Gnangara Mound groundwater resources

Water and Rivers Commission

Proposed Change to Environmental Conditions

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 817
May 1996

THE PURPOSE OF THIS REPORT

Proposals to change environmental conditions set by the Minister for the Environment as a result of assessment under the Environmental Protection Act, must be referred to the Environmental Protection Authority for advice in accordance with s.46 of the Act.

This report contains the EPA's environmental assessment and recommendations to the Minister for the Environment.

Immediately following the release of the report there is a 14-day period when anyone may appeal to the Minister against the Environmental Protection Authority's report.

After the appeal period, and determination of any appeals, the Minister consults with the other relevant ministers and agencies and then issues his decision about whether the proposal may or may not proceed. The Minister also announces the legally binding Environmental Conditions which might apply to any approval.

APPEALS

If you disagree with any of the contents of the assessment report or recommendations you may appeal in writing to the Minister for the Environment outlining the environmental reasons for your concern and enclosing the appeal fee of $10.

It is important that you clearly indicate the part of the report you disagree with and the reasons for your concern so that the grounds of your appeal can be properly considered by the Minister for the Environment.

ADDRESS

Hon Minister for the Environment

12th Floor, Dumas House

2 Havelock Street

WEST PERTH WA 6005

CLOSING DATE

Your appeal (with the $10 fee) must reach the Minister's office no later than 5.00 pm on 5 June 1996.

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Summary

The Gnangara Mound Groundwater Resources proposal (Pinjar groundwater extraction Stage 1) was proposed by the Water Authority of WA (WAWA) in 1986, assessed by the EPA as an Environmental Review and Management Programme (ERMP) and approved by the Minister for the Environment in 1988 subject to the Minister's Environmental Conditions. The ERMP addressed a range of issues concerning the overall management of groundwater resources on the Gnangara Mound, taking into account the requirements for public and private water supplies and environmental considerations. The regional effects of groundwater abstraction were considered and a strategy for the development and management of the shallow groundwater resources on the Mound were presented.

Since then, the understanding of wetlands on the Swan Coastal Plain has increased significantly as a result of additional work on wetland areas. This increase in knowledge has led the WAWA (now the Water and Rivers Commission (WRC)) to re-think its strategy with regard to wetlands. The WRC has proposed new criteria to protect the ecological values of groundwater-dependent vegetation. These criteria are aimed at allowing for continued groundwater abstraction while maintaining the ecological integrity of groundwater-dependent vegetation communities.

If, environmental clearance to the proposed changes is given by the Minister for the Environment, and the new wetland criteria are adopted, the WRC propose to review water allocation quotas for particular areas on the Mound.

The WRC also propose to review the land use and management strategies currently in place, to ensure adequate management of land use on the Gnangara Mound where that use has the potential to impact on groundwater quality.

Accordingly, the WRC propose that the changes summarised in Table 1 be made to the current Environmental Conditions, in accordance with Section 46 of the Environmental Protection Act.

The WRC are also seeking approval to abstract an additional 1.5 million m^3, of groundwater, to be allocated for public water supply. Approval for an additional three bores to allow this abstraction to occur is likely to be sought at a future date if approval for this additional abstraction is granted.

The EPA has examined the environmental issues associated with the proposal. The EPA's views on the issues raised in public submissions are summarised in Table 3.

The EPA has concluded that the proposal by the WRC to adopt alternative groundwater criteria to ensure maintenance of the ecological values of groundwater-dependent vegetation on the Gnangara Mound is consistent with the EPA's environmental objectives. Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs) will take account of the environmental objectives and the lake and well water levels nominated by the WRC.

Table 1. Summary of proposed changes to Environmental Conditions

Topic	Existing Environmental Conditions Arising from 1988 Assessment	Requested Changes, the Subject of this Section 46 Assessment
Specific groundwater levels to protect environmental and social values of wetland areas	Environmental Condition 3 identified the need to establish water levels for wetlands determined by the EPA, to ensure that the social and ecological values of the wetlands are maintained.	New groundwater levels are proposed to be set as a result of additional research. These new levels may affect areas other than wetlands, for example Banksia Woodlands, Yanchep Caves, and associated fauna. New criteria recognising these changes are proposed, to allow for continued groundwater abstraction while maintaining the ecological integrity of groundwater-dependent vegetation communities.
Private groundwater allocation quotas to protect specific water levels within wetland areas	Environmental Condition 9 (and proponent's commitments 2 and 6) require that private groundwater allocation quotas ensure that the required water levels for wetlands, specified by the EPA, are met.	Continuing urban development in the Wanneroo area and changes in land use have led to changes in groundwater use since the 1988 assessment. It is expected that the proponent will review these allocation quotas in line with the proposed new criteria.
Interaction between land and water resource planning	Environmental Conditions 14, 15 and 20 relate to the interaction between water and land use planning on the Gnangara Mound. These Conditions have implications on a 'third party', ie. the former Department of Planning and Urban Development (now Ministry for Planning) which are not enforceable	Provide a means for interaction between land planning and water resource planning through other statutory mechanisms.
Provision of specific water levels	Proponent Commitment 28 requires the proponent to maintain specific minimum water levels to maintain social and environmental values of nominated wetlands.	A review of these commitments will be undertaken as part of the EPA's assessment of new groundwater levels, based on the adoption of new water level criteria.
	Proponent Commitment 30 requires the proponent to maintain existing regimes of water quality and quantity within normal climatic variation, for nominated wetlands.	
	Proponent Commitment 32 requires the proponent to maintain water levels within nominated wetlands to preferred minimum summer levels, to maintain or enhance the social and environmental values of those wetlands.	

In reaching this conclusion, the Authority has taken into consideration:

- adoption of the concept of ecological benefit resulting from a change from the current wetland water criteria to Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs);
- the method by which the EWRs and EWPs will be given effect, ie. in the terms of environmental objectives and control of water levels in lakes and wells nominated by the WRC; and
- a commitment by the proponent to adopt a revised monitoring programme to ensure the maintenance of ecological diversity in wetland areas where identified environmental water requirements are likely to be greater than environmental water provisions.

The EPA concludes that private groundwater bore allocations shall not form part of Environmental Conditions imposed as part of this assessment, but be granted by licence issued by the Water and Rivers Commission, which would recognise environmental water requirement levels.

The EPA also notes that the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' is likely to involve the preparation of Environmental Protection Policies and State Planning Policies to control land use over private and publicly owned land over the Gnangara Mound.

Summary of conclusions and recommendation	
1	The EPA recommends that the Environmental Conditions set by the Minister for the Environment on 8 March 1988 can be amended without prejudicing the EPA's objectives in relation to the conservation of environmental values of groundwater-dependent vegetation on the Gnangara Mound.

1. Introduction and background

1.1 Purpose of this Report

This report and recommendations provides the Environmental Protection Authority's advice to the Minister for the Environment in relation to proposed changes to Environmental Conditions set on the use of groundwater on the Gnangara Mound.

1.2 Background

The Gnangara Mound Groundwater Resources proposal (Pinjar groundwater extraction Stage 1) was proposed by the Water Authority of WA (WAWA) in 1986, assessed by the EPA as an Environmental Review and Management Programme (ERMP) and approved by the Minister for the Environment in 1988, subject to a number of Environmental Conditions (included in Appendix 1).

The ERMP identified a range of issues in the overall management of groundwater resources on the Gnangara Mound in addressing the environmental implications. The regional effects of groundwater abstraction were considered and a strategy for the development and management of the shallow groundwater resources on the Mound was presented.

The ERMP document specifically aimed to:

- provide an overview of the demand and supply of water to the North West Corridor and identify the need for new public water supply developments;
- review alternatives for the supply of that water and select a preferred alternative;
- provide an overview of public, private and environmental demands associated with the preferred alternative, ie. the shallow groundwater resource of the Gnangara Mound;
- identify the potential regional environmental and social effects as well as any conflicts associated with private and public development on the Gnangara Mound;
- outline strategic approaches to the management of the resource;
- identify the preferred next development for the Gnangara Mound - the Pinjar Groundwater Scheme; and
- define a management strategy for the Pinjar area, with due regard for environmental and social effects.

Environmental Conditions subsequently imposed on the WAWA by the Minister for the Environment in 1988 included a requirement for the maintenance of water levels for wetlands to ensure that the social and ecological values of the wetlands are maintained. Other conditions specifically related to limits on private groundwater allocations, the need to establish a management and monitoring programme and set in place a range of administrative mechanisms for inter-agency interaction on groundwater management.

Since 1988, the proponent, now the Water and Rivers Commission (WRC) has identified a number of factors which have led to the need to review some of the environmental conditions. These factors fall into three broad categories:

- wetland water levels - it is proposed to maintain the groundwater regime required by the environment to retain its ecological values through the use of 'Environmental Water Requirement' (EWR) levels and 'Environmental Water Provisions' (EWPs), i.e.; that part of the EWR that can be met and is provided for after the consideration of economic and social issues;
- allocation quotas; and
- land use issues.

The management of water quantity is to be based on a water resources allocation process, which includes the determination of EWRs. EWRs are determined by the identification of values or beneficial uses of water-dependent components of the environment and the establishment of water levels for ecosystem protection. The water levels then define the EWR. However, in some instances those water levels cannot be met. Water abstraction quotas will result in lower water levels (EWPs) and influence the vegetation community.

In 1993 the Minister for the Environment agreed to the need to review the original Environmental Conditions and requested the then WAWA to prepare a review document which would allow for public input and would allow for the EPA to assess the proposed changes to the Environmental Conditions under the provisions of Section 46 of the Environmental Protection Act.

1.3 Structure of this Report

This report is divided into 7 sections.

Section 1 introduces the report by stating its purpose, describing the historical background to the proposal and its assessment, and outlining the structure of the report.

Section 2 summarises the proposal. The proposal is described in more detail in the proponent's 'Review of proposed changes to Environmental Conditions' document (Water Authority of WA 1995c).

Section 3 explains the method of assessment and provides a summary of topics raised through the setting of guidelines and in public submissions. From those topics and others raised through the assessment process, those considered to be issues that require further evaluation by the EPA are identified. A table summarising this process is provided (Table 2).

Section 4 sets out the evaluation of the environmental issues associated with the proposal. Each issue is dealt with in its own subsection, which initially states the objectives of the assessment for that issue. The relevant EPA policy is stated and any technical information is provided. Comments from key agencies/interest groups are summarised, and the proponent's response is presented. The subsection on each issue is concluded with the EPA's evaluation in terms of achieving the stated objectives.

Section 5 summarises the conclusions and recommendations and includes a table summarising the evaluation of the environmental issues (Table 3). Section 6 describes the recommended environmental conditions. References used in the preparation of this report are provided in Section 7.

2. The Proposal

The review of Environmental Conditions for the Gnangara Mound is proposed in relation to three broad areas.

- A. Wetland Water Levels: In recommending the setting of water levels as part of Environmental Condition 3 in 1988, the EPA acknowledged that there was little information available on which to determine Environmental Water Requirements (EWRs), and that therefore there may be some changes in the future. Environmental Condition 18 required the then WAWA to initiate research to improve the understanding of wetland ecology as a basis for revision of the wetland water criteria.

  A series of research programmes has now been completed and the WRC proposes that the wetland water levels and the methodology for determining EWRs, be reviewed in the context of the findings of this research. Further, the WRC has acknowledged that the EWRs have been applied only to individual wetlands. The significance of other groundwater-dependent ecosystems such as shallow cave systems and phreatophytic vegetation (ie. groundwater-dependent vegetation) has now been recognised and it is proposed that these factors now be taken into account is setting EWRs.

- B. Allocation Quotas: Environmental Condition 9 and proponent commitments 2, and 6 relate to groundwater allocation quotas. Continuing urban development in the Wanneroo region and changes in land use have led to changes in the demand for groundwater use. It is therefore proposed that groundwater availability be reviewed with the objective of allocating further resources in high demand areas.

  The WRC intend to proceed with allocating further groundwater resources in particular areas. However, it is acknowledged that the EWRs for particular ecosystems need to be taken into consideration. Therefore the WRC will await the outcome of this assessment, regarding criteria for wetland water levels, before proceeding.

  Information on groundwater allocation on the Gnangara Mound is presented in the Section 46 report to allow for a balanced overview of the expectations for groundwater use. The information is not presented for environmental impact assessment by the EPA and it is not the intention of the WRC for the EPA to review this information.

- C. Land use issues: Environmental Conditions 14, 15 and 20 relate to land use issues. Some of the requirements of these conditions involve responsibilities of a third party, ie. organisations other than the WRC, and are therefore not legally binding. There is therefore a need to review these conditions to ensure there are appropriate land use and management strategies in place on the Gnangara Mound.

The EPA's objectives for the Gnangara Mound are:

- to ensure that continued abstraction of groundwater from the Gnangara Mound is managed such that the EWRs of groundwater-dependent ecosystems are maintained in the long term; and
- to ensure that appropriate land use management mechanisms are in place to adequately co-ordinate land use on the Mound so that there is no long term adverse impact on the groundwater.

Accordingly this assessment will address components identified in A and C above. Issues associated with B above will be addressed separately by the proponent, based on the conclusions of the EPA's assessment of A and C.

2.1 Wetland water levels

The WRC propose to gain environmental acceptance in principle, to the application of the concepts of Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs), rather than the allocation of specific water amounts. In essence, this involves the setting of minimum water levels in sensitive environmental areas in the same way as past environmental water criteria, but removing the groundwater abstraction allocations to private users from the environmental conditions. Instead, the Water and Rivers Commission will have the responsibility for managing groundwater allocation to meet the water levels set in the Environmental Water Provisions. This gives flexibility in allocating groundwater, but ensures specific water levels in environmentally sensitive groundwater dependent areas are maintained.

EWRs are defined as the minimum groundwater levels required to be maintained to ensure the maintenance of the ecological integrity of a particular wetland. The EWR can include elements of quantity and duration, and applies both spatially and temporally.

An Environmental Water Provision (EWP) is defined as that part of the EWR that can be met and is provided, after consideration of social and economic issues. The EWP is the actual environmental allocation.

Wherever possible the EWP is set to equal the EWR, however in certain instances, where there are issues in the use of the finite water resource, this may not be achievable. The EWP will be less than the EWR when other requirements (social or economic) are considered to be more important than providing the full environmental requirement.

In determining EWRs and EWPs, the WRC have identified a number of wetlands as representative of the range of geomorphic units and wetland types across the Gnangara Mound.

These wetlands have also been identified as having significant ecological value, and are indicated in Figure 1. It is proposed by the WRC that if the EWRs for these wetlands are maintained then the ecological values of the wetlands will be maintained. The EPA has been advised by the WRC that the adoption of the concept of EWPs and EWRs has been endorsed by other states in Australia with success in ensuring the maintenance of groundwater dependent vegetation.

2.2 Land use management

The EPA will review the existing land use management strategies existing on the Gnangara Mound to ensure that adequate statutory controls are in place.

3. Identification of environmental issues

3.1 Method of assessment

The purpose of this assessment of a proposal to amend Environmental Conditions is to determine whether the proposed change to Environmental Conditions meets the EPA's objectives, or under what conditions it could be determined as doing so.

The process is initiated by the Minister for the Environment requesting the EPA, under Section 46 of the *Environmental Protection Act 1986*, to report to him on the proposed change to the Environmental Conditions.

The first step in the assessment method is to identify the environmental topics to be considered. As part of this process an outline of the proposed change to the Environmental Conditions is distributed to those agencies and groups who may have an interest in the proposal.

The responses received are summarised by the Department of Environmental Protection on behalf of the EPA. This process can reveal additional environmental topics which need to be considered in terms of potential environmental impacts.

Proponents are invited to respond to the topics raised in submissions, as summarised by the Department of Environmental Protection. Appendix 2 contains a summary of the topics raised in submissions and the proponent's response.

The proponent's document, the submissions and the proponent's response, are then subjected to analysis. The environmental topics are reviewed to identify issues that require further evaluation by the EPA. For each environmental issue, an objective is defined and where appropriate an evaluation framework is identified.

The expected impact of the proposed change to Environmental Conditions, with due consideration to the proponent's commitments to environmental management, is evaluated against the assessment objective. The EPA then determines the extent to which its objectives can be met.

The EPA then reports to the Minister on the environmental factors relevant to the proposed change in conditions and any further conditions and procedures which may be appropriate.

As part of the Section 46 assessment the opportunity is taken to review all existing conditions and commitments, in order to achieve a single environmental statement that provides for adequate protection of the environment and for efficient and effective environmental auditing of compliance criteria.

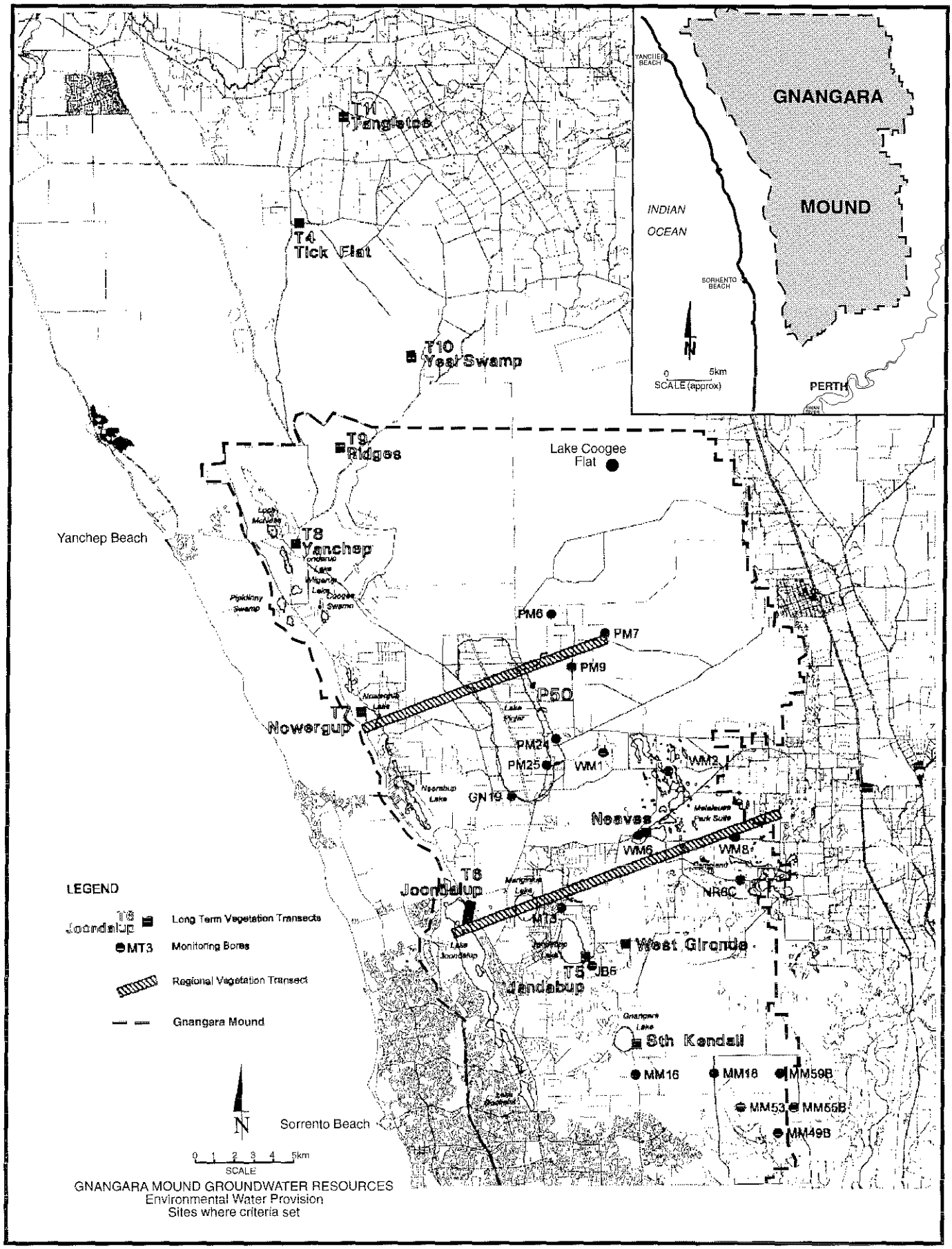

Figure 1. Map indicating location of wetlands, groundwater bores and transects proposed to be monitored to as part of on-going monitoring and management of Environmental Water Requirements of groundwater dependent vegetation on the Gnangara Mound. (Source: Waters & Rivers Commission 1995.)

Limitation

This evaluation has used information currently available, which has been provided:

- by the proponent in the 'Review of proposed changes to Environmental Conditions - Gnangara Mound Groundwater Resources (Section 46)' document;
- by Department of Environmental Protection officers utilising their own expertise and reference material;
- by utilising expertise and information from other State and local government agencies; and
- by contributions from EPA members.

The EPA recognises that further studies and research may affect the conclusions.

3.2 Public and agency submissions

Comments were sought on the acceptability of the proposed change to the Environmental Conditions from community groups and State and local government authorities. During the eight-week public submission period, ending on 1 August 1995, thirteen (13) submissions were received. A summary of these submissions was forwarded to the proponent for response.

The principal topics of concern raised in the submissions included :

Bio-physical Impacts

- the principle of using the concepts of Environmental Water Requirements and Environmental Water Provisions;
- the distinction between private and public groundwater allocation, which may lead to conflict between groundwater users;
- the new environmental criteria may compromise the ecological values of vegetation;
- protection of groundwater dependent cave fauna;
- adequacy of existing land use management plans;
- need for co-ordinated land management arrangements to protect or enhance groundwater resources;
- need for strategic drainage management with general water resource management strategies for the Gnangara Mound.

Social Surroundings

- impact on Aboriginal and local community; and
- long term sustainable use and management of the Gnangara groundwater resources.

Pollution Potential

- nutrient management issues.

The EPA has considered the submissions received and the proponent's response in its evaluation of the Section 46 review document.

3.3 Review of topics

3.3.1 Identification of topics

Fifteen topics were raised in the environmental impact assessment process including those topics identified in the guidelines for the Section 46 document, subsequent consultations and the submissions described above. The topics are as follows :

Bio-physical Impacts

- principle of using the concepts of Environmental Water Requirements and Environmental Water Provisions;

- distinction between private and public groundwater allocation;
- environmental implications when the Environmental Water Requirement is not the same as the Environmental Water Provision;
- use of groundwater modelling as a management tool;
- protection of phreatophytic vegetation;
- protection of groundwater dependent cave fauna;
- adequacy of existing land use management plans to manage impacts from private and public groundwater allocation;
- co-ordinated land management arrangements to protect or enhance groundwater resources;
- long term impact of abstraction on groundwater quality within the unconfined aquifer;
- additional abstraction of groundwater in the vicinity of Little Coogee Flat; and
- long term impact on water in the superficial unconfined aquifers through abstraction from the confined aquifer; and
- integration of strategic drainage management with general water resource management strategies for the Gnangara Mound.

Social Surroundings

- impact on Aboriginal and local community; and
- long term sustainable use and management of the Gnangara groundwater resources.

Pollution Potential

- nutrient management issues; and
- management of groundwater allocations to minimise impact on groundwater quality.

The EPA has evaluated the above topics and considers that a number of them can be managed by the proponent in accordance with their environmental management commitments. Each topic is discussed below in order to identify those issues warranting further evaluation by the EPA.

3.3.2 Identification of issues requiring EPA evaluation

Bio-physical Impacts

Principle of using the concepts of Environmental Water Requirements and Environmental Water Provisions

The Water and Rivers Commission proposes to use the concepts of Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs), to manage groundwater allocation, rather than the allocation of specific groundwater amounts, as was proposed in the original environmental conditions.

The use of EWRs and EWPs involves the setting of minimum water levels in environmentally sensitive areas in the same way as past environmental water criteria. However, the new criteria allow for a more flexible allocation of groundwater, while still protecting the environmental values of groundwater dependent wetlands and vegetation.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.1.

Distinction between private and public groundwater allocation

Original groundwater allocation quotas, identified in 1988, make minimal distinction between private and public groundwater users

The use of EWRs and EWPs involves the setting of minimum water levels in environmentally sensitive areas in the same way as past environmental water criteria, but removing the groundwater allocation to private users from environmental conditions. This is proposed to give more flexibility in allocating groundwater resources, but still ensures that water levels are maintained at an environmentally acceptable level.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.1.

Environmental implications when the Environmental Water Requirement is not the same as the Environmental Water Provision

The Water and Rivers Commission advise that in some cases, the EWR may be less than the EWP. This is thought to be as a result of the present rate of groundwater abstraction in some areas. In some cases artificial recharge is proposed to be used to supplement groundwater supplies. However, in other areas, this may lead to a gradual loss of mature trees, and replacement with more drought tolerant species.

The proponent has advised that in such an event, alternate criteria are proposed to be used to ensure that the ecological values of the groundwater-dependent vegetation are maintained, such as species diversity indices, presence of indicator species and similarity indices.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.1.

Use of groundwater modelling as a management tool

The use of modelling of groundwater levels is proposed to be used by the proponent to determine groundwater levels, in relation to known groundwater requirements of particular groundwater dependent vegetation communities. This method is used to determine the EWR and EWPs, and is considered to be an effective management tool.

The use of and adequacy of groundwater modelling as a management tool was endorsed by the EPA in the assessment of the Gnangara Mound Groundwater Resources ERMP in 1988.

Further evaluation of this topic by the EPA is not required.

Protection of phreatophytic vegetation

The Water and Rivers Commission proposes to maintain the ecological values of phreatophytic (i.e. groundwater-dependent) vegetation by the provision of specific water levels in a number of environmentally sensitive locations throughout the Gnangara Mound. Water levels are proposed to be specified through the use of EWRs and EWPs.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.1.

Protection of groundwater-dependent cave fauna

The proposed EWRs include consideration of maintaining cave water levels and hydrological regimes which allow for the protection of cave fauna.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.1.

Adequacy of existing land use management plans to manage impacts from private and public groundwater allocation

It is acknowledged that properly implemented and co-ordinated land use control and management of the Gnangara Mound is vital to ensure that the groundwater quality is maintained to provide a sustainable potable water resource.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.3.

Co-ordinated land management arrangements to protect or enhance groundwater resources

Co-operation with other State Government agencies to achieve satisfactory land management arrangements whilst protecting or enhancing water resources. Effective land management arrangements need to be in place to ensure that land above the groundwater mound is managed effectively.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.4.

Impact of abstraction on groundwater quality within the unconfined aquifer

Abstraction of groundwater from the Gnangara Mound has the potential to have an impact on groundwater quality, through contamination or movement of the fresh/salt water interface eastwards from the coast.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.5.

Long term impact on water in the superficial unconfined aquifers through abstraction from the confined aquifer

Continued groundwater abstraction from the confined aquifer has the potential to impact on the water in the superficial aquifer. The long term impacts of continued abstraction for the unconfined aquifer are unknown.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.6.

Additional abstraction in the vicinity of Little Coogee Flat

Little Coogee Flat is located within the Wanneroo Borefield. The abstraction of additional groundwater for public water supply in the vicinity of Little Coogee Flat is likely to have implications on groundwater-dependent vegetation near the Flat.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.2.

Integration of strategic drainage management with general water resource management strategies on the Gnangara Mound

This issue is not considered to be part of the scope of the Section 46 assessment, as it focuses on groundwater only. It is acknowledged that strategic drainage is an important issue, however it should be addressed outside the context of this assessment report.

Separate evaluation of this topic by the EPA is not required.

Social Surroundings

Impact on Aboriginal and local community.

The proponent has advised that there has been considerable consultation with Aboriginal and local community groups during the preparation of the Section 46 document, and that this consultation will continue.

Other processes, including the implementation of the requirements of the *Aboriginal Heritage Act* are in place to address this topic. Accordingly, it is considered that separate evaluation of this topic by the EPA is not required.

Long term sustainable use and management of the Gnangara groundwater resources

This topic raises the principle of whether continued use of groundwater within the Gnangara Mound is environmentally sustainable in the long term.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.7.

Pollution Potential

Nutrient management issues

Nutrient management measures associated with land use activities on the Mound are considered to be beyond the scope of the Section 46 document. It is considered that this issue can be best addressed in the context of specific land use plans and management for the Mound.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA and is discussed in Section 4.4.

Management of groundwater allocations to minimise impact on groundwater quality

It is considered that continued abstraction from the confined Leederville Formation may lead to a deterioration in water quality in the superficial unconfined aquifer in the long term.

This topic has been identified as an issue which requires further and detailed evaluation by the EPA - see Section 4.7.

3.3.3 Summary

Table 2 summarises the process used by the EPA to evaluate the topics raised during the environmental impact assessment process, The table identifies the topics, the comments received from relevant local and government agencies, and members of the public. If a topic is considered to be environmentally significant, it becomes an issue and is further evaluated by the EPA (as summarised in Table 3). Section 4 of this report provides the detail of this evaluation.

The issues identified in Table 3 as requiring further evaluation by the EPA are :

- the protection of groundwater dependent communities through the principle, application and adequacy of EWPs and EWRs. This issue combines the following topics:
  - principle of using the concepts of Environmental Water Requirements and Environmental Water Provisions;
  - proposed distinction between private and public groundwater allocation;
  - environmental implications when the EWR is not the same as the EWP;
  - protection of phreatophytic vegetation; and
  - protection of groundwater dependent cave fauna.
- additional abstraction in the vicinity of Little Coogee Flat;
- existing land use and management on the Gnangara Mound. This issue includes discussion of the management of land use activities which have the potential for nutrient input into groundwater
- co-ordination of land management on the Gnangara Mound;
- impact of abstraction on groundwater quality within the unconfined aquifer;
- long term impact on water in the superficial aquifers through abstraction from the confined aquifer; and
- long term sustainable use of the Gnangara Mound groundwater resources.

4. Evaluation of key environmental issues

4.1 Protection of groundwater-dependent ecological communities

4.1.1 Objective

The EPA's objective is to:

- ensure that the ecological integrity of all groundwater-dependent communities located on the Gnangara Mound is maintained; and
- ensure that additional groundwater abstraction from the Gnangara Mound does not have an adverse impact on groundwater-dependent vegetation.

Table 2. Identification of issues which require Environmental Protection Authority evaluation

Topic	Local and State Government advice to the EPA	Public submissions	Proponent's response	Issues
Biophysical Topics				
Principle of concepts Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs).	The City of Wanneroo express concern regarding the 'snapshot approach' taken by the WRC to the setting of EWRs. The City of Wanneroo also express concern regarding the removal of specific groundwater allocation quotas.	The majority of public submissions expressed concern regarding the use of EWRs and EWPs as the basis for groundwater level criteria	The concept of EWPs and EWRs has been widely accepted as the basis of groundwater level criteria in other Australian states. It is considered to be a pro-active approach	The concept of EWPs and EWRs require assessment by the EPA. *(Issue 1, Table 3)*
Proposed distinction between private and public groundwater allocation.	The DEP advise that this distinction differs from the original groundwater allocation quotas, identified in 1988, which makes no distinction between private and public groundwater abstraction.	The distinction between private and public allocation may lead to conflict.	The removal of specified groundwater allocation quotas is considered to allow greater flexibility in allocating groundwater to private users	Existing Environmental Conditions specify allocation volumes. The Section 46 document proposes to vary total abstraction amounts within each wetland area according to identified EWRs and EWPs. This issue is evaluated within the context of EWPs and EWRs. *(Issue 1, Table 3)*
Environmental implications when EWR is not the same as the EWP.	The DEP advises that this issue is especially relevant in the Bombing Range Wetlands and Melaleuca Park.	Concern was expressed regarding the implications of this on vegetation communities.	It is acknowledged that vegetation communities may be affected however here is expected to be a gradual loss of mature trees and replacement with more drought tolerant species in some areas, however this will not lead to a loss of species diversity.	Alternate criteria are proposed to be used in the event that the EWPs do not meet the identified EWRs. This is an issue which requires detailed evaluation by the EPA. *(Issue 1, Table 3)*
Use of and adequacy of groundwater modelling as a management tool.	This method was originally adopted by the WAWA and EPA in 1986 as part of the groundwater allocation strategy.		This method is still considered to be the best approach in ensuring the ecological values of wetland systems on the Gnangara Mound are maintained.	This topic does not warrant further evaluation by the EPA.
Protection of phreatophytic vegetation.	This was identified as a key environmental issue by the DEP in the Section 46 guidelines.	Conservation values of wetland dependent vegetation may be compromised as a result of the implementation of the EWR and EWP principles.	Protection of phreatophytic vegetation is proposed to be achieved via the implementation of EWPs and EWRs.	This issue is evaluated within the context of EWPs and EWRs. *(Issue 1, Table 3)*
Protection of cave fauna		Groundwater should take into account the potential impact on troglobitic fauna living in caves in the vicinity of the Yanchep National Park.	Implementation of the EWRs will ensure the current hydrological regime within the caves is maintained.	This issue is evaluated within the context of EWPs and EWRs. *(Issue 1, Table 3)*
Existing land use management on the Gnangara Mound	This was identified as a key environmental issue by the DEP in the Section 46 guidelines, and was also raised by the Ministry for Planning and the City of Wanneroo.	More stringent land use and management controls are required to manage and co-ordinate land use activity on the Mound to avoid pollution of the groundwater resource.	There are a number of relevant land use policies which exist or are in various stages of development to control land use and minimise impacts on potable groundwater quality.	This issue requires detailed evaluation by the EPA. *(Issue 3, Table 3)*
Co-ordination of land management on the Gnangara Mound	This was identified as a key environmental issue by the DEP in the Section 46 guidelines.	Concern regarding the on-going use of large areas over the Mound for pine plantations. This has the potential to have a significant impact on groundwater levels. The on-going use of herbicides and pesticides by CALM within the pine plantations was also of concern.	Any potential to impact on groundwater quality as a result of land use is beyond the scope of the Section 46 document.	This issue requires detailed evaluation by the EPA. *(Issue 4, Table 3)*

Table 2. Identification of issues which require Environmental Protection Authority evaluation *(cont'd)*

Topic	Local and State Government advice to the EPA	Public submissions	Proponent's response	Issues
Impact of abstraction on groundwater quality within the unconfined aquifer	The City of Wanneroo express the view that as the WRC acknowledges that there is a degree of conductivity between the confined and unconfined superficial aquifers, the WRC should be requested to demonstrate how it would cope with a 'dry period' without impacting on the unconfined aquifer.	-	Additional abstraction is unlikely to have an impact on water quality within the unconfined aquifer.	This issue requires detailed evaluation by the EPA. *(Issue 5, Table 3)*
Additional abstraction in the vicinity of Little Coogee Flat	The DEP advise that approval 'in principle' was granted to the location of 19 additional bores on the Pinjar borefield by the EPA in it's assessment of the Gnangara Mound Water Resources ERMP in 1988. The WRC are now looking to supply an extra 1.5 million m^3, to be allocated for public water supply.	-	Approval for an additional 3 bores is expected to be forthcoming at a future date.	This issue requires detailed evaluation by the EPA. *(Issue 2, Table 3)*
Strategic drainage management	The City of Wanneroo express the view that rising wetland (and groundwater) levels have significant implications for local Government, and strategic drainage control should be considered as part of the overall water resources management strategy for the Gnangara Mound.	Increasing urbanisation on the Mound has led to a water table rise in some areas.	This topic is not considered to be part of the scope of the Section 46 assessment.	This topic does not warrant further detailed assessment by the EPA.
Social topics				
Impact on the Aboriginal and local community	The Aboriginal Affairs Department emphasises the importance in involving the Aboriginal community when developing public involvement and awareness programmes.	The WRC should attempt to liaise more closely and often with residents on the Mound, to ensure that their views are understood.	There has been and will continue to be considerable consultation with Aboriginal community groups and the local community.	This topic can be appropriatey addressed through other statutory mechanisms such as the *Aboriginal Heritage Act*, and does not require further evaluation by the EPA.
Long term sustainable use of Gnangara Mound groundwater resources.	The City of Wanneroo advise that it is important that the EPA considers WRC's proposals for the Gnangara Mound in the context of ensuring sustainable utilisation and management of its environmental resources.	Implications are made to the effect that artificial recharge may be used where EWRs are breached which is inconsistent with the EWR logic.	This issue has been considered in a local context in the Section 46 document. The broader issue of sustainable development is addressed in the Perth Water Future Study.	This issue requires detailed evaluation by the EPA. *(Issue 7, Table 3)*
Pollution topics				
Nutrient management		The WRC did not present any information on nutrient management on the Mound.	This topic is beyond the scope of this assessment as it addressed water allocation criteria only.	The relevant aspects of this issue are considered in the co-ordination of land management. *(Issue 4, Table 3)*
Long term impact on superficial unconfined aquifer through abstraction from the confined aquifer.	This was identified as a key environmental issue by the DEP in the Section 46 guidelines.		Acknowledged that pumping from the confined aquifer has the potential to impact on the superficial aquifer.	This issue requires detailed evaluation by the EPA. *(Issue 6 Table 3)*

4.1.2 Policy framework

Conservation Through Reserves - System 6 Areas

Areas which have been identified as having high conservation value on the Gnangara Mound, and which have been identified in the 'Conservation through Reserves Committee' - The Darling System (System 6).

Gnangara Mound Environmental Protection Policy

The purpose of this Policy is to protect the level and quality of groundwater on or under the policy area which is Crown Land, and to protect native vegetation on the Mound. The Policy recognises that there are activities which can cause groundwater, native vegetation or wetlands to be degraded and disallows discharge of contaminants, excavation and mining, abstraction of groundwater, and filling of wetlands without authorisation.

Swan Coastal Plain (Lakes) Environmental Protection Policy (1992)

The purpose of this Policy is to protect the environmental values of designated lakes on the Swan Coastal Plain. The Policy prohibits the mining, draining, filling or polluting of these wetlands.

4.1.3 Technical information

Gnangara Mound Groundwater Resources - ERMP Appendices (1988)

Appendix A : Effects of Gnangara Mound Groundwater Developments on Native Vegetation of the Northern Swan Coastal Plain (E M Mattiske and Associates, 1985).

This report identifies the types of vegetation complexes which are found on the Northern Swan Coastal Plain and identifies the biological effects of draw down (by groundwater bores). It concludes that the majority of native species can tolerate fluctuations in soil moisture, however some species are intolerant of change. It was recommended that monitoring systems should be implemented to monitor lake levels and fringing vegetation and to establish vegetation monitoring transects, across predicted impact and control areas, to determine potential impacts of groundwater level fluctuation on vegetation communities.

Appendix C : The Gnangara Mound Groundwater Area : Landforms, Soils and Vegetation (W M McArthur and E M Mattiske, 1985).

This report describes the mapping units, primarily 'Bassendean Dunes', 'Spearwood Dunes', and 'Alluvial Terrain' in the Gnangara area and the vegetation communities which are typically associated with these units.

Appendix D : Gnangara Mound Region Ecosystems, Sensitive Species and Conservation Reserves (A S Weston 1986).

This report adapts and summarises previous work undertaken on native vegetation on the Gnangara Mound and discusses rare, geographically restricted and poorly known flora and fauna for the area. The report finds that national parks and other conservation reserves are as vulnerable to changes in groundwater regimes as natural ecosystems outside the reserves. Accordingly, the report finds that development of the unconfined groundwater resource and the management of its abstraction should take a cautious and conservative approach to ensure that conservation values are protected.

Gnangara Mound Vegetation Stress Study (Water Authority of WA, 1992)

The report discusses the results of investigations of vegetation deaths which occurred on the Gnangara Mound during January and February 1991. These deaths have been ascribed to low soil moisture levels resulting from long periods of low rainfall combined with high maximum daily temperatures.

The Effect of Altered Water Regimes on Wetland Plants (Froend et al, 1993)

This report is part of the 'Wetlands of the Swan Coastal Plain' series (Volume 4). The objective of this document was to predict the consequences of altered water level regimes on the survival of individual species of common emergent plants and on the composition of emergent plant

communities. The report concluded that the threat of lower wetland water regimes, due to groundwater abstraction for public and private use, is not necessarily a significant one for wetlands. Relative to long term variation in rainfall, groundwater abstraction has generally less impact on wetland water levels, although it would exacerbate the effects of a series of low rainfall years. Abstraction does not affect all wetlands equally because it produces localised rather than widespread effects.

The report concludes that a lowering of the water regime would most likely result in a gradual change in vegetation. The exact nature of vegetation response to specific groundwater reduction should be determined by assessing the current vegetation distribution relative to the water regime at the wetland in question.

Wetland Classification on the Basis of Water Quality and Invertebrate Community Data (Davis et al (1993)

This report is part of the 'Wetlands of the Swan Coastal Plain' series (Volume 6) and represents the first comprehensive examination of the physical, chemical and biological attributes of a large group of wetlands in Australia. Forty-one wetlands on the Swan Coastal Plain were identified and studied, which were considered to be representative of a wide range of different types of wetland.

Major results of the study included specific information on a number of parameters including salinity, pH, thermal stratification and mixing, colour, trophic status, occurrence of pesticides and heavy metals and aquatic invertebrates. Suggestions on further monitoring and management programmes, and approaches to wetland preservation and rehabilitation were made in the document as a result of these studies.

Gnangara Mound Section 46 document (1995)

This document defines the concepts of Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs). The adoption of these involves the setting of minimum water levels in sensitive environmental areas. The Water and Rivers Commission will have the responsibility for managing groundwater allocation to meet the water levels set in the Environmental Water Provisions.

EWRs are defined as the minimum groundwater levels required to be maintained to ensure the maintenance of the ecological integrity of a particular wetland. The EWR can include elements of quantity and duration, and applies both spatially and temporally. An Environmental Water Provision (EWP) is defined as that part of the EWR that can be met and is provided, after consideration of social and economic issues is the actual environmental allocation.

Wherever possible the EWP is set to equal the EWR, however in certain instances, where there are issues in the use of the finite water resource, this may not be achievable. The EWP will be less than the EWR when other requirements (social or economic) are considered to be more important than providing the full environmental requirement.

In determining EWRs and EWPs, the WRC have identified a number of wetlands as representative of the range of geomorphic units and wetland types across the Gnangara Mound. These wetlands have also been identified as having significant ecological value, and are indicated in Figure 1. It is proposed by the WRC that if the EWRs for these wetlands are maintained then the ecological values of the wetlands will be maintained.

This document also contains a detailed description of the proposed method of groundwater allocation in Chapter 7, a description of the proposed impact of land uses and groundwater abstraction on water levels in Chapter 8, a comparison of groundwater impacts with EWRs in Chapter 9, and a proposed monitoring and management programme in Chapter 10.

4.1.4 Government and local government comments

The City of Wanneroo expressed concern at the 'snapshot approach' taken by the WRC to the setting of EWRs. As stated by the WRC, the EWR is based on maintaining the current values of the representative wetlands chosen. These values are a function of their present condition. However, the current state of the wetlands and their conservation values reflect the generally below average rainfalls since 1975, and a significant impact from pine plantations. If these

scenarios were different, the EWRs would be different, and therefore the appropriateness of this approach is questioned.

The City of Wanneroo also expressed concern at the removal of specific groundwater allocation quotas, as the EWRs for terrestrial vegetation in some areas are likely to be compromised under the preferred abstraction strategies for the Lexia and Pinjar Schemes. The City also considers that reliance on artificial recharge to maintain EWR levels, as proposed by the WRC in some instances, is inappropriate and that, if this is the case, the proposed groundwater abstraction strategy is not sustainable. It is considered that if EWR levels are identified, groundwater abstraction should be managed so that the identified level is not compromised.

The DEP advise that:

- the proposed distinction between private and public water allocation differs from the original groundwater allocation quotas, identified in 1988, which make no distinction between private and public groundwater abstraction;
- the adoption of water allocation criteria, in the event that EWPs do not equal EWRs, is especially relevant in the Bombing Range Wetlands and Melaleuca Park; and
- the measures proposed to ameliorate environmental impacts on groundwater-dependent vegetation as a result of continued groundwater abstraction were identified as a key environmental issue in the Section 46 guidelines.

4.1.5 Comments from public submissions

The majority of public submissions expressed concern at the use of EWRs and EWPs as the basis for groundwater level criteria. Points raised included:

- the criteria are based on present levels using a 'snapshot approach', and conservation values may not be accurately reflected;
- the EWR and EWP figures are based on the assumption that vegetation units are moving towards the xeric or dry end of the vegetation association. This may not accurately represent the change in vegetation communities in the long term or protect conservation values, and may lead to tree deaths such as occurred on the Mound in 1991; and
- not all important wetland areas have EWRs set. It is considered unclear what would happen to those wetlands which have no specific EWR set.

The Section 46 document indicates that there is no longer a need to specify volumes, as EWRs and EWPs would be adequate. Concern was expressed that if the need to specify individual groundwater allocation quotas is removed, unless there is explicit acceptance that the EWR takes precedence over the EWP, this may lead to the values of terrestrial vegetation being compromised, and the process will become demand driven. This is likely to create conflict between groundwater users during dry years and compromise vegetation communities. The Section 46 document indicates that in some areas, the EWP is less than the EWR. Concern was expressed that this may have serious consequences on vegetation in the vicinity. The concept of 'trade offs' as proposed by the WRC ie. death of mature trees against the demand for water resources, is considered to be unacceptable.

4.1.6 Proponent's response

The proponent reiterates that the concept of EWPs and EWRs has been widely accepted as the basis for water allocations in other Australian states. It is considered to be a pro-active approach, based on computer modelling, to determine the EWRs, ie. the preferred allocation figures. EWPs reflect actual allocation figures, which take into consideration the EWRs. EWRs are expected to be continually reviewed and refined, based on climatic conditions, draw down data, and information on the status of vegetation from transects across the Mound. It is also acknowledged that not all wetlands on the Mound have EWRs set, as this is impractical. EWRs have been set for those wetlands which are considered to have the highest conservation values, and are presumed to be representative of other wetlands in the Study Area.

The proponent considers that the intention to remove the groundwater quotas has been misunderstood. The concept of EWRs and EWPs would in fact offer a higher degree of protection than past approaches for groundwater-dependent vegetation as they acknowledge specific water requirements. It is expected that vegetation transects would be monitored, and if impacts are detected, abstraction rates would be altered accordingly. (Commitments P 33 to 37 inclusive, 39, 42, 43, 46, 47 to 54 inclusive, Appendix 3). There is no perceived need to reduce private quotas, and any reductions if required are likely to be in the public water allocation. Therefore no conflict is anticipated.

The proponent acknowledges that in one area (Bombing Range Wetlands) the proposed EWPs are less that the EWRs. It is acknowledged that vegetation communities may be affected. There is expected to be a gradual loss of mature trees and replacement with more drought tolerant species in some areas, however this is not expected to lead to a loss of species diversity but rather to a change in the abundance of some species in some areas. Criteria such as 'indicator species', 'species diversity' and 'similarity indices' are proposed to be used as an appropriate measure of change by the proponent to ensure that there is no loss in species diversity (Commitment 34a, Appendix 3).

The use of EWPs and EWRs to protect phreatophytic vegetation may lead to a more xeric vegetation community in the Pinjar area, however this is considered to be an acceptable 'trade-off' when the current status of the land is considered and the existing investment in groundwater abstraction infrastructure. The proponent has emphasised that this is likely to occur as a result of the current rate of abstraction.

The proponent considers the proposed method is currently the best approach to ensuring the ecological values of wetland systems on the Gnangara Mound are maintained in the face of continued groundwater abstraction.

The proponent has undertaken a commitment to undertake artificial recharge in some instances, to meet the requirements of EWPs (Commitments P 48 and 49, Appendix 3). The proponent has also undertaken to implement alternative criteria to ensure that the conservation values of groundwater dependent vegetation are retained (Commitment 34a, Appendix 3).

4.1.7 EPA's evaluation and recommendations

The WRC propose the concepts of Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs), in place of the allocation of specific water amounts.

The concept of Environmental Water Provisions (EWPs) is that part of the EWR that can be met and is provided after consideration of social and economic issues. It is proposed by the WRC that if the EWRs for these wetlands are maintained then the ecological values of the wetlands will be maintained.

The EWRs are proposed to be established via a "snap shot" approach, ie. maintaining the current values of a number of representative wetlands and vegetation, based on information available to date. The proponent has committed to implement an on-going monitoring programme, to provide for regular review of EWRs at the monitoring sites in specified lakes and wells. These data will then be used to ensure that the EWRs for specific areas are continually updated to reflect the needs of the wetland and vegetation communities.

In considering the application of EWPs and EWRs to ensure the protection of groundwater-dependent ecological communities, the EPA has evaluated a number of environmental implications:

- *distinction between private and public groundwater allocation*

The proponent proposes to set minimum water levels near sensitive groundwater-dependent ecological communities including wetlands, phreatophytic terrestrial vegetation, banksia woodlands and cave ecosystems in the same way as past environmental criteria, but propose to remove specified groundwater allocation quotas to private users from the environmental conditions.

The EPA acknowledges that this approach allows the Water and Rivers Commission flexibility in allocating groundwater to private users, while ensuring that specific water levels in sensitive environmental areas are maintained.

- *more xeric vegetation - the implementation of these criteria may lead to a more xeric vegetation community in the Pinjar area.*

The EPA notes:

- the proponent's proposed 'trade-off' when the current status of the land is considered;
- the xeric trend is likely to occur as a result of the present rate of abstraction and is not linked to any likely increase in abstraction;
- there is likely to be a gradual loss of mature trees in some areas, with replacement by more drought-tolerant species leading to a change in the abundance of some species in some areas, but not a loss of species diversity.

The EPA's objective is that the biodiversity of these areas should be retained and not decline as a result of abstraction. This concern is also raised in the public submissions. The EPA notes the commitment by the proponent:

- to implement a monitoring programme, to ensure the maintenance of ecological diversity in wetland areas, and other groundwater-dependent communities such as cave streams and banksia woodlands;
- to review the EWRs based on the results of this monitoring; and
- if, as a result of this continuing monitoring, adverse impacts on vegetation communities are detected, the proponent will direct the Water Corporation to alter abstraction rates accordingly.

In order to set appropriate EWPs to ensure the protection of groundwater dependent communities as a result of continued abstraction, the proponent has determined water regime management objectives. The objectives have corresponding water level criteria. The water regime management objectives for each wetland proposed to be monitored, performance indicators, and the corresponding water level criteria for these wetlands are included in Appendix 3.

The EPA notes that the proponent has committed to monitor specified vegetation transects (indicated in Figure 1) on a regular basis. If impacts are detected, abstraction rates are proposed to be monitored accordingly. The proponent has also committed to report to the Department of Environmental Protection on the management of the groundwater within the Gnangara Study area every three years. This is proposed to include information on the operation of groundwater schemes and private groundwater use, compliance with EWPs and environmental conditions, and environmental impacts. In those years where a triennial report is not submitted, the proponent with report to the Department of Environmental Protection on compliance with environmental conditions.

- *EWPs may be less than EWRs*
- *EWPs are likely to be less than EWRs for some wetland areas, eg. the Bombing Range vegetation*

The EPA understands that the EWR defines the water requirements of the groundwater-dependent vegetation. In most instances, the WRC consider that the EWRs can be met as a result of groundwater abstraction. However it is acknowledged that in some areas on the Gnangara Mound, groundwater abstraction is likely to exceed the groundwater-dependent vegetation requirements, for example in the vicinity of the Bombing Range Wetlands, and Melaleuca Park.

The WRC have indicated that in these instances, it is likely that the EWRs cannot be achieved even with no further groundwater abstraction, due to climatic effects, ie as a result of reduced rainfall over the last 20 years. At locations such as Melaleuca Park, which has been identified as having a high conservation value, further groundwater abstraction is considered undesirable and is not proposed by the WRC. However, in some areas, such as the Bombing Range Wetlands,

it is acknowledged that continued abstraction is likely to result in some tree death. This is expected to result in a change in the **abundance** of some vegetation species, but is not likely to lead to a loss in **species diversity**.

In adopting alternative criteria, it is acknowledged that there may be a loss of some mature trees which may result in a change in vegetation composition.

The EPA understands that in instances where the EWP is likely to be less than the EWR, such as at the Bombing Range, alternative criteria may be utilised by the WRC to ensure that the ecological values of the groundwater dependent vegetation are preserved. Alternative criteria proposed to be used include the monitoring of 'indicator species', 'species diversity' and 'similarity indices'. A summary of the meanings of these criteria is included in Appendix 4. The proponent has committed to implement the alternative criteria to ensure that where EWRs do not meet EWPs, the conservation values of these areas are retained.

The EPA concludes that the proposal by the WRC to adopt alternative criteria to ensure retention of the conservation values of groundwater-dependent vegetation in these areas, is consistent with the EPA's environmental objectives.

In reaching this conclusion, the Authority has taken into consideration:

- adoption of the concept of ecological benefit resulting from a change from the current wetland water criteria to Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs);
- the method by which the EWRs and EWPs will be given effect, ie. in the terms of environmental objectives and control of water levels in lakes and wells nominated by the WRC;
- a commitment by the proponent to implement alternative criteria to ensure that where EWRs do not meet EWPs, the conservation values of groundwater dependent vegetation are retained; and
- a commitment by the proponent to adopt a revised monitoring programme to ensure the maintenance of ecological diversity in areas where the identified EWP is likely to be less than the EWR.

4.2 Additional groundwater abstraction in the vicinity of Little Coogee Flat

4.2.1 Objective

The EPA's objective is to ensure that additional groundwater abstraction from the Gnangara Mound does not have an adverse impact on the groundwater-dependent vegetation, particularly in the vicinity of Little Coogee Flat.

4.2.2 Policy framework

Swan Coastal Plain (Lakes) Environmental Protection Policy (1992)

The purpose of this Policy is to protect the environmental values of designated lakes on the Swan Coastal Plain. The Policy prohibits the mining, draining, filling or polluting of these wetlands.

System 6 Recommendation M8 Wanneroo Wetlands (eastern chain)

Little Coogee Flat is included within this recommendation. The area has been identified as having conservation value for nesting and feeding for waterbirds at certain times of the year. It was recommended that this area, amongst other wetland areas identified within Recommendation M8, be reserved for 'Parks and Recreation' under the Metropolitan Region Scheme.

4.2.3 Technical information

Gnangara Mound Groundwater Resources - ERMP Appendices

Appendix A : Effects of Gnangara Mound Groundwater Developments on Native Vegetation of the Northern Swan Coastal Plain (E M Mattiske and Associates, 1985).

This report identifies the types of vegetation complexes which are found on the Northern Swan Coastal Plain, including those found in the vicinity of Little Coogee Flat.

4.2.4 Government and local government comments

The DEP advised that approval 'in principle' was granted to the location of 19 additional bores on the Pinjar borefield by the EPA in its assessment of the Gnangara Mound Water Resources ERMP in 1988. The WRC is now looking to supply an extra 1.5 million m^3 per year, to be allocated for public water supply near the corner of Neaves Road and Pinjar Road on Little Coogee Flat as part of the Wanneroo Borefield. The Wanneroo borefield currently has an allocation quota of 12.2 m^3.

4.2.5 Proponent's response

The proponent has indicated that approval for the allocation of extra water in the vicinity of Little Coogee Flat is only requested at this stage. A formal request for three additional bores to supply this water is expected to be forthcoming at a future date if the additional allocation is approved by the EPA. It is acknowledged that the ultimate position of the bores is likely to have some impact on Little Coogee Flat.

4.2.6 EPA's evaluation

The EPA reiterates that the purpose of this assessment is primarily to assess the environmental acceptability of new groundwater level criteria to ensure the protection of groundwater dependent ecosystems. It is not the EPA's intention to review specific private and public groundwater bore allocations. However, it is noted that the proponent has undertaken a commitment to issue subsequent groundwater licenses in accordance with specified EWRs wherever possible, to meet groundwater allocation requirements.

Any additional abstraction from groundwater resources should be in accordance with specified EWRs. Where this is not possible, alternative criteria must be implemented to determine rates of change to the groundwater dependent vegetation. Alternative criteria proposed to be adopted include the monitoring of 'indicator species', 'species diversity' and 'similarity indicies' (as described Section 4.1.7 above).

The EPA notes and endorses the proponent's overall commitment to continue to monitor the groundwater levels on the Gnangara to specified wetland management objectives. It is expected that Little Coogee Flat will also be managed in accordance with this objective.

4.3 Existing land use management on the Gnangara Mound

4.3.1 Objective

The EPA's objective is to ensure there are mechanisms in place to achieve well co-ordinated land use control and management on the Gnangara Mound.

4.3.2 Policy framework

Gnangara Mound Environmental Protection Policy

The purpose of this Policy is to protect the level and quality of groundwater on or under the policy area which is Crown Land and to protect native vegetation on the Mound. The Policy recognises that there are activities which can cause groundwater, native vegetation or wetlands to be degraded and disallows discharge of contaminants, excavation and mining, abstraction of groundwater, and filling of wetlands without authorisation.

Swan Coastal Plain (Lakes) Environmental Protection Policy (1992)

The purpose of this Policy is to protect the environmental values of designated lakes on the Swan Coastal Plain. The Policy prohibits the mining, draining, filling or polluting of these wetlands.

Gnangara Crown Land Statement of Planning Policy (SPP)

This Policy was formulated by the Ministry for Planning to complement the Gnangara Mound EPP and to provide advice to planners which is consistent with the intent of the EPP.

4.3.3 Technical information

Select Committee on Metropolitan Development and Groundwater Supplies (1994)

This report provides a summary of issues relating to land use conflicts on the Gnangara Mound. As a result of this Study, the State Government has initiated the 'Gnangara Land Use and Water Management Strategy' (GLUWMS) . A steering committee for this group has been established, which involves representatives of the Water Corporation (WC), Department of Conservation and Land Management, Ministry for Planning (MfP), Department of Environmental Protection (DEP), Health Department, and the Shires of Wanneroo, Gingin and Swan. A 'Senior Officers Group' has also been established which includes representation for the WC, DEP, MfP, Health Department and the Water and Rivers Commission. This group is working through the implementation of the State government's response to the Select Committee recommendations, and will include appropriate land use management initiatives for groundwater protection on the Gnangara Mound.

Water Authority of WA Groundwater Protection Areas (1992)

The former WAWA identified 'Public Groundwater Source Protection Areas' and 'Underground Water Pollution Control Areas' on the Swan Coastal Plain (to minimise risk to groundwater pollution), and 'Public Water Supply Areas' in the 1970's. Priority 1, 2 and 3 Source Protection Areas were identified in 1992 to guide acceptable land use activities on the areas.

- Priority 1 - protection of the public water supply, to ensure there is no degradation of water resources in those areas. Strict limitations on land use within these areas exist;
- Priority 2 - areas which have a high priority for public water supply, but on which restricted development may take place within WRC policy guidelines, to ensure that there is no increased risk of pollution; and
- Priority 3 - areas where water supply needs can co-exist with other land uses. The WRC's objective in these areas is to keep the risk to the water source to a practical minimum while allowing other land uses.

The majority of the Gnangara Mound is a Priority 1 Protection Area.

Hydrogeology and groundwater Resources of the Perth Region, Western Australia (W A Davidson, 1995)

This document summarises the legislation and institutional responsibilities of the various government departments which have major responsibilities in groundwater management in WA.

Gnangara Mound Section 46 Document

The document identifies the following groups which have a role in providing management on the Gnangara Mound:

- Gnangara Mound Technical Advisory Group (GMTAG) - to provide specific planning and management advice to the Water and Rivers Commission;

- Gnangara Mound Community Consultative Committee - to provide advice to the former WAWA on the Gnangara Mound and provide a forum for information exchange on general water management issues; and
- Wanneroo Groundwater Advisory Committee - this Committee includes community and local government representatives and provides advice to the Water and Rivers Commission on groundwater issues in the Wanneroo Groundwater area.

4.3.4 Government and local government comments

Land use control and management on the Gnangara Mound was identified as a key environmental issue by the DEP in the Section 46 guidelines.

The Ministry for Planning advised that the WA Planning Commission has declared a 'Planning Control Area' over parts of Lake Pinjar, to protect the Priority 1 Gnangara Mound Protection Zone for the purpose of State Forests, Water Catchments and Parks and Recreation areas.

The City of Wanneroo expressed the view that more stringent land use management control should be implemented to better protect groundwater quality in the long term.

4.3.5 Comments from public submissions

A number of submissions expressed concern that more stringent land use and management controls are required to manage and co-ordinate land use activity on the Mound to avoid pollution of the groundwater resource. Concern was expressed that development is proceeding in a 'piecemeal' fashion without due regard to strategic planning to protect groundwater resources.

Concern was also expressed that developments such as major roads (eg. the proposed Perth to Darwin Highway), and airports are unsuitable forms of land use on the Mound.

4.3.6 Proponent's response

The proponent has responded that there are a number of relevant land use policies which exist or are in various stages of development to control land use and minimise impacts on potable groundwater quality. These include the Gnangara Crown Land Environmental Protection Policy (EPP) and the Gnangara Crown Land Statement of Planning Policy (SPP). Similar instruments for the control of land in private ownership are in draft form. A 'Select Committee on Metropolitan Development and Groundwater Supplies' to investigate land use conflict has also been established. Interim findings and recommendations of the Committee recommend a 'Gnangara Land Use and Water Management Strategy', be developed by the WRC in conjunction with the Ministry for Planning and that provision be made under the Metropolitan Water Supply and Service Act to declare Underground Water Pollution Control areas (UWPCAs) to protect potable water supplies.

The proponent pointed out that any new roads or airports would be subject to separate assessment by the EPA.

4.3.7 EPA's evaluation

The EPA understands that there are a number of existing statutory mechanisms to ensure adequate land use control and management over the Gnangara Mound. These include :

- Gnangara Crown Land Environmental Protection Policy;
- Swan Coastal Plain (Lakes) Environmental Protection Policy;
- Gnangara Crown Land Statement of Planning Policy ;
- WA Planning Commission 'Planning Control Area' over parts of Lake Pinjar, to protect the Priority 1 Gnangara Mound Protection Zone for the purpose of State Forests, Water Catchments and Parks and Recreation areas;

- declaration of Underground Water Pollution Control areas ;
- Gnangara Land Use and Water Management Strategy;
- Gnangara Mound Technical Advisory Group; and
- Gnangara Mound Community Consultative Committee.

The EPA notes the findings of the 'Select Committee on Metropolitan Development and Groundwater Supplies' and recommendations to form a the Gnangara Land Use and Water Management Strategy,(GLUWMS) and the Senior Officers Group (SOG) to promote a 'whole of government approach' to managing land use on the Gnangara Mound.

The EPA considers it is likely that initiatives proposed by the GLUWMS and SOG will replace existing policies.

4.4 Co-ordination of land management on the Gnangara Mound

4.4.1 Objective

The EPA's objective is to ensure there is a strategic and well co-ordinated approach across Government, to ensure satisfactory land management on the Gnangara Mound, to protect groundwater resources.

4.4.2 Policy framework

Gnangara Mound Environmental Protection Policy (1986)

The purpose of this Policy is to protect the level and quality of groundwater on or under the policy area which is Crown Land and to protect native vegetation on the Mound. The Policy recognises that there are activities which can cause groundwater, native vegetation or wetlands to be degraded and disallows discharge of contaminants, excavation and mining, abstraction of groundwater and filling of wetlands without authorisation.

Swan Coastal Plain (Lakes) Environmental Protection Policy (1992)

The purpose of this Policy is to protect the environmental values of designated lakes on the Swan Coastal Plain. The Policy prohibits the mining, draining, filling or polluting of these wetlands.

Gnangara Crown Land Statement of Planning Policy (SPP)

This Policy was formulated by the Ministry for Planning to complement the Gnangara Mound EPP, and to provide advice to planners which is consistent with the intent of the EPP.

4.4.3 Technical information

Hydrogeology and Groundwater Resources of the Perth Region, Western Australia (Davidson, 1995)

This document provides a description of investigations undertaken to date on groundwater contamination, including vulnerability of groundwater within the confined aquifers to contamination from sources such as industrial discharge, nutrient enrichment from fertiliser use associated with from market gardens, septic tanks, land fill sites, liquid waste disposal and contaminated urban run-off.

Select Committee on Metropolitan Development and Groundwater Supplies (1994)

This report provides a summary of issues relating to land use conflicts on the Gnangara Mound. It includes a number of recommendations including that a 'Gnangara Land Use and Water Management Strategy' (GLUWMS) be developed, and a review of the WAWA's groundwater priority area boundaries be reviewed. A Senior Officers Group has bee formed to implement the recommendations of the Select Committee Report.

4.4.4 Government and local government comments

This was identified as a key environmental issue by the DEP in the Section 46 guidelines, and principally relates to pine plantation management on the Gnangara Mound by the Department of Conservation and Land Management (CALM).

4.4.5 Comments from public submissions

A number of submissions expressed concern regarding the on-going use of large areas over the Mound for pine plantations. This has the potential to have a significant impact on groundwater levels. The on-going use of herbicides and pesticides by CALM within the pine plantations was also of concern.

4.4.6 Proponent's response

The proponent has advised that pine plantation management, including replanting (and thinning) will form part of a Memorandum of Understanding between CALM and the Water and Rivers Commission (Commitment p38, Appendix 3).

Water quality issues associated with the use of pesticides or herbicides will form part of a separate assessment by the EPA.

The WRC considers that any potential impact on water quality as a result of land use activities is beyond the scope of the Section 46 assessment.

4.4.7 EPA's evaluation

The EPA notes that co-ordination of land management described in Section 4.3.7 are currently in place to protect groundwater within the Gnangara Mound from adverse impacts associated with land use.

Additional measures to achieve co-ordination of management include the implementation of the recommendations of the 'Select Committee on Metropolitan Development and groundwater Supplies', including the 'Gnangara Land Use and Water Management Strategy' (GLUWMS).

The EPA considers that the implementation of the strategies proposed as part of the 'Select Committee on Metropolitan Development and groundwater Supplies' are adequate to ensure the continued protection of the Gnangara groundwater resources under future land uses. This is likely to involve the preparation of Environmental Protection Policies and State Planning Policies to control land use over private and publicly owned land.

4.5 Impact of abstraction on groundwater quality within the unconfined aquifer

4.5.1 Objective

The EPA's objective is to ensure that the long term abstraction of groundwater from the Gnangara Mound does not have an adverse impact on water quality in the unconfined aquifer.

4.5.2 Policy framework

'National Water Quality Management Strategy - Australian Water Quality Guidelines for Fresh and Marine Waters' Australia and New Zealand Environment and Conservation Council (1992).

These guidelines define the standards of groundwater for drinking purposes.

Gnangara Mound Environmental Protection Policy

The purpose of this Policy is to protect the level and quality of groundwater on or under the policy area which is Crown Land and to protect native vegetation on the Mound. The Policy

recognises that there are activities which can cause groundwater, native vegetation or wetlands to be degraded and disallows discharge of contaminants, excavation and mining, abstraction of groundwater, and filling of wetlands without authorisation.

Swan Coastal Plain (Lakes) Environmental Protection Policy (1992)

The purpose of this Policy is to protect the environmental values of designated lakes on the Swan Coastal Plain. The Policy prohibits the mining, draining, filling or polluting of these wetlands.

Gnangara Crown Land Statement of Planning Policy (SPP)

This Policy was formulated by the Ministry for Planning to complement the Gnangara Mound EPP, and to provide advice to planners which is consistent with the intent of the EPP.

4.5.3 Government and local government comments

The DEP considers it important that management of the resource quality is maintained to protect the potable groundwater resource. It is acknowledged that the Gnangara Environmental Protection Policy is designed to address this issue.

4.5.4 Proponent's response

The WRC advise that a small increase in groundwater abstraction is proposed for the private area, however a much larger increase is proposed for the publicly owned area. Proposed abstraction rates are considerably less than the anticipated recharge rates. Additional abstraction as proposed is therefore considered unlikely to have a significant impact on groundwater quality.

4.5.5 EPA's evaluation

The EPA acknowledges that the continued abstraction of groundwater from the Gnangara Mound has the potential to have an impact on water quality through, for example, the movement of the fresh/salt groundwater interface eastwards from the coast. The EPA also notes the proponent's response to this issue.

It is understood that to date there is no serious threat to water quality as a result of continued abstraction. Further, in view of the distance of the abstraction from the coast, it is considered that the abstraction is unlikely to have an adverse impact on the fresh/salt water interface, and is therefore unlikely to impact on water quality.

The EPA also acknowledges the water quality of wetlands on the Gnangara Mound depends upon the quality of the groundwater and surface water entering the wetlands (as well as on chemical and biological processes taking place within the lake) (Townley et al, 1993).

It is the EPA's expectation that the management of groundwater quality will be appropriately managed in the long term through the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' (1994). Accordingly, no further recommendation on this issue is considered necessary.

4.6 Long term impact on water in the superficial unconfined aquifers through abstraction from the confined aquifer

4.6.1 Objective

The EPA's objective is to ensure there is no adverse impact on water in the unconfined aquifers as a result of groundwater abstraction from the confined aquifer.

4.6.2 Technical information

Hydrogeology and Groundwater Resources of the Perth Region, Western Australia (Davidson 1995)

This document provides a technical review of the geology, hydrogeology, groundwater resources and groundwater management of groundwater resources in the Perth Region. It includes a description of superficial aquifers and states that the most important shallow-groundwater resources in the Perth region are within the Gnangara Mound. Where the water table is less than 3 metres below ground level, water in the superficial aquifer supports phreatophytic vegetation and wetland ecosystems. Recharge of the superficial aquifer is mostly from direct rainfall.

The groundwater resources of the unconfined and confined aquifers are limited by rainfall recharge rates to the superficial aquifer, which is influenced by climate, geology, land use and soil condition.

The Leederville Aquifer is a confined aquifer which is recharged by the downward leakage of groundwater from the superficial aquifer in areas where the two aquifers are in direct hydraulic connection. The report concludes that increased groundwater abstraction from the superficial aquifer will 'steepen the hydraulic gradient' between the superficial and Leederville Aquifers and induce additional groundwater recharge to the Leederville Aquifer.

4.6.3 Government and local government comments

The City of Wanneroo expressed the view that as there is a degree of conductivity between the confined and unconfined superficial aquifers the WRC should be requested to demonstrate how it would cope with a 'dry period' without impact on water in the unconfined aquifer.

4.6.4 Proponent's response

The proponent acknowledges in the Section 46 document that pumping from the confined Leederville Formation has the potential to impact on water levels in the superficial aquifer levels (Section 2.4.5). It is also acknowledged that the lowering of pressure heads on the superficial aquifer is unknown. The proponent has recently commenced the development of a computer-based hydraulic model of the Leederville Aquifer. This model will provide the understanding necessary for management of potential impacts on superficial aquifers. The proponent has undertaken a commitment to continuously monitor the impact of confined aquifer abstraction on water levels in the unconfined aquifer. (Commitment P 53.13, Appendix 3). If significant impacts are observed, the proponent has undertaken a commitment to discuss these impacts with the EPA.

Drought periods will be managed via strategies which include a forced reduction of abstraction for public water supply.

4.6.5 EPA's evaluation

The EPA understands that abstraction from the Leederville Formation has the potential to impact on water in the superficial unconfined aquifers (Davidson, 1995). In the short term, this issue is not considered to be critical, as the EWPs proposed to be retained by the proponent will maintain groundwater dependent ecosystems. However, the long term effects are unknown.

The EPA notes that the proponent intends to develop a computer-based model to provide a better understanding of the long term impacts on water in the superficial unconfined aquifer. These studies will allow for a better understanding of the linkages between the confined and unconfined aquifers, and therefore the potential impact of continued abstraction on water table levels.

The Authority also notes the proponent's commitment to continuously monitor the impact of confined aquifer abstraction on water levels in the unconfined aquifer. If significant impacts are observed, the proponent has undertaken a commitment to discuss these impacts with the EPA.

for detailed discussion. However, it is understood that the proponent is unable to commit to any specific remedial action in the event of adverse impacts of groundwater abstraction until there is a better understanding of the hydrological implications

The EPA expects that the WRC will submit the findings of the additional research on the impacts on water in the unconfined aquifers to the Department of Environmental Protection as soon as additional information is available. It is understood that additional information on this issue, which will allow a better understanding of the long term trends is likely to be forthcoming in August 1996.

The EPA concludes that the proponent's commitment to ensure that the EPA is kept informed on this issue as a matter of priority is acceptable.

4.7 Long term sustainable use of Gnangara Mound groundwater resources

4.7.1 Objective

The EPA's objective is to ensure that groundwater abstraction is sustainable in the long term.

4.7.2 Technical information

Select Committee on Metropolitan Development and Groundwater Supplies (1994)

Recommendations included within this report are expected to initiate a whole of government approach to manage long term sustainable use of groundwater within the Gnangara Mound.

4.7.3 Comments from key government agencies

The City of Wanneroo expressed the view that it is important that the EPA considers WRC's proposals for the Gnangara Mound in the context of ensuring 'genuinely sustainable utilisation and management of its environmental resources', ie. groundwater within the Mound.

4.7.4 Comments from public submissions

The view was expressed that implications are made in the Section 46 document to the effect that artificial recharge may be used where EWRs are breached. This is inconsistent with the EWR logic and cannot be considered to be sustainable. Concern was also expressed that the groundwater demand implications from long term population growth is not addressed. It is important to consider this in the context of ensuring genuine sustainable utilisation and management of groundwater resources.

4.7.5 Proponent's response

The WRC advise that this issue has been considered in a local context in the Section 46 document. The broader issue of sustainable development is addressed in the 'Perth Water Future Study'.

4.7.6 EPA's evaluation

This issue is of concern to the EPA. It is acknowledged that the issue of sustainable use of groundwater is dealt with in the 'Perth Water Future Study', which is currently being assessed by the EPA under Section 16 (e) of the Environmental Protection Act. Accordingly it is concluded that no recommendation on this issue is required in this report and the EPA will consider this issue in its assessment of the Perth Water Future Study.

5. Conclusions and recommendations

5.1 Conclusions

The EPA has examined the environmental issues associated with the proposal. The Authority's views on the issues raised in public submissions are summarised in Table 3.

The EPA concludes that the proposal by the WRC to adopt alternative groundwater criteria to ensure that the ecological values of groundwater-dependent vegetation on the Gnangara Mound meets the EPA's objectives. In reaching this conclusion, the Authority has taken into consideration:

- adoption of the concept of ecological benefit resulting from a change from the current wetland water criteria to Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs);
- the method by which the EWRs and EWPs will be given effect, ie. in the terms of environmental objectives and control of water levels in lakes and wells nominated by the WRC;
- a commitment by the proponent to monitor a number of specific sites as well as vegetation transects across the Gnangara Mound on a regular basis to review the environmental water requirements of groundwater dependent ecosystems and EWRs amended as required in accordance with these monitoring results;
- a commitment by the proponent to adopt a revised monitoring programme to ensure the maintenance of ecological diversity in wetland areas where identified environmental water requirements are likely to be greater that environmental water provisions.

The EPA has also concluded that private groundwater bore allocations shall not form part of Environmental Conditions imposed as part of this assessment, but be granted by licence issued by the Water and Rivers Commission, which would recognise environmental water requirement levels.

The EPA also concludes that the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' is likely to involve the preparation of Environmental Protection Policies and State Planning Policies to control land use over private and publicly owned land over the Gnangara Mound.

Table 3. Summary of Environmental Protection Authority Advice

Issue	Environmental Objective	Proponent's response	EPA advice and recommendation
1. Protection of groundwater dependent communities through the principle, application and adequacy of Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs).	Ensure that the ecological integrity of groundwater dependent ecosystems on the Gnangara Mound is protected.	These concepts allow for greater protection of conservation values of groundwater dependent vegetation. EWRs will be monitored on a regular and continuing basis, and water allocation altered in accordance with monitoring results.	The EPA accepts the concept of EWPs and EWRs, and the proposed adoption of alternative criteria in the event that EWPs are not the same as EWRs, to ensure the long term protection of groundwater dependent ecosystems on the Gnangara Mound.
	Ensure that additional groundwater abstraction from the Gnangara Mound does not have an adverse impact on groundwater-dependent vegetation.	Commitment to undertake on-going monitoring on a regular basis, and implement alternative criteria to ensure that the conservation values of groundwater-dependent vegetation are retained.	Although a trend to more xeric vegetation is likely, the commitments meet EPA conservation objectives.
2. Additional abstraction in the vicinity of Little Coogee Flat.	Ensure that additional groundwater abstraction from the Gnangara Mound does not have an adverse impact on groundwater dependent vegetation, particularly in the vicinity of Little Coogee Flat.	Approval for the allocation of the extra water only is requested at this stage. Proponent has undertaken an overall commitment to monitor and manage groundwater levels to meet specific wetland management objectives.	Any additional abstraction from groundwater resources should be in accordance with specified EWRs, or alternative criteria, in order to protect the groundwater vegetation in the vicinity of Little Coogee Flat.
3. Existing land use management on the Gnangara Mound.	Ensure that there are mechanisms in place to achieve well co-ordinated land use control and management on the Gnangara Mound.	There are a number of existing land use management policies already in place, and recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' are in the process of being implemented.	A number of statutory mechanisms already in place to control land use. The findings and implementation of the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' are also noted.
4. Co-ordination of land management on the Gnangara Mound.	Ensure that there is a strategic and well co-ordinated across Government approach to ensure satisfactory land management on the Gnangara Mound, to protect groundwater resources.	Management of Pine plantations on the Mound are currently the subject of discussion with CALM. Management of other land use issues form part of separate studies not part of the Section 46 document.	The findings and implementation of the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies' are also noted, which will ensure the co-ordination of land management on the Mound.
5. Impact of abstraction on groundwater quality within the unconfined aquifer.	Ensure that the long term abstraction of groundwater from the Gnangara Mound does not have an adverse impact on water quality in the unconfined aquifer.	A small increase in groundwater abstraction is proposed , however abstraction rates are less than anticipated recharge rates, are therefore unlikely to have a significant impact on groundwater quality.	EPA expects that long term management of groundwater quality will be managed through the implementation of recommendations contained within the implementation of the recommendations of the 'Select Committee on Metropolitan Development and Groundwater Supplies'
6. Long term impact on superficial unconfined aquifer through abstraction from the confined aquifer.	Ensure that there is no adverse impact on the unconfined aquifer as a result of groundwater abstraction from the confined aquifer.	Commitment to continuously monitor the impact of confined aquifer abstraction on unconfined aquifer levels, and to discuss detected impacts with the EPA.	EPA notes the commitment to further investigate the impacts on the superficial unconfined aquifer. It is expected that the WRC will submit the findings of the additional research on the impacts on the unconfined aquifers to the DEP as soon as information becomes available.
7. Long term sustainable use of the Gnangara Mound Groundwater resources	Ensure that groundwater abstraction is sustainable over the long term.	The broader issue of sustainable development is addressed in the Perth Water Future Study.	The issue of sustainable use of groundwater is dealt with as part of the 'Perth Water Future Study', which is currently being assessed as a separate proposal by the EPA.

5.2 Recommendations

Recommendation 1

The EPA recommends that the Environmental Conditions set by the Minister for the Environment on 8 March 1988 can be amended as set out below without prejudicing the EPA's objectives in relation to the conservation of environmental values of groundwater-dependent vegetation on the Gnangara Mound.

STATEMENT TO AMEND CONDITIONS APPLYING TO A PROPOSAL (PURSUANT TO THE PROVISIONS OF SECTION 46 OF THE ENVIRONMENTAL PROTECTION ACT 1986)

PROPOSAL: (041/697)	GNANGARA MOUND GROUNDWATER RESOURCES
CURRENT PROPONENT:	WATER AND RIVERS COMMISSION
CONDITIONS SET ON:	8 MARCH 1988

NB: The original condition numbers are in square brackets.

The implementation of Stage 1 of the Pinjar Groundwater Scheme is now subject to the following conditions which replace all previous conditions:

1 Proponent Commitments

The proponent has made a number of environmental management commitments in order to protect the environment.

1-1 In implementing the proposal, the proponent shall fulfil the relevant environmental management commitments made in "Review of Proposed Changes to Environmental Conditions", as revised in May 1996, and reported on in EPA Bulletin 817; in the Environmental Review and Management Programme (November 1986), and published in EPA Bulletin 295 as Appendix D, and in response to issues raised following public submissions; provided that the commitments are not inconsistent with the conditions or procedures contained in this statement.

The consolidated environmental management commitments (May 1996) were published in EPA Bulletin 817 (Appendix 3) and a copy is attached.

2 Implementation

Changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

2-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the EPA with the proposal.

2-2 Where, in the course of the detailed implementation referred to in condition 2-1, the proponent seeks to change the designs, specifications, plans or other technical material submitted to the EPA in any way that the Minister for the Environment determines, on the advice of the EPA, is not substantial, those changes may be effected.

3 Groundwater-dependent Ecosystems

3-1 The proponent shall ensure that the integrity of all groundwater-dependent ecosystems located on the Gnangara Mound is protected, to the requirements of the Minister for the Environment on advice of the EPA.

4 Management of the Water Resource

4-1 [2] The proponent shall base decisions affecting the management of groundwater resources of the Gnangara Mound on the concept of sustainable yield of resources and maintenance of ecological systems in accordance with the objectives of the State Conservation Strategy.

4-2 [4] In conjunction with the Ministry for Planning and the Department of Conservation and Land Management, the proponent shall subject to regular review the basis for management decisions and the criteria specified for conservation of the environment and of the groundwater resource of the Gnangara Mound, to the requirements of the EPA.

5 Groundwater Availability

5-1 [10] The proponent shall continue the current approach in widely publishing the limits on groundwater availability for the Gnangara Mound.

5-2 [10] The proponent shall update and publish annually the figures published according to the requirements of condition 5-1 with emphasis on those areas of high conflict for the use of the resource so that limits to growth and development can be clearly seen by all interested parties.

6 Water Conservation

6-1 [11] The proponent shall actively encourage further reduction in public water demand through its Water Conservation Strategy.

7 Referral of Subsequent Stages

7-1 [16] The proponent shall refer Stages 2 and 3, and subsequent stages, of the Pinjar Groundwater Scheme to the EPA.

8 Research and Monitoring

8-1 [18] In addition to those areas of research and monitoring proposed in the existing monitoring programme and commitments in the Environmental Review and Management Programme, the proponent shall undertake the following specific areas of research and monitoring:

1 clarification of the relationship between groundwater level and wetland water quality; and

2 improvement in understanding of the conservation value of wetlands on the Gnangara Mound, especially those for which information on their value is limited;

to the requirements of the EPA.

9 Reporting

9-1 [19] The proponent shall submit brief annual and more detailed triennial reports on environmental monitoring and management of the Gnangara Mound, to the requirements of the EPA.

10 Proponent

These conditions legally apply to the nominated proponent.

10-1 No transfer of ownership, control or management of the project which would give rise to a need for the replacement of the proponent shall take place until the Minister for the Environment has advised the proponent that approval has been given for the nomination of a replacement proponent. Any request for the exercise of that power of the Minister shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement proponent to carry out the project in accordance with the conditions and procedures set out in the statement.

11 Compliance Auditing

To help determine environmental performance and compliance with the conditions, periodic reports on the implementation of the proposal are required.

11-1 The proponent shall submit periodic Performance and Compliance Reports, in accordance with an audit programme prepared by the Department of Environmental Protection in consultation with the proponent.

Procedure

1 Unless otherwise specified, the Department of Environmental Protection is responsible for assessing compliance with the conditions contained in this statement and for issuing formal clearance of conditions.

2 Where compliance with any condition is in dispute, the matter will be determined by the Minister for the Environment.

3 The Water and Rivers Commission and the Ministry for Planning will ensure efficient interaction and liaison between land use planning and water resource planning through relevant plans, policies and strategies.

4 [5] In the management plans for land on the Gnangara Mound (existing and proposed), the Department of Conservation and Land Management will include protection of native vegetation and wetlands as principal objectives. These management plans, as far as they relate to State Forest 65, will clearly reflect the priority purpose for State Forest 65 which is "water production". Management objectives for the wetlands will be consistent with the water levels specified by the EPA.

5 [6] The Department of Conservation and Land Management will manage the pine plantations in State Forest 65 with the objective of achieving and maintaining their water use at a level that is no more than that of pre-existing native vegetation. This will be

based on an average basal area within the pine plantations of approximately 11 square metres per hectare.

6 [7] The Western Australian Planning Commission and the Department of Conservation and Land Management will initiate the consolidation into managed conservation reserves, of those wetlands and other native vegetation areas on the Gnangara Mound identified by the EPA as having conservation value. For wetlands within the public estate, priority will be for those which fall into:

Category 1 (Wetlands of exceptionally high natural and/or human use attributes);

Category 2 (Wetlands with relatively intact natural systems); and

Category 3 (Wetlands which have been highly modified but which are considered to play important roles in their urban and/or rural settings),

in EPA Bulletin 374 "Draft Guidelines for Wetland Conservation in the Perth Metropolitan Area" (1991).

7 [8] Where areas of high conservation value occur on private property, the Department of Conservation and Land Management and the Western Australian Planning Commission will initiate the means for protecting and ensuring their management.

6. References

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Water Authority of Western Australia (1995c) Review of Proposed changes to Environmental Conditions - Gnangara Mound Groundwater Resources (Section 46)

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Appendix 1

Statement of conditions of approval, 8 March 1988

MINISTER FOR ENVIRONMENT

STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED (PURSUANT TO THE PROVISIONS OF THE ENVIRONMENTAL PROTECTION ACT 1986)

GNANGARA MOUND GROUNDWATER RESOURCES

Water Authority of Western Australia

Stage 1 of the Pinjar Groundwater Scheme may be implemented, subject to the following conditions:

1. The Water Authority adhering to the proposal as assessed by the Environmental Protection Authority and fulfilment of the management commitments it has made. (copy of commitments attached)

2. Decisions affecting the management of groundwater resources of the Gnangara Mound should be based on the concept of sustainable yield of resources and maintenance of ecological systems in accordance with the objectives of the State Conservation Strategy.

3. The Water Authority of WA shall manage public and private groundwater abstraction from the Gnangara Mound in accordance with water quality and level criteria for wetlands determined by the Environmental Protection Authority. The criteria, which are specified in Appendix 1, shall be reviewed and varied from time to time by the Environmental Protection Authority to ensure that the social values and the ecological values of the wetlands are maintained.

4. The basis for management decisions and the criteria specified for conservation of the environment and of the groundwater resource of the Gnangara Mound shall be subject to regular review by the Water Authority in conjunction with the State Planning Commission and the Department of Conservation and Land Management, to the satisfaction of the Environmental Protection Authority.

7th Floor, May Holman Centre,
32 ST. GEORGE'S TERRACE, PERTH 6000 W

5. Management plans for the land managed by the Department of Conservation and Land Management (existing and proposed) on the Gnangara Mound shall include protection of native vegetation and wetlands as principle objectives for management. These management plans, as far as they relate to State Forest 65, shall clearly reflect the priority purpose for State Forest 65, ie, water production. Management objectives for the wetlands shall be consistent with the water levels specified by the Environmental Protection Authority.

6. The pine plantations in State Forest 65 shall be managed by the Department of Conservation and Land Management with the objective of achieving and maintaining their water use at a level that is no more than that of pre-existing native vegetation. This should be based on an average basal area within the pine plantations of approximately 11 square metres per ha.

7. The State Planning Commission and Department of Conservation and Land Management shall initiate the consolidation into managed conservation reserves, those wetlands and other native vegetation areas on the Gnangara Mound identified by the Environmental Protection Authority as having conservation value. For wetlands within the public estate, priority shall be for those which fall into:

   . Category 1 (Wetlands of exceptionally high natural and/or human use attributes);

   . Category 2 (Wetlands with relatively intact natural systems); and

   . Category 3 (Wetlands which have been highly modified but which are considered to play important roles in their urban and/or rural settings),

   of the Environmental Protection Authority's Draft Guidelines for Wetland Conservation in the Perth Metropolitan Area.

8. Where areas of high conservation value occur on private property, means for protecting and ensuring their management shall be initiated by the Department of Conservation and Land Management and State Planning Commission.

9. The private water allocation quotas proposed in the Environmental Review and Management Programme shall be reviewed and revised if necessary, to ensure that they meet the water levels for wetlands specified by the Environmental Protection Authority.

10. The current approach of the Water Authority in widely publishing the limits on groundwater availability for the Gnangara Mound be continued. These figures shall be updated and published annually with emphasis on those areas of high conflict for the use of the resource so that limits to growth and development can be clearly seen by all interested parties.

11. The Water Authority shall actively encourage further reduction in public water demand through its Water Conservation Strategy.

12. The Water Authority of WA should initiate a scheme whereby costs associated with the environmental management of the Gnangara Mound be identified as such and borne by the users of the water resource.

13. The Water Authority shall continue to review and develop methods to improve monitoring and control of all public and private bores, for the purpose of managing the water resource.

14. The Water Authority, State Planning Commission and Environmental Protection Authority shall develop Environmental and/or Planning Policies for the Gnangara Mound which minimise the impact of land use activities (especially those that have a high water use or are likely to cause pollution to groundwater) on groundwater and wetlands, and provide protection of the water resource and conservation of wetlands and upland vegetation.

15. The Minister for Planning shall ensure that the local authorities located on the Gnangara Mound incorporate in their statutory Town Planning Schemes, policies, zones and such other mechanisms as appropriate and in accordance with Polices instituted under condition 14; with the objectives of:

    . protection of the groundwater resource of the Gnangara Mound; and

    . conservation of wetlands, including any suitable buffer areas.

16. In principle, Stages 2 and 3 of the Pinjar Scheme are environmentally acceptable but the Water Authority shall revise these stages in the light of the Environmental Protection Authority's Report and Recommendations and shall refer these and other stages to the Authority for further consideration.

17. The staged development of groundwater schemes, which permit the matching of growth in demand with supply and the tailoring of schemes to minimise environmental impact, is an environmentally acceptable approach and shall be applied to future groundwater schemes.

18. The Water Authority shall undertake the following specific areas of research and monitoring, in addition to those proposed in the existing monitoring programme and commitments in the Environmental Review and Management Programme:

    . clarify the relationship between groundwater level and wetland water quality; and

    . improve understanding of the conservation value of wetlands on the Gnangara Mound, especially those for which information on their value is limited;

    to the satisfaction of the Environmental Protection Authority.

19. The Water Authority shall submit brief annual and more detailed triennial reports on environmental monitoring and management of the Gnangara Mound to the Environmental Protection Authority.

20. As the many issues in relation to the Gnangara Mound cannot be considered by any single agency, policy direction, broad planning and management on the Gnangara Mound should be undertaken as follows:

- A Policy Coordinating Group, be established with responsibility to Cabinet for formulation of policy directions, including representatives from:

  Department of the Premier and Cabinet (Chair)
  Water Authority of WA
  State Planning Commission
  Environmental Protection Authority.

- A Technical Advisory Group, be established to provide specific planning and management advice to the Policy Coordinating Group, including representatives from:

  Water Authority of WA
  Western Australian Water Resource Council
  State Planning Commission
  Department of Conservation and Land Management
  Department of the Premier and Cabinet
  Environmental Protection Authority
  Department of Agriculture
  City of Wanneroo
  Shire of Gingin

- The Wanneroo Groundwater Advisory Committee continue, and other such Committees as appropriate be established, to provide advice to the Water Authority on management of private abstraction of groundwater.

Barry Hodge, MLA
MINISTER FOR ENVIRONMENT

8 MAR 1988

MANAGEMENT COMMITMENTS MADE BY THE WATER AUTHORITY OF WA FOR THE PINJAR GROUNDWATER SCHEME AND THE WATER RESOURCE OF THE GNANGARA MOUND

The Water Authority will develop, within 12 months, a model to allow the local effects of the Pinjar Scheme to be better defined, monitored and managed.

Private abstraction in the Wanneroo Groundwater Area north of Flynn Drive will not exceed 15 million cubic metres per year unless further monitoring and modelling shows the impact on water table levels to be acceptable.

The unconfined and confined aquifers will be developed concurrently to provide some capacity for managing water table declines under severe drought conditions.

LAYOUT OF SCHEMES FOR PUBLIC WATER SUPPLY

The layouts of the proposed Lexia, Yeal and Barragoon Schemes will be further assessed as part of detailed investigation prior to selection of the preferred strategies for management of the groundwater resource.

ABSTRACTION STRATEGIES FOR PUBLIC WATER SUPPLY SCHEMES

Groundwater levels will be monitored using the existing network of over 900 monitoring points in conjunction with measurements from the production wells. The abstraction strategy will be reviewed, and if necessary, modified taking into account the results of monitoring and the need to maintain the resource to meet public, private and environmental needs. The Water Authority will not exceed the quota or substantially modify the abstraction strategy from the scheme without prior Environmental Protection Authority approval.

MANAGEMENT OF PRIVATE WATER USE

The Water Authority will manage private abstraction within the Wanneroo Groundwater Area, so as not to exceed the private groundwater abstraction quota. This quota will be reviewed as part of the annual reporting procedure for the Environmental Protection Authority. Provision will be made for the Wanneroo Groundwater Advisory Committee to have appropriate public representation from the entire Wanneroo Groundwater Area.

COOPERATIVE LAND MANAGEMENT

The Water Authority will liaise with the Department of Conservation and Land Management so that plans for thinning, control burning and future management of pine plantations recognise the effect of plantation management on the groundwater resource.

The Water Authority will provide advice during preparation of management plans for conservation areas and recreational activities to ensure protection of water quality.

The Water Authority will continue to liaise with the State Planning Commission to ensure that appropriate consideration is given to water resource management when land planning issues are being considered.

The Water Authority will continue to liaise with the Departments of Conservation and Environment, and Conservation and Land Management to assist them in developing guidelines for water level changes which take into account the need for environmental conservation.

The Water Authority will continue to liaise with the Mines Department and the Department of Conservation and Environment to ensure that consideration is given to water resource management when mining applications are evaluated.

The Water Authority will take account of future land management in the area of the proposed Yeal Nature Reserve extension when planning future groundwater management in the area, by liaison with the Department of Conservation and Land Management.

DEMAND MANAGEMENT

The Water Authority will prepare a demand management strategy.

ON-GOING REVIEW

Monitoring of water levels will be used to assess the effectiveness of management strategies which will be reviewed as appropriate.

MONITORING

The programme of groundwater investigations and vegetation monitoring will continue, forming the basis for the monitoring to be undertaken in connection with existing and future developments on the Gnangara Mound area generally and the Pinjar Scheme in particular.

PROPOSED WATER MONITORING

Regular monitoring of groundwater levels will be carried out within the Pinjar area. This will include observation bores at the site of proposed production wells to monitor the local drawdown effects and selected lakes and swamps. These lakes will include Lake Carabooda, Nowergup, Neerabup, Pinjar, Adams, Maringiniup, Jandabup and Loch McNess. Water level monitoring from over 900 other existing stations will continue. The existing regional groundwater quality monitoring programme will continue. The quality of water produced by the Pinjar Scheme will be monitored frequently to ensure that the water meets potable standards.

The need for specific water monitoring data in conjunction with vegetation and fauna monitoring, will be evaluated in consultation with the Departments of Conservation and Environment, and Conservation and Land Management.

PROPOSED VEGETATION MONITORING

The Water Authority will prepare an appropriate vegetation monitoring programme in consultation with the Departments of Conservation and Land Management, and Conservation and Environment.

PINE PLANTATION MONITORING

The Water Authority will liaise with the Department of Conservation and Land Management regarding future monitoring of the basal area of pine plantations in State Forest No 65.

PROPOSED FAUNA MONITORING

The existing wetland invertebrate monitoring programme will continue and be expanded to include Lake Goollelal and Loch McNess. The Water Authority will continue to support this programme.

The Water Authority will continue to liaise with and provide support to the Western Australian Water Resources Council's Groundwater Management Project study team.

The Water Authority will continue to take into account the advice of the Groundwater Advisory Committees as an important contribution to the management of the resource.

REPORTING AND ASSESSMENT

The results of the management and monitoring programmes will be reported regularly for review by the Environmental Protection Authority and the programmes modified where appropriate. Reporting on the existing Wanneroo and Mirrabooka Schemes will continue in the established format with brief annual reports complimented by comprehensive triennial reviews for submission to the Environmental Protection Authority.

PINJAR DEVELOPMENTS

The existing reporting to the Environmental Protection Authority will be extended to cover the proposed Pinjar Scheme, together with a review of private groundwater usage in the area.

A brief annual report will be submitted to the Environmental Protection Authority. It will contain:

- a review of operations and productions volumes;
- a summary of well, lake level and water quality monitoring;
- brief reviews of the vegetation and fauna monitoring programme; and
- an overview of any other developments which may be significant to the operation of the scheme, have potential environmental effects or may be of relevance to management of the groundwater resource.

A comprehensive triennial review of the Pinjar Scheme will also be submitted, covering similar topics to the annual reports but in more detail, with the emphasis on any important changes in the resource and the implications for any alterations required to future management. Management strategies will be reviewed and modified as appropriate.

FUTURE DEVELOPMENTS

The Water Authority will provide appropriate environmental documentation to enable the Environmental Protection Authority to assess future groundwater developments on the Gnangara Mound.

APPROACH

For nominated wetlands, two water levels are specified in Table 1:

- the preferred minimum summer level, which reflects the level that would ensure maintenance of the social and environmental values of the wetland; and

- the minimum water level, below which the social and environmental values of the wetland would be significantly threatened.

In addition, the maximum sequence of months that the wetland water levels are below the preferred minimum summer level in any 12 month period is also specified, beyond which the social and environmental values of the wetland would be significantly threatened.

Protection of the social and environmental values of wetland also requires that existing regimes of water quality and quantity, within normal climatic variation, are maintained for Category 1 and Category 2 wetlands.

MANAGEMENT RESPONSE

Management responsibility for the water resources of the State rests with the Water Authority of WA, which has as a primary objective "to conserve, assess and efficiently manage the State's water resources for the continuing benefit of the community" (Water Authority of WA Corporate Plan 1987-1992).

To ensure protection of the social and environmental values of nominated wetlands in Table 1, the following management response shall apply:

- should the water level decline below the preferred minimum summer water level, public and/or private groundwater abstraction should cease unless positive action is instituted to minimise the extent of the decline.

- should the water level decline below this preferred minimum summer water level for a period of one month or such other period as specified or to the defined minimum water level the Water Authority of WA shall take appropriate remedial action, which may include the cessation of public and/or private groundwater abstraction, to ensure that the minimum water level and sequence of months criteria are complied with; and

- the Water Authority should investigate means of maintaining water regimes and levels in wetlands whereby social and environmental values of the wetlands are maintained or enhanced.

Appendix 2

Summary of submissions and proponent's response to submissions

RESPONSE TO PUBLIC SUBMISSIONS TO THE GNANGARA MOUND REVIEW OF PROPOSED CHANGES TO ENVIRONMENTAL CONDITIONS

1. Land use management

1.1. Management and control of land use

1.1.1. More stringent land use management controls to safeguard groundwater quality are required. In this context, the adoption of an effective Environmental Protection Policy (EPP) by the WAWA for private lands on the Gnangara Mound is supported.

1.1.2. One submission suggested that 'Guidelines for Acceptable Development' be prepared for the Mound.

1.1.3. Development on the Mound is proceeding in a 'piece meal' fashion without due care for strategic planning to protect the Mound resources.

Response to 1.1.1-3
It is not the role of the Water Authority to develop EPPs and carry out land use planning and management on the Gnangara Mound. However the Water Authority will support the Environmental Protection Authority and the Ministry for Planning in these areas.

There are a number of relevant policies which currently exist or are in various stages of development:

- The Gnangara Crown Land Environmental Protection Policy (EPP) aims to protect groundwater underlying the large area of contiguous Crown Land.
- The Gnangara Crown Land Statement of Planning Policy (SPP) was established by the Ministry for Planning to complement the EPP and to provide advice to planners.
- The Private Land EPP and SPP are still in draft form. They aim to provide for protection of groundwater in the areas of the Gnangara Mound which are not covered by the Crown Land EPP and SPP.

The Government also established a "Select Committee on Metropolitan Development and Groundwater Supplies" to help resolve the increasing conflict between land use and groundwater protection on groundwater mounds. It's report was published in December 1994 and provides an excellent insight into issues relating to land use conflicts. The report has a number of very significant recommendations including that a Gnangara Land Use and Water Management Strategy be developed and that the Water Authority's Priority Area boundaries be reviewed.

The Ministry for Planning is currently commencing on the Strategy with a high level of involvement from the Water Authority. The objectives of this strategy are

1) Defining the areas of the Mound requiring groundwater protection in order to define land use
2) To map existing land use to determine which are desirable and which are not in relation to groundwater protection, and

3) To develop policies, legislation and zoning's to give effect to any land use changes.

It is proposed that the draft Private Land Environmental Protection Policy, the Crown Land Environmental Protection Policy and the Statements of Planning Policy will be reviewed to compliment the Gnangara Land use and Water Management Strategy.

The Water Authority has commenced the review of the boundaries of the P1, P2 and P3 Priority Areas.

It is expected that these projects will provide a planning and management framework which will alleviate current problems with piece meal development proposals.

1.2. Pine plantation issues

1.2.1. The timing of land use changes and groundwater abstraction are important to the actual groundwater changes (rise or fall) which occur in the Ellenbrook and Lexia Wetlands areas, for example pine plantation thinning. The timetable of such operations would therefore be important for regional groundwater management.

1.2.2. Water table rise due to factors such as pine plantation thinning may exceed the effects of urbanisation in increasing groundwater levels near to the Lexia Wetland area. The responsibility for management of the water table rise therefore becomes a complex matter.

Response to 1.2.1-2.
The Water Authority agrees that the timing of land use changes and groundwater abstraction are important for actual groundwater changes, particularly pine plantation management. This issue is to be resolved in a Memorandum of Understanding between the Water Authority and The Department of Conservation and Land Management. This is listed as commitment P38 in the s46 document. It is proposed that the MOU will describe how CALM will establish an average pine density of $11m^2/ha$ and the program for getting there. This density achieves a similar groundwater recharge level as to native Banksia woodland. In the short term water regimes which protect environmental values will be achieved through the Memorandum of Understanding.

If high water levels do occur in the area of the Lexia wetlands this will need to be dealt with as part of the MOU. Management of water levels in the Lexia wetlands and potential impacts of groundwater abstraction are being dealt with in the East Gnangara Water Resource Allocation and Management Project currently being produced by the Water Authority, and which is subject to a separate environmental impact assessment report by the EPA.

1.2.3. CALM should be required to undertake a pine plantation thinning programme, especially for plantations to the east of Yanchep National Park. This would increase the amount of water percolating into groundwater storages and ensure the flow of non-perennial cave streams.

CALM is developing a plan which identifies actions that need to be taken to protect the cave ecosystems near Yanchep National Park. This plan aims to ensure a flow of water in the cave streams. . It identifies areas of pines which need to be thinned, a notional catchment boundary for the caves and other strategies CALM proposes to use to enhance recharge in the caves. This has been discussed in section 9.4 of the s46 document. Actions taken so far include prescribed burning of the pine plantation and native vegetation upstream to remove leaf litter to increase recharge; some pine thinning and soon some scrub control activity will be undertaken in the pine plantation.. As a part of the MOU mentioned above minimising the environmental impacts on the caves will be considered. This is listed in the s46 document as commitment P38.

1.2.4. In the light of the known impact of pine plantations on groundwater levels, careful scientific appraisal needs to be undertaken before replanting of pines is commenced anywhere on the Mound.

Pine plantation management including replanting will form part of the Memorandum of Understanding between CALM and the Water Authority (commitment P38)

1.2.5. Consideration should be given to use of fertilisers and pesticides by CALM for the pine plantations, surrounding Lake Pinjar, and consequent potential impact on groundwater quality.

Water Quality issues are beyond the scope of the s46 document, as it was produced to look at water quantity issues. However, fertiliser application on pine plantations is low and pesticide application is currently being considered by the Environmental Protection Authority as part of a separate assessment. CALM is undertaking a series of trials on pesticide application in plots on the pine plantation to find a solution which minimises impact on groundwater.

1.3. Urbanisation in the Ellenbrook area

1.3.1. The modelling results presented in the Section 46 document do not appear to take into account the effects of urbanisation in the Ellenbrook area (refer Section 46 Figure 21). It is considered that the induced water table rise due to urbanisation may be beneficial in view of draw-down predictions due to the Lexia Scheme.

Although urbanisation in the Ellenbrook area was not taken into account in the modelling in the s46 document a Water Resource Allocation and Management Plan is currently being developed for the East Gnangara area which will include this modelling. This project deals specifically with the Lexia groundwater scheme and other land use impacts in this area. It will include more detailed modelling of these impacts. The project is subject to a separate environmental impact assessment by the EPA as a Public Environmental Review.

1.4. Whiteman Park

1.4.1. It was claimed that there is no need for greater statutory protection by the WAWA to control activities or developments within the Park, as they are adequately managed at present.

In section 10.1.2 the Water Authority has included a brief discussion on the adequacy of statutory and non-statutory mechanisms for protection of groundwater in order to give an overview of other management issues on the Gnangara Mound. Within this discussion the Water Authority has expressed an opinion that the Environmental Protection (Gnangara Mound Crown Land) Policy 1992 should or needs to be strengthened in order to control activities on Crown Land that have potential to pollute groundwater. However it does not form part of the changes to proposed conditions in the s46. The s46 seeks changes to conditions in relation to water quantity issues. Accordingly, there have been no commitments in the document to seek greater protection. This is an issue which is being dealt with through other avenues such as the Select Committee recommendations, the Gnangara Land use and Water Management Strategy and the proposed review of bylaws.

1.5.Roads

1.5.1. Major highways, such as the proposed Perth - Darwin Highway and access roads to Reid Highway should not be located over priority groundwater areas. If such roads are essential, they should be specially designed using engineering techniques to prevent contaminated or polluted run off reaching groundwater resources.

The Perth to Darwin Highway is not going to go through a priority 1 groundwater area. Any upgrade to Gnangara Road or Neaves Road will require specially designed drainage provisions to avoid contaminated runoff from entering the groundwater. This would be ensured through the environmental impact assessment process.

1.6. Lake Pinjar

1.6.1. Planning Control No. 29 was imposed on Lake Pinjar in December 1994, to co-ordinate recommendations of the Groundwater Select Committee Recommendations. Since that time, the view was expressed that advice to landowners in the vicinity has been misleading and contradictory. Better communication and co-ordination needs to exist between the involved state government and local authorities, so the community is better informed and the Mound better managed.

The Water Authority and Ministry for Planning have come to a decision that the Ministry for Planning will co-ordinate all action in Planning Control Area No 29. This should reduce confusion in this area in the future.

1.6.2. Section 4.3. of the Section 46 document makes reference to urban development on Nisa Road, Lake Pinjar. It is unclear to what area this refers.

Nisa Road is located to in the northern region of Lake Pinjar and extends north of Lake Pinjar in a northerly direction for approximately 4km. Section 4.3 of the section 46 document is slightly confusing where it discusses Nisa Road. This area was not actually an urban development but a rural sub-division.

1.6.3. The establishment of a General Aviation Airport at any of the three short listed sites to the west of Lake Pinjar would be incompatible to the protection of groundwater (bulk fuel storage, potential for accidents over priority protection areas)

The Water Authority agrees that the establishment of a General Aviation Airport to the west of Lake Pinjar would be incompatible with the protection of groundwater.

2. Groundwater level criteria

2.1. Use Environmental Water Requirement levels

2.1.1. It is acknowledged by the WAWA in the Section 46 document that the EWR levels have been set on the basis of a 'snapshot' approach, i.e. they are based on maintaining the current values of the representative wetlands, as a function of their present condition. Further, it is acknowledged that the current state of the wetlands and associated conservation values reflect the below average rainfall levels since 1975. Pine plantations would have contributed to this effect.

It is correct that Environmental Water Requirements have been determined using a snapshot approach and thus based on current values which have been influenced by past and current land use and climate. However this approach is felt to be most appropriate as average conditions are not known. It would also be socially and economically unacceptable to change surrounding land use to achieve another scenario which we do not know is necessarily better. The rational for setting of water level requirements using current values is discussed in section 5.2.2.4 of the s46 document.

2.1.2. The appropriateness of this 'snapshot approach' is questioned. For example, would the same approach have been adopted if the rainfall levels over the last 20 years were above average, and there were no pine plantations. Conservation values of the wetlands would have been quite different under this scenario.

The approach of maintaining current values was also taken in the 1986 Gnangara Mound Environmental Review and Management Programme. In this document the Environmental Protection Authority endorsed the approach (see EPA Bulletin 295) and it is assumed that this approach is supported by the current EPA.

2.1.3. Section 5.2.2.4. of the Section 46 document refers to 'Setting Water Level Requirements'. Speeds at which levels drop (i.e. from minimum to absolute minimum levels) should be carefully considered to allow time for plants to adapt to the change. It was also claimed tree deaths in the vicinity of Perry Road after 2

consecutive years of low water levels suggests that the Jandakot Mound Research referred to in this Section is not applicable to the area, and that separate research is needed before assumptions are made. It was also suggested that selecting six years as an acceptable deviation frequency as it is 'convenient for management' is not an acceptable method of selection.

The s46 document has not suggested that vegetation should adapt to absolute minimum water levels. Absolute minimum water levels have been set for wetland vegetation and are only allowed to be reached twice in every six years. Recent and current research indicates that plants are able to recover from these low water levels at this frequency, which at the same time provides for variability in water levels which is a consistent with natural conditions.

In regards to comments about deaths of vegetation in the vicinity of Perry Road no Jandakot Mound Research has been referred to in the s46 document in relation to terrestrial vegetation water requirements. Environmental Water Requirements for terrestrial vegetation are discussed in 5.4 of the document. The only research done on the Jandakot Mound is on wetland vegetation, not terrestrial vegetation. This is referred to in section 5.2.2.4. This research illustrates that wetland vegetation can tolerate high water levels for two years.

Deaths in the vicinity of Perry Road are due to low water levels in 1989 and 1990 as a result of below average rainfall and high temperatures in the summer of 1991. Low water levels have been exacerbated by abstraction from stage 1 of the Pinjar groundwater scheme.

Environmental Water Requirements for terrestrial vegetation have been based on findings from the Gnangara Mound Vegetation Stress Study which found that terrestrial vegetation can tolerate a drawdown of 1.5m in total at a rate of 0.2m per year.

A six year deviation frequency for wetland vegetation water requirements was not only selected as it is convenient for management or reporting period. A two in every six years deviation from low water levels is a ratio developed based on the tolerance of wetland vegetation. Based on recent and current research, it is believed that vegetation can tolerate deviations from the proposed water regimes at this frequency.

2.1.4. Concern was expressed that the EWP for Pinjar and Wanneroo is less than the EWR. This is likely to have serious consequences on vegetation in the vicinity, as presumably vegetation will has less water available than is required, under the WAWA's own definitions.

As discussed in section 9.3 and 9.5 of the s46 document the EWP for Pinjar monitoring wells PM25, PM6, PM7 and PM9 are less than the EWR. This means that vegetation in the Bombing range will be affected. There will be a gradual loss of some mature trees with their replacement by seedlings of the same species and by more drought tolerant species. Current research and monitoring suggest this will lead to a change in the abundance of some species in some areas, but will not lead to a loss in diversity. Similar changes have been observed in vegetation not influenced by current

borefields, and are attributable to reduced rainfall over the last 20 years. Groundwater abstraction will therefore increase the rate of this natural transition.

The reason for the trade-off of some of the existing environmental values in this area is in order to allow continued groundwater abstraction from Pinjar wells P40 to P90 which were commissioned in 1989. The loss of the use of these wells would be a significant cost to the Water Authority and the community in terms of capital infrastructure. However the EWP will not enable full abstraction quotas in dry periods in order to avoid extensive vegetation death. It is believed a change in the vegetation in this area towards the xeric end is an acceptable trade off when the current status of the land is considered.

In regards to the concern that EWPs are less than EWRs in Wanneroo it is assumed the submission is referring to Melaleuca Park near the Wanneroo groundwater scheme as this is the only other area where EWPs are less than EWRs. As discussed in section 9.3 of the s46 document the EWPs in wells WM6, WM8, and WM2 are less than EWRs. This is because EWRs cannot be achieved even with no further groundwater abstraction due to climatic effects. The EWPs do not allow for any further groundwater abstraction which may impact on Melaleuca Park as it is considered to be unacceptable given the conservation status of the land.

2.1.5. It was claimed that the EWR requirements are meaningless in helping to protect native vegetation, and are misleading to the public. The new WAWA abstraction levels assume that vegetation units are moving towards the xeric end of vegetation association, and the EWR's and EWP's have been set based on this premise. The Section 46 document is not 'up front' in highlighting this premise to the public, and potential consequences, i.e loss of higher groundwater level dependent vegetation.

EWRs have not been determined assuming that vegetation is moving towards the xeric end. EWRs have been determined based on current values of the vegetation. All vegetation currently dependent on groundwater was mapped and monitoring wells were selected within these areas. EWRs which would continue to support this vegetation were then determined. Methodology is discussed in section 5.4 of the document.

There is one area where the Water Authority proposes to allow vegetation to move towards the xeric end by setting EWPs below EWRs and this is in the Pinjar area. The trade -off proposed here is discussed in section 9.3 of the document and the above response in 2.1.4.

The Water Authority has been "up front" in that it has established a process which is "transparent" by clearly identifying the assumptions in setting EWRs and identifying where the trade-offs are made in establishing the EWP.

2.2. Extraction during drought periods

2.2.1. The issue of groundwater extraction and associated maintenance of acceptable groundwater levels during periods of extreme drought was raised .

Under drought conditions, surface water supplies may 'dry up', and it has been acknowledged by the WAWA that Perth's population would be dependent upon groundwater supplies from confined aquifers. It has also been acknowledged by the WAWA that there is a degree of connectivity between the unconfined and underlying confined aquifers.

In view of this the WAWA should be asked to demonstrate how it would cope with a drought period, and how it would increase its draw to the degree necessary to maintain public water supply on the confined aquifers without having an impact on the unconfined aquifers.

The Water Authority has a drought response strategy which is put into place when certain triggers become apparent, particularly in relation to storage levels in hills reservoirs. A major component of this drought strategy is the enforced reduction in water usage through appropriate levels of restriction on customer water use. Other components of the strategy relate to modes of operation in relation to the sources. Further detail of the strategy is available on request.

During drought periods the Water Authority may change quotas on wells to meet EWPs. Abstraction from wells closer to environmental areas will be reduced so that EWPs are not breached. The reduced quotas in these areas would be made up with other wells. If possible the abstraction would still come from the same scheme but wells more distant from critical areas would have increased quotas. If possible, increased use of superficial wells further from environmental areas such as the Quinns Scheme would be used. Alternatively abstraction from the confined aquifer will be increased.

The Water Authority clearly has considerable information on the impacts of drawdown from the confined aquifer through pump testing of new confined wells. However in order to provide a greater level of certainty the Authority is currently reviewing the connectivity between the confined and superficial aquifers. Consultants have been contracted to look at the interaction between the two. This will aid the development of a groundwater model which will predict the impacts of the abstraction from the confined aquifer on the superficial aquifer. This knowledge will then assist management of groundwater abstraction to avoid drawdowns in the unconfined aquifer.(See also 3.5)

In addition to changing where water comes from during drought the
Water Authority may also influence the demand for water through water restrictions for example.

2.3. Artificial maintenance of EWR's

2.3.1. The WAWA identifies the need for contingency plans to maintain minimum wetland water levels. Concern was expressed that the implied approach towards such plans is premised on the artificial recharge of the representative wetlands for which the minimum EWR would be excessively breached. This approach is not consistent with the logic of setting EWR for representative wetlands as a basis for maintaining

water levels in wetlands elsewhere on the Mound, and cannot be considered to be genuinely sustainable.

The Water Authority agrees with this statement, however it considers that artificially maintaining high value wetlands during low rainfall periods is an appropriate strategy. The Environmental Protection Authority has also endorsed this approach in previous assessments. EWRs for terrestrial vegetation and groundwater monitoring in the network of wells over the Gnangara Mound will ensure maintenance of regional groundwater levels. In order to assess impacts on other wetlands two regional transects will be monitored. Refer to section 10.3.4 of the document.

Impacts on some of the wetlands for which EWRs have not been determined is discussed in section 9.2 of the document. Given that many of the wetlands in the study area are perched, not affected by groundwater abstraction or significantly degraded from other land use activity, it is considered unnecessary to set EWRs for all wetlands. It is also impractical to do this. The wetlands which have had EWRs determined are those with the highest conservation values.

Artificial maintenance is put in place to ensure a high level of security to the high value lakes.

2.3.2. Artificial maintenance of water levels by recharge is not consistent with managing groundwater abstraction in a manner that protects all the environmental qualities of the Mound.

Refer to 2.3.1. Areas of the mound which have ecological value other than wetlands are the terrestrial vegetation and cave fauna. A series of monitoring wells have had EWRs and EWPs determined for protection of vegetation and therefore minimum water levels will be maintained which ensure protection of the current values of vegetation (apart from in the Bombing Range as discussed above in submission 2.1.4). It is proposed that protection of the cave fauna will be ensured through the maintenance of permanent water . Water levels in caves are monitored continually using data loggers. Refer to section 10.3 of the s46 document.

2.3.3. Artificial recharge may have an adverse effect on surrounding terrestrial vegetation.

In terms of concerns about low water levels, ie concerns that in having to maintain wetlands, groundwater levels under terrestrial vegetation nearby are low - terrestrial vegetation can withstand considerably greater drawdowns in groundwater levels than wetland vegetation. In terms of effect of high water levels on surrounding terrestrial vegetation, artificial recharge is conducted to maintain wetland vegetation and would not pose a threat to terrestrial vegetation.

2.4. Groundwater monitoring

2.4.1. Minimum groundwater levels for Whiteman Park are set too low and will result in further environmental damage at Whiteman Park. Minimum levels should be set higher to maintain flora value.

Minimum water levels in Whiteman Park have been set above the water levels in 1991 which were associated with tree deaths. Therefore the new EWPs (equal to EWRs) will ensure no further loss of values in the Park. Refer to section 5.4 and table 12, section 9.5 of the s46 document. The minimum water levels are also consistent with levels over the past ten years.

2.4.2. Concern was expressed that no wetland areas within Whiteman Park are proposed to be monitored by the WAWA. WAWA predictions indicate that further decline of water levels of over 2 metres will occur at the Park, which will inevitably impact on Park flora. The Park supports the highest density borefield on the Mound, and yet it is the least monitored section. It was considered that the WAWA must monitor and maintain water levels in Mussel Pool, Horse Swamp, the Bennet Brook system and Village Lake. It was suggested that monitoring of transects of vegetation within the Park be also be undertaken regularly, and results reported every 5 years.

There will be no further decline in water levels in Whiteman Park as EWPs are set above water levels associated with tree deaths in 1991. See section 5.4.4 and 6.3 and table 12 in the s46 document. Hydrographs from the 111 year model runs illustrate that non- compliance with these water levels is zero for most wells in Whiteman Park and only 2% of years in MM55B which is extremely low. Refer to table 12 p79.

Figure 28 p68 of the preferred scenario model run indicates a small fall in groundwater levels at the top of Whiteman Park of approximately 0.5m. This predicted drawdown is a result of the proposed Lexia groundwater scheme. However the model run looks at the change in water levels in comparison to 1992. A drop of 0.5m from 1992 levels brings water levels in monitoring wells at the top of Whiteman Park to the EWR and EWP level or just above that level. Impacts on Whiteman Park will be considered in greater detail in the East Gnangara Water Resource Allocation and Management Plan currently being produced by the Water Authority.

Wetlands in Whiteman Park are not proposed to be monitored as it is considered that there is already sufficient monitoring of water levels in the park . There will be no further decline in wetland water levels as levels will be achieved through maintenance of EWPs for terrestrial vegetation. These EWPs will maintain water levels over the entire park.

The borefield in the Park was commissioned in between 1979 and 1982 and at this time it was accepted that the impacts of groundwater abstraction in the area were acceptable. The Water Authority is now proposing to have no further impact on the Park. A terrestrial vegetation transect was established in Whiteman Park in 1991 jointly by the Water Authority and the Whiteman Park Board of Management. The Water Authority is willing to recommence monitoring of this transect on the basis of shared costs.

2.4.3. There is no information presented by the WAWA on the combined effects of pine plantations, Lexia and Mirrabooka borefields on groundwater levels in Whiteman Park.

The s46 document does present information on the combined effect of pine plantations, the Lexia and Mirrabooka borefields on groundwater levels in Whiteman Park. Figure 28 illustrates the impact of the preferred land use and abstraction scenario which includes pine management and the Lexia groundwater scheme other land- use and abstraction impacts. The impact of this future scenario is compared to 1992 levels. The existing Mirrabooka wells therefore cancel out as they are also present in 1992. Table 9 p68 illustrates what has been included in this model run. Figure 28 shows a drawdown of 0.5-1m at the top of Whiteman Park. However as stated above in 2.4.2 a fall of 0.5m from 1992 levels does not breach the EWR and EWP.

Modelled hydrographs predicting future breaches of EWRs and EWPs in monitoring wells in Whiteman Park also include all these factors of the preferred scenario run in figure 28. Results of this modelling are presented in tables 11 and 12 . Locations of monitoring wells are illustrated in figure 14 It can be seen from these tables that Whiteman Park will not be impacted.

Impacts on Whiteman Park will also be considered in the East Gnangara Water Resource Allocation and Management Plan currently being produced by the Water Authority.

2.4.4. Computer modelling of groundwater levels (Ref : Section 8.2.1) should be continually refined as knowledge increases and never relied on as an absolute. Concern was expressed that within the Section 46 document, modelling has been referred to as predicting a 1 to 1.5 m drop in groundwater level. Indications are that groundwater levels in that area referred to have dropped up to 3 metres (as a result of Pinjar Stage 1 pumping and climatic conditions). Greater detail and identification of input data should be included.

2.4.5. All observations suggest that groundwater levels at Lake Pinjar have dropped below the acceptable minimum, causing tree deaths in remnant vegetation stands. The Pinjar Groundwater Scheme needs further moderation, especially during low rainfall periods. Further consideration also needs to be given to the effects of the Pinjar Stages 1, 2 and 3 pumping on the whole Lake Pinjar area if vegetation is not to be degraded further. Zoning the southern portion of the Lake to protect native vegetation will be pointless if vegetation is lost anyway through over - pumping.

2.4.4 - 5.
The Water Authority agrees that computer modelling should be continually refined and never relied on as an absolute. As part of the project, the model was re-calibrated based on the actual climatic conditions and drawdowns. However modelling is essentially used a predictive tool to look at what impacts might be. The environment will be protected by ensuring that EWPs are met and monitoring is carried out to ensure EWPs are sufficient in achieving the desired outcome.

Around the Pinjar area, as illustrated in figure 28, modelling of the preferred scenario has predicted a fall in groundwater level of up to 1.5m, being approximately 0.5 -1m directly north east of Lake Pinjar. The modelled hydrograph for Lake Pinjar predicts an average fall of 1m , maximums up to 1.8m. However it is thought that in Lake Pinjar falls will not be this great due to characteristics in the area which modify changes in water levels in the lake, preventing major impacts on the Lake. Refer to section 9.2 of the document which discusses this. Environmental water provisions in monitoring well PM24 will ensure that water levels do not fall to unacceptable levels and will protect native vegetation in the southern portion of the lake.

Monitoring shows that water levels in the base of Lake Pinjar have not dropped below acceptable minimums even though drawdowns of greater than 1.5m were approved as part of the 1986 Environmental Review and Management Programme. There has been no change in minimum water levels since monitoring began in 1977. A hydrograph can be found in Appendix 5 (see monitoring well PM24).

Outside the drawdown cone minimum water levels in monitoring wells in terrestrial vegetation nearby have only fallen by a maximum of 0.75m between 1986 and 1991 (wells PM25, PM6, PM9 and PM7). Falls in groundwater levels in the Pinjar area in 1991 causing deaths of native vegetation along Perry road was mainly due to low rainfall in 1989 and 1990, but exacerbated by the first stage of the Pinjar groundwater scheme. High temperatures in the summer of 1991 would have also added to the stress of the vegetation. Although as stated in the s46 it is expected that some deaths of trees will usually occur within the drawdown cone of a well, the Water Authority acknowledges that the extent of tree deaths which occurred in 1991 is unacceptable. However the Authority has been able to use experience gained as a result of this incident to avoid tree death in the future.

The fall in groundwater levels predicted under the bombing range vegetation will exceed the Environmental Water Requirement. As this will be the result of pumping from existing Pinjar bores P40-P90 the proposed Environmental Water Provision is less than the Environmental Water Requirement. The Water Authority is proposing some trade-off in this area to allow continued production from established wells. See response to submission 2.1.4 and section 9.3 of the s46 document.

2.4.6. It is unclear how this will work, to avoid adverse impacts on the vegetation. The timing of recording of groundwater levels is critical, as once a groundwater level is detected to be too low as a result of monitoring, it is likely to be too late to remediate the situation. There are obvious time lags between detection of the low level, action to reduce this impact, and time for groundwater levels to respond accordingly

The Water authority will produce "ideal hydrographs" for each of the monitoring wells with environmental criteria. Hydrographs with past water level trends will be used to predict future hydrograph trends. This gives an indication of when water levels might approach EWPs. This helps to guide operation of the groundwater schemes. Monthly monitoring of water levels is also carried out. This provides an indication of when water levels are approaching the EWP and if necessary the regularity of monitoring will increase if it appears minimum water levels will be reached. The Water Authority is then able to cease groundwater abstraction before

there are breaches of the EWP. Monitoring of vegetation health is also undertaken along several transects. Therefore any signs of stress on the vegetation can be detected and groundwater abstraction can be modified accordingly.

2.5. 'Trade-offs' between EWR's and EWP's

2.5.1. The use of the term 'trade off' is used by the WAWA in the context of the certain death of native trees against the demand for increased water resources. It was claimed that the use of this term implies a compromise the health of native vegetation, which is considered to be unacceptable. They do not in fact protect the vegetation at all (see Table 12, p. 79). Responsible management of the water resources should be the most important consideration, which adopt precautionary planning principles.

The Water Authority uses the terminology "trade -off" to indicate where there may be some impact on the environment. This is done to make it clear and transparent where this could occur rather than hedge around the problem.

It is correct that the Water Authority is proposing a trade off in the Pinjar area in the bombing range. This does mean a compromise on the health of the vegetation, resulting in deaths of some mature native trees which will be gradually replaced by more drought tolerant seedlings. In other words, a change in abundance but not diversity. However this trade off is not in order to increase groundwater abstraction but to continue abstracting from stage 1 of the Pinjar groundwater scheme. See section 9.3 of the section 46 document which explains the trade off. It is not true to say that the vegetation is not protected at all. There will be a gradual loss of some vegetation, and its replacement by more drought tolerant species. Production from wells will be modified in dry periods to avoid extensive deaths of native vegetation.

2.5.2. It is considered that unrepresentative samples have been used by the WAWA in setting EWR's for the whole Gnangara Mound, and it is unclear what will happen to the wetlands for which no EWR has been determined, for example the less degraded wetlands near the top of the Mound such as the Bombing Range, about which least is known, and which will be potentially adversely impacted upon due to lower groundwater levels. It is not sufficient to assume that these wetlands are perched and therefore not dependent upon groundwater. Other areas may in fact suffer excessive inundation, for example the Yellagonga chain.

The wetlands selected to have EWRs set in the study area are believed to adequately represent wetlands within the study area. They include damplands, sumplands and lakes which are found in a range of geomorphic settings. Representativeness was not the only criteria used in selecting the wetlands. Rather than select wetlands purely on a representative basis their conservation values played a large role in their selection. Therefore the wetlands with highest conservation value have been selected. As outlined in section 5.2 selection criteria included the management category of the wetland assigned using EPA bulletin 373, system 6 wetlands and wetlands protected under the Swan Coastal Plain lakes Environmental Protection Policy. The likelihood

of a wetland being impacted by groundwater abstraction was also taken into consideration.

The reasoning for selecting a group of wetlands is that as discussed above in 2.3, it is unnecessary to set EWRs for all wetlands given that some are perched, others are not going to be impacted by groundwater abstraction, and others are degraded. It is also impractical to set EWRs and monitor all of the 200 or so wetlands.

A selection of wetlands with environmental water requirements does not mean that other wetlands will suffer any adverse impacts. The protection of some wetlands will also aid protection of those nearby. EWRs and EWPs for terrestrial vegetation will also be maintaining regional groundwater levels. Two regional transects will also be monitored to ensure no adverse impacts on other wetlands. The impacts on wetlands without EWRs, Lake Carabooda, Neerabup, Adams and Pinjar are discussed in section 9.2 of the document.

Existing monitoring bores and bores drilled as part of the project indicate that the Bombing Range wetlands are not dependent on on the true enconfined aquifer but are reliant on perched lenses of subsurface water beneath the bed of each wetland (Fig. 1). The shallow root systems of the wetland plants are adapted to accessing this perched aquifer. The distance in depth between the perched aquifer and the true unconfined water table may be as much as 8 metres at these wetlands. Therefore these wetlands will not be impacted by the proposed drawdowns of the true watertable level in the bombing range.

Excessive inundation of wetlands is a symptom of urbanisation and local drainage. Therefore the Water Authority does not take responsibility for these impacts but it does develop conceptual drainage plans and advise the City of Wanneroo of appropriate mitigation measures (see also 4.3.1.)

2.5.3. It was considered that Table 12 (p. 79) is misleading. For example, are the EWP's an absolute minimum to which groundwater management is geared, or are breaches factored in ?

Table 12 illustrates the Environmental Water Provision in comparison to the Environmental Water Requirement and an indication of likely breaches of the EWP under the preferred land use and abstraction scenario. The Environmental Water Requirement is the preferred allocation of groundwater to the environment. The Environmental Water Provision is the actual allocation that will be made to the environment. It is the minimum groundwater level assigned after social and economic considerations in addition to the environmental requirements have been taken into account. For example in the Pinjar Bombing range the EWP is less than the EWR because of the costs involved if water can not be abstracted from stage 1 of the Pinjar groundwater scheme.

The Environmental Water Provision is the allocation that will be made to the environment at all times and wellfield operation will be planned to avoid any breaches. This may mean modifying abstraction from wells in some periods in some areas in order to meet the EWP. The column in table 12 showing the percentage of

non-compliance with the EWP is merely what the model predicts may happen under the preferred scenario assuming full wellfield quotas. This gives the Water Authority an indication of how often abstraction activity may need to be modified in order to meet the EWP.

3. Private groundwater allocation quotas

3.1. The WAWA in the Section 46 document has contended that provided adequate EWR's are incorporated in the revised Environmental Conditions as proposed, the need to specify particular groundwater allocation quotas no longer exists. This was raised as an issue of concern, as unless there is explicit acceptance that the EWR (i.e. requirement to maintain the natural environment) takes precedence over the Environmental Water Provision (EWP i.e. desired abstraction yield), this may lead to the values of terrestrial vegetation being compromised. The WAWA specifically acknowledges that the EWR for terrestrial vegetation would be compromised under the preferred abstraction strategies for the Lexia and Pinjar schemes.

3.2. It is considered that the removal of allocation quotas and their replacement with EWR's for a handful of wetlands as a means of managing the whole of the Gnangara Mound is unscientific and basically flawed. Some lakes which require EWR's include Lake Carabooda, Lake Adams and Lake Pinjar as the vegetation associated with these lakes have a high conservation value.

3.3. The replacement of abstraction limits by the EWR approach as suggested by the WAWA ensures that the process becomes demand driven, and contravenes stated WAWA policy to 'manage demand and sustainably manage our scarce water resources and the ecosystems which the Gnangara Mound supports'. A precautionary approach should be adopted by the WAWA, which 'phases in' quotas, and allows for more conservative EWP's which are subject to further review, to allow the conclusions of valid studies of the effects of abstraction to be considered and appropriate action undertaken accordingly.

3.1-3
The issue of "removal of groundwater quotas" has been misunderstood. What is being proposed is that the Minister for the Environment does not set quotas as part of the environmental conditions as exists at the moment. This is consistent with the approach suggested by the EPA as part of the 1986 Environmental Review and Management Programme assessment.

The new Water and Rivers Commission will set quotas on the water utility and private users through the licensing process. These quotas will be directly aligned to ensure that EWPs are met. Reporting on actual abstraction will form part of the process of annual reporting to EPA. It is unlikely that annual quotas will vary to any considerable extent. However, not having quotas in the conditions will enable some discretion in setting annual quotas within a context of not compromising environmental outcomes but without requiring formal changes in conditions.

It is believed that the Water Resources Commission will be in the best position to determine what can be abstracted in order to meet EWPs. The role of the

Environmental Protection Authority in this assessment is to ensure that the proposed EWPs are environmentally, acceptable and then to ensure that they are met as part of the conditions placed on the Water and Rivers Commission by the Minister of the Environment at the completion of the Environmental Impact Assessment process.

Environmental Water Requirements and Environmental Water Provisions offer higher protection than the past approaches to environmental management of groundwater abstraction as they give specific water requirements or allocations to the environment, to ensure its needs are met.

Vegetation transects both in wetlands and in terrestrial vegetation will be monitored to ensure EWPs are achieving the desired goals of maintaining current environmental values. If EWPs are found to be inadequate through this monitoring process they will be adjusted accordingly. Monitoring will provide early warnings of adverse impacts and therefore groundwater abstraction activity can be modified before any damage occurs.

Submission 3.3 suggests that quotas be 'phased in'. New production wells are 'phased in' in areas of high value phreatophytic vegetation to ensure that adverse impacts are avoided outside of the drawdown cones of the wells.

3.4. Removal of allocation quotas will encourage unsustainable development and lifestyles within the Wanneroo area. Concern was expressed that a return to below average rainfall (as postulated in Figure 9 of the Section 46 document) would place agricultural producers and suburbanites in a position where they could not carry out their business as usual without seriously compromising the EWR's.
This is sure to create conflict during dry years, and some sort of ruling must be made between the use of water for agriculture, domestic use and the environment.

Allocation quotas have not been removed, refer to 3.1. Allocations of water made between private users, public water supply and the environment are such that current planning shows they can be sustained. Reductions in annual quotas have historically only been applied to public water supplies. It is not expected there will be a need to reduce private quotas , although this cannot be ruled out in extreme situations (see also 3.6). Therefore there should not be conflict between agricultural, domestic and environmental uses.

3.5. Pinjar Stages 2 and 3 should not be allowed to proceed until the effects of abstraction of water from both confined and unconfined aquifers is better understood.

The Water Authority disagrees with this statement. The effects of abstraction from unconfined aquifers are sufficiently known to allow for approval of the allocation plan. The Water Authority is currently carrying out a study to look at the impacts of confined aquifer abstraction in more detail. This study is being undertaken by consultants and will look at the interaction between the unconfined and confined aquifers. A model which predicts groundwater drawdowns in the superficial aquifer from confined aquifer abstraction will be developed. The Water Authority has a very

good knowledge of the impacts of confined groundwater abstraction which is being improved all the time (see also 2.2).

3.6. It was claimed that it is economically and socially unacceptable for the WAWA to consider randomly banning private extraction, given that the private abstraction on Lake Pinjar is minimal. Privately owned animals and crops rely on certainty of water supply. Public abstraction is the main user, and should be controlled and maintained at acceptable levels.

The Water Authority is not proposing to randomly ban private abstraction, and there are no suggestions of this in the document. People with private bores are allocated groundwater which is believed to be able to be abstracted on a sustainable basis. Therefore there is considerable certainty of water supply, even in extreme situations (which are not currently envisaged) sufficient water will always be available for stock and domestic supply (see also 3.4).

3.7. Any consideration of introduction of charges for private water licences needs to take into account the fact that private licensees pay their own costs for the actual abstraction and delivery of water

The Water Authority agrees with this statement. However users are beneficiaries of management in that the resource is managed to ensure that use is sustainable and they should therefore contribute to the cost of management. This issue will be considered further in the Water Resources Commission's Water Industry and Law Reform program to be commenced in 1996.

4. Other

4.1. Principle of abstraction from confined aquifers

4.1.1. Section 2.4.5 of the Section 46 document states that 'the lowering of the pressure heads on the superficial aquifer is unknown at present', yet Pinjar Stages 2 and 3 include 9 public water supply wells designed to extract water from confined aquifers, as well as another 19 unconfined aquifer wells. In addition, there are proposed confined and unconfined wells for each of the other schemes. Rapid urban growth of the northern suburbs has put increased pressure on the WAWA to provide water resources, but this should not be allowed to proceed without valid scientific investigation into the combined impact of extraction from both the confined and unconfined aquifers.

4.1.2. Significant head loss has occurred in the Leederville formation. One submission claims there has been a loss of 17 metres over the past 5 years (i.e. 14 to 31 metres), and this is considered to be a direct result of the WAWA west of the Mound. It is claimed that the Department of Geological Survey has predicted that the Leederville Formation will suffer a loss of 0.5 metres per year for the next 50 years, if there is no further increase in abstraction. This has significant implications on existing bores. For

these reasons, further abstraction by the WAWA from the Leederville Formation should not be allowed.

4.1.1-2
The Water Authority is currently managing a project which looks at the connectedness between the unconfined and confined aquifers. Consultants have been appointed to review the impacts of confined aquifer abstraction. A groundwater model will be developed which predicts impacts on the superficial aquifer from abstraction from the confined aquifer and confined aquifer quotas will be reviewed.

There has been some head loss in the Leederville formation as expected. However the Water Authority is not allowing any significant increases in private abstraction from the Leederville formation. Management of the Leederville formation is based on the predicted recharge and that pressure levels will stabilise over time. The confined aquifer study will aid in the management of Water Authority abstraction from the Leederville formation.

Ultimately the development of EWRs and EWPs ensures that the environment is protected from groundwater abstraction activities. EWPs relate to groundwater levels in the superficial aquifer and levels in the superficial aquifer are effected by unconfined abstraction and to a lesser extent by confined abstraction. Therefore EWPs protect the environment from both confined and unconfined abstraction. The Water Authority will manage the abstraction from both aquifers within the limits set by the EWPs.

4.2. Long term sustainable use of groundwater

4.2.1. The demand implications of long term population growth on use of groundwater is not discussed in the document. It is considered important that WAWA's proposals for the Gnangara Mound is considered in the context of ensuring genuine sustainable utilisation and management of the groundwater resources

Management of the groundwater resource to achieve sustainable utilisation has been considered in the document in a local context.

In the broader context sustainable development of groundwater resources is considered in studies such as the Perth Water Future Study which looks at future sources of water for water supply to meet growing demand.

Outside of Water Authority activities the sustainability of planned development is considered by the Ministry for Planning. It is not the Water Authorities role to develop policies on population growth.

4.3. Surface water drainage management

4.3.1. The EPA's assessment of the Section 46 document could provide a useful opportunity to ensure the integration of general drainage management issues and the overall water resources management strategy for the Gnangara Mound.. Rising

wetland (and groundwater) levels have significant implications for local government. It was considered that the environmental acceptability of remedial drainage schemes on the Mound could be addressed in the context of this assessment.

Consideration of drainage management issues is not part of the scope of the s46 document. The document was prepared to look at groundwater abstraction issues only. In the time frame available it would be impossible to do a comprehensive water management plan.. Drainage issues are considered separately in other reports produced by the Floodplain Management and Strategic Drainage Planning section of the Water Authority. An example of such studies is "Management of Lake Water Levels in the North West Corridor" which looks at management options for controlling high water levels in Lakes Joondalup, Goollelal, Jandabup and Mariginiup. This document was used in negotiations with the City of Wanneroo on high lake water levels and their management (see also 2.5.2).

4.4. Impact on remnant wetlands

4.4.1. The WAWA has not presented any information on the vegetation transects of the Gnangara Mound in the Section 46 document.

The s46 document has not gone into details of observations found from monitoring of long term vegetation transects. There are only general statements on the findings of this monitoring such as that the transects have showed changes in vegetation to more drought tolerant community structure due to lower groundwater levels in some areas. Lower groundwater levels being due to both to climatic impacts alone and the additional impacts of groundwater abstraction. However the latest report produced by Mattiske and Associates is referenced and the results of this monitoring is reported to the EPA in annual and triennial reporting. The reports are available for review at the Water Authority and the Department of Environmental Protection. Anybody with an interest is welcome to make an appointment with the Environmental Management Section of the Water Authority to look at the documents.

4.4.2. It is well acknowledged that System 6 is inadequate in representing wetland types and ecosystems, yet the WAWA review is limited to a small number of, almost exclusively, System 6 lakes. This review would miss small remaining wetlands which may have a high conservation value. Further degradation of Perth's wetlands must not be sanctioned.

4.4.3. Exclusion of Wetland category types H and C (Ref : EPA Bulletin 374, EPA 1990) is not justified as this Bulletin was never intended to act as rationale for permitting the conservation values, other than categories C and H, to be further degraded.

4.4.2-3
As discussed above in submission 2.5.2 it is not practical to set environmental criteria for all wetlands within the study area. Environmental criteria have been determined for the wetlands with the highest priority for protection. Wetlands were not selected solely because they were in System Six areas. Other conservation values were also taken into consideration (refer to section 5.2 of the document). H and C category

wetlands were considered to have high conservation value and part of the criteria for selection were these management categories. The selection of a group of wetlands only for EWRs does not mean other wetlands are not protected. Groundwater monitoring is done all over the Gnangara Mound and regional wetland transects are being established as part of the management and monitoring programme of the s46. Refer to section 10.3 of the document.

4.5. Impact on terrestrial vegetation

4.5.1. Figures included within the document indicate that groundwater modelling under preferred abstraction rates for existing and proposed Pinjar and Lexia Schemes show that there will be serious breaches of conditions required to maintain phreatophytic vegetation in the 'Bombing Range' and Melaleuca Park.

These areas have been recognised as having high conservation value. They are poorly studied and impacts unpredictable. Therefore accepting these impacts is not considered to be responsible management of the resource.

See 2.1.4

4.5.2. Cumulative effects of weather, excess drawdown, increased human disturbance through access to more bores and changed fire regime can severely impact on the chances of natural regeneration and survival of seedlings, subsequent to the deaths of mature trees of drought sensitive species. Data presented within the document is dependent upon regeneration being effective, and this may be a false assumption. This may in turn lead to increased exotic weed invasion, decreasing regeneration opportunities further, and ultimately impact on a range of native animals.

Water Authority experience has indicated that often good regeneration occurs naturally after vegetation death due to drought. There are examples of regeneration after vegetation death from low water levels in several areas of the Mound, both in regions of groundwater abstraction and distant from groundwater abstraction. What has been observed however, is there may be a bias towards regeneration of drought tolerant species.

The Water Authority established a vegetation transect at P50 prior to the 1991 tree deaths. This transect has shown a good regeneration of vegetation. As new seedlings develop in areas with lower groundwater levels they grow to become adapted to the water regime prevailing in the area. *Banksia attenuata* and *Banksia menzessii* for example, are growing in areas of high as well as low depth to groundwater in many regions on the Gnangara Mound.

The influx of weeds into an area after deaths of vegetation from drought stress can occur, however groundwater drawdown does not effect understorey to the extent that overstorey species may be affected. Therefore room for weed invasion is limited. Weeds also need to be introduced initially. No weed invasion has been observed along the P50 transect. In reference to changed fire regimes, fire is actually beneficial as it aids

the regeneration of seedlings provided that it does not occur too frequently and fire equally effects areas distant from groundwater abstraction.

The Water Authority is confident of managing groundwater abstraction impacts. The Water Authority does not have responsibility for cumulative impacts.

4.5.3. The number of tree deaths has increased significantly since Pinjar Stage 1 commenced. This has been especially evident over the last two seasons, and suggests that the impact of production wells on phreatophytic vegetation is not being minimised. It was claimed that observation of private soaks last summer suggests that the water table fell up to 3 metres. Basing well operation on a total water table fall of 1.5. metres (see Section 5.4.4 regarding groundwater level requirements) maybe invalid and be contributing to tree deaths rather than trying to prevent deaths.

Significant areas of tree deaths near the Pinjar Stage 1 groundwater scheme have only occurred in the summer of 1991. This has been the result of low rainfall in 1989 and 1990 (refer to figure 9 in the s46 document). The low groundwater levels and low soil moisture levels at this time combined with high temperatures in the summer of 1991 has been detrimental to the vegetation. At this time deaths were also evident on other areas of the Gnangara Mound and other areas of the south west both near areas of groundwater abstraction and distant from groundwater abstraction. These were some of the findings of the Gnangara Mound Vegetation Stress study , 1992. This has been discussed in section 2.4.6 of the section 46 document. The Pinjar groundwater scheme did exacerbate the effects of climate.

During the summers of 1993/94 and again in 1994/95 some tree deaths would have occurred as they did in many parts of the Perth area due to relatively severe climatic conditions. However there were no areas of tree deaths on a scale in any way similar to 1991.

The water table did not fall by 3m in this area last summer. Hydrographs for monitoring wells nearby to the Pinjar groundwater scheme show rises in minimum water levels after 1991 and only small falls in groundwater levels occurred in the summer of 1994. They are below minimum water levels in 1993 by a maximum of 0.25m. They have fallen from maximum water levels in the winter of 1993 between 0.75 and 2m depending on the monitoring well. This includes the normal seasonal fluctuation, which is usually between 0.5 and 1.5 metres. See hydrographs for PM25, PM6, PM7 and PM9 in appendix 5 of the s46 document.

Basing well operation on a total water table fall of 1.5m is valid as it is consistent with the findings of a tree death study in Whiteman Park which was carried out due to observations of tree deaths in Whiteman Park in 1991.. It was found that the water table can be drawn down by a total of 1.5m from historic levels if it occurs slowly, that is at a rate of no greater than 0.2m per year without having any adverse impacts on the vegetation.

4.6. Well head protection zones

4.6.1. The WAWA has recently implemented greatly increased well head protection zones surrounding all production bores, within which special development restrictions apply. However, no information is given by the WAWA on details of the well head protection zones, for example in some areas a 500 m radius is required and in others a 300 m radius is required, with no apparent reason. The question was asked - can the density of bores be justified and must the well head protection zones remain at 500 m when other areas are 300 m ?

4.6.2. It was claimed that the 900 hectares of well protection zone at Whiteman Park is a major problem for future developments. It was suggested that well head protection zones within the Park should be re-assessed on a scientific basis.

4.6.1-2
The Mirrabooka wellfield was commissioned in 1971 and the Underground Water Pollution Control Area was declared at about the same time. This was prior to the development of Whiteman Park and any developments in the area. Whiteman Park development has always and will need to continue to be, compatible with the need to protect groundwater quality for public water supply. Wellhead protection zones are required as an immediate management tool to avoid contamination of public water supplies. They have been developed in all areas as a method of short term protection for drinking water against pollution incidents which could quickly lead to poor quality water entering the collector mains.

Wellhead protection zones are currently being reviewed on a scientific basis. The Water Authority has hired consultants to determine capture zones for wells. This will be done through groundwater modelling. These capture zones will then be used to determine new wellhead protection zones and priority areas. The Ministry for Planning will then assess these new boundaries against current land use in a study titled the Gnangara Land use and Water Management Strategy. This study will look at where it might be appropriate to change current land use to coincide with new boundaries.

Note that the assessment of the rationale of the Water Authorities water quality protection strategies is beyond the scope of this document.

4.7. Draw-down areas

4.7.1. In some areas changes in vegetation have occurred beyond the draw-down cone areas, leading to extensive loss of native vegetation. It was considered that WAWA water requirements should be pro-active rather than just reactive in abstracting water.

There have been areas over the Gnangara Mound where there have been deaths of native vegetation. Two of these areas which are near wellfields are Whiteman Park and Pinjar. This has been a result mainly of climatic impacts. The issue is discussed in section 2.4.6 of the s46 document.

The approach of using Environmental Water Requirements and Environmental Water Provisions by the Water Authority is pro-active. Through this method the water requirements of vegetation and wetlands are being determined prior to any

increased abstraction being allowed. After identification of environmental requirements , allocations are made to private users and to public water supply using the available groundwater not required for protection of the environment. Groundwater abstraction activity will be managed to ensure that EWPs are met which will in turn ensure the environment is protected.

4.7.2. Water level declines, particularly in the area east of Lake Pinjar are greater than the amounts quoted in the Section 46 document, i.e. it is greater than 1 metre, rather than up to 1 metre as claimed by the WAWA.

The s46 document states on p18 in section 2.4.1 that groundwater levels have fallen up to 1m east of Lake Pinjar. This level has been obtained from figure 6 which provides groundwater contours to show the difference in groundwater levels between 1986 and 1994. If the actual hydrographs in this area (for wells PM25, PM6, PM7 and PM9 - see appendix 5 and figure 14) are analysed the difference in minimum water levels between the summers of 1986 and 1994 is up to 0.5m. If you look at the difference in minimum water levels between 1986 and 1991 there is a fall of up to 1.5m (this is in PM7, others are 0.5m). However water levels have risen again since 1991 with higher rainfall in 1992 and 1993 (see figure 9). Water levels fell to minimums in 1991 due to low rainfall in 1989 and 1990..

4.8. Nutrient management

4.8.1. The WAWA has not presented any information on nitrogen or phosphate management on the Mound. Sensible limits for both nitrogen and phosphorous maximum application rates need to be set.

Nutrient Management is beyond the scope of the s46 document. The document was produced to look at water quantity issues not water quality issues. Nutrient management issues will be considered in the Gnangara Land Use and Water Management Strategy.

4.9. Priority area boundaries

4.9.1. Priority areas on the Mound have been determined on cartographic boundaries and need to be reassessed.

This is a water quality issue which is beyond the scope of the s46 document. However the Water Authority is currently reviewing priority area boundaries. The Water Authority has commissioned consultants to determine capture zones fro production wells and other important water resource areas. This is a scientific investigation which will incorporate computer modelling. The capture zones will aid in the determination of new priority boundaries.

The new boundaries will then be assessed as part of a project being undertaken by the Ministry for Planning. That is the Gnangara Land use and Water Management Study

(GLUWMS). This study will compare old boundaries to new and determine were land use changes may be appropriate to incorporate this information.

4.10. Public education

4.10.1. An additional requirement for the WAWA should be to increase the public's education of water and associated environmental issues.

The Water Authority has major public awareness programs in these areas. Some of these include:

- three videos recently produced on groundwater and its use
- booklets such as "Perth's groundwater and your lifestyle" and " Groundwater- how do we use it"
-topic sheets for schools eg " Groundwater in W.A"; "Water and the Environment"; "Perth's water supply"
- Posters on wetlands and groundwater

The Water Authority will continue to work to increase public education and awareness of water and related matters.

4.11. Suggested management strategies

4.11.1. The following strategies were forwarded :

- *develop the Priority 3 areas before any further wells are placed higher on the Mound. This will allow water to be allocated for human use without further affecting the more sensitive areas of the Mound;*
- *pump water from the Mound during winter to recharge the hills dams so that peak demands can be met from sources other than environmentally sensitive groundwater areas. This course of action would ensure protection of phreatophytic vegetation such as banksias;*
- *pine plantations should be thinned after successive dry years to help increase recharge rates to maintain long term groundwater levels (even if there is no immediate market for wood); and*
- *waste management strategies should be implemented to ensure long term sustainable groundwater quality.*

The development of production wells in priority 3 areas does not provide for long term protection of groundwater drinking water quality. There is limited control of development impacts in priority 3 areas in comparison to priority 1 and 2 areas. Development of groundwater schemes in priority one areas does provide the long term security required in a major public water supply system.

The pumping of groundwater from the Mound during winter to recharge dams and then pump it back into public water supply in summer is not viable due to the extremely large costs involved. This would also be inefficient use of the system of

dams which are designed to efficiently use surface water conjunctively with groundwater.

With respect to pine thinning, these types of issues will be considered in the Memorandum of Understanding to be developed between CALM and the Water Authority. Refer to commitment P 38. However CALM has rarely agreed to such action in the past.

Water quality issues are beyond the scope of the s46 document. . Water quality issues on the Gnangara Mound are being addressed through the recommendations of the Select Committee on Metropolitan Development and Groundwater Supplies. The Water Authority is not aware of any plans for future waste disposal in the Gnangara study area.

4.12. Aboriginal interests

4.12.1. Water within the Mound is connected to Nyungah spiritual beliefs, and is part of their spiritual religion and culture. It affects many streams and brooks including Bennett Brook - the Dreaming Track of the Rainbow Serpent Waugal. Proposed changes to groundwater abstraction rates should take into consideration existing cultural information networks within the metropolitan area, and include consultation with the Nyungah Elders of the Aboriginal community, before any changes are implemented

In the development of the 1986 Environmental Review and Management Programme which established the long term strategy for the whole of the Mound, there was considerable consultation with the Aboriginal community. A document has also been produced since by the Western Australian Water Resources Council which identifies the aboriginal significance of wetlands and rivers in the Perth to Bunbury region. The Water Authority also obtained a list of Aboriginal sites in the study area from the Western Australian Museum. Refer to section 4.3.3 of the s46 document. The Water Authority is not aware of any new issues. However we are happy to consult with Aboriginal people if there are any issues which have been overlooked.

4.13. Protection of cave fauna

4.13.1. Extraction of water from the Mound must take into consideration the potential impact on troglobitic fauna, particularly in the vicinity of Yanchep National Park. These are rare organisms which require a damp humid environment and are very sensitive to any small changes in water levels, fed by the Gnangara Mound.

Protection of troglobitic fauna found in the caves in Yanchep National Park has been addressed within the s46 document. Environmental Water Requirements for the caves aim to ensure the current hydrological regime within the caves is maintained, in particular the permanent water which is supporting the aquatic fauna. Refer to sections 5.5, 6.4, 9.4, 10.3.3,10.4.3 and appendix 3 of the document

4.14. Long term monitoring and management

4.14.1. Ref : Section 10.1.2 - Adequacy of statutory and non-statutory mechanisms. Policies and statutes can only be effective if implemented, and land use activities in Priority 1, 2 and 3 areas seem to have been imposed in a random manner, e.g. Gas turbine Station on highest and most important recharge area (bulk fuel storage and leaking sumps), service station on Gnangara Road in Priority 1 area, and small cattle feed lot on Parry Road after imposition of Planning Control No.29. Policies are therefore clearly not implemented consistently.

Water quality issues are beyond of the scope of the s46 document. However the Water Authority recognises there are some non-conforming activities in priority areas.. Some of the current Land use activities such as the pig farm and cattle feed lot are being examined for relocation opportunities. There have been other developments occur however, which have been out of the control of the Water Authority, such as the development of the service station in Gnangara road and a gas turbine power station. However this certainly does not justify any further activity which has the potential to degrade water resources. The Water Authority is reviewing strategies to control such developments The implementation of the recommendations of the Select Committee
will be of considerable help in this regard.

4.14.2. It was suggested that the publication of the location of the 11 vegetation monitoring transects, in a similar way to the which the monitoring bore locations are published, would be useful for members of the public.

The Water Authority does not publish the location of monitoring transects to reduce ongoing problems with vandalism. However, if anyone has a good reason for wanting to know their locations the Water Authority will provide the information directly on enquiry.

4.14.3. It was suggested that groundwater sampling (Ref : Table 14) should be undertaken in autumn as well as spring, when levels are at their lowest. It is unclear to what reference data, for example, the U.N.O. will the collected data be referred.

No groundwater quality sampling is mentioned in the document. Table 14 only refers to groundwater level monitoring and monitoring of water quality in wetlands. This is done in order to assess changes in water quality resulting from land use developments as well as changes in water level regime. Hence if aquatic fauna, for example, appear to be stressed at any stage the Water Authority is able to determine whether it is because of water level changes or water quality changes. The water quality guidelines published by the Australian and New Zeland Environment and Conservation Council (ANZECC) can be used for comparison in relatively pristine systems.

4.14.4. It was suggested that more opportunity be given for consultation with local landowners (Ref : p. 45) to overcome lack of detailed site specific knowledge of WAWA employees.

The Water Authority does consult with local landowners and the local community. This is done through the Wanneroo Groundwater Advisory Committee which is concerned with water allocation and policy issues; and the Gnangara Community Consultative committee which is made up of community representatives and key stakeholders concerned with environmental issues associated with groundwater on the Gnangara Mound. The Water Authority is always interested to obtain knowledge of other people who wish to be provided information on groundwater management issues.

4.14.5. Government should ensure adequate funds area available to implement the proposed on-going monitoring and management programme and associated commitments made by the WAWA.

There is a budget for the establishment (or continuation) of the monitoring and management programme developed as part of the s46 review. This will be adequately funded.

Appendix 3

List of proponent's revised commitments associated with the Section 46 Review

WATER AND RIVERS COMMISSION COMMITMENTS

Water and Rivers Commission Commitments

The following commitments are made by the Water and Rivers Commission on the allocation and management of groundwater within the study area of the Gnangara Mound. The new commitments are number consecutively, starting after to existing commitments, to avoid confusion.

Commitments to be Fulfilled At Specific Times During the Project

P33 The Water and Rivers Commission will, within three months of receiving environmental approvals, request the Water Corporation to establish further monitoring wells at a 200 m radius from production wells located within areas of phreatophytic vegetation. These wells will be monitored monthly, and more frequently if necessary, to guide wellfield operators in minimising environmental impacts.

P34 The Water and Rivers Commission will, within three months of receiving environmental approvals, establish additional monitoring wells in those areas where suitable wells do not exist to monitor groundwater levels under phreatophytic vegetation, to the satisfaction of the EPA.

P34a The Water and Rivers Commission will, by Spring 1996, select a range of indicator species at established terrestrial vegetation transects and determine an "acceptable" rate of change in vegetation composition at those transects impacted by groundwater abstraction. Rates of change will be measured using the indicator species and similarity indices.

P35 The Water and Rivers Commission will, within six months of receiving environmental approval, require the Water Corporation, through their licence conditions, to prepare an environmental operations plan to provide specific detail on environmental management of groundwater schemes in the study area. This will provide detailed management prescriptions for wellfield operators and water resource managers.

P36 The Water and Rivers Commission will prepare a water resources allocation and management plan for the Yeal area to identify groundwater allocations, prior to the development of the Yeal Groundwater Scheme, to the satisfaction of the EPA.

P37 The Water and Rivers Commission will prepare a water resources allocation and management plan for the Lexia area to identify groundwater allocations, prior to the development of the Lexia Groundwater Scheme, to the satisfaction of the EPA. In particular, it will include detailed modelling of the Lexia Groundwater Scheme to optimise groundwater availability while minimising environmental impacts.

P38 The Water and Rivers Commission will, by June 1997, in conjunction with the Department of Conservation and Land Management and Water Corporation develop a memorandum of understanding on pine management regimes within State Forest 65 which recognises the dual use of water and forests, and optimises water and timber production, while minimising environmental impacts.

Ongoing Commitments Throughout the Life of the Project

General

P39 The Water and Rivers Commission will manage all groundwater allocation and use on the Gnangara Mound with the aim of meeting wetland management objectives listed in table 15. Environmental water provisions have been determined to aid achievement of these objectives. The Water and Rivers Commission will manage all groundwater allocation and use on the Gnangara Mound to meet the

environmental water provisions which are listed in table 16 and to minimise environmental impacts. (The achievement of wetland objectives and performance criteria will be measured against minimum water level requirements only, other landuse impacts will not be managed by the Water and Rivers Commission).

TABLE 16 ENVIRONMENTAL WATER PROVISIONS

Wetland/Well	Proposed EWP (mAHD)			
	Preferred Lowest Peak Level *	Preferred Minimum Level	Lowest Peak Level	Minimum Level
Lake Jandabup	44.7		44.2	
Lake Gnangara		42.0***		41.3
Lake Mariginiup	42.1		41.5	
Lake Joondalup		16.2*		15.8
Lake Goollelal		26.2*		26.0
Lake Nowergup	17.0		16.8	
Coogee Springs	12.0		11.25	
Loch McNess		#		6.95
Lake Yonderup		#		5.9
Lake Wilgarup				**
Pipidinny Swamp				**
Melaleuca Park Wetland				**
MM49B		#		24.7
MM53		#		33.3
MM55B		#		29.5
MM59B		#		36.3
MM16		#		38.8
MM18		#		38.6
JB5		#		44.8
MT3		#		43.0
NR6C		#		58.5
WM6		#		58.3
WM8		#		64.8
WM1		#		55.7
WM2		#		66.5
PM25		#		42.3
PM24		#		40.5
PM6		#		53.5
PM7		#		60.5
PM9		#		56.3

Preferred minimum not set. * Breaches permitted a maximum of two years in six and no more than 2 consecutive years. ** To be set at the time of the first triennial report. ***Target level for management - no minimum set.

P40 The Water and Rivers Commission will continue to facilitate and undertake strategic research on environmental water requirements, and the management of groundwater use to minimise environmental impacts.

P41 The Water and Rivers Commission will continue to provide advice to the City of Wanneroo, Department of Planning and Urban Development, Department of Conservation and Land Management, and other relevant agencies, on the impact of land uses on groundwater resources.

P42 The Water and Rivers Commission will, as necessary, in conjunction with the Department of Conservation and Land Management, continue to develop catchment strategies to minimise changes in the hydrological regime within the caves in Yanchep National Park

P43 The Water and Rivers Commission will, as necessary to manage water levels, prepare strategic drainage plans for the study area, including options for management of high water levels in lakes Joondalup, Goollelal, Mariginiup and Jandabup.

Administrative Arrangements

P44 In consultation with other relevant agencies, the Water and Rivers Commission will, within six months of receiving environmental approvals, reconvene and provide ongoing executive support for an inter-agency technical advisory group for water resources planning and management issues on the Gnangara Mound. This will be done in the context of the recommendations of the Select Committee on Metropolitan Development and Groundwater Supplies.

P45 The Water and Rivers Commission will continue to Chair and provide support for the Community Consultative Committee as an ongoing forum for information exchange and advice to the Water and Rivers Commission on general water management issues.

Reporting

P46 The Water and Rivers Commission will continue to report every three years to the Department of Environmental Protection on the management of groundwater within the Study area of the Gnangara Mound. This will include information on the operation of groundwater schemes and private groundwater use, compliance with environmental water provisions and environmental conditions, and environmental impacts. In those years when a triennial report is not submitted, the Water and Rivers Commission will report to the Department of Environmental Protection on compliance with environmental conditions.

Contingency Plans

P47 The Water and Rivers Commission will require the Water Corporation as a part of their licence conditions to design and operate production wells to limit the potential for tree deaths around production wells to within specific distances from those wells. Tree deaths will only occur within a 100 m radius of the well under normal climatic conditions, and within a 200 m of the well in climatic extremes (eg droughts, high temperatures). Contingency measures may include closing down wells in sensitive areas during extreme climatic conditions.

P48 The Water and Rivers Commission will, when necessary to meet EWPs, upgrade the artificial maintenance facility for Lake Nowergup to provide more rapid recharge to the lake, to the satisfaction of the EPA.

P49 The Water and Rivers Commission will when necessary to meet EWPs, establish an artificial maintenance facility for Coogee Springs, to the satisfaction of the EPA.

P50 For Lakes Nowergup and Coogee Springs, should environmental water provisions not be met by 1 November, the Water and Rivers Commission will implement artificial supplementation until the EWP has been reached.

For Lake Jandabup, should environmental water provisions not be met by 1 November, the Water and Rivers Commission will request the Water Corporation to implement artificial supplementation until the EWP has been reached. This requirement will form part of the Water Corporations licence conditions.

P51 Where water levels below preferred water levels are permitted 2 years in every 6, the Water and Rivers Commission will, where possible, only allow drops below the preferred level to occur in low-rainfall years in order to mimic natural regimes.

Management and Monitoring Programme

P52 The Water and Rivers Commission will formally review the environmental water provisions every six years as a minimum, or as required for adaptive management, as a component of reporting to the Environmental Protection Authority, to the satisfaction of the EPA. Any review will incorporate mechanisms for public involvement.

P53 The Water and Rivers Commission will, after receiving environmental approvals, implement and undertake the following monitoring programme, to the satisfaction of the EPA:

P53.1 - Groundwater level monitoring across the established monitoring network, at a frequency of 1 or 3 months, depending on the wells.

P53.2 - Vegetation transects will be established at all wetlands for which EWPs have been set, except Lake Gnangara, Pipidinny Swamp, and Coogee Springs. A minimum of one transect will be established for each wetland. Monitoring will be undertaken yearly, in November, for the first three years, to be reviewed in the first triennial report.

P53.3 - Wetland vegetation will be mapped every two years from large scale aerial photography for Lakes Jandabup, Mariginiup, Nowergup and Loch McNess.

P53.4 - Water quality will be monitored annually in November at all wetlands for which EWPs have been set.

P53.5 - Wetland habitats will be mapped along two regional transects in November, using large scale aerial photography, every year for the first three years, then every three years.

P53.6 - Established terrestrial vegetation transects will continue to be monitored in spring, with 6 transects monitored every three years, and 5 transects every six years.

P53.7 -Indicator species will be monitored at established terrestrial vegetation transects when transects are monitored in spring. Parameters that will be assessed for each indicator species are age (size), class distribution, vigour and recruitment

P53.8 - A Similarity Index for each terrestrial vegetation transect at each monitoring period will be calculated with the aim of summarising spatial and temporal changes in vegetation composition.

P53.9 - Continuous water level monitoring in three caves in Yanchep National Park will continue, with further cave monitoring established in suitable caves.

P53.10 - Aquatic fauna will be monitored within those cave streams containing root mats once per year in November.

P53.11 - Water levels in wells for which EWPs have been established will be monitored every month.

P53.12 - Water levels in piezometer transects in the Yanchep area will be monitored each month.

P53.13 - The impact of confined aquifer abstraction on unconfined aquifer water levels will be monitored. If significant impacts are observed the Water and Rivers Commission will discuss the observed impacts with the EPA.

P53.14 - Water levels will continue to be monitored once per month in 28 wetlands within the study area.

P53.15 - Water level monitoring in the 13 wetlands for which EWPs have been set will occur more frequently than once per month, when necessary, to determine compliance with set levels.

P53.16 - Aquatic fauna will be monitored at the 13 wetlands for which EWPs have been set two times per year (but only when open water is present), in November and March.

P54 The Water and Rivers Commission will, on receiving environmental approvals, prepare monitoring protocols for aquatic fauna monitoring within the wetlands, to the satisfaction of the EPA.

Table 15: Wetland Management Objectives

Wetland	Water Regime Management Objectives	Performance Indicators
Lake Jandabup	.No expansion in the area of sedge vegetation, but maintenance of existing areas. . Maintenance of the current extent of wading bird habitat. . Maintenance, and if possible, expansion of the M raphiophylla and E rudis fringing woodlands. . Removal of mosquito-fish from the Lake. . Maintenance of the high species richness of aquatic macroinvertebrates and macrophytes.	The existing extent of sedge and wading habitats within the Lake will be maintained (within +/- 10%), and should not change by more than 5% in any 2 year monitoring period.
Lake Gnangara	. To improve water quality through increased water levels as a means of enhancing both environmental and social values of the Lake.	The pH of the Lake should increase. The extent of any expected increase is unknown.
Lake Mariginiup	. To maintain the current area of sedge vegetation to within +/- 10 %. . To maintain the current area of wading bird habitat. . To maintain invertebrate diversity through some lake-bed drying in summer. . To maintain, and if possible, enhance, fringing woodland vegetation.	The existing sedge area to be maintained to within +/- 10%, and should not change by more than 5% in any 2 year monitoring period.
Lake Joondalup	. To conserve existing wetland vegetation, including sedge beds, fringing woodlands, and aquatic macrophytes; . To maintain and if possible enhance the aquatic fauna of the Lake; . To support the full range of habitats for avian fauna found at Lake Joondalup to help ensure its continued value as a major water-bird habitat within the Region. This includes areas of deep and shallow water, and exposed banks in late summer; . To ensure the landscape amenity value of the Lake is maintained, except under low rainfall climatic conditions.	

Lake Goollelal	. To protect, and if possible enhance, fringing wetland vegetation, including woodland and sedge vegetation. . To maintain permanent, deep water for water-bird purposes and as a drought refuge; . To maintain the landscape amenity benefits of the wetland.	. No loss of fringing melaleuca woodlands as a result of flooding. . Maintenance of fish species in the Lake.
Lake Nowergup	. To maintain the existing areas of fringing sedge vegetation. . To maintain deep, permanent water as a bird habitat and drought refuge, and to protect aquatic invertebrates and fish dependent on permanent water. . To maintain the existing extent of the baumea fringe between typha stands and the fringing woodland. . To provide some area of wading bird habitat at the end of summer, although it is recognised that this is limited by the shape of the wetland. . To maintain the areas of fringing woodland on the western shore	The existing extent of sedge habitat within Lake Nowergup should be maintained to within +/- 10%.
Coogee Springs	. maintenance of the diversity of invertebrate fauna within the Lake; . maintenance and if possible enhancement of wetland vegetation; . maintenance of water necessary for bird breeding.	Invertebrate species richness should be maintained.
Loch McNess	To maintain all existing values of Loch McNess.	The current, unaltered water regime for Loch McNess should be maintained.
Lake Yonderup	To maintain the current unaltered water regime of Lake Yonderup	The current unaltered water regime should be maintained.
Lake Wilgarup	To maintain the existing extent and variety of wetland vegetation	To be determined.
Pipidinny Swamp	. To maintain and enhance wetland vegetation. . To protect and enhance waterbird habitats	To be determined.
Melaleuca Park wetlands	To maintain the existing areas of wetlands and wetland vegetation	
Bombing Range wetlands	To maintain the existing wetland vegetation.	

Appendix 4

List of criteria proposed to be used by the proponent to monitor vegetation in wetland areas in addition to proposed statutory management criteria

PROPOSAL FOR MONITORING CRITERIA FOR PHREATOPHYTIC VEGETATION ON THE GNANGARA MOUND.

Issue

Drawdown of the unconfined aquifer due to public and private groundwater abstraction in the Gnangara area has resulted in incidents of tree death, particularly adjacent to Water Authority borefields. As stated in the Gnangara Mound Groundwater Resources Section 46 document, proposed commitments include the setting of preferred and absolute minimum groundwater levels beneath phreatophytic vegetation and the monitoring of water levels in designated monitoring bores.

To determine changes in the state of vegetation on the Mound and the effectiveness of Environmental Water Provisions in preserving identified conservation values, a long-term vegetation monitoring program is being conducted on eleven (11) transects in the area (conducted by E. M. Mattiske and Associates). Transects are located within and outside the influence of existing and proposed (Lexia) borefields for comparison.

Although the vegetation is monitored for change every three years, the preferred and absolute minimum groundwater levels are the only proposed statutory management criteria. In discussion with the EPA and DEP, it was suggested that additional criteria be developed that reflect the actual response of the vegetation and its perceived values.

This proposal outlines the arguements for and against the use of particular indices and indicators as management criteria, and makes recommendations on the appropriate application of vegetation parameters as management criteria.

An Appropriate Measure of Vegetation Change

Selection of appropriate vegetation criteria for management depends on the identification of characteristics that are considered to be of importance in the functioning and ecological integrity of the vegetation within an ecosystem.

Discussion with E. M. Mattiske and Associates has established the arguments for and against the use of particular measures of vegetation change. On the basis of previous monitoring and research on the Swan Coastal Plain by Havel, Mattiske (nee Heddle) and Froend, a range of criteria were considered for assessing the effects of groundwater drawdown on phreatophytic vegetation.

Species Diversity

Species diversity indices should not, on their own, be used as a management criteria as they can be easily influenced by common factors such as fire frequency, timing and intensity. If diversity indices are used in isolation then species can be replaced by another more drought-tolerant species without a marked difference in species diversity. Some vegetation types have naturally lower species diversity than others, e.g. damplands where the infrastructure of the plant community can still persist despite a low diversity. Weed invasion of a plant community can also give the impression of maintaining species diversity if the proportion of native species is not measured as well.

Indicator Species

This is an option that has been used in the past with substantial success, however it also needs to be used in conjunction with other criteria. The species would need to be selected from previous studies such as

Havel, Heddle, Mattiske, Gibson and Froend. Some larger tree species of the genera *Eucalyptus* and *Melaleuca* are capable of tolerating some change; while other indicators such as *Banksia* have responded to smaller changes. The biology and lifeform of the different species then becomes critical in the selection process of suitable indicator species. Therefore there is a need to include a range of indicator species in long term monitoring programmes.

Similarity Indices

Similarity indices could be used to monitor changes in species composition over time. This approach has been used in other situations with some success. These indices could also be used to determine differences between sites e.g. sites near abstraction vs sites not influenced by drawdown. Similarity indices can qualitative and based on presence/absence data, or quantitative using abundance data. Four indices are worth considering. They are the Jaccard coefficient, Sorenson coefficient, Czekanowski coefficient and the coefficient of squared Euclidean distance. All coefficients are suitable for either quantitative and qualitative data.

Generally, the Sorenson coefficient is preferred to the Jaccard because it give weight to the species that are common to the samples rather than to those that only occur in either sample. As an example of the parameters considered, the Sorenson coefficient is explained below:

$$S_s = \frac{a}{2a+b+c}$$

where S_s = Sorenson coefficient
a = number of species common to both samples
b = number of species in sample 1
c = number of species in sample 2

Proposed Use of Vegetation Criteria

In view of the complexity and range of plant communities on the Gnangara Mound, it would be necessary to utilise a combination of indicator species and similarity indices. Diversity would also be measured but it is suggested that it not be employed as a management criterion.

Irrespective of the criteria adopted there is an essential need for an understanding of the biology of the species and their water requirements, and for an understanding of the difference between natural dynamics of plant communities and abnormal changes. The significance of control sites and the continued monitoring of groundwater levels and soil moisture becomes critical in this evaluation.

The proposed adoption of vegetation criteria is as follows:

- All vegetation data will continue to be collected from the 11 permanent transects monitored by E. M. Mattiske & Associates. Two additional transects will be established to supplement sampling in the Lexia area and Melaleuca Park. One existing transect in Whiteman Park will be re-established. All transects will continue to be monitored on a triennial basis.
- Indicator species will be determined for key plant community types within existing transects. Parameters that will be assessed for each indicator species are age (size) class distribution, vigour and recruitment.
- A Similarity Index for each transect at each monitoring period will be calculated with the aim of summarising spatial and temporal changes in vegetation composition.

- As indicator species assessments and indices will be determined from triennial monitoring results, reporting on adherence to vegetation criteria to the EPA will also be on a triennial basis. Inclusion in annual reports may be required if rapid or unexpected changes occur at some sites.
- Quantifying the vegetation criteria will require further analysis of "acceptable" rate of change in vegetation composition. It is suggested that this analysis be conducted before the next vegetation monitoring period in Spring 1996 and be reported in the next annual report.
- The Water Authority will support further research to gain a greater understanding of the water requirements of phreatophytic vegetation and appropriate measurement of vegetation change and response.
- The effectiveness of vegetation criteria will be reviewed on a triennial basis and modified in consultation with the EPA.