (Secretary)	Water Authority of Western Australia

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