Criteria of environmental acceptability for land use proposals within the catchment of Lake Clifton

Environmental Protection Authority
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Purpose of this report

The purpose of this report is to describe the Environmental Protection Authority's environmental criteria which would provide the basis for the Lakelands Strategy currently being developed by the Ministry for Planning for the Western Australian Planning Commission. The criteria provide a basis for managing new land uses and changes to certain existing land uses on private land within the catchment of Lake Clifton.

The report is in three parts. Part 1 provides background information about the lake, its catchment and a history of recent developments in the catchment. Part 2 describes the EPA criteria. Part 3 is the supporting technical information.

These criteria are released as a draft for public comment for an eight week period. The EPA will consider all submissions and any other relevant technical information and then release its final criteria.

Appeals

There are no appeal rights associated with this report.

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Contents

Contents (cont'd)

Figures

Part 1 — Background

1. Introduction

Lake Clifton is one of the most significant wetlands in Western Australia. It is internationally important as a waterbird habitat and because it contains the largest known example of living stromatolites[1], properly called thrombolites, in a lake environment in the southern hemisphere. It is one of only seven lakes in the southern hemisphere where stromatolite-like structures are known to occur in hyposaline water (salinity less than seawater), and has been listed under the Ramsar Convention as having international importance.

Lake Clifton is a wetland recommended for protection in System Six Red Book (Department of Conservation and Environment, 1983), and is protected by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992.

Lake Clifton is located about 100 km south of Perth on the western edge of the Swan Coastal Plain between the Harvey Estuary and the coast (Figure 1). The lake proper and much of the catchment to the west, north and south are within the Yalgorup National Park. However, for most of the eastern catchment only a narrow foreshore reserve is within the park, with the remainder of the land privately owned.

Criteria have been developed to limit the environmental effects of changes to land use on private land within Lake Clifton's catchment in order to conserve the thrombolites and the environmental processes which enable the thrombolites to continue to exist. The most important environmental aspects are hydrology, water quality and direct disturbance.

One crucial aspect is to manage the growing development pressure within the catchment from three sources:

- land uses using large quantities of water and fertilizer, in particular, horticulture;
- increasing demand for rural/residential developments as the Mandurah urban area expands further south; and
- increased tourist interest in the lake and the stromatolites.

The development of these criteria complements two other studies currently being undertaken:

- Yalgorup Lakes study being carried out by the Water Authority and Geological Survey of Western Australia funded by a grant from the National Landcare Programme; and
- Coastal and Lakelands Planning Strategy being carried out by the Ministry for Planning for the Western Australian Planning Commission.

The Yalgorup Lakes study will examine the hydrological regimes of Lakes Clifton and Preston. It aims to map groundwater movement in and out of the lakes and examine sources of nutrient export.

The Lakeland Strategy will propose a landuse management strategy for land within the catchments of the Yalgorup Lakes (refer to Section 2).

2. Planning context - the Coastal and Lakelands Planning Strategy

The area of land near the coast between the rapidly growing cities of Mandurah and Bunbury is experiencing considerable pressure for urban, rural residential and horticultural developments. This area is also environmentally sensitive and has high landscape value because of the presence of Lakelands wetland system, significant stands of remnant native vegetation, and significant coastal features.

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[1] There is some confusion regarding terminology. Refer to Section 2 for a full explanation.

In January 1995, in response to this pressure, the Western Australian Planning Commission, through the Ministry for Planning, initiated a planning study for this area called the Coastal and Lakelands Planning Strategy. This Strategy seeks to:

- protect the environmental values and visual qualities of the area;
- enable private land owners to use their land whilst maintaining water quality of the wetlands and their groundwater catchments;
- plan for the use of the coastal strip whilst maintaining its environmental values; and
- recommend appropriate long term land uses for the area.

The Strategy is being developed with the involvement of relevant government agencies including local government. The Ministry for Planning has advised that this Strategy will be released as a draft early in 1996.

The Environmental Protection Authority believes that these criteria and the Coastal and Lakelands Planning Strategy should be compatible documents. To this end, these criteria have avoided the mention specific land use controls other than where it is unavoidable. Instead, the criteria set environmental objectives and standards. The translation of these objectives and standards into land use controls, where appropriate, will be done through the Planning Strategy. The Western Australian Planning Commission has agreed with this approach.

3. Microbialites and stromatolites

Microbialite is the general name given to organosedimentary structures (structures made out of organic materials and sediments) built by benthic (living on the bottom of a lake or ocean) micro-organisms. These non-living structures protect the micro-organisms from a range of threats, and are built as part of normal growth processes by:

- trapping and binding sediments; and
- precipitating certain minerals.

The sediments are often bound together by calcium carbonate precipitated as a result of the metabolic activity of the micro-organisms.

Microbialites can be classified into various types of structures depending on the process involved and the internal arrangement within the structure. Stromatolites are one such structure type, and are typically laminated or layered. Another type of structure are thrombolites which have a "clotted" internal structure. It is often difficult to distinguish stromatolites from thrombolites as they have almost identical external appearances.

The microbialite structures in Lake Clifton are thrombolites, but have traditionally been called stromatolites. To avoid confusion, this Bulletin will use the generic term microbialites.

The micro-organisms responsible for the microbialites are called cyanobacteria, or 'blue-green algae'.

Microbialites are known to have existed up to 3 400 million years ago, and their fossils are one of the earliest records of life on Earth.

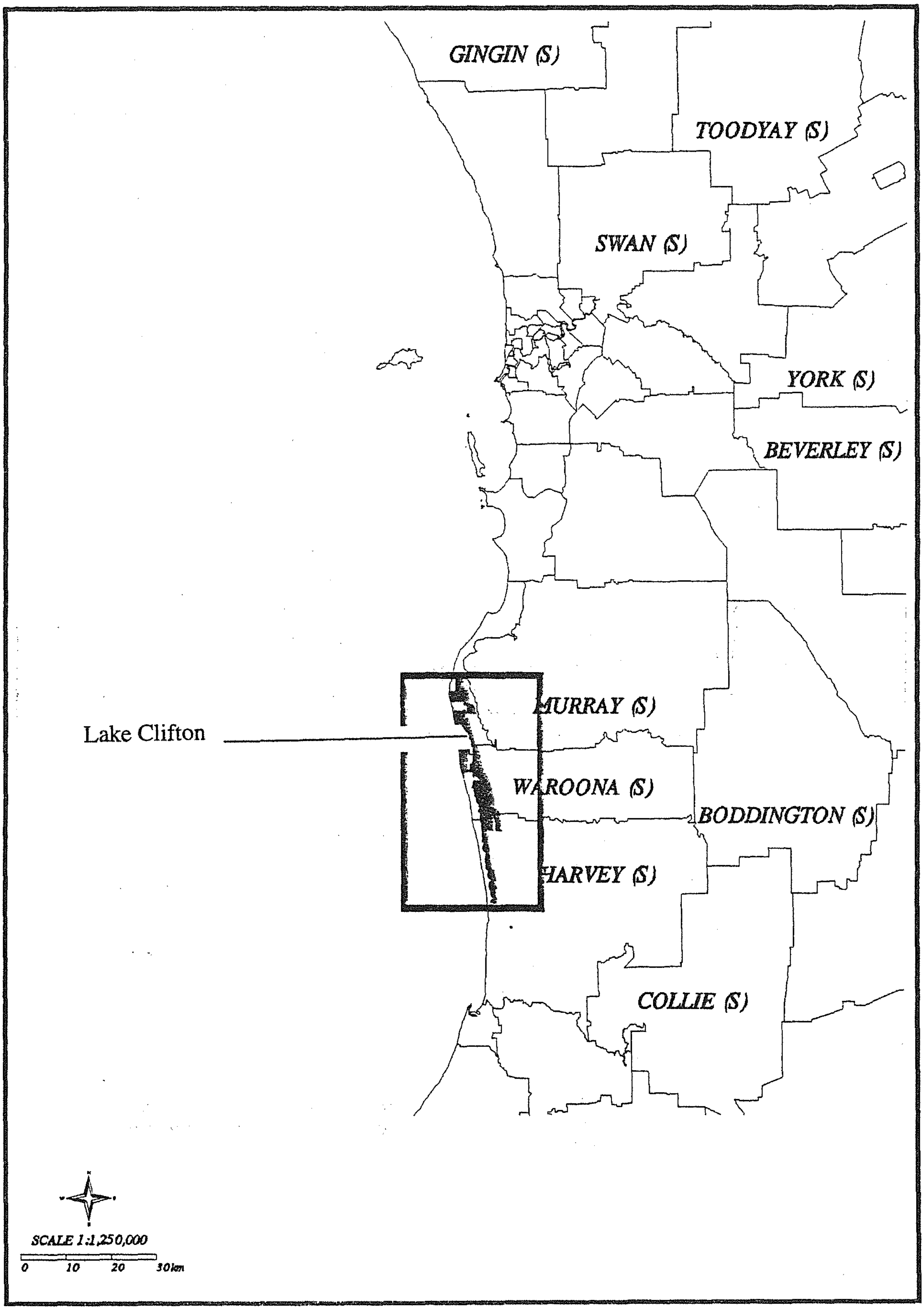

Figure 1. Location map.

4. Lake Clifton and the microbialites

Lake Clifton is one of 11 lakes making up the Clifton-Preston lakeland system. These lakes occupy depressions between a series of linear ridge lines thought to have been formed through the actions of changing sea levels (Figure 2). Lake Clifton is a long narrow lake, 21.5 km long with a maximum width of 1.5 km. Most of the lake is less than 1.5m deep, reaching a maximum depth of 3.5m in a few places.

The microbialites are confined almost exclusively to the eastern shore, and are most prolific in the north of the lake where they form a reef more than eight kilometres long and up to 120 m wide. In general, the microbialites are less than half a metre in diameter, with some up to 1 m across. The tallest microbialites grow to 1.3m.

The Lake Clifton microbialites are up to 2 000 years old.

It is worth noting that relic microbialite structures are found in some of the other lakes in the Clifton-Preston lakeland system. The cause of their death is unknown.

5. Hydrology and geomorphology

Lake Clifton is a sink for water, including groundwater, with no direct drainage to the ocean, although there is some evidence suggesting that some water flows out of the lake into other lakes in the wetland system (J Turner, *pers. comm.*). Its hydrology is complex involving freshwater inflow from direct precipitation and groundwater, and water loss through evaporation.

The groundwater catchment is thought to extend about 1.5 km in the northern section between the Harvey estuary, but is less well defined south of the estuary. The groundwater gradient between the estuary and the lake is very low, which means that the groundwater divide is poorly defined. Further, the location of the divide will shift depending on the season and amount of rainfall. Research currently being carried out by the Water Authority should enable the groundwater divide to be determined.

The groundwater consists of a "lens" of freshwater over a hypersaline (salt content greater than sea water) body.

Fresh groundwater enters the lake either directly or indirectly as overflow from a freshwater wetland directly adjacent to the east side of the lake. This wetland ranges in width from a few meters to up to 100m. It is thought that there is an impermeable barrier just to the east of Lake Clifton which prevents the freshwater entering directly into the lake in many places (R Hammond, *pers. comm.*). Instead, the water appears at the surface as a freshwater wetland which, when full, overflows into Lake Clifton (Figure 3).

Water levels in the lake respond to rainfall, rising in winter and falling in summer. At the end of summer the water levels usually drops to below 1 m exposing much of the microbialite reef. Water levels fluctuate up to 1 m throughout the year.

The catchment of Lake Clifton is mainly set in the Spearwood land form type. Soils are categorised broadly as either Cottesloe (shallow yellow/brown sand over limestone), Karrakatta (deep yellow/brown sand) or Vasse (poorly drained soil of marine or estuary origin). The Vasse soils are found in a narrow band near the lake.

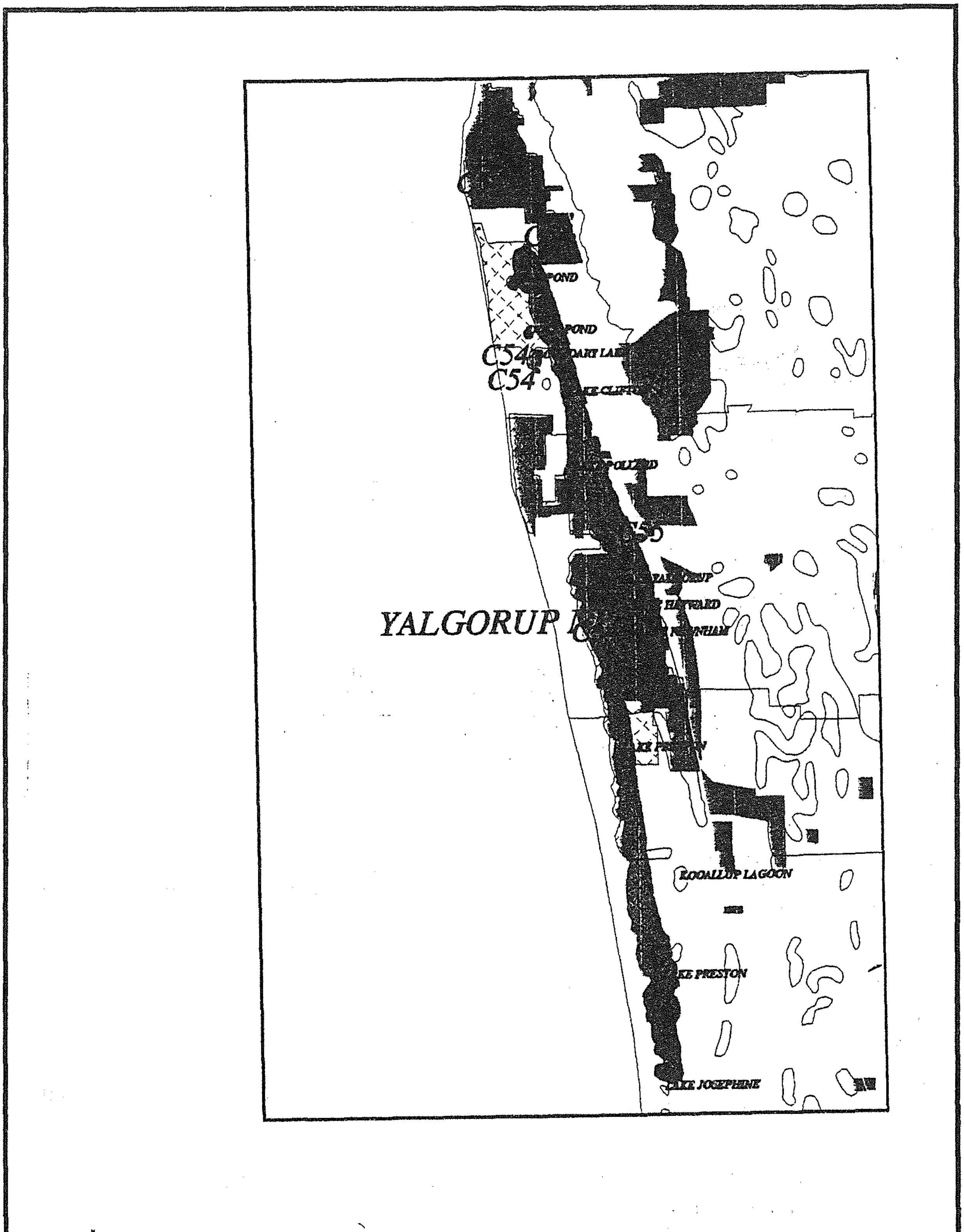

Figure 2. The Clifton-Preston lakeland system

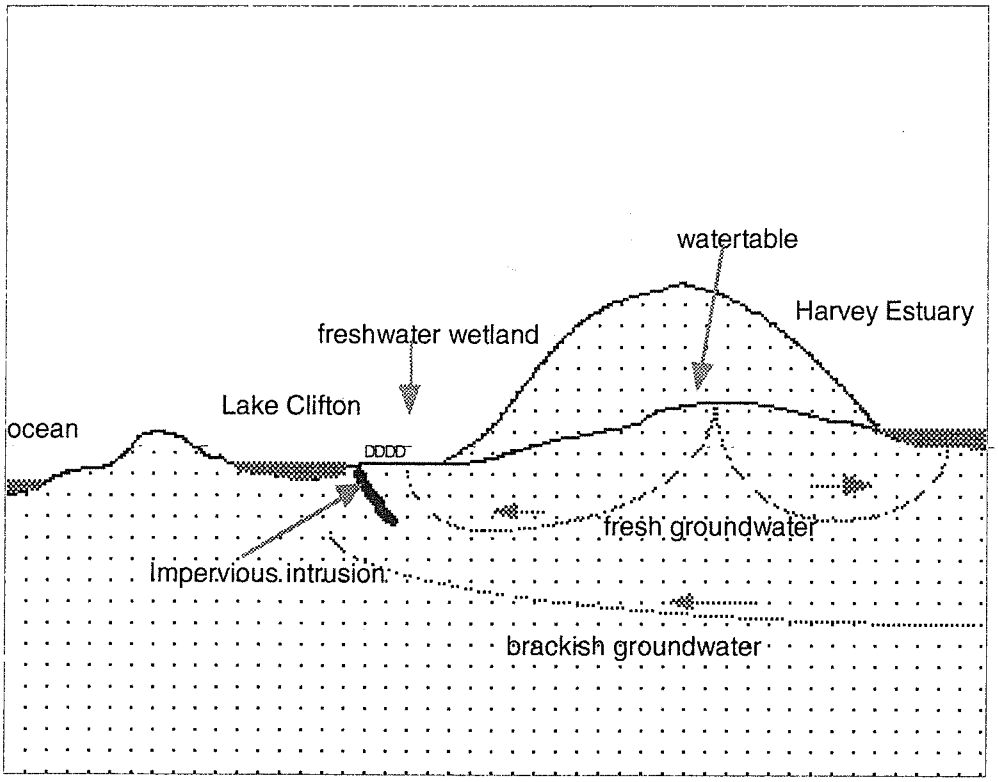

Figure 3: Diagrammatic section showing groundwater flow

6. Key environmental issues

6.1 Requirements for microbialite growth

The most significant research carried out on the microbialites at Lake Clifton to date is by Dr Linda Moore (Moore, 1993). Information provided in this report draws on the work of Dr Moore and other workers in the field.

The critical requirements for microbialite growth are:

- constant source of carbonate and bicarbonate ions;
- minimal levels of nutrients; and
- light.

The fresh groundwater that flows into the lake, while not directly important to microbialite growth, has two important indirect effects:

- it regulates lake salinity; and
- it provides carbonate and bicarbonate ions necessary for continued microbialite growth.

This aquifer is contained within the Spearwood landform which is typically sand over limestone. The limestone is high in calcium carbonate providing a rich supply of the carbonate and bicarbonate ions.

Whilst nutrients are essential for microbialite growth, excessive levels of nutrient will encourage the growth of other algal species. Algal blooms will reduce the amount of light reaching the microbialites, inhibiting or stopping growth.

6.2 Human pressures

Microbialite growth is strongly influenced by a number of human-induced factors including:

- nutrient input to the lake;
- changes in the water balance; and
- direct physical impacts (from humans and stock allowed to graze at the water's edge) — trampling of microbialites, loss of fringing vegetation, erosion through trampling, and increased water turbidity.

As discussed above, excessive levels of nutrient and changes to the flow of fresh groundwater flow could inhibit microbialite growth.

Certain land uses could pose potential threats to the microbialites if not managed carefully or excluded from the catchment. These land uses include:

- intensive horticulture;
- rural/residential developments; and
- tourist developments.

Conventional intensive horticulture uses large amounts of water, fertilizer and pesticides, which could directly affect the freshwater aquifer or export large quantities of nutrients and other pollutants to the lake.

Rural residential developments, if unmanaged, could impact on the microbialites through: excessive use of groundwater; export of nutrients through an intensification of land uses (for example, horticulture); loss of vegetation cover through excessive clearing causing changes to water balance; impact of stock; and, increased recreational impacts on the lake.

Tourist developments pose two threats: increased recreational pressures, and nutrient export through inappropriate effluent disposal.

Other land uses that could be of concern include extensive replanting with high water using tree species because of their possible effect on the freshwater aquifer.

7. History of recent developments within the catchment

7.1 Horticulture in the catchment

Since 1991 the Water Authority has received a number of applications for well licences from land owners wishing to carry out some form of horticulture within the Lake Clifton catchment. Five of these were referred to the Environmental Protection Authority (EPA) for assessment.

In 1991 the EPA assessed the following four proposals:

- application to irrigate 0.05 ha of fruit trees requiring 2 000 kL of groundwater per year;
- application to irrigate 0.3 ha of fruit trees requiring 3 900 kL of groundwater per year;
- application to irrigate 0.95 ha of vegetables and fruit trees requiring 12 000 kL of groundwater per year; and
- application to irrigate 3.6 ha of lucerne/clover requiring 13 500 kL of groundwater per year

Based on proposed water usage and fertilizer application rates, the EPA recommended that only the first application be approved.

In March 1993 the EPA recommended approval for a licence to irrigate 2 ha of asparagus requiring 5 000 to 6 000 kL of water per year, provided that:

- irrigation area be no greater than 2 ha;
- total P application rates to be no greater than 45 kg per ha per year;

- western boundary of the irrigation area to be no less than 300m from the Lake Clifton shoreline; and
- no surface drainage leaves the irrigated area and enters the Lake.

In assessing these well licence applications the EPA made the following in-principle statements:

- land owners within the catchment should not have unrealistic expectations of allowable land uses, and that environmental constraints should apply; and
- intensive horticulture requiring large quantities of water and fertilizer are considered environmentally unacceptable within 1 km of the lake.

7.2 Rural Residential — the Mt John Wood proposal

This proposal was referred to the EPA in November 1991, and involved subdividing a portion of lot 721 Mt John Road into 25 ten ha lots. The EPA determined that whilst this development could pose a threat to Lake Clifton if not properly controlled, the management provisions proposed to deal with the environmental issues were acceptable with some modifications. Consequently, the level of assessment was set at Informal Review with Public Advice.

One of the original management provisions was that domestic water would be self supplied through rainwater tanks. This was proposed as one way of minimising the impact on the freshwater aquifer.

The proponents subsequently sought to install either a single bore to supply water for the whole development, or one bore for each lot. The proponent also sought two other variations to the original planning approval. These three changes were included in Amendment 203 to the City of Mandurah's Town Planning Scheme. Amendment 203 was the subject of a separate assessment by the EPA, level of assessment set at Informal Review with Public Advice.

Concern has been raised by various members of the community that the abstraction of groundwater to provide water for these lots could impact on the freshwater aquifer that flows into Lake Clifton and impact on the microbialites.

Whilst excessive groundwater abstraction would impact on the aquifer, in this case it is expected that sufficient additional recharge would take place, through the clearing of native vegetation for building envelopes and service requirements, to compensate abstraction. The EPA advised that ground water bores on each lot would be acceptable provided that:

- the water allocation is either 650 kL per lot unmetered or 1000 kL per lot metered;
- the Council enforces restrictions on ancillary land uses; and
- where additional water is required, a rainwater tank is provided.

The EPA did not support the use of one bore to provide for all the lots as this would localise the impact of the groundwater abstraction. The support for the 25 individual bores was based on advice from officers of the Water Authority and the Department of Environmental Protection. Whilst some members of the community strongly opposed the granting of these licences, their concerns were based on a general view that excessive abstraction of fresh groundwater would impact adversely on the microbialites. The EPA shares this general concern, but considers that the allocation recommended above, given the size of the lots and controls on clearing of native vegetation, is acceptable.

7.3 Need for environmental criteria

With increasing pressure for further development in the Lake Clifton catchment, it is appropriate to set out criteria of environmental acceptability for land use proposals within the catchment of the lake. These environmental criteria are needed so that individual proposals can be assessed for their environmental acceptability at the early planning stages and avoid case-by-case assessments when applications for development (rezoning or subdivision) are made to the planning agencies. These environmental criteria aim to limit the environmental effects of land use changes in order to conserve the microbialites and environmental processes which support them.

Part 2 — the EPA draft criteria for the protection of Lake Clifton

8. Criteria aim

The broad aim of the criteria is to provide a framework so that changes to land uses on private land within the Lake Clifton catchment can be managed to ensure the on-going survival of the microbialites.

Changes to land uses refer to:

- rezoning and subsequent subdivision of land to more intensive uses;
- subdivision of land under existing zoning; and
- changes to land uses under existing zoning not requiring subdivision but involving an intensification of land uses (for example, applications for well licences for irrigated agriculture, and development applications through the local authority Town Planning Scheme for tourist related activities).

The criteria do not address existing land uses. If the threats to the microbialites continue despite the application of these criteria, the EPA may decide that the impacts of existing land uses may need to be addressed through other mechanisms and advise Government accordingly. The results of the Yalgorup Lakes Study (Section 1, Part 1) will provide the basis for on-going monitoring of the lake to test the effectiveness of these criteria.

9. Basis for the criteria

These criteria have been developed with significant consultation with officers of the following agencies. It should not be inferred that each agency necessarily supports the provisions of these criteria.

The agencies consulted are:

- Department of Agriculture Western Australia;
- Water Authority of Western Australia;
- Ministry for Planning;
- City of Mandurah;
- Shire of Waroona;
- CSIRO;
- Geological Survey of Western Australia; and
- Department of Conservation and Land Management.

The approach of the EPA has two key elements:

- a list of management criteria against which the environmental acceptability of new proposals can be measured; and
- an efficient decision making process which would only require Environmental Protection Authority and Department of Environmental Protection involvement in exceptional circumstances.

Section 10 describes the management criteria, which are summarised in Section 11. Section 12 deals with the decision making process and referrals to the Environmental Protection Authority.

10. Defining the catchment

Figure 4 shows the area of land which is the subject of these criteria and is a reasonable estimate of the land within the surface and fresh groundwater catchment of the lake. As indicated in Section 4, Part 1, there is a lack of good data on groundwater movement. In the absence of better information the catchment is generally defined as being between the ocean and the high ridge line to the east of the lake. The northern and southern boundaries have been chosen to run along convenient cadastral boundaries.

The north eastern section of the catchment is quite narrow and the eastern edge of the catchment boundary is less likely to coincide with the ridgeline between the lake and the Harvey Estuary. In this area, the catchment is extended east to the Old Coast Road.

In summary, the catchment includes:

- all the land to the west of Old Coast Road between an east-west line about 1.5 km south of White Hill Road and Preston Beach road; and
- all the land east of Old Coast Road which is also
  - west of the ridge line approximately 2 km from the lake,
  - south of where the ridgeline crosses Old Coast Road, and
  - north of Johnston Road.

11. Environmental management criteria for new developments

11.1 Introduction

Proposed management criteria have been set for certain land uses in the catchment: horticulture, rural/residential and tourist. Many of the criteria have been proposed by officers of the key agencies managing the impacts of particular land uses, with the remainder developed by officers of the Department of Environmental Protection. All except one criterion have received endorsement by the Environmental Protection Authority. The exception is the maximum fertilizer application rates as proposed by the Western Australia Department of Agriculture: this has received conditional endorsement by the Environmental Protection Authority (refer to Section 10.2.3).

Each section below is set out as follows:

- identification of issues;
- discussion of management criteria; and
- Environmental Protection Authority conclusions (bold type).

11.2 Horticulture

11.2.1 Key issues

The key environmental issues are:

- water allocation/abstraction; and
- fertilizer application — nutrient export.

11.2.2 Water allocation

The Water Authority has developed a policy for allocating water in the catchment (refer to Appendix 1). The following is a summary of that policy.

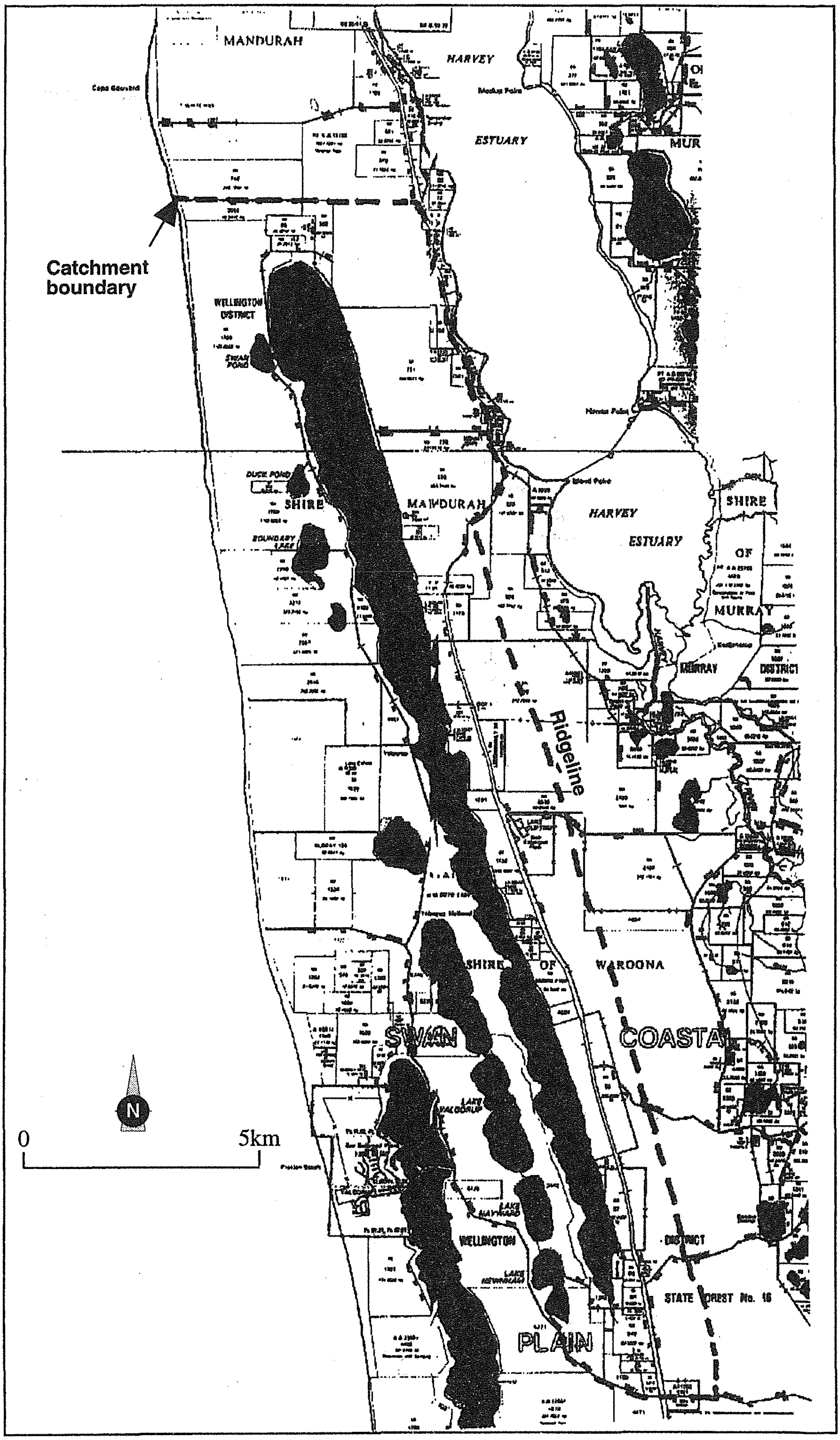

Figure 4. Land considered to be within the catchment of Lake Clifton for the purposes of this Strategy.

The catchment is comprised of three sub catchments (refer to Figure 4): Lake Clifton; Island Point and Coastal. The Water Authority have determined the water balances for each sub catchment and have allocated water for human purposes on a sustainable yield basis as follows:

- Lake Clifton 2 000 kL/Ha/year;
- Island Point 750 kL/Ha/year; and
- Coastal 375 kL/Ha/year.

These figures have been checked and endorsed as being accurate by officers/scientist from the Water Authority, Geological Survey of Western Australia, CSIRO and Department of Environmental Protection. It is expected that the application of this policy would lead to minimal changes to water levels in the lake.

A copy of the Water Authority's paper detailing its water allocation policy has been included as Appendix 1 in Part 3 of this report.

The Environmental Protection Authority concludes that the Water Authority's water allocation policy is sustainable, and would not in itself be a threat to Lake Clifton and the microbialites. The Environmental Protection Authority recommends that these volumes of water could be made available for human uses in the catchment provided that other impacts discussed in this Bulletin are managed within the other constraints proposed here.

11.2.3 Management measures required for new horticultural developments

As discussed earlier, horticulture has the potential to export significant quantities of nutrients which could end up in the groundwater and, ultimately, a nearby waterbody. Factors which determine the rate (if any) of nutrient loss include:

- fertilizer application rates;
- crop uptake;
- soil type (ability to retain nutrients);
- depth to groundwater;
- horizontal distance of the crop area from the waterbody (setback); and
- surface drainage.

There are two major soil types in the catchment: Spearwood and Vasse. The Department of Agriculture Western Australia has classified the Vasse soils as being unsuitable for horticulture, and the Spearwood soils as being amongst the best soils on the Swan Coastal Plain for horticulture. Appendix 2, Part 3, contains correspondence from the Department of Agriculture Western Australia regarding its proposed policy for horticulture in the catchment. In summary, the policy involves the following elements:

- no horticulture on the Vasse soils;
- a minimum set back from the lake of 100m with at least 20m of unused Spearwood sand between the crop and the Vasse soil;
- minimum depth to groundwater of 2m;
- a vegetated buffer of at least 20m to be retained within the horticulture exclusion zone;
- no surface water run-off from the horticultural area;
- maximum fertilizer rates for land west of Old Coast Road to be
  * nitrogen 200 Kg/Ha/Year
  * phosphorus 100 Kg/Ha/year;
- no limit set for fertilizer application east of Old Coast Road; and
- management should include soil testing so that fertilizer application rates can be modified accordingly to avoid "breakthrough" of phosphorus into the watertable.

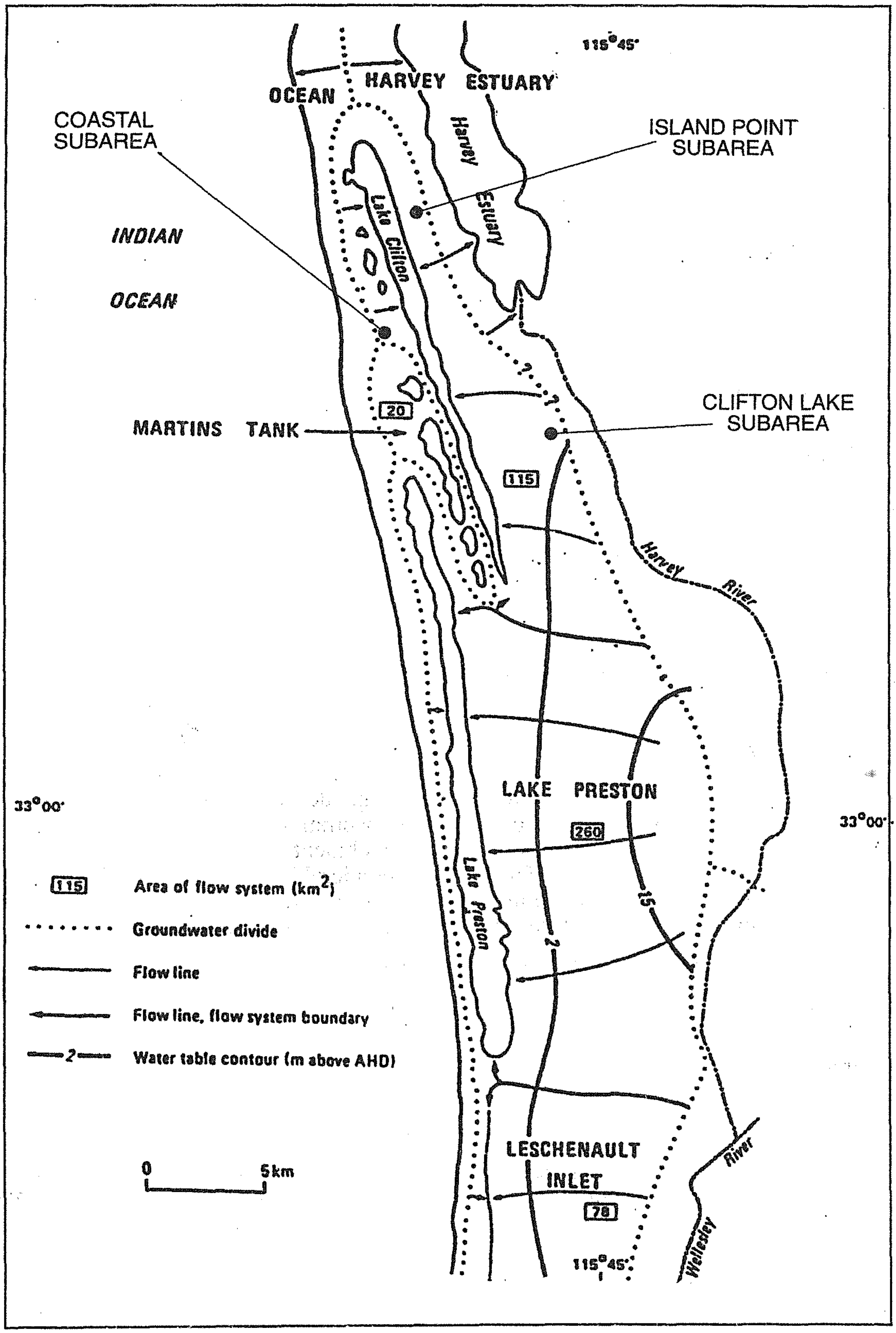

Figure 5. Water Authority sub catchments for the Lake Clifton catchment.

Advice from the Department of Conservation and Land Management indicates that setbacks from the lake should be at least 150m (Lane, *pers. comm.*).

The Environmental Protection Authority concludes that these measures provide a useful basis for managing horticulture in the catchment on a sustainable basis so that nutrient export to the lake is acceptable. However, the Environmental Protection Authority expresses some concern over the maximum fertilizer application rates being proposed by the Western Australia Department of Agriculture and seeks public comment on this issue in particular.

In the interim, maximum fertilizer application rates should be set at nitrogen, 100 Kg/Ha/year and phosphorus, 50 Kg/Ha/year. Decisions on proposals requiring greater than this but less than nitrogen, 200 Kg/Ha/year and phosphorus, 100 Kg/Ha/year should be deferred until the Environmental Protection Authority finalises these criteria.

Setbacks from the lake should be at least 150m with at least 20m from the edge of the wetland (refer to Section 4).

11.3 Rural residential developments

11.3.1 Environmental issues

The key environmental issues are:

- water balance;
- nutrient export; and
- physical impacts on the microbialites and vegetated lake buffer.

11.3.2 Water balance

Rural residential developments can lead to a significant change to the existing water balance, caused by clearing of deep rooted native vegetation and greater runoff of stormwater from hard surfaces and less loss of groundwater through evapotranspiration. Changes to water balance in Lake Clifton, particularly in the northern part of the catchment, which would lead to either an increase or decrease recharge to the aquifer, could affect microbialite growth. Ideally, the aim of any management controls is to maintain conditions to ensure microbialite survival which requires the post-development water balance to be the same as the pre-development level.

The critical factors in controlling water balance post-development are:

- amount of clearing of remnant native vegetation or amount of re-vegetation where lots are already cleared of native vegetation;
- the area of hard surfaces (roads and buildings); and
- water abstraction for human purposes.

For a development site which is to be subdivided in a standard way into smaller lots, the size of the new lot is important in determining the amount of clearing of native vegetation. Lot size determines the number of building envelopes, and the length of service roads and fire breaks needed. In short, the greater the size of the new lots the less total clearing of native vegetation will be required: in other words, changes to water balance would be less.

To maintain water balance for standard development of uncleared land, lot sizes should be set (ie. area of cleared vegetation restricted) so that the amount of water abstraction balances the increased recharge due to the loss of deep rooted native vegetation. Whilst this may seem to be a simple matter, in reality there are many uncertainties involved in carrying out the calculations required to determine the water balance. The matter is further complicated because many of the areas which could potentially be sub-divided are already cleared of native vegetation, and substantial re-vegetation can be expected following subdivision as new owners improve the rural aspects of their lots. In these cases, maintaining water balance to pre-development conditions is not possible.

Appendix 3 is a technical report prepared by the Department of Environmental Protection in consultation with the Water Authority showing likely changes to the overall water balance as the extent of clearing, re-vegetation and groundwater abstraction changes with lots size for standard rural residential developments. As the results suggest, there is considerable uncertainty involved in carrying out these calculations. However, it is the trends in the data which are useful in determining the effects of changes associated with rural residential developments on water balance for the lake.

The calculations in Appendix 3 should be seen as a reasonable estimate of the water balance changes as development proceeds. There is a lack of reliable information available which can be used to carry out these calculations, and estimates have had to be used in many cases. It is this lack of reliable information which prompted the Water Authority to carry out the Yalgorup Lakes study referred to in Section 1.

The matter of controlling water balance through appropriate lot size and design of subdivision is probably the most contentious issue in dealing with proposals for special rural residential developments.

Appendix 3 indicates that, based only on water balance considerations, a standard subsivision with lot size of 5 ha would not lead to a significant change in water balance. It also assumes that no additional clearing will take place outside the building envelopes. The final calculations were carried out assuming half of the lots to be created in the catchment will be on cleared land and half on land not cleared of native vegetation.

11.3.3 Water balance and subdivision design

In arriving at a conclusion about subdivision design including lot size the EPA took into account the following:

- advice from scientists with expertise in the management of Lake Clifton;
- advice from officers from relevant government departments; and
- Appendix 3 of this report.

The Environmental Protection Authority concludes that based on (a) advice from relevant scientists and officers from government departments, and (b) water balance considerations, assuming no additional, clearing is to take place outside the building envelopes or that required for service requirements and a domestic allocation of 1 500 kL per lot per year, if the lot size for standard rural residential developments is set at 5 ha, this would not result in a significant change in water balance. However, it may be possible for proponents to vary lot sizes below 5 Ha where the variables which cause water balance changes are set at what would be expected for 5 Ha lots: for example, the amount of clearing could be reduced.

Further, the environmental objectives as set out in this report could be achieved through more innovative subdivision design rather than the traditional largely single sized lot design.

The Environmental Protection Authority specifically seeks advice and comment on this issue.

The Environmental Protection Authority would support more research being carried out to look at the link between subdivision design and environmental impacts.

11.3.4 Nutrient export

The major sources of nutrients from rural residential developments are:

- effluent disposal;

- domestic gardens; and
- stock.

Nutrients from human effluent are highly mobile because they are dissolved in water and are considered to be of more concern than nutrients from fertilizers.

Septic tanks produce around 3.5 kg of phosphorus per year (human effluent and P detergents), and 18 kg of nitrogen per year (Gerritse et al, 1992). Work carried out by the Water Authority in Kwinana and Canning Vale where secondary treated effluent was allowed to recharge the superficial aquifer via treatment ponds built directly on different soils types showed that Spearwood soils were very poor at removing nutrients from the effluent as it leached through to the watertable, and that most of the nutrients reached the watertable (Ho et al, 1992).

Nutrients from stock (horses and sheep) should not pose a risk to the lake provided that the feed is produced on the lot and no supplementary feeding of stock is carried out. If stocking rates are determined in this manner, it is expected that the nutrient balance on the lots (excluding human sources) will be maintained with no export of nutrients.

The Environmental Protection Authority concludes that future rural/residential developments should be required to install alternative effluent systems which use amended soil with high nutrient retaining capacities to treat human effluent.

Domestic gardens are not considered to be a major concern provided that adequate land uses controls are applied through the planning process to exclude commercial horticultural activities.

Stock should only be allowed to control fire risk from uncontrolled growth of grasses, and at stocking rates for dry pasture with no importation of feed to be allowed. Stocking rates should be determined based on area of usable cleared land (excluding any buffer zone) and not total lot size.

11.3.5 Physical impacts on the microbialites and vegetated lake buffer

The microbialites and the vegetated fringe around the lake can be damaged by physical impacts, most notably, trampling. This is, in part, an issue of risk (the more people who visit the lake the greater the chance that damage will occur), and in part a question of providing an adequate buffer — ie keeping activities likely to cause damage as far as possible from the lake.

In managing rural residential developments, physical damage can be minimised by:

- limiting the number of people with direct access to the lake by either minimising the number of lots with direct frontage to the lake or other controls;
- limiting the number of people in the catchment (ie those people who may want to regularly recreate there);
- setting building envelopes and irrigation areas back from the lake;
- keeping stock away from the lake; and
- providing special management measures at the lake itself to control visitor access.

The first issue can be dealt with in one of two ways:

- lots sizes adjacent to the lake are to be larger; or
- lots adjacent to the lake should have a wider frontage than normal lots — lots should have a rectangular shape with the long side along the border with the lake or foreshore reserve. Taking into account lot size and setback constraints, the side of the lot abutting the lake should be as close as possible to 300m.

The Environmental Protection Authority concludes that, in order to minimise the direct physical impacts on the lake, its vegetated fringe and the microbialites, lots sizes for future rural/residential lots adjacent to the lake should be as large as possible, taking into account other constraints (ie set

backs). These lots should be designed to minimise the number of lots directly abutting the lake by having the longest side of each lot facing the lake.

The second issue relates to lot sizes: the smaller the lot size the greater the number of people in the catchment. This is a complex issue as it relates to risk, which is difficult to quantify and relate directly back to recommended minimum lot sizes. The risk can be reduced by addressing the last issue (providing management measures at the lake).

In the absence of any hard data on risk, the lot size recommended in Section 10.3.2 based on water balance considerations, would provide an acceptable level of risk as it relates to the issues discussed here provided that other management measures are put in place.

The issues in the third and forth bullet points above relate to adequate setbacks. Set backs should be set consistent with that specified for horticulture developments discussed earlier (section 10.2.3).

The Environmental Protection Authority recommends that, in order to minimise the direct physical impacts on the lake, its vegetated fringe and the microbialites, building envelopes should:

- **not be located on the Vasse landform type,**
- **be set back at least 150m from the highwater mark of the lake taking into account the landform and vegetation cover, and**
- **be set back at least 20m between the edge of the Vasse landform and/or freshwater wetland.**

Further, stock should be excluded from the area of the lot between the building envelopes and the lake.

11.3.6 Other land uses which could impact on Lake Clifton

There are numerous activities which if carried out within the catchment of Lake Clifton could threaten the quality of groundwater and ultimately the lake itself or the existing cover of native vegetation: for example disposal of engine oil, use of herbicides and high stocking rates. It is expected that these types of activities would be controlled through appropriate planning instruments: for example, Town Planning Schemes.

11.3.7 Summary

The recommendations made here should be seen as a package and any loosening of one criterion would require tightening of others. For example, recommended set backs from the lake are based on the assumption that alternative septic systems with amended soils will be installed. If conventional septic tanks were to be used, setbacks and lot sizes would need to be increased substantially.

11.4 Tourist developments

The key environmental issues associated with tourists (day visits) and tourist developments (for example, chalets) are:

- disposal of effluent; and
- physical impacts.

These developments should be assessed on a case-by-case basis but must be consistent with the Department of Conservation and Land Management's (for the National Park and Nature Conservation Authority) management plan for the Lake and Yalgorup National Park.

In the long term, the Western Australian Planning Commission's Coastal and Lakelands Planning Strategy will address tourist developments in the area.

The Environmental Protection Authority recommends that tourist developments must be consistent with the Department of Conservation and Land Management's (for the National Park and Nature Conservation Authority) management plan for the Lake and Yalgorup National Park (once finalised) and should be referred to the Environmental Protection Authority for environmental impact assessment.

Further, the City of Mandurah and the Shire of Waroona, in consultation with the local tourist industry and the Department of Conservation and Land Management, should develop a co-ordinated strategy, or Code of Practice, to manage day tourist visitors to Lake Clifton.

11.5 Other land uses — re-vegetation with high water using tree species

Proposals involving the revegetation, or the replacement of existing native vegetation, with high water using tree species (for example, blue gums) have the capacity to draw heavily on the superficial aquifer and affect the water balance of Lake Clifton, and should be assessed on a case by case basis.

Proposals involving the revegetation, or the replacement of existing native vegetation, with high water using tree species (for example, blue gums) should be referred to the Environmental Protection Authority for environmental impact assessment.

12. Summary of acceptability criteria

1. Horticultural developments

(a) water allocation:

- Lake Clifton sub-catchment 2 000 kL/Ha/year;
- Island Point sub-catchment 750 kL/Ha/year; and
- Coastal sub catchment 375 kL/Ha/year.

(b) management criteria:

- no horticulture on the Vasse soils;
- a minimum set back from the lake of 150m with at least 20m of unused Spearwood sand between the crop and the Vasse soil;
- minimum depth to groundwater of 2m;
- a vegetated buffer of at least 20m to be retained within the horticulture exclusion zone;
- no surface water run-off from the horticultural area;
- maximum fertilizer rates to be
  - * nitrogen 100 Kg/Ha/Year
  - * phosphorus 50 Kg/Ha/year

  with some flexibility to go up to 200 Kg of N and 100 Kg of P; and
- management should include soil testing so that fertilizer application rates can be modified according to avoid "breakthrough" of phosphorus into the watertable.

2. Rural residential developments

- for conventional subdivision design lot size to be 5 Ha with flexibility depending on detailed design elements;
- domestic water allocation to be 1 500 kL per lot per year;
- conventional septic systems should not be permitted and alternative effluent systems which use amended soil with high nutrient retaining capacities to treat the effluent should be used instead;
- stock should only be allowed to control fire risk from uncontrolled growth of grasses, and at stocking rates for dry pasture with no importation of feed should be allowed. Stocking rates should be determined based on area of cleared land excluding any buffer area, and not total lot size;
- either lots adjacent to the lake should be as large as possible, taking into account other constraints (ie set backs), and designed so the longest side of the lot abuts the lake or other control measures implemented;
- building envelopes should:
    * not be located on the Vasse landform type;
    * be set back at least 150m from the highwater mark of the lake, and
    * be set back at least 20m between the edge of the Vasse landform and/or freshwater wetland, and
- Stock should be excluded from the area of the lot between the building envelopes and the lake.

3. Tourist developments

- tourist developments must be consistent with the Department of Conservation and Land Management's (for the National Park and Nature Conservation Authority) management plan for the Lake and Yalgorup National Park and may require referral to the Environmental Protection Authority for environmental impact assessment. In the long term the Coastal and Lakeland Planning Strategy will address this issue;
- the City of Mandurah and the Shire of Waroona, in consultation with the local tourist industry and the Department of Conservation and Land Management, should develop a co-ordinated strategy to manage day tourist visitors to Lake Clifton.

4. Other proposals

- proposals involving the revegetation, or the replacement of existing native vegetation, with high water using tree species (for example, blue gums) should be referred to the Environmental Protection Authority for environmental impact assessment

5. Proposals not meeting these criteria

- where a proposal cannot meet the above criteria the Environmental Protection Authority would likely formally assess the proposal to ensure that it complies with the above criteria, or it would recommend to the Minister for the Environment that it be refused.

13. Making decisions on proposals in Lake Clifton catchment — referrals to the Environmental Protection Authority

13.1 General

It is expected that these criteria will provide developers and decision makers with clear guidance on the environmental acceptability of proposals in the catchment. The relevant government agencies (including local government) have been requested to deal directly with land owners/developers prior to any consideration of a referral to the EPA. Land owners/developers should be encouraged to modify proposals to be consistent with these criteria. **Proposals consistent with these criteria as determined by the planning agencies, once finalised, would not require a referral to the Environmental Protection Authority.**

Inquiries regarding rural/residential and tourist developments should be made directly to the relevant local authority, which will then decide on whether a referral to the Environmental Protection Authority is required. Applications for new, or for expansions to existing, horticultural developments involve a number of government agencies, and should be dealt with as described in Section 12.2.

13.2 Gaining approval for new horticultural developments

Horticultural developments normally require a licence to abstract groundwater. In addition, if the property is within the Shire of Waroona planning approval is also required. It is recommended that individuals wishing to carry out new horticultural pursuits should follow this process:

- Contact the local office of the Department of Agriculture Western Australia to obtain a copy of a horticulture application questionnaire.
- In consultation with officers of the Department of Agriculture Western Australia complete the questionnaire providing all the relevant information — use the above criteria as a guide in formulating the proposal.
- Take copies of the completed questionnaire to the Water Authority (and Shire of Waroona if in that Shire) to seek the necessary approvals.
- If the application meets the above criteria, including water availability, <u>and involves the application of less than 50 Kg of phosphorus per Ha per year and 100 Kg of nitrogen per Ha per year,</u> then the proposal would be environmentally acceptable and no referral to the Environmental Protection Authority is required.
- If the application meets the above criteria, including water availability, <u>and involves the application of more than 50 Kg of phosphorus per Ha per year and 100 Kg of nitrogen per Ha per year (but less than 100 Kg of phosphorus per Ha per year and 200 Kg of nitrogen per Ha per year)</u> then a decision to approve it should be deferred until after the Environmental Protection Authority has finalised the criteria.
- If the application can not meet the above criteria then a referral to the Environmental Protection Authority is required, and it is likely that the Environmental Protection Authority would find the proposal environmentally unacceptable.

14. Public participation

The criteria have been released as a draft for public comment for eight weeks. Submissions on these criteria should reach the Department of Environmental Protection by the 26 January 1996, marked to the attention of Garry Middle. The Department's address is 141 St Georges Tce, Perth 6000.

Following the review of submissions, the Environmental Protection Authority will release its final criteria.

15. Review of the criteria

It is expected that the results of the Yalgorup Lakes Study would establish a monitoring programme for the superficial aquifer and Lake Clifton's water quality. The EPA will seek advice from the relevant agencies regarding the outcomes of that monitoring to assess the success of these criteria.

Should the monitoring suggest that, despite the efforts of land owners and government agencies in managing the catchment, the microbialites may not survive in the long term, the Environmental Protection Authority may consider that an Environmental Protection Policy is required for the catchment.

16. References

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Part 3 — Technical information/Appendices

Appendix 1

Report from the Water Authority of Western Australia on water balance in the catchment of Lake Clifton

DEVELOPING A GROUNDWATER MANAGEMENT STRATEGY FOR PROTECTING LAKE CLIFTON'S ECOSYSTEM

Tim Katsavounidis
Groundwater and Environment Branch
Water Authority of Western Australia
June 27, 1994

Lake Clifton is one of eleven lakes which comprise the Clifton-Preston wetland system, south of Mandurah. The lake has been nationally and internationally recognised as significant due to the presence of living microbialites (sometimes called stromatolites) and the hydrology that supports them. The microbialites form large reefs on the eastern side of Lake Clifton, and are dependent on fresh groundwater discharging into the lake.

Because of the location of Lake Clifton, near Mandurah, and its scenic nature, there is a demand for land development in its vicinity. The existing large rural lots are being subdivided into smaller mainly rural residential lots. Small horticultural activities have been established south east of the lake, and tourist activities may also be developed. Without proper management, these developments may adversely impact on the Lake Clifton ecosystem.

Clearing of land may cause water levels to rise, and the application of fertilisers, the establishment of large numbers of sceptic tanks, and the presence of livestock may increase the nutrient concentration in the lake and lead to the formation of algae, which would be detrimental to the microbialites.

The Water Authority recognises the need for developing a strategy to protect the ecosystem in Lake Clifton. This strategy requires the selection of appropriate criteria to limit water level changes and nutrient inputs into the lake and the development of a contingency plan if the lake shows signs of degradation. Based on these criteria, a land planning strategy should be developed limiting activities which may endanger the lake's ecosystem.

Hydrogeology

Lake Clifton lies at the western edge of the Swan Coastal Plain. Most of the area around the lake is occupied by the Spearwood Dune System. This consists of interbedded limestone and sand, extending to a depth of 20 to 30 metres. These sediments form an unconfined aquifer system containing significant water resources.

The direction of groundwater flow in the unconfined aquifer is influenced by the presence of lakes Clifton and Preston, the Harvey Estuary and the Harvey River. The water level in Lake Clifton is maintained mostly by direct rainfall recharge and groundwater flow. Some surface flow also discharges into the lake after major rainfall events, but this is thought to be small.

Lake Clifton, is a groundwater sink, where evaporation is believed to be the only outflow. The groundwater discharging into the lake, is believed to equal the deficit between rainfall input and evaporation from the lake in a given year. Using this approach, the Geological Survey of Western Australia in 1988, calculated groundwater discharge into the lake to be of the order of 4×10^6 kL/year.

The groundwater flow system discharging into Lake Clifton, is believed to cover an area of around 97 km^2, see figure 1. The lake itself covers an additional 18 km^2 when full. The groundwater flow system is bounded to the south by the Lake Preston flow system, to the east by the Harvey Estuary and Harvey River flow systems and to the west by the Martins Tank flow system. The boundaries of the flow system are not accurately known and further studies are required to define these boundaries and study the hydrogeology of the lake's flow system in more detail.

Recharge to the Lake Clifton flow system is from direct rainfall over the area of the flow system. Groundwater flow is towards the lake under a very low hydraulic gradient.

Due to the limestone environment, the water levels are not expected to vary significantly. Figure 2 shows the seasonal variation of the water level in Lake Clifton. The water level in the last two years has varied between 0.8 and -0.2 metres AHD. Also included are hydrographs of Geological Survey of W.A. and privately owned and operated bores, located east of Lake Clifton as indicated in figure 4 (Note that the property and the bore of Mr Ellis has been sold to Mr Hansen, but in the Authority's data base, the bore still retains the previous owner's name. Similary Mr Roberts bore has been sold to Mr Collins). These hydrographs show the water levels near the lake have not changed significantly over the past ten years.

Groundwater salinity is least in the south eastern part of the flow system, at around 250 mg/L TDS. Salinity increases towards Lake Clifton. In the vicinity of the lake, the groundwater is stratified, with fresh groundwater overlying saline water. The fresh / saline water interface may be found at a depth of around 10 metres below the water table. The salinity of the water in the lake itself, varies seasonally between 15 000 and 26 000 mg/L TDS.

Water Authority's Groundwater Management Policies

Lake Clifton is located in the South West Coastal Groundwater Area, which was proclaimed by the Water Authority in 1977. In September 1989, the Water Authority developed a Groundwater Management Plan, which outlines the Water Authority's policy on the exploitation of the groundwater resources in the area.

The Groundwater Management Plan, estimated groundwater availability in the unconfined aquifer as a percentage of average annual rainfall. It is believed this method provides a better estimate of groundwater availability in the unconfined aquifer, than throughflow calculations.

The rate of aquifer recharge from rainfall is depended on several factors. The most important of which are outlined below:

Vegetation Cover	CSIRO experimental studies on the Gnangara Mound (Sharma et al) have estimated annual recharge rates as a percentage of average annual rainfall, depending on vegetation cover. These studies have found that recharge increases as the land is cleared, for example recharge to a natural Banksia Woodland is 15% to 30%, a dense Pine Plantation 0% to 8% and pasture 50% to 60%.
Depth to Water Table	When the water table is near the surface, less recharge occurs because of the combined impact of increased evapotranspiration and reduced aquifer storage. In the Lake Clifton flow system, the water table varies between 0 and 15 metres below the surface.
Surface Soil	Recharge decreases significantly as the clay or silt content of the soil increases. Recharge over sand or limestone is very high.
Land Use	Buildings and roads result in a significant increase in recharge if excess water is not routed out of the catchment. Irrigated pasture tends to have a higher recharge rate than non-irrigated pasture.

To better manage the groundwater resources around Lake Clifton, the Water Authority has divided the Lake Clifton groundwater flow system into three subareas. Lake Clifton subarea is found east of Lake Clifton and south of the Harvey Estuary. Island Point subarea is located between Lake Clifton and the Harvey Estuary, while the Coastal subarea is found west of Lake Clifton.

For each of these subareas a groundwater allocation policy has been developed by accounting for the local hydrogeology and for the previously mentioned factors effecting rainfall recharge. The Lake Clifton subarea has a higher clay content than the Island Point and Coastal subareas, which translates to a lower rainfall recharge figure. Based on previous experience, the annual recharge to the aquifer, as a percentage of the average annual rainfall, was conservatively estimated to be 10% for the Lake Clifton subarea, and 20% for the Island Point and Coastal subareas. The remaining 80% to 90% is accounted for by evapotranspiration.

Table 1, summarises the total annual recharge expected in the Lake Clifton flow system (excluding the lake itself), assuming that the land is naturally vegetated and has not been cleared. Average annual rainfall was taken as 900 mm.

TABLE 1

Subarea	**Area of Lake Clifton Groundwater Flow System (km^2)**	**Estimated Recharge as a Percentage of Rainfall**	**Total Annual Aquifer Recharge From Rainfall (kL)**
Lake Clifton	71	10%	6.4×10^6
Island Point	12	20%	2.2×10^6
Coastal	14	20%	2.5×10^6
Total	97		**11.1×10^6**

A portion of the rainfall that becomes groundwater, flows into Lake Clifton to maintain the lake's ecosystem, and to maintain the salt water interface found around Lake Clifton. The remaining groundwater is either extracted from the aquifer by groundwater users, or is taken up by the vegetation.

The Water Authority has developed a policy of allocating a percentage of the annual rainfall recharge for interface maintenance. This policy was developed based on previous experience and is being widely used throughout the State. The nature of the flow systems and location of saltwater interfaces will determine the percentage of rainfall recharge allocated for interface maintenance in each subarea.

In the Lake Clifton subarea, a saltwater interface occurs at the eastern side of the lake and extends a short distance to the east. In this subarea, 25% of the rainfall recharge has been allocated for saltwater interface maintenance.

In the Island Point subarea, the saltwater interface found adjacent Lake Clifton extents further to the east and saltwater occurs beneath the groundwater divide. Because of this, 50% of the annual rainfall recharge in the Island Point subarea is required to maintain the interface.

West of the lake, in the Coastal subarea, fresh groundwater occurs as a thin lens underlain by salt water. Salt water interfaces occurs on the western side of the lake and along the coast. Here, 75% of the annual rainfall recharge has been allocated for interface maintenance.

Table 2 below, summarises the quantity of groundwater allocated for interface maintenance which discharges into Lake Clifton from each subarea based on current Water Authority policies. This policy should ensure sufficient groundwater to discharge into Lake Clifton and maintain the lake level and the associated ecosystem.

TABLE 2

Subarea	Area of Lake Clifton Groundwater Flow System (km^2)	Estimated Recharge as a Percentage of Rainfall	Percentage of rainfall discharging into Lake Clifton as groundwater	Annual groundwater discharge into Lake Clifton (kL)
Lake Clifton	71	10%	2.5%	1.6×10^6
Island Point	12	20%	10%	1.1×10^6
Coastal	14	20%	15%	1.9×10^6
Total	97			**4.6×10^6**

The remaining water recharging the aquifer has been allocated for private use, through the Water Authority's groundwater licensing system. Table 3, below summarises the maximum groundwater quantities that may be abstracted without detrimentally effecting the lake's water level.

TABLE 3

Subarea	Area of Lake Clifton Groundwater Flow System (km^2)	Allocation for Private Use as a Percentage of Rainfall Recharge	Total Annual Groundwater Availability for Private Use (kL)	Annual Groundwater Availability for Private Use (kL/hectare)	Water Authority Allocation Policy (kL/hectare)
Lake Clifton	71	7.5%	4.8×10^6	2 300 *	2 000
Island Point	12	10%	1.1×10^6	920	750
Coastal	14	5%	0.6×10^6	430	375
Total	97	7.5%	6.5×10^6		

Note: * In the Lake Clifton subarea, only around 21 km^2 of the 71 km^2 have the potential to be developed in the future. The remaining land consists of a State Forest, and land just west of the Harvey River. For the remaining two subareas, due to their proximity to the lake and major access roads, as a worst case scenario, it was assumed that all of these areas have the potential to be developed.

The Water Authority has developed a management strategy that reduces the risk of salt water upconing and minimises the possibility of recycling salts. The policy allocates water on a per hectare basis, and limits the use of high yielding bores. Again a conservative approach was taken, where groundwater abstraction in the Lake Clifton subarea was limited to 2 000 kL/ha, in the Island Point subarea to 750 kL/ha, and in the Coastal subarea to 375 kL/ha. Also, not all of the groundwater extracted from the aquifer is lost. Previous studies have shown that a significant portion of the water used for irrigation, infiltrates into the water table to become groundwater.

The policy adopted by the Water Authority, reduces the risk that excessive groundwater abstraction may disturb the very low hydraulic gradient which would potentially impact on the groundwater flow system and in particular on the groundwater discharge into Lake Clifton.

Future Land Clearing

If the land surrounding Lake Clifton is substantially developed in the future, the rainfall recharge will increase. To obtain a rough estimate of the likely increase in rainfall recharge due to land clearing, results from previous studies may be used.

Following from the Perth Urban Water Balance Study (PUWBS), the Water Authority completed a sensitivity analysis in June 1989, of the recharge model used in PUWBS. This work can be assumed to be directly transferable here (as the rainfall, soil types, etc for Perth and Mandurah are similar), and may be used to estimate the possible impacts to water levels due to future land clearing.

Figure 3 illustrates how annual rainfall recharge varies as a function of canopy cover (an indication of land clearing) and depth to the water table, in a vacant rural lot. As land is being cleared, rainfall recharge increases significantly.

Increased recharge will result in rising water levels and an increase of the aquifer storage. In a limestone environment like Lake Clifton's, water level rises are expected to be small, as groundwater is able to flow more readily. Significant water table rises may only be experienced beneath the cleared land. As the water table rises over these areas, the local hydraulic gradient may change, altering the local groundwater flow directions. Areas in the vicinity of the cleared land will also experience water table rises, and the lake's level may also rise since discharge into the lake will increase.

Should significant areas of land be cleared or even urbanised, the additional rainfall recharge may be higher, and larger water level rises may be experienced.

Eventually a new equilibrium will be reached and the water table rise at a given area will be a combination of a number of factors, such as the local hydrogeology, increased recharge, evapotranspiration losses, distance from the cleared areas, aquifer storativity and groundwater discharge and abstraction.

Land clearing in the vicinity of Lake Clifton carried out between 20 and 40 years ago, may have already caused water levels in the lake to rise. If land clearing continues the water levels are expected to continue to rise. The rise will be more pronounced if groundwater abstraction is restricted. Instead, by increasing groundwater abstraction (ie allocating more water groundwater for private use), the rise may be limited.

To better define the local hydrogeology and the possible water level changes due to land clearing and groundwater abstraction, a hydrological study is proposed under the National Landcare Program (NLP).

Developing a Set of Criteria

(a) Water Level Criteria

In a limestone environment any natural seasonal water level variations are likely to be small. The microbialites present in Lake Clifton are therefore believed to be susceptible to significant water level changes, that may be brought about by large developments and land clearing in the vicinity of Lake Clifton.

Developing a set of criteria to protect Lake Clifton's ecosystem using groundwater allocation policies, is not thought to be appropriate due to the number of variables which need to be taken into account. A better method is to develop appropriate land planning strategies, and a set of environmental criteria for the lake itself by setting limits on water level and water quality changes. The proposed NLP study may define the required environmental criteria, based on scientific data.

In the absence of detailed scientific data and until the appropriate criteria are established by the proposed study, preliminary environmental criteria may be set, in conjunction with the Department of Environmental Protection (DEP) and CSIRO.

The preliminary set of criteria may include a minimum and a maximum water level for the lake. Currently a total of eight bores located in the Lake Clifton's groundwater flow system are being monitored for water level variations. These are privately owned and operated. In addition CSIRO monitors the water level of the lake (figure 2).

The lake's water level has only been monitored for the last two years. These data by themselves are not regarded sufficient to develop water criteria for the lake, since they do not reflect the variation in annual rainfall. However, water level data collected from the eight private bores monitored by the Water Authority, indicate that levels have not changed for the last ten years. It can therefore be assumed with some confidence that the lake's level does not vary significantly from year to year. The criteria may then be set as the minimum (-0.2 m AHD) and maximum levels (0.8 m AHD) recorded in the lake. As more data become available, the criteria may be changed to better reflect the lake's environment.

If levels fall below the minimum limit, the Water Authority can modify the groundwater abstraction from the lake's catchment area. This can be done using the Rights in Water and Irrigation Act (1987). Section 26 G of the Act states:

> "(1) *If the Authority is of the opinion that water drawn from any artesian well or from a non-artesian well in relation to which subsection 26B (3) applies, whenever constructed -*
>
> ....
>
> *(c) is having harmful effect*
>
> ...
>
> *the Authority may, after giving 30 days notice of the intention in that regard, direct the closing or partial closing of the well or direct such other steps (including any reasonable repairs and*

alterations) to be taken as the Authority thinks necessary to prevent the continuance of any of the things mentioned in paragraph ... (c)..."

If the lake's level rise significantly, a drainage scheme to remove water from the lake may have to be considered.

(b) Nutrient Inputs

The discharge of significant quantities of nutrients may also endanger the natural ecosystem of the lake. Increased nutrient concentrations in the lake may lead to the formation of algae, increasing competition for the resources, which may be detrimental to the microbialites.

The majority of the land in the Lake Clifton's catchment area is zoned rural, where the application of fertilisers is the major contributor of nutrients in the groundwater. Previous studies have been carried out in the Swan Coastal Plain, which estimated the nitrogen and phosphorous application rates for different land uses. Indicative nitrate and phosphorous application rates for a given land use are shown in Table 4 below.

TABLE 4

Land Use	**Nitrogen Application Rates (kg of N / ha / year)**	**Phosphorous Application Rates (kg of P / ha / year)**
Horticulture	600	100
Other Irrigated Land	200	40
Non-Irrigated Land	40	10
Special Rural Use	35*	10*
Grazing	170	10
Residential	180	40

Note * These figures area based on the use of conventional septic tanks.

As can be seen in Table 4, the nutrient application rates in Special Rural zoned lots are small compared with the application rates expected for other rural activities, such as horticulture. Although the phosphorous application rates are much lower than the application rates of nitrogen, phosphorous is regarded as more significant, because it is directly related to the formation and growth of algae.

The results obtained from the CSIRO studies regarding the leaching of phosphorous below the root zone were not very consistent. However, a study carried out by Townley and Turner during 1992/93, in the Mandogalup area which has similar soils to Lake Clifton, indicated that most of the phosphorous was absorbed in the soil. The study examined the mobility of phosphate through the soil, and estimated the travel time for phosphate to move vertically through 1 metre of soil, to be of the order of 6 to 50 years, depending on application rates. Another CSIRO report, completed by Sharma in 1991, estimated the time required for a PO_4 parcel to move vertically 1 metre through Spearwood sands, to be of the order of 20 years.

Previous studies carried out at Rottnest Island with similar calcareous soils, concluded that most of the phosphorous will be bound with calcium when passing through the soil to form calcium phosphates. Because the transformation mechanism is slow, the amount of phosphorous that is bound will depend on its rate of movement through the soil, but theoretically it could be as high as 99%.

Altough not as significant as phosphorous, the concentration of nitrogen is nevertheless important to the ecosystem of the lake. As for phosphorous, not all of the nitrogen applied will leach to the water table, as denitrification occurs in the subsoil, and a portion will also be absorbed in the root zone. Denitrification varies with the nature of the soil, the fertiliser type application rates and the watering regime.

Most of the work on nutrient leaching completed to date, studied the process on Bassendean sand profiles, rather than on Spearwood sands, which are found around Lake Clifton. A study carried out by CSIRO investigated the denitrification rates of the Bassendean soils in the Swan Coastal Plain (Wanneroo). This study estimated that around 60% of the nitrogen applied on lots used for horticulture, was lost through denitrification, or absborbed in the root zone.

Work carried out comparing the denitrification capacity of Bassendean and Spearwood sands has not been conclusive. In 1988, Gerritse's studies in the Swan Coastal Plain, indicated that in Spearwood sands conditions were less suitable for denitrifying bacteria, with nitrate concentrations in groundwater significantly higher than those in Bassendean sands. However, recent work by Sharma, in the Perth Metropolitan Area, suggest that for the same amount of applied N, leaching is much higher in Bassendean sands, than in Spearwood sands. Clearly more work has to be carried out on Spearwood sand profiles to accurately determine their denitrifying capacity.

The Water Authority's groundwater allocation policy for thai area, does not provide for land activities requiring large quantities of water and which provide a significant pollution threat. Only small scale horticulture projects can be considered under the existing policy.Therefore the contribution of nutrients in groundwater discharging into the lake will not be significant, if current policies are implemented.

A study by CALM and the Water Authority currently underway, has identified several other mechanisms of nutrient discharge into the lake that may be more significant than groundwater. High water levels in the lake may be the greatest contributor of nutrients into the lake. As the water level of the lake rises due to winter rainfalls, the land around the lake is inundated, and nutrients from fertilisers or livestock are washed into the lake as the waters retreat.

Also, as the water table on the land around the lake is near the surface, major rainfall events produce some surface flow into the lake. Although the surface flow has a high nutrient content, the quantity of the water discharging into the lake is small. A farm located in the south eastern part of the lake, may be a significant contributor of nutrients into the lake due to localised surface flows.

To reduce the risk of nutrients discharging into the lake from the surface sources, a buffer zone around the lake may be declared. Also, the establishment of a fence around parts of the lake would assist to limit any livestock going near the lake. Other methods of reducing the nutrient inflow into the lake, include the use of more appropriate fertilisers and application rates, effective on-site sewage disposal systems, and restrictions on land activities such as horticulture.

Due to a lack of historical data, it may be premature at this stage to develop a set of water quality criteria for Lake Clifton. It is recommended though that the concentration of nutrients in Lake Clifton is monitored on a regular basis (every three months) to determine if there is a trend. The NLP study should investigate more fully the mechanism of nitrate and phosphorous inflows to the lake, and attempt to determine appropriate strategies for limiting these inflows.

Conclusion

The Water Authority recognises the need to develop a set of criteria to protect the delicate Lake Clifton ecosystem. The regional hydrogeology of the lake is not well known, but the NLP study may provide more details on the local hydrogeology.

Current data, suggest that Lake Clifton is a groundwater sink where evaporation is believed to be the only outflow from the lake. The lake's water level is maintained by groundwater discharging into the lake which has been estimated to be around 4×10^6 kL/year.

The Water Authority has developed a groundwater management policy allocating water for private use on a per hectare basis, limiting the groundwater that may be abstracted from a given area. This policy allows sufficient groundwater to flow to Lake Clifton to maintain water levels, while restricting the establishment of rural activities which may endanger the lake's ecosystem.

If significant land developments in the lake's catchment area are allowed to proceed, the water levels and possibly the nutrient content of the lake could increase. This may adversely effect the natural ecosystem of the lake. Appropriate land planning strategies and environmental criteria for the lake should be developed to protect the lake's ecosystem.

In the absence of detailed scientific data, preliminary environmental criteria may be set, in conjunction with the Department of Environmental Protection (DEP) and CSIRO. Presently, the preliminary set of criteria may include a minimum and a maximum water level for the lake. Using previous water level data of the lake, the minimum level of the lake may be set at -0.2 m AHD, and the maximum level at 0.8 m AHD.

The current Rights in Water and Irrigation Act (1987) provides a means to modify the groundwater abstraction from the Lake Clifton's catchment area should a need arise.

A drainage scheme may need to be considered to limit any significant water level rise in the lake.

The discharge of significant quantities of nutrients are not encouraged by the Water Authority's groundwater allocation policies, which limit the water usage. On site denitrification and the binding of phosphorous by carbonate in the soil, will further limit the amount of nutrients discharging into the lake.

A buffer zone around the lake will reduce nutrient movement into the lake, from surface flows, which are thought to be the main mechanism of nutrient discharge into the lake. A fence established around part of the lake, would assist to reduce the number of livestock near the lake.

Because of the lack of historical data, it may not be appropriate to develop a set of water quality criteria for Lake Clifton at this time. Rather, a set of water quality criteria should be determined after further study and monitoring is completed.

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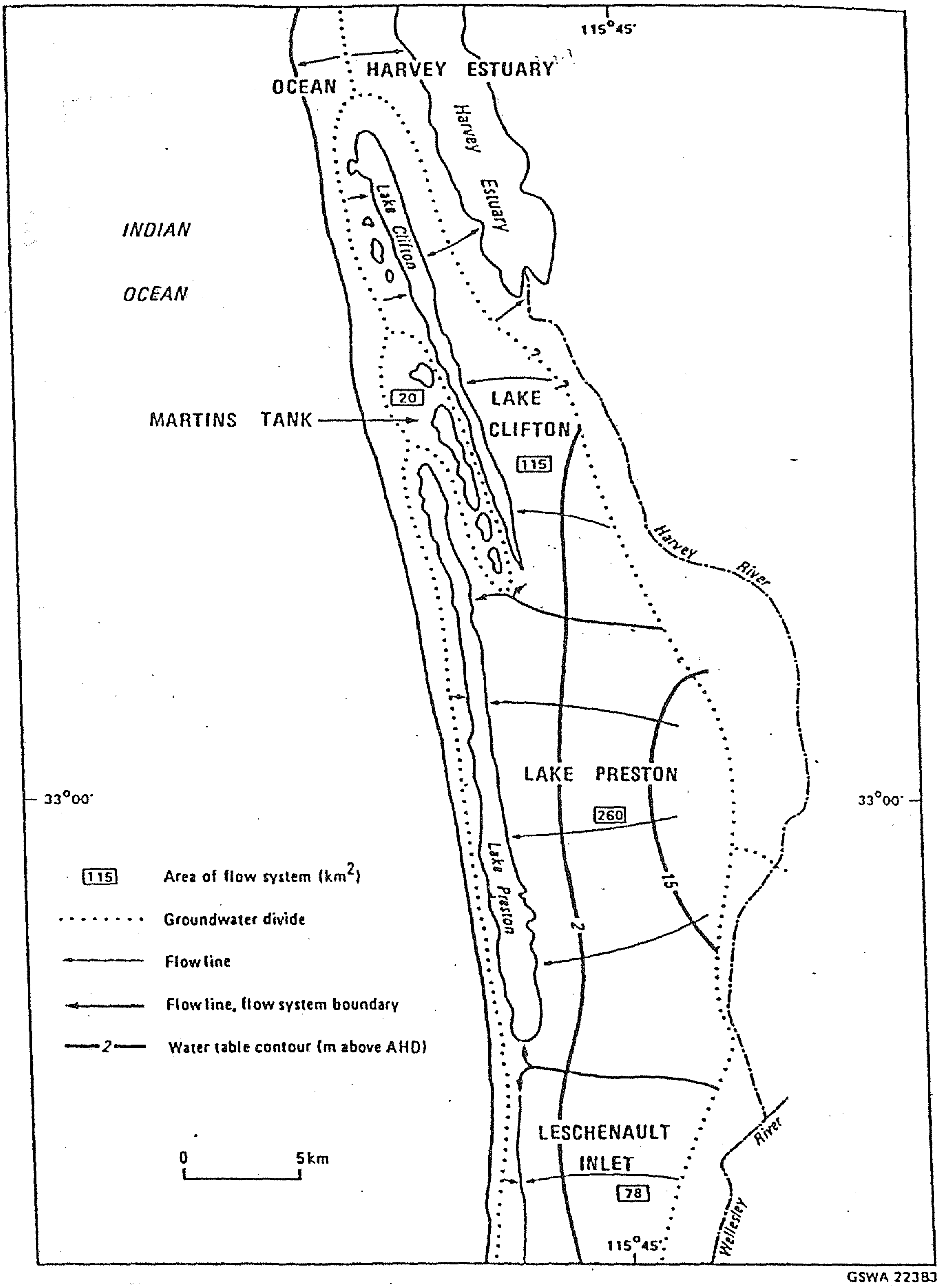

Groundwater Flow System - Lake Clifton

Reproduced From GSWA Reports

Figure 1

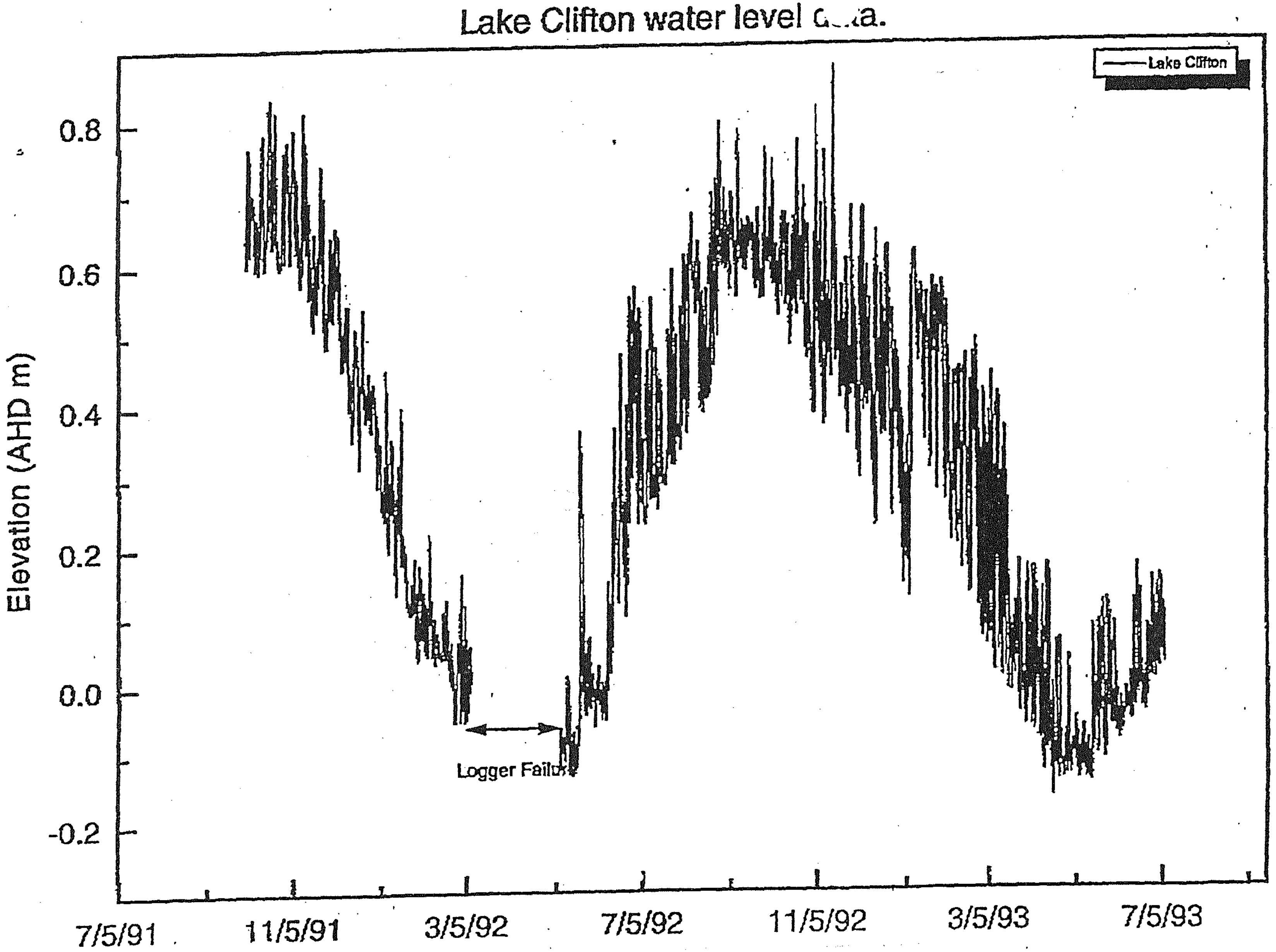

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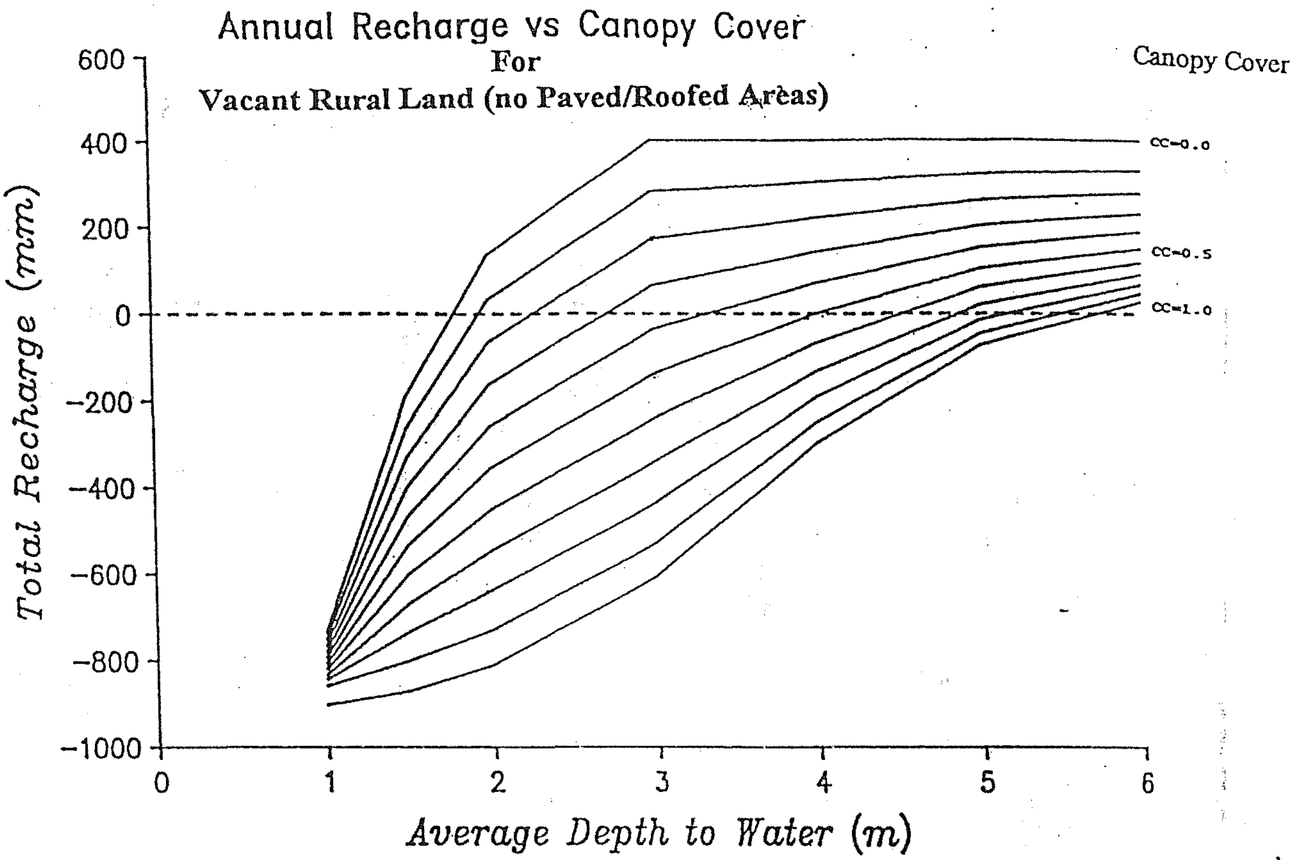
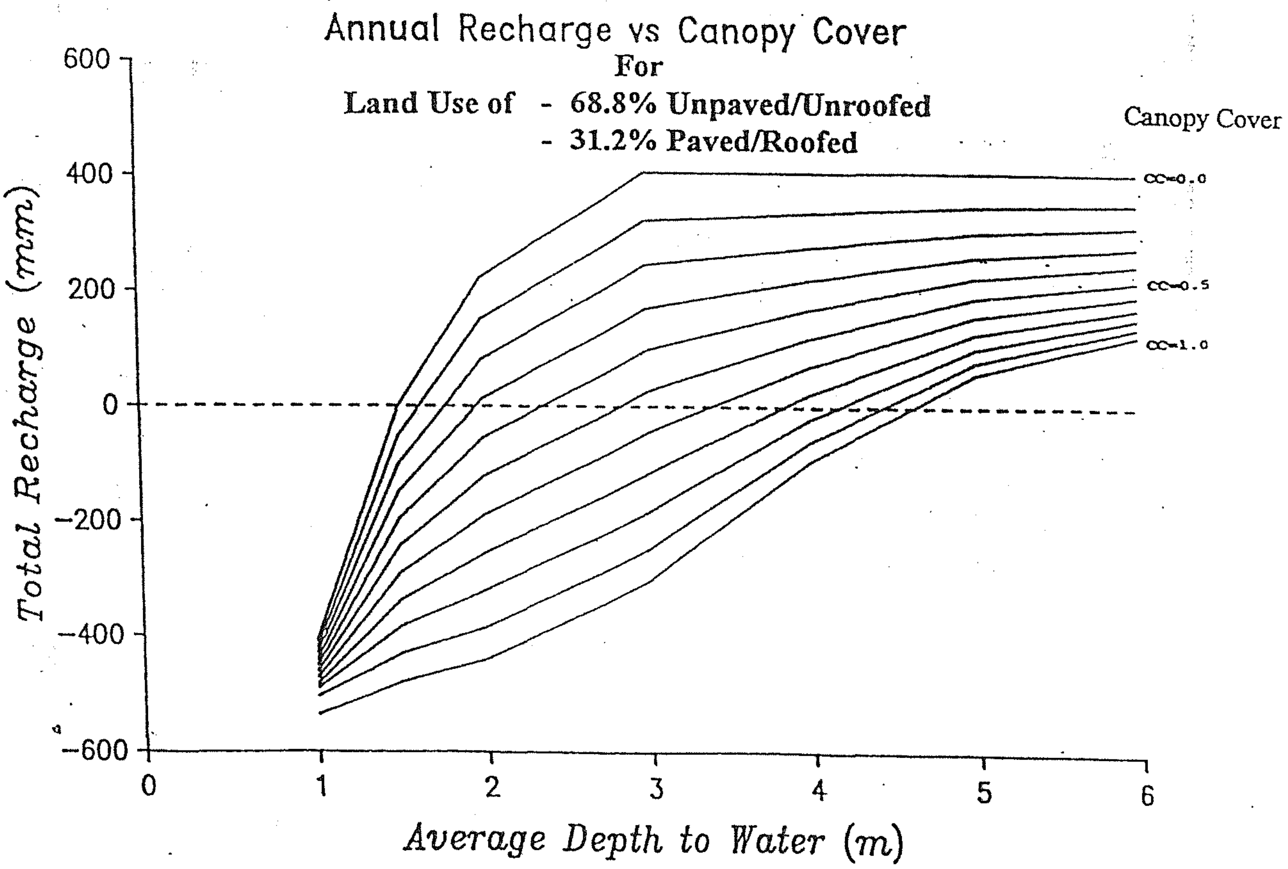
Figure 2





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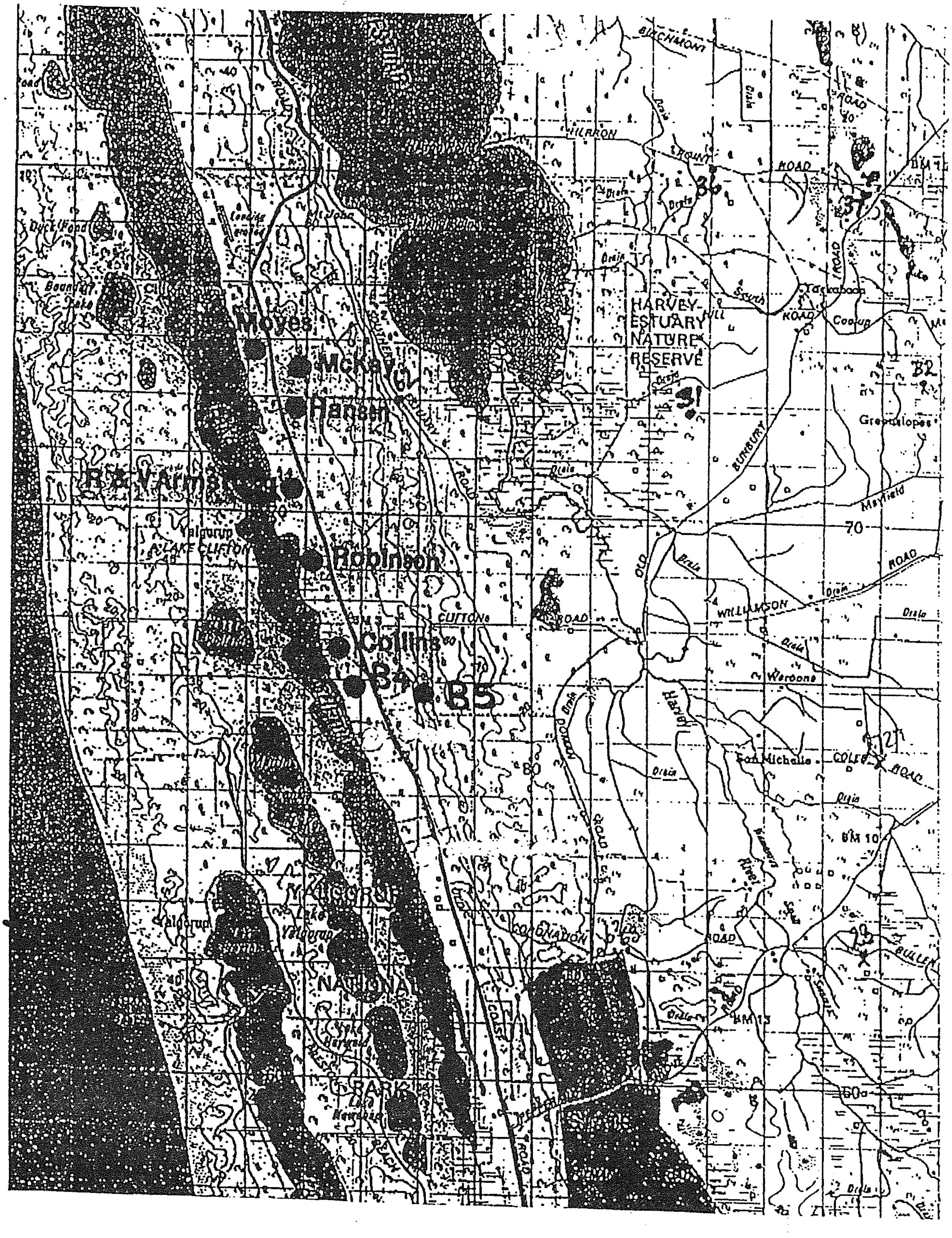
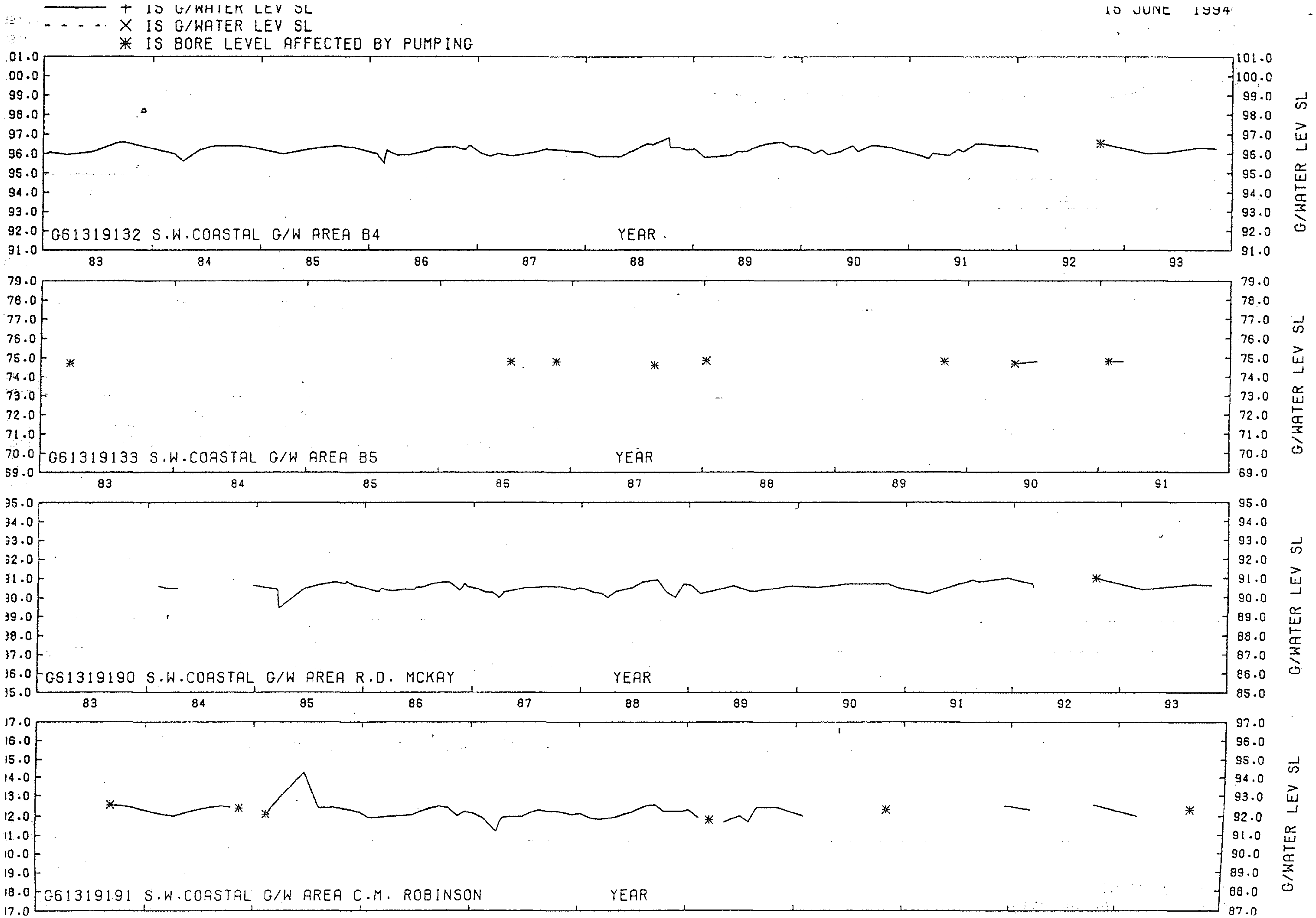


Private Bores Being Monitored Around Lake Clifton

Figure 4

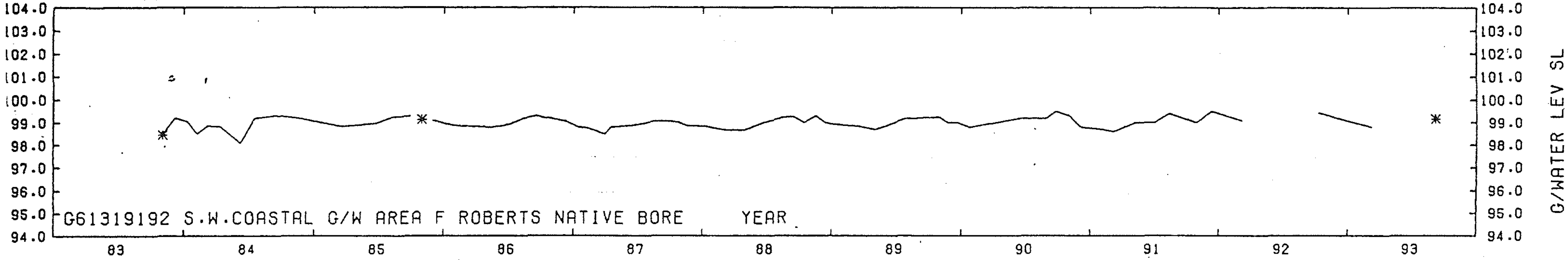


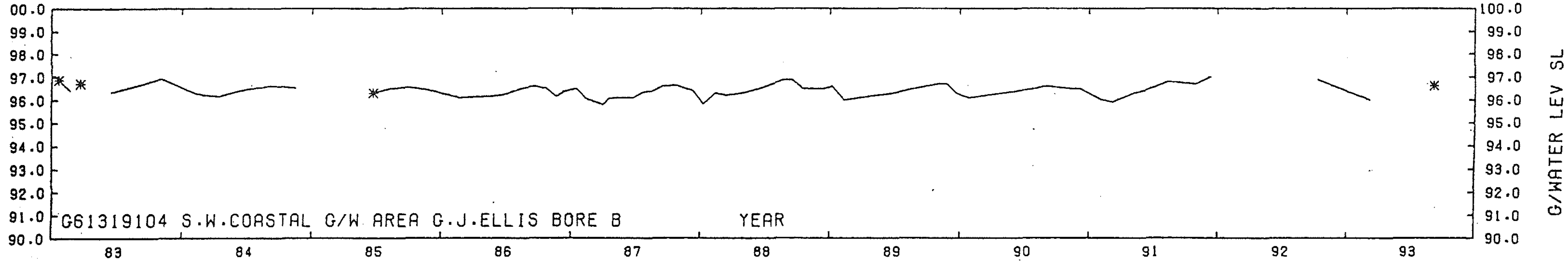
+ IS G/WATER LEV SL
X IS G/WATER LEV SL
* IS BORE LEVEL AFFECTED BY PUMPING
15 JUNE 1994
G61319132 S.W.COASTAL G/W AREA B4
G61319133 S.W.COASTAL G/W AREA B5
G61319190 S.W.COASTAL G/W AREA R.D. MCKAY
G61319191 S.W.COASTAL G/W AREA C.M. ROBINSON
YEAR
G/WATER LEV SL

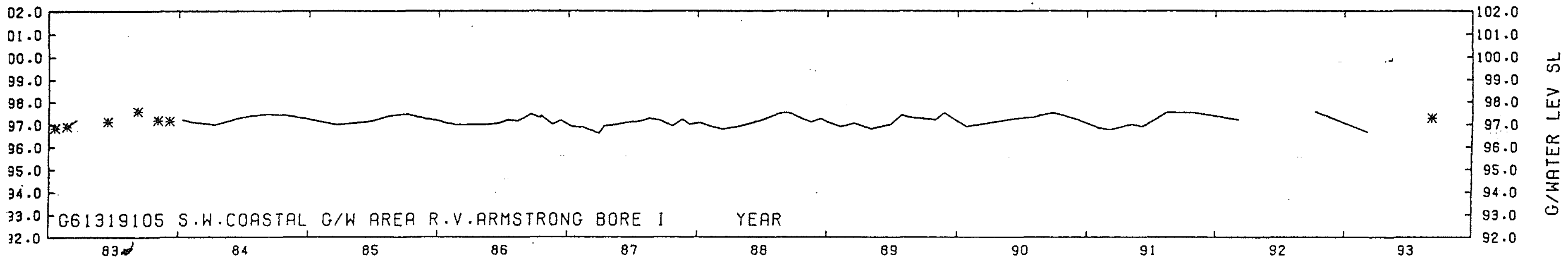
GAPS ARE LEFT IN PLOTS IF NO DATA FOR PERIOD IN EXCESS OF 0.5 YEARS

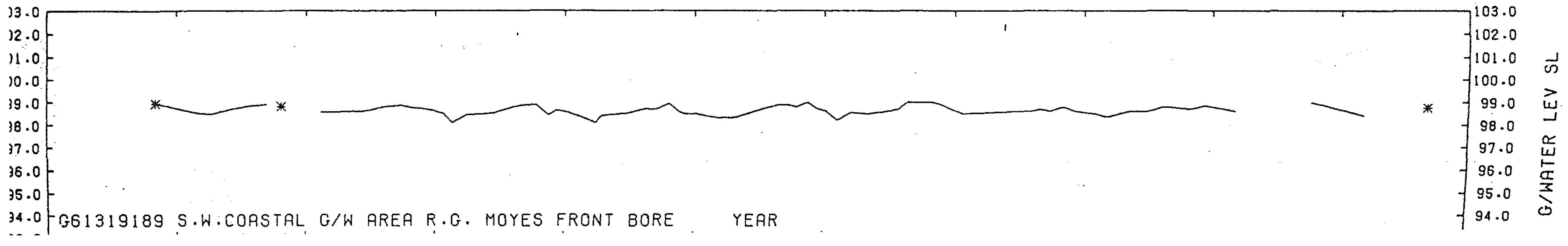
WATER AUTHORITY OF W.A.
15 JUNE 1994

——— + IS G/WATER LEV SL
- - - - X IS G/WATER LEV SL
✳ IS BORE LEVEL AFFECTED BY PUMPING









Appendix 2

Correspondence from the Department of Agriculture Western Australia on the management of horticulture in the catchment of Lake Clifton

DEPARTMENT OF AGRICULTURE
WESTERN AUSTRALIA

3 Baron-Hay Court South Perth Western Australia 6151

1850/94H:JM:RO
R Paulin
5 December 1994

Mr G Middle
Director, Evaluations Division
Department of Environmental Protection
Westralia Square
141 St George's Terrace
PERTH WA 6000

4 8/95 Gm / 6

HORTICULTURAL MANAGEMENT CRITERIA FOR LAKE CLIFTON CATCHMENT

Following the recent Environmental Assessments Committee's briefing on Lake Clifton, supporting information on upper phosphorus and nitrogen application rates to horticulture in this catchment is provided.

As indicated the Department of Agriculture considers that environmental controls for horticulture need to be based on limits to management inputs rather than limits to types of horticulture.

It is suggested that the upper limits for nitrogen and phosphorus application in the Lake Clifton Catchment should be:

Nitrogen	200 Kg/Ha/year
Phosphorus	100 Kg/Ha/year.

These annual application limits are based on soil phosphate retention information and guided by good management practices for perennial horticultural crops.

The upper phosphorus application rate of 100 Kg per hectare per year is based on research work of Dr Ian McPharlin and others which was reported in the Western Australia Journal of Agriculture, Volume 31, 1990. A copy of this article is attached and I have highlighted information that was referred to in an attachment to previous correspondence on Lake Clifton, dated 3 August 1994, by Neil Lantzke.

These findings suggest that after allowing for some crop removal, the Spearwood soils adjacent to Lake Clifton would retain, within the top metre of soil, 80 years of phosphorus application, at the suggested maximum rate.

81795 /A110

As levels of phosphate held in the soil build up, phosphate availability increases, and as a consequence, the quantities required for crop production can be steadily reduced. Providing crop requirement information is available, soil test results can be used to determine phosphate application requirements, and ultimately it is possible to apply less phosphorus than is removed by the crop. Coupled with greater phosphate fixing ability of the limestone that underlays Spearwood sands at around 1.0 one metre depth, then the time for phosphate break through to two metres, the proposed minimum allowable depth to groundwater, will be several hundred years.

To maximise the period before breakthrough occurs, phosphate application based on soil testing needs to be included as a management requirement.

With regards nitrogen, we do not have information on which to carry out a similar risk assessment and our suggested application limits are based on moderate application rates coupled with appropriate application practices.

Therefore nitrogen application should be made at frequent, not less than weekly, intervals, during periods of active crop growth and should be applied through or in conjunction with uniform irrigation application. Irrigation should be applied in accordance with climatic conditions as indicated by evaporation rates and schedules in accordance with soil type, climatic conditions and crop rooting depth.

Regards

Bob Paulin
SUSTAINABLE HORTICULTURE CO-ORDINATOR
DEPARTMENT OF AGRICULTURE

RPMIDDLE:RO:JM

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3 August 1994

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Attention: Mr G Middle

DRAFT STRATEGY FOR MANAGING DEVELOPMENT CRITICAL TO THE CATCHMENT OF LAKE CLIFTON

Thank you for the opportunity to comment on the draft 'Strategy for managing new developments within the catchment of Lake Clifton'. Whilst supporting the intent of this strategy we cannot support the implied presumption against new horticultural development

The acceptable location of horticulture as well as agriculture must be based on land capability principles to which considerations of environmental sensitivity and management approach are then applied.

Although not indicated within the strategy document, we understand that there is approximately 2000 kl of water available per hectare within the catchment area. This will limit the potential for horticultural development to between 20% and 40% of the land, depending on the crop selected.

Based on consideration of soil type and water table depth, as outlined in the attached document 'Phosphorus pollution risk from horticulture in the Lake Clifton Catchment', horticulture as well as irrigated agriculture, should not be practiced within 100 metres of the lake. Therefore recognising that there are also wetlands adjacent to Lake Clifton we would recommend that:

- Horticulture and irrigated agriculture are not located closer than 100 metres from the edge of Lake Clifton and there must be at least 20 metres of yellow/orange sands, with a minimum depth to water table of 2.0 metres, between the horticultural activity and either the wetland or Lake Clifton. Within this zone, a 20 metre vegetated buffer should also be planted or retained.

- There should be no surface water run-off from these areas to the lake or wetland

Acknowledging the significance of Lake Clifton and the possible impacts of other nutrients such as nitrogen, a wider buffer of 200 m could be applied to annual vegetable production. However this requirement should be reviewed within three years when current projects to monitor nitrogen levels in groundwater adjacent to vegetable properties are completed. Mr R Paulin is available to further refine these guidelines for locating new horticultural as well as irrigated agricultural developments within the Lake Clifton Catchment.

M D Carroll
DIRECTOR GENERAL OF AGRICULTURE

RPMIDDLE:RO:JM

THE PHOSPHORUS POLLUTION RISK OF HORTICULTURE IN THE LAKE CLIFTON CATCHMENT

N Lantzke

Two soil systems occur within the catchment of Lake Clifton.

The Vasse system contains poorly drained flats that fringe the lake. This system generally extends less then 200 m from the lake but can be greater than 500 m in width in places. The soils are variable consisting of mud, deep sands and humic sandy loams.

The soils of the Vasse system have a high phosphorus pollution risk because of the shallow watertable and their proximity to the lake. These soils are not suited to horticulture.

The Spearwood system contains orange sands over limestone and deep yellow sands. The depth to groundwater is generally greater than 6 m, though is only about 2-3 metres on the flats between the Old Coast Road and the lake. These soils have a moderate to high phosphorus retention index (see Table 1).

Table 1 Phosphorus Retention Indices for Three Spearwood system soils located on the flats west of the Old Coast Road, within the Lake Clifton Catchment

Site A		**Site B**		**Site C**	
0-10 cm	4	0-10 cm	33	0-10 cm	2
10-20 cm	20	30-40 cm	65	20-30 cm	21
50-60 cm	25	90-100 cm	12	50-60 cm	19
70-80 cm	27	120-130 cm	11	Limestone	
Limestone		Limestone			

The depth to the watertable at the three sites was approximately 2.5 m.

McPharlin (1990) showed that after 25 years of vegetable cropping on a Spearwood sand, with a phosphorus retention index (PRI) of 7 all applied phosphorus could be accounted for in the top 100 cm. The areas of Spearwood system soils with the highest risk of polluting the lake, ie the soils on the flats adjacent to the lake, generally have PRI greater than 7. The limestone layer beneath these soils also has a high PRI. A survey of the groundwater beneath 30 market gardens on the Swan Coastal Plain (unpublished) showed low phosphorus concentrations in all cases. High phosphorus concentrations have only been found in the shallow groundwater beneath the pale sands of the Bassendean system.

Runoff from the sandy soils of the Spearwood system is very rare as the infiltration rate is high.

The soils of the Spearwood system are suitable for horticulture and present little or no phosphorus pollution risk within the medium to long term.

Recommendations

1. **No horticulture on Vasse system soils.**

2. **No horticulture be allowed within 100 m of the lake, and there must be at least 20 metres of Spearwood (orange/yellow) sand with a minimum depth of 2.0 metres water table, between the horticultural activity and the low capability soils of the Vasse system.**

3. **A vegetated buffer of 20 m be planted or retained within this horticultural exclusion area.**

4. **No surface water run-off from horticultural areas to the lake or wetland.**

This set back area or buffer strip will intercept any phosphorus laden runoff leaving the horticultural property and provide a physical barrier to any chemical sprays.

References

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Appendix 3

Preliminary recharge calculations for Lake Clifton Catchment

Garry Middle, Department of Environmental Protection.

1. Introduction and aim

Limitations

The calculations in this appendix are based on design elements of standard rural residential developments.

This Appendix contains information on changes to recharge rates for land within the catchment of Lake Clifton following development for special rural purposes. Development would lead to clearing of native vegetation to provide for roads, building envelopes and firebreaks. Where land is already cleared, some revegetation would be expected as owners seek to improve the amenity of their property. Groundwater would also be abstracted for human use, some of which would infiltrate back into the aquifer again.

All of these changes are likely to lead to a change in the amount of freshwater recharging the aquifer. Freshwater is vital for the survival of the thrombolites at Lake Clifton (refer to the main part of this report).

The aim of this Appendix is to examine the relationship between (average) lot size in rural residential developments and change to recharge rates following development.

The lot size of a subdivision indirectly impacts on the change in recharge following development: it can control the total area of native vegetation cleared for service requirements and can control the number of homes to be built and, therefore, the total volume of groundwater abstracted for human purposes.

An attempt is made in this Appendix to define an ideal lot size based on water balance considerations. Ideally, the minimum lot size would be defined as the lot size where the recharge following development is the same as that prior to development. In other words, there is no net change in recharge following development.

This turns out to be difficult to determine given the uncertainties involved in the calculations. Instead, the minimum lot size recommended will be such that any reduction in lot sizes below this size will lead to a significant change to recharge. Put another way, decreasing lot size to this point would only lead to small changes to recharge.

The remainder of this Appendix is set out as follows. Section 2 gives an overview of the model used to carry out the calculations in the proceeding Sections, and describes the assumptions and data used to carry out those calculations. Section 3 gives determines the change in recharge following development for land covered with native vegetation whereas Section 4 deals with land cleared of native vegetation prior to development.

Section 5 is the conclusion and proposes minimum lots size based on the data provided in previous sections.

Note

This Appendix covers only recharge considerations and does not consider nutrient issues and human use impacts.

2. An overview of the model and assumptions used in the calculations

2.1 The general model

Figure 1 shows the groundwater inputs and outputs beneath an area of land with a full cover of native vegetation prior to development. Figure 2 shows the groundwater inputs and outputs following development where there is some loss of vegetation cover and some abstraction of groundwater for human purposes.

The terminology used is based on that used by Townley *et al* , 1993.

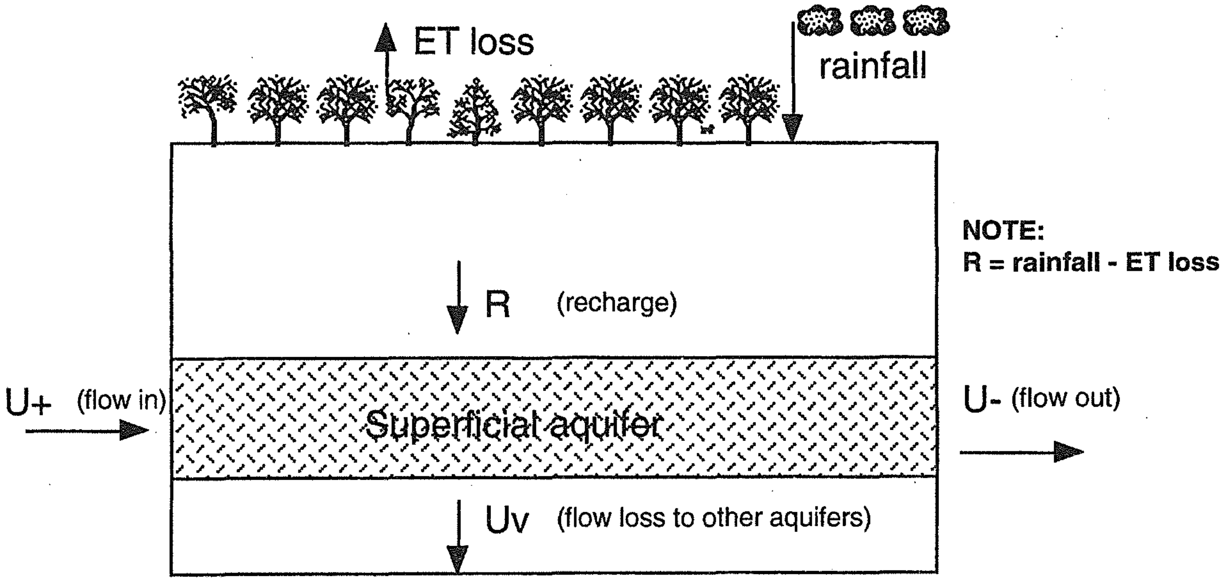

Figure 1: Idealised water flow model used in calculations - pre-development conditions with little clearing of native vegetation

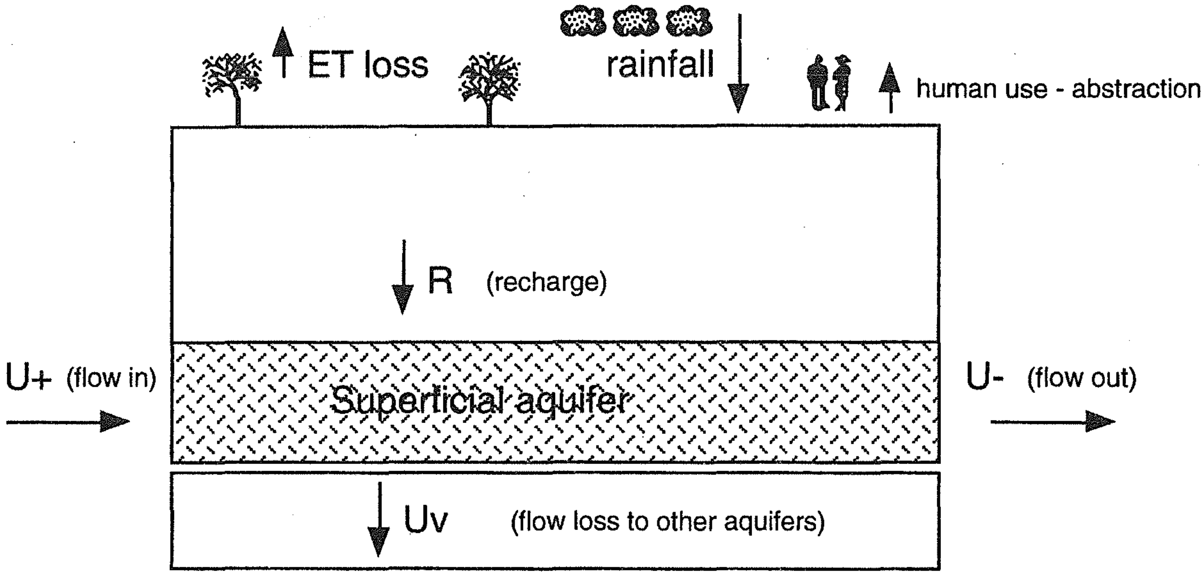

Figure 2: Idealised water flow model used in calculations - post-development conditions following limited clearing of native vegetation

Based on this model it can be seen that, prior to development, when ET loss is less than rainfall there would be a net recharge to the aquifer. If losses to other aquifers is negligible, then the groundwater flow leaving the site is greater than the groundwater entering the site: ie U- > U+.

With the loss of deep rooted vegetation following development, the ET following development would be less than that prior to development. By itself, this would lead to greater recharge to the aquifer. However, there is now some abstraction of groundwater for human uses: some of this will be lost as ET whilst the remainder will infiltrate to the groundwater as recharge through septic tanks and watering of gardens.

There are, therefore, three possibilities when comparing the recharge to the aquifer before and after development:

- if net loss through human abstraction is greater than the reduction in ET then LESS recharge will occur following development.;

- if net loss through human abstraction is <u>less</u> than the reduction in ET then MORE recharge will occur following development; and
- if net loss through human abstraction is <u>equal</u> to the reduction in ET then recharge pre-development will EQUAL post development.

In the first two cases the amount of groundwater flowing into Lake Clifton will change. This could have a significant impact on the thrombolites in the lake (refer to main part of this report).

Similar figures can be drawn showing land which is cleared of native vegetation prior to development. The principles discussed above still hold.

The calculations below focus on the changes in recharge using this simple model. They assume that a fix area of land is subdivided and that lot size (therefore total number of lots) varies. They also assume that the quantity of groundwater flowing in from upstream of the site does not alter and that loss to other aquifers is negligible.

2.2 General assumptions

The following general assumptions are made, some of which are made to simplify the calculations:

1. recharge from land covered by native vegetation is 10-15%* of rainfall
2. recharge from land covered by pasture (cleared areas) is 30-40%* of rainfall;
3. recharge from land covered by hard surfaces is 50-80%* of rainfall;
4. building envelope 2000 m^2 , 1500 m^2 cleared and 500 m^2 house pad (hard);
5. building envelope located in centre of lot;
6. length of track leading to the house = 1/3 length of one side of lot;
7. lots are square, with length of one side $\sqrt{\text{lot area}} = b$;
8. fire break run the lengths of each side of the lot;
9. width of fire break 4m;
10. width of track 6m;
11. width of pavement for road 7m;
12. width of additional clearing either side of road 1.5m;
13. length of road required for each block = 1/2 length on one side. This assumes that most of the new road(s) will have lots on either side, some of the new road(s) will have lots on one side only, and some lots will be serviced by existing roads requiring no new clearing;
14. private groundwater abstraction is 1500 kL per lot per year (some variation would be expected, but no range will be used in this figure to carry out the calculations as no hard data exist on water usage in rural residential developments);
15. recharge from the private usage 30-50% * of abstraction;
16. annual rainfall 900 mm (Commander, 1988); and
17. prior to development half of the land to be developed will be covered with native vegetation and half cleared and currently used for grazing, pasture and general farming.

The calculations in Sections 3 & 4 shows the CHANGE in recharge to the aquifer following development calculated on an annual basis as total volume of water.

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* all figures from R. Hammond, *pers comm*

3. Extra recharge following development of land covered with native vegetation

3.1 Introduction

The following sub-sections deal with the following:

- Section 3.2 develops a general formula for extra recharge per new lot created;
- Section 3.3 calculates the area of lot cleared of vegetation for building envelops and fire breaks but not turned into hard surfaces;
- Section 3.4 calculates area of lot cleared of vegetation and turned into hard pavement;
- Section 3.5 calculates total area cleared for all lots;
- Section 3.6 calculates total area paved for all lots; and
- Section 3.7 calculates extra recharge following development for all lots.

3.2 Extra recharge per lot general formula

A general formula will be presented here which shows the CHANGE in recharge to the aquifer following development for rural-residential purposes. It will be calculated on an annual basis as total volume of water. The formula is for each newly created lot.

Change recharge (total) = change in recharge from newly cleared area compared to when vegetated + change in recharge from newly paved area compared to when vegetated — water abstracted pvte use + additional infiltration from pvte use (through septics tanks & gardens)

$\Delta R(\text{total}) = \Delta R(c) + \Delta R(p) - Ab + I(\text{pvte})$

$\Delta R(c)$ = area cleared x % diff recharge/100 x annual rainfall

$\Delta R(p)$ = area paved x % diff recharge/100 x annual rainfall

Ab = abstraction for private use = 1500

I(pvte) = Ab x % recharge/100.

3.3 Estimate of cleared area per lot

Area cleared (lot) = building envelope not paved + fire breaks + track to building envelope

+ road verge

= 1500 + (4 x b x width of fire break) + (1/3 x b x width of track) + (length of road per block x width of clearing either side of the road)

$= 1500 + (4 \times b \times 4) + (1/3\ b\ 6) + (1/2 \times b \times 3)$

$= 1500 + 16\ b + 2\ b + 1.5\ b$

$= 1500 + 19.5\ b$

3.4 Estimate of paved area per lot

Area of pavement = building pad + length of road x width

$= 500 + 1/2\ b \times 7$

$= 500 + 3.5\ b$

3.5 Estimate of total area cleared for all lots

Total area cleared = area cleared per lot x No lot

= (1500 + 19.5 b) x (total area of land/area of lots).

For an area of land of total size = A, where the size of the newly created lots = a;

Total No of lots = A/a.

Therefore:

Total area cleared = (1500 + 19.5 b) x (A/a)

= 1500 A/a + 19.5 Ab/a

Now, because $b = \sqrt{a}$

Total area cleared $= 1500\ A/a + 19.5\ A/\sqrt{a}$

Or as size of lots decreases, total area cleared increases.

3.6 Estimate of total paved area for all lots

Total pavement area = pavement per lot x No lots

= (500 + 3.5 b) x A/a

= 500 A/a + 3.5 Ab/a.

Again, because $b = \sqrt{a}$

Total pavement area $= 500\ A/a + 3.5\ A/\sqrt{a}$

Again, as size of lot decrease, total area of pavement increases.

3.7 Calculation of extra recharge following development

3.7.1 General

As discussed in 3.2, change in recharge per new lot can be determined as follows:

$\Delta R(total) = \Delta R(c) + \Delta R(p) - Ab + I(pvte)$

= area cleared (diff recharge pasture and natives) x rainfall

+ area paved (diff recharge paved and natives) x rainfall

- Ab + (Ab x % recharge/100).

Recharge for all lots

$\Delta R(total)$ for all lots $= \Delta R(total)$ x No lots

$= \Delta R(total)$ x A/a

= {[(1500 + 19.5 b) x % diff recharge/100 x 0.9]

+ [(500 + 3.5 b) x % diff recharge/100 x 0.9]

- Ab + (Ab x % recharge/100)} x A/a

Using the range of estimates for the data shown in 2.2, two scenarios can be set up showing the full range of values for the calculations: a low and high recharge scenarios. The low recharge scenarios uses the figures from 2.2 which would lead to the lowest possible additional recharge (a reduced recharge following development is possible). The high recharge scenario uses the figures which would lead to the highest recharge possible.

3.5.2 Low recharge scenario

ΔR(total) for all lots = [(1500 + 19.5 b) (30-15))/100) x 0.900] A/a

+ [(500 + 3.5 b) (50-15)/100 x 0.900 - Ab + (Ab x 30/100)] A/a

= [(1500 + 19.5 b) (30-15))/100) x 0.900] A/a

+ [(500 + 3.5 b) (50-15)/100 x 0.900 - 1500 + (1500 x 30/100)] A/a

3.5.3 High recharge scenario

ΔR(total) for all lots = [(1500 + 19.5 b) (40-10))/100) x 0.900] A/a

+ [(500 + 3.5 b) (80-10)/100 x 0.900 - Ab + (Ab x 50/100)] A/a

= [(1500 + 19.5 b) (40-10))/100) x 0.900] A/a

+ [(500 + 3.5 b) (80-10)/100 x 0.900 - 1500 + (1500 x 50/100)] A/a

Table 1 and Figure 3 provide a summary of the calculations for a range of lots sizes from 1 to 10 Ha for a 250 Ha development site.

Table 1: Summary of changed recharge calculations.

lot size	change in recharge per lot - low recharge scenario - m^3	change in recharge per lot - high recharge scenario - m^3	change in recharge all lots - low recharge scenario - m^3	change in recharge all lots - high recharge scenario - m^3
10	491	2332	12278	58306
8	366	2083	11451	65089
6	225	1800	9370	74990
5	145	1640	7259	82017
4	57	1464	3563	91500
2	-162	1026	-20224	128302
1	-317	717	-79125	179250

Figure 3: Change in recharge as a function of lots size following development for land uncleared of native vegetaion prior to development

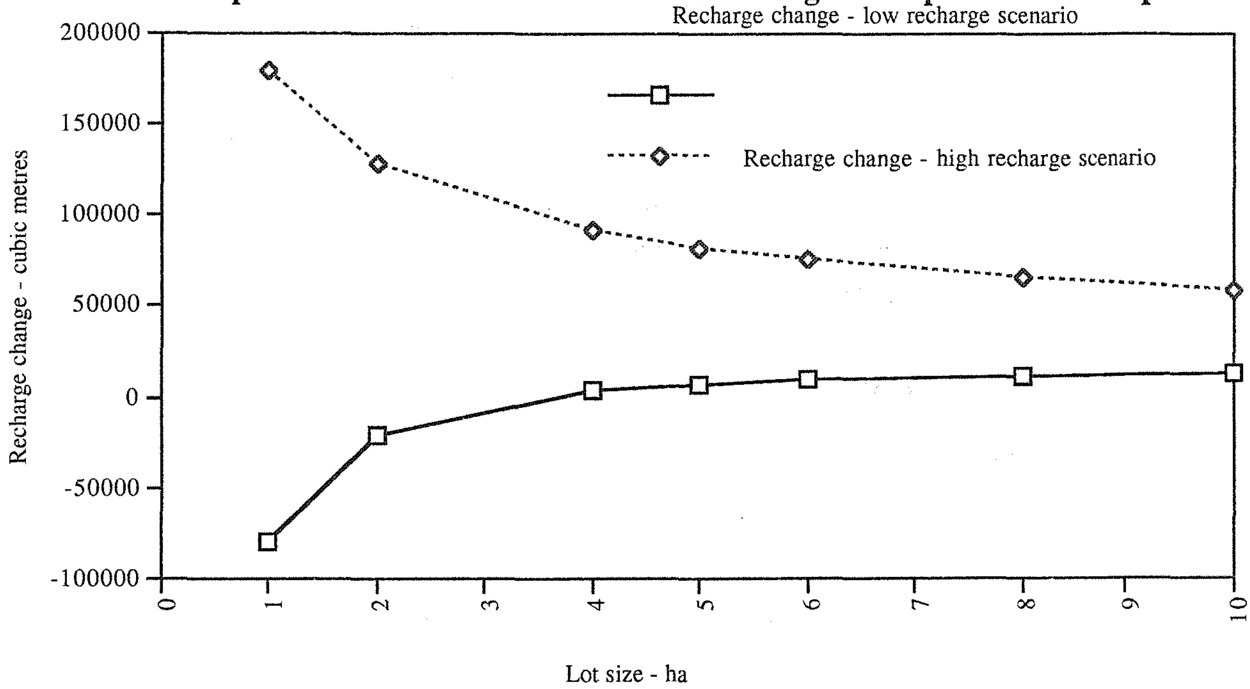


Table 1 shows that as lot size decreases the extra recharge per lot decreases. This is to be expected because whilst the amount of private abstraction remains the same irrespective of lot size, the area of the each lot cleared decreases with decreasing lot size (smaller sized fire breaks and shorter track length through the lot to the house).

Table 1 also shows the trends for all lots (using total area developed). The observed trend in recharge vs lot size will depend on the relative sizes of recharge changes due to clearing and abstraction for private usage. Under the high recharge scenario extra recharge due to clearing is greater than abstraction resulting in a trend of increasing recharge with decreasing lot size. However, with the low recharge scenario the trend is reversed with recharge decreasing with decreasing recharge.

The general trend from the graph shows that there is a slow change in recharge with decreasing lot size until around 4 Ha. For lot sizes less than this, there is a rapid acceleration in change recharge.

4. Extra recharge following development of land cleared of native vegetation

4.1 Introduction

The sub-sections which follow parallel those in Section 3.

On additional assumptions is made here: the new owners will rehabilitate some of the cleared land with deep rooted native vegetation equivalent to native vegetation. A reasonable estimate of the area rehabilitated would be between $2000m^2$ and $5000m^2$.

4.2 Recharge per lot general formula

ΔR(total)	= extra recharge from paved area - extra ET from revegetated area - water abstracted pvte use + recharge pvte use
ΔR(total)	= ΔR(p) - ΔR(rehab) - 1500 + I(pvte)
ΔR(p)	= area paved x % diff recharge/100 x annual rainfall
I(rehab)	= area rehab x % diff recharge/100 x annual rainfall
1500 kL	= annual allocation for private use
I(pvte)	= 1500 x % recharge/100

4.3 Calculation of recharge following development

4.3.1 General

ΔR(total) = ΔR(p) - ΔR(rehab) - 1500 + I(pvte)

= area paved x % diff recharge cleared vs cleared/100 x annual rainfall
- area rehab x % diff recharge cleared vs native/100 x annual rainfall
- 1500 + (1500 x % recharge/100)

ΔR(total) for all lots = ΔR(total) x No lots

= [R(p) - ET(rehab) - 1500 + R(pvte)] x A/a

= [(500 + 3.5 b) % diff recharge/100 x 0.900
- (4000 x % diff recharge/100) x .900 - 1500 + (1500 x 30/100)] x A/a

As with Section 3, two scenarios will be discussed: low and high recharge scenarios.

4.3.2 Low recharge scenario

ΔR(total) for all lots = [(500 + 3.5 b) (30-29)/100 x 0.900 - (4000 x (29-6)/100) x .900 - 1500 + (1500 x 30/100)] x A/a

4.3.3 High recharge scenario

ΔR(total) for all lots = [(500 + 3.5 b) (50-24)/100 x 0.900 - (2000 x (24-8)/100) x .900 - 1500 + (1500 x 50/100)] x A/a

Table 2 and Figure 4 provide a summary of the calculations for a range of lots sizes from 1 to 10 Ha for a 250 Ha development site.

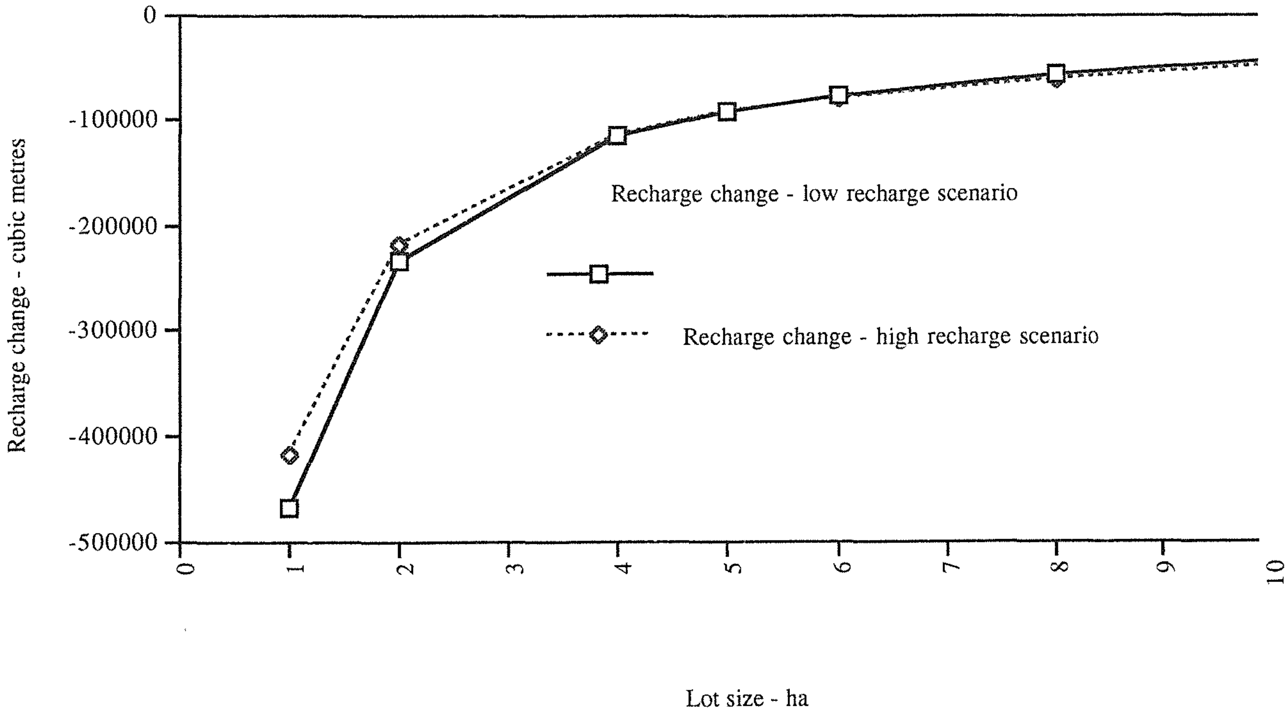
The data show that for lots on cleared land recharge decreases with decreasing lot size for both scenarios. This is because water used for private use and by the replanted tree species will be greater than and extra recharge due to run-off from the hard surfaces.

The data for cleared land are similar to that for uncleared land in that decreasing lot sizes beyond 4 Ha produces a significant acceleration in change in the recharge.

Table 2: Summary of changed recharge calculations.

lot size	change in recharge per lot - low recharge scenario - m^3	change in recharge per lot - high recharge scenario - m^3	change in recharge all lots - low recharge scenario - m^3	change in recharge all lots - high recharge scenario - m^3
10	-1805	-45135	-2013	-50326
8	-1816	-56747	-1960	-61265
6	-1828	-76160	-1901	-79200
5	-1835	-91728	-1867	-93359
4	-1842	-115125	-1830	-114375
2	-1860	-232557	-1738	-217217
1	-1874	-468375	-1673	-418125

Figure 4: Change in recharge as a function of lot size following subdivision for land cleared of native vegetaion prior to development



5. Conclusions.

1. The data show that there is considerable uncertainties involved in determining what the expected change in recharge will be following development.
2. Notwithstanding this uncertainties, it appears that the larger the lot size of a rural/residential development, the more likely it is that the post development hydrology will be the same as pre-development hydrology.
3. The data suggest that allowing lot sizes of less than 4 Ha would cause a significant change in the hydrology following development.
4. Whilst the data show that the most significant changes in hydrology occur below 4 Ha, given the uncertainties involved in the calculations, a conservative approach should be adopted and minimum lot sizes for rural/residential developments based on hydrology changes should be 5 Ha.

6. References

Townley, L. R., Turner, J. V., Barr A. D., Trefry, M. G., Wright, K. D., Gailitis, V., Harris C. J. and Johnston, C. D. 1993. Wetlands of the Swan Coastal Plain, Volume 3: Interactions between lakes, wetlands and unconfined aquifers. Water Authority of Western Australia & Environmental Protection Authority, Perth, Western Australia.

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